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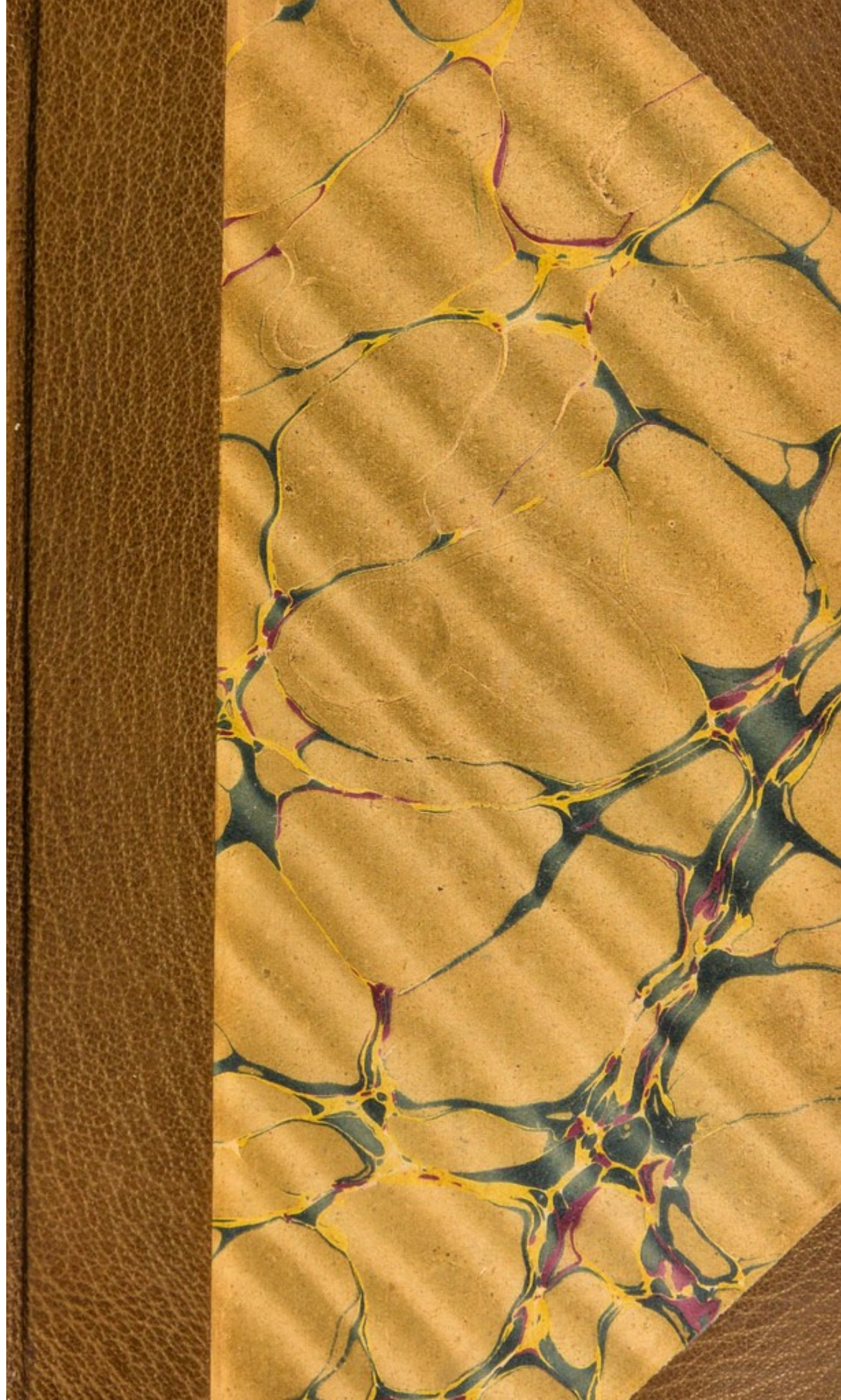
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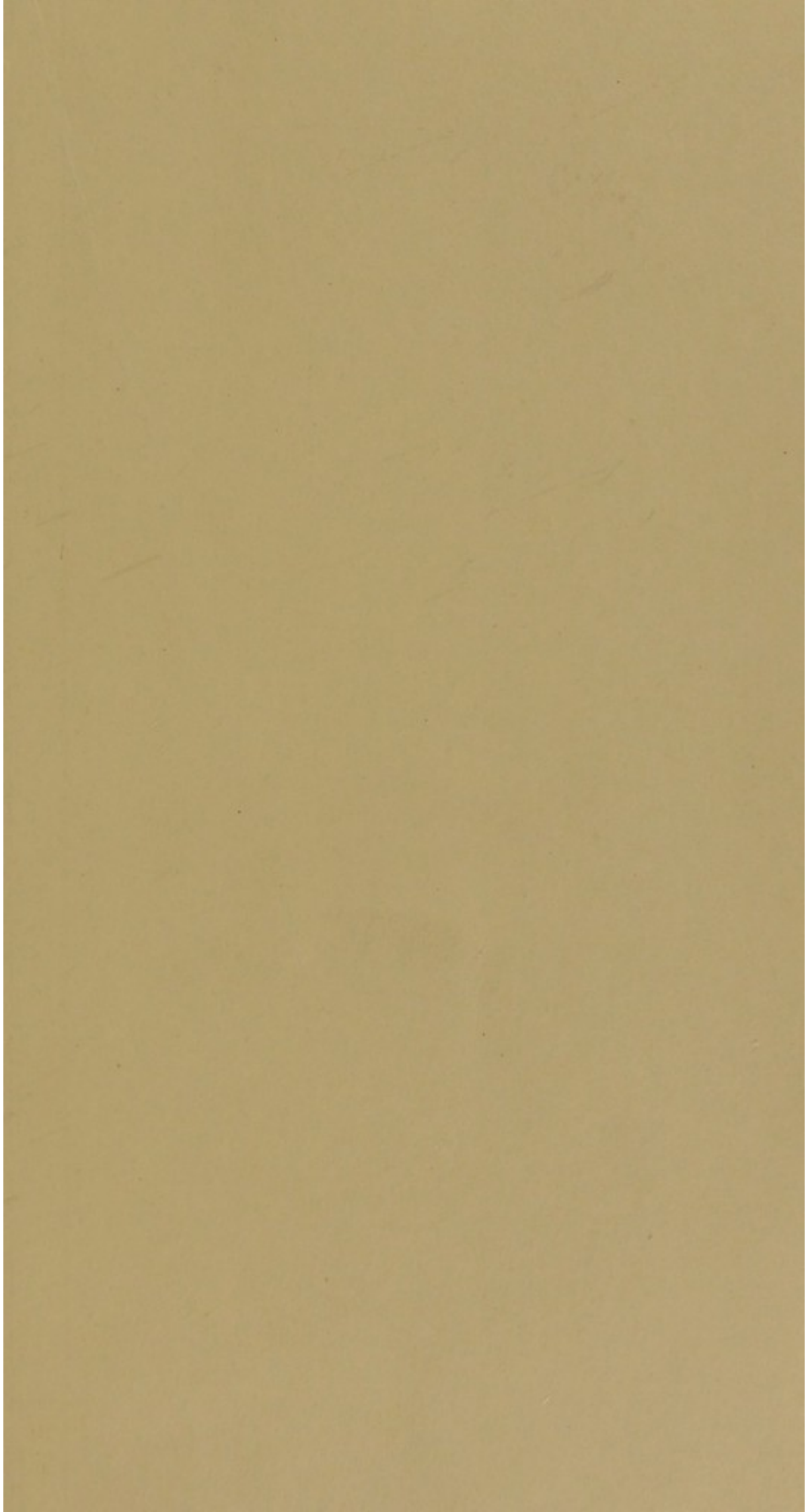
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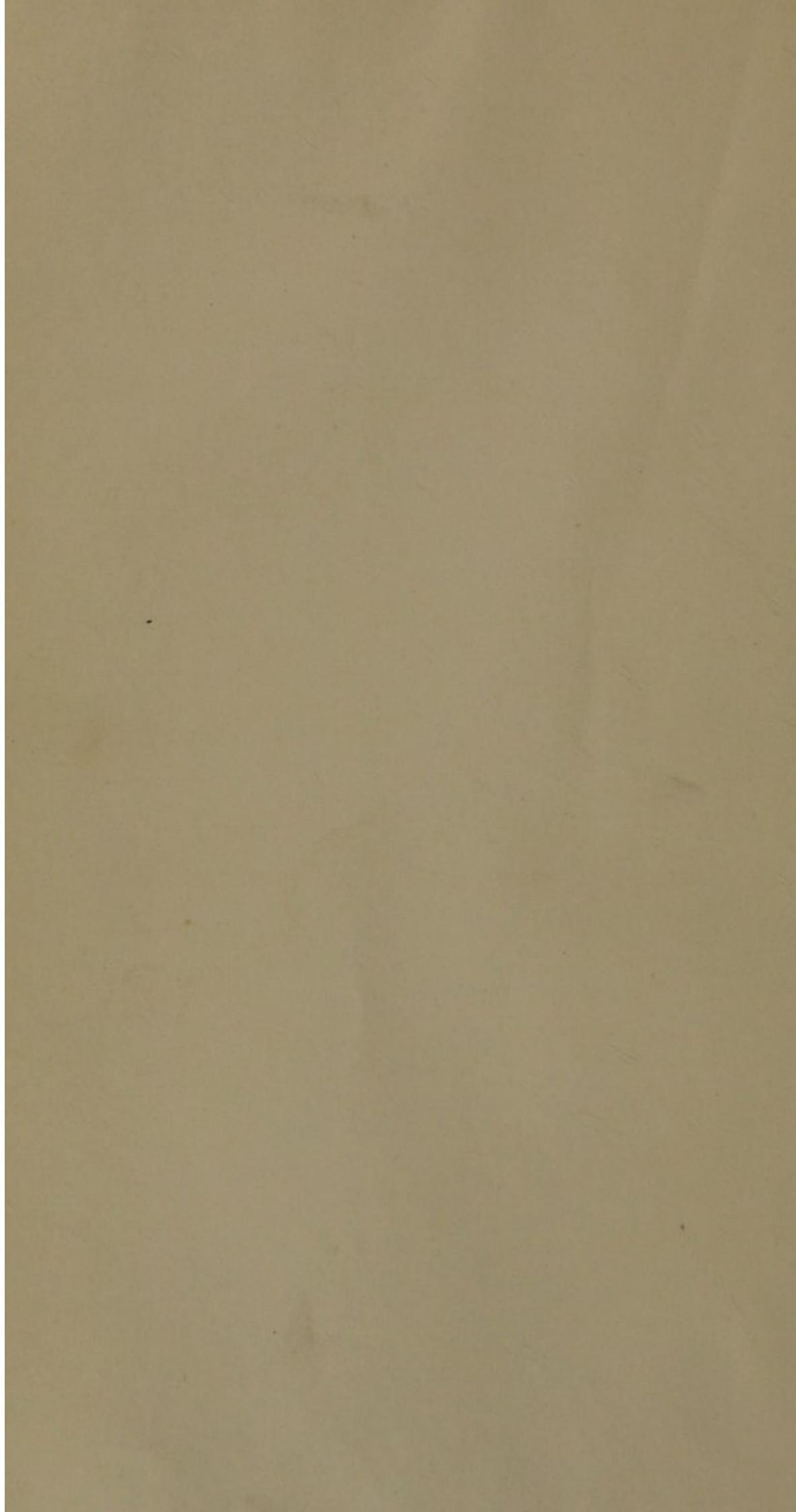
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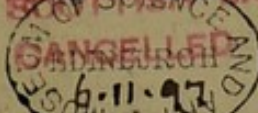
of the 19th March 1901



PHYSICAL AND CHEMICAL

E S S A Y S:

ROYAL SCOTISH MUSEUM



18. 8.

TRANSLATED FROM THE ORIGINAL LATIN OF

SIR TORBERN BERGMAN,

KNIGHT OF THE ORDER OF WASA, PROFESSOR

OF CHEMISTRY AT UPSAL, &c. &c. &c.

By EDMUND CULLEN, M.D.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS

AT DUBLIN.

TO WHICH ARE ADDED

NOTES AND ILLUSTRATIONS,

BY THE TRANSLATOR.

V O L. I.

L O N D O N:

PRINTED FOR J. MURRAY, N^o 32. FLEET-STREET;

AND WILLIAM CREECH, EDINBURGH.

MDCCLXXXVIII.

Quam ob rem, si qua est erga Creatorem humilitas, si qua operum ejus reverentia et magnificatio, si qua caritas in homines, si erga necessitates et ærumnas humanas relevandas studium, si quis amor veritatis in naturalibus, et odium tenebrarum, et intellectus purificandi desiderium; orandi sunt homines iterum atque iterum, ut missis Philosophiis istis volaticis et præposteris, quæ hypotheses thesibus anteposuerunt, et experientiam captivam duxerunt, atque de operibus Dei triumpharunt, submisce, et cum veneratione quadam, ad volumen creaturarum evolvendum accedant; atque in eo moram faciant, meditentur, et ab opinionibus abluti et mundi, caste et integre versentur.—In interpretatione ejus eruenda nulli operæ parcant, sed strenue procedant, persistant, immorentur,

BACO DE VERULAMIO.

300,080



TO THE
ILLUSTRIOUS
ROYAL SOCIETY OF
LONDON,

THIS FIRST VOLUME OF

E S S A Y S

IS DEDICATED,

AS A PROOF OF RESPECT,

BY THE AUTHOR,

WHO HAS BEEN A FELLOW

FIFTEEN YEARS.

WPSAL, 1779.

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1779

TRANSLATOR'S

P R E F A C E.

TO enlarge on the literary abilities of the illustrious Author of the following Work would be unnecessary: an assemblage of philosophical qualifications, very rarely found united in one person, has long since sufficiently established his reputation. But among the many endowments of this great philosopher, none is more conspicuous than the anxious concern he every where discovers for the advancement of human happiness, and the earnestness with which he applies the great powers of his mind to such points as may be immediately applicable to the uses of

life. He despises barren and unproductive speculation; he considers science as desirable only so far as it is beneficial; and proves himself, upon every occasion, not only the Teacher, but the Friend of mankind.

Works like those of Mr Bergman should have an universal circulation; they are written not to the scholar alone, but to the artist, to the manufacturer, and to the world in general. In presenting the following pages, therefore, to the English Reader, the Translator flatters himself he is acting in perfect conformity with the sentiments of the Author, and the duty which, as an individual, he owes to the community.

As the Author writes chiefly to those conversant in chemistry; and as it requires more than a moderate acquaintance with some of the latest discoveries, to be able to follow him through the whole of the Work; it has been judged necessary to add a few explanatory notes, such as may render the book useful to those who are only

only acquainted with the elements of the science. An Appendix is accordingly subjoined to each volume, which, though by no means necessary to the accomplished and experienced chemist, will, it is hoped, prove considerably useful to the general run of readers, and those who are but moderately skilled in the knowledge of the chemical principles and art.

Mr Bergman, in his experiments, has employed the Swedish thermometer: and it has not been thought expedient to reduce the temperatures, so ascertained, to Fahrenheit's scale in the body of the Work, because the degrees upon the Swedish thermometer are not reducible to integral numbers upon that of Fahrenheit; but, for the accommodation of such as chuse to compare them, a plate is inserted, containing the Swedish and the French thermometers, together with that of Fahrenheit, which is at present universally employed in England.

The Swedish measures being also so adjusted that they are not reducible exactly

to those of England, have been suffered to stand as in the original; but a table is given, which contains these weights and measures accurately reduced.

ADVER-

ADVERTISEMENT.

THE great distance of the Translator obliged the publisher to call in the assistance of another person to superintend the press. That person, being unacquainted with the translator's design of adding annotations at the end of the volumes, was induced to add a few inconsiderable observations, such as his recollection could furnish, during an hasty perusal of the MS. He, moreover, thought, that the addition of M. De Morveau's notes would be acceptable to the English reader. He accordingly has selected such as afford any new views of the facts related by the Author, or supply any experiment by which the text is illustrated. He has omitted several that did not seem to contain much useful information. That no blame might be imputed to the Translator, on account of these additions, he has been careful to distinguish those of M. de Morveau by his name: his own by the letter B. Those marked C. belong to the Translator; who has been obliged, on account of some domestic interruption, to defer the greater part of his remarks to the end of the second volume; which will appear without delay. The Author's notes and references are without a signature.

C O N T E N T S.

I. Of the AERIAL ACID. p. 1.

Quid verum — — curo et rogo, et omnis in hoc sum.
HOR.

This Dissertation was read in 1774, before the Royal Academy of Sciences at Upsal; and the year following it was printed in the 2d vol. of the New Transactions.

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II. Of the ANALYSIS of WATERS. p. 95.

Neque vero negligentiore se circa aquarum facultates cognoscendas exhibere convenit. Quemadmodum enim gustu differunt, et pondere ac statione, sic quoque virtute aliæ aliis longe præstant.
HIPPOCRATES.

The first seven sections of this Dissertation were publicly defended by J. P. Scharenberg of Stockholm, on the 26th of June, 1778.

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III. On the WATERS of UPSAL. p. 196.

Tales sunt aquæ, qualis terra per quam fluunt. PLINIUS.

The part of this Dissertation relative to the Mill-spring, was published in Swedish, after having been defended by P. Dubb, of Westrogothia.

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IV. On the ACIDULOUS SPRING in the PARISH of DENMARK. p. 213.

Iusta confessione, omnes terræ quoque vires aquarum sunt beneficii. Quapropter ante omnia ipsarum potentiae exempla ponemus. Cunctas enim quis mortalium enumerare queat?
PLINIUS.

This Dissertation was publicly defended by C. H. Wertmüller, of Stockholm, on the 15th of December 1773.

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V. Of SEA-WATER. p. 228.

Mari late patenti saporem incoqui salis, quia exhausto inde dulci tenuique, quod facillime trahat vis ignea, omne asperius crassiusque linquatur: ideo summa æquorum aqua dulciorem profundam. PLINIUS.

This Essay was printed in the Stockholm Transactions for 1777.

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VI. Of the ARTIFICIAL PREPARATION of COLD MEDICATED WATERS. p. 234.

Si quid novisti rectius istis, Candidus imperti; si non, his utere mecum. HORATIUS.

This Dissertation was inserted in the Stockholm Transactions for 1775; it was written in Swedish. I have seen a Danish translation.

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VII. Of the ARTIFICIAL PREPARATION
of HOT MEDICATED WATERS. p. 281.

*Emicant benigne passimque in plurimis terris, alibi frigida,
alibi calida, alibi juncta. PLINIUS.*

This Dissertation was inserted, in Swedish, in the Stockholm Transactions for 1778.

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VIII. Of the ACID of SUGAR. p. 305.

Magni omnino res fuit, naturæ latebras dimovere, nec contentum ejus conspectu introspicere et in Deorum Secreta descendere. SENECA.

This Dissertation was defended, on the 13th of June 1776, by J. A. Arvidsson, now master in philosophy, lecturer in chymistry, and a very dextrous experimenter.

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Intrandum est in rerum naturam, et penitus, quid ea postulat, pervidendum. CICERO.

This Dissertation was defended, on the 1st of April 1767, by G. Suedelius. It was translated into German; but I have not yet seen the translation.

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X. Of ANTIMONIATED TARTAR.

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Paucis utatur Medicus remediis, iisque selectis.

This Dissertation was defended by J. A. Level, on the
22d of December 1773.

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Opinionum commenta dies delet, judicia naturæ confirmat.

CICERO.

This Dissertation was defended by C. Norell, on the 23d of December 1775.

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OF THE
INVESTIGATION
OF
TRUTH.

THE great difficulty attending the investigation of truth, must be known to every man who has ever seriously attempted it. *Involutam veritatem in alto latere*, was long since observed by the experienced Seneca.

With respect to such historical facts as are remote from our times, modern scepticism frequently exceeds all bounds, and determines arbitrarily what are to be considered as fictions, what as misrepresentations, and what as omissions. But we shall soon cease to wonder at this; for if we undertake, on the faith of others, to explore facts, which, even with respect both to time and place, are at hand, and almost under our immediate inspection, (especially if we wish to learn the causes, motives, and connec-

tions of actions and circumstances), we are often confounded by the most contradictory narrations, infomuch that we have occasion for opportunity and laborious study, must divest ourselves of preconceived opinions, and be unbiased by any interested motives, in order to solve a number of difficulties, which owe their origin partly to ignorance, partly to negligence, and not unfrequently to deliberate malice. Should a number of historians even agree concerning a fact, yet the different descriptions of it will, to a certain degree, exhibit the characters of the respective authors :—Thus, while one relates an action with the most extravagant encomiums, another will detract from its real merit—a third, by some oblique insinuation, cast suspicion upon the motive of it—and a fourth represent it as a crime of the blackest dye. But to quit this line of inquiry.—It may be expected that we should find things otherwise in physics, and that, though we may not be able to dive into the thoughts of men, the phænomena exhibited by nature would be liable to no such ambiguity.

So indeed it might seem, did not daily experience fully evince the contrary. Among the most celebrated expounders of nature, how many divisions have there been? how many schisms? and what numbers do we find springing up every day?

But

But when we examine these disputes more minutely, we shall find that they relate not so much to facts, as to explanations. The labour of the natural philosopher is chiefly employed in endeavouring to discover the means and the methods made use of by Nature in her operations, (that is, causes and their connections), and from thence to form what is called a theory; and upon this point has arisen wonderful dissension.

Des Cartes, assuming matter and motion, and thus beginning *ab ovo*, constructs the world, imagines certain forms and affections of bodies, and, led away by a sublime imagination, connects and demonstrates mechanically, *a priori*, every phænomenon and every operation. A stupendous work indeed, were it but conformable to the system of nature, which it undertakes to explain; but, upon comparison, so great a disagreement appears, that in circumstances where, according to the principles of the inventor, the most powerful cause is operating, there, in reality, is the smallest effect produced; and reciprocally. This whole imaginary structure, therefore, being reared without foundation, has necessarily fallen to ruin.

The immortal Newton next appeared. This illustrious personage, rendered cautious by the failure of his rash predecessor, acknowledges that a conception of the theory of creation exceeds human powers: He therefore follows the

inverse method. He first solicitously collects facts; these he examines with accuracy, and compares with acuteness: Hence he deduces the laws of nature, and, from effects well established, he infers their causes. Thus he proceeds, more slowly indeed, but more securely; and though his method be tedious, yet it is continually leading to further discovery. An edifice like this, built on a solid foundation, becomes the more firm the higher it is raised.

Although, at present, it is universally agreed, that nothing is known concerning bodies *a priori*, but that their nature and different properties must be discovered *a posteriori*, by observation and experiment; nevertheless, in practice, there are still not a few who, if not publicly, at least privately, incline to Cartesianism. I call it Cartesianism, not because that method of reasoning was invented by Des Cartes, (for in the most remote periods of time, there have been philosophers who, confiding too much in their own strength, have expected to be able to discover the nature of things by abstract meditation); but I employ the names of Des Cartes and Newton as affording the most striking examples of the different methods of philosophizing.

I have said, that a tendency to Cartesianism still subsists; and, upon attentive consideration, it will not appear wonderful that the human
mind

mind should delight to indulge in this method ; for, on the one hand, the way of experiment is expensive, troublesome, and tedious. All minds, therefore, are not capable of enduring it : Many are without the proper instruments ; others want the necessary dexterity ; but the most universal defect is that of patience and perseverance ; so that if the experiment does not at once succeed, it is abandoned in disgust. Man, in his ordinary state, seems by nature prone to indolence. On the other hand, the contemplative method favours the desire of knowledge ; by pretending to unlock the secrets of nature with ease and expedition, it soothes the natural rage of explaining all things ; and, by supposing every thing accessible to the human intellect, administers pleasing flattery to vanity and arrogance.

At present, however, the necessity of experiment appears so obvious, that no one can deny it, without exposing himself to ridicule. It is therefore acknowledged, but with a tacit limitation. A number of experiments, made during a succession of ages, is collected ; and an accurate and attentive consideration of them is thought sufficient to unravel the chain of causes. Thus a philosopher at his table, surrounded with books, undertakes to penetrate the arcana of nature, and to deal out truths as if by inspiration ; and, without a laboratory, without a suitable apparatus, without expence, trouble, or

c 3

danger,

danger, pronounces concerning substances, which, far from examining as he should, he has never so much as seen. Nor has this invention even the recommendation of novelty; for, many ages since, Aristotle established experiment and reasoning as the two foundations of natural philosophy; but by means of the latter he miserably corrupted the former. In this way, at present, the purity of truth is corrupted by preconceived opinions concerning the genesis and metamorphosis of matter.—Opinions such as these, if modestly and candidly proposed as conjectures, might be useful, by giving occasion to new experiments; but are of the most pernicious tendency when obtruded as axioms; when they wrest such experiments as contradict them to a constrained agreement; or, if that cannot be done, impugn the truth of the experiments. Another evil has originated from favourite hypotheses, namely, experiments mutilated, and not to be relied on. He who is governed by preconceived opinion, may be considered as a person viewing objects through coloured glasses, each assuming a tinge similar to that of the glass employed. The slightest and most vague similitudes, if agreeable to the system, are sufficient, nay, afford arguments of the greatest weight; while differences of the most striking nature are disregarded as altogether nugatory.

The time which is employed in discussing these trifles, would surely be better applied in experiment and observation; a labour by which truth may be made to shine forth in full lustre, and due honour be given to science, which now (tarnished by contradictions and dissensions) is, if not totally despised, at least suspected by those who are incapable of deep inquiry.

Add to this, that, even in natural philosophy, the turbulent passions of the mind are not always idle: Sad experience has shewn us the most beautiful inventions brought into contempt, and the highest merit blasted, by malignant clamour. But our business is not with those who are wilfully blind to truth; to argue with such would be to tell tales to the deaf.

Since then truth is, or at least ought to be, the end of every investigation, to obtain this end with ease and expedition—*hoc opus, hic labor*,—I think it therefore necessary, at the beginning of this Collection of Essays, to explain to the reader the principal rules which, in the progress of them, I laid down for myself. In the examination of any body, two circumstances are chiefly to be considered, namely, *the composition of that body*, and *the explanation of phænomena*.—These two we shall consider separately.

I. (A) *In investigating the principles of a body, we must not judge of them from a slight agreement with other known bodies, but they must be separa-*

ted directly by analysis, and that analysis must be confirmed by synthesis.

It is well known that bodies, by composition, acquire new properties, which did not appear in any of the component parts separately; and, on the contrary, some of the original properties decay, or even disappear: Hence it appears how little analogy is to be trusted to.

Thus, although terra ponderosa and magnesia agree with lime in this particular, that, when united with aerial acid, they effervesce with other acids; and that, when it is expelled, they become caustic, we are not hence to conclude that lime is contained in those substances. This analogy is certainly a loose one, and, when rightly considered, only shews that the aerial acid possesses the property of uniting with a variety of substances, and that by its presence causticity is repressed. If we were to deduce conclusions from this analogy, then the alkaline salts must contain lime, as they also effervesce with acids, and, in similar circumstances, exhibit a much greater degree of causticity.

The history of the learned world shews us the absurd arguments which were formerly made use of against the existence of the fossile alkali, which is now acknowledged by every one to exist distinct from the vegetable alkali, inasmuch as, when combined with the acids, it never fails to produce salts of a different sort. In the same manner

manner terra ponderosa and magnesia, with acids, yield salts very different from those produced by lime with the same acids: We may therefore conclude these to be distinct substances.

That perhaps they contain a lime somehow changed, I will readily acknowledge, as soon as lime can be extracted from them, or they can be converted into lime. Conjectures the most plausible are yet at a distance from truth, and, upon close examination, are frequently found altogether repugnant to it.

What has now been said holds, *mutatis mutandis*, of aerial acid and the acid of sugar; as also of nickel, cobalt, and manganese.

In general, any body which differs in properties from every other, and can be always had *similar to itself*, I consider as a different and distinct body, although it be produced by another known body; for properties new and constant cannot spring up, unless the primitive be changed by the addition or subtraction of some principle, in which case it is not the same body as before.

(B) *Analysis should chiefly be conducted in the humid way.*

I do not deny, but that the dry way may sometimes be useful, and ought to be employed; but, in most cases, fire tends rather to confound than to separate different substances.

Some

Some contend that matters extracted by menstrua are changed, and that they had existed in the decomposed body in a state very different from that in which they are found after the decomposition; but, let us not rest upon vague assertion; let us inquire into the truth by experiment, and our doubts will soon vanish:—Let us dissolve a given quantity of pure chalk in marine acid; let this again be precipitated by a fixed alkali; and if this alkali be mild, the chalk is recovered entirely similar to itself in properties and in weight: But, if the alkali employed be caustic, not more than half the weight is obtained, and the precipitate agrees with lime burned and slacked; for it is soluble in water, and raises no effervescence in acids. This experiment, if repeated an hundred times with the same chalk, will always afford the same product. The same thing is true of terra ponderosa and magnesia, and also pure clay, of which the weight, however, is scarce sensibly altered by a difference in the precipitant. The same holds in the other acids. Let us now dissolve some metal, precipitate with a fixed alkali, and we shall have a calx of that metal; but, if we precipitate with another metal, we shall recover the dissolved metal itself, only very minutely divided. Mild alkali, in certain cases, produces a much heavier calx than the caustic, namely, when the calx absorbs the aerial acid: Besides,

the

the different acids occasion, in this case, no other difference than a greater or less privation of phlogiston. These things, of which no one conversant in chemistry is ignorant, being known, let us suppose either lime, magnesia, clay, or iron, extracted by any acid menstruum; I ask, can we reasonably doubt whether these substances actually existed in the body subjected to the experiment, or not? From the qualities of the integrant body, it will easily be judged whether these have entered into its structure, mild or caustic; in the form of a calx, or in that of a metal.

Upon this occasion, I must mention the inveterate error concerning the origin of vegetable alkali by fire. The silly and absurd reasons on which they denied the prior existence of that salt, may now be retorted upon the authors.

(c) *Such experiments should be instituted as are adapted to the discovery of truth.*

Light is thrown upon a subject not by the multitude, but by the quality of experiments: Most commonly many different points are to be illustrated, and then the experiments should be varied according to circumstances, so as clearly to ascertain the point in question.

For example, in examining the mineral fluor, one question arises concerning the acid inhering in it, another concerning the basis. To obtain the first, pure vitriolic acid must be applied in
less

less quantity than is sufficient to expel it all, and a degree of heat applied less than what is sufficient to volatilize the vitriolic acid. In examining the base, the fire must be more intense, and a large quantity of vitriolic acid poured on, that no part may escape its action, which, mixed with the base, might obscure its true nature: Thus, unless the operations and the means be adapted to the end proposed, we only every day accumulate mistakes.

(D) *Experiments should be made with the utmost possible accuracy.*

Experiments which are only carelessly and slightly observed, frequently either do not illustrate the truth, or establish errors. By weight, by measure, and other fit means, all the principal circumstances should be settled, and all the phænomena carefully observed. With respect to facts, indeed, which are collected by experiment, no dispute can arise, as they may at pleasure be appealed to, and considered in every point of view with sufficient care. The case is otherwise with those circumstances which depend solely upon the operations of nature; for these, if the fit time be neglected, do not again occur, but accidentally, or perhaps after an interval of years. “*Fronte capillata, post est occasio calva.*” In many cases, however, imitation may be able to diminish that interval.

I am

I am almost ashamed to relate, that I knew a chemist who considered thermometers, and such instruments, as physical subtleties, superfluous and unnecessary in a laboratory. It is beyond a doubt, that the most minute circumstances have their efficient causes; and these causes, for the most part, are so interwoven with the more powerful ones, and so moderate their efficacy, that, without the former, the whole effect cannot be appreciated. In natural philosophy, no observations are trivial, no truths insignificant. That which to us is barren, is often so for this reason only, that we do not sufficiently know, nor sufficiently examine it. How many millions had uselessly beheld the falling of a pear; yet, to Newton, this most common of all phænomena suggested the theory of gravitation.

(E) *The experiments of others, particularly the more remarkable ones, should be candidly reviewed.*

We should never distrust the experiments of authors of credit; but I hold it useful to have new inventions confirmed by many witnesses in different places, which opens a wide field to industry.

It must be confessed, that many things occur which are more clearly and better understood by being seen, than by the most exact description. In repeating any of Margraaf's experiments, I never entertained even the smallest doubt of the event. The accuracy, the dexterity,

rity, and sound reasoning of that chemist are known to every one instructed in these matters; nevertheless, I have repeated many of them, not without advantage. He who, at his desk, meditates on the saccharine acid, readily concludes it to be sugar dissolved in the nitrous acid, and afterwards crystallized; but, better instructed on making the experiment, he changes his opinion, and learns not to give judgment rashly upon the experiments of others.

One thing particularly necessary is candour, in observing with equal eye those facts which controvert our opinions, and those which favour them. It is well observed by the celebrated Morveau, that we never profit more than by those unexpected events of experiments which contradict our analogies and theories: It often happens, however, that he who sees the better, follows the worse. Thus he who denies that the earth of vegetables, separately taken, is not a compound body, yet grants that a part of it is soluble in acids, confutes himself with his own argument; for, of an homogeneous mass, either the whole or none must be taken up.

II. The phænomena of a body, either considered by itself, or in reference to other bodies, have their foundation either in the body itself, or in external circumstances. The explanation of these, then, must be sought for,—“*bene scire,*
“*est*

“*est per causas scire.*” These being rightly known, the nature and properties are clearly understood, and may be moulded to our wish. The greatest care, however, must be taken not to embrace falsehood for truth—therefore,

(A) *In the investigation of causes, we must begin by phænomena sufficiently varied, and well observed; and proceed in order, from proximate causes to the more remote.*

The quantity and quality of a cause are to be judged from its effect; hence the better that is known, the more nearly can those be determined. This way is extremely laborious and troublesome, and, besides, very tedious; inso-much that we are often found to confess the cause of this or that phænomenon to be yet unknown: But the laws by which a cause is governed in its operations, being once established, we are at liberty, in many cases, to assume the cause, as if known; and I had rather, with Newton, ingenuously confess my ignorance, and know few things, but these certain and determinate, than, with Des Cartes, explain every thing upon forged or false principles. Cicero long since said, “*præstat naturæ voce doceri quam ingenio suo sapere.*”

By how trifling an appearance, if it be a pleasing one, we may be deceived, the following example will shew:—It is known, that lime, well burned, has lost the property of efferves-

cence

cence with acids. This phænomenon is troublesome to many who deny the existence of aerial acid. At length, however, an evasive expedient was supposed to be discovered, namely, if burned lime be put into highly concentrated acids, a visible effervescence is said to take place, which, when the acids are weak, cannot be seen, as the substance, being dried by the fire, readily absorbs them. In order to clear up this mistake, it is only necessary to observe the phænomena with accuracy:—Let a small glass vessel be filled with nitrous acid, throw into it a piece of chalk, immediately innumerable bubbles are emitted from its whole surface, which continue while a single particle remains visible; during this violent agitation a thermometer, dipped into the glass, shews not the slightest alteration of temperature (*a*). Whether the acid be diluted
or

(*a*) M. Morveau, in a note, which I have translated (see p. 38), truly observes, that when chalk is dissolved in a concentrated acid, heat is produced. The author himself (*Opusc.* vol. iii. p. 64.) says, that calcareous earth, while it was dissolving in nitrous acid, raised the liquor in the Swedish thermometer from $+14^{\circ}$ to $+20^{\circ}$, and lime, not slacked, from $+14^{\circ}$ to $+84^{\circ}$. He attributes the mistake in the text to his having made the experiment with too small a quantity of materials, and having employed a thermometer not sufficiently sensible.

or concentrated, the same phænomena occur.
Let now the experiment be repeated, only, in-
VOL. I. d stead

In the same note, M. Morveau gives an explanation, undoubtedly erroneous, as I have there observed, of the heat and cold produced in chemical experiments. Sir T. Bergman has assigned the true theory in his third volume. He has deduced it from the different quantity of *specific fire*, or, according to his mode of expression, of *matter of heat*, contained in different substances: "The menstruum," says he, "destroys the present aggregation of particles, and a new compound is formed, which sometimes fixes a greater quantity of the matter of heat than the former compound; in this case, in order to restore the equilibrium, the heat in the contiguous bodies must undergo a diminution, and the liquor in the thermometer will of course descend: If the new compound fixes a smaller quantity of the matter of heat, the surplus will be let loose, and flow into the contiguous bodies: When the quantity of heat is the same in both compounds, (which seldom happens), the thermometer will not be at all affected."—Mr Kirwan has lately given nearly the same explanation of these phænomena, in the Philosophical Transactions. Evaporation must be taken into the account: Wherefore, in the last case supposed by Professor Bergman, the liquor in the thermometer must fall a little. Mr Kirwan, if my memory does not fail me, intimates this circumstance, but does not expressly mention it.

Professor Bergman, I think, in more passages than one, observes, that the great difference of heat in a solution of aerated and caustic calcareous earth, is a proof that this earth, when it yields its air, fixes a quantity

stead of crude chalk, let an equal piece, well burned, be used : Let the acid be diluted, and, at first, a very few bubbles appear, but soon fall ; besides, in this case, a considerable degree of heat is produced, somewhat less than 100°.

If

quantity of the matter of heat ; but he who reflects how much of this active fluid must be absorbed by the aerial acid, as it passes from its solid to its fluid form, will easily be persuaded that this consideration will explain much of the difference. The specific fire in the compound of nitrous acid and calcareous earth is, doubtless, in both cases equal.

Those who are acquainted with the usual order observed in printing books, know that prefaces, preliminary dissertations, &c. pass through the press last. This circumstance obliges me to place here an observation which refers to page 48. I have there ventured to reject both the author's and the French annotator's hypotheses respecting lime too much burned, and to offer another explanation. Since that note was written, the third volume of the *Opuscula* has fallen into my hands, in which I have found that the author himself has explained this phenomenon from the very same supposition.—“ It is most probable,” says he, “ that a strong heat, suddenly applied, and long continued, occasions a kind of fusion of many particles lying on the surface, *moleculæ—fusionis fere more in ambitu coalescere incipient, &c.*” The reader may now safely refuse to admit the author's first supposition, since more mature consideration has induced him to reject it himself. B.—But it is now certain that this semi-vitrification was owing to the admixture of argillaceous earth, which is very often contained in lime-stone.

If the acid be sufficiently concentrated (but not too much) at first, not only small, but even large and numerous bubbles arise, which, however, soon die away, and all visible motion stops, both in the calcareous mass and in the acid liquor. In this case, however, a very intense degree of heat is generated, which, if the piece be large, exceeds 100° .

From these phænomena, attentively considered, an explanation will easily and naturally be deduced. In the latter case, for instance, so much heat is produced, that the watery parts in contact with the burned chalk boil for some moments; but when the acid is diluted, only a few air-bubbles, which occupied the pores of the spongy mass, are discharged by the expansive power of the heat. In both, however, the motion is soon at an end. But, with the crude chalk, the motion continues until the chalk is totally dissolved: This motion is called effervescence, and must carefully be distinguished from ebullition.

(B) *A cause, any how indicated by phænomena, may for a while be assumed as true; and from it may be deduced the necessary consequences, which, being separately examined by suitable experiments, either confirm or overturn the position.*

This method has been often used to advantage in mathematics, and ought to be applied in natural philosophy, as a test for the examination
of

of various hypotheses and conjectures ; and we must confess, that a position, all the legitimate consequences of which are confirmed by experiment, may properly be admitted as true. In this case we have a problem indeterminate, of which the unknown quantities are sought by experiment.

(c) *Besides, the cause should, if possible, so be compared with the effect, that the exact relation may be discovered, even as to quantity.*

By this it will appear whether the cause alone be adequate to the effect, or whether it has been assisted. An instance of this kind occurs in the consideration of agriculture, where a question arises concerning the use of water in vegetation.

Finally, *I aim at giving denominations to things as agreeable to truth as possible.*

I am not ignorant that words, like money, possess an ideal value, and that great danger of confusion may be apprehended from a change of names ; in the mean time, it cannot be denied that chemistry, like the other sciences, was formerly filled with improper names. In different branches of knowledge, we see those matters long since reformed : Why then should chemistry, which examines the real nature of things, still adopt vague names, which suggest false ideas, and favour strongly of ignorance and imposition ? Besides, there is no doubt but that many corrections may be made without any inconvenience :

convenience :—If, instead of oil of vitriol, and spirit of vitriol, we used the terms *concentrated vitriolic acid*, and *diluted vitriolic acid*, I think that no one would be thereby either confounded or misled.

But, in describing new substances, it is necessary that names should be conformable to the nature of the substances. Thus, instead of *fixed air*, I use aerial acid, because that fluid is in its nature acid, and not only possesses the subtleness and elasticity of air, but either contains pure air, or some of its constituent principles ; for the purest air that can be got, on the accession of phlogiston produced this fluid, (the aerial acid) ; I could not therefore find out a name better adapted. Some think that this subtile acid is the same as phlogisticated vitriolic acid ; but whoever has seen and compared the two, cannot seriously defend that opinion.

Let me have permission to mention here an observation, which seems to indicate the presence of phlogiston in the aerial acid :—Pure vitriolic acid cannot be resolved into a permanently elastic fluid ; but, on the addition of phlogiston, an aerial fluid is generated, (totally different from the aerial acid), which is not condensed by cold, unless it touch water (*b*). The same is
to

(*b*) We have now much stronger and more direct proofs of this hypothesis ; and the experience of every
day

to be said of the nitrous acid ; but the marine acid by itself is resolvable into an aerial fluid. Now, as this last acid contains phlogiston as a proximate principle, as is demonstrated by analytic and synthetic experiments, it hence seems to follow, that the aerial acid contains the principle of inflammability : I say, *seems* to follow, for all things which are like truth, are not therefore true.

These few reflections it was proper to premise. Let the skilful and impartial determine with what success I have sought for truth in the following

day seems to add to the number. I shall not consider them here ; the last Essay in the third volume will afford a more favourable opportunity. I have in contemplation some experiments calculated to elucidate the question : If the results shall furnish me with any information, I will there lay it before the public. In the mean time, experimental philosophers would be well employed in analysing this acid : The solution of few problems will throw so much light upon the theory of chemistry. If the aerial acid shall be found to consist of dephlogisticated air and phlogiston, Mr Scheele's doctrine of heat must fall to the ground ; if not, it will be difficult, in the present state of chemical knowledge, to find arguments sufficient to overthrow it. B.—Mr Scheele's doctrine is now universally abandoned. The composition of fixed air, too, is become very problematical, since it has been discovered that water consists of vital and inflammable air, and since the existence of phlogiston has been rendered so doubtful.

following essays, and whether, as I endeavoured to avoid one rock, I have not split upon another.

Most of the essays contained in this first volume have already been published separately; but, as the copies were soon dispersed, and, moreover, as some were written in Swedish, some in Latin, and others in French, I have undertaken, at the instance of my friends, and more especially such as are foreigners, to collect them, and translate into the common language of the learned, those which were written in other languages. I have not disposed them in the order of the time in which they were printed; but I have rather endeavoured that the preceding should illustrate those which follow. I have, however, mentioned in a note the time of the first publication of each essay.

In the first volume I have inserted those essays which relate to salts; in the second, those which refer to mineralogy and metallurgy shall be comprized; the third shall contain the doctrine of attractions, together with the analysis of some organized bodies; the fourth, various matters relative to natural philosophy and natural history; and in the following I will publish, if God grant me life and strength, other chemical essays.

I shall be satisfied if the following experiments, which were instituted with all the accuracy

racy and fidelity that circumstances would permit, shall not be displeasing to those who, with me, seriously seek for truth. Of others, I neither desire the praise, nor fear the censure. I shall not be surpris'd if it shall appear that I have committed mistakes; but I wish they may be corrected as soon as possible. I myself will add, to the following volumes, whatever corrections or additions more accurate observation shall suggest to me. Those who shall attempt to obscure what is true, will find to their disgrace, that it will shine with greater lustre. Some things which, in one place, are barely mentioned, without any proofs being adduced, are fully proved elsewhere; for I have been anxious to advance nothing rashly. I therefore intreat those who shall examine my assertions, not to reject them hastily, but to consider the foundation on which they rest.

OF THE
AERIAL ACID.

ABOUT the year 1770, I communicated my ideas concerning the nature and properties of that elastic fluid, which, under the title of Fixed Air, exercises the sagacity and industry of the philosophers and chymists of the present age, to my foreign correspondents; among whom it is sufficient to name the celebrated Dr Priestly, who not only mentions my opinion in the Philosophical Transactions for the year 1772, but, in a new edition of his excellent Observations on Air, has confirmed it by several fine experiments. The Royal Academy of Sciences at Stockholm have, it is true, inserted in their Transactions for the year 1773, a short treatise of mine upon that subject. However, as the doctrine contained in it deserves the most accurate examination and the most minute and attentive consideration, I here republish it, confirmed by experiments and observations.

§ 1. *What is to be understood by the term
“ Fixed Air.”*

For the purpose of avoiding ambiguity, it is necessary to begin by explaining certain terms. The term “ Fixed Air” has been used in two acceptations, one more extensive, the other more limited; in the former it is taken for every elastic fluid set at liberty during the decomposition of bodies, by whatever means it is extricated, and whatever be its nature. These fluids, however, are far from being all of the same kind; for some are very susceptible of inflammation, others instantly extinguish fire. The rest differ not a little from each other; but all agree in this, that although very like to common air in many properties, yet they appear to have existed as it were fixed in bodies, and deprived of their elasticity, which they do not recover until the instant of their extrication: hence they have generally been distinguished from common air by the epithet *fixed*. If this denomination must be retained, I do not deny but that the general signification above explained agrees perfectly well with it; but the other more restricted sense has for some time obtained; and as it is in general use, I am under the necessity of adopting it in the following Treatise, denoting by it only that species of air which is found in alkaline earths and salts, extricable by
fire

fire or acids, and which issues in great quantities from many vegetables during fermentation. This, when properly depurated, possesses always the same qualities, and, as it evidently exhibits the properties of an acid, I call it (conformably to its nature) the Aerial or Atmosphæric Acid, the reason of which denomination will hereafter appear, particularly in § XXII. and XXIII.

That species of air which suddenly destroys animals, and is entirely unfit for respiration, is called Mephitic Air, such as is found in the cavern near Naples, called Grotto del Cane, and in many others. This pernicious quality is common to most elastic fluids which have been fixed in bodies; so that this denomination is nearly the same with that of *Fixed Air*, taken in the more extensive sense.

§ II. *How pure Fixed Air is procured.*

There are three different methods of obtaining fixed air:—It may be expelled with effervescence by a stronger acid (*a*); it may be expelled by a sufficient degree of heat; or, finally, it may be extricated by fermentation. We shall describe all these methods in order.

(*a*) The author in this place considers fixed air as an acid, which may be expelled from the substances with which it is united, by means of a stronger acid; and this extrication of fixed air is attended with an effervescence. C.

To the orifice A (Pl. I. fig. 2.) of a glass phial A B, let there be cemented, so that no air can escape, the crooked glass tube E F G; let the vessel be nearly half filled with distilled water; let there be added pellucid calcareous spar, coarsely powdered, until it almost rises to the surface of the water C D, through the funnel O, cemented to the orifice L, and imperfectly closed by the glass rod P; let concentrated vitriolic acid fall in drop by drop; upon which innumerable bubbles will instantly arise from the calcareous particles: in the mean time let the orifice G of the tube remain open, until the atmosphæric air contained in the upper part of the bottle, and in the tube, be entirely expelled by the more ponderous fluid discharged (§ XXIV.); let the orifice G then be introduced under the mouth of the vessel H G, filled with water, and inverted with its mouth beneath the surface of the water in the vessel M N.

This being done, numerous bubbles will rise into the vessel H I, which collecting above, by degrees force out the water. When the water is entirely forced out from the vessel H G, the extremity of the tube is to be removed, the bottle close stopped under water (*b*), and the air conveyed

(*b*) The design of passing the elastic fluid from one vessel to another, is merely to free it from vitriolic acid, whose attraction for water is so great, that, during its passage, it quits the fixed air, and unites with the water. C.

from

from it into another vessel Q R, of a size somewhat smaller : as a portion of the air is absorbed in its passage through the water, the aerial acid thus collected in Q R, will certainly be found pure, unless, perhaps, mixed with a small portion of atmosphæric air, which can scarcely have been completely expelled by the fluid extricated during the effervescence. If the vapour should contain any vitriolic acid, this last will certainly remain in the water, at least after the second passage through it.

If, in place of the vitriolic, the nitrous, muriatic, or any other acid (so diluted as not to smother (c)) be applied with proper care, the very same kind of air is produced, the strength and quantity of the acid must be so regulated, that scarcely any heat shall be generated. I avoid making use of chalk, as it almost always contains marine acid (d).

SECOND

(c) If the smothering, nitrous, or marine acid, be employed, it is obvious, that these acids, being in this state extremely volatile, will rise, in part, along with the fixed air, which consequently will not be pure. The caution against heat is founded on the same principle. C.

(d) If chalk containing marine acid be employed, the heat which vitriolic acid generates on mixture with water, will volatilize the marine acid, and consequently render the fixed air impure. C.

Mr Morveau having let fall a few drops of a solution of silver and mercury in the nitrous acid into distilled water in which chalk had been boiled, observed, that the former solution instantly clouded the water ; and that by the latter a small quantity of yellow precipitate was produced. I have

SECOND METHOD.

Let a retort of green glass, not above one inch in diameter, be provided, with a very slender neck; let the body of the retort be filled with magnesia alba, and placed in a crucible surrounded with gypsum, and the whole apparatus be set in a portable furnace contiguous to its side, so that the neck shall not be exposed to the fire; let a glass tube be luted to the neck of the retort very

repeated the experiment, with the same result, upon one specimen of chalk; but having boiled another in distilled water, I found that neither solution of silver nor the acid of sugar destroyed the transparency of the water. Mr Duhamel has long since remarked, that “during the combination of quick-lime with the mineral acids, a quick and penetrating vapour is discharged, which precipitates the solution of silver. This circumstance, added to its odour, led him to suspect that it was the marine acid.” See Lavoisier’s Essays.—In order to bring this suspicion of Mr Duhamel to the test of experiment, I boiled some quick-lime in water; and having precipitated the dissolved earth by means of fixed air, I filtered the water, and added solution of silver and acid of sugar, but the liquor was not rendered turbid by either of these tests. It is natural to suppose, that the marine acid generally contained in calcareous earth would be volatilized by calcination. That which I employed had been well burned: perhaps Mr Duhamel’s had not. If, therefore, this supposition be admissible, his observation will coincide with that of Professor Bergman. B,

closely,

closely, (so as not to give exit to the elastic fluid), and so bended, that the aperture of the vessel H I, inverted in water, may be hung over the extremity G; let the crucible then be made red hot, and suffer the air bubbles to fly off until the common air is dissipated; then let the air which afterwards comes over be collected in the vessel H I, as in the former method.

I make use of a small retort, both that the mass contained may easily acquire a due degree of heat, and that the quantity of common air lodged in its neck and the tube may be small: I chuse a glass vessel, as those made of earth have often disappointed me, by giving passage to the elastic fluid through chinks so small as not always to be discovered by the eye. Magnesia, when scarcely ignited, emits its fixed air with ease; whereas calcareous earth retains it with much greater obstinacy; so that if the latter be employed, a much more vehement fire is necessary: I surround the body of the retort with gypsum, that it may not flow by the violence of the heat, but, on the contrary, grow more refractory by the cementation, and acquire the properties of Reaumur's porcelain.

THIRD METHOD.

This method differs from the two former; for here the elastic fluid is produced by fermentation. It is nearly immaterial what fermenting mixture

we employ ; but I generally make use of the following : —

In a bottle, of which the capacity is 350 cubic inches, I mix 20 oz. of sugar, and as much of good yeast, with 200 cubic inches of water ; in six or seven hours, and in about 15° (*e*) of heat, the common air is generally expelled ; I then adapt the orifice G of the crooked tube to the mouth of the bottle H I, and bubbles immediately rise. The fermentation goes on equally well, if the tube be at first adapted to the neck of the bottle, the access of air not being necessary ; it is sufficient that an exit be allowed to the elastic fluid, as I have often experienced.

It is necessary to take care, in this as well as the former methods, that the tube E F G be not too long, as the difficulty of the process increases, in proportion to the quantity of air to be removed : let us suppose this resistance = R , and the elastic force of the fluid generated at one time = E , it is manifest, that if $R = E$ there will be no room for expansion, and consequently no disengagement can be effected, either by effervescence, by fire, or fermentation, as the following experiment may serve to shew :—

(*e*) In the Swedish thermometer, the space between the freezing point and the heat of boiling water is divided into 100 deg. ; so that 10 of these degrees are equal to 18 of Fahrenheit's scale. Wherefore, $15^{\circ} = 27$, and $27 + 32 = 59$. B.

Prepare

Prepare a strong bottle, nearly full of water, to which let chalk or crystallized alkali be added; let it then be filled with any acid, and quickly and closely stopped: at first, indeed, a few bubbles appear, but this appearance soon ceases, and the mixture remains clear, even for years, provided no exit is allowed to the elastic fluid, and such a portion (*f*) only be saturated, that the water can take up its fixed air; but the very smallest aperture immediately excites a most violent effervescence.

The air which is collected by the second and third methods may, like that got by the first, be washed (*g*); and by whichever of these methods (though so very different) it is obtained, it exhibits exactly the same properties.

§ III. *General Properties of Acids.*

Saline substances are usually distinguished from others by their sapidity, and solubility in water. Those which are specifically called acids, exhibit

(*f*) If so large a portion of the chalk or alkali be saturated, before the vessel is closed, that the water is not able to absorb the elastic fluid extricated by the saturation, the vessel will burst. It is necessary therefore to close the vessel very suddenly, or the experiment will not succeed. C.

(*g*) By passing it through water from one vessel into another. C.

very

very distinct characters, peculiar to themselves, which are now to be enumerated; of these the 1st, 6th, and 8th, are common to other saline bodies, but in a mode and degree very different.

1st, They very readily unite with water; 2d, They have an acid taste; 3d, They change the blue juices of vegetables to red; 4th, They have a very strong affinity with alkaline salts, and form with them compounds milder than either of the constituent parts, which are frequently disposed to crystallize; 5th, They dissolve several earths; and also, 6th, Some metals; 7th, They precipitate substances dissolved in alkalis; and 8th, They frequently attract inflammable matters strongly.

If, then, every one of these properties be found to belong to pure fixed air, properly collected and depurated, I hope its acidity will no longer be called in question. We shall therefore examine all these circumstances in order.

§ IV. *Aerated Water.*

Let the bottle Q R, filled with the pure elastic fluid (§ 11.) in a place where the thermometer stands but a little above the freezing point, be set in a vessel of water, with its mouth depressed, by means of weights, almost to the bottom of the vessel, that the union may be accelerated by the pressure; and the water will be found to rise by degrees, so that at the end of 8, 10, 12, or more hours,

hours, according to the size of the bottle, it will be filled with water, for the union will have completely deprived the fixed air of its elasticity. If after that a portion of the elastic fluid be introduced into the bottle, the water will rise but little, or none at all. In an heat of about 5° (*h*) water will absorb a quantity of fixed air, somewhat more than equal to itself in bulk; in 10° (*i*) a quantity scarcely equal; and in temperatures still warmer it absorbs a quantity so much the less, as the mercury stands the higher. The quantity necessary to saturation can hardly be determined with perfect accuracy, as the water, becoming heavier when saturated with the elastic fluid, sinks by degrees to the bottom, and leaves the space it before occupied to the lighter water, as would happen to any other saline solution.

This union may be effected, and that even in a few minutes, by other methods; for instance, if by agitation we encrease the number of points of contact.—But of this I treat more at large elsewhere (*k*), therefore have here only mentioned the most simple method.

The specific gravity of aerated water (to make use of a new expression) I found to be to that of distilled water, nearly as 10,015 to 10,000, the thermometer standing at 2° (*l*).

(*h*) 41° of F. B.

(*i*) 50° of F. B.

(*k*) Vid. *Analys. Aquarum*.

(*l*) 35° or 36° of F. B.

Water, therefore, and that subtile vapour of which we are treating, readily unite; but as the latter is very volatile, a great part of it flies off in the open air, and the quicker in proportion to the heat of the mass; in the mean time, as it diminishes, the remainder is retained more obstinately; so that boiling for half an hour is necessary, to discharge the whole. Congelation separates it readily and completely.

The air-pump, it is true, extracts bubbles from equal quantities of plain water and of aerated water, but a considerable difference is observed; for when a portion of the aerial acid is thus discharged, it may be easily discovered by the taste, the water being found to have a vapid, less acidulous, and less pungent flavour.

§ v. *Fixed Air has an acid Taste.*

As this air is in form of an elastic vapour, it can hardly be tasted by itself, at least distinctly; but if it be united with water, which is in itself void of flavour, being accumulated and rendered less volatile by this union, it readily affects the tongue with a weak but agreeable acidity. This is the real spirit of the cold mineral waters, which undoubtedly occasioned them to be called acidulous; and by means of which, together with a due proportion of suitable salts, we may perfectly imitate the Seltzer, Spa, and Pyrmont waters.

Such

Such artificial waters, I have now been using for eight years with signal advantage.

It is very remarkable, that water so cold as only to exceed the freezing point by a few degrees, though saturated with fixed air, gives out scarce any sensible flavour, but if set for a quarter or half an hour in 15° or 20° (*m*), it by degrees evolves its pungent and grateful acidity: nor is it difficult to account for this phænomenon, as it is sufficiently illustrated by the known properties of neutral salts, the more closely the two principles cohere, the less sapid is the compound; on the contrary, the looser their connection, the more sensible is the effect of the compound on the tongue: now in this case, as cold strengthens the union of the water with the air, and heat tends to loosen it, from thence the explanation of the phænomenon is easily derived.

But alkaline salts not only very quickly destroy the pungent flavour, but even make the water totally vapid, which it is not difficult to account for: if any portion of them be caustic, that is, not saturated with fixed air, (§ VII.) their producing the same effect, though in a slighter degree, even when they are fully saturated with air, seems to indicate that they attract fixed air more powerfully than water does, and have even the property of accumulating it, so as to be supersaturated; particularly as a few drops of the mineral acids re-

(*m*) $15^{\circ} = 59^{\circ}$, and $20^{\circ} = 68^{\circ}$ of F. B.

store the flavour of the water, by attacking the alkaline salts, and expelling the elastic fluid, which is therefore again absorbed by the surrounding water (*n*).

§ VI. *Fixed Air acts like a weak Acid.*

The acid nature of fixed air is discoverable by other signs besides its taste. If the water in the
bottle

(*n*) "This accumulation of gas in aerated alkali," observes Mr Morveau, "does not coincide with the laws of the crystallization of neutral salts: perhaps it would be better to say, that the union of the water and the salt loosens the combination of the latter with the fixed air. There is at least no proof that the restoration of the flavour, on the addition of the acid, is not solely owing to the fixed air, which was a constituent part of the aerated alkali, and is thus disengaged, according to Mr Venel's method." The law to which Mr M. alludes is not without exception. Cream of tartar and tartarus tartarificus, calomel, and corrosive sublimate, volatile vitriolic acid, and sulphur, are such obvious instances of the union of the same principles in different proportions, as should have made him more cautious of pronouncing on the improbability of a superabundant portion of fixed air combining with alkali. On this occasion it may not be impertinent to remark, after an ingenious teacher of chemistry, that there prevails very generally an inaccurate and unphilosophical way of conceiving and expressing such combinations as are mentioned above. Two bodies can hardly be imagined to combine in more than one certain proportion. How, then, it will be asked, are we to explain these instances?

bottle Q R be tinged with turnsole to a perfect blue, when fixed air sufficient to fill about the $\frac{1}{50}$ of the vessel has passed through it, it will be manifestly red: a saturated tincture of turnsole is ordinarily of a violet colour, but when sufficiently diluted loses all the reddish tinge, and in that state therefore it is particularly proper for this purpose.

In like manner, one part of water saturated with fixed air, makes 50 parts of the above tincture distinctly red.

This change of colour, however, occasioned by the fixed air, soon disappears in an open vessel, particularly if it be exposed to heat, or the rays of the sun; a circumstance which indicates the volatile nature of the acid that produces the change: a small portion of mineral acid, it is true, seems to yield a fugitive red, but when accurately examined, a fallacy appears, for the water abounds with the alkaline materials with which the turnsole juice has been prepared; these seize the mineral acid as soon as it is added, and give out their fixed air to the surrounding liquor,

stances?—By supposing that a compound becomes in this respect an element, and unites with one of its constituent parts, in order to form a new compound. Thus corrosive sublimate, which is itself formed by the union of mercury and another salt, unites with mercury to compose calomel. In the same way we are to conceive of the combinations of vitriolic acid and phlogiston, and of many others. B.

hence

hence a redness is observed, which vanishes when this air is evaporated.—Let us now suppose that the alkali contained in the liquor requires m parts of mineral acid for saturation, hence $\frac{m}{10}$ parts may be ten times added before the saturation is complete, and so often a fugitive redness will be produced; but after the saturation is completed, what is added will either at once produce a permanent red, or gradually change the blue to red; here then, it is obvious that the fugitive red colour is not to be attributed to the mineral acid, but to the fixed air.

Syrup of violets, and such other blue vegetable juices as I have hitherto tried, are not reddened by fixed air; the tincture of turnsole is of all known tinctures most easily acted upon by acids, therefore the slightest vestiges, which cannot by any other means be discovered, are by this tincture easily detected. Besides, all acids have by no means equal strength and efficacy: distilled vinegar makes syrup of violets red, yet is not powerful enough to cause any alteration in the colour of the blue paper which is used to cover sugar-loaves; and the colour of indigo does not yield even to the most concentrated vitriolic acid. Hence, though the aerial acid alters only tincture of turnsole, no conclusion is to be deduced from this circumstance against its acidity, all we can infer is, that it is weaker than the rest; on the contrary, we are confirmed in the opinion that its
acid

acid properties do not depend upon an extraneous acid; for if that were the case, this extraneous acid might be so accumulated as to overcome the more permanent blue colours.

It is also observable, that aerated water, free from every other acid, scarcely makes any change in the colour of paper tinged with turnsole, although it makes the tincture distinctly red; the reason is, partly because a sufficient quantity of this subtle acid cannot come at once in contact with the plane surface, and partly because the acid is in the former case at liberty to follow its natural tendency to volatilization (o).

§ VII. *Aerated vegetable Alkali.*

Let the mouth of the vessel Q R, filled with fixed air, be immersed under the surface of water nearly saturated with pure alkali of tartar, and the lixivium will gradually rise in the vessel; when it is at length saturated with the elastic fluid, let it be poured into a proper vessel, and set by in a dry place for some weeks, by that time crystals will be seen adhering to the sides and bottom of

(o) The aerial acid being diffused over the paper, presents a much larger surface to the contact of air, and is therefore sooner volatilized, than when, being mixed with the water, the surface of the water is the only surface of evaporation. C.

the vessel; such of these crystals as are regular appear to be quadrangular prisms, the apices consisting of two triangular planes, inclined to each other, somewhat like the roof of an house (*p*). The saturation of the ley may be collected from its not imbibing any more fixed air. If the water contains too much alkaline salt, crystals will be produced even in the bottle. The same alkali, dissolved in water, previously saturated with air, produces by crystallization similar figures; these crystals neither deliquesce in moist air, nor effloresce in dry, but always retain their transparency: they may not improperly be called aerated vegetable alkali, as those salts which are saturated with vitriolic acid are distinguished by the term *vitriolated*, joined to the name of that base with which the acid is united.—All substances saturated with fixed air I shall call hereafter, for brevity sake, *aerated*, thereby indicating that they contain that acid which is always present in common air (§ XXII. XXIII).

These crystals, in a moderate temperature, require for solution four times their quantity of water. On calcination they fall to powder, and lose $\frac{5.2}{100}$ of their weight, but by a slow dissolution in acids they lose $\frac{2.0}{100}$ only; hence it appears that in

(*p*) As two of the faces are much larger than the others, it would be as exact to define them parallelopipeds, of which the opposite sides have parallel inclinations. Morveau.

100 parts of these salts, there are 32 of water, 20 of fixed air, and 48 of pure alkali (*q*); hence it also appears that 100 parts of pure vegetable alkali require nearly 42 of fixed air to saturate them. Complete calcination expels both the fixed air and the water, whereas the acids, if properly applied (§ VIII.), expel the former only. However, in the present case, it is scarcely possible to expel all the fixed air by means of fire, unless by an exceedingly tedious and troublesome calcination. The principle on which the corrosive quality of alkaline salts depends will be explained in § XI.

The effervescence which these salts raise with acids, depends upon expulsion of the particles of fixed air by the superior power of the stronger acid, and upon the recovery, at the same instant, of their elasticity, which had been either lost or repressed; they must therefore rise to the top by their specific levity, and occasion a foam on the surface.

The taste of the crystals is indeed alkaline, but mild, and not at all acrid; if, however, by means of calcination, or, which is better, by means of quick-lime, they be entirely deprived of fixed air, they are converted into a salt highly acrid and corrosive, which is therefore commonly called caustic, and very readily deliquiates in the open air; the reason is, that it is now left to itself, and can

(*q*) For $48 : 20 = 100 : 41\frac{2}{3}$, or 42 nearly. C.

fully exercise its natural acrimony, which had been repressed and weakened by the union of fixed air. The same phænomenon takes place with the strongest acids, which being saturated with an alkaline or earthy basis, yield mild compound salts. Those who attribute causticity to phlogiston seem to have forgotten that by means of that substance the most highly concentrated vitriolic acid becomes a sulphur, totally void of acrimony; that by means of the same, the acids of vitriol and nitre are so weakened that they may be expelled by concentrated vinegar; and finally, that all acids are dulcified by spirit of wine (*r*).

The

(*r*) “ I am sensible of all the force of these objections; yet I will observe, First, That the vitriolic acid does not exist entire in sulphur, any more than the nitrous acid in nitrous air, or the phosphoric acid in phosphorus; that these acids do not combine with phlogiston till they have lost their air; and that they cannot resume their acidity till they have recovered their air, which is a constituent principle of that state.

“ On the other hand, it is no less evident, that a substance can yield those principles only which it contains: now the caustic alkalis evidently impart phlogiston to the precipitates of metallic solutions; and hence I have delivered it as my opinion, that alkalis and calcinable earths ought to be placed among those substances, perhaps more common than is generally supposed, which cannot be disengaged from all combination, and which do not lose one component part, but by the interposition of another principle
that

The caustic alkali, when pure, (by which I understand, deprived of its water, and particularly of its fixed air), if exposed to the atmosphere, attracts from thence moisture in such quantity as to be dissolved; and hence it is called oil of tartar per deliquium. This again is gradually saturated with fixed air from the atmosphere, in consequence of which it forms crystalline vegetations on the sides of the vessel.

There are to this day persons who insist that the vegetable alkali cannot be exhibited in form of crystals, notwithstanding that Professor Bohnius (s), of Leipzig, so long ago as the end of the last

that continues to adhere to them. (See *El. de Chémie. Dijon. vol. iii. p. 247.*). It will be seen in the sequel of this dissertation, that the author himself inclines to this opinion, since he admits a portion of the matter of heat in caustic earths and salts, of which even solution in water cannot deprive them." Morveau.—I think that the considerations here alledged do not much invalidate the author's objections to that opinion which attributes causticity to phlogiston. Causticity may perhaps be defined—that tendency to combination which matter in general possesses, exerted on the living and sensible body. Thus the causticity of acids seems to be in proportion to their power of combination, and that of neutral salts inversely, as the adhesion of the acid to its basis. But I beg leave to refer the reader to the article "Causticity," in the new edition of Mr Macquer's Dictionary, where he will find the subject discussed with the usual address of that elegant and perspicuous writer. B.

(s) See Bohnius, *Diff. Physico Chym. ann. 1696, p. 381.*

century, had demonstrated the contrary; but his method had been so long unknown, that it was lately offered to the public as a new discovery (*t*).

Although the vegetable alkali attracts fixed air very powerfully, yet it is difficult to obtain a complete saturation; for in proportion as the number of caustic particles is diminished, they are the more widely diffused through the fluid mass; hence it follows that they more faintly attract, and more difficultly meet with the elastic fluid, a circumstance which occurs in almost every saturation. During crystallization some particles still remaining caustic, fully the water of the crystals, as is seen from the colour of the precipitate of corrosive sublimate which this alkali produces. Thus pure fixed alkali precipitates a ferrugineous mercurial calx, but when fully saturated with fixed air, it precipitates a white one. The vegetable alkali, perfectly crystallized, precipitates a whitish calx, fullied with yellow particles; whereas, if these crystals be powdered, and exposed to the air upon bibulous paper for some days, they lose all their causticity, and precipitate sublimate in form of a white powder: this white colour depends upon fixed air adhering to the mercurial calx. — § XXI. Mercury dissolved in nitrous acid

(*t*) Hence we may see how far Mr Lavoisier is mistaken, when he asserts, that the original discovery of the crystallization of vegetable alkali belongs to Mr Duhamel, B.

produces different appearances, according to the different methods of preparation: thus, if the solution be effected in the cold, and with diluted acid, a considerable quantity of the phlogiston remains adherent; whereas, if fire be employed, a great part of it flies off in the red vapours: now the more the dissolved mercury is impregnated with phlogiston, the paler is the precipitate made by fixed alkali; and on the contrary, the less it is impregnated, the darker is the red colour it yields with caustic, and the more fullied the white one with aerated alkali.

In experiments which require great accuracy, I make use of alkali prepared from burned cream of tartar, as this is generally free from the marine acid, which, as well as the vitriolic, is in general mixed with salts elixated from vegetable ashes. All alkalis effervesce with acids, from which we may in some measure judge of their general nature; for the most part they are actually saturated with fixed air, that very subtile acid, which nevertheless is not powerful enough to prevent them from changing blue vegetable juices green; if however, on the other hand, the acid is superabundant, the alkali which it saturates does not prevent it from turning tincture of turnsole red, as any one may experience in water which is impregnated with fixed air, and at the same time holds dissolved an aerated alkali. But dry alkali of tartar seldom contains more than $\frac{2\frac{3}{5}}{100}$ of fixed air, $\frac{5}{100}$ of water,

water, $\frac{2}{100}$ of siliceous earth, and $\frac{70}{100}$ of pure alkali, of which $\frac{75}{100}$ would be in a state perfectly caustic if the $\frac{23}{100}$ of fixed air were absorbed by $\frac{55}{100}$ of the pure alkali, which it is sufficient to saturate, but as it is equally distributed through the whole, each particle wants $\frac{2}{100}$ (v) of its weight; which deficiency, for the reasons lately stated, will be made up but (u) slowly, and with difficulty, even in the open air.

§ VIII. *Aerated mineral Alkali.*

Fixed mineral alkali, which, when obtained from marine plants, is commonly called sal sodæ, is usually found so much loaded with fixed air, that without any further accumulation it naturally forms crystals with ten, or rather eight sides, of which opposite apices are for the most part trun-

(v) '23 of fixed air are sufficient to saturate '55 of pure fixed alkali; for (see p. 18.) $100 : 42 = 55 : 23$ nearly. I am inclined to think, that into the calculation of the deficiency of weight a typographical error has crept; for this deficiency, which Mr Bergman says will be recovered in the open air, can, I apprehend, amount to no more than '0, '06; for, if '23 saturate 55 parts, '70 will be saturated by $29\frac{3}{4}$, for $55 : 23 = 70 : 29\frac{3}{4}$, and $0,29 - 0,23 = 0,06$; and therefore I conceive the deficiency to be only $\frac{6}{100}$. C.

(u) Because all the particles are partly saturated, and therefore attract the saturating matter with less rapidity and force. C.

cated

cated (fig. 6.); and if it be rendered caustic by quick-lime, it may again, like the vegetable alkali, be saturated with fixed air, § VII.

100 parts of the fresh crystals contain of fixed air 16, water 64, and pure alkali 20, so that 100 parts of the pure alkali require, to saturate them, 80 parts of fixed air (*w*): this is the more extraordinary, as it is certain, that an equal weight of the vegetable alkali, though (*x*) stronger, requires no more than 42; but such is in general the nature of simple salts, that the stronger they are, the more easily are they saturated (*y*). The truth of this chymical paradox may be shewn in the following manner:—Let two bottles be provided, the larger containing a given quantity of alkaline

(*w*) According to Mr Lavoisier, the quintal of crystals of soda contains 63 lb. 10 oz. of water, 15 lb. 15 oz. of elastic fluid, and 20 lb. 7 oz. of saline matter. This analysis coincides nearly with that of the author: but Mr Kirwan (Phil. Trans. vol. lxxii.) departs widely from both. According to him, in 100 grs. of crystallized fossil alkali, there are 35 of alkali, 20 of fixed air, and 45 of water. Mr Kirwan thinks that the difference is owing to the two former chemists having used soda recently crystallized. B.

(*x*) By stronger we are to understand possessing the power of dislodging other alkalis from acids. C.

(*y*) This ingenious artifice affords a very easy method of ascertaining the quantity of fixed air expelled from an alkali by means of acids, together with the quantity of acid necessary to saturate that alkali. C.

salt dissolved in water; and let the weight of the solution, the bottle, and the stopple, taken together = A ; let the weight of the lesser, containing some species of acid, = B ; from the lesser bottle pour into the greater a quantity of acid, and stop both slightly; the effervescence being over, let more acid be poured in, and again stop the bottles, and so on until the saturation is complete; then let the weight of the greater = a , that of the lesser = b ; since then $B - b$ has been added to the greater bottle, the decrement of the lesser must equal the increment of the larger; that is, $B - b = a - A$; but this can never happen, unless the alkali be perfectly caustic, otherwise we shall always have $B - b > a - A$; and their difference $B - b - a + A$, indicates the weight of the fixed air expelled. The effervescence should be conducted gently, without heat, and in a bottle of proper size, lest some watry vapour should fly off with the fixed air, and render the conclusion erroneous.

Let the solution in the larger bottle be evaporated to dryness, and the residuum be gently ignited, in order to expel the water of crystallization, and the superfluous acid, if any there be. Let it then be weighed, and from the increment of weight in the given alkaline salt, and the weight of the fixed air expelled, we discover what quantity of acid is sufficient to saturate the fixed alkali, when freed from water and fixed air; by
this

this method I discovered that one hundred parts of pure mineral alkali require, to faturate them,

	Parts.
of vitriolic acid - - -	177
— nitrous - - -	135 $\frac{1}{2}$
— marine - - -	125
— atmosphæric - - -	80

and that one hundred parts of pure vegetable alkali require, for faturation,

	Parts.
of vitriolic acid - - -	78 $\frac{1}{2}$
— nitrous - - -	64
— marine - - -	51 $\frac{1}{2}$
— atmosphæric - - -	42

The quantities of fixed air before assigned to the mineral and vegetable alkalis agree precisely with this table.

What has been already affirmed of alkalis holds good of acids, deprived of their superfluous water: Thus 100 parts of vitriolic acid require

	Parts.
of pure vegetable alkali - - -	127 $\frac{1}{2}$
— mineral - - -	56 $\frac{1}{2}$
— volatile - - -	42

Cryftal-

Crytallized mineral alkali, in a dry air, loses its water, together with its transparency, and breaks down into a powder; it dissolves in a moderate heat in about twice its weight of water: besides, many properties of the vegetable alkali (mentioned in § VII.) belong to the mineral. The reason why it cannot, like the vegetable alkali, precipitate corrosive sublimate in a white powder, shall be explained in § XXI.

§ IX. *Aerated volatile Alkali.*

To obtain the volatile alkali regularly crytallized, I chose that which, being obtained from sal ammoniac by means of chalk, and a due degree of heat, is saturated with fixed air; I then saturated water with it in a closed bottle, and finally exposed it gradually to intense cold; notwithstanding which, I could not obtain figures perfectly regular—they seemed indeed somewhat octaedral, with four truncated angles.—See fig. 7. which exhibits the upper surface.

The caustic volatile alkali, prepared with quicklime, attracts water very vehemently; it is therefore always fluid, very penetrating, and exceeding volatile: by the method described § VII. it is easily rendered mild, and is to a certain degree fixed, and disposed to crytallize.

This alkali is weaker than the fixed; and therefore, according to the rule above mentioned, it should

should require a greater quantity of fixed air to saturate it: And experiments confirm the truth of this; for 100 parts of this alkali, when pure, take up near 105 of the aerial acid; and hence also it occasions a more violent effervescence with acids—100 parts of concrete volatile alkali usually contain 12 of water, 45 of fixed air, and 43 of pure alkali.

§ x. *Aerated Terra Ponderosa.*

That basis which, saturated with vitriolic acid, forms the spathum ponderosum (the marmor metallicum of Cronstedt, § xvii. xix.) bears a strong resemblance to calcareous earth; but as it differs in many particulars, it is necessary to make a distinction, until new experiments throw more light on the subject. The effervescence which this substance occasions with acids manifestly indicates the presence of fixed air: that I might be more intimately acquainted with this combination, I expelled the fixed air by burning; poured water on the residuum, shook it, and then filtered it—after it had stood a few hours in the open air, I saw the surface slowly covered with a cream, and all that was dissolved in the water separated by degrees, in the very same manner as happens with lime-water. This pellicle effervesces with acids; hence we may certainly conclude, that the principle which had been expelled by the fire is now restored:

red : by a sufficient degree of heat, 0,35 of the weight are lost, and the bottom of the vessel acquires a bluish colour ; but by slow solution in acids, not more than 0,07 are lost : hence it appears, that one hundred parts contain 7 of fixed air, 28 of water, and 65 of pure terra ponderosa. Water can take up about $\frac{1}{900}$ of its own weight of this earth in its pure state, and when saturated with it precipitates corrosive sublimate in the form of a yellow powder : it blackens merc. dulcis, and changes the colour of vegetable extracts, in the same manner as lime-water does. It is also to be observed, that this earth acquires solubility in water more easily, if it be separated from the nitrous acid by fire, than it does by being calcined alone. Although this earth, saturated with fixed air, will not enter into an union with common water, yet it dissolves in water impregnated with that subtile menstruum ; for water in that state takes up $\frac{1}{1550}$ of its weight, and even much more, if the earth be reduced to a powder as fine as that of a precipitate : this solution changes the red colour of paper tinged with Brazil wood, to a blue ; it heightens the colour of paper slightly tinged with turnsole ; but when the menstruum is superabundant, it reddens the tincture ; it scarcely changes paper stained yellow by turmeric root : in the open air, the superabundant menstruum gradually flying off, a crust is formed of the same kind as that occasioned in the former solution,

lution, by the same menstruum being attracted to saturation from the atmosphere (z).

§ xi.

Experiments show that the transparent calcareous spar, when exposed to a sufficient degree of heat, loses 0,45 of its weight, together with the property of effervescing with acids, at the same time that it acquires acrimony and solubility in wa-

(z) "Ponderous earth," says M. Morveau, "is hitherto but imperfectly known to the French chemists. Mr Monnet alone has paid attention to it: he found that the ponderous spar is far less fusible than gypsum; that the earthy basis forms, with the mineral acids, salts very different from those produced by the combination of the same acids with calcareous earth."—He differs widely from Sir T. Bergman on a point of some consequence; for he contends for the existence of sulphur completely formed in the ponderous spar; he asserts, that he has obtained liver of sulphur, by treating it alone with alkali in close vessels; he consequently considers it as a true earthy crystallizable liver of sulphur. On communicating to Sir T. Bergman this experiment and deduction of Mr Monnet, that chemist returned for answer, That he could not but allow that the ponderous spar may sometimes contain sulphur; but he considers the sulphur as an extraneous substance; in confirmation of which he observes, that it is only present by accident, and that the ponderous spar may be re-produced by synthesis, possessed of all its essential properties, viz. by combining vitriolic acid and ponderous earth. This answer seems decisive. B.

ter : the cause of this change has been of late the source of much contention ; but if I am not totally deceived, this dispute may now be decided, both analytically and synthetically. Thus, if, by the second method (§ 11.) we collect the volatile fluid expelled in burning, it, upon examination, is found to be no other than fixed air, and is equal in weight to about 0,34 of the crude mass ; the same loss is sustained by slow solution in acids, the remainder, which is $0,45 - 0,34 = 0,11$, consists of water necessary to crystallization, which may also be separated by a proper distillation. The prodigious velocity with which the fixed air flies off occasions it to carry off a small portion of watery vapour ; infomuch that the whole of the water cannot be collected in this way, unless by means of an apparatus adapted to that purpose. This analysis is fully confirmed by synthesis :—Let the bottle Q R be filled with clear lime-water, and let a sufficient quantity of fixed air be introduced through a very slender tube, so that it may be immediately absorbed ; by degrees the liquor grows turbid, and slowly deposits a powder, which effervesces with acids, is not soluble in water, and is void of acrimony, that is, possesses all the properties of lime-stone, which properties, together with the above-mentioned part of its weight, it loses again, upon exposure to fire.—It is with justice, therefore, that we consider calcareous matter as a neutral salt, of which crystals are of an obliquely paral-

parallelopiped figure, which is called spathaceous —of which the composition is such, that 100 parts contain about 34 of atmosphæric acid, 11 of water, and 55 of pure calcareous matter, quite freed from air and water.

Pure lime can be wholly dissolved in water; but we must take particular notice, that not only a considerable quantity of water is required, (as it scarce takes up $\frac{1}{700}$ of its own weight), but the water must also be completely purged of fixed air, by violent boiling for half an hour; for if the smallest portion of fixed air remain, it saturates more than its own weight of pure lime, which thereby becoming indissoluble falls to the bottom. If, therefore, any of the lime remains undissolved, it shews, either, 1st, a mixture of heterogeneous matters; 2d, That the lime is not well burned; 3d, That the water is unfit for the purpose; or, 4th, That it is used in too small a quantity. The 2d and 3d impediments are easily discovered, by the effervescence of the residuum with acids; nor will the detection of the other two give much trouble to an expert chymist.

Since then pure lime and fixed air separately are with ease dissolved in water, it may be asked, Why should not the compound be also soluble?—We have long since observed, that the accession of fixed air diminishes the solubility of alkaline salts and terra ponderosa; it shall now be demonstrated, that other acids produce the same effect.

Pure vegetable alkali is very deliquescent, and vitriolic acid retains water with such force, that it cannot be exhibited in a separate state by any means yet known; yet if these two be combined to the point of saturation, a neutral salt is produced, one part of which, in a moderate heat, requires 16 of water to dissolve it. This is one notable example, and upon inquiry hundreds more will occur.

We know that vitriolated vegetable alkali, gypsum, and other salts difficultly soluble, are more easily taken up by water, if it be acuated by an acid. May not aerated lime, therefore, be acted upon in the same way by superabundant fixed air? at least, if we admit fixed air to be an acid, we should expect such an effect; and upon experiment this appears to be the fact. Let a small portion of lime-water be dropped into water impregnated with fixed air, slight clouds are immediately formed, occasioned by the saturation of the lime by the fixed air: these clouds, however, disappear upon gently shaking the vessel, the lime being again dissolved by the superabundant fixed air. Put into a bottle, filled with aerated water, transparent calcareous spar, reduced to an exceedingly fine powder; let this bottle be kept well corked in a cool place for some days, and a part of the spar will be found dissolved: this solution, filtered through paper, by its superabundant fixed air reddens the tincture of turnsole (lime-water heightens

heightens its blue colour); it scarcely stains blue a paper tinged red by Brasil wood (lime-water occasions a deep blue colour); it does not change the yellow colour of turmeric (lime-water makes it ferruginous); in the open air it forms a cream upon the surface, as it is there the superabundant menstruum first flies off (whereas the cream of lime is to be ascribed to the attraction of fixed air from the atmosphere); finally, by gentle evaporation, it deposits an aerated lime, of about $\frac{1}{1500}$, its own weight, which to the eye, assisted by a glass, frequently exhibits the spathaceous figure (a).

It

(a) M. de Saussure has a curious observation relative to this subject:—he was analysing a sulphureous spring in the neighbourhood of Geneva. “A lucky accident,” says he, “presented me with a new and curious observation upon the calcareous earth held in solution by this water. I had been trying to separate by the filter the sulphur, which in the course of a few hours precipitates spontaneously, and renders the water turbid. I afterwards put that which had passed through the filter, and was rendered limpid, into a large bottle which had a ground stopple. It had remained quite full for a year in the same place of my study, when I wanted it for some other purpose; but before I threw away the water, I was desirous of seeing whether it had undergone any change. At the bottom I perceived a species of conferva of a green colour. In order to inspect this plant more minutely, I half emptied the bottle, and then shook it, in order to disengage the plant; which, notwithstanding, continued firmly attached to the bottle; but

It may perhaps be said, that it is in the fire the lime acquires its saline properties; many are still of that opinion; and it is certain, that this thesis may be so explained as not to contradict the synthesis and analysis above described: for, say they, the whole difference between crude lime and

in the mean time I perceived a great number of white, shining, oblong, and narrow laminæ, floating in the water, which drew all my attention. Having collected them carefully, I found that the longest were about half an inch in length, and $\frac{1}{24}$ in breadth, and of the thickness of a sheet of paper. The microscope shewed them to be formed by the junction of several transparent crystals, of which the prominent summits had the shape of a triangular pyramid, and exactly resembled the spar commonly called *pig's tooth* spar. I further found that these crystals were entirely soluble with effervescence in the nitrous acid, and that with the vitriolic acid they composed selenite; so that I could not doubt that they were real crystals of calcareous spar.

“ By scraping the bottom of the bottle, a concretion like tartar was detached, which I found to be composed of small crystals of the same shape and nature as those just described; but the laminæ formed by their junction, instead of being straight, were variously reticulated.

“ It was known before, that earthy crystals might be obtained by the evaporation of water, holding chalk in dissolution by means of fixed air. This interesting discovery belongs to Mr Achard of Berlin; but I believe there is no instance on record of such crystals formed in the water without the aid of evaporation. This fact, however trivial in appearance, seems to me of great importance with respect to the theory of the formation of the mountains in the midst of the waters.” B.

quick

quick lime does not depend upon the presence or absence of fixed air and the water of crystallization; for the lime receives in the fire the matter of heat (*b*), (the fixed air and water being previously expelled), by which the efficacy of its attraction is in some degree diminished; by this new union it is that it becomes soluble: but the causticity is to be explained entirely upon the loss sustained by means of the fire, as we shall soon see. Terra ponderosa, and all the alkaline salts, in the same way receive the matter of heat; and hence we understand how, by a double elective attraction, lime, dissolved in acids, and precipitated by caustic fixed alkali, is entirely similar to lime prepared by fire, and slacked in water. The heat which new-burnt lime generates with water indicates no more than a loose adherence of the matter of heat, which is repressed, and prevented from producing sensible heat, nearly in the same way as the properties of acids are rendered latent by their union with alkalis: but upon the access

(*b*) Numberless phenomena, which we cannot here consider, evince beyond a doubt that heat is the effect of a certain material substance.—It is sufficient here to observe, that the subtile matter of heat occurs in two distinct states; either it is at liberty, in which state it pervades all bodies, so that all attain the same temperature; or it is fixed by attraction, and does not exhibit sensible heat, until set free by some more powerful attraction.

of a sufficient quantity of water, the matter of heat is immediately separated by means of a stronger attraction, and, being thus set at liberty, communicates sensible heat to the superabundant water(c). If the lime be gradually slacked by the moisture of the surrounding atmosphere, no sensible heat is generated: but we must take particular notice, that lime, which generates heat with water, is scarcely deprived of all its fixed air; for the intimate nucleus, at least, is found still to effervesce with acids; and if this residuum be expelled, the lime becomes as it were dead and inert; and, although still soluble in water, it neither splits in slacking, nor occasions any heat. It may be here asked, How it comes, that by the intensity of the fire the faculty of heating is lost, while the solubility remains?—This is perhaps owing to the vehemence of the fire, to which the greatest part of the matter of heat, being very volatile, is obliged to yield. The workmen reject lime which is too much burned, as being useless, as it does not fall into powder, which is necessary

(c) Of all this there is neither proof nor probable presumption. The heat in this case proceeds from the water, which, in consequence of the attraction of the lime, becomes solid, and must therefore give out that heat or fire which, as we are taught by Dr Black, constitutes its liquid state. There is no fact which might lead us to suppose, that a great quantity of fire is fixed or rendered latent by quick-lime.

for

for mixing it; whereas lime less burned, in the instant of slacking, breaks into a powder: for in the latter case, the greater part of the fixed air being expelled by the burning, the bulk of the lime is indeed much contracted; but it yet remains of a very spongy texture:—water poured upon this readily penetrates it, sets at liberty the hidden particles of heat; and being by that heat resolved into vapour, breaks the whole mass to pieces, and reduces it to a fine powder. Lime, as well as terra ponderosa, and magnesia, and also the alkaline salts, when caustic, even after extinction in water, produce heat on mixture with acids, the residuum of the matter of heat, which water alone was unable to expel, being set at liberty; but these substances, being crystallized, produce no heat with acids (*d*).

All

(*d*) “When chalk, crystallized vegetable alkali, &c. are dissolved in concentrated acids, a very considerable heat is produced, a phenomenon which naturally ought to appear; because, without attending to the fixed fire, collision always produces heat. As the sum of the synchronous collisions is far less considerable, when diluted acids are employed, the cold occasioned by evaporation compensates, or even surpasses, the heat produced, as I have proved in the 2d vol. of the Dijon Mem.” Morveau.—Having never seen the relation of these experiments to which M. de M. alludes, and on which his opinion is founded, I cannot well judge concerning its validity: I am, however, somewhat inclined to suspect it; for if the heat produced by

All the circumstances mentioned in this section, as well as the preceding, (§ VII.—X.), being considered, or, for fuller conviction, being often put to the proof, I doubt very much whether causticity can with propriety be derived from any adventitious matter, especially as it may be explained simply and plainly by elective attraction, a power to which all bodies on this globe are found to be obedient; for the purer any matter, the more powerful is its effort towards an union with other substances; so that in this state, acting with undiminished force, it seizes with the greater vio-

the collisions be compensated or surpassed by evaporation, when a weak acid is used, an effect not very dissimilar ought to follow, when a more concentrated one is used; for in this case, the collisions being more numerous and instantaneous, the evaporation, and consequently the quantity of fire carried off in vapour, should likewise be more considerable: besides, it is scarce credible that the cold produced in some solutions can be owing to evaporation, it is so intense. I am therefore much more inclined to attribute, with Dr Black, the production of cold to the conversion of a quantity of absolute into latent heat. B.

To this it may be added, that the solution is not Morveau's, but Newton's; and that it rests upon a theory not received by Morveau himself, viz. That heat consists in a tremor of the particles of bodies: wherefore the French annotator is neither original nor consistent. The solution of the problem is perfectly easy upon Dr Black's principles. The combined bodies attract less fire than in their separate state; and therefore a quantity of that which was before latent must become sensible,

lence

lence those substances with which it has an affinity, and, if powerful enough, dissolves their former connection : hence it exerts a violent acrimony ; but as it is gradually saturated, its force becomes weaker, until a full saturation taking place, all this corrosive faculty vanishes, and can no other way be restored, than by expelling the saturating matter. The matter of heat rather represses than quickens causticity : it, however, represses it but imperfectly ; and hence the presence of causticity always indicates a powerful attractive effort, together with the absence of the substances for which the caustic body possesses a very violent attraction (*e*).

It

(*e*) “ The more chymistry is improved, the more numerous and cogent will be the proofs of this theory. But I will here add a few remarks to those upon § VII. — 1. as quick lime cannot be deprived of all the fixed matter of heat, it cannot be affirmed that its properties, in this state of combination, belong exclusively to one of its constituent parts ; 2, it is certain, not only that compounds, quatenus compounds, have their peculiar affinities ; but it is besides certain, that, in some cases, these affinities can be exerted only on compounds. Mr Bucquet has observed, that quick lime does not slack in fixed air, but it may be instantly slacked in aerated water ; which proves, that water is a necessary intermede to the union of the gas ; 3. the inertness of burnt lime seems very difficult to be explained. Sir T. Bergman’s conjecture appears repugnant to the general law ; according to which, every
body

It has already been said, that the most simple figure of aerated lime is that which is called spathaceous :

body that cools in any fluid always retains a portion of that fluid, as a crystallizing body always retains part of the liquor in which it was dissolved. I should therefore rather suppose that the violence of the heat must have destroyed part of those principles which this earth derives from organized bodies, and which constitute it calcareous earth." Morveau.—I am ready to allow that the author's conjecture is not very probable : but the annotator's seems also very vague and unsatisfactory, more especially if we consider that there still subsist doubts concerning the origin of calcareous bodies.—M. Buffon, and therefore, of course, the whole herd of French chemists and naturalists, contend, that they are the product of the accumulated spoils of marine substances. Mr Pallas and M. Saussure too, incline to this opinion : but a distinguished naturalist has of late combated this opinion, with arguments of great apparent weight. " Calcareous matters," says M. de Luc, " cannot have derived their characteristic properties from the spoils of marine animals ; 1. because those spoils must necessarily have been less abundant during the most remote times, and it was during those remote times, that the most considerable accumulations of calcareous matter were made ; 2. because those great accumulations, such as the calcareous Alps, contain a far smaller number of marine substances than many accumulations of a different nature ; 3. because calcareous matters have been found among *primordial* substances, that is to say, such as are prior to all those in which the probable effect of known causes can be recognised." So far M. de Luc.—With respect to the change produced on lime by calcination, carried too far, is it absurd to suppose that it
may

thaceous: I have, I imagine, elsewhere sufficiently explained how from this are formed the granatic, basaltic, and other figures (*f*).

§ XII. *Of aerated Magnesia.*

The magnesia which is found in the shops, although vulgarly called an earth, is yet of a saline nature; for in a moderate heat distilled water is capable of dissolving $\frac{1}{856}$ of its own weight; and analysis confirms this opinion, as it shews that the primary principles of magnesia, are a peculiar kind of earth saturated with fixed air and water. Common magnesia, by proper calcination, loses 0,55 of its weight, but a vehement and long-continued fire dissipates somewhat even of the earthy basis; by slow effervescence in acids, only 0,25 are lost: hence it appears, that 100 parts of magnesia contain about 25 of fixed air, 30 of water,

may arise from such an alteration as bears some analogy to an incipient vitrification? But in questions of so great obscurity, there are no bounds to the licentiousness of conjecture. B. — The inertness of lime is certainly often owing to an imperfect vitrification; and the imperfect vitrification to the impurity of the limestone, or to the admixture of clay. But, I believe, there are instances of lime slacking without that degree of heat which is generally observed. I know not if this depends on the same cause.

(*f*) Treatise on the Formation of Crystals.

and

and 45 of pure magnesia, which appears to be a true earth; at least, although blended with the matter of heat, I have never yet been able to dissolve it in water. Magnesia fully saturated with air, and crystallized, in 100 weight, contains 30 lb. of fixed air: the vapour which is expelled either by fire, or acids collected by the methods described § 11. and examined, exhibits all the marks of fixed air; in this instance the collection of the elastic vapour expelled by the fire in the bottle (§ 11.) is attended with the less trouble, as it is more loosely connected with the magnesia; whereas, it adheres very strongly to lime, so as to require a more violent fire: hence, when lime is used, it becomes necessary to provide a glass of proper thickness, and very difficult of fusion, and to surround it with powder of burnt bones, or gypsum, to prevent it from being fused. In general too, we may remark, that the greater the diameter of the body of the retort, the more difficult will it be to make the necessary heat penetrate to the centre; besides it will be necessary to increase the force of the fire continually, for if it at any time is remitted, the tube *C F E* draws up the water; this inconvenience is somewhat lessened by continuing the extremity *G* of the tube nearly to the bottom *H* of the vessel:—I have fitted up common tobacco-pipes for this purpose, and found them very convenient.

The greatest part of the magnesia which is
found

found in the shops is prepared by precipitation from Epsom salt ; but if the alkali made use of be well impregnated with air, the precipitation will be small, particularly in a large quantity of water ; for the fixed air, expelled from the alkali by the vitriolic acid, attacks the deserted magnesia, and dissolves it ; but by a boiling heat the superabundant volatile menstruum is dissipated, the magnesia is brought to the point of saturation, and almost all precipitates.

Water well saturated with fixed air dissolves, in a moderate heat, about $\frac{1}{300}$ of its own weight of common magnesia, and double that quantity, if it be as fine as a precipitate. This solution turns the tincture of turnsole red, but heightens that of paper slightly tinged by it ; makes paper tinged with fernambucum blue, but scarcely obscures the yellow colour of turmeric (for reasons assigned below, I do not make use of syrup of violets) ; upon the addition of an acid, innumerable bubbles appear : pure fixed alkali precipitates an earth which does not effervesce with acids, provided the alkali be used in quantity sufficient to take up all the fixed air, if in less proportion an effervescence takes place. If the alkali used be fully saturated with fixed air, it has no effect on the solution, unless the water be insufficient to hold both dissolved, in which case the magnesia separates. Pure volatile alkali also throws down a precipitate, but an effervescing one, as it can attract only the superabundant

superabundant air; with solution of corrosive sublimate it grows milky, and gradually deposits a small quantity of white powder; afterwards thin blackish crystals concrete, composed of mercurius dulcis, and a calx of mercury partially aerated. The smallest drop of a solution of mercury, made by heat in nitrous acid, occasions a copious yellowish brown precipitate: but the same solution, made without heat, yields a white powder, which after some days grows greyish, as in this case the metal has lost but a little of its phlogiston. These changes may perhaps be ascribed to a mixture of alkali adhering to the precipitate of corrosive sublimate, and which cannot be washed away: but this suspicion soon vanishes, for magnesia has the same effect, whether it be precipitated by fixed or volatile alkali; and besides, precipitates occasioned by volatile alkali, disappear in a few minutes, while those which depend on magnesia are permanent.

§ XIII. *Aerated Clay.*

Fixed air scarcely ever attacks pure clay, that is, the earth of alum dry and compact; yet the precipitation of alum by aerated alkali shews that it does not altogether refuse to unite with it, when sufficiently fine and comminuted; for the liquor, well filtrated, although clear, after standing a few days in the open air, and in a degree
of

of heat sufficient to expel the fixed air, grows turbid, and by degrees deposits a small portion of earth, which had been suspended by the volatile menstruum (*g*). Common clay, exposed to violent heat, gives out a quantity of fixed air several times greater than itself in bulk, mixed with a small portion of inflammable air, which comes off by the first action of the fire.

We have already compared (§ VIII.) the alkaline salts, with respect to the quantity which will saturate equal parts of the same acid; we shall here add numbers proportioned to the weights of the different earths dissolved by the same measure of marine acid :

pure clay,	-	1,0		
pure magnesia,	-	2,2	aerated	5,7
pure lime,	-	3,5	aerated	6,0
pure terra ponderosa,		8,7	aerated	13,5

(*g*) Professor Schreber, in a Collection of which he is the editor, (*Naturforscher*, ft. 15.), describes experiments upon a sort of *lac lunæ*, found near Halle, from which it appears to be argillaceous earth, saturated with aerial acid, and mixed with a very small quantity of calcareous earth. But there are substances to which this denomination is given, which certainly contain no clay, as any one may convince himself, by examining the *lac lunæ* that appears upon the face of the basaltic rock, called Salisbury Craig, near Edinburgh. And Mr Kirwan should not have represented *lac lunæ* as clay *saturated with aerial acid*, (*Mineralogy*, p. 71. 72.) without annexing some caution respecting the ambiguity of the appellation.

Here

Here follow the weights of absorbent earths, which can unite with 100 parts of aerial acid :

pure magnesia,	-	150	(§ XII.)
pure lime,	-	162	(§ XI.)
pure terra ponderosa,		926	(§ X.)

Therefore the law demonstrated (§ VIII.) of alkaline salts also holds good of earths.

Silecious earth eludes the force of fixed air, and all the other acids, except that of the mineral fluor. The more simple earths, therefore, being now considered with relation to the aerial acid, we go on to the metals.

§ XIV.

As far as I know, fixed air alone, in its elastic state, does not dissolve nor even corrode any metal, unless perhaps during calcination ; but when united with water it attacks some of them. Let iron-filings be put into aerated water, let the bottle (well stopped and inverted) be set in a cold place, and in twenty-four hours a portion of the iron will be found dissolved, so that the water will strike a purple colour with (h) tincture of galls, make syrup of violets green, and form, with phlo-

(h) I make use of spirituous tincture, as it is more efficacious than the watery tincture, and can be kept uncorrupted.

gified

gificated alkali, Prussian blue. If this solution be exposed to the open air, the surface which first loses the menstruum exhibits a party-coloured pellicle, composed of particles of iron, reduced to such tenuity as to reflect different colours; by degrees all the iron is separated in form of a subtile ochre, which amounts to nearly $\frac{1}{10500}$ part of the weight of the water, and when fresh retains so much of the principle of inflammability as to obey the magnet, and be soluble in the mineral acids:—Caustic alkali, whether fixed or volatile, separates this metal from the water, but when fully aerated has no effect.

Water, impregnated with the fixed air expelled by heat from magnesia or calcareous spar, or that collected from fermenting substances, scarcely takes up any calcined iron, except at the instant of its precipitation, when it is scarcely obedient to the magnet; but if the ordinary method of effervescence without washing be employed, the water is always contaminated with vitriolic acid; most commonly, indeed, so sparingly as not to change the colour of syrup of violets distinctly, though it reddens paper tinged with turnsole, which water loaded with pure fixed air is never able to do (§ VI.); and besides, a drop or two of solution of terra ponderosa in the nitrous or marine acids, acts as a very certain test, and by a slow congru-
mation detects even the smallest traces of vitriolic acid, which cannot so well be discovered by any

other means yet known. I am the more certain that this mixture is most commonly the cause of the solution of iron calx, as I have often, by adding it, produced this effect, which water fully aerated was unequal to ;—during calcination, indeed, the iron seems to unite with fixed air, but water can scarcely take up that compound.

§ xv. *Aerated Zink.*

Aerated water will dissolve zinc very copiously, either in its metallic state, or calcined by the process described in the foregoing section. The metallic solution, exposed to the open air, soon shews its surface, covered with party-coloured atoms of zinc ; whereas, that which contains the calx appears more obscure, with less variety, and less resplendency of colour. The pellicles which earthy and metallic bodies dissolved by aerated water yield, on exposure to open air, nearly agree with those which appear upon evaporating solutions of other salts, as in both instances the necessary quantity of menstruum becomes first deficient on the surface.

Alkali, when perfectly caustic, as also tincture of galls, and phlogisticated alkali, precipitate the metal of a yellowish ash colour. Alkalis fully aerated produce no effect ; but as those in common use possess some degree of causticity (§ vii.), they are not entirely inactive.

§ XVI. *Aerated Manganese.*

That semimetal which is found in the magnesia nigra, or glass-makers magnesia, and which seems to be distinct from all the other semimetals hitherto known, I call manganese. Aerated water takes up the black calx of this metal, but far more copiously the regulus, in such a manner however that it also takes up the iron which is mixed with it. If the regulus be employed, the solution diffuses a particular smell, not unlike that which proceeds from burned fat; but the precipitate and pellicles are the same as above described, except as to colour, which is generally influenced by the presence of iron: moreover, phlogisticated alkali precipitates pure manganese of a yellowish white, and tincture of galls produces nearly the same colour.

§ XVII. *Union of Fixed Air with other Metals attempted.*

The metals above-mentioned are easily dissolved by aerated water; whereas some of the others cannot unite with it, except when divided, as in the very instant of precipitation; and most of them cannot, even by this artifice, be brought to do so. The following metals I put into aerated water, and kept them in bottles well stopped and

inverted, in a cool place, for eight days, at the end of which time I examined them: viz. gold leaf, aurum fulminans, platina, silver leaf, mercury, Æthiops mineral prepared without heat, turbeth mineral, granulated lead, calcined copper, granulated copper minium, cerusse, leaf tin, calcined tin; as also the semimetals bismuth, nickle, arsenic, cobalt, and antimony, both reguline and calcined;—the water of each bottle was filtered through paper into a separate vessel, and was found still to retain all its fixed air, for it reddened the tincture of turnsole as before; but most of them shewed no signs of solution having taken place. The bismuth indeed, the cobalt, and the antimony, both reguline and calcined, as also the regulus of arsenic, in the open air, shewed exceeding thin party-coloured pellicles, which could hardly be observed; but on the addition of caustic alkali, they exhibited slight clouds, and produced, with tincture of galls, a violet-coloured precipitate, so that I could scarcely doubt but these phænomena were owing in a great measure to an admixture of iron: yet pure cobalt, as well as nickle, gave some tokens of being dissolved, but these tokens I hold to be still ambiguous.

I tried gold leaf in another way, but in vain; namely, I put into distilled water, along with the leaf, either the calcareous spar, or aerated alkali, then by degrees I poured in vitriolic acid, so as not to produce a full saturation, yet after some days

days I found no solution had taken place: once indeed, when I used chalk and common water, I saw some vestiges of a solution; but upon examining more accurately, I found a little marine acid in the chalk, and discovered lime dissolved in nitrous acid in the water, from whence a small portion of aqua regia had been generated. The vitriolic acid itself is frequently found to contain a portion of nitrous acid, which is usually employed to discharge its brown colour:—The most extreme caution is necessary to avoid being deceived by adventitious circumstances.

But, because the metals were tried in this way in vain, we are not to affirm that they cannot be united with fixed air, for perhaps it might be done, if they were minutely divided by precipitation; I examined this supposition in the following manner:—To the solution of a metal in its proper solvent, diluted with a sufficient quantity of distilled water, I added, by degrees, either aerated vegetable alkali, magnesia, or calcareous spar; the saturation being completed, I kept the bottles closed and inverted, in a cold place, for some days, and then examined the water after filtration: I avoid making use of chalk, which is often mixed with marine acid, and therefore in certain cases might occasion confusion; with crude lime, the saturation is obtained very slowly, especially if the menstruum be vitriolic acid, partly because the surface, assuming a gypseous nature, defends the

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internal

internal particles, partly because the last portion of the acid can only meet with the chalk at the bottom of the vessel, unless the liquor be frequently stirred; while, on the contrary, the magnesia, and especially the alkali, by their solubility, are spontaneously dispersed through the whole mass; magnesia, however, is best, inasmuch as, though it dissolves spontaneously, yet the solution goes on so slowly, that the water has time to take up the greatest part of the fixed air, as it is expelled; whereas, when the effervescence is violent, a great number of bubbles rise to the surface, and fly off.

By this method, besides those metals formerly enumerated, which may be directly dissolved in aerated water, a small quantity of gold appears to be taken up, but that in so ambiguous a manner, that, upon examination, I am still undecided. Gold is precipitated from aqua regia very slowly, by magnesia and by lime, and but imperfectly by alkalis, as a part of the precipitate is redissolved by the precipitant; so that the liquor can scarcely be divested of its yellow colour. The solution of gold, which with tin deposits a purple powder, does not hold the gold dissolved by the fixed air alone; for, to occasion a precipitation, it is necessary that there should be present a menstruum such as may be able to take up the tin — which aerial acid cannot do.

I subjected platina, silver, mercury, lead, and
the

the other metals and semimetals, to similar experiments; but the event was the same, and I found no certain tokens of solution. That cerusse should refuse solution by the medium of fixed air, surprised me, especially as it is itself nothing more than an aerated calx of lead, and therefore dissolves in acids, with effervescence, and the vapour which is expelled possesses all the properties of fixed air. In this experiment I employed cerusse perfectly free from chalk.—In like manner silver, mercury, copper, tin, bismuth, nickle, and the other metallic substances, dissolved in acids, and precipitated by aerated alkalis, take up the fixed air, but yet cannot by its means be dissolved, except that when the acid is superabundant, before the precipitation, a small portion of copper is taken up;—a complete precipitation is with difficulty obtained by lime and magnesia, though used in large quantities. The metallic salts always redden paper tinged with turnsole, a property which it is extremely difficult to repress by means of the above-mentioned earths.

§ XVIII. *Inflammable Matters greedily attract fixed air.*

The common acids frequently attack inflammable bodies with peculiar avidity, as is well known; although the union of an acid with pure phlogiston (which is commonly called sulphur)

takes place but in few of them—fixed air also possesses this same property.—If the bottle Q R, filled with fixed air, be plunged with its mouth under spirit of wine, the spirit will be found to absorb, in a temperature of 10° , double its own bulk of fixed air.—Let the same experiment be tried with olive oil, and it will be found that it will absorb an equal, nay sometimes a greater, bulk than its own; so that a stratum of oil floating upon water is of little use, as it scarcely, if at all, retards the absorption of fixed air. Oil of turpentine absorbs nearly twice its own bulk, and that in the beginning with such avidity, that in the first half hour about a fourth part of the fixed air disappears. Ether does not diminish fixed air, but expands it nearly to a double volume; however, if this vapour be again passed through water, it reassumes its original quantity and quality, so that the extraneous mixture present in this case cannot effect a permanent change.

Fixed air is not without difficulty combined with pure phlogiston (yet they appear united in charcoal) (g); and perhaps this union may also be

(g) “As charcoal necessarily contains a portion of earth, it ought, I think, to be considered as an hepar, or salt of three ingredients; besides, neither the phlogiston nor the fixed air are quite pure; the former is in the oily state, and it is probable that the latter is only a constituent part of a mere compound acid.” Morveau.—This (I fear conjectural)

be effected by electric sparks drawn quickly through it, by which means the fixed air is so loaded with phlogiston as to reject an union with water: if the fixed air which olive oil holds united with it be again expelled by fire, and received in a vessel, it is found either to a certain degree changed, or mixed with heterogeneous matters; for it can now sustain flame, and is almost insoluble in water (*h*).

§ XIX.

jectural) analysis of charcoal will not be intitled to much attention, if the result arising from some unpublished experiments made by Dr Priestly may be admitted. That indefatigable philosopher is said to have converted almost the whole of a quantity of charcoal into inflammable air, by throwing the focus of a lens upon it. This fine experiment will very much contribute to support the opinion, that inflammable air and phlogiston are only different modifications of the same substance; an opinion very ingeniously maintained by Mr Kirwan in a late vol. of the Phil. Transf. B.

But it is now a matter in dispute, whether charcoal contain any inflammable air at all. Dr Priestly could not obtain any without water, which is now known to yield it. This doubt cannot be finally resolved, till the tottering doctrine of phlogiston is quite overturned, or replaced *firmo talo*.

(*h*) " If these experiments be joined to those related in the Elem. de Chémie. Dijon. vol. i. p. 334. and vol. iii. p. 384. &c. it will be evident that our knowledge of the combinations of fixed air with inflammable substances, and in particular with oils, is very deficient: it is not, for instance, easy to comprehend why vegetable alkali crystal-
lizes,

§ XIX. *Fixed Air precipitates Bodies dissolved in pure Alkalis.*

It is a known property of acids, that they precipitate bodies dissolved in alkalis; and the same may be done by fixed air.

Let

lizes, when immersed in oils, whether essential or expressed, without altering their sensible qualities; why caustic alkali reduces them to the state of soap, while their rancidity seems to arise from the loss of fixed air, since it is corrected by the restitution of this fluid; and lastly, why quick lime slacks in oils but very slowly and imperfectly. The solution of these problems will certainly lead us to the discovery of some important truths." Morveau.—The solution of the last problem would not perhaps be very difficult, if we may assume, with Professor Bergman, that in quick lime calcareous earth is united with fixed fire; and with Stahl, that fixed fire is phlogiston; a liberty, however, for which I would not very strenuously contend. As oils are already saturated with phlogiston, they must be incapable of taking it from quick lime, and therefore this substance can only lose such a portion as can be transmitted through the oil into the air. If such an explication of the phenomenon was admissible, it would seem to follow, that quick lime cannot slack in fluids saturated with the inflammable principle. *Sed hoc ariolari est.*

The reader will not perhaps be displeased, if I transcribe the passages referred to by M. de Morveau, especially as they are to be found in a work not very commonly to be met with in this country.

“Oils cannot unite with alkalis, unless they be perfectly caustic; but if deliquescent alkali be poured into oil,
and

Let sulphur, dissolved in lime-water, be exposed to fixed air in the bottle Q R ; immediately the solution grows turbid, depositing a lime which effervesces

and the vessel remain for some time unshaken, very fine crystals, in the shape of parallelpipeds with oblique angles, will be formed at the bottom. They form alike in unctuous oil, in essential oil of turpentine, and still better in animal oil. Now, as the heavier alkali falls to the bottom of the vessel, we must infer that there is an affinity between the oil and fixed air ; whether it furnishes alone that which is attracted by the alkali, or receives, at the surface which is in contact with the atmosphere, a quantity equal to that which it is obliged to yield to the superior attraction of the alkali.

“ As the rancidity of oils is occasioned by the dissipation of the fixed air that formed a constituent part of them, this alteration may be prevented by restoring as much as they have lost. The Abbè Rozier observes, that if a sponge, imbibed with a soft paste of alum and absorbent earth, be kept at the bottom of a vessel containing oil ; as the absorbent earth has a greater affinity with vitriolic acid than clay, a slow decomposition of the alum is effected, and a new salt is formed ; but in every such combination a considerable quantity of air is extricated, which, as it escapes, will mix with the oil, and prevent rancidity : in like manner ranced oils may be recovered by restoring the fixed air. M. Sieffert has given a very good process, in which he employs air extricated by fermentation : it consists in mixing with the altered oil $\frac{1}{10}$ of apples, plumbs, or strawberries, &c. reduced into a pulp ; in setting this mixture in a place where it will ferment, and assisting it with a little honey, provided fermentation should not go on with sufficient rapidity : the oil, if drawn off after this process is over,

effervesces with acids, because pure calcareous earth adheres more readily to fixed air than it does to sulphur.

Hepar sulphuris, prepared with fixed alkali, is likewise precipitated, but somewhat more slowly, as the aerated alkali is easily retained by the water, therefore in this case the sulphur precipitates alone; besides if (as is usually the case) more alkali is present than is sufficient to dissolve the sulphur, no turbidness is occasioned, until the superabundant alkali is first completely saturated.

The volatile hepar sulphuris, which contains sulphur dissolved in pure volatile alkali, and is commonly called the sulphurated smoking spirit of bejuin, is very quickly and speedily rendered turbid by fixed air. No alkali, except when caustic, can attack sulphur; and therefore, upon the accession of fixed air, all the alkalis are rendered unfit for retaining it.

Liquor of flints, in the open air, gradually deposits its siliceous earth; a deposition which is quickly effected, if fixed air be made to float on its surface, and that the sooner, as the alkali is less predominant. This is the reason why a solution of alkali of tartar, although repeatedly filtered,

over, will be not only restored, but improved; since oils naturally acrid may be brought, by this method, almost to the mildness of oil of olives." *Elemens de Chémie*. Dijon. B.

tered, continues for a great length of time gradually to deposit earthy flocculi; for this alkali contains, intimately mixed with it, flinty particles, which it has acquired either during vegetation or combustion.—The calciners of pot-ashes sometimes fraudulently add sand, in order to increase the weight; which, during the operation, so unites with the ashes, that the flinty matter, by means of the alkaline salts, becomes soluble in water along with them.—This flinty matter afterwards gradually separates, in proportion as the alkali is saturated with fixed air, with which this latter more willingly unites. Now, as the alkali is kept in a bottle with a narrow neck, and generally stopped, it must receive the precipitating matter from the atmosphere very slowly.—The separation therefore proceeds very gradually; but if it be dissolved in a large quantity of water containing fixed air, or if, from the solution having been long made, it is sufficiently loaded with fixed air, the whole earthy matter at once falls to the bottom (*k*).

Soap

(*k*) Hence we learn what respect is due to M. Baumé's opinion, which has been frequently copied into elementary books, concerning the cause of this deposition: according to him, it happens in consequence of a real decomposition of the alkali, of which the constituent parts are far less intimately united than those of the acids. A portion of the nearly pure fire, to which it is indebted for its saline properties,

Soap is hardly decomposed by fixed air, partly because the alkali is almost always superabundant, partly because this subtile acid among all known acids is the weakest, and is accordingly required in great quantity; for even of common distilled vinegar no small quantity is requisite to separate the oil from the alkali: the apparent difficulty of this decomposition is also occasioned by this, that the small oily globules which are gradually separated, being viscid, cannot easily run together in distinct drops.

Aerated as well as pure volatile alkali attacks copper; and hence it happens, that neither in the open air, nor by the addition of vitriolic acid, is this solution made turbid or precipitated.

perties, is dissipated, and a proportional quantity of earth is separated, and falls to the bottom;—this salt may be easily decomposed, by driving off the air and fire that are among its constituent parts: at the end of these operations, the earth and water, the other constituent parts, may be collected separately. *Chymie Exp. & Raisonn. tom. i. p. 322.*—Of M. Baumé's work, whatever merit the experimental part may possess, candour must allow, that it is too full of idle speculations and groundless conjectures; and that the inexperienced reader cannot be put too much on his guard against being misled by such false lights. I was desirous of an opportunity to introduce this caution, and to confirm it by an example, as M. Baumé's Chymistry has been strongly recommended to the attention of English students by Dr Watson, in his popular Essays. B.

§ XX. *The simple elective Attractions of fixed Air.*

We have seen, in the foregoing sections, that fixed air unites with alkaline salts, with earths, and metals, after the manner of an acid; it remains now to examine the different degrees of intensity with which it attracts these different matters.—I mixed them in their pure state with aerated substances, and kept them in distilled water, and in bottles which were immediately closed, lest the access of heterogeneous matter should render the conclusion ambiguous; I then accurately observed such changes of weight and quality as could be subservient to the end proposed.

(A) I added aerated terra ponderosa to pure vegetable alkali; but after a few days neither was the former diminished in weight, nor the acrimony of the latter in the least mitigated. Terra ponderosa, therefore, retains fixed air with greater force than the vegetable alkali attracts it, which is also confirmed by mixing the pure terra ponderosa with a solution of the same alkali aerated; for then the terra ponderosa is increased in weight, and becomes mild, and the alkali is rendered caustic. If vegetable alkali, perfectly pure, be added to water loaded with pure terra ponderosa, no precipitation takes place; but if the alkali be
aerated,

aerated, immediately a turbidness arises, the alkali is rendered caustic, and the terra ponderosa precipitates aerated; but since, agreeably to its strength (l), terra ponderosa is saturated by a very small portion of fixed air, we must determine the quantities to be mixed together (§ VII. VIII. X.); — now 100 parts of aerated vegetable alkali contain as much fixed air as is sufficient to saturate 390 parts of pure terra ponderosa, if each of the materials be disengaged (compare also B.)

All the circumstances just now mentioned take place when lime is used instead of terra ponderosa, except the proportions, which in this case are, that 100 parts of aerated alkali cannot, with its fixed air, saturate more than 68 parts of pure lime.

Let 263 parts of mineral alkali, newly crystallized, and 100 parts of pure vegetable alkali, be dissolved together in 300 parts of warm water; then let the solution evaporate over the fire, in a proper vessel; and let the pellicles which successively appear on the surface be taken away, and collected in a cone of filtering paper, so as to be freed from the adhering caustic liquor; and let this be continued until the pellicles make up from 150 to 200 parts; these, upon examination, are found to be the true vegetable alkali aerated; and the remaining lixivium contains the mineral al-

(l) Vid. Sect. VIII.

kali in a caustic state : hence we may easily form a judgement concerning the superiority of attraction between the vegetable and mineral alkalis.

93 parts of aerated volatile alkali give over their fixed air to 100 parts of pure vegetable alkali, and assume a caustic nature, but the latter portions are more slowly decomposed.

168 parts of aerated magnesia contain only so much fixed air as is sufficient to saturate 100 parts of pure vegetable alkali.

We have already observed, that metals dissolved in water by means of fixed air are precipitated by caustic vegetable alkali.

(B) What has been already said of the vegetable alkali holds good with respect to the mineral, with relation to terra ponderosa, lime, volatile alkali, magnesia, and metals, only changing the proportions ; but it is in general to be observed, that the numbers coming out in any case, according to the principles already established, only indicate accurately how much fixed air is sufficient to saturate the substance employed, when at liberty ; but as the operation proceeds much more easily at the beginning than at the latter end, the complete resolution frequently requires double, triple, or even six times the quantity of the decomponent.

(c) Volatile alkali surrenders its fixed air, not only to terra ponderosa, lime, and fixed alkalis, but even to pure magnesia ; for this last, being added to a solution of aerated volatile alkali, re-

quires the power of effervescing, and renders the alkali pure.

(D) Aerated terra ponderosa, so far as I have yet been able to observe, neither is itself changed, nor occasions any change in lime-water; but when burned and dissolved in water, it somewhat obscures the transparency of the calcareous spar added to it; but the difference of the attractive force of these bodies is so small, that the prevalence of the terra ponderosa is not yet quite free from doubt.—Magnesia most certainly gives out its fixed air to terra ponderosa.

Terra ponderosa, dissolved by superabundant fixed air, is precipitated by all alkalis, by pure lime, and pure magnesia; all which bodies, by absorbing the superabundant menstruum, reduce the terra ponderosa to exact saturation, in which state it is indissoluble in water, § X.

(E) If aerated magnesia be put into water loaded with pure lime, it softens the acrimony of the lime-water, and a lime, possessing the property of effervescing, is at length found at the bottom, together with pure magnesia. Lime, dissolved by means of the superabundant fixed air, exhibits the same phænomena as the terra ponderosa in the same state; for the menstruum, when superabundant, adheres more loosely than when it is only sufficient for saturation.

(F) Pure magnesia is not soluble in water, so far as is yet known; but if it be taken up by means

means of fixed air, it is precipitated by alkalis, terra ponderosa, and lime. When they are caustic, the precipitate is sometimes pure, sometimes aerated, in proportion to the quantity of the precipitant;—for the small portion which can be saturated by the superabundant fixed air, reduces the magnesia to a state of saturation; so that, being rendered indissoluble, it falls for the most part to the bottom, unless the quantity of water be large; and even the pure volatile alkali is able to effect this precipitation (§ XII.), although inferior in attractive power (c). Terra ponderosa and lime applied in the same way, being themselves saturated, fall in like manner to the bottom; but if the first-mentioned substances be added in sufficient quantity to the magnesia, they not only seize the superabundant fixed air, but also that which is necessary to saturate the magnesia, which therefore, in this case, is precipitated pure (G). Metallic bodies dissolved by fixed air (§ XIV.—XVI.) are precipitated by alkalis, or earths when caustic. As to zinc, its solution, like that of the rest, grows turbid with pure volatile alkali; but being gently shaken, the clouds again disappear, because the volatile alkali easily dissolves this semi-metal.

Alkalis fully aerated, as also magnesia and lime in the same state, do not at all disturb the metallic solutions, when newly made; but if they be exposed either to the open air or to heat, so that

part of the fixed air shall have flown off, and the remainder adhere but slightly, a separation is occasioned, owing to the slight connection which now takes place between the metals and the water.

It is well known that zinc precipitates all the other metals from menstrua; and that this would, in the present instance, take place, I have no doubt, provided the quantity of fixed air could be so adjusted as to be sufficient only to dissolve one of the metals; but this can hardly be hoped for: so long, therefore, as the menstruum is sufficient for dissolving two or more together, neither any separation or precipitation will be observed. I have added filings of iron to solutions of zinc, both in the state of regulus and of calx; and again, to solutions of iron I have added zinc, and after some days I have found the metals last added partly dissolved, without any separation of the former. It may therefore be asked, Why the aerated water does not take up the former to saturation, as we find that it can afterwards attack the latter? The following explanation appears to me to be most satisfactory:—Aerated metals are salts extremely difficult of solution, so that by experience we find that only a very minute portion of them can be taken up by water; water, however, when saturated with one salt, not only does not refuse to take up more, but the presence of many increases their mutual solubility; which may be
illustrated

illustrated by several examples: thus, when saturated with nitre, it will not only take up common salt, but, being fully saturated with the latter, will again dissolve more nitre. In the present instance, this is the less wonderful, as we know for certain, that the first metal leaves untouched a sufficient quantity of the menstruum (fixed air) for the solution of the latter.

If, therefore, a table of affinities is to be drawn up for the metals, we have no reason for departing from that which belongs to the other acids;—that, namely, which has zinc first, manganese next, and last iron.

We deduce, therefore, from the preceding experiments, the following table of elective attractions.

AERIAL ACID.

Pure terra ponderosa
 — lime
 — fixed vegetable alkali
 — fixed mineral alkali
 — magnesia
 — volatile alkali
 zinc
 manganese
 iron.

(H) With respect to the acids hitherto known, the aerial appears to be the weakest; for it is expelled,

pelled, not only by vinegar, but by the phlogisticated acids of nitre and vitriol. In the mean time, however, I have more than once seen water loaded with the very purest fixed air (which had been extricated by fermentation, fire, or nitrous acid) grow turbid with a solution of lead in vinegar; yet, although at other times I had disposed the quantities of the ingredients, and every other circumstance, in the same way, no vestige of turbidness appeared. It is known that boiling vinegar takes up cerusse, and expels its fixed air. Perhaps, then, old crystals lose by age a part of the vinegar; perhaps they are decomposed by abundance of water, so that the aerated water can take up the calx of the lead, and with it form a salt which altogether rejects water, but is dissolved again in the vinegar, without any visible effervescence.—I leave this question undecided, until I can explain the cause of disagreement between these experiments: I do not make use of the vitriolic acid, as the very smallest mixture of that acid precipitates acetated lead.

§ XXI.

Pure volatile alkali cannot precipitate either terra ponderosa, lime, or magnesia, dissolved in any common acid; but aerated volatile alkali effects such a precipitation very readily: hence, although the former, by many experiments, plainly appears

appears to be the stronger, yet some persons, from this circumstance, (the true reason of which they do not understand), think it weaker. But the truth is quite otherwise; namely, the volatile alkali attracts all acids with much less force than lime (I take this instance only by way of example); therefore, when that salt is pure or alone, no decomposition takes place; but if it be impregnated with fixed air, then a fourth substance is added, which attracts the lime, so that the calcareous salt is acted upon by a double force; one the attraction of the pure alkali, soliciting the acid, the other that of the fixed air for the lime; and these forces joined together overcome the original adhesion of the lime with the acid.

The same is to be said of aerated magnesia, which in like manner decomposes calcareous salts.

Besides, although pure fixed alkalis can separate acids from many earths, and from metals, it does not follow, that this process may not be performed by a double decomposition, when the alkalis employed are aerated. Hence that remarkable difference of weight which is often observed in precipitating the same substance. Let 100 parts of calcareous spar be dissolved in an acid; these, precipitated by crystallized fixed alkali, being accurately collected, washed, and dried, yield nearly 100 parts again, similar in their nature and properties to crude lime. But if the operation be performed with pure alkali, the precipitate will

not be more than 0,55, and agrees in properties with burned and slacked lime; and the same is true of all substances which in their natural state abound with fixed air. Metals indeed differ in this respect; yet they too gain from aerated precipitants a considerable increase of weight; for instance—mercury $\frac{1}{3}$, iron nearly an equal weight, and so on. Silver dissolved in nitrous acid is more easily precipitated by aerated than by caustic alkali, and the precipitate is heavier. These accessions of weight are to be attributed to the fixed air, which being expelled by the stronger acid, adheres to the deserted metal, and, according to its quantity, alters not only the weight, but sometimes even the colour. We said before, that pure vegetable alkali precipitates corrosive sublimate of a ferruginous colour, but when fully aerated of a white (§ VII.): we said also, that the mineral alkali can never produce a white calx of mercury (§ VIII.): let us now see the reason.

Let there be precipitated only so much as is united with 100 parts of marine acid, and let the precipitation be made with vegetable alkali, fully aerated; for which purpose about 415 are necessary; for 100 parts of marine acid require 199 of pure vegetable alkali (§ VIII.); and these 199 can receive 84 of fixed air, and 132 of water (§ VII.). But if the mineral alkali be used, 100 parts of marine acid require only 80 parts of alkali; which in crystallization receive 64 parts of fixed air, and

256 of water. Since, therefore, the mercurial calx, in this instance, requires 84 parts of fixed air to be made white, and the mineral alkali sufficient for the precipitation can supply only 64, it appears plainly why this alkali cannot throw down a white precipitate (*m*).

It is very probable that even the calxes of the baser metals, although prepared by fire, are not altogether void of fixed air.—With respect to old flowers of zinc, I entertain no doubt, as they effervesce with acids, and yield a fluid endowed with all the properties of fixed air; when newly made, they scarcely excite any sensible motion; and even the old ones, by roasting, are deprived of that volatile menstruum which they had attracted from the atmosphere. The same holds of

(*m*) “In order to complete the proof of this fine theory, it would perhaps be requisite to show that the quantity of mercury which may be combined with 100 parts of marine acid, takes up more than 64 parts of fixed air, when it is precipitated by crystallized vegetable alkali; for it is not easy to presume that this really happens, when it is considered, that the author has just asserted, that this metal gains, by such a precipitation, an addition of only one third of its weight. It may be moreover observed, that several phænomena indicate the presence of a quantity of phlogiston in the intimate constitution of fossil alkali. I have shewn that it reduces gold, in the same circumstances in which vegetable alkali affords only an earthy precipitate.—(El. de Chem. Dij. tom. ii. p. 310). Now the colour of the mercurial precipitate may be explained just as satisfactorily by this hypothesis.” Morveau.

old cerusse;—new cerusse I have not yet examined (*n*).

§ XXII. *Fixed Air is a true Acid.*

From the foregoing experiments, we may conclude concerning the agreement of fixed air with acids; for from them it appears that this vapour excites a distinct sensation of taste upon the tongue (§ v.); that it reddens tincture of turnsole (§ vi.); that it attacks fixed alkalis violently, and renders them mild; that a smaller quantity of it than of the stronger acids saturates them, renders them crystallizable, and less soluble (§ vii. viii.); that by its union it makes volatile alkali more fixed, less odorous and penetrating, and crystallizes it (§ ix.); that when it just saturates pure lime, it takes away its solubility and acrimony, and crystallizes it, but that when superabundant, it renders it again soluble (§ xi.); that it produces the same effects with terra ponderosa (§ x.); that with magnesia, it constitutes a neutral crystallizable earthy salt (§ xii.); that with iron, zinc, and manganese, it forms salts, which, when dissolved

(*n*) “This observation is of great importance, as it announces a metallic earth, free from all combination, either with phlogiston or the aerial acid; and as it furnishes the first exception to this general rule, That the metals do not lose their *metallizing* principle, but to unite with another menstruum, and reciprocally.” Morveau.

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in water, redden the tincture of turnsole, like all other metallic salts (§ XIV.—XVI.); that it exerts elective attractions, both simple and double, after the manner of acids (§ XX. XXI.); that it precipitates substances dissolved in pure alkalis (§ XIX.); that its last particles, notwithstanding its extraordinary volatility, adhere very tenaciously to boiling water, and are not without great difficulty entirely separated from it, but that by congelation they are easily detached, in the same manner as by that same degree of cold the weak acids are concentrated (§ IV.); and finally, that it greedily attracts phlogisticated matters (§ XVIII.). Every one of these properties belong to acids in general, and most of them are considered as characteristic marks which are peculiar to acids, and distinguish them from all other substances: either then, fixed air, being endowed with all these qualities, is an acid, or we are reduced to confess that no certain criterion of acids is yet known.

The acidity of fixed air being, as I think, demonstrated, many reasons induce me to apply to it the name of aerial, or atmospheric acid, as being adapted to its nature. It so much resembles common air in levity, transparency, elasticity, and other properties, that it is only of late they have begun to be distinguished.—Besides, in that aerial ocean, which, under the name of atmosphere, surrounds our globe, this vapour is continually present, either free or entangled in combination with

with other bodies. Its existence in the former state is manifestly seen in phænomena which daily occur; lime-water every where separates a cream, when exposed to the open air, which does not happen in bottles perfectly closed; and never can happen, unless fixed air be in contact with its surface (§ XI.). Quick lime, exposed for a long time to the atmosphere, by degrees recovers what it had lost in the fire, so as entirely to re-assume the nature of crude lime, and be unfit for the mason's use, unless it be again deprived of its acid. Terra ponderosa and magnesia, reduced to a state of purity, in like manner recover from the open air their weight, power of effervescing, and other lost qualities. Pure alkalis are made mild in the open air, lose their deliquiating quality, and form crystals which effervesce with acids, circumstances which can only be ascribed to their attracting fixed air. Since then, these phænomena all take place at every time, and in every part of the world, a quantity of uncombined fixed air, by no means inconsiderable, must be perpetually present in the atmosphere.

But it is not only in an elastic and disengaged state that fixed air surrounds us, but it also seems to constitute a primary principle of common air. This ingenious conjecture of the indefatigable Dr Priestly comes now to be examined.

The experiment indicating this composition of atmospheric air, is as follows:—Let tincture of
turnsole

turnsole include a bubble of common air in a glass tube, bended into the form of a syphon; let either leg, filled to a certain height with mercury, be immersed in a vessel filled with that fluid metal; then, by means of an electrical machine, let strong sparks be plentifully passed from the mercury in one leg, through the bubble in the other. This being continued for some minutes, the surface of the tincture will be found to rise higher in both legs, and to change its blue colour to a red; the tincture, thus reddened, recovers its blue colour in the open air. If, instead of the tincture, lime-water be used, it is rendered turbid, and deposits an effervescing lime. In this case then, the air seems to be decomposed, and to be divided into two different elastic fluids, one of which tinges the tincture of turnsole with a fugitive red, is absorbed by water, and precipitates lime-water, that is, is endowed with all the criteria of fixed air; but the other fluid does not combine with water, extinguishes flame, and destroys animal life, as it suffers no change from the vapour of phlogisticated nitrous acid. That these phænomena do not depend upon the electric fluid alone, appears plainly; for if, by means of an air-pump, the bubble of air be so dilated that all the reddened tincture is expelled from the legs of the syphon, and in its place a blue tincture be poured in, to the same height, then, though the sparks be passed through the bubble, as before, no vestiges

tiges of fixed air appear. Hence then it appears, that somewhat which reddens tincture of turnsole, and precipitates lime-water, is found in the air, and has been taken away in the former operation.

We now know that common air consists of three elastic fluids mixed together, viz. 1st, of the aerial acid, in its disengaged state, but in so small a quantity, that it alone cannot impart a visible redness to tincture of turnsole; 2d, of an air unfit for sustaining flame, or being subservient to respiration (this we may call vitiated air (*o*), until we are better acquainted with its nature and properties); and 3d, of air indispensably necessary to flame, and animal life, which forms only about one fourth of common air, and which I call pure air. Here a question may arise, which of these fluids has been altered by the electric aura? I am

(*o*) The nature of this elastic fluid, which Dr Priestly has denominated *phlogificated*, seems to have been less elucidated than that of almost every other species. It is generated by phlogistic processes, and immersion of animal substances in nitrous acid: it is specifically lighter than atmospheric air; is fatal to respiring animals, though some insects live in it; it is restored by vegetation, and in some degree by agitation, in orange-coloured nitrous acid. B. This obscurity has been cleared up by Mr Cavendish, whose late discoveries have rendered more service to chemistry than those of any person since Dr Black. If we admit the existence of phlogiston, it is nitrous acid and phlogiston; if we reject it, it is nitrous acid deprived of all its vital air or acidifying principle; in other words, a constituent part of nitrous air and nitrous acid.

inclined

inclined to think the latter, inasmuch as it attracts phlogiston more violently than even the nitrous acid does: let us now suppose this air compounded of two principles, namely, of the aerial acid, and some other substance, which unites more readily with the electrical phlogiston than with the aerial acid; when the electrical phlogiston therefore is added, the aerial acid is separated, and, as it were, precipitated. Although all this appears very probable, yet other experiments, in which, by means of phlogiston, air is changed, without any appearance of the extrication of fixed air, prevent us from concluding with certainty concerning the composition of the air. Let us use, as an example, the sulphurated salt of Stahl. I exposed strips of linen, wet with caustic vegetable alkali, for a sufficient time to the fumes of burning sulphur; I then put them into different cucurbits, and pressed them to the bottom, shut the mouths very closely with wet bladders, and kept them in an heat of about 18° for 16 days;—at the end of that time I opened the mouth of one cucurbit under the surface of tincture of turnsole, which immediately rushing in, filled a little more than $\frac{1}{5}$ of the cavity: hence, therefore, it appears, that the phlogiston had by degrees deserted the vitriolic acid, and changed the included air, yet no redness could be perceived in the tincture. I opened the mouth of another cucurbit, under lime water, which entered

in

in the same manner, but shewed no signs of turbidness (*p*). If electrical sparks extricate fixed air, purely by the addition of phlogiston, why does not the same extrication take place in this last experiment?—It is indeed true, that in the former case the electrical phlogiston penetrates the whole mass much more violently, and thence may

(*p*) Was the fixed air produced in this experiment absorbed by the vitriolated tartar, as it was gradually formed, in consequence of the dissipation of the phlogiston?—Perhaps this conjecture will not appear so very improbable, if we consider that Dr Priestly obtained from $\frac{1}{2}$ an ounce of that neutral salt, $1\frac{1}{2}$ ounce measure of air, chiefly fixed; vol. ii. p. 116.—See also vol. v. p. 164, where he says, that he procured fixed air mixed with another species of elastic fluid, both from vitriolated tartar and Glauber's salt.

M. Morveau contends, that the experiment above related only proves that fixed air is produced by the electric spark taken in common air; and that, when a given quantity of air has been once exposed to the influence of that fluid, no more fixed air is produced by fresh sparks. He inclines to think that fixed air is generated by the combination of some other principle with pure air. Those who adopt the opinion so ingeniously maintained by Mr Kirwan, in vol. lxxii. of the Phil. Trans. that fixed air consists of dephlogisticated air and phlogiston, will readily suppose, that the fixed air is generated, not disengaged, by the electrical fire. B.

We have been since taught by Mr Cavendish, that the aerial acid comes from the turnsole, which is burned by the electric spark; and that lime-water is not rendered turbid in this experiment.

perhaps

perhaps decompose some primary principle; and perhaps if the circumstances of our experiment were charged, the same effect will be produced; but the laws of sound reasoning oblige us to suspend our judgement until a number of apt experiments shall determine the truth.

In the mean time fixed air may with great propriety be called the aerial, or (if more agreeable) the atmospheric acid; it might also be called the universal acid, as it is found in great abundance throughout all nature: but as it is usual by that denomination to indicate that saline principle which, differently modified, produces all the other acids and alkalis; and as these properties cannot as yet be affirmed of fixed air, I think we should abstain from that name, as being ambiguous. I am not ignorant that the volatile alkali, and the marine acid, contain phlogiston as one of their primary principles; and that, being spoiled of the inflammable principle, they are resolved into elastic vapours: but the vapours which are in both cases obtained, although not condensable by cold, are not of the same nature, and neither of them is similar to fixed air. The vitriolic acid, which is supposed to be contained in the atmosphere, is neither every where, nor at all times, to be found there: I have for several years, by means of the purest fixed alkali, endeavoured to obtain it, but have not as yet obtained a single particle. The vegetable alkali often contains vitriolated tartar, and the alkali of tartar itself is not always free from

it, owing doubtless to the practice of fumigating wine-vessels with sulphur—unless, therefore, the purity of the alkaline salt which is exposed to the air, be well known, errors can scarcely be avoided: the vitriolic acid, therefore, is not present in the atmosphere, unless accidentally; the same may be said of the nitrous and marine acids, which are sometimes found in it.

§ XXIII. *Whether Acidity be essential to fixed Air.*

Although I imagine I have established beyond doubt the acid nature of fixed air, yet some persons may suspect that this acidity is accidental, and to be ascribed to a foreign acid, which is intimately united, by way of solution, with the common air;—but I hope the following observations will shew that this opinion is entirely without foundation.

(A) Let us suppose that common air, extricated from lime by vitriolic acid, is, notwithstanding the washing, contaminated by that foreign acid, in such a way that they can hardly be separated; and that, while this union lasts, the air is rendered fixed;—now let lime-water be saturated with this elastic fluid, and the precipitated lime examined, it will be found in all respects similar to cream of lime, or crude lime.—I would ask, whether the common air, when it is again joined to the pure lime, retains the acid adulteration,

tion, united to it in the same manner as before? or, whether it shakes it off, and leaves it at liberty to unite with other matters? If the former be asserted, either the lime precipitated by fixed air ought to differ from common lime, which contains no vitriolic acid (a supposition contradicted by the most accurate chemical examination), or the distinction between fixed air and common air is reduced to nothing; which overturns the hypothesis of the generation of fixed air: if the latter, distilled vinegar would dissolve the precipitated lime, leaving the gypsum untouched; but experiments made with the greatest accuracy shew that distilled vinegar dissolves the whole of the precipitate.

(B) Again, if the acidity depends upon a foreign admixture, different species of fixed air should be produced by different acids. Now experience shews, that fixed air, extricated by marine acid, and properly washed, precipitates lime-water in the same manner with that obtained by vitriolic acid; and finally, that not the slightest difference in any of its properties can be discovered, whatever acid it is extricated by, provided it be sufficiently depurated by washing. If the fixed air obtained by vitriolic acid possesses, on that account, the property of dissolving iron and zinc, that procured by the nitrous ought to attack silver mercury; and that by aqua regia, gold and many other metals;—but experiments, which I made myself for that purpose, shewed me that no such thing happens.

(c) Besides, grant that the fixed air expelled during effervescence is adulterated by an acid, whence does that which is produced entirely similar by fermentation gain it; especially that which appears in the beginning, a long time before even the first stage of fermentation has attained its height? If the acidity of fixed air be foreign, why can it not be so accumulated as to redden syrup of violets, paper tinged with turnsole, and the other vegetable blues?

(D) Finally, calcareous spar and magnesia afford genuine fixed air, purely by the force of fire (§ 11.); although, by the most scrupulous examination, they do not betray the smallest vestige of a mineral acid. And this fixed air is produced, although they have been very minutely powdered and boiled for half an hour in a pure alkaline lixivium, and afterwards washed and dried, before they are put into the retort;—thus then all suspicion of a foreign acid vanishes.

Since then, fixed air, rightly depurated, though extricated by the most different means, from the most different materials, whether by fire or by solution, is nevertheless always the same, and always acid; I conclude, with all the certainty attainable in physics, that acidity is a property essential to that elastic fluid.

Some consider fixed air as the same with the vapour of phlogisticated vitriolic acid; yet any one who but slightly compares the properties of the two, will easily see that this opinion is without foundation

foundation—for the one has an irritating pungent odour, and destroys the colours of any organised substance; and, to pass over other circumstances of moment, may easily be reduced to genuine vitriolic acid, neither of which is true of fixed air, which possesses a much less powerful attractive force than the other.

§ XXIV. *Specific Gravity of the Aerial Acid.*

By means of an hollow globe I measured the specific gravity of fixed air in the same way as natural philosophers weigh common air.—I compared the weights of equal bulks of fixed air and distilled water three several times. The first time I found the proportions as 1 to 555; the second, as 1 to 563; and the last as 1 to 560. I employed, as nearly as I could, a moderate heat (15°) together with a mean height of the barometer (25,3) but yet could not avoid some minute differences.—The medium of the three observations is $559\frac{1}{3}$, or, in round numbers, 559,—so that its specific gravity comes out 00,018;—now common air, in the same circumstances, is scarcely 00,012,—so that fixed air is about 00,006 heavier than common air.

The noxious vapour which abounds in certain caverns is entirely of the same nature as the aerial acid; for it is absorbed by water, and communicates to it a pungent acidity; it reddens tincture

of turnsole, makes lime-water turbid, extinguishes flame, kills animals, and, above all, rises but a little way, on account of its specific gravity. In a pit which was opened in the year 1717, at the Pyrmont Spa, the lowest stratum of air, which is scarcely two feet in depth, is noxious, and when the sun's rays can reach down to it, it may be perceived, by means of the exhalations mixed with it. Over the medicinal fountain itself there is a poisonous stratum of air hardly a foot in depth, so that geese, by means of their long necks, can swim across it without damage. The exhalations from the caves in the neighbourhood of the Swalbach, and other acidulous waters, are of the same nature. In the Grotto del Cane, near Naples, men, and even large dogs, suffer nothing while they stand erect; but if the nostrils of any animal are brought near the ground, it is instantly seized by stupefaction,—This deadly vapour may be seen like a very subtle smoke, which in summer rises about a foot from the ground; but in winter not above a few inches.

From the gravity of fixed air it also follows, that the lower strata of the atmosphere abound more with it than the higher; for the prodigious quantity which is generated by fermentation, putrefaction, effervescence, and other natural operations, every day going on, for the most part remains close to the surface of the earth;—this must be again fixed by the continual generation of new bodies,

bodies. Certain portions of it also, which are perhaps generated from the common air, in the higher regions of the atmosphere, by lightning, and by various meteors, must by degrees all subside, were it not that the continual agitation of the atmosphere, mixing the common air and aerial acid with each other, together with the friction and the smallness of the difference in specific gravity, contribute much to prevent it: which, together with the above-mentioned diminution of it, all contribute to avert destruction from the animal world. Hence I imagine the reason is plain why higher situations are in general more healthful than lower ones (*r*); and I have no doubt but that various disorders, both epidemic and endemic, arise

(*r*) Though elevated situations may in general be more salubrious than low ones, it is not to be supposed that the healthfulness of any place is in proportion to its elevation, on account of the different quantities of aerial acid to be found in different strata of the atmosphere. But it is not unusual with those who are contemplating one of the principal agents in nature, to ascribe too many effects to it. M. Saussure found that the air of the valley of Chamouni absorbs a volume of nitrous air equivalent to 28 grains of water more than the air at the summit of the Buet. Three other experiments concurred with this to shew that the air of the summits of mountains is less pure than that of the vallies lying at the foot of them. The air on the glacier of Taléfre alone appeared, by the nitrous test, superior to that of the valley of Chamouni. The air of Geneva was

arise from the different quantities of aerial acid in the atmosphere. At the surface of the earth it is rarely found to form $\frac{1}{16}$ of the common air.

The aerial acid is not always of the same degree of tenuity, which seems to depend upon this, that water absorbs certain particles more readily

of equal goodness with that of Chamouni, and superior to that of the plains of Piedmont.

“ Since then,” says M. Sauffure, “ of the tops of five mountains, four afforded an air less pure than the plains lying at their feet; and the only one on which the air is more salubrious than in the plains, owes that advantage to a particular situation; it seems as if we may conclude that the air, at a certain height, loses somewhat of its purity.

“ I should, however, have been more cautious than to deduce a general conclusion from so inconsiderable a number of observations, if the fine experiments of S. Volta on inflammable air had not proved, that an immense quantity of this elastic fluid is constantly produced, which, as it is much lighter than common air, must rise to the more elevated regions of the atmosphere.

“ It appears, therefore, that if the air of the low plains is rendered less salubrious by the gross exhalations which its density enables it to support; on the other hand, the air of mountains raised more than 500 or 600 fathoms [toises] above the level of the sea, is vitiated by other exhalations, which do not less diminish its wholesomeness, because they happen to be lighter than common air; so that, even in the present instance, there is a certain medium, at which the density of the air, *ceteris paribus*, is best adapted to the life and health of man—I should fix the height at that of the plains and great vallies of Switzerland, which are elevated between 200 and 300 fathoms above the level of the sea.” B.

than

than others. It is not wonderful that the union should be continually retarded from beginning to end, as this effect is entirely conformable to the nature of attraction; yet the following phenomenon seems to confirm the former opinion:—

Let us suppose the bottle Q R filled with fixed air, and one half of it by degrees consumed. A subsequent union will be effected, in a given time, more slowly with the remainder, than with fixed air which had not been exposed to water, though the surface of contact be the same. Hence it would appear, that certain particles, either by reason of their figure, their magnitude, or some extraneous mixtures, are rendered more unfit for union with water (s).

§ xxv. *Aerial Acid extinguishes Fire.*

Fixed air not only prevents fire from being kindled, so as to prevent the explosion of bombs and fire arms, but it also instantly and completely extinguishes a body red hot, and flaming; so that to determine the presence of mephitic air by flame is a common experiment.

(s) “Difference of figure between elementary particles seems repugnant to the theory of affinities, as produced by this figure; for it is evident that a body not having the same affinities, has not the same properties, consequently cannot be the same body. I therefore think the last-mentioned cause the only one admissible. Morveau.”

If

If a glass cylinder, A D, filled with aerial acid in the manner above described (§ 11.), and then stopped by a cover, be carefully inverted and opened, the fluid contained will, by its specific gravity, remain there; let then a lighted candle or coal be immersed in it, and in an instant all the fire will be extinguished. But if the vessel remain open, the upper strata mix gradually with the common air, so that flame can at length subsist in them; and in this manner, by degrees, the whole mass is changed; but the more slowly in proportion as the cylinder is more lofty, and the circumjacent air more tranquil. The same phenomenon may be observed on the surface of fermenting liquors.

The aerial acid very strongly attracts smoke, extends it in a stratum parallel to its own surface, and holds it a long time. This may be observed in caverns where mephitic air is produced by means of the smoke of an extinguished torch, or a gun fired over the noxious stratum (f).

§ XXVI. *Aerial Acid kills Animals.*]

In these experiments I generally employ the following apparatus:—A glass vessel, A B (fig. 9.),

(f) This amazing phenomenon is, I think, owing to the attraction of aerial acid for the water contained in the smoke.

when

when the animal is enclosed, is suddenly cemented to the wooden bottom, B C ; this vessel is perforated at the top by a hole, D ; the tube, E F, which introduces the noxious vapour, is fitted closely to the bottom, that no air can escape ; the noxious vapour expels the lighter common air through the hole D : at first, however, they are in some degree mixed together, which is the reason why the animal does not as quickly die as when at once immersed in the aerial acid : but experiments have shewn me, that by this very circumstance the phænomenon may be more easily distinguished.

As soon as the noxious vapour rushes in through the tube E F, the animal looks about with great anxiety, in order to escape ; it then begins to pant—the eye-balls are protruded—it trembles—and at length expires as if going to sleep. By regulating the influx of aerial acid, the approach of death may at pleasure be deferred. The difference in the species of animals, their age and vigour, make some difference : thus birds generally die sooner than dogs ; these sooner than cats ; amphibious animals endure longer ; and insects longest of all. With respect to age, the younger animals are less quickly destroyed, especially those that are somewhat accustomed to it ; for such as have been often exposed to the open air in the very agony of death, and recover, are afterwards more slowly destroyed by that fluid than

than such as are for the first time exposed to it. After death, the lungs appear somewhat collapsed; they do not sink in water, like those of an animal which has perished in vacuo, but float; and often are in many places inflamed. The trunk of the pulmonary artery, the right ventricle of the heart, with its auricle, the vena cava, the jugular veins, and the vessels of the brain, are distended with blood; and I have more than once seen a firm polypus in the right ventricle. The pulmonary veins, the aorta, the left ventricle of the heart, with its auricle, are generally flaccid. The irritability of the muscular fibres all over the body is found destroyed: nor could I, either by blowing into it, by the knife, or by vitriolic acid highly concentrated, excite to motion the heart of an animal thus destroyed, although taken out warm (*t*).

Authors disagree concerning the effective cause of death in this case; and it would be presump-

(*t*) I have seen the direct contrary in so many experiments, that I hesitate not to reject this account of the destruction of the irritability of the muscular fibres. The author must have left his animals too long unopened; otherwise he would have seen the heart contract, when stimulated. The cause of death is the same, whether an animal be drowned in water, aerial acid, or any other kind of air, or whether it be killed by hanging. When the access of air is prevented, the blood is not changed to arterial, and is therefore incapable of stimulating the left cavities of the heart.

tion

tion in me to attempt the decision of so important a question.—Contented if I have been able, in this Essay, to establish the acidity of fixed air, which was my chief purpose, I have adapted all the experiments to the end proposed with as much accuracy as I was able; I repeated them diligently, and considered them carefully;—I therefore thought it unnecessary to particularise those which have been made by other persons, and for purposes different from mine, especially as they cannot escape the observation of the learned reader (*u*).

(*u*) Mr Bewly, in some letters, dated towards the close of the year 1775, and published in the Appendix to Dr Priestly's 2d vol. describes a series of experiments, undertaken in order to prove the proposition maintained in the foregoing Dissertation. It will appear a little strange, that he should not have been apprised of Professor Bergman's opinion on the nature of fixed air, (for if he had known it, his candour would not have permitted him to pass it over in silence), as it had been published by Dr Priestly, three years before the date of Mr Bewly's experiments. We are therefore to consider the present instance as a confirmation of the observation, that the same discovery is often made by different persons, without any communication with each other, when science has arrived at a certain pitch of maturity. Of this truth Mr Scheele's discovery of dephlogisticated air, without knowing that Dr Priestly had previously obtained the same elastic fluid, furnishes another still more remarkable example. On comparing the dates, it will be found, that priority of claim as evidently belongs to the
Swedish

Swedish professor in the former, as it is acknowledged to belong to our industrious countryman in the latter case. On perusing Mr Bewly's observations, it will be seen, that he was also led to adopt another opinion, advanced by Sir T. Bergman, and called in question by M. de Morveau, viz. That fixed alkali is capable of uniting with a quantity of aerial acid exceeding that which is necessary for its saturation. B.

H.

II.

OF THE

A N A L Y S I S

OF

W A T E R S.

§ I. *A brief History of the ANALYSIS of*
WATERS.

MUCH time could not have elapsed, before mankind first began to perceive the difference of waters, although furnished with no other criterion than that of taste. But the preparation of food, and the various arts and manufactures which afterwards began to be studied, must gradually have suggested a difference in the properties and goodness of waters, with respect to certain purposes, although we are at present ignorant of the manner and order in which these discoveries occurred. Hippocrates judges those waters to be most proper for common use, which are clear, light,

light, void of taste and smell, and which run from the east; observations, the justice of which is to this day generally acknowledged, with the exception of the last, which perhaps, in the country of Hippocrates, rested upon some local advantage. He (*a*) condemns, as worst of all, such as are hard, salt, aluminous, and the waters of lakes and marshes. Pliny not only distinguishes waters into nitrous, aluminous, bituminous, salt, sulphurated, acidulous, chalybeate, salubrious, poisonous, medicated, cold, warm, hot, such as boil pulse slowly, such as incrust the vessels in which they are boiled, such as intoxicate, such as change the colour of cattle, &c.; but mentions water boiled, and cooled again by snow, according to Nero's method; and asserts, that vitiated waters are restored by being boiled to one half (*b*).

But as to the art of accurately examining waters, with regard to their contents, we scarce find any traces of it worthy of observation, until the seventeenth century. Tabernæmontanus, whose true name was (*c*) Jacob Theodore, about the end of the sixteenth century, enumerates a variety of the waters of Germany, and among the rest Seltzer water; but he gives no analysis of them. (*d*) Andrea Bacci, an Italian physician, whose

(*a*) Lib. de Aëre, Aquis et Locis.

(*b*) Hist. Nat. lib. xxxi. passim.

(*c*) Wasserschatz. Frankf. 1593.

(*d*) Septem de Thermis Libri. Rom. 1596.

work was published in the year 1596, makes not the least mention of analyses of this kind, altho' no one before him had written so accurately upon the subject of waters.

The illustrious Mr Boyle, in the year 1663, had discovered the use of several precipitants. It had been before known, indeed, that syrup of violets was made red by vitriolic acid, and by lemon-juice : but this effect was attributed to some peculiar quality in these two liquors. Mr Boyle discovered this to be a property common to all acids; and was also the first who observed the green colour occasioned by alkalis, which he instances in the juice of blue-bell. He mentions the blue solution of copper in volatile alkali; he relates that the colour of roses is destroyed by the fumes of sulphur, but heightened by its acid; that water tinged by Brazil wood grows yellow on the addition of an acid, while that tinged by cochineal has its red colour made more dilute; and that alkalis restore the original intensity of colour; that silver is precipitated from nitrous acid by fixed alkali, by common salt, and by marine as well as vitriolic acid, but not by volatile alkali; that salited silver grows black in the open air; that vitriol of mercury grows yellow, when washed with water; that mercury dissolved in acids yields a white precipitate, on the addition of volatile alkali, but with fixed alkali a sediment of an orange colour, which colour, on the addition of vitriolic acid, immediately

diately disappears, as does afterwards the whole of the precipitate; and that silver is as it were gilded in solutions of a sulphureous nature; together with several other circumstances, many of which had doubtless been discovered (*e*) before. Thus, to pass over other instances, Gassendi says, that tincture of roses has its colour heightened by vitriolic acid.

Nearly about the same time Dominic du Clos, at the first institution of the Royal Academy of Sciences at Paris, in the year 1667, attempted to examine all the waters of France, and continued his investigation for some years. He made use of several precipitants besides those above mentioned, such as infusion or powder of galls, and juice of the flowers of lesser iris, to which he afterwards added martial vitriol, and juice of turnsole. He examined the residuum after distillation, investigated its figure by the microscope, its flavour, its solubility in water, and put its properties to the test of hot iron.

So long since as the year 1680, some remarkable experiments upon this subject made by Urbanus Hierne, were published in Sweden. This very expert chymist makes three classes of acidulous waters; namely, the acid, the vinous, and such as contain a latent acid; he affirms that each of them contains a peculiar ore, mostly martial,

(*e*) Experiments touching Colours. Oxon. 1663.

together with a small portion of sulphur, either manifest, as in the acid gas of Spa, Pyrmont, and other waters of that nature; or occult, being dissolved by a concealed alkali; or as yet in a nascent state. He considers the examination of the residuum as of little consequence, on account of the loss of the volatile particles; and thinks weighing useless, imagining that volatile spirits do not gravitate. He thinks that the tinging linen will detect waters saturated with a mature ore, but will not discover acidulous waters: he denies that the goodness of medicated waters can be determined by infusion of galls alone, inasmuch as all waters containing a gross vitriolic salt strike a black with that infusion, while various acidulous waters of a more subtile nature, are not affected by it; nor does he think the tinging of raw flesh sufficient, as all vitriolic waters induce on it the very same colour (*f*).

In the year 1678, Hierne examined the acidulous (*g*) Medway waters, which had been discovered the year before, and soon after this species of water came into general use in (*i*) Sweden.

Mr Boyle again, in the year 1685, proposed a number of substances for the more accurate exa-

(*f*) Lilla Vattu-Profvaren. h. e. brevis Aquarum explorator. Stockh. 1683.

(*g*) De acidul. Medviens. 1680.

(*i*) Hiilphers de Font. foteriis Sueciæ.

mination of waters. He extols very much the volatile hepar sulphuris, distilled from fixed alkali, sulphur, and sal ammoniac; this instantly grows black, either with green or blue vitriol; hence he thinks that concealed sulphur may be discovered by vitriol; he observed that solution of arsenic grows black, and is precipitated by vitriol; he also affirms that he was acquainted with a method of discovering common salt in water, without any evaporation, but he does not describe the method (*k*). He can scarcely, in this case, allude to solution of silver, as, though known before, it was then but little used, but afterwards began to be more frequently employed; for in the year 1697 it was applied to this purpose by Nic. Valerius, a Swede, who in his travels examined the hot waters of Aix; and, besides the above-named substances, employed solutions of nitre, common salt, sal ammoniac, and saccharum saturni, the acids of nitre and sea-salt, and spirit of sal ammoniac (*l*).

About the beginning of the present century other substances began to be used: in the year 1699, D. Regis and Didier employed tincture of mallow-flowers, which is made red by acids, and

(*k*) Apparatus brevis ad naturalem & experimentalem Aquarum Mineralium Historiam, concinnatus in forma Epistolæ, Lond. 1685.

(*l*) Tentam Physico Chim. circa Aquas Thermal. Lugd. Batav. 1699.

green by alkalis (*l*). At the same time Boulduc introduced lime water, and vinegar of lead. Some person sent to Aix by Burlet mentions with astonishment a silver cup, which having been kept for three days in the Bath water, became as it were gilded, a phænomenon long before known to Boyle, and by him ascribed to sulphur: it was afterwards accounted for upon the same principle, by Homberg (*m*).

In the year 1707, Burlet availed himself of solution of alum, paper tinged blue by turnsole, the same paper afterwards reddened by vitriolic acid, distilled vinegar, tincture of damask roses extracted without acid, together with some other substances. In the same year too, Geoffroi substituted broad open glass vessels to the close retorts, which had been used until that time.

Besides, in 1726 and 1729, Boulduc employed various other contrivances. For instance, until that time evaporation had been continued to dryness, and the saline part of the contents again dissolved; but Boulduc thought it more expeditious either to separate the strata of the whole residuum, or to separate the different substances, in order as they presented themselves during the evaporation. He also shewed the method of disco-

(*l*) L'Histoire de l'Acad. des Scien. de Paris, 1699.

(*m*) Ibid. 1707.

vering, by precipitation with highly-rectified spirit of wine, the salts contained in any water; without exposing it to heat (*n*).

From hence it appears, that the principal precipitants at present known were in use at least from the middle of the seventeenth century; but if we examine the conclusions deduced from the observation of their effects, we shall be forced to acknowledge that they have been frequently unsatisfactory, and often more or less false.

It would be tiresome and useless to relate the opinions of the ancients concerning the heterogeneous matters found in water. Theophrastus Paracelsus was of opinion, that all the species of earths with which he was acquainted, together with salts, bitumens, and certain metals, might be suspended and carried about by that fluid: but, laying aside these unproductive speculations, we shall proceed to a period more advantageous to natural philosophy. It has been already observed, that alum was long supposed to be present in waters; nay, D. Giure, in the year 1669, contended that the peculiar nature of acidulous water was not constituted by vitriol but by alum, and a certain vein of soft iron, or, as he calls it, the *ens primum* of that metal. This, so far as regards the alum, was however soon contradicted by Du Clos.

(*n*) Mem. de l'Acad. de Paris, 1726 and 1729.

—At present, alum is very rarely found in natural waters.

Du Clos at the same time speaks of a certain salt, similar to gypsum; but Mr Allen (*o*) was perhaps the first who observed in waters a salt consisting of vitriolic acid and lime, and which he calls selenite. By the word *nitre* nothing more was formerly understood, than natron, or mineral alkali, which Hierne first observed in the acidulous waters of Egra (*p*), and F. Hoffman afterwards discovered in several medicated springs (*q*). The nature of this substance was accurately explained by Boulduc, in the year 1729.

The sal catharticus amarus, or more properly, vitriolated magnesia, has been in high esteem at Epsom, from the year 1610; and in 1696 Dr Grew published a small treatise upon that subject; but, although it was found in the waters of Seidlitz, Seidschutz, and at several other places, and was consumed in great quantity, yet the true composition of it remained unknown until the year 1755, when the celebrated Dr Black (*r*) undertook the accurate examination of the nature of magnesia, the presence of which, even united with fixed air alone, was afterwards discovered in

(*o*) Nat. Hist. of Min. Waters of Great Britain, Lond. 1711.

(*p*) Brevis Aquarum Explorator.

(*q*) Opera, tom. v.

(*r*) Edin. Acts, tom. ii.

several waters (*t*). Glauber's salt is found in many springs, and is often confounded with vitriolated magnesia. About the end of the seventeenth century a new method of detecting common salt was discovered, although its taste, and the form of its crystals, had been before that time generally considered sufficient for the purpose.

In the year 1682 Lister discovered lime in waters; and in 1752 Le Roy found salited lime in the last lixivium (*v*).—Margraaf discovered salited magnesia in 1759 (*u*); and F. Home nitrated lime in 1756 (*x*). As vitriolated water strikes a black colour with galls, and as most acidulous waters possess that property, it was immediately supposed that such waters contain a vitriol: Theophrastus Paracelsus (*y*) imagined he had put that matter beyond doubt; but others, who by evaporation in vain attempted to obtain crystals of vitriol, began to entertain doubt of the fact, yet by different ways endeavoured to get rid of the difficulty:—Some alledged that these waters contained neither iron nor vitriol, but a soft ore, as they called it, an *ens primum* of that metal—others had recourse to a volatile vitriol, &c.

(*t*) Acta Stockh. 1773.

(*v*) Mem. de l'Acad. de Paris.

(*u*) Mem. de l'Acad. de Berlin.

(*x*) Experiments on Bleaching. Edin. 1756.

(*y*) De Thermis.

In the beginning of this century, F. Hoffman attempted to establish a new theory of mineral waters, denying that there was in the acidulous waters any true and actual acid: he grants indeed, that an acid vapour does exist, which, together with a certain elastic ethereal principle, which he calls *spiritus mundi*, constitutes the spirit and life of the medicated waters; but he considers this as volatile, and therefore easily dissipated. On the contrary, he insists that the acidulous waters are alkaline, because they effervesce with acids, and change the colour of syrup of violets to a green: these are marks, however, which we know to be ambiguous (§ VII.). As we are not acquainted with any alkali but such as has passed through fire, and as alkalis are consequently considered as the products of fire, many persons denied the possibility of their existence in waters (z). Hoffman himself thinks that the alkali originates from a spirit of sulphur, which, according to the degree of its subtlety, would form with lime an alkalis either fixed or volatile;—Henckel thinks the alkali derived from common salt, though he owns he is ignorant how its acid can be expelled.

At length Dr Seip (a) gave an explanation, which was thought to remove all the difficulties

(z) Opera, tom. v.

(a) Beschreibung der Pyrmontischen Mineral Wasser, 1771.

completely : he, with many of the ancients, supposes that the genuine mineral spirit is the volatile vitriolic acid ; but as the ancients (from the sudden change which the water undergoes on exposure to air) concluded that this volatile substance flew off, he, on the other hand, contends, that the subtile acid which had formerly been united with iron, now forsakes the metal to unite with the alkali, which in the subterraneous caverns could not exert its superior attractive power ; and hence it is that the remarkable change which acidulous waters undergo when exposed to the air, takes place : this spirit, he thinks, may be again expelled by distillation, and then obtained in its proper form. How far this explanation is agreeable to truth, will be seen (§ VIII.)

In the year 1748, Dr Springfield (*b*) delivered it as his opinion, that air was the effective cause by which the contents of the subtile waters were kept in a state of perfect clear solution, because the departure of air always occasions a turbidness and precipitation. And this opinion was afterwards further confirmed ; for, in the year 1755, Venel's Memoirs on Seltzer water were published ; in which, by very convincing arguments, he shews that the volatile sulphureous acid is not the true mineral spirit, which, on the contrary, he contends is no other than the air itself ; and he de-

(*b*) Iter Medicum ad Aquas Spadanas.

monstrates

monstrates these propositions by arguments both analytical and synthetical (c); and, although he did not arrive at the truth altogether, it must yet be confessed, that he came nearer to it than any one before his time : he also attempted to prepare Seltzer water artificially. It is to be lamented that this very acute chymist, who superintended the examination of the waters in France, did not publish any thing more upon that subject before his death.

It is at length shewn, by incontrovertible experiments, that the genuine mineral spirit, which gives character and life to the cold mineral waters, is altogether the same with that fluid which is now called fixed air : this principle is common to the Seltzer, Spa, and Pyrmont waters ; but different salts, in different proportions, determine the different species of these waters.

Hence water, by bare impregnation with fixed air, cannot properly be called either Seltzer, Spa, or Pyrmont ; nor can he be said to understand the artificial preparation of these waters, who merely knows the method of saturating water with fixed air.—The particular quantity of the different salts which constitute the peculiar nature of each, must also be known.—The vapour which is found in hot baths consists sometimes of the aerial acid, as in the Caroline waters of Bohemia, but is fre-

(c) Mem. der Sc. Etr.

quently of a different nature, as we shall see hereafter.

In the year 1771, at Upsal, several persons made use of waters artificially prepared, which exactly resembled the natural waters of Seltzer, Spa, and Pyrmont, not only as to the volatile part, but as to the entire contents (*d*); and the use of these waters afterwards obtained through most of the provinces of Sweden.

In the year 1772, Dr Priestly published a book at London, in which he taught how water might be saturated with the fixed air expelled from chalk by vitriolic acid — Mr Lane had before employed fermentation for the same purpose, with the addition of iron, by which the water became a chalybeate.

The hepatic vapour, with which many hot baths are impregnated, has occasioned much perplexity, because sulphur cannot artificially be obtained from them, though it sublimes spontaneously, as at Aix.—Of those who have laboured in this field it is sufficient to name Charles Lucas, who yet did not succeed (*e*). At present the mystery is unfolded (§ IV. VII. F. VIII. E.)

Finally, I should mention, that the knowledge of the heterogeneous matters contained in waters, lately acquired, has excited many to under-

(*d*) Vet. Acad. Handl. 1773.

(*e*) Essay on Waters. Lond. 1756.

take a classification of waters, according to their contents. On this principle the celebrated Professor Sir J. G. Wallerius, published, in the year 1748, his *Systema Hydrologicum* (*f*).—F. A. Cartheuser, in 1758 (*g*), published a work of the same kind; as did also Mr Monnet, in 1772 (*h*); not to mention those who, limiting their researches to the waters of certain countries, have not treated the subject at large.

The nature of the present Work does not permit me to spend any time in relating the several discoveries of the moderns, which have led the way to a complete examination of waters: besides, these are all to be found in the modern books. Let the candid and skilful judge whether the demonstration of the acid nature of fixed air, the solution of chalk and magnesia in water, by means of that subtile menstruum, and the analysis and synthesis of Seidschutz, Seltzer, Spa, and Pyrmont waters, have contributed any thing to that purpose.

(*f*) Wattu-Riket. ad Fin. comparet brevis Introd. ad Aquas examinand.

(*g*) Rudimenta Hydrol. Syst. Fr. ad. V. 1758.

(*h*) Nouv. Hydrologie, 1772.

§ II. *The Examination of Waters highly necessary.*

Water, considered by itself, and free from any heterogeneous mixture, is, as far as conjecture can reach, always of the same nature; but, during its passing over or penetrating various strata, it is loaded with heterogeneous matter, more or less, according to circumstances; very subtile powders being partly mechanically suspended in it, and partly united intimately with it, in the way of chymical solution: hence no water is ever found upon the surface of the earth in a state of perfect purity; nay, even rain and snow-water, although elaborated by the peculiar powers of nature from the most subtile vapours, with a degree of perfection inimitable by art, these, I say, though collected with all possible care, are yet found variously contaminated, according to the seasons of the year, the climate, and other circumstances.

The heterogeneous particles which waters contain differ with respect both to quality and quantity: hence it is that some are fit for the uses of life, others unfit, noxious, or even sometimes mortal; while others are found extremely efficacious in curing, or at least in alleviating distempers. The medicinal waters differ very much in power, according to the quantity and quality of the particles contained in them: hence some which experience

rience shews to have been employed with the best success in certain cases, in others may prove either inert or noxious. In the brewing of malt liquors, the baking of bread, the boiling of pulse, the washing and bleaching of linen, the dying of different substances, the preparing of hides, skins, and paper, and in a number of other arts, the quality of the water employed is of so much consequence, that, unless one be chosen fit for the purpose, the whole process fails.—Water is used in considerable quantity in the preparation of food, and always constitutes the greater part of our drink; inso-much that if we allow one kanne per diem to each adult, our calculation will rather fall short, than exceed.

Hence it readily appears how a quantity of pernicious heterogeneous matter, though small, being daily accumulating, may soon lay the foundation of numberless diseases.

From what has been said, I believe it is sufficiently obvious, that the analysis of waters is highly necessary, not only as a speculative branch of natural philosophy, but as subservient both to public and private advantage.—From thence we are enabled,

- 1st, To chuse the purest water for internal use.
- 2d, To avoid such as is either unfit or noxious.

3d, To form a proper judgement concerning such as are useful in medicine. Thus, if long experience has shewn the efficacy of the water in a certain fountain, and if at the same time the contents of that water be known, we are enabled to anticipate the experience of years, and instantly to form a judgement concerning the virtue of other waters, which exactly resemble in their contents the water whose properties are already established.

4th, To select such waters as are best adapted to the several arts and manufactures.

5th, To amend the impure (in scarcity of good water), and to separate from it those heterogeneous particles which chiefly impede its use.

6th, To imitate such as are celebrated for extraordinary virtues, if a sufficient quantity of the natural water cannot conveniently be had.

§ III. *An accurate Analysis of Waters is justly considered as one of the most difficult Problems in Chymistry.*

In proportion as an ingredient forms a smaller part of a compound substance, the more difficult it is to discover that ingredient, because it is the more enveloped and hidden.—By means of fire

we

we sometimes discover $\frac{1}{12000}$ part, and even sometimes a smaller proportion;—but in the analysis of waters it is often necessary to detect $\frac{1}{50000}$, nay $\frac{1}{100000}$.

When the substance contained is not only small, but also composed of different ingredients, the separation becomes still more difficult. Sometimes the heterogeneous matters in water amount only to $\frac{1}{8000}$, yet this is found to be composed of six, seven, or eight different ingredients, mixed together in such a manner as to be easily confounded; it is, notwithstanding, necessary to determine the quantity and quality of each.

Add to this, that some of the contents are so subtle as to elude the senses, or so volatile as to fly off imperceptibly; some of the principles also are decomposed during the examination—hence they require to be investigated by peculiar contrivances.

It may be thought that the difference of a few grains in a kanne will not essentially alter the peculiar virtue of the water; but experience shews the contrary very clearly.

These circumstances will serve to shew the difficulty of the question before us, even to those who are altogether ignorant of chymistry.—And persons who are even more than moderately skilled in that science, must exercise peculiar address, in order to perform the necessary operations with sufficient accuracy. We can by no means there-

fore imagine, that powder of galls and syrup of violets are altogether sufficient for this purpose.

I should now proceed to describe the method which I found most convenient in conducting this process; but it will be advantageous, previously to know what heterogeneous substances are usually found in cold waters.

§ IV. *What heterogeneous Matters are generally found in Waters.*

Very minute particles of flint, lime, magnesia, and clay, are sometimes found mechanically suspended in water. The argillaceous particles obscure its transparency, and render it of an opal colour; the others occasion variations which are less observable, because the subtilty of their particles and the surrounding water render them transparent.—All these substances, when sufficiently comminuted, acquire a surface so large, in proportion to their weight, that the friction necessary to be overcome in their descent becomes superior, or at least equal, to the difference of specific gravity between the particles of the earth and those of the water, which is the force with which the earthy particles tend to the bottom; and so long as this equilibrium takes place, the particles, once diffused in the water, will remain suspended.

But various substances are found united with
water,

water, and with each other, much more intimately, that is, by means of chymical solution—these are now to be enumerated, and to each we shall subjoin a reference indicating the place, in the following pages, where the specific nature and quantity of each of them are particularly treated of.

Pure air is contained in most waters, in the proportion of about one cubic inch to a kanne; this, when expelled by boiling, or by the air-pump, is gradually recovered from the atmosphere (VII. s; VIII. A, B.)

Aerial acid also is found in every water, but in very unequal quantity, from $\frac{1}{1000}$ of the bulk of the water, to a bulk equal to that of the water itself. This, as well as the pure air, by its dilatation under the receiver, produces a number of bubbles;—it communicates to water an agreeable, pungent, and refrigerant flavour (VI. A, B, C; VII. A, F, K, S; VIII. A, B, C, D.)

Inflammable air sometimes issues from waters; this species of air, however, is not united with the water, but rises from the bottom, and is expanded at the surface.

The other acids, in a disengaged state, are only found in waters accidentally (VI. C; VII. A, H; VIII. D.)

Vegetable alkali is rarely found in waters, and almost always in combination (VI. C; VII. B, C.); sometimes vitriolated or salited, but more frequently nitrated (XI. B, 1, 2, 3.)

Mineral alkali, however, often occurs, either aerated, vitriolated, or falited (VII. F; XI. B, 1, 2, 3.)

Volatile alkali is sometimes present, probably communicated by putrid vegetable or animal substances (VI. B, C; VII. B, C; VIII. F.)

Terra ponderosa is sometimes accidentally found united with marine acid (VII. F, L; X. D, 6; XI. B, 4.)

Lime frequently occurs aerated, vitriolated, nitrated, or falited (VII. G; X. D; XI. A, C.)

Magnesia is not so frequently found; yet sometimes it occurs either aerated, vitriolated, nitrated, or falited (X. D; XI. A, B, 4.)

Vitriolated clay (i), or alum, is rarely found in waters (VI. C; VII. N; X. D; XI. B, 4.)

Among the metals *iron* is most frequently discovered in waters, and that, aerated, (VI. F; VII. D, E; X. D, 4.) vitriolated, or sometimes perhaps falited (XI. B, 5.)

Manganese has not yet been found, except falited, although it may possibly be discovered aerated or vitriolated (VI. F; X. D, 4; XI. B, 5.)

(i) An ingenious English physician has detected an earthy salt, which one should still less expect to find in water. He has met with muriated or falited clay in Nevil Holt water, which has long baffled the attempts of chymists to analyse it.—His analysis has not been published. B.

Copper

Copper has only been found vitriolated (VI. A, F; XI. B, 5.)

Arsenic very rarely, and in the form of a calx (XI. B, 5.)

Extracts from vegetable and animal substances, with which water, passing through strata containing such bodies, is sometimes contaminated.

Somewhat of *an hepatic* nature is also found, especially in hot waters, and sometimes also in cold chalybeate waters; but in general it is so subtile that it instantly flies off in the open air, and manifests itself no other way than by its smell (VI. B.). A genuine *hepar* is rarely present, although it is fallaciously indicated by an hepatic vapour, consisting of sulphur resolved into the form of vapour by means of phlogiston and the matter of heat; as is clearly demonstrated in the Treatise on the products of subterraneous fire. The method of separating the sulphur in its proper form will be explained, (VII. F, T.)

I could not discover any certain signs of *bituminous oil*, it being immiscible with water, unless by means of an alkali. Petroleum, agitated with distilled water, separates again upon standing. It must be acknowledged, however, that the water, even after the most careful filtration, still retains a strong bituminous smell; yet nitrated mercury occasions no precipitate (VII. P.)

These heterogeneous matters are never found all

together, but are more or less numerous in different waters. Thus some of them are contained in atmospheric waters; others in those found on the surface of the earth; and, finally, others in sea-water.

Snow-water contains a small quantity of salited lime, together with some slight vestiges of nitrous acid; this water, when newly melted, is totally void both of air and of the aerial acid; substances which are found, in greater or less quantity, in almost all other waters:—and hence it is, perhaps, that snow-water is noxious to animals.

Rain-water is generally contaminated with the same substances as the former; but in greater quantity: it is obvious that these waters, while suspended in the air, must collect and absorb the various heterogeneous matters with which the atmosphere abounds, and therefore can never be obtained pure. Immediately after long continued rain or snow, these waters are found least loaded with heterogeneous matter.

Spring-water, when of the purest kind, contains but little heterogeneous matter, otherwise we find in it aerated lime, salited lime, common salt, and sometimes a small quantity of alkali.—Those springs which are called mineral also contain gypsum, aerated and vitriolated magnesia, vitriol, aerated iron, &c.

River-waters are often so much purified by their motion as to contain nothing more than aerated

rated lime, common salt, and sometimes a little alkali. These are generally lighter than spring-waters, and the more pure, in proportion to the rapidity of their course, and the hardness of the bottom over which they run.

Well-waters, besides a large quantity of the above-mentioned substances, often afford gypsum and nitre.

Lake-waters are less clear than any of the former, they are also heavier, and deposit spontaneously some earthy sediment: they sometimes contain all the substances above recited; and besides, are generally vitiated by an animal or vegetable extract.

Marsh-waters have less motion, and therefore are less clear, more heavy, and more vitiated by extractive matter; hence they generally exhibit somewhat of a yellowish brown colour.

Sea-water contains common salt, vitriolated and salited magnesia, gypsum, and a considerable quantity of the putrid extract, which is generated partly from the innumerable crowd of animals which there live, die, and are decomposed; and partly is there collected by falling into it from the earth.

In examining the products of subterraneous fire, I have particularly enquired whence these heterogeneous matters, and the different degrees of heat in waters, are derived.

§ v. *Water may be examined in two different ways, by Precipitants, or by Evaporation.*

We attain the knowledge of the heterogeneous matters in water chiefly by two methods, by precipitants, and by evaporation. Precipitants are substances which, on being added to waters, either immediately, or after some short time, by altering their colour, or disturbing their transparency, shew the heterogeneous matters they contain. These, for the purpose of expedition, are very commodious; but they do not afford an accurate decision, especially when the question is concerning quantity. The weight of the precipitate may often, indeed, be of considerable use even in that view, as shall presently be shewn, though it has not yet been employed for that purpose.

The other method consists in separating the contents by evaporation and crystallization.

When there is time sufficient, and we wish to examine a water very accurately, both these methods should be employed, as they reflect mutual light upon each other, and the precipitants indicate the proper method of conducting the evaporation.

Finally, in order to form a right judgement, we must confirm our analysis by synthesis. For this purpose the purest snow-water, gently distilled,
and

and freed from empyreuma by standing in the open air, should be employed; and when the heterogeneous matters which have been discovered are added in due proportion, the artificial water should be precisely like the natural in every circumstance.

§ VI. *The Physical Qualities to be observed.*

In forming a judgement of the nature of waters, their sensible qualities afford no inconsiderable assistance.

(A) The sight is capable of ascertaining many circumstances of consequence.

A *clearness* equal to that of crystal indicates great purity. On the contrary, muddiness, and a brown colour shew plainly that heterogeneous matters are so grossly mixed with the water as to obstruct the passage of the rays of light. When the bottom is clay or mud, the water is never perfectly clear; but when it runs over sand it is in general extremely transparent.

Good water is entirely without colour, but it does not thence follow that all colourless water is to be considered as good. A brown colour, verging to red or yellow, is found in dull stagnant waters; it is sometimes occasioned by iron, sometimes by putrid extractive matter, and sometimes, perhaps, is derived from some unctuous substance.

—A blue colour indicates vitriol of copper; a green, martial vitriol, &c.

If the water, upon agitation, emits a number of airy bubbles, a quantity of aerial acid is indicated.

(B) Good water has no *smell*.—Such as abounds with the aerial acid diffuses a subtile and penetrating odour; such as contains any portion of hepar sulphuris yields a smell resembling that of putrid eggs or fired gunpowder.—Stagnant and corrupted waters have a putrid offensive smell.

(c) Water is the better, in proportion as it is the more completely void of taste; yet a palate which is delicate, and accustomed to the taste of waters, will discover some difference even among the purest.—Aerial acid occasions a gently pungent acescent taste;—a bitterness accompanies Glauber's salt, nitre, vitriolated, nitrated, or salited magnesia; as also nitrated or salited lime;—a slight austerity proceeds from lime or gypsum— a sweet astringency from alum— a saltishness from common salt— a lixivious flavour from alkali— an æruginous one from copper— and an inky one from iron.

(D) The specific gravity lays in some degree a foundation for estimating the quantity of heterogeneous matters contained in water; but cannot always determine the matter with accuracy; because, in some instances at least, a mutual penetration may take place.

It

It is, however, in general true, that the lighter waters are more pure than the heavier; and for determining this point an hydrostatic balance, and a good aerometer, are peculiarly convenient: but if these instruments are not to be had, an ordinary balance may be so managed as to compare the weight of distilled, or very pure snow-water, with that of other waters; this is done by means of a glass vessel with a narrow neck, which is to be filled with water to a certain mark, and exactly weighed. The larger this vessel is the better—but one containing a quadrans (*k*) or two, is generally sufficient; for greater quantities require large weights, which are less accurate.

Finally, in whatever way these experiments are made, the waters compared must be of the same temperature, otherwise the conclusion will necessarily be fallacious.

(E) In the examination of waters, the temperature should be determined by an accurate thermometer, and the following particulars observed:—whether the temperature of the water under examination is the same throughout the year, or whether it follows the changes of the atmosphere—whether it freezes in winter—whether the hot waters form any deposition during refrigeration—and whether, in consequence of cool-

(*k*) The Kanne contains 8 quadrantes, of which each contains $12\frac{1}{2}$ Swedish inches.

ing, their smell and taste grow faint, or entirely disappear.

(F) Local circumstances are by no means to be neglected; to these belong the situation of the water, with respect to its geography both political and natural, and the elevation and properties of the surrounding soil. The quantity of the water should also be observed—whether it remains the same at all seasons of the year, or is obviously dependent upon dry weather and rain—whether it is stagnant—whether it runs swiftly or slowly—what quantity flows from the spring in a given space of time—how many veins the spring consists of, &c.

Whether the water deposits in its bed a saline, an earthy, an æruginous, or an ochry sediment—whether bodies lying in it are covered with a crust—whether saline efflorescences are to be found in its neighbourhood—whether, in the channels and caverns through which it passes, sulphur is sublimed—whether it issues gently, or bursts forth with a sort of ebullition, &c.

It is also proper to observe whether any vegetables grow in the water, and what—and whether any animalculæ live in it.

§ VII. *The Principal Precipitants.*

(A) *Tincture of Turnsole* is obtained from the pigment called lakmus, enclosed in a clean linen cloth,

cloth, and steeped in distilled water. This water soon assumes a blue colour; but, when viewed against the light, it shews a violet tinge. If water be gradually added, the reddish tinge is diminished, and at last entirely disappears. This tincture is capable of detecting the most minute particle of disengaged acid, by instantly growing red. A single grain of highly concentrated vitriolic acid communicates a visible red tinge to 172,300 grains (*l*), or 408 cubic inches, of the blue tincture.

In these experiments the same glass vessel, or at least vessels nearly similar, should always be employed; for a small difference in the diameter of the containing vessel will occasion a difference in the colour of the tincture, when viewed with the rays of light passing through it:—The vessel which I make use of in these experiments is cylindrical, and 17 decimal (*m*) lines in diameter.

Paper tinged by saturated tincture of turnsole, with a little starch boiled in it, is in certain cases more readily changed;—a paper thus prepared, dipped into distilled water containing 12 grains of highly concentrated vitriolic acid to the kanne, and instantly taken out, is found to be

(*l*) The Swedish apothecaries pound consists of 12 ounces, and each ounce of 480 grains.

(*m*) The Swedish foot consists of 10 inches, and each inch of 10 lines.

red—and this same paper, after being made red by distilled vinegar, serves to discover alkalis, by recovering its blue colour more or less completely. The presence of an alkali may, to a certain degree, be discovered by means of the blue paper—its blue colour being heightened by the alkali. Distilled water, containing 40 grains of crystallized fal sodæ to the kanne, restores the blue colour to the paper reddened by vinegar, and a much less quantity of alkali renders the red colour obscure.

We must not, however, be without the tincture itself, as being more sensible than the paper. Thus, water saturated with aerial acid, does not change the colour of the paper; yet one part of such water makes about 50 parts of the tincture distinctly red. Nearly the same effect is produced by a single grain of highly concentrated vitriolic acid, mixed with 3,445 grains of distilled water; therefore, supposing the specific gravities of distilled water, concentrated vitriolic acid, and aerial acid, to be, respectively, as 1, 2, and 0,0018, we can in some measure compare the forces of these acids; for, upon calculation, they are found to be in equal weights, as 3,445 to 555, or as $6\frac{1}{3}$ to 1—and in equal bulk as 6,890 to 1.

(B) *The watery tincture of Brasil wood* is red, but readily takes a blue colour from alkalis; paper steeped in this tincture, with a little starch boiled in it, is also red, and is equally fit for the
present

present purpose; we may therefore dispense with the tincture, the application of which is more troublesome. One grain of newly crystallized sal sodæ, dissolved in 4,295 grains of water, or (which is the same) 10 grains in a kanne, changes the red colour of this paper to a blue, faint indeed, but easily distinguishable; nay, an experienced eye will perceive the change, even though there be no more than six grains to a kanne.

Acids induce a yellow colour upon paper tinged by Brazil wood, and restore immediately the original red colour to the paper which has been made blue by alkalis.

(c) *Watery tincture of turmeric* is more or less changed to a brown by alkalis: paper tinged, as in the former case, by this tincture and starch, possesses the same property with the foregoing; so that the tincture may be dispensed with. A single grain of newly crystallized sal sodæ, dissolved in 859 grains of distilled water, communicates to it the property of manifestly obscuring the yellow colour of the paper: hence a kanne of water will not produce the same effect, unless it contains 49 grains of that alkali—acids render the yellow colour somewhat paler—volatile alkali produces changes upon all these papers, but these changes are very fugitive.

All these precipitants may be advantageously employed; the first, chiefly for discovering acids, and the two last for alkalis; it is true, indeed, that

that the blue of the turnsole, when changed to a red by acids, may serve to discover alkalis, so that the papers tinged by turmeric and Brazil wood may seem unnecessary;—but we must observe that the latter of these two exceeds all other tests in sensibility, so as even to discover certain earths dissolved in water by means of aerial acid, such as terra ponderosa, lime, and magnesia. As to the former, it is indeed more slow, but by this very slowness it indicates in some degree the relative quantity; and besides, when it is necessary to observe the change of colour occasioned by alkalis by candle-light, the effect upon turmeric is more distinguishable.

Syrup of violets, therefore, is by no means necessary, especially as, 1st, we can seldom have any genuine, at least in Sweden; 2d, this syrup spontaneously acquires a red colour by fermentation; and, 3d, it is rendered green not only by alkalis, but by iron; which renders any conclusion drawn from thence ambiguous (*n*).

The

(*n*) It may be doubted whether the reasons here alleged are sufficient to justify the learned Professor in expelling so contemptuously syrup of violets from the place that it has so long held in the class of reagents. For, 1st, we are taught by chemical writers how to distinguish the genuine from the spurious syrup, viz. by solution of corrosive sublimate, which changes the former to a green, while it reddens the latter. 2. It is not easy to be misled by the alteration produced by the spontaneous fermentation, be-
cause

The general rule, namely, That blue vegetable juices are made red by acids, and green by alkalis, is liable to two exceptions already known, viz. lakmus is rendered more intensely blue by alkalis, and indigo dissolves in vitriolic acid, without any change of colour. The blue juices of different vegetables are unequally affected by acids and alkalis; a circumstance which demands a series of experiments, in order to ascertain the relative power of these salts. Pure aerial acid does not exert its power, except upon tincture of turnsole;—distilled vinegar changes syrup of violets, but has no effect upon the blue paper used for covering sugar-loaves, which yet is made red by the stronger acids; and so of the rest.—Besides, determined

cause the experimenter cannot fail to perceive that beforehand. 3. He who has once compared the green produced by iron with that produced by alkalis, will easily be enabled to distinguish them on every future occasion; the latter being a lively and pleasant tinge, the former a yellowish dirty hue. 4. "When certainty," says M. de Morveau, "can only be attained by the coincidence of many results, this additional instrument, which in some cases shews properties different from other analogous reagents, ought not to be entirely thrown aside."

"M. Neuman and the Count de Saluces," adds the same judicious annotator, "have observed that syrup of violets passes from green to yellow when the alteration has been made by alkaline liquors, but continues green when the change has been produced by neutral salts." Mem. de Turin. B.

weights of vitriolic acid and of alkali should be successively mixed with different quantities of water, and their various effects upon the vegetable juices accurately noted. Thus, from a comparison of their effects, the quantities of acids and alkalis, which are at present unknown, might in some degree be determined. But this useful investigation requires a long train of experiments.

(D) *A saturated tincture*, extracted by spirit of wine from powdered galls: the watery tincture may also be employed, but it soon grows mouldy.—By this tincture iron is discovered, being slowly precipitated:—if the quantity of metal be small, the precipitate is purple; if large, black. Distilled water, containing three grains of crystallized martial vitriol in the kanne, upon the addition of a single drop of this tincture, grows distinctly purple in less than five minutes. Yet three grains of martial vitriol contain no more than $\frac{1}{4}$ grain of iron.

(E) *The phlogisticated alkali*, as it is commonly called, is best prepared from four parts of Prussian blue, boiled with one part of alkali in a sufficient quantity of water. The clear liquor, saturated with an acid, must then be freed by filtration from the small portion of Prussian blue which is separated.—This preparation is extremely well adapted for discovering the smallest portion of iron. Distilled water, containing in the kanne one, or at most two grains of green vitriol, on the

the addition of a single drop of this lixivium instantly shews a Prussian blue.—It also precipitates other metals ;—copper it precipitates of a reddish brown colour—manganese, white ; and so of the rest.

(F) *Concentrated vitriolic acid* dropped in water immediately precipitates a spathum ponderosum, if (which rarely happens) there be present any terra ponderosa (iv.) The appearance of a number of bubbles shews whether there be any considerable portion of alkaline salt, lime, or magnesia, dissolved by the aerial acid.—In order to occasion a sensible effervescence there should be at least 390 grains of newly crystallized sal sodæ in a kanne, a quantity which however is not affected by strong marine acid. The other mineral acids may be employed for the same purpose ; but the effects of these will be always less remarkable, as they are less susceptible of concentration to so great a degree as the vitriolic acid.—The concentrated nitrous acid is however very useful for discovering sulphur in the hot waters which have an hepatic smell—for this acid, seizing the phlogiston, precipitates the sulphur which, by its means, was united to the matter of heat, though the sulphur so combined is able to elude all the ordinary modes of examination ;—concentrated nitrous acid, added in proper quantity, soon takes away the hepatic smell, thereby indicating a decomposition,

tion, and the sulphur, subtilely divided, falls slowly to the bottom.

(G) *The acid of sugar* is one of the most delicate tests hitherto known for the discovery of lime, however mixed. A single grain of pure lime dissolved in a kanne of distilled water, shews white clouds and striæ, if a small portion of crystallized acid of sugar be laid on the surface, or dissolved and dropped in.

If the lime be in a still smaller quantity, and the most minute crystal of saccharine acid let fall to the bottom, in a short time a sort of powder, consisting of saccharated lime, is found about the spot where the crystal falls. Scarce any water is entirely free from lime; and the purest, within twenty-four hours at least, deposits a portion of saccharated lime, although sometimes so sparingly as to escape observation, unless lines be drawn on the bottom of the vessel with a glass rod.—Such is the water of Varby, which is justly enumerated among the best waters in Sweden.

Essential salt of wood-sorrel, and the *microcosmic salt*, also precipitate lime; but more slowly and less effectually than the acid of sugar does.

(H) *Aerated fixed alkali* precipitates all earths and metals from their solutions: if the substance to be precipitated is easily soluble in the aerial acid, the caustic alkali in general effects a more remarkable separation—generally, I say, for this
is

is not always the case; for *terra ponderosa* is not precipitated by that alkali.—If there happens to be present a disengaged mineral acid, every particle of the aerated alkali emits bubbles.

(1) *Aerated volatile alkali* precipitates all earths and metals; but caustic volatile alkali has no effect on lime or *terra ponderosa*. Distilled water, containing 98 grains of vitriol of copper to the kanne, is scarcely blue. If in the same quantity of water there be only $6\frac{1}{2}$ grains, the copper is distinctly precipitated on polished iron; but a few drops of solution of volatile alkali only occasions a cloud, which is scarcely visible. This cloud, if the vitriol be in larger quantity, soon changes from an ash colour to a blue; and, when well diffused by agitation, communicates to the water a faint and dusky tinge. If the volatile alkali be superabundant, all the precipitated copper is re-dissolved with a most beautiful azure colour; for the quantity of this metal which is contained in four grains of blue vitriol, is sufficient to give a visible tinge to a whole kanne of water, if the copper be precipitated by a proper quantity of volatile alkali, and afterwards re-dissolved by a superabundance of the same alkali.

(K) *Lime-water* dropped into water which contains any aerial acid, renders it instantly turbid; because that portion of the lime which is saturated by that subtle acid loses its solubility.

(L) *Salited terra ponderosa* is of considerable

use in discovering the smallest vestige of vitriolic acid, with whatever menstruum it may be united; for this acid separates terra ponderosa from all others, forming with it a spathum ponderosum, scarcely any of which water is able to take up. Distilled water, containing 12 grains of newly crystallized Glauber's salt to the kanne, on the addition of a few drops of solution of salited terra ponderosa, immediately exhibits white striæ.—If there be present no more than three grains of the Glauber's salt, after a few minutes a cloud forms at the bottom, which also happens even when there is but one grain in the kanne; but in this case the water must stand some hours before the cloud becomes visible. Now, that we may the better judge how great the nicety of this precipitant is, let us consider that 12 grains, 3 grains, and 1 grain of Glauber's salt, contain respectively no more than 3, 0,78, and 0,26 grains of vitriolic acid; so that this substance exceeds turnsole itself in sensibility.

(M) *Salited lime* is generally considered as a useful medium for discovering fixed alkali, for the aerated lime separates, and falls to the bottom; but this experiment is ambiguous, because, if any vitriolated magnesia be present, a double decomposition takes place, and a gypsum is formed.

(N) *Solution of alum* has sometimes been employed, but is of little use, as it is decomposed by
alkalis,

alkalis, either fixed or volatile, and by aerated, falited, or nitrated lime. If a piece of alum, the bulk of a small pea, be put into the water under examination, in a quarter of an hour a spongy stratum is observed, horizontally suspended near the bottom: however, as before observed, the cause of this phænomenon is uncertain, unless determined by other experiments.

Seven grains of alum dissolved in a kanne of water; upon the addition of a single drop of solution of alkali, either mild or caustic, instantly shew a manifest argillaceous precipitate.

(o) *Nitrated silver* dissolved in distilled water affords a most complete method of discovering the smallest traces of marine acid; for this acid, whether disengaged or united with another base, instantly seizes the silver, forming with it a metallic salt very difficult of solution, which therefore separates in the form of a white mucilage. A single grain of common salt dissolved in a kanne of distilled water, at the first drop of solution of silver, exhibits white striæ, which, however, are not produced, if the water contains no more than half a grain—but a grain of common salt contains about half a grain of marine acid.—Solution of silver is acted upon by vitriolic acid far more slowly, for no visible turbidness will arise, unless the kanne of water contains 98 grains of Glauber's salt, which contain 25 grains of vitriolic acid. Now, since the acid constitutes one fourth of falited silver, we may

determine the quantity of marine acid from the weight of the precipitate effected by the solution of silver when the precipitation is complete.—The quantity of acid contained in vitriolated silver is very little greater.

If any hepar be present, the salited silver which precipitates is of a lighter or darker brown colour. It is also proper to observe, that a single drop of solution of silver occasions a visible precipitation in water altogether destitute of both marine and vitriolic acid, provided it contains 12 grains of newly crystallized sal sodæ to the canne. Lime and magnesia, united with aerial acid, in like manner precipitate silver: but the quantities have not yet been exactly determined.

(P) *Nitrated mercury* is to be employed with great circumspection, as it possesses different properties, according to the circumstances of the solution; for if the solution has been conducted without heat, very little phlogiston is lost, and the salt easily crystallizes, being white, and scarcely acrid. This is precipitated, by caustic vegetable alkali, of a yellowish white: by the same alkali, saturated with aerial acid, white: by sal sodæ, yellow, which soon grows white: by volatile alkali, greyish black: by Glauber's salt, or disengaged vitriolic acid, white, granulated, and in small quantity; nor, if the precipitant has been sparingly used, does it appear in less than an hour: by marine acid, common salt, and other saline substances

stances containing that acid, white, in large quantity, and of a caseous consistence. Solution of mercury, made without heat, immediately discovers the marine acid, even although there be no more than half a grain of common salt in a kanne of distilled water: but it discovers vitriolic acid more slowly; for about four grains of Glauber's salt (that is, one grain of acid) are requisite in a kanne of water, in order to occasion a visible precipitation with the same degree of quickness.

When neither vitriolic acid nor marine acid is present, the mercury is precipitated by alkalis; as also by lime or magnesia dissolved by means of aerial acid.—A single drop of solution of mercury forms visible clouds, although there be no more than six grains of newly crystallized sal sodæ in a kanne of water.

Solution of mercury, made by long continued boiling in superabundant acid, is more dephlogisticated, as appears from the red vapours which it sends forth. This solution crystallizes with more difficulty, and has a very acrid taste. It is precipitated by vegetable alkali of a brownish yellow, but by degrees assumes a paler yellow tinge; and, if the alkali be fully saturated with aerial acid, the precipitate is at first of a brownish yellow, but afterwards becomes of a yellowish white. A brownish yellow powder is precipitated by sal sodæ; this powder afterwards grows white. The precipitate occasioned by volatile alkali is white; that by vitriolic

trilic acid, either disengaged or united with any base, yellow; but the precipitate immediately grows white upon the affusion of a little marine acid. The smallest quantity of marine acid, either disengaged or otherwise, occasions a very copious white mucilaginous precipitate.—A blackness in the precipitate indicates either the presence of an hepar, or that the mercury is nearly in its metallic state (o).

Mucilage

(o) It sometimes happens, not only that the precipitate is black, but that there appears upon the surface of the liquor a shining pellicle, which announces a species of revivification. When it is considered, that such reductions are effected more especially by the volatile alkali, which contains phlogiston among its constituent parts, it would seem certain, that the precipitates are so much the more coloured, and the nearer reduction, as the liquor itself contains or receives from the precipitant more phlogiston. Professor Bergman furnishes an additional fact in favour of this opinion, when he observes, that volatile alkali produces a precipitate of a dark grey colour, when the solution has been made without loss of phlogiston; and of a white colour, when red vapours arise during solution. He, however, establishes here an opposite principle, viz. the more there remains of phlogiston in the solution, the less is the precipitate coloured. Each, therefore, of these systems is inadequate to the explication of the phenomena. We want some further knowledge, in order to conciliate them, and to explain why, for instance, the same solution of corrosive sublimate is precipitated of a yellow colour by lime-water, and of a white by caustic volatile alkali.

The author's observation is, notwithstanding, not less valuable :

Mucilage is also precipitated by nitrated mercury: thus distilled water, containing three grains of cherry-gum in the kanne, on the addition of nitrated mercury instantly forms white clouds and striæ.

(Q) *Corrosive sublimate* is also in use for the examination of waters, especially for the discovery of aerated alkali. If a kanne of distilled water contains 280 grains of newly crystallized sal sodæ, a single grain of saturated solution of corrosive sublimate immediately produces a reddish powder; a small piece of the sublimate itself, added to the water, discovers alkali, even better than the solution. —The cause of the redness of this precipitate is explained elsewhere (p).

Both lime and magnesia, when aerated, by means of a double elective attraction, precipitate a calx of mercury, though slowly.

(R) *Acetated lead* is precipitated in the form of a white powder by the marine acid, either dis-

soluble: it may enable us to discover why solutions of the same metal, in the same acid, are less permanent; why solutions of metallic calxes are less apt to form depositions, when they proceed slowly, &c. Mr Maret has already made a very happy application of this observation, by shewing, in the Dijon course of lectures, that his process for precipitating iron in the form of Ethiops martial, by caustic volatile alkali, never fails, but when a nitrous solution, made by heat, and with red vapours, is employed. Morveau.

(p) *Treatise on the Aerial Acid*, § xxi.

engaged

engaged or otherwise; and this new combination is soluble in vinegar, but is not a convenient precipitant, because salited lead is also soluble in a large quantity of water: it is more convenient for discovering vitriolic acid, for the precipitate or vitriol of lead, which is in the form of small grains, is scarcely soluble in water, or even in vinegar. Distilled water, containing 118 grains of common salt in the canne, shews striæ somewhat milky, if a small piece of acetated lead be laid on the surface; upon increasing the quantity of common salt, the appearance becomes more remarkable. Nearly the same weight (115 grains) of Glauber's salt is requisite, in order to occasion a visible separation of vitriol of lead—and hence it would appear, that these two acids are almost equally discoverable by acetated lead; but we must observe, that in 118 grains of common salt, the acid amounts to about 60 grains; whereas, in 115 grains of Glauber's salt, the acid is no more than $29\frac{1}{2}$.—Now, as vitriolic acid forms nearly 0,28 of vitriol of lead, we may, from the weight of the vitriol, in some degree judge of the quantity of acid, if the water be completely precipitated by the acetated lead. However, when muriatic acid is present, which is almost always the case, the conclusion is rendered inaccurate, on account of the much greater solubility of salited lead.

Acetated lead seems to lose its acid spontaneously

ly by age; for a piece of it, when old, put into water, remains insoluble at the bottom.

A brown or black sediment indicates the presence of sulphur in a state of solution; alkalis, lime, and magnesia, dissolved in water by means of aerial acid, also precipitate lead, without the presence of either marine or vitriolic acid. A single drop of solution of lead exhibits white striae, in water containing no more than six grains of newly crystallized sal sodæ to the kanne.

(s) In some cases, *martial vitriol* promises to be of use. If a crystal of this salt be put into an ounce phial filled with distilled water, the phial immediately well closed, and set in a cool place, the vitriol is dissolved, without depositing any ochre, unless the water has taken up pure air, which very powerfully attracts phlogiston, and therefore separates a portion of it from the base of the vitriol; so that the base, being calcined, requires more acid than before to suspend it; and if the deficient acid be not added, the iron necessarily falls in the form of an ochre. The same is evidently seen, when the precipitation is effected by means of an alkali; for the sediment, which is at first green, preserves its colour in a vessel full and perfectly closed, provided the water be deprived of air, but in an open vessel it soon changes to a ferruginous colour; because, even though the water had not contained any air, the external air acts upon the precipitate. When the water
does

does not contain any thing capable of precipitating the vitriol, a few drops of alkaline lixivium may be added before the vessel is shut; but if the water contains air, the alkali is not necessary, as the base of the vitriol is quickly dephlogisticated; and hence, as has been before observed, the same quantity of acid is not sufficient to dissolve it, and consequently some ochre is deposited. If there be present at the same time a considerable quantity of aerial acid, the ochre is rendered white.—The quantity of ochre serves in some measure to determine the quantity of air present.

It is also necessary to observe, that not only alkalis, but also lime and magnesia, united with aerial, marine, or nitrous air, decompose martial vitriol, although a precipitate does not appear in every case; for marine acid holds iron suspended, although it be very much dephlogisticated.

(T) *White arsenic* is only useful when water is more or less impregnated with hepatic vapour, but does not contain a genuine hepar (x). If to such water a small piece of white arsenic be added, the arsenic grows yellow by attracting the sulphur, and is thus converted into orpiment.

(U) *Soap* is not soluble in every kind of water; this is occasioned either by a disengaged acid, or by a large proportion of middle salt, with an earthy or metallic base; in either case a decomposition takes place, the acid unites with the alkali, and the oil is disengaged: such waters as
these

these are generally called hard waters, and are unfit for washing clothes, as also for boiling pulse, and the harder kinds of flesh.

Distilled water scarcely takes up 0,1 its own weight of soap, and that imperfectly, for it contracts an opal colour; and after some time the soap, which had been suspended, falls to the bottom in the form of a mucilage. Spirit of wine acts upon soap more powerfully, for it takes up more than $\frac{1}{3}$ its own weight, after which it admits without growing turbid, the addition of distilled water, but not of hard. If there be present in a kanne of water but 8 grains of alum, salited magnesia, or salited lime, a single drop of this water occasions a turbidness in solution of soap in alcohol, diluted with an equal bulk of distilled water.

(x) Some persons add to the above mentioned precipitants *hepar sulphuris*, because it is decomposed by the weakest acid, and even by the purest aerial acid; however, in the examination of waters, we may readily dispense with it, as well as with salited lime, alum, corrosive sublimite, nitrated mercury, (at least that prepared by heat) and acetated lead;—the same is true of milk. If to *hepar sulphuris* a small quantity of vitriolic acid be added, an elastic vapour is immediately generated, with which water may be impregnated in the same way as with aerial acid, and it will then possess the hepatic odour (VIII. E).

(y) *Alcohol* added in sufficient quantity precipitates

pitates all the salts found in waters which are insoluble in spirit of wine. Such are all those containing vitriolic acid, but those consisting of marine or nitrous acid are generally soluble, but require different quantities of spirit for their solution (*q*). Here it may be useful to remark, that, according to experiments which I have made for the purpose, alcohol, in an heat of 15 degrees, can take up, of dry nitrated magnesia, $\frac{1}{10}$ its own weight; of dry salited magnesia, $\frac{1}{7}$; of dry nitrated lime, $\frac{1}{7}$; and of dry salited lime, $\frac{1}{8}$.

Besides the precipitants already mentioned, many others have been employed, which, I imagine, we may pass over untouched, as they discover no more than those already proposed, nor are they more accurate. Nor indeed is it necessary to employ the whole of the substances already examined:—it is true, that when time and circumstances permit, even superfluous trials are not improper, as they tend to confirm one another; yet, for the most part, a few, when well chosen, are sufficient for the purpose.—For the discovery of acids, when disengaged, we have occasion only for the tincture and paper of turnsole;—when they are united with other substances, they are easily discovered by nitrated silver and salited terra ponderosa;—uncombined alkalis are detected by the papers tinged with Brazil-wood and tur-

(*q*) Vid. M. Macquer Exp. in Comm. Taurenfibus.

meric, and when combined with acids they are discovered by spirit of wine.—Aerated calcareous earths are precipitated by the acid of sugar; and, when thus completely separated, that species which can afterwards be thrown down by aerated alkali is either magnesia or clay; the former of which dissolves in distilled vinegar, with effervescence, while the latter is taken up slowly, and without any effervescence.—Metals are plainly discovered by phlogisticated alkali, but these, iron only excepted, are rarely found in waters; so that, for the most part, tincture of galls is sufficient.—If terra ponderosa be at any time present, it is discovered by vitriolic acid.—Saline or earthy hepar is very rarely found in the natural cold waters, but may be easily decomposed by any acid whatever; and when the sulphur, which occasions a turbidness, is separated, the transparency returns. In general, water contains only an hepatic vapour, which, though it resembles hepar in smell, is not decomposed by the addition of any acid, excepting only those which, even though diluted, powerfully attract phlogiston;—of this kind is the nitrous acid. Besides, at Aix pure air, out of the water, separates the sulphur from the hepatic vapour, which, in this instance, is not confined by union with an alkali (VIII. E).

Finally, precipitants may be employed, not only with the waters newly taken from the spring, but after they have been reduced by evaporation

to a small bulk.—If it be only necessary to determine the quality of heterogeneous matters, one or two cubic inches of the water, and a few drops of the proper precipitants, will suffice; but if we desire also to know the weight of the different substances, large quantities of water must be subjected to experiment, and these should be conducted in transparent glass vessels.

§ VIII. *Method of collecting the heterogeneous volatile Matters.*

The elastic vapours, resembling air, which are more or less abundant in waters, have occasioned considerable difficulty in the examination of them; and the method of exactly collecting these volatile substances was unknown until the present age: besides, the methods at first employed (such as agitation in a glass vessel, with an empty bladder tied to its neck; or boiling the water, and conducting the vapour into a vessel filled with water, and inverted) were lame and imperfect;—for, in the former method, the whole of the volatile ingredient can scarcely be elicited—and in the latter, no small part of that which is extricated is again concealed, being absorbed by the water through which it passes.

But by the following method, that vapour, commonly known by the name of mineral spirit, may,

may, with the greatest accuracy, be separated and collected.

(A) In proportion as the water is more fully impregnated with aeriform matter, the less is the quantity necessary to be subjected to examination;—of such as abound with it, half a quadrans is sufficient, and eight times that quantity of the very poorest will be enough.—For this purpose a glass retort is employed, with a long narrow neck, the end of which is bended upwards, (A B C, tab. ii. fig. 2.). The retort must be chosen of such a size that the water may not boil out through the neck, nor yet too great a space be left above the water, lest too large a quantity of common air be included.

The quantity of water whose volatile vapour is to be determined, being put in, let the retort be so placed that it may be exposed to heat; but before the fire is lighted let the glass vessel D E, filled with mercury, be inverted over the extremity of the tube A B C, (which is turned upwards, and sustained in the vessel F G, full of mercury) in such a manner that the mouth of the vessel D E may be somewhat beneath the surface of the fluid metal in the vessel F G. This operation requires a dexterous and experienced hand, to prevent the mercury from falling out during the inversion of the vessel; or, which comes to the same, to prevent the admission of air into the vessel D E: the size of that vessel should be such that it may be able to con-

tain all the elastic fluid extricated, together with the portion of common air contained in the retort above the surface of the water;—its capacity ought therefore to be somewhat greater than the sum of the bulks of the air contained in the retort, and of the water under examination, if the water be saturated with elastic vapour; but if it be common water, a much less size will suffice.

The whole apparatus being properly prepared, fire must be applied, and continued to full ebullition. The heat penetrating the water, occasions a quantity of bubbles, which, increasing as the heat increases, pass through the mercury, and are collected in the upper part of the vessel D E. A few minutes boiling will not indeed be sufficient to expel all the elastic fluid, but the portion remaining will be very small, and of little moment.

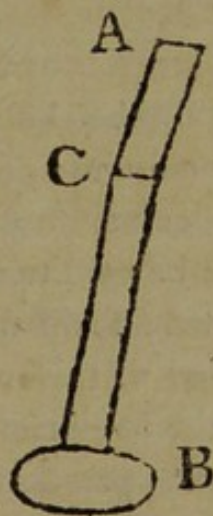
After this process, let the height at which the mercury stands in the inverted vessel be noted, and thus we may ascertain the space apparently empty, in cubic measure. If the vessel D E be cylindrical, and divided into known parts of dimension, the bulk of the elastic fluid appears barely from inspection; from hence, subtracting the bulk of the common air contained in the retort, the bulk of the elastic vapour extricated from the water is determined.—If this apparatus be not at hand, a Florence flask, or some other vessel of proper size, may be used, and a bladder, well compressed, tied to its neck, to receive the vapour extricated
by

by boiling : but the conclusion in this case will be less accurate.

Before the retort cools, the bended part of the neck must be taken out of the mercury, otherwise that metal will gradually fill the retort; for the apparent vacuum over the surface of the water is only occupied by a watery vapour, which is reduced to the form of water by cold (*r*).

(B) The

(*r*) The author here supposes, that the quantity of mercury displaced *A c*, in the cylindrical receiver here sketched, indicates the quantity of elastic fluid disengaged by boiling; but this estimation is not exact, because the air contained in the space *A c* is in a greater state of dilatation than the atmospherical air; for instead of being charged with the whole weight of the atmosphere, it is only charged with that weight, diminished by the weight of the column of mercury *c B*; so that if the present state of the barometer in the open air is expressed by *n*, the height of the column *c B* by *h*, the density of the air in *A c* will be to that of the open air, in the proportion of $n - h$ to *n*. If then the column *c B* is of seven inches, while the barometer stands at 28, four measures of the air contained in *A c* would be only equivalent to three, at the degree of condensation of the open air. Further, the error may be total, *i. e.* by following this method one might be led to believe that there was air in water which contained none at all, because the air remaining in the neck of the retort, driven



(B) The elastic fluid, thus collected, generally consists partly of pure air and partly of aerial acid. To demonstrate this, and (if both be present) to determine the quantity of each, one of them must be separated; which is performed in this manner: Let the aeriform fluid be agitated with lime-water, which may be introduced into the inverted vessel, by closing it carefully, and transferring it from the mercury into a vessel filled with lime-water, and then opening it; by these means the aerial acid is absorbed, and the pure air, if any there be, remains alone—the bulk of which subducted from

ven by the ebullition into A c, will be the more expanded the more the pressure of the air is diminished, or the higher the column B c happens to be. Attention should therefore be paid to this dilatation, and it may easily be ascertained; for if the volume of air remaining in the retort is called v , the volume of mercury displaced in the receiver r , the height of the mercury in the barometer at the time of the operation H , and the height of the column of mercury c B, h , the quantity or bulk of the air really disengaged from the water by boiling, and reduced to the density of the atmospherical air, will be $r - c - \frac{r h}{H}$. If, for instance, three measures of air had been left in the retort, and that air had displaced four in the receiver, and the column of mercury c B had been 7 inches, and the barometer at 28, the quantity of air produced would be $4 - 3 - \frac{4 \times 7}{28} = 0$. Note, communicated by M. de Saussure to M. de Morveau.

the whole shews the quantity of aerial acid (s).

(c) The aerial acid constitutes the genuine *spiritus mineralis* of the ancients, as is most evidently demonstrated by the analysis above proposed; for all the mineral waters celebrated for virtue give out a considerable quantity of an elastic fluid, (even sometimes a portion equal in bulk to the water itself), possessing all the properties of that subtile acid. And what puts the matter beyond doubt is, that if the elastic fluid of such waters be either

(s) Mr Gioanetti is of opinion, that the quantity of aerial acid may be better determined by weight than bulk: his method certainly does not require either an apparatus on purpose, or so much nicety: he puts into a large bottle two pounds of aerated water, and pours in a superabundant quantity of lime-water, he then corks it; as soon as all the precipitate has fallen to the bottom, he separates the liquor by means of a syphon, and, havingedulcorated and dried the precipitate, estimates the weight of the aerial acid by the weight of the calcareous earth. In order to distinguish the uncombined aerial acid from that which might be united with some basis, he repeats the same operation upon water deprived of its air by boiling. Mr Gioanetti assumes, for the foundation of his calculation, the experiments of Mr Jacquin; according to which, 32 parts of calcareous earth contain 13 of fixed air, 2 of water, and 17 of earth; but this estimation differs from that of Professor Bergman by $\frac{53}{800}$; whence it appears, that it is not less difficult to determine with precision the quantity of fixed air contained in calcareous earth than the proportion which the bulk of this fluid bears to its weight. See *Analyse des Eaux de St Vincent*, p. 14. Morveau.

gradually dissipated in an open vessel, or suddenly expelled by heat, the water loses its grateful pungent acidity, which it recovers altogether, when the loss of that elastic fluid is supplied: analysis and synthesis then agree so perfectly on this occasion, that whoever considers the operations with due attention must be clearly satisfied of the truth of the position—in another place, I have at large explained the method by which the natural aerated waters may be imitated.

It may happen, indeed, that the phlogisticated vitriolic acid (commonly called volatile acid of sulphur) shall be mixed with the aerial acid; but most undoubtedly this is a very rare occurrence: at least, I do not hesitate to assert, that the Pyrmont, the Spa, the Seltzer, and other waters, whose penetrating and volatile efficacy has been attributed to a disengaged phlogisticated vitriolic acid, do not contain the smallest particle of it. These waters, upon analysis, are found to contain lime and magnesia aerated; and the last (the Seltzer) also contains an aerated mineral alkali, which is utterly incompatible with the existence of a disengaged vitriolic acid; for this acid, to whatever degree it may be phlogisticated, attracts lime, magnesia, and alkali, with a force superior to that of the aerial acid: if present, therefore, it must expel the weaker acid, and take its place—that is, it must lose its disengaged state. The presence of phlogisticated vitriolic acid cannot therefore be asserted,

ed, without a palpable contradiction, so long as any aerated alkaline substances are found in the same water. It is alledged, indeed, that this decomposition cannot take place in the bosom of the earth, and no doubt (*t*) that is sometimes the case; but it certainly cannot hold with respect to Pyrmont, of which, however, it is particularly asserted; for, at its very first appearance, upon the addition of spirit of wine, it separates its magnesia and lime completely vitriolated. No person who has seen or examined the phlogisticated vitriolic acid, can possibly confound it with the aerial acid; for the smell of the former is pungent and highly penetrating, that of the latter scarce sensible: the taste of the former, acrid and nauseous; that of the latter, very mild and agreeable: the former may be reduced to a liquid form; the latter is always in a state of vapour: the former, being stronger, expels the latter from every kind of base, and forms, with each of them, compound salts of a species very different from those formed by the same with aerial (*v*) acid;—in short, they scarcely possess any property in common, excepting only the general properties of acids. If the opinion of such as confound those two acids were well founded, the former would not change the colour of syrup of violets, which the latter is never

(*t*) Aerial Acid, see p.

(*v*) Treatise on elective Attractions.

found to do ; but I have always observed that phlogisticated vitriolic acid, unless when mixed with iron, changes syrup of violets to a red.

(D) Waters abounding with fixed air, as I before observed, possess a pungent but agreeable acriscent flavour ; and from hence, doubtless, it is that from the most remote times they have been called *acidule*. The propriety of this denomination is called in question by many persons at this day, because these waters effervesce with acids, and not with alkalis ; and also change the colour of syrup of violets to a green ; which are considered as certain signs of an uncombined alkali. But here we must observe, 1st, That, strictly speaking, effervescence with acids never indicates a pure alkali, but an alkali united with the aerial acid, which, upon the addition of a more powerful acid, is separated, and, recovering its elasticity, must float in the form of bubbles on the surface of the more ponderous fluid ; whereas an alkali perfectly caustic does not excite the smallest effervescence with acids : 2d, A similar effervescence also takes place, when lime or magnesia aerated meet with an acid ; and this is the case with Pyrmont water, which does not contain any aerated alkaline salt.—Spa water, indeed, contains a small portion, and Seltzer still more : 3d, Alkaline substances, whether saline or earthy, though saturated with aerial acid, yet act as precipitants, in virtue of their alkaline nature, and exert a certain

tain force upon various bodies, which force is not altered by the aerial acid, on account of its extreme weakness; this force is, however, somewhat diminished, though it can be entirely suppressed by the quantity of acid necessary to the saturation of the alkaline salt and the water which dissolves it: 4th, The aerial acid cannot effervesce with alkalis, because it is the expulsion of this acid by a stronger one, that occasions the motion and the spumescence, appearances which are not occasioned by the meeting of an alkali with the aerial acid. Thus the most completely aerated Pyrmont or Seltzer water, upon the addition of a small quantity of alkaline salt, particularly if caustic, immediately grows flat, and acquires a vapid taste, and that without any visible motion: 5th, The green colour induced upon syrup of violets is evidently a fallacious test (vii. c); for distilled water, in which a small quantity of martial vitriol is dissolved, possesses the property of immediately rendering that syrup green.

Since, then, in the acidulous waters, not only the alkali is saturated with aerial acid, but the water also contains it so copiously as to render tincture of turnsole red, such waters cannot properly be considered as alkaline. This acid, though superabundant, is so weak, that it is not able totally to repress the alkaline properties; it is also volatile, but neither its weakness nor its fugacity can subvert its essential properties.

(E) From the sulphurated hot waters an hepatic vapour is collected, the presence of which is readily discovered by its peculiar factor: this is sometimes present, together with aerial acid disengaged, and it is decomposed, when it has quitted the water, by pure air; which cannot appear surprising, as concentrated nitrous acid is capable of effecting that decomposition, even in the water. The explanation of both is the same: Thus the hepatic aura is tenacious of its form of vapour—hence a very large and dry surface of contact is presented to the atmosphere, in consequence of which the pure air seizes the phlogiston, which in a hepatic vapour connects the sulphur with the matter of heat, and thus, the bond of union being removed, the sulphur appears in its proper form. This is the origin of the sulphur which is sublimed at Aix-la-Chapelle; hence, too, we understand how hepatic vapour is quickly decomposed, and deposits its sulphur, upon the addition of any substance which is capable of separating the phlogiston.—I before mentioned the constituent parts of hepatic vapour; but as this is particularly examined in the Treatise on Subterranean Fire, I omit the analytical demonstration of it here.

(F) The volatile salts, which, if I may be allowed the expression, are more corporeal when they happen to be present, are found to be driven over into the recipient, or sometimes, though very rarely,

rarely, adhering to the neck of the retort, as the watery vapours dissolve and carry them over; this applies particularly to volatile alkali and the ammoniacal salts, which may be easily separated by the precipitants described (§ VII.). Sometimes, however, the water, passing over also, contains a portion of acid, which, upon examination, is found to be of different sorts: thus, when nitrated lime or magnesia is present, the nitrous acid comes over, because the constituent principles of those salts cohere so loosely, that they are separated by boiling, if continued for any length of time: but the muriatic acid cannot, by this degree of heat, be separated from any salt, except salited magnesia; the phlogisticated vitriolic acid may also be obtained in this manner, if it be uncombined—the quantities of the salts thus decomposed may be discovered by saturating the acids respectively with bases of the same sort with those from which they have been expelled. The weight of the new compound indicates the quantity of salt decomposed by the fire.

§ IX. *Method of collecting the fixed heterogeneous Matter.*

During the evaporation of the water, the fixed heterogeneous matters are continually reduced to narrower compass, and at length the water becomes insufficient to retain them all: hence they
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are separated by degrees, the least soluble first, and then such as require less water for their solution. — I shall now proceed to describe the method of conducting this operation more particularly.

(A) The vessels employed ought to be broad, because fluids evaporate more or less quickly, in proportion to their surfaces. We may safely employ for this purpose earthen vessels, provided they are so compact as not to absorb any saline matter, with a dense and smooth surface, which will not be liable to desquamation; so that such matters as adhere to it during evaporation may be easily separated, and scraped off pure. Iron and copper are corroded, and therefore are in general altogether unfit for this purpose: neither is tin convenient: silver, besides being expensive, is sometimes unsafe, especially if there be any uncombined nitrous acid in the water: vessels made of stone ware are excellent in many respects, but are liable to two objections: For, first, Their surface is somewhat rough, hence a part of the residuum may easily be concealed in the holes and inequalities; and, secondly, they are soft, so that such particles as adhere very closely cannot be scraped off, without danger of scraping off also a part of the vessel: glass vessels would be the most convenient, if the operations could always be conducted in them without breaking; — small and sufficiently thin glass vessels may, without danger, be exposed

exposed to an intense open fire, if properly regulated; but such as are necessary for containing large quantities require for that purpose a sufficient degree of thickness; and hence, being unfit to endure sudden changes of heat and cold, are easily broken. The size of the vessels depends upon the quantity of water necessary for the several experiments.

(B) The quantity of water necessary to be subjected at one time to experiment is generally determined by the quantity of heterogeneous contents; if these are abundant, one kanne is sufficient; but when the quantity is small, six, eight, or more are requisite. If our vessels are not of size sufficient to contain the whole quantity at once, we must add the water from time to time, according as room is made by the evaporation; but this must be done with great circumspection, lest the warm vessel should be broken by the coldness of the water.

(c) A gentle evaporation is most proper; for by violent ebullition a portion of the ingredients is dissipated, nay sometimes decomposed. A cover is necessary, to keep out the charcoal, dust, and embers; this cover must give exit to the vapours by an hole several inches in diameter; but the hole should be kept shut until the issuing vapour is so far condensed as to prevent the dust from falling in.

(D) In this process different phenomena appear,
according

according to the different contents of the water. If there be present lime and iron aerated, in an intense degree of heat, such as 80° or 90° , they are deprived of the quantity of aerial acid necessary to render them soluble; they collect, therefore, on the surface, where the volatile menstruum first becomes deficient, and form a pellicle, which being broken by the agitation of the water, falls to the bottom when the motion ceases. This happens because lime and iron, when barely saturated with aerial acid, refuse to unite with water, but may be taken up when this subtile menstruum is superabundant in the water. This superabundance adheres to them but slightly, and therefore flies off during evaporation;—which also happens spontaneously, upon keeping the water for some days in an open vessel.

The above-mentioned pellicle is found whole, when formed by iron; and in this case it is tinged with the different prismatic colours, according to the different points of view. It has been thought that this contained a certain bituminous oil, particularly because it detonates with nitre; but not the smallest particle of this unctuous matter has as yet been discovered in it. As to the detonation, that is occasioned, in the present case, by the phlogiston remaining in the martial earth, which when fresh contains so much of that principle, that it is soluble in all acids.—But this remainder of phlogiston is gradually dissipated, and that the more quickly.

quickly, and in proportion as it has been exposed to the more heat during evaporation, and to the more free access of atmospheric air. The simultaneous variation of colour indicates nothing more than various degrees of tenuity, or various states of dephlogistification in the particles.

If aerated magnesia be present in water, it is not separated all at once, but continues to fall by degrees during the whole process, from the beginning of the evaporation even to dryness.

Aerated lime and siliceous particles fall rather before a boiling heat.

Of all the salts, gypsum falls first, but not until long after aerated lime and aerated iron.

If saturated solutions of different salts be mixed, they all appear, during the evaporation, in an order conformable to their degree of solubility; that is, such as are least soluble in water appear first:—thus, alum is the foremost, then vitriolated vegetable alkali (if any there be) afterwards, in order, martial vitriol, common nitre, vitriol of copper, salited vegetable alkali, mineral alkali, common salt, vitriol of zinc, vitriolated magnesia, and, lastly, the deliquescent salts: but this order is frequently interrupted by the quantity of the dissolved matters.

The different heterogeneous matters may accordingly be either separated as they successively appear, or, by continuing the evaporation to dryness, be obtained all mixed together. The former method is

in some instances sufficiently commodious, but is generally of little use, especially when aerated magnesia is present, as this substance does not separate altogether; besides, the salts, however carefully collected in this way, are more or less mixed with each other, and the deliquescent salts occasion much inconvenience, especially about the end of the operation. If every particular ingredient is to be separately and accurately collected, the water must be frequently filtered, a process which is attended with as much trouble as the repeated solution and evaporation of the residuum, but is much more uncertain, on account of the particles which are lost upon the filter—hence the latter method appears to be more eligible. If circumstances permit us to repeat our analysis, the former method may be tried, for the sake of comparison.

() The evaporation being continued to dryness, the whole residuum should be carefully collected, and, if thought necessary, weighed; but the weight of the whole will be more accurately determined from the sum of the several ingredients; because, on account of the inequality of exsiccation, more or less of the water of crystallization may be expelled.—Such salts as can be reduced to the form of crystals should be weighed when in that form.

§ X. *Examination of the Residuum not soluble in Water.*

(A) The whole residuum, well dried, is then put into a bottle, and alcohol poured over it, to the height of an inch; the vessel is then shut close, and shaken; and, after standing for a few hours, the liquor is filtered.

(B) To the residuum is then added eight times the quantity of cold distilled water; the mixture shaken; and, after standing some time, it is filtered.

(C) Finally, the residuum is boiled for a quarter of an hour in somewhat more than four or five hundred times its weight of distilled water, and afterwards filtered.

(D) The residuum now is not soluble, either in spirit of wine or water. If it abounds in particles of iron, let it be exposed in an open vessel for some weeks to the rays of the sun, and moistened from time to time: by these means the metal is so much dephlogisticated, that it is not soluble in vinegar, (an effect which may be produced in a shorter time, by means of heat), but at the same time the magnesia is calcined, and the weight suffers a (u) diminution. The presence of iron is very easily discovered by the brown colour. The

(u) Diff. on Aerial Acid.

flow calcination by the sun's rays occasions no inconvenience ; for the residuum being dry, a traveller may easily carry it with him where-ever his occasions lead him.

The residuum generally consists of three or more ingredients mixed together ; these may be separated from each other by the following method :—1st, Upon this residuum, previously calcined, if necessary, and weighed, is poured distilled vinegar, which, by digestion, dissolves the aerated lime and magnesia remaining in the residuum. Any mineral acid may be employed for this purpose, if there be no iron present, a circumstance which ought to be previously examined by the colour and by the precipitants above described ; but as there is sometimes present an argillaceous matter, which is more easily taken up by the mineral acids, I rather recommend the use of distilled vinegar. The residuum, which is not taken up by the vinegar, when washed and dried, shews, by its loss of weight, how much has been dissolved.

2dly, The acetous solution, evaporated to dryness, yields acetated lime, filamentous, and resembling moss. This substance is permanent in a moist air, if it only consists of lime ; but deliquescent, if it contains magnesia. This point may also be further ascertained by diluted vitriolic acid, (which, to guard against superabundance, should be dropped in sparingly and slowly) ; for this acid,
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in the former case, converts the whole mass into gypsum, which falls to the bottom, and is nearly void of taste; but in the latter, it dissolves the magnesia perfectly, forming vitriolated magnesia extremely bitter, and which, on evaporation, forms prismatic crystals; or, if the base be mixed, it forms partly gypsum, partly vitriolated magnesia.

3dly, In order to know the weight of soluble earth which had been suspended in the water, let the gypsum and vitriolated magnesia be separately dissolved, precipitated by an aerated alkali, washed, dried, and weighed; but this tedious process may be avoided, if we recollect that 100 parts of gypsum contain about 34 of pure lime, which are equivalent to nearly 62 of aerated lime; and that 100 parts of vitriolated magnesia contain 19 of pure magnesia, which are equal to 42 of aerated magnesia.

4thly, That part which is not soluble in the vinegar, is either argillaceous, martial, or siliceous. The presence of the first always renders the water somewhat turbid, and of an opal colour: this, as well as the martial earth, is soluble in marine acid; but the metallic earth may be precipitated alone by a phlogisticated alkali; after which the argillaceous part may be thrown down by an alkali. Such portion as resists a sufficient quantity of marine acid, is siliceous earth, which may be further determined by the blow-pipe; for this earth, when

added to the mineral alkali in fusion, unites with it, with a violent effervescence, and is thereby totally dissolved (*e*).

5thly, Aerated manganese may, perhaps, sometimes be discovered in waters; in which case it is found in the residuum, N^o 4, and may be separated in the following manner:—First let the residuum be violently calcined, then pour upon it diluted nitrous acid, with the addition of a little sugar; and, after standing for about an hour, let the liquor be filtered. Upon dropping an alkali into the filtered liquor, a white powder falls, which by ignition grows black, and the weight of which is to be determined by the balance. The rationale of this operation will readily appear (*f*) hereafter; I therefore pass it over here, in order to avoid repetition as much as possible.

(*e*) Mr Gioanetti (l. c. p. 22.) is of opinion, that the quantity of iron may be determined by precipitation with galls; he pours in the infusion till there is a superabundant quantity; and he afterwards exposes the precipitate to heat in a luted crucible;—it loses about $\frac{3}{4}$ of its weight, and becomes sensible to the magnet. This process may be useful to verify or compare results, but alone is not sufficient, as it affords no indication of the state of the iron, nor of the menstruum. Besides, the great diminution of the precipitate after calcination, does not allow us to suppose that its magnetic properties are destroyed by excess of phlogiston. Morveau.

(*f*) Of the white Ores of Iron.

6thly,

6thly, If at any time aerated terra ponderosa is contained in the residuum, (which certainly may be the case, although no person has hitherto discovered it), it dissolves in vinegar like the other absorbent earths, and differs from lime in this particular, that it forms, with vitriolic acid, a spathum ponderosum, which is not soluble in a thousand times its weight of water. 100 parts of this spar contain about 84 of pure terra ponderosa, which are nearly equivalent to 130 of that earth when aerated.

§ XI. *Examination of the Residuum soluble in Water.*

We shall now proceed to examine the solutions mentioned in the preceding section.

(A) The solution obtained by alcohol (x. A) contains chiefly lime and magnesia salited, lime and magnesia nitrated, together with salited terra ponderosa, if one or more of these substances be contained in the water. In order to discover the quality and quantity of the ingredients, evaporate to dryness, pour on diluted vitriolic acid, and continue the process as described (x. D, 2, 3.). Sometimes the alcohol also contains a dephlogisticated martial vitriol, which may be separated from the solution, diluted with a sufficient quantity of water, by a phlogisticated alkali. The solution is of a reddish brown.

(B) The solution made by cold water (x. B.) is to be thus examined: 1st, Crystallization is to be attempted by gentle evaporation—this crystallization succeeds better when the deliquescent salts are separated. Excepting common salt, (of which cold water dissolves nearly as much as hot, and which therefore is crystallized by continual evaporation), all the salts easily assume regular forms, if the evaporation be carried on in a heat of 80° or 90° , until a drop of the solution let fall upon a cold glass, in the space of a minute, exhibits crystalline grains or spiculæ. Slow refrigeration is also preferable to a quick one. Evaporation conducted with a boiling heat, will sometimes produce perfect crystals on the surface; but these generally consist of an aggregation of various sorts. When we are only inquiring into the species of the salt, and not its figure, we must proceed in another way:—

Let the crystals which successively appear be put upon bibulous paper and dried, but not so much as to expel any of the water of crystallization: the form, taste, and other qualities, mentioned in D, will in some measure serve to determine the true nature of each salt: but in order to avoid the smallest doubt, we shall consider them all in the following manner: in No 2. alkaline salts alone are comprehended; 3. neutral salts; 4. earthy salts; 5. metallic salts; and, finally, 6. a number

ber of mixed salts, which are separated with more difficulty.

2. Whether any given salt be alkaline or not, may be discovered to a certainty by various methods; viz. by its lixivious taste, effervescence with acids, and the various precipitants (VII. B. c). By uniting it with vitriolic (*g*) acid, we may determine the species of alkali.

Authors speak of a certain imperfect mineral alkali; but all of that sort, which I have had an opportunity of seeing, appear to be no other than a genuine alkali, but impure, particularly vitiated by deliquescent salts. But we shall have occasion, perhaps, to say more of this hereafter.

3. I call those salts *neutral*, which are composed of an acid and an alkali; and I call those *middle* salts, which have not a saline, but an earthy, or metallic base. Perfect neutral salts, such as are found in water, do not shew any signs either of acid or alkali in a disengaged state, nor are solutions of them rendered in the least turbid on the addition of an alkaline salt.

In the examination of either neutral or middle salts, two circumstances must be particularly attended to; namely, 1st, to determine what the constituent acid is; and 2d, what base the acid is united with.—Vitriolic acid is disco-

(*g*) Distilled vinegar is preferable, as it forms, with vegetable alkali, a deliquescent salt, and with the fossil a foliated crystallizable salt. Morveau.

vered

vered by falited terra ponderosa (VII. F, L) or by acetated lead (VII. R). When the nitrous acid is present, it is expelled by the affusion of concentrated vitriolic acid, and may be distinguished by its peculiar smell, and its red smoke. In like manner, marine acid yields to the vitriolic; but has a different kind of smell, and a grey smoke. When these acids are only in very small quantity, the smoke will scarcely be visible in a dry place; but in this case the very slightest vestige of nitrous acid is made apparent, by exposing to the fume a paper moistened with volatile alkali. To discover the most minute quantity of marine acid vapour, nothing more is necessary than a paper moistened with water: the vapour instantly surrounds this paper, in the same manner as the nitrous vapour attaches itself to the paper impregnated with volatile alkali.

Besides, nitrous acid is discoverable by detonation; and the marine, by various means, such as nitrated silver (VII. O), nitrated mercury (VII. P.), and acetated lead (VII. R).

It is somewhat more difficult to discover the bases; the vegetable alkali cannot be separated in the humid way, unless by terra ponderosa; but this separation may be effected in various ways, by means of a double elective attraction (*h*). The mineral alkali is expelled by the vegetable, but in

(*h*) On elective Attractions.

this case does not manifest itself by turbidness (*i*); yet it may be discovered by crystallization. Both the fixed alkalis expel the volatile, with a peculiar pungent odour.

Vitriolated mineral alkali should be carefully distinguished from the combination of vitriolic acid with magnesia. These two salts agree in forming bitter prismatic crystals, which suffer spontaneous calcination in a dry air; but the crystals of the former are generally larger, much depressed, with a cooler and milder taste; but they may very easily, and instantly, be distinguished from each other, by the addition of a small piece of each to lime-water; for the lime-water is not rendered in the least turbid by the vitriolated mineral alkali, but the vitriolated magnesia is instantly decomposed; for in this last case the acid unites with the lime, and forms a gypsum, which together with the deserted magnesia, is found at the bottom. If these, mixed together, be present in water, they cannot be completely separated by crystallization. I determine the quantity of each in the following manner: I gradually precipitate the magnesia by a solution of mineral alkali; I unite this again with vitriolic acid, and obtain, by crystallization, a vitriolated magnesia; the weight of which, subducted from the whole mass of saline matter, previously crystallized and weighed,

(*i*) Ibid. § vii. sub initio.

yields the weight of the vitriolated mineral alkali. The same may be collected from the weight of the precipitated magnesia alone, if we know the proportions of the principles which constitute the two salts. Authors speak of many varieties of vitriolated mineral alkali, and vitriolated magnesia, varieties which, however, depend entirely upon the difference of purity: thus the sal Anglicus, Epsom salt, Leydschutz salt, Seidlitz, and others, when well depurated, all yield the very same vitriolated magnesia.

The vegetable and mineral alkali, when united with marine acid, form salts which agree in their cubic figure, decrepitation in the fire, and to a certain degree in their taste; yet the former is somewhat more acrid, and is besides perfectly distinguishable by another property, for if into a saturated solution of this salt be dropped the acid of tartar, a pure and genuine tartar falls to the bottom; this does not take place in a solution of common salt, because the mineral alkali has far less affinity with acid of tartar than the vegetable alkali has.

4. If the base of the salt be earthy, which is known by its precipitating on the addition of aerated alkali, the species of the earth may be thus determined:—terra ponderosa produces, with the vitriolic acid, a spathum ponderosum (x. D, 6.); calcareous earth, with the same acid, produces a gypsum (x. D, 2.); magnesia, the salt commonly
called

called *sal catharticus amarus* (x. D, 2.); and clay produces alum.

5. If any metal be present, it may generally be known by the colour, or by an ochre.—If the base be cupreous it is precipitated in a metallic form upon iron, if the moistened salt be rubbed upon the metal, or a polished piece of iron laid in the solution; it is discoverable also by a blue colour, an æruginous taste, by the volatile (vii. 1), or by the phlogisticated alkali (vii. E).

Iron is detected by its colour, which is greenish, or yellowish, according to the degree of dephlogistication, by its inky taste, by an ochre, by tincture of galls (vii. D), and by phlogisticated alkali, which precipitates a Prussian blue (vii. E).—In the Treatise on Alum, I shall explain at large the method by which martial vitriol may be separated from vitriolated magnesia and alum.

Zinc forms, with vitriolic acid, a white vitriol, of which the crystals have a prismatic figure.—This metal is precipitated white by alkalis; as also by the phlogisticated alkali; but is not at all affected by any metal.

Manganese also yields a white vitriol and white precipitates; but it differs from zinc in growing black by calcination, and being afterwards insoluble in acids, unless they are either themselves phlogisticated, or rendered so by the addition of some suitable substance, such *v. g.* as sugar.

Arsenic, in its reguline form, is not soluble in water;

water; and of the white calx of arsenic, cold water takes up no more than a few grains in a kanne;—besides, this calx is very rarely found naturally soluble in water; nevertheless, as it may sometimes happen, especially in countries abounding with metals, that water shall be vitiated by arsenic, I shall here shew by what method it may be discovered.

If the dry residuum be thrown upon live coals, or, which is better, exposed upon a piece of charcoal to flame, by means of a blow-pipe, a smell like that of garlic will be distinctly perceived;—this is the most certain indication of the presence of arsenic. Many other methods have also been thought of, but they are in general such as cannot be employed, unless the water contains arsenic alone, which is seldom or never the case.—If a clear solution of hepar sulphuris be dropped into water containing arsenic, and no substance be present to prevent it, a yellow precipitate immediately falls, which is found to be a species of orpiment or sulphurated arsenic.

6. The various salts, although very different from each other, when once mixed together, are not easily separated; hence often arises considerable difficulty in the analysis of waters; for certain of the neutral and middle salts, enter into more compound combinations, and obstinately resist separation, even though crystallization be many times repeated; at least they adulterate one another,

ther, and are not obtained pure without the utmost difficulty.

This difficulty has already been in some degree removed by separating the deliquescent salts (X. A), which otherwise would enter the water necessary for crystallization, and prevent that process from going on regularly.—The following are the principal inconveniences which still remain:—

The uncombined mineral alkali can scarce be perfectly separated from common salt: the weight of both these taken together being known, let the alkali by degrees be exactly saturated with vitriolic acid; this being done, let an equal quantity of the same acid be saturated with mineral alkali; which being crystallized, the weight of alkaline salt mixed with the common salt, and consequently the weight of the sea-salt itself, will appear (*k*).

We

(*k*) As the operator can never be sure of attaining the precise point of saturation, even though he should use the precautions of diluting the acid or alkali, and mixing a tincture with the liquor; that he may be able to perceive the progress of its changes, the process of M. Gioanetti to obtain the separations of the same salts seems more advantageous; it consists in reducing all the fossil alkali into foliated earth, by the addition of a sufficient quantity of distilled vinegar; and, after crystallizing the whole mass again, to dissolve the terra foliata in spirit of wine: the sole attention necessary is, not to burn the terra foliata, and consequently to evaporate by a very gentle heat. The learned physician of Turin found that spirit of wine would not take up sea-salt, even when mixed with terra foliata.

By

We have already shewn (B. 3.) how mineral alkali and magnesia, when united with the same vitriolic acid, as also vegetable and mineral alkali, when salited, may be separated;—the weight of the whole and of one ingredient being known, that of the other is easily determined.

Alum and vitriolated magnesia are separated by chalk, but not by quick lime, which decomposes both; whereas chalk, or rather aerated lime, decomposes alum, but induces no change upon vitriolated magnesia.

Finally, if distinct concretions cannot otherwise be obtained, the metallic salts are to be precipitated by phlogisticated alkali, the earthy ones by fixed alkali, and the precipitates managed as directed (x. D): the quantities of the precipitating alkalis, and of the salts produced by their means, cannot fail to give the requisite information (D).

(c) The solution made by boiling water (x. c) contains scarcely any thing more than gypsum, which may be either separated by crystallization, or decomposed by an alkali.

(D) In order that the different salts may be the more easily distinguished, and their mutual rela-

By distilling the spirit of wine, and calcining the residuum, the fossil alkali which existed in the first saline mass will be retrieved in substance without mixture. The quantities then may be verified in this case, both by subtraction and addition, and by procuring the matter itself. Morveau.

tions

tions the better understood, I add the following sketch of the most remarkable among them, having treated elsewhere of the aerated alkalis.

Vitriolated vegetable Alkali; vulgo vitriolated Tartar.

(1) 100 parts contain about 52 of pure vegetable alkali, 40 of vitriolic acid, and 8 of water. In an heat of 15° one part of this salt requires, for solution, 16 of water, but of boiling water no more than 5. The taste is weak and somewhat bitter; it does not deliquesce in a moist, nor suffer spontaneous calcination in a dry air; it decrepitates in the fire, and is fused with difficulty.

The original form of the crystals is that of an

(1) I shall subjoin Mr Kirwan's estimation of the respective quantity of ingredients in these saline compounds. The reader will probably be surprised at the difference between his numbers and those of the author; but such problems are among the most difficult in chymistry. There is, however, a circumstance which must not be concealed, and which will contribute to reconcile much of the difference:—Mr Kirwan considers the acids as pure, and totally free from water; whereas Professor Bergman considers them in a state of considerable concentration indeed, but as containing a very large proportion of water.

100 grains of this salt, perfectly dry, contain, according to Mr Kirwan, 30, 21 of real acid, 64, 61 of alkali, and 5, 18 of water: when crystallized, they contain 6, 18 of water. B.

hexagonal prism, terminated at both ends by an hexaedral pyramid.—The accidental figure varies in many different ways.

Vitriolated mineral Alkali; vulgo Glauber's Salt.

(m) 100 parts contain 15 of pure mineral alkali, 27 of vitriolic acid, and 58 of water. In a moderate heat, one part requires $2\frac{6}{7}$, of water, of boiling water only $\frac{4}{5}$.—It does not deliquesce in a moist air; it suffers spontaneous calcination in heat; it liquefies in the fire, again grows dry, and then fuses.—The taste, bitter and cold.

The form irregular hexagonal prisms; two opposite sides broader, the apices oblique, formed of two planes, consisting of the two opposite narrow sides of the prism, inclined to each other in a manner resembling the roof of an house.

Nitrated vegetable Alkali; vulgo common Nitre.

(n) 100 parts contain 49 of pure vegetable al-

(m) 100 grains, perfectly dry, contain 29, 12 of mere vitriolic acid, 48, 6 of mere alkali, and 22, 28 of water.—In crystals they contain 13, 19 of vitriolic acid, 21, 87 of alkali, and 64, 94 of water. B.

(n) 100 grains, perfectly dry, contain 30, 86 of acid, 66 of alkali, and 3, 14 of water.—In crystals they contain 29, 89 of acid, 63, 97 of alkali, and 6, 14 of water. B.

kali,

kali, 33 of nitrous acid, and 18 of water; one part requires 7 of water, but of boiling water scarce more than 1. The taste, acrid, bitterish, cold;—it neither deliquesces nor effloresces;—it detonates with ignited phlogiston.

The form prismatic, hexagonal, often striated. The apices hexagonal, pyramidal, generally obliquely truncated.

Salited vegetable Alkali; vulgo Sal digestivus Sylvii.

(o) 100 parts contain 61 of pure vegetable alkali, 31 of marine acid, and 8 of water; 1 part requires, for solution, 3 parts of water in a moderate temperature; of boiling water 2. The taste, salt and acrid; it neither suffers deliquescence, nor spontaneous calcination; it decrepitates in the fire, and fuses.

The form cubic, sometimes prismatic, quadrangular, perpendicularly truncated.

Salited mineral Alkali; vulgo Sea Salt, or Muria.

(p) 100 parts contain 42 of pure mineral alkali,

(o) 100 grains, perfectly dry, contain 29, 68 of acid, 63, 47 of alkali, and 6, 14 of water; but when crystallized they contain 7, 85 of water. B.

(p) 100 grains, perfectly dry, contain nearly 35 of real acid, 53 of alkali, and 13 of water. 100 grains of the
M. 2 crystals

kali, 52 of marine acid, and 6 of water. One part in a moderate heat requires $2\frac{1}{7}$ of water, of boiling water $2\frac{1}{7}$. The taste, salt.—It suffers neither deliquescence nor spontaneous calcination; it decrepitates in the fire, then flows.

The form cubic.

Vitriolated Lime; vulgo Gypsum.

(q) 100 parts contain 32 of pure lime, 46 of vitriolic acid, and 22 of water. One part requires of water at a moderate heat 500, of boiling water 450. The taste, earthy, scarcely sensible. It splits in the fire; and in a very intense heat it fuses.

The form spathaceous or octaedral; the two opposite apices deeply truncated, so as to resemble a table with a cuneiform margin.

Vitriolated Magnesia; vulgo Sal catharticus amarus—Epsom Salt.

(r) 100 parts contain 19 of pure magnesia, 33 of

crystals contain 33, 3 of acid, 50 of alkali, and 16, 7 of water. B.

(q) The proportion of ingredients in natural gypsum varies, but of artificial 100 grains are estimated, by Mr Kirwan, to contain 32 of earth, 29,44 of acid, and 38,56 of water; when well dried it loses about 24 of water, and therefore contains 42 of earth, 39 of acid, and 19 of water, per cent. B.

(r) 100 grains, perfectly dry, contain 45, 67 of mere vitriolic

of vitriolic acid, and 48 of water. One part requires 1 of water at a moderate heat, of boiling water scarce $\frac{2}{3}$. The taste excessively bitter, and somewhat cold; it suffers spontaneous calcination in heat; in the fire it foams, grows dry, and fuses.

The form prismatic, tetragonal, with pyramidal quadrangular apices.

Vitriolated Clay; vulgo Alum.

(s) 100 parts contain 18 of clay, 38 of vitriolic acid, and 44 of water; 1 part requires 30 of water in a moderate heat, of boiling water $\frac{3}{4}$. The taste sweetish, astringent; it suffers neither deliquescence nor calcination; in the fire it foams, dries, and grows hard.

The form octaedral.

Nitrated Lime.

(t) 100 parts, well dried, contain 32 of pure

vitriolic acid, 36, 54 of pure earth, and 17, 83 of water: in crystals they contain 23, 75 of acid, 19 of earth, and 57, 25 of water. B.

(s) 100 grains, perfectly dry, contain 42, 74 of acid, 32, 14 of earth, and 25, 02 of water; in crystals they contain 23, 94 of acid, 18 of earth, and 58, 06 of water. B.

(t) 100 grains, carefully dried, contain 33, 28 of acid, 32 of earth, and 34, 72 of water. B.

lime; the water is not easily ascertained, as a part of the acid is also expelled by calcination; it is probable that it amounts to 25 at least, and if so, the acid will be 43: it deliquesces. The taste extremely bitter and acrid; alcohol dissolves it, and by ebullition takes up its own weight: it cannot be reduced to the form of permanent crystals.

Nitrated Magnesia.

(v) 100 parts, well exsiccated, contain 27 of pure magnesia; setting down the water at 30, which in this case it rather seems to exceed, the acid will amount to 43: it deliquesces, yet may be obtained in the form of oblique, truncated, tetragonal, prismatic crystals; but they soon again deliquiate: the taste, extremely bitter, acrid: 1 part in a moderate heat requires, for solution, 9 parts of alcohol.

Salited Lime; vulgo Fixed Sal Ammoniac.

(u) 100 parts, well exsiccated, contain 44 of pure lime; supposing the water to be 25, the marine acid will be 31: it deliquesces, and cannot be reduced to permanent crystals. The taste ex-

(v) 100 grains, well dried, contain 35, 64 of acid, 27 of pure earth, and 37, 36 of water. B.

(u) 100 grains, well dried, contain 42, 56 of acid, 38 of earth, and 19, 44 of water. B.

tremely

tremely bitter: boiling spirit of wine dissolves its own weight of this salt.

Salited Magnesia.

(w) 100 parts, well exsiccated, contain 41 of pure magnesia; supposing the water to be 25, the marine acid will be 34; in deliquescing it attracts 0,66 of water: 1 part in a moderate heat requires 5 parts of alcohol: The taste extremely bitter.

(x) *Vitriolated Copper; vulgo blue Vitriol.*

100 parts, crystallized, contain 26 of copper, 46 of vitriolic acid, and 28 of water. The taste acescent, æruginous, caustic; it calcines in heat: 1 part, in a moderate heat, requires nearly 4 of water, but of boiling water much less.

The figure compressed, hexagonal, prismatic, obliquely and parallelly truncated on both sides.

Vitriolated Iron; vulgo green Vitriol.

(y) 100 parts contain 23 of iron, 39 of vitrio-

(w) Of this salt Mr Kirwan affirms, that it cannot be tolerably dried, without losing much of its acid, together with the water. B.

(x) 100 grains contain 27 of copper, 30 of acid, and 43 of water; of which it loses about 28 by evaporation, or slight calcination. B.

(y) 100 grains of this salt, in crystals, contain 25 of iron, 20 of real acid, and 55 of water. B.

lic acid, and 38 of water: in moderate heat, 1 part requires 6 of water, of boiling water $\frac{3}{4}$: in heat it splits into a yellow powder, in the fire, into a ferruginous powder. The taste acescent, styptic, caustic.

The form, spathaceous: when dephlogisticated it deposits a portion of calcined iron; the ferruginous deliquescent residuum is readily taken up by spirit of wine.

Vitriolated Zinc; vulgo white Vitriol.

(z) 100 parts contain 20 of zinc, 40 of vitriolic acid, and 40 of water; in a moderate heat, 1 part requires more than 2 of water, but much less of boiling water. The taste acescent, astringent, caustic.

The form, tetragonal prismatic, terminated by tetragonal pyramidal apices.

The advantage of knowing the proportion of the constituent principles is signal and extensive;—thus, for example, suppose the weight of the magnesia precipitated (B, 3) to be equal m , then $\frac{33}{19} : \frac{45}{100} m =$ quantity of vitriolic acid necessary for saturating it; and $\frac{45}{19} m =$ vitriolated magnesia arising from thence — $\frac{33}{27} : \frac{45}{19} m$, indicates the weight of that vitriolated mineral alkali, which is

(z) 100 grains contain 20 of zinc, 22 of acid, and 58 of water. B.

produced

produced by precipitating the vitriolated magnesia by means of mineral alkali — $\frac{1}{2} \frac{5}{7} : \frac{3}{1} \frac{3}{9} : \frac{4}{1} \frac{5}{6} =$ the pure mineral alkali necessary for that precipitation; and $\frac{4}{2} \frac{5}{6} : \frac{1}{2} \frac{5}{7} : \frac{3}{1} \frac{3}{9} m =$ the aerated alkali necessary for the same purpose. In the present case m is given, and hence all the formulæ are easily determined. In like manner, 'on other occasions, the causes are found so connected, that one phenomenon being given, many others are immediately suggested.

§ XII. *Analysis is to be confirmed by Synthesis.*

When, by the experiments above proposed and described, the several heterogeneous matters are determined, as to quantity and quality, and reduced by accurate analysis to perfect certainty, nothing remains but to unite with pure water all the separated matters in due proportion: if then the water, thus treated, exactly and perfectly resembles the water which has been examined, it must afford an irrefragable argument that the analysis has been properly conducted.

It is indeed but rarely necessary to examine all waters with the extreme accuracy above described; but as the question was concerning the art of examining waters in general, no circumstance which has any relation to the subject could properly be omitted, as all such may, in certain cases, be useful, nay altogether necessary.

§ XIII. *The Selection and Correction of Waters.*

Waters, with respect to their use, may be divided into four classes: 1st, Those which may without difficulty be applied to daily use, such are, good fountain, river, and lake waters. 2d, Those which may indeed be used, but yet are attended with certain inconveniencies, unless previously purified by some means or other: to this class belong hard waters as they are called, and stagnant waters, which have not sufficient motion. 3d, Those which, on account of their contents, cannot be daily employed for the purposes of life, but are used at certain times, and under certain regulations, against infirmities and diseases; such are the medicated waters. Finally, 4th, Those which, on account of the nature and quantity of their heterogeneous matters, are seldom or never used internally. but nevertheless may in other respects be extremely useful.

(A) It is unnecessary to bestow much labour upon the first class, as daily experience evinces it to be harmless, and therefore not to require any correction. In proportion as water is rendered less turbid by acid of sugar, fixed alkali, or solution of silver, it is the more pure, and with the greater justice referred to the first class.

(B) The second class is rendered very turbid,
by

by solution of sugar, or of fixed alkaline salt, and is considered as the more impure in proportion to the quantity of precipitate.—These waters are austere, with a styptic disagreeable earthy taste; they are apt to occasion obstructions; and a long continued use of them appears to be unsafe.

These are much less fit for obtaining extracts from solid substances than the former class, and are therefore much less efficacious in brewing, in distilling, in preparing decoction of coffee, or infusion of tea, and many others;—for the washing of linen, these waters are more or less unfit, partly because they do not easily dissolve the impurities, partly because they decompose the soap, and render it unfit for the purpose. Hard waters, for the reasons above mentioned, are totally useless in the bleaching of linen; they are also unfit for boiling pease, beans, and other pulse, as they neither macerate nor make them soft—the same is observed of old and hard flesh.

For the purposes of preparing hemp and flax by putrefaction, these waters are the less useful, as it is certain that they possess an antiseptic power; hence substances immersed in them preserve their strength and texture longer than they would do in better water. This circumstance affords a hint for trying whether these waters may not be usefully employed in long voyages, as they can, upon occasion, be easily made fit for use. Tin, in general, grows black with waters of this sort; they

they have been thought, by some persons, to be unfit for the watering of plants ; but, as far as can be conjectured they should be, in this intention, not only harmless, but singularly useful.

Waters endued with these properties are called hard ; and in such waters their effects are chiefly produced by an absorbent earth, united with an acid : if the aerial acid be the menstruum, boiling alone is sufficient to correct the water. As this subtile acid is expelled by heat, the earth which had been suspended by it is no longer soluble in the water, and therefore precipitates, and all the minute particles attach themselves to the inequalities of the substances they meet with, and adhere firmly ; hence it is that tea kettles are generally in a short time covered with a crust of absorbent earth ; and hence too it happens that the surface of pulse is obstructed, so that the water cannot penetrate them. The hardness of waters which depends upon this circumstance is of little consequence, as it may be corrected simply, by boiling and cooling : but, in order to make it agreeable to the palate after the deposition of the calcareous matter, it must be exposed to the open air, in broad shallow vessels, by which it recovers from the atmosphere a portion of the aerial acid.

But if the absorbent earth be suspended by means of any other acid, it is not so easily separated ; and it is then particularly that it occasions many
of

of the above-mentioned inconveniences. The decomposition of the soap takes place, because the alkali unites more willingly to the mineral acid of the middle earthy salt, than to the oil, which therefore is expelled, and being insoluble by itself, is collected at the surface of the water in the form of drops or of a floating membrane.

The other effects are occasioned either by the middle salt itself, or take place from hence, that during the boiling a part of the menstruum flies off, upon which the deserted base closely attaches itself to such bodies as it meets with. This dissipation readily happens to the nitrous acid, whether united with lime or magnesia, as also to the marine acid, when united with magnesia.

This species of hardness cannot be corrected by boiling alone, but may be removed by a fixed alkali, which precipitates the earthy base. For this purpose, let a solution of pot ashes, or any other alkaline salt, be poured into the water, so long as it occasions any turbidness: after the precipitate has fallen to the bottom, it must be tried whether any turbidness is occasioned by the addition of more alkali; when no more is found to fall, we may easily determine what quantity of alkaline salt any given water requires, by weighing the alkali, and its solution, previous to the experiment. Finally, let the water, thus purified, be decanted off from the sediment, or, if necessary, filtered.

Stagnant waters are liable to corruption in warm weather, and afford lodgement to millions of insects. This inconvenience is obviated in the southern parts of Europe, by a sort of sandy stone, called filters. The water to be used for the preparation of food, or for drink, is made to pass through these filters; and is thus freed from all such heterogeneous matters as are not united with it in the way of solution.

(c) The cold medicated waters, which possess peculiar power and efficacy, contain a much larger quantity of aerial acid than the common waters; and, in general, their excellence is chiefly derived from the quantity of their subtile acid: however, as they are seldom or never without a mixture of other saline substances, it is by these that their peculiar effects are specifically determined: for, tho' the Seltzer and Pyrmont waters contain a large proportion of the aerial acid, no one estimates their efficacy by the quantity of aerial acid, it being rather dependent upon grosser salts; though these latter are certainly vivified by this true mineral spirit, and from it receive a more active and penetrating power.—The method of determining the quantity of this volatile acid contained in waters has been explained (VIII. A. B).

Cold medicated waters in general may be divided into such as are impregnated with iron, and such as are destitute of that metal; and hence arises a considerable difference with respect to their use.

use. Besides, there are many chalybeate waters which contain iron, either totally or partially dissolved in vitriolic acid : such waters, when only moderately impregnated, may in some cases be successfully used, but are for the most part improper, and sometimes highly pernicious ; therefore, as the number of chalybeate springs is very great, it is of much consequence to be able to distinguish the good from the bad, the wholesome from the noxious : it would be extremely advantageous to establish certain characteristic marks, by means of which, without any artificial apparatus, without any operose experiment, and without a knowledge of chymistry, we may in any case readily discover whether a chalybeate water may be safely used or not.—The following observations will be found particularly useful for that purpose :—

Let about half a kanne of the water to be examined boil vehemently for about a quarter of an hour, in a stone vessel ; let it then be removed from the fire, and cooled ; this being done, let about $\frac{1}{8}$ of the water be poured out into a glass vessel ; and add 2, 4, or at most 6 drops of tincture of galls (VII. D). If, now, no purple or violet tinge is produced—if no blackness appears, even after standing for some hours, this is a favourable sign, affording sufficient proof that the spring is of a good quality, and truly acidulous ; but if the vitriolic acid be the menstruum, it deposits an ochre

chre upon boiling, without losing its power on astringents.

There occurs also a third case, namely, where the iron is partly dissolved by aerial acid, partly by vitriolic acid : Supposing, then, the quantity of the latter to be so small, that when the former is separated by boiling, the water has no sensible effect upon tincture of galls ; there will in this case, it is true, be present a vitriol of iron, but in far less proportion than that of three grains to a kanne (VII. D), so that it is free from any noxious quality ; and even this minute portion may, if necessary, be easily made visible ; for let the water be boiled until only a twentieth part remains, add then a few drops of tincture of galls, and it will instantly be tinged.

It is thus that the hot waters, which are remarkable for efficacy, abound either in atmospheric acid, as the Caroline waters in Bohemia, or with hepatic vapour, as those of Aix. Waters containing the grosser salts, without any elastic vapour, without a vivifying principle, are as it were dead ; and, if not entirely inert, are at least heavy, and of small virtue.

In general, the various medicated waters, both hot and cold, contain fixed principles in a proportion so small, that they may be rendered fit for domestic uses, only by boiling and cooling, if scarcity of other water should render that process necessary.

If

If a water be rendered unfit for use by the admixture of a small quantity of metallic salt, this may be removed by a fixed alkali in the manner described (B); but if it be in large quantity, this inconvenience is occasioned by the correcting it, namely, that another, though a more innoxious salt, succeeds to the first. Thus, when a vitriol is precipitated, there arises a vitriolated vegetable alkali, which, though of a weaker taste, yet occasions a degree of bitterness, greater or less, according to its quantity: however, this salt does not produce any noxious effects in the human body, but is reputed a gentle purgative; nor does it prevent the water from being converted to a great number of uses: hence it appears, that a water contaminated, even by a vitriol, may, in cases of urgent necessity, afford an useful supply, by means of the remedy just described.

(D) Waters which contain a large quantity of any neutral salt, such as vitriolated mineral alkali, common salt, &c. or any noxious metallic salt, such as green, blue, or white vitriol, are unfit both for internal and domestic uses, though the substances with which such waters are loaded may be advantageously collected, and applied to other uses.

Sea-water has not only the strong taste of common salt, and the bitter one of salited magnesia, but occasions a very singular nausea, which is frequently attended with vomiting. This nauseous

ingredient is not to be found at all, or but very little, in sea-water taken up at the depth of sixty fathom, as experiments made upon water taken up at that depth evidently shew; the reason perhaps is, that the immense quantity of fish, worms, and other animals, which inhabit in the ocean, dying, are gradually carried up to the surface, and there, by the assistance of the air, are destroyed by putrefaction, (at least this is the case with such parts of them as are soluble in water); and this putrefactive process is much assisted by the salt which, at the surface, is present in precisely the quantity necessary to promote that operation.

To render sea-water fit for the uses of mariners is an art long wished for, and of the highest moment. That which is taken up at the depth of sixty fathoms, or more, on account of its extreme saltness, is indeed unfit for allaying thirst; but when mixed with an equal quantity of fresh water, may, beyond doubt, be very usefully applied to the preparation of food, as it thereby saves one half of the stock of fresh water.

That water which is found at the surface can only be rendered fit for drink by distillation, as recent experiments have shewn. Many different sorts of apparatus have been contrived for this purpose; and even the vapour arising from the vessels in which food is prepared has been employed. The most suitable apparatus for this purpose is such as will at once yield the greatest possible quantity of
water,

water, and require the smallest quantity of fuel : but this is not to the present purpose ; suffice it to say, that sea-water distilled, and then exposed to the air, becomes agreeable and wholesome ;—that which first comes over should be thrown away, if it contains any thing putrid. Some part of the marine acid will be disengaged by violent and long continued boiling ;—but this inconvenience may be easily avoided, by adding at the beginning a little pot-ashes, which decomposes the salited magnesia.

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DIS.

DISSERTATION III.

ON THE

WATERS OF UPSAL,

Tales sunt aquæ, quales terra per quam fluunt.

PLIN.

§ I. *Good Springs are to be met with in great plenty, at Upsal.*

WHOLEFSOME water, in sufficient plenty, is one of the greatest advantages any place can possess, and the most likely to induce people to settle in it; because water is among the most indispensable necessities, not only for men and animals cooped up in a small space, but likewise for a single family, however small it may be; so that scarcity or the bad quality of water, exposes them to numberless inconveniencies. If any city in Sweden may boast of being fortunate in this respect, it is certainly Upsal; for, besides the

the river which runs through it, there are several excellent springs, and very good wells. As it is important to know the substances contained in them, I will relate some experiments made with this view; but, to avoid too tedious a detail, I shall only speak of the most remarkable, such as are common to the whole city, overlooking the others, of which each serves only a single family. —I shall then confine myself to the examination of the six following.

1. The spring belonging to the citadel rises at the bottom of the hill on which that fortress is built; this eminence consists of sand; its elevation is of 100 Swedish feet above the level of the river; it extends on each side to a great distance from the city; it has various heights and windings, being sometimes low, and as it were creeping, at others, rising to a considerable height. This hill supplies all the water, not only of the spring in the citadel, but of the other springs and wells to the south of the river, except that mentioned in the 6th section. Fresh ones may easily be found, by sinking at its foot.

This spring was almost forsaken till within these few years; and as it was exposed, it became gradually full of impurities, which obstructed its veins; so that, in February 1767, it was almost dry—much less rain than usual had fallen the preceding autumn. It however again made its appearance; but the strongest branches opened an-

other issue nearer the river, where a stone basin was made for it, with the addition of a roof, and where it furnishes water of a quality superior to all the other springs.

2. The spring that rises near the mill of the University was defended by walls during the whole of the 17th century; but they were destroyed in 1702, at the time of the fire, which consumed great part of the city. As it was neglected afterwards, it was obliged to bear its waters to another place, where it was again surrounded by stone-work in 1759. As it is very near the banks of the river, it is every spring and autumn overflowed by the floods during some days.—I shall call it the mill-spring, though it is sometimes called St Eric's fountain.

3. The Sandvik spring, which takes its name from a little hamlet in the neighbourhood, is situated at the distance of about $\frac{1}{8}$ of a mile from the city;—it rises near the river.

In 1776 the King built a still-house for the distillation of corn spirit, for which it furnishes a very good water in sufficient plenty: it is so dammed up, as to form a kind of lake.

4. The well which has obtained the name of Odin, and which yet is not of so high antiquity, is situated near the college of Gustavus; it is deep, and enclosed with stones, but there is no bed to convey away the water, and it is therefore necessary to pump it.

5. The

5. The well, which bears the name of Luth, formerly professor of divinity, is situated further to the north; it is enclosed with stone; and they who chuse to use it, are obliged to raise it.

6. The draw-well (*puteus tractorius*) so named, for I know not what reason, is the only one on the other side of the river; it is open to every body, nevertheless is seldom used, unless for some mean purpose.

§ 11. *A Comparison of the Physical Qualities of the Upsal Waters.*

(A) The water of the springs is as limpid as crystal; the wells are little inferior, except the 6th, which has a slight opal tinge, but less perceptible than the river water.

(B) Good water should be tasteless: the spring in the citadel excels in this respect; next follow those of Sandvik, and the mill; but these waters, though excellent, impress, upon a delicate and practised palate, somewhat of an earthy flavour. The water of Odin's and Luth's wells is agreeable, but rather less brisk; because it is almost stagnant. The water of the draw-well, being more impregnated with earth, is by no means agreeable to the taste.

(C) The temperature of the springs is at 6 during almost the whole year; in the dog-days, it scarce increases 2° or 3° : that of the wells is

generally at 7. The water of the river follows the changes of the atmosphere.

(D) There is a small difference in the specific gravity—the river water is the lightest of all; next, that of the spring in the citadel. Their weight is as follows, at a temperature of 15° (a):

Distilled water,	-	-	10,000
Pure snow-water,	-	-	$10,000\frac{1}{2}$
Water of the river,	-	-	$10,001\frac{1}{2}$
of the spring in the citadel,			10,002
of the mill spring,	-		10,002
of the Sandvik spring,	-		10,002
of Odin's well,	-	-	10,003
of Luth's well,	-	-	10,003
of the draw-well,	-	-	10,012

(E) The water of the springs and wells is rather more copious in very wet seasons; but does not diminish in long droughts. The mill spring affords 3,900 kannes every hour, or $3\frac{9}{16}$ cubic feet; that of the citadel less; but the Sandvik spring much more.

§ III. *The Principles of these Waters, collected by Evaporation.*

(A) All these waters deposit, during ebullition,

(a) $6 = 42$ or 43 , $7 = 44$ or 45 , and $15 = 59$ of F. B.

a grey powder, which in time forms a crust on the internal surface of the vessels. As most of them afford only a small deposition, it is not necessary to collect it, as it separates: it is better to continue the evaporation to dryness. Having evaporated, at the beginning of June, after a long continuance of dry weather, 6 kannes of each of these waters, I found the quantity of residuum to be per kanne as follows:

	grains.
The river water, - - -	8
That of the mill-spring, - - -	9 $\frac{1}{2}$
of the citadel, - - -	10
of the Sandvik spring, - - -	10
of Odin's well, - - -	12
of Luth's well, - - -	12 $\frac{1}{2}$
of the draw-well, - - -	51

(B) In order to separate the saline from the earthy part, the several residua should be washed in distilled water, dried, and weighed; then some marine acid should be poured on the earthy matter, which, in the present instance, produces a violent effervescence, and dissolves the greater part; what is not dissolved by the acids cannot be fused by itself upon coals excited by the blow-pipe, when it has been well washed; it resists fusion after the addition of microcosmic salt; borax produces this effect, but very slowly; mineral alkali, fused in a silver spoon or ladle, attacks it with effervescence.

effervescence, and completely dissolves it; the residua of the river water, and that of the draw-well, must be excepted; for a small portion of them remains insoluble (*b*): this, therefore, is siliceous earth, which although it is specifically heavier than water, seems to have been suspended by means of its tenuity; for it is possible that, by being pulverized, an heavier substance may be made to acquire so much surface, that the friction of the water, which must be overcome before it can subside, may form an equilibrium to the excess of its weight. Though quartz is of a truly saline nature (*c*), yet I can scarce believe that it is dissolved in so large quantity; I must not, however, omit to remark, that it cannot be separated from our waters, either by filtration or rest: it is found among the aerated calcareous earth, adhering to tea-kettles.

The solution in the marine acid affords only calcareous earth on addition of alkali; wherefore our waters contain only aerated calcareous earth, and a little quartz; but in different quantities, as we shall soon see. The river water, and that of the draw-well, are besides charged with a little

(*b*) In the second volume of this Collection will be found an Essay on the Blow-pipe, and the way to use it.

(*c*) Here the author refers to the 12th Dissertation of the first volume; but there are only 11. It is the 2d of vol. ii.

clay,

clay, which we said that the alkali was incapable of dissolving by means of heat.

(c) The distilled water which has been poured on the residuum to dissolve the saline part, furnishes, by spontaneous evaporation, common salt, salited lime, and vitriolated fossil alkali: the calcareous sea-salt may be separated by highly rectified spirit of wine (*d*). The last ley, when concentrated by evaporation, affords very often a little mineral alkali, which is of a dark red; but the phlogisticated alkali does not give a blue precipitate: the water of the draw-well affords moreover a few small prisms of nitre, which may be known by their detonation on charcoal; and, instead of Glauber's salt, a little selenite.

(D) In order to learn the nature of the elastic fluid contained in these waters, I boiled a certain quantity of each in a glass retort, of which the end of the neck was bent upwards, and introduced under a little phial inverted, and full of mercury. The fluid thus obtained is partly absorbed by water, and consequently must be aerial acid; the remainder is pure air, fit for the support of ignition and respiration. It is obvious, that the quantity of common air remaining in the upper part, and the neck of the retort, before the vapours begin to rise, should be deducted.

(E) Nearly the same substances are to be

(*d*) See the foregoing Dissertation, § X. A. § XI. A.

found

found in all these waters; but the quantities differ.—The following are what they contain per kanne:—

	grains.
The river-water contains of aerated calca-	
reous earth, - - -	2
That of the citadel-spring, - - -	5
of the mill-spring, - - -	$5\frac{1}{2}$
of Sandvik spring, - - -	$5\frac{1}{2}$
of Odin's well, - - -	$5\frac{1}{2}$
of Luth's well - - -	6
of the draw-well, - - -	21
The river-water contains of filiceous powder, - - -	$\frac{1}{2}$
of the citadel-spring, - - -	$\frac{1}{2}$
of the mill-spring, - - -	$\frac{1}{2}$
of Sandvik spring, - - -	$\frac{1}{2}$
of Odin's well, - - -	$\frac{1}{2}$
of Luth's well, - - -	$\frac{1}{2}$
of the draw-well, - - -	1
The river-water contains of clay, - - -	$\frac{1}{2}$
The draw-well, - - -	1
The others, - - -	0
The river-water contains of common salt, - - -	$1\frac{1}{2}$
The citadel-spring, - - -	$3\frac{1}{2}$
The mill spring, - - -	$2\frac{1}{4}$
Sandvik spring, - - -	$2\frac{1}{4}$
Odin's well, - - -	$3\frac{1}{4}$
Luth's well, - - -	$3\frac{1}{4}$
The draw-well, - - -	$18\frac{1}{2}$
The river-water contains of falited lime, - - -	$\frac{1}{4}$
The	

	grains.
The citadel-spring, - - -	$\frac{1}{2}$
The mill-spring, - - -	$\frac{1}{2}$
The Sandvik spring, - - -	$\frac{1}{2}$
Odin's well, - - -	$\frac{1}{2}$
Luth's well, - - -	$\frac{1}{2}$
The draw-well, - - -	1
The river-water contains of vitriolated tartar, 0	
The citadel-spring, - - -	$\frac{1}{4}$
The mill-spring, - - -	$\frac{1}{4}$
Sandvik spring, - - -	$\frac{1}{4}$
Odin's well, - - -	$\frac{1}{2}$
Luth's well, - - -	$\frac{1}{2}$
The draw-well, - - -	0
The water of the draw-well contains of se-	
lenite - - -	$8\frac{1}{4}$
The rest, - - -	0
The river-water contains of aerated fossil	
alkali, - - -	0
The citadel-spring, - - -	$\frac{1}{4}$
The mill-spring, - - -	$\frac{1}{4}$
Sandvik spring, - - -	$\frac{1}{4}$
Odin's well, - - -	$1\frac{1}{2}$
Luth's well, - - -	$1\frac{1}{2}$
The draw-well, - - -	0
The river-water contains of extractive mu-	
cilage, - - -	$\frac{1}{4}$
The draw-well, - - -	$\frac{1}{3}$
The others nearly, - - -	0
The water of the draw-well contains of nitre	$\frac{1}{2}$
The others - - -	0
	All

All these waters contain about the same quantity of air, viz. 6 cubic inches; of which nearly 4 are aerial acid, the rest pure air, which is carefully to be distinguished from common air (*e*).

The quantities just laid down vary a little: they increase or diminish in the different seasons, according to the quantity of rain and snow, and from other circumstances. It is possible, nay, it does undoubtedly come to pass, that the proportions undergo some change in the course of several years; for at first the water dissolves with facility all the soluble substances of the strata over which it passes; and after it has successively carried them away, it meets with no more, at least the quantity is diminished: besides, these subterraneous canals themselves are liable to various changes. In one place the old ones are stopped up, in another, new ones are opened: now, since the particles of the strata traversed by the waters are not constantly of the same nature, it cannot appear strange that they should partake of these varieties.

(F) We have already observed, that the siliceous earth was suspended in our waters, on account of the extent of surface arising from the tenuity of its particles: the same remark may be applied to the greater part of the aerated calcareous earth, which separates along with the fæx during

(*e*) See above, Diff. I. § xxii.

ebullition. In reality the water, when rarefied by the heat, loses so much of its specific gravity that the earths are precipitated: the increased mobility of the particles of the water facilitates this separation. The calcareous earth held in solution by the aerial acid still further contributes to the production of this effect; because, as the heat volatilizes the solvent, it joins the substances which are only diffused, and enlarges their molecules. It is now easy to conceive why tea-kettles come to be covered with a calcareous crust, of which the quintal contains about 3 or 4 pounds of particles of quartz.

A kanne of water, completely aerated, is capable of dissolving 27 grains of aerated calcareous earth (*f*); wherefore our waters, which contain in that quantity only four cubic inches of this acid, will dissolve little more than a grain. It will perhaps appear strange that the particles which are suspended in a fluid, only on account of their smallness, should not impair its transparency: but, in the first place, I have remarked, that the water of the draw-well, which contains most earth, is a little opal coloured; on the other hand, it should be considered, that particles of sufficient tenuity to pass through the filter, and to remain suspended in water by friction alone, must necessarily be transparent, at least as long as they are surrounded by water.

(*f*) See Diff. I. § 11.

§ IV. *Effects produced by Precipitants on the Waters of Upsal.*

(A) These waters scarce heighten paper coloured blue by turnsole; they give a slight shade of blue to paper made red by Brazil-wood; they do not at all alter paper tinged by turmeric. The causes of these changes have been assigned above (g).

(B) Spirituous tincture of galls shews no vestige of iron, any more than the phlogisticated alkali.

(c) The mineral acids produce no perceptible change. If a little of the crySTALLIZED acid of sugar be thrown into them, it generally forms white streaks as it passes through the liquor, and a white powder, which is real saccharated calcareous earth, collects round it at the bottom of the vessel. These phænomena are but faintly exhibited by the river water; they are more perceptible in that of the springs; and very evident in those of the wells, especially of the draw well. The saccharine acid also occasions a small precipitate in snow-water, but it is not visible for some hours (h). This acid scarce makes our waters turbid after boiling, especially the spring-waters, which deposit most of their earth during the boiling.

(g) See Diff. II. § VII.

(h) See below, Diff. VIII. § VI.

(D) The

(D) The fixed alkalis precipitate a white earth, which on examination is found to be real calcareous earth. A copious precipitation takes place immediately in the draw-well water; in the rest it is flower, and far less considerable. The water of the draw-well is scarce made turbid, after boiling, by addition of alkali.

(E) Lime-water turns white instantly, and a calcareous precipitate is formed; this is owing to the aerial acid which combines with the pure calcareous earth, and carries down with it the earth which was held in solution by the excess of this acid, and which is then deprived of its solvent (*i*).

If these waters be made to boil briskly, and a larger quantity of lime-water be then added, a slight turbid appearance is perceived, which announces the obstinate adherence of the last portions of aerial acid.

(F) Salited ponderous earth in the space of 24 hours causes no alteration in the water of the river; a very slight one in that of the springs; and a much more perceptible one in that of the wells, particularly of the draw-well, from which it precipitates a white powder; this clearly announces the presence of the vitriolic acid (*k*).

(G) Salited lime produces no change in these

(*i*) See Diff. I. § XI.

(*k*) See Differtation II. § VII. and the Essay already quoted on the Elective Attractions.

waters ; they indeed contain no substance capable of decomposing it.

(H) If a piece of alum be thrown into any of these waters, it is decomposed as it dissolves : the aerated calcareous earth attracts the vitriolic acid ; and the argillaceous basis, left alone, forms, as usual, a stratum parallel to the bottom of the vessel.

(I) The solution of silver clouds all these waters ;—it scarce affects snow-water.

(K) Nitrated mercury, made without heat, occasions a white precipitate in them ; that made with the aid of heat occasions a yellow precipitate, which, in the water of the draw-well, is very copious. Snow-water is scarce rendered turbid by the former of these preparations, and very sensibly by the latter.

(L) Corrosive sublimate sometimes occasions a slight precipitate, of a white colour, which should perhaps be attributed to a little volatile alkali.

(M) Acetated lead instantly renders these waters milky. The lead precipitated in the river-water is entirely soluble in distilled vinegar ; a small part of that precipitated in the water of the springs remains insoluble in that menstruum ; but it is visible only when large quantities have been submitted to examination. More of the precipitate formed in the water of the wells resists the action of vinegar, which attacks salited but not vitriolated lead.

(N) A

(N) A piece of martial vitriol, thrown into these waters, occasions a precipitation of martial earth as it dissolves. If a few drops of the solution of this vitriol be poured into a small phial, containing about an ounce of water, and the precipitation be immediately made by a few drops of liquid vegetable alkali, the precipitate, which at first is green, soon changes to a yellow colour, though the bottle is full, and well stopped: this phænomenon indicates the presence of pure air in our waters, which attracts the phlogiston of the precipitate. Let the same operation be repeated on these waters immediately after boiling; if they are kept in well closed phials, the martial precipitate will preserve for whole years the green colour which it owes to the phlogiston.

(O) Soft Venice soap, rubbed in our waters, produces a copious foam, except in that of the draw-well, in which it lathers very imperfectly: they all take up a portion of the soap, which renders them milky; — even that of the draw-well does not recover of itself its former transparency.

§ v. *On the Uses for which these Waters are fit.*

From these observations we are enabled to judge of the superior excellence of the Upsal waters: that of the draw-well must be excepted; but it may be corrected by boiling, and would be much

improved, if it was oftener drawn, and less stagnant; it is indeed not quite crude, since it dissolves a little soap. If we overlook this water, and that of the river, they are all agreeable to the taste, when they are drank cold; but the spring belonging to the citadel has some advantage over the others; the waters of all the springs, however, are equally good to be drank hot. The river-water is generally used for washing, for boiling garden-stuff, making coffee, beer, and spirit of corn, principally because a large quantity may be procured with less trouble. The water of all the springs, and the two first wells, would serve equally well, and indeed, on some occasions, would be preferable; for instance, for the washing of fine linen, for starching it, and tinging it with a slight blue, by means of turnsole—the water of the springs should be preferred, because that of the river gives it a reddish hue.

DIS-

DISSERTATION IV.

ON THE ACIDULOUS SPRING IN THE PARISH OF DENMARK.

Iustâ confessione omnes terræ quoque vires aquarum sunt
beneficii. Quapropter ante omnia ipsarum potentiæ ex-
empla ponemus. Cunctas enim quis mortalium enume-
rare queat? PLIN.

§ I. *Of medicinal Waters in general.*

Physicians have two principal ways of curing,
or at least of alleviating, the numberless ma-
ladies by which the human frame is assailed. They
either employ remedies of such efficacy as to pro-
duce an evident effect in the course of a few
hours; or else they prescribe a frequent repetition
of mild medicines in small doses, of which the ac-
tion does not become sensible till several weeks,
and sometimes till several months, have elapsed:
among the latter, mineral waters are justly enu-
merated; they effect surprising cures every day,
and such as could not be expected from any other

mode of cure hitherto discovered. We are not to attribute these effects to simple water, considered by itself; for, according to such a supposition, they would be produced in every place alike, but to the substances mixed with it, and dissolved in it, by which it is sharpened, and, as it were, armed with such efficacy. Hence, in all ages, good physicians, desirous of establishing the salutary art on a firm foundation, have considered it as a duty incumbent upon them to submit to chymical analysis such waters as were famous for the cure of any disease; and if this task had been performed with proper exactness, we should now be enabled to form a certain judgement upon the use and virtues of all mineral waters. When the composition of any medicine is perfectly understood, and its mode of operation has been carefully observed on various occasions, the physician has then fixed and clear notions concerning its effects, which cannot fail of becoming highly serviceable in future, whenever a mixture of the same substances, in the same proportion, is discovered: if so necessary a part of knowledge has not been hitherto acquired, it is because the analysis of waters forms one of the most difficult problems in chymistry. The substances held in solution are of various kinds, and always in very small quantity: not to mention that several of these substances, and those the most important, have not been well known till of late; and hence it happened,

pened, that the most accurate analyses have fallen very far short of perfection.

Henceforward, let us rely on no analysis, until a mineral water, in every respect resembling the natural water, has been recomposed, with pure water and the substances that have been obtained.

§ II. *Situation of the Spring at Denmark.*

The spring which I propose to examine with some attention is situated at the distance of about three-quarters of a mile south-west from Upsal, in the parish of Denmark. In the neighbourhood several veins of mineral water have been discovered, but four especially are in repute; they are very near together, and rise in the meadow Wallby, of which the soil is argillaceous. These acidulous springs were discovered in 1733, and frequented with great advantage; they were afterwards forsaken and neglected, for what reason I know not, till the spring of the present year (*a*). Then Ab. Scoderberg, a skilful surgeon of the

(*a*) The celebrated G. J. Wallerius published, thirty-six years ago, a description of this fountain newly discovered, in a work entitled, “*Tankar om Danemarks Halso-brunc.*” He mentions some fortunate cures effected by them; but they have probably undergone great changes since that time, as will appear from a comparison of his description with that which I shall give below.

Upland regiment, caused a proper reservoir, and the necessary buildings, to be constructed, a little nearer the royal road than they were before. Last summer a great concourse of people resorted to these waters, and took them with benefit. This fountain lies in a plain between the south and the west: there is an eminence situated at some distance, from which the springs probably derive their origin.

§ III. *Physical Qualities of this Fountain.*

The four veins afford much more than one hundred kannes of water every hour, which appears very limpid; but, when compared with that of the springs at the mill, or citadel, a considerable difference is perceived. When it is at rest, or runs but slowly, its surface shews the several colours of the rainbow, and a deposition of ochre is seen at the bottom. If the reservoir has been kept long closed, a strong hepatic smell is exhaled from it, which may also be perceived after shaking the water for a few moments in a corked bottle, and then applying it to the nose.

This water has a taste of ink, but it is very soon found to be in a great measure destitute of that brisk and agreeable acid which makes the acidulous springs in repute so volatile and so efficacious.

The

The temperature is between (b) 9° and 10°.

The specific gravity is to that of distilled water as 100,26, 10,000.

§ IV. *The Quantity of Aerial Acid.*

I have made many experiments to determine how much of that elastic which is properly called the aerial or atmospherical acid, is contained in this acidulous spring. One part changes ten parts of the blue tincture of turnsole to a very perceptible red; however, four parts do not alter this tincture so much as one part of the Spa water.

Agitation in a corked phial produces rather more bubbles in this water than in that of common springs treated in the same manner. If what has been said above of its taste be recollected, it will appear that there is a deficiency of aerial acid; as will be seen still more clearly, if it be disengaged by heat, and collected by means of quicksilver (c): in truth, it is scarce found to contain seven cubic inches in a kanne; whereas the same quantity of Spa and Pyrmont waters, as they are imported into Sweden, contain, the former near seven times, and the latter thirteen times as much.

(b) 48 and 50. B.

(c) See Diff. II. § VIII.

§ v. *The Principles obtained by evaporation.*

In order to obtain the fixed substances which do not fly off at a boiling heat, I evaporated given quantities of this water in the following manner:—after exposing it to the fire for four minutes, I suffered it to cool. I then filtered it, and obtained a kind of ochre, amounting to $1\frac{3}{4}$ grain per kanne. As it is necessary to adopt some process for procuring an equal exsiccation of the residua before they are weighed, I expose them for fifteen minutes to an heat of 100° (*d*). This term, which is that of boiling water, seemed the most convenient, because it may always be very easily obtained.

The filters should be dried at this degree, and afterwards weighed, in order to estimate what they contain. It is indeed impossible to prevent some very subtile particles from passing through; but it is still more difficult to separate the substances completely which adhere to and penetrate white paper not alumed, which is proper for this purpose. After thus weighing the substance, along with the filter, we have only to deduct the weight of the latter to find exactly that of the former: moreover, this mode of drying is more convenient, because, after the filter and its con-

(*d*) 212° of Fahrenheit. B.

tents have been left exposed to the air, it may be rolled up, and put into a glass phial, and the boiling heat thus applied to it.

My aim, by this first evaporation, was to learn, whether a little calcareous earth or magnesia was not held in solution by the aerial acid; for we have seen that they lose, at this temperature, the excess of that fluid necessary for their solution, when they precipitate, and remain on the filter, along with the ochre. In the present instance, there was no observable vestige of them, and the residuum did not effervesce in the least with the acids. I then continued the evaporation till the water was reduced to $\frac{1}{10}$; and, after having filtered the liquor again, the residuum, when dried, amounted to $2\frac{3}{4}$ grains per kanne.—All the following numbers are to be referred to this measure, which I will mention no more, and which ought always to be understood, unless another is particularly specified.—When the evaporation of the rest was finished, and it had been dried, there remained 16 grains; wherefore we have $20\frac{1}{2}$ grains for the sum of the several residua, of which we are now to examine the nature.

§ VI. *This Water contains aerated vitriolated Iron.*

The presence of iron is known by the ochre which it deposits, its taste, the black colour it strikes

strikes with astringents, and the blue colour produced by phlogisticated alkali. But it soon appears, that a very small portion only of this metal is held in solution by the volatile acid; that the greater part is combined with an heavier and a more fixed acid, because this water retains the property of turning black with astringents (c), after having been long exposed to the open air, and even after boiling, to the last drop; whence we may conclude, that it is a vitriolic water; for if the iron was dissolved by the aerial acid only, it would be all precipitated by boiling: on the contrary, water impregnated with martial vitriol, kept in an open vessel, is continually depositing successive portions of ochre; because, as the metallic basis gives out its phlogiston to the air, which attracts it with great eagerness, the acid can no longer hold the same quantity as before in solution; for, as iron is more deprived of inflammable principle, it requires more acid for its dissolution, and heat promotes the dissipation of the phlogiston. In water containing a very small

(c) It should be observed, that an excess of tincture of galls may easily mislead, because common water, containing a little aerated calcareous earth, without an atom of iron, precipitates it. The precipitate is of a yellowish white colour, and not perceptible at first; if a little iron should be present, there will be a mixture of violet-coloured particles, and in two hours a greenish tinge will appear.

portion

portion of vitriol of iron, it may be so far diminished by this means, that neither tincture of galls nor phlogisticated alkali produce any sensible effect.

According to some modern chymists, whatever water gives a blue colour with phlogisticated alkali certainly contains green vitriol; but this opinion is refuted by experiment, for distilled water, impregnated with aerated iron, assumes the same tinge, only a little more slowly; a circumstance that will not surprise those who consider the unequal strength of the two acids with which the iron is combined: it is even certain, that vitriol of iron, completely saturated, does not afford a fine Prussian blue so speedily, nor so copiously, as that in which there is excess of acid; for the precipitate of the latter shews instantly the finest blue, whilst that of the former has at first a blackish or whitish tinge. In the present instance, the vitriolic acid is more clearly detected by other processes:—the addition of vinegar of lead produces small angular grains, which are not attacked by vinegar; besides, if the iron is precipitated by the fixed vegetable alkali, a true vitriolated tartar may be obtained by crystallization. Now, this could never happen, if no vitriolic acid was present to combine either with the lead or the alkali.

It is possible to determine the quantity of iron, by the colour which the water receives from the tincture of galls; by trying, with an equal number

ber of drops of the tincture, equal quantities of water, more or less impregnated with vitriol : when the shade is the same, the bulk of water equal, and the quantity of the astringent principle the same, the quantities of iron must needs be equal ; and as the operator knows how much is contained in the solution which he made, he will also know the weight of that contained in the water which he is analysing : this process is not to be rejected with disdain ; but to be certain of the result, requires a tedious exactness. Others, after washing the whole residuum in pure water, then drying and weighing it, pour one of the mineral acids upon it ; and afterwards, pouring off the acid, wash what remains undissolved ; then dry and weigh it again, and from the diminution of weight collect that of the iron. This method is not a bad one ; but care must be taken not to use too strong an acid, not to add too much of it, and not to continue the digestion long ; for if there should be any selenite in the residuum, as it is soluble in the acids, they may take up more or less of it, perhaps the whole, and the operation would not be exact ;—the surest way is to precipitate all the iron with phlogisticated alkali.

A kanne of this water furnishes, by this process, near 16 grains of precipitate, which contain about 14 grains of martial vitriol, as 100 of this salt in crystals afford 115 of Prussian blue : the small quantity of iron dissolved by the aerial acid
must

must be deducted; but this scarce exceeds $\frac{1}{4}$ of a grain; for 100 cubic inches of this acid take up only 4 of iron (*f*).

§ VII. *Of the Selenite.*

When the iron has been parted from the residuum by means of an acid, a whitish matter, of the weight of 14 grains, remains, which exhibits almost all the properties of selenite; it is also found in the ochre collected by the first filtering (§ v.). All the residuums, and especially the last, are easily fused, with an appearance like boiling, upon coals excited by the blow-pipe; they leave a globular matter, which is attracted by the magnet, unless it has been too long exposed to the fire. The little solubility of this substance in water, and the appearances it shews in the fire, whether by itself or in mixture, sufficiently shew it to be selenite. Above all, it may be known by decomposing it by fixed alkali in the liquid way; for the calcareous earth is precipitated, and by crystallization Glauber's salt or vitriolated tartar may be obtained, according to the kind of alkali employed.

The selenite may be still better separated from the iron, by boiling the dried residuum in 500 times its weight of distilled water, which dissolves

(*f*) See Dissertation I. § XIV.

all the saline part, and afterwards it is easy to determine the quantity by weighing, after it has been dried, the ochre which remains.

§ VIII. *Of the Siliceous Powder.*

If the felenite is dissolved along with the iron, (§ VI. VII.), there remains about half a grain of very fine powder, which resists the acids, even when assisted by heat;—when it has been washed and examined, it is found to be true siliceous earth.

§ IX. *Of the Salts.*

By a slow evaporation of the water with which the residuum has been washed, about three grains of perfect crystals of Glauber's salt may be obtained, which contain only the small portion of iron that the water of crystallization retains: the remaining liquor is greenish, and does not easily afford crystals; but when reduced to dryness, it affords two grains of a deliquescent matter of an astringent, and at the same time salt taste: this matter, tried by different tests, and especially by precipitants, is found to be vitriol, but in a highly dephlogisticated state, and a little Glauber's salt mixed with common salt; this last shews itself both by its taste, and one or two cubical crystals, but chiefly by the grey and acrimonious fumes which arise

rise, and by the particular smell which it exhales, when it is moistened with a little concentrated vitriolic acid, and some wet substance is held over it.

§ x. *Principles of the Denmark Water.*

From what has been said before, it may be concluded, that a kanne of the Denmark water contains,

of aerial acid	-	7	cubic inches
of aerated iron	-	$0\frac{1}{4}$	grains, § VI.
of vitriol of iron	-	14	§ VI. and IX.
of Glauber's salt	-	$3\frac{1}{2}$	§ IX.
of selenite	-	14	grains, § VII.
of com. salt, at most		$0\frac{3}{4}$	§ IX.
of siliceous, nearly		$0\frac{1}{4}$	§ VIII.

In all $32\frac{3}{4}$ grains, which considerably exceed the weight of the whole residuum (§ v.); but this difference arises from the water of crystallization, which here enters into the account, and which the heat had dissipated when the residuum was weighed the first time. If the same substances, in the same proportions, are added to distilled water that has lost its empyreuma, a solution perfectly resembling the natural water in taste and every other quality will be obtained; and thus our analysis is completely confirmed by synthesis.

It should however be added, that the acidulous water of Denmark contains a little extractive vegetable matter, which without doubt it has received from the roots that it met with in its passage under ground; and probably this is what impairs its limpidity (§ III.). One may sometimes discover, by mere inspection, fragments of vegetables.

The variegated pellicle on the surface does not come from any mineral unctuous substance, but from iron in a certain degree dephlogisticated: similar pellicles appear on solutions of any metallic salts exposed to the air; they are also formed by iron dissolved in water by the aerial acid. Pure air forcibly attracts the inflammable principle; and it is evident, from many experiments, that the colours of metallic calxes vary according to the quantity of phlogiston of which they have been deprived. The hepatic smell plainly points out the way employed by nature to impregnate this water with its mineral particles.

Such are the substances contained in the acidulous springs at Denmark; to treat of their uses and efficacy does not fall within my plan. It is however, in general, evident that they must possess virtues different from those of lighter waters in which the iron is dissolved by the aerial acid: but although the same effects which the latter every day produce, cannot be expected from them, they probably possess greater power and efficacy
in

in those cases which may require a vitriolic water.

Moreover, the vitriol and felenite are here the active principles; the other substances are present in such small quantity that they can have little share in producing the effects. With respect to the felenite, it is found in the Pyrmont water, as well as many other waters of high reputation; but there is great reason to question its salubrity.

DISSERTATION V.

O F

S E A - W A T E R.

§ 1. *Water taken up from the Sea at a considerable Depth.*

THE experienced Dr Sparrman, who lately visited the Southern Ocean in company with the Forsters, and who in that voyage, with indefatigable care, has investigated, collected, and described the wonderful stores of nature, endeavoured, during his passage from the Cape of Good Hope to Europe, to ascertain the nature and properties of sea-water, taken from a very great depth:—for this purpose, a number of glass bottles, with narrow necks, and well corked, were successively sunk, in the beginning of June 1776, about the latitude of the Canaries; one bottle taken up from the depth of 80 fathom, was found cracked

cracked in the body by the pressure of the surrounding fluid; another, sunk to 30 fathom, had the cork a little thrust in, but not so that any water could enter; it was therefore let down to 60 fathom, and when brought up, was found filled with water up to the third part of its neck—in that place the cork, which had been thrust in, stuck, so as not to permit any water to escape: afterwards many bottles were filled at that depth, which, upon his return, Dr Sparrman sent to me, requesting me to examine with all possible accuracy the heterogeneous matters it contained.

§ II. *Its Habits with Precipitants.*

This sea-water had no smell, and the taste intensely salt, not agreeable indeed, but by no means nauseous, like that which is got at the surface.

(A) Paper tinged with Brasil-wood was rendered a little blue, that with turnsole had its colour somewhat heightened: these phænomena shew some weak tokens of an alkaline substance; namely, magnesia dissolved by means of aerial acid. Tincture of turnsole was not sensibly changed.

(B) Acid of sugar immediately precipitated a white powder consisting of saccharated lime.

(C) Fixed alkali quickly precipitated a white earth, which on examination proved to be magnesia.

(D) Salited terra ponderosa immediately threw down a spathum ponderosum.

(E) Phlogistigated alkali produced no signs of a blue colour.

Hence we may distinctly perceive the presence of lime (B), of magnesia (C), of vitriolic acid (D); —with respect to common salt there was no doubt.

In order to determine the quantity and quality of the proximate principles, I continued the investigation in the following manner.

§ III. *Principles collected by Evaporation.*

A kanne of this water (the specific gravity, compared with distilled water, was 1,0289) upon evaporation to dryness, yielded a residuum which, when well exsiccated, weighed 3 ounces 378 grains.

(A) This residuum, well washed with alcohol, and dried, was diminished in weight 380 grains.

The solution, diluted with distilled water, deposited, on the addition of mineral alkali, a magnesia; and the liquor, on evaporation, yielded common salt.

(B) In order to discover whether there was any vitriolated magnesia present, I added to the saline mass, washed with alcohol, a small quantity of warm water, and suddenly decanted it off. This water, on examination, shewed no signs of vitriolated

lated magnesia, either in taste or by precipitation, and contained nothing but a small portion of common salt.

Vitriolated magnesia is very easily dissolved in boiling water, whereas of pure common salt scarcely any more is taken up by hot than by cold water; by the above method, therefore, they may easily be separated. Some moderns contend, that more of common salt is taken up by cold, than by warm water; but this assertion is contrary to the nature of things, and to experience: upon accurate examination, I found the quantities taken up by boiling water, and by water of a moderate heat, to be respectively as 77 to 71½.

(c) The common salt was dissolved in a quantity of cold water so small, that it could take up no more; and therefore a white powder remained, which appeared to be gypsum.

(d) This gypsum excited in distilled vinegar a very slight effervescence, which soon went off, but the gypsum was scarce sensibly diminished.

(e) Upon collecting and weighing all the contents, each kanne is found to contain

	Ounces.	Grains.
of common salt,	2	433
of salited magnesia,	0	380
of gypsum,	0	45
	<hr/>	<hr/>
	3	378

The magnesia which adhered to the gypsum, and had been dissolved by the aerial acid, is found in such small quantity as not to amount to $\frac{1}{8}$ of a grain.

§ IV. *The Uses of Sea-Water.*

If sea-water taken from a considerable depth be always of the same nature with that above examined, we may conclude that such water is free from the ordinary nauseous flavour; and this supposition also agrees with other phænomena; for the innumerable croud of fish, insects, and vegetables, that grow, live, and perish in the water, as soon as they begin to grow putrid, swell, and rise to the surface, or at least such parts of them as are extracted by the water: on the surface these meet with a sufficient quantity of salt, and free access of air, circumstances which wonderfully promote putrefaction. This destruction is a necessary part of the œconomy of nature; and thus many circumstances, with joint force, contribute to this operation; the necessary consequence of which I apprehend is, that nauseous and loathsome taste occasioned by the putrid particles near the surface;—but, whatever be the cause, provided the fact be uniform and constant, an advantage of no trivial nature may be derived from it for the benefit of seamen; for sea-water, taken up at this depth at least, diluted with an
equal

equal quantity of fresh water, may be employed for the boiling of provisions, by which means one half of the fresh water will be preserved; and perhaps in time of urgent necessity a greater saving might be made.

DIS-

equal quantity of fresh water, may be employed for the boiling of provisions, by which means one

DISSERTATION VI.

OF THE ARTIFICIAL PREPARATION OF COLD MEDICATED WATERS.

§ I. *Reasons for the present Undertaking.*

THERE are four remarkable species of mineral waters; namely, the Seydschutz, Seltzer, Spa, and Pyrmont waters, which are imported into Sweden; physicians having found these so useful against infirmities and diseases, that a considerable quantity of them is prescribed and used every year.

But as these waters either cannot be had amongst us at all during the winter and spring, or at least not fresh, although the most powerful remedy for the diseases which prevail at that time of the year: as the poor cannot purchase them at
the

the price which they commonly bear;—as they lose more or less of their virtue during the voyage;—and finally, as they draw yearly considerable sums of money out of the kingdom;—I thought it worth while to examine, with all possible accuracy, the constituent principles of these waters: hoping that, these principles being once known, the waters themselves might be prepared in any part of the world. Whether or not I have succeeded let the candid and skilful judge from the following pages. — We now proceed to the analysis of these waters, as they must be thoroughly known, before they can be imitated.

§ II. *Analysis of Seydschutz Water.*

Principles collected by Evaporation.

The taste of Seydschutz water is extremely bitter and disagreeable: in boiling it separates a white powder, which, collected on a filter, washed and dried, exhibits a genuine aerated lime; for, when saturated with vitriolic acid, it is all converted into gypsum.

(B) After the greatest part of the water is evaporated a gypseous pellicle appears on the surface, which must be carefully taken away, as long as the least vestige of that salt shall appear during the evaporation. The gypsum, collected and washed, effervesces a little with distilled vinegar; this effervescence

vescence depends upon the admixture of magnesia alba, which may also be precipitated from the acid menstruum by alkali of tartar: however, a small quantity of gypsum will remain in the water, even after it has ceased to produce distinct pellicles.

(c) The residuum is of a brown colour; and on repeated evaporation this water yields, almost to the last drop, crystals of a bitter salt, which is totally decomposed by lime-water, and is therefore genuine (a) vitriolated magnesia: for Glauber's salt contains the mineral alkali, which does not yield the vitriolic acid to lime. The crystals, collected and dissolved in a small quantity of water, deposit on the bottom of the vessel that small portion of gypsum above mentioned (b). These crystals also contain a salited magnesia, which partly unites with the water of the crystals, partly adheres to them externally, and may be separated by spirit of wine.

Salited lime cannot exist in water which contains vitriolated magnesia, for the proximate principles of these salts are immediately changed by a double elective attraction; the vitriolic acid seizing the lime, and leaving the magnesia to the marine acid.

Upon repeating the analysis of Seydschutz water, I found that the different substances may be separated as well, or better, by continuing the

(a) On Magnesia, § v.

evaporation at first to dryness, and afterwards separating the one from the other.

(D) In order to determine the quantity of fixed air contained in the water, I at first made use of a copper cylindrical vessel, fitted with a conical top (A B C D, tab. ii. fig. 1.) into this I put another lesser cylinder (E F G H) open at the bottom, and standing upon three feet, but closed at the top, except the little tube I, whose upper orifice should stand about half an inch beneath the surface of the water, filling the vessel; and the process is thus conducted:—the external and internal vessels are filled with the water under examination; then a glass bottle, filled with warm water, is inverted, by means of the spoon L, in such a manner over the tube I, that no air bubbles shall enter: the water is then boiled as long as the vapour, and that only, arises in the form of bubbles; meantime the water contained in the internal vessel is forced by the heat to emit its air, which rises through the tube I, and is collected in the bottle; if necessary the first bottle may be removed, and set in a vessel of warm water, while another is inverted over the tube as quickly as possible, in order to prevent the escape of any of the air: finally, the space occupied by the air in one or more bottles is to be measured, and that in an heat of 50° , to prevent the absorption of air.

This space, compared with the capacity of the internal vessel, shews nearly the quantity of air contained in a given measure of the water. Such

a method I practised at first; but, although the water in the bottle be heated to the 50th degree, I have found that it absorbs some of the air; I therefore afterwards made use of mercury, which, if the operation be properly conducted, shews exactly the quantity of air required (see Analysis of Waters, VIII. A, B). The bulk varies according to the gravity and temperature of the atmosphere;—hence we should, as much as possible, chuse determined degrees of heat and weight.

It is also to be observed, that the aerial matter thus collected generally consists of two different elastic fluids, the one perfectly agreeing with the aerial acid, the other with pure air; that is, air fit for supporting flame and animal respiration. Common water absorbs the first of these, but not the latter, being already saturated with it; and by this method the two fluids may be separated to a certain degree.

(E) The several matters obtained by the analysis above described are in quantity as follows: a Swedish kanne (that is, 100 cubic inches) of Seydschutz water contains

	grains.
of aerated lime	$4\frac{1}{2}$
of vitriolated lime	$24\frac{1}{2}$
of aerated magnesia	$12\frac{1}{2}$
of vitriolated magnesia	$859\frac{1}{2}$
of salited magnesia	$21\frac{3}{4}$
	<hr/>
	$922\frac{3}{4}$
	The

The aerial fluid expelled by heat amounts to little more than six cubic inches, nearly four of which are aerial acid; and the remainder pure air.

(F) As 100 cubic inches of aerial acid can dissolve no more than 27 grains of aerated lime in a kanne of water (see Treatise on Aerial Acid), 4 cubic inches can scarcely take up more than one; the greatest part, therefore, of the aerated lime found in Seydschutz water is mechanically suspended in it, by means of the minuteness of its parts.

Salited magnesia may be partly decomposed, by bare evaporation to dryness—hence we must not conclude, that all the magnesia which, upon analysis, is found in a disengaged state, has always existed in the water in that same state, but rather that it has been united with marine acid in greater or less quantity, according to the degree of heat applied in the evaporation. Salited magnesia is easily discovered, as it dissolves slowly, and without effervescence, in acids.

§ III. *The Appearances of Seydschutz Water with Precipitants.*

(A) Tincture of turnsole, made with distilled water, and so diluted as to appear distinctly (b)

(b) On Aerial Acid, § vi.

blue,

blue, does not grow red upon the addition of Seydschutz water—this is owing to the small quantity of aerial acid; but paper tinged by turnsole is made more distinctly blue, which is occasioned by the aerated lime and (c) magnesia. If any disengaged alkaline salt be present, it is easily discovered, by means of paper tinged by turmeric, which is quickly and distinctly made brown by alkalis, but is not affected by aerated earths.

Paper tinged by fernambucum grows 'quickly blue, upon the addition of Seydschutz water.

(B) Spirituous tincture of galls (as well as phlogisticated alkali) neither changes the colour of Seydschutz water, nor precipitates any thing metallic.

(c) Caustic vegetable alkali immediately renders Seydschutz water turbid, and precipitates white spongy flocculi. The precipitate in this case is magnesia detached from vitriolic and nitrous acid.

(D) A few drops of concentrated vitriolic acid occasion no visible change; the particles of aerated lime and magnesia are too much diffused to make the effervescence observable; it may, however, be made manifest, by bringing them closer together by evaporation, although in this case the calcareous particles have before totally separated; a circumstance which takes place even in a moderate degree of heat.

(E) The acid of sugar, either alone or united with vegetable alkali, instantly discovers the most

(c) On Aerial Acid, § xi and xii.

minute

minute particle of (*d*) lime, whatever acid it be united with; for this acid attracts lime with such force, that it expels even the vitriolic itself, and all the other acids hitherto known, and forms with it a salt very difficult of solution, which therefore immediately falls to the bottom in form of a white powder. This acid, when added to Seydschutz water, instantly precipitates a saccharated lime.

(*F*) That substance which is commonly called *oil of lime* separates, though slowly, a gypsum from Seydschutz water; and this is effected by a double decomposition, the vitriolated magnesia and the salited lime changing primary principles.

(*G*) A small piece of pure alum, put into Seydschutz water, in the space of a quarter of an hour occasions an earthy stratum near the bottom of the vessel, which on examination is found to be argillaceous. This is produced by the vitriolic acid forsaking its base, and seizing the aerated magnesia.

(*H*) Solution of silver makes Seydschutz water immediately turbid; for vitriolic and marine acid, when present, separate the silver from nitrous acid.

(*I*) Solution of mercury in this case precipitates a turbith mineral, and that white, in inverse proportion to the dephlogistication of the metal du-

(*d*) Of the Acid of Sugar, § VI.

ring its solution. If the mixture be suffered to stand quiet, a whitish cloud is formed over the turbith mineral, which is no other than a falited mercury

(K) Corrosive sublimite precipitates slowly a white sediment, which consists of an aerated (*e*) mercurial calx, and is readily precipitated by means of lime or magnesia aerated.

(L) Saccharum saturni, or, to speak more properly, acetated lead, precipitates a white powder, which is a vitriol of lead, occasioned by the decomposition of vitriolated magnesia. The whiteness of this powder demonstrates the absence of sulphureous matter

(M) Martial vitriol is converted into an ochre, during its solution in Seydschutz water, because the aerated lime and magnesia separate the vitriolic acid, and the pure air contained in the water dephlogisticates the metallic base: vitriol in like manner deposits an ochre in a bottle full, and well stopped. All these phænomena, therefore, demonstrate the presence of the several matters which were before asserted to be contained in Seydschutz water.

§ IV. *Specific Gravity.*

I compared the specific gravity of Seydschutz water with that of the best common water, (di-

(*e*) On Aerial Acid, § XII.

stilled

stilled by a slow fire), and that in an heat of 15° : repeated experiments determined its specific gravity to be to that of distilled water as 1,0060.

Although the specific gravity of a solution is rarely agreeable to that of the ingredients taken together, the following comparison will not be without its use :

A kanne of the purest snow-water, distilled slowly, is nearly equal in weight to 42,250 grains; the same measure of Seydschutz water weighs 42,503; the difference therefore is 253 grains. But in § 11. we got, from a kanne of Seydschutz water, no less than $922\frac{3}{4}$ grains, which is nearly four times the last number.—We must now take into consideration the water of the crystals, which in 100 of aerated lime makes 11; of vitriolated lime 22; of aerated magnesia 30; of vitriolated magnesia 48; and of salited magnesia nearly 40.—Hence, a calculation being made, we find the water of crystallization of the substances contained in a kanne of Seydschutz water to be 431 grains. Hence, $923 - 431 = 492$; but $492 - 253 = 239$; which still shews a considerable difference; but this difference will soon vanish, supposing the specific gravity of the salts to be in general 2; and that, conformable to the most accurate experiments, no mutual penetration takes place;—for 492 grains of salts, put into a kanne of distilled water, displace only so much water as is equal to $\frac{492}{2} = 246$; the weight therefore of a kanne

Q 2

of

of distilled water, in which 492 grains of salts are dissolved $= 42,250 + 246 = 42,496$; but $42,503 - 42,496 = 7$. Now, since 6 cubic inches of atmospheric acid weigh about 3 grains, we have at length $7 - 3 = 4$ grains, indicating nearly how much has been lost, during the operation, on the filters and vessels.

§ v. *Analysis of Seltzer Water.*

Principles collected by Evaporation.

Seltzer water, besides a subtile pungent acidity, excites upon the tongue a taste gently salt, and mildly alkaline.

(A) By quick boiling, it deposits an aerated lime, which had been dissolved by means of superabundant aerial acid;—this, collected on a filter, is found to contain scarce any aerated magnesia, as this last is both more easily dissolved, and retains the quantity of volatile menstruum necessary for solution more obstinately than the lime does.

(B) By a continued evaporation, the magnesia separates; but as it continues to separate during the whole evaporation, it cannot be collected by filtration; we must therefore evaporate to dryness, wash the residuum with hot distilled water, and at length the magnesia will remain alone at the bottom.

(c) The

(c) The solution which is obtained by warm water yields, on crystallization, two salts; the one an alkali, which, with vitriolic acid, forms a true and pure Glauber's salt, and is therefore no other than genuine mineral alkali; the other cubic, agreeing perfectly with pure culinary salt.

Salited magnesia, which almost always accompanies culinary salt, is in this case not to be found; nor could it possibly be so, on account of the disengaged alkali.

(D) The weights of the several matters contained in a canne of Seltzer water are as set forth in the following table.

			grains.
Aerated lime,	-	-	17
Aerated magnesia,	-	-	$29\frac{1}{2}$
Crystallized mineral alkali,	-	-	24
Common salt,	-	-	$109\frac{1}{2}$
			<hr/>
			180

The aerial fluid sometimes amounts to 60 cubic inches, which is almost all aerial acid; for the pure air scarcely exceeds a single cubic inch.

§ VI. *The Habitudes of Seltzer Water with Precipitants.*

(A) Tincture of turnsole grows red upon the addition of a small portion of Seltzer water; but

in the open air the blue colour gradually returns—a change which takes place immediately upon the application of heat.

Paper tinged with tincture of turnsole is rendered more distinctly blue by this water; that tinged by Brazil wood grows blue; and that tinged yellow by turmeric is but little changed: however, if the ingredients be reduced to a small space by evaporation, this paper assumes a brownish red.

(B) Tincture of galls and phlogisticated alkali produce no signs of any thing metallic.

(c) Crystallized vegetable alkali produces no effect; but the caustic alkali precipitates a white powder, which effervesces with vitriolic acid, and forms a gypsum: this therefore is aerated lime, deprived of the portion of volatile menstruum necessary for its solution.

(D) The strong acids occasion a great number of bubbles, which consist of the aerial acid expelled from the alkali and the aerated earths.

(E) Acid of fugar immediately seizes the lime, and falls to the bottom.

(F) Salited terra ponderosa precipitates no spathum ponderosum, which most evidently shews the absence of vitriolic acid; for that acid attracts terra ponderosa with such force, that, deserting every other base, it unites with that earth in the form of nearly insoluble atoms.

(G) Salited lime does not precipitate a calcareous

reous powder until after a day or two.—This precipitate is occasioned by the mineral alkali which the aerial acid, so long as it remains in sufficient quantity, holds suspended.

(H) Alum is decomposed in like manner by the disengaged alkali.

(I) Solution of silver renders Seltzer water immediately milky, being partly converted into a saluted silver, partly yielding its acid to the alkaline salt.

(K) Solution of mercury, made without heat, in nitrous acid, occasions a copious white precipitate;—the solution made by heat causes a yellow one.

(L) Corrosive sublimate precipitates a white powder, but not until after some days.—If about $\frac{1}{3}$ of the water be dissipated by evaporation before the sublimate is added, no change is observed; but after a few days blackish crystals appear by degrees. Of these crystals we have already treated, (on Aerial Acid, § XII).

(M) Crystallized saccharum saturni immediately precipitates a white sediment, which is all soluble in vinegar — The same happens with lead, either united with marine acid, or precipitated by fixed alkali. Vitriol of lead is not soluble in vinegar.

(N) Vitriol of iron deposits a white sediment, which gradually grows yellow, even in a bottle full and well stopped.

§ VII. *Specific Gravity of Seltzer Water.*

In a moderate heat, I found the specific gravity of Seltzer water to be 1,0027; hence the weight of one kanne should be 42,363 grains, which, calculating from the ingredients, will be $42,250 + \frac{180-31}{2} = 42,324\frac{1}{2}$, as the water forms about 31 grains, 64 to every hundred of alkali, allowing 6 to the sea-salt, and the rest as in § IV. The weight of 60 cubic inches of aerial acid is nearly 30 grains; therefore $42,363 - 42,324\frac{1}{2} - 30 = 8\frac{1}{2}$; the difference of weights of a kanne, one of which is computed by the specific gravity, the other from the quantity of the heterogeneous contents.

§ VIII. *Analysis of Spa Water.**Principles collected by Evaporation.*

Spa water has a martial sub-alkalescent, mild, and gently pungent taste. On exposure to the open air for some hours, it contracts a shining variegated pellicle on the surface.

(A) By quick boiling it separates a ferruginous powder; let this, collected by filtration, and a little roasted, be put into vinegar; for this menstruum dissolves the earthy parts, leaving the dephlogisticated iron untouched.—Whatever is afterwards precipitated

precipitated from the vinegar by an alkali is no other than an aerated lime.

(B) During the whole progress of evaporation, even to the very end, a white powder is continually separating, which may be obtained from the dry residuum by sufficient washing carefully conducted. This generally dissolves in vinegar, with effervescence, and is found to possess the properties of aerated magnesia; but sometimes a part remains untouched; this is gypsum, and rarely amounts to a grain in a kanne.

(c) The water with which the residuum has been washed, on crystallizing, exhibits the mineral alkali, mixed with a few cubes of common salt. This alkali, united with vitriolic acid, forms a genuine Glauber's salt, sometimes intermixed with a few crystals, resembling vitriolated vegetable alkali.

(D) The experiments hitherto made shew, that a kanne of Spa water contains,

		grains.
of aerated iron,	- -	$3\frac{1}{4}$
of aerated lime,	-	$8\frac{1}{2}$
of aerated magnesia,	-	20
of crystallized mineral alkali,		$8\frac{1}{2}$
of common salt,	- -	I
		<hr/>
		$41\frac{1}{4}$

The aerial fluid collected rarely amounts to 45 cubic inches; which is all aerial acid, and is absorbed by water.—I found not any pure air, and perhaps it could not long exist together with aerated iron, as the pure air seizes the phlogiston, and flies off with it.

§ IX. *Habitudes of Spa Water with Precipitants.*

(A) One part of Spa water generally reddens 25 of tincture of turnsole. The paper tinged by turnsole is rendered of a more vivid blue; that tinged by fernambucum is made blue; but paper coloured by turmeric is scarcely changed, until the water has been a good deal reduced by evaporation.

(B) A single drop of tincture of galls renders Spa water purple; and phlogisticated alkali produces, though slowly, Prussian blue.—Spa water, after boiling, does not exhibit the smallest sign of iron, either by these precipitants, or by any other method.

(C) Caustic fixed alkali, after 24 hours, separates, though sparingly, a white calcareous powder. The crystallized alkali has no other effect than to deprive the water of its pungent flavour.

(D) Concentrated acids occasion a great quantity of bubbles.

(E) Saccharated

(E) Saccharated vegetable alkali, as also acid of fugar alone, precipitates lime but sparingly.

(F) Salited terra ponderosa very rarely separates any thing, and when it does, it is very flowly; which indicates either the absence of vitriolic acid, or that its quantity is extremely small.

(G) Salited lime, after 24 hours, is precipitated by the fixed alkali of the water.

(H) Alum deposits its earth.

(I) Solution of silver throws down a fine white powder.

(K) Solution of mercury, made without heat, yields a yellowish white precipitate; that made with heat a brownish yellow.

(L) Corrosive sublimate, after 24 hours, separates a grey powder, which, if the water be previously concentrated by evaporation, is of a brownish yellow.

(M) Acetated lead forms a white precipitate.

(N) Martial vitriol yields a white powder, which gradually grows yellow.

§ X. *Specific gravity of Spa Water.*

In an heat of 15° the specific gravity of Spa water is 1,0010, hence the weight of one kanne should be 42,292 grains;—but the water of the residuum is about $14\frac{1}{2}$, and the weight of 45 cubic inches of atmospheric acid = $22\frac{1}{2}$;—therefore $42.292 - 42,250 + \frac{41-12}{2} + 22\frac{1}{2} = 5$; which is the difference sought.

§ XI. *Analysis of Pyrmont Water.**Principles collected by Evaporation.*

Pyrmont water possesses a most agreeable subaccescent, pungent flavour, not unlike that of Champagne wine, but at the same time martial, and a little bitterish; in the open air, it contracts a pellicle like the Spa water.

(A) During ebullition aerated iron, together with aerated lime, is separated; the former may be easily separated from the latter, by means of vinegar, as above described (VIII. A).

(B) After filtration, let the evaporation be continued to dryness; let the residuum, washed with a sufficient quantity of distilled water, be put into vinegar: the part thus dissolved shews the properties of magnesia; that which remains untouched is found to be gypsum.

(C) The water with which the residuum has been washed, being evaporated, exhibits at first true vitriolated magnesia; but towards the end, magnesia mixed with common salt, which may in some degree be separated by conducting the evaporation very slowly.

(D) All the ingredients being carefully weighed, there are found in each kanne of Pyrmont water,

grains.

		grains.
of aerated iron	-	$3\frac{1}{4}$
of aerated lime	-	20
of vitriolated lime	-	$38\frac{1}{2}$
of aerated magnesia	-	45
of vitriolated magnesia	-	25
of common salt	-	7
		<hr/>
		$138\frac{3}{4}$

The aerial fluid collected sometimes amounts to more than 90 cubic inches, and consists entirely of aerial acid; in general, however, the quantity of aerial acid is much smaller.

§ XII. *Appearances of Pyrmont Water with Precipitants.*

(A) Pyrmont water communicates a deeper red tinge to tincture of turnsole than Spa water does. The paper stained by turnsole has its colour heightened; that with fernambucum grows blue; that with turmeric is not changed, even though the water has been much evaporated.

(B) Tincture of galls and phlogisticated alkali soon discover iron; but the water, after boiling, shews no signs of that metal.

(C) A single drop of caustic fixed alkali, throws down a white earth, which, on examination, exhibits the qualities of magnesia.

(D) Con-

(D) Concentrated acids occasion an effervescence.

(E) Acid of sugar precipitates lime quickly and copiously.

(F) Salited terra ponderosa indicates vitriolic acid, for a spathum ponderosum precipitates.

(G) Salited lime occasions a gypseous precipitate, which after 24 hours becomes visible.

(H) Alum is decomposed, even after the lime is separated; this effect is therefore produced by the aerated magnesia.

(I) Solution of silver occasions a milky turbidness.

(K) Solution of mercury, made without heat, occasions a whitish yellow precipitate; that made with heat, exhibits a more copious sediment, of a deeper yellow; in both cases, if the solution be gently dropped in, and the water suffered to stand quiet, a white cloud is suspended over the bottom of the vessel, which indicates a salited mercury.

(L) Corrosive sublimate after 24 hours produces an ochry precipitate, soluble in vitriolic acid; Pyrmont water, much evaporated, deposits a white powder, upon the addition of corrosive sublimate.

(M) Acetated lead yields a white powder, great part of which resists the action of vinegar.

(N) Martial vitriol yields at once a white precipitate, which grows yellow, though slowly.

§ XIII. *Specific Gravity of Pyrmont Water.*

The specific gravity of Pyrmont water is found, in a moderate heat, to be 1,0024; the weight, therefore, of one kanne is 42,351 grains; but as the water of the residuum is $36\frac{3}{4}$, and the weight of 90 cubic inches of atmospheric acid is 45, $42,250 + \frac{138\frac{3}{4} - 36\frac{3}{4}}{2} + 45 = 5$; the difference by which the weight of a kanne, computed by its specific gravity, exceeds the weight deduced from the quantity of heterogeneous contents.

§ XIV. *Comparison of the Waters above examined.*

That we may have, in one synoptical view, the contents of all these waters, we shall set the whole in order in the following Table.

TABLE

TABLE of CONTENTS of the Cold Medicated Waters, in Grains.

	Seydchütz.	Seltzer.	-Spa.	Pyrmont.
Aerated lime,	—	—	—	—
Vitriolated lime,	—	—	—	—
Aerated magnesia,	—	—	—	—
Vitriolated magnesia,	—	—	—	—
Salited magnesia,	—	—	—	—
Aerated mineral alkali,	—	—	—	—
Salited mineral alkali,	—	—	—	—
Aerated iron,	—	—	—	—
Sum total,	—	—	—	—
Greatest quantity of aerial acid, in cubic inches,	—	—	—	—
Pure air,	—	—	—	—
Specific gravity,	—	—	—	—

Seydchütz.	Seltzer.	-Spa.	Pyrmont.
4½	17	8½	20
24½	—	—	38½
12½	29½	20	45
859½	—	—	25
21¾	—	—	—
—	24	8½	7
—	109½	1	3½
—	—	3¼	—
922¾	180	41¼	138¾
4	60	45	90
2	1	—	—
1,0060	1,0027	1,0010	1,0024

§ xv. *Conjecture concerning the Way in which Nature prepares these Waters.*

Among the waters now examined, the Seydshutz contains scarcely more aerial acid than common fountain water: to account, therefore, for the origin of this water, such a situation of its channels as may conduct it through strata of aerated lime, &c. is sufficient; and these strata are found in many places; the water passing through these by degrees takes up the quantity which is found in it as above.

The three others possess so large a quantity of aerial acid, that they could not have received it from the atmosphere. This elastic vapour is abundantly extricated in three different ways (on Aerial Acid, § 11.) namely, by fermentation, by fire, and by the action of a more powerful acid: the first of these can scarcely be supposed to take place in the bowels of the earth; but I see no reason why the other two may not operate, either jointly or separately:—Thus subterranean fire expels the aerial acid from calcareous earth, and still more readily from magnesia; and it is the more readily absorbed by the water which it meets with, in proportion as that water is the more divided into channels, as it is the more cold, and the more compressed by the subtile elastic fluid. Nor is the third method attended with any

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difficulty; for although, on the surface of the earth, water scarcely ever contains an uncombined mineral acid, yet in the bosom of the earth, the vitriolic acid must be often set free by the deflagration of sulphur; and perhaps the marine acid may be extricated from salited lime and magnesia by subterraneous fire.—We shall soon see the effects of earthy and metallic salts, when decomposed by mineral alkali or alkaline earths.

Let us first consider the Seltzer water; and begin by enquiring whether it owes its aerial acid (which is the chief point in question, the other ingredients being found in the bosom of the earth) to the decomposition of middle salts by an alkali; or to alkalis directly dissolved in acids; or, finally, to the extrication of that elastic fluid by subterraneous heat alone.

To examine the first supposition, let us suppose that water loaded with salited lime and magnesia meets with an aerated alkali; now a kanne of Seltzer water contains $109\frac{1}{2}$ grains of common salt, in which there are about 46 of pure mineral alkali; and these require about 37 of aerial acid to saturate them; that is, 74 cubic inches, because each cubic inch weighs about half a grain: but $45\frac{1}{2}$ grains of pure lime may be precipitated by that quantity of alkaline salt; and these immediately absorb about 28 grains of aerial acid. In the same manner, by an equal quantity, upwards of 35 grains of pure magnesia are precipitated; and
this

this quantity, in precipitating, carries along with it at least $19\frac{1}{2}$ grains of aerial acid. Making a calculation, therefore, it appears, that in the first case there only remain to saturate the water $37 - 28 = 9$ grains $= 18$ cubic inches of aerial acid, which is not sufficient for the purpose (§ XIV); and in the case of the magnesia $37 - 19\frac{1}{2} = 17\frac{1}{2}$ grains $= 35$ cubic inches; a quantity far too small (§ XIV). The common salt, therefore, which is present in Seltzer water, does not seem to originate in this way, supposing that the water at once receives the 60 cubic inches of aerial acid; but if the water contains so much marine acid as is sufficient for the immediate production of 109 grains of common salt, the end will be completely obtained, as all the 74 cubic inches can without diminution be applied to that purpose. There is no doubt but this may take place, if the aerial acid be expelled by fire.—We now proceed to consider the two martial waters.

Pyrmont water contains 7 grains of common salt in a kanne; which, if we suppose them generated from salited magnesia, precipitated by mineral alkali, will give scarce more than 3 cubic inches for aerating the water. The vitriolated lime and magnesia are of no use in this process, unless generated in the water itself, either by means of a disengaged vitriolic acid, or, as is more probable, by the decomposition of martial vitriol.

A kanne of Pyrmont water contains $38\frac{1}{2}$ grains of gypfum, and 25 of vitriolated magnesia: these two falts together contain about as much vitriolic acid as 67 grains of cryftallized green vitriol. Let us then fuppofe, that water, impregnated with this quantity of vitriol, meets with $20\frac{1}{2}$ grains of aerated lime, and about 11 grains of aerated magnesia, and the above-mentioned falts will appear; and during this operation the former bafe gives out $16\frac{1}{2}$ cubic inches of aerial acid, and the latter 6; but $22\frac{1}{2}$ cubic inches fcarce amount to a fourth part of the neceffary bulk, even adding 7, which are got from the common falt, fuppofing it to be generated in the water;—a great deficiency, therefore, ftill remains, fo that we muft try another method.

Let us fuppofe a kanne of water loaded with 276 grains of vitriol (which is by no means extravagant, as that quantity of water can take up upwards of 6,000 grains) meets with 235 grains of aerated lime; in this cafe not only 100 cubic inches of aerial acid will be extricated, but enough of the iron and gypfum will be diffolved to faturate the water. Thus, then, by the addition of 25 grains of vitriolated magnesia, we have a complete Pyrmont water.

It is otherwife with the Spa water—this is very poor with refpect to the quantity of faline contents; and, with regard to the nature of these falts, is fuch, as to require a quantity of aerial acid,

acid, that has been extricated externally ;—in this water, besides the mineral alkali, lime, magnesia, and iron, (all of which are united with aerial acid), there is nothing contained, except a single grain of common salt—hence it is plain, that this water cannot be aerated, either by the saturation of marine acid, or by the decomposition of middle salts in the water itself. Now, in the neighbourhood of Spa there are no vestiges of subterraneous fire ; how then does the water acquire the aerial acid in the bosom of the earth ? We first observe, that vestiges of subterranean fire, once abundantly manifest, are by lapse of time often so defaced, as to be scarcely discernible ; besides, a degree of subterraneous fire, sufficient to extricate this subtile acid, may easily exist, without producing earthquakes or eruptions of any kind, and that for any length of time, provided the causes be so tempered that the effects may remain the same ; neither is it necessary that the efficient cause should be in the neighbourhood, for the superficial strata of this globe are perforated in almost every direction, so that the elastic fluid may come through a variety of channels, from places very remote. In the present instance it appears, that the aerial acid must have passed through a length of way, as it is found to have deposited all its heat ; but martial vitriol alone, dissolved in water, and penetrating strata, which contain either alkaline salts, lime, or magnesia, may, by

decomposition, extricate a sufficient quantity of aerial acid ; which being conducted to a great distance from the place of its origin, may be so united with water, that such water shall not exhibit the slightest marks of those substances which contributed to its impregnation.

I have sometimes found a small portion of gypsum in Spa water, in the quantity of about one grain to a kanne ; but how can this be, if we suppose a disengaged mineral alkali (or rather an alkali only, united with aerial acid) to be present, as such an alkali attracts the vitriolic acid more powerfully than lime does ? We may observe first, that there is only $\frac{1}{100}$ of a grain of gypsum in a cubic inch of water ; and of the mineral alkali, no more than $\frac{1}{10}$ of a grain ; for the combination of mineral alkali and aerial acid is not spontaneously decomposed : substances, therefore, which are so thinly scattered through the water, may reasonably be supposed to act very slowly upon each other, especially as the alkali, when aerated, is very inactive. An example will shew how the activity of substances is repressed by aerial acid : — let vitriolated magnesia be dissolved in water ; drop in a little lime-water, and instantly the magnesia falls to the bottom, having yielded its acid to the lime ; but if pieces of chalk or calcareous spar be put into the solution, no decomposition can be produced, even by boiling : hence

we see how, in Seydschutz water, vitriolated magnesia may exist, together with aerated lime.

Besides, most commonly, there is no gypsum found in Spa water: whether this happens because the water is taken from different springs, or whether the number of principles is not always the same in the same spring, I have no doubt but that the proportion of the ingredients does frequently vary, and I am confirmed in this opinion by experience, and the nature of the thing itself.

§ XVI. *Whether the Waters above examined be imitable by Art.*

The completion of any analysis can by no other means be so clearly evinced as by producing synthetically a perfect imitation of the thing analysed; as it thence appears that we have not only discovered the primary principles, but also the true method of uniting them. We are now to try what can be done in the present case. From what has been said, it appears, that the art of preparing medicated waters comprehends two circumstances of moment; first, it is requisite that water, pure, and totally destitute of every sort of taste, be as it were vivified by aerial acid, which constitutes the genuine mineral spirit as it is called; by this the water acquires a grateful, subtile, penetrating taste, together with singular virtues; but the efficacy of this acid must be se-

conded by other grosser substances, which determine the peculiar nature of the water; so that one shall resemble Seltzer, another Spa, and a third Pyrmont water;—the first of these differs much from the other two in its nature and properties, nor do the two chalybeate waters altogether agree. It is not therefore sufficient, for the imitation of these mineral waters, to be acquainted with the method of impregnating water with aerial acid: the principles proper to each, from whence their specific virtue and efficacy is derived, must also be accurately understood.

Many persons are firmly persuaded, that in the natural production of medicated waters, there takes place a certain degree of fermentation, as they are pleased to call it, which can never be imitated by art: but those who are well acquainted with the subject are of a very different opinion. The question is entirely reducible to this, viz. to discover accurately the heterogeneous contents of those waters, and to unite those heterogeneous matters with pure water. It can be of little consequence whether the water dispersed through the bowels of the earth, by passing through certain strata extract certain materials, or whether those very materials be artificially added in proper quantity:—the hand that supplies the ingredients can make no difference in the result.

§ XVII. *The Method of Aerating Water.*

The most simple method is that which Venel has employed, and I believe is the same as that frequently employed by nature for the same purpose (§ XVI.): but in order to generate in water the proper neutral or middle salts, a more laborious and cautious management is necessary; as we are not in possession of an easy and commodious method of measuring either the strength of the menstrua, or the quantities necessary for saturating them.—The following is the method which I at first employed:—

A B is a glass vessel, somewhat (fig. ii.) more than half filled with water, and chalk coarsely powdered; the tube A C D is so fitted to the mouth of the bottle, that not the least air can escape. The tube E, in the side of the bottle, is accurately closed by the stopper F, as soon as some drops of vitriolic acid have been poured in: this acid, as soon as it falls, begins to expel the weaker aerial acid from the chalk; which, rising in the form of an elastic fluid, is conducted by the tube to the bottom of the water in the vessel G H: this vessel is chosen long and narrow, that the aerial acid may be more completely absorbed in its passage through the water. A wet bladder is tied round the neck of the bottle G H, and the tube, so as to confine the aerial acid, which would otherwise escape:

escape : this resistance, however, must not be too great, as in that case no aerial acid will be produced, (on Aerial Acid, § 11.). The escape of the aerial acid may therefore be regulated by a pin-hole in the bladder ; as soon as the effervescence ceases, more acid is to be poured in, through the tube, and this repeated until the water has received the proper quantity of aerial acid, which may be determined by the taste, or more accurately by tincture of turnsole. In this manner I first prepared aerated water ; but it may be done much more commodiously by the funnel o, which, according to Mr Lavoisier's method, is so shut by the glass rod p, that the vitriolic acid falls down spontaneously and gradually.—I sometimes have employed a small fermenting mass (fig. vii. tab. 2.), and that with the best success ; but after I had learned, from the writings of Dr Priestly, the advantage arising from agitating the water, I effected this purpose in two more easy ways.

(A) Fig. iv. will explain the first of these methods better than any verbal description. A B is a glass bottle, fitted with a lateral tube, and a glass stopper ; in this bottle an effervescence is produced by means of chalk and vitriolic acid : E is a common glass bottle, filled with the purest water, and then stopped by a cork, so closely that it cannot admit any air ; it is then inverted, and set in a groove, cut in the board G F, laid across the vessel H I, filled with water ; the cork is then
taken

taken out, and the aerial acid expelled by the vitriolic is conducted into the bottle by the tube A C D : the glass tube L N O passes through the cork : P Q is also made of glass, and is fitted to the former by the intervention of the tube O P, which is made of elastic resin, and tied to both, (this might be made of flexible leather, but where the sides cross, it must be sewed only half through, otherwise the air will escape through the holes made by the needle) : the joint O P is made flexible, that the bottle A B may be shaken, by which the extrication of aerial acid is much expedited ; but this must be done gently, lest some of the chalk should enter the tube A C, and mix with the water. For the same reason, only a small quantity of vitriolic acid is to be added at one time ; for if too much be added, so violent an effervescence will be occasioned, as to carry over into the tube a quantity of the chalk : it is necessary to observe, that not the smallest cranny should be left open for the escape of aerial acid ; therefore the stopper of the lateral tube must be closely fitted, and every part about the neck of the bottle A B, and tube, completely shut up : the extremity Q may be easily put in and taken out of the bottle, by the forceps, fig. vi.

The apparatus being prepared, I impregnate the water in the following manner :—I fill the bottle somewhat more than half with aerial acid ; this being done, I let fall to the bottom of the vessel

vesel the faucer κ ; I then cautiously remove the bottle from the groove in the board, keeping its mouth still under the surface of the water, and setting its mouth upon the faucer κ , I agitate it violently for some minutes: during this operation the empty space in the bottle diminishes, the water, by agitation, presenting a larger surface of contact to the aerial acid, which is therefore more readily absorbed; the bottle, however, cannot be entirely filled the first time, as some portion of common air remains, which will not unite with water; I therefore cork the bottle under the surface of the water, turn it up, and fill the empty space with water; I again invert the bottle in the water, half fill it again with aerial acid, agitate it as before, and then generally obtain it full. As the water expelled from the bottle is diluted with that in the dish, it is necessarily the less impregnated when it re-enters the bottle. If, therefore, the water is to be saturated, in which process it takes up nearly its own bulk, (on Aerial Acid, iv.), the above-mentioned operation must be repeated a third time; and hence may easily be deduced a method of impregnating water in any given lesser proportion.

It is in general to be observed, that the colder water is, the more aerial acid will it absorb; therefore this operation should be performed in a cool place, and the body of the bottle handled as little as may be.

I make use occasionally of bottles of different sizes, generally such as contain half a kanne, but sometimes (for expedition sake) those of 2, 3, or 4 kannes; but the larger are both inconvenient, on account of their weight, and are liable either to be broken themselves or to break the faucer, unless handled with caution.

By this method a bottle of water may be saturated in about ten minutes: if the bottle, half filled with aerial acid, be suffered to stand inverted upon the board, the water will, in a cool place, rise spontaneously without any agitation; but this will happen slowly, as before observed.

(B) The other method is much more easy, and impregnates a large quantity at one time, but is attended with this inconvenience, that it requires a very large fermenting mass: when this can be had, let a vessel be prepared, similar to that in which the mass is set to ferment, but of smaller diameter, so that the vessel which holds the fermenting mass may contain it; let its height be so adjusted to the empty space in the larger vessel, that when the bottom of the lesser touches the fermenting mass, its upper edge may stand three or four inches at least beneath the upper edge of the larger vessel.

In the middle of this vessel, let an axis be erected perpendicularly, so that, by means of an handle, it may be turned round horizontally; let there be fastened to this axis three or four wooden plates,
some

some inches broad, at several distances from the bottom; these must be shorter than the diameter of the vessel, with the plane of their surfaces inclined to the horizon in an angle of about 45° . The vessel being then filled with cold water, and suspended over the fermenting mass, so as nearly to touch its surface, let the axis be turned round, and it will give a circular motion to the water; so that by enlarging and continually changing the surface, the aerial acid is very quickly absorbed — Thus a very large quantity of water may be completely saturated in a single minute.

§ XVIII. *Observations concerning the Addition of the Salts.*

The water being sufficiently impregnated with aerial acid, and poured into bottles, the materials determining the particular species are next to be added: what these are, and in what quantity they are to be employed, will appear from the foregoing analysis. The mineral alkali, and the other salts, should be chosen pure and newly crystallized — the earths in a crystalline form, fully saturated with aerial acid, and reduced to a very fine powder; for otherwise they dissolve slowly: iron is to be employed, in the form of fresh filings tied in a linen cloth, or that of a plate of convenient form, with a smooth and polished surface: the cloth or plate is to be suspended in the water, to promote

promote the solution; the bottle is then to be well closed, inverted, and set in a cool place for some days. In that space of time the water takes up the salts, and, by means of the aerial acid, not only dissolves the lime, but also a small portion of the iron. I know that the celebrated Monnet contends, that water can, by itself, take up iron; but common water always contains some aerial acid; and when that is expelled, not the smallest particle of iron is taken up by it, except that species which, when red hot, is (*f*) brittle, as such always contains some vitriolic acid.

The same filings will serve repeatedly, provided the cloth, when taken out of the impregnated water, be plunged into cold water, and suffered to remain there until used again; for when exposed to the air, it contracts rust, and thereby becomes insoluble: for the same reason, the surface of the

(*f*) Such was the general supposition concerning the cause of this fault in iron: but it was not founded on any accurate experiments; and when Professor Bergman came to investigate the subject himself, (*de Analyfi Ferri*, § viii.), he could discover no vestiges of vitriolic acid, by means of any test. His experiments lead him to impute this defect to some depravation of the inflammable principle. Hot-short iron (*calidum fragile*) affords inflammable air, which, when fired, shews phænomena different from that which is obtained from other iron: it has a peculiar smell, approaching to an empyreuma, and, when forged, emits more sparks. B.

plate must be polished afresh as often as it loses its splendour.

By the method just described waters are obtained, agreeing both in flavour and virtue with those brought from foreign countries ; but as some of the substances contained are justly esteemed of a suspicious nature, I am of opinion that they should by all means be omitted : these are the calcareous and gypseous matters ; and I am persuaded that no person will imagine that chalk or gypsum can contribute to the salubrity of waters ; but that, on the contrary, they may give occasion to grievous obstructions. The Pyrmont water contains these substances in considerable quantity, and for that reason is hurtful to many constitutions : for twelve kannes of this water (which is the quantity usually taken in twenty-four days) contain half an ounce of aerated lime, and an ounce and a half of gypsum—a load which few stomachs are able to bear.

As to the magnesia, I do not indeed consider it as noxious ; but as it dissolves slowly, and whatever effect it has may be easily supplied in another way, I omit it ; especially as experience shews that the waters thus corrected are equal, if not superior, both in taste and virtue, to the natural waters.—I generally make use of water fully impregnated with aerial acid.

The imported waters which have been examined have no doubt suffered some change during the voyage.—The experienced Seip relates, that

a phlogisticated vitriolic acid, and a true sulphur, may be extracted from the vitriolated magnesia of Pyrmont water, by distillation, without any addition. In order to obtain half a pound of this vitriolated magnesia (which is necessary for his experiment) we must evaporate upwards of 115 kannes of the water, which I have never had an opportunity of doing;—I have, however, tried smaller quantities, but never could discover the smallest particle of the substances he mentions:—perhaps the magnesia which is united with phlogisticated vitriolic acid in the fresh water, loses the inflammable principle during the voyage; so that, on its arrival in Sweden, it retains little or none of it; in the same manner as the sulphurated salt of Stahl changes by time into vitriolated vegetable alkali. This ingenious philosopher (Seip) to whom the aerial acid was unknown, contends, that the phlogisticated vitriolic acid is the true mineral spirit; that it adheres to the iron in Pyrmont water until exposed to the air; and that then, by means of a stronger elective attraction, it seizes the magnesia, which it was not able to do in the close and confined subterraneous passages.—This explanation, though approved of by many, is found, upon examination, to be quite contradictory to fact;—for, let us suppose the water loaded with a quantity of vitriol sufficient to generate 25 grains of vitriolated magnesia, that is, containing 21 grains of martial vitriol in three cubic inches of

distilled water; let this water be put into a bottle of such a size that it will be quite filled by the addition of 10 grains and an half of magnesia, and let the bottle be then closely stopped; let this bottle be shaken from time to time, the magnesia will quickly disappear, and in its place will be found a large quantity of ochre, of a greenish colour, as containing both aerial acid and a considerable portion of phlogiston; and all this takes place without any motion or effervescence: in the space of about an hour the water is found totally void of vitriol, loaded with 25 grains of vitriolated magnesia, saturated with aerial acid, and containing an aerated iron:—the reason of this is evident, $10\frac{1}{2}$ grains of magnesia contain about 3 cubic inches of aerial acid, which an equal bulk of water is able to absorb; no such obstacle therefore occurs in this case, much less in a whole kanne of water, as I have elsewhere mentioned. In the same instant, then, that the vitriolic acid expels the aerial, the water absorbs it. The quantity of vitriol employed contains above $4\frac{1}{2}$ grains of iron slightly calcined; now, 100 cubic inches of aerated water can only take up 3 grains, so that 3 cubic inches of water can scarcely dissolve more than $\frac{9}{100}$. The bottle being opened, the vitriolated magnesia may soon be separated by alcohol; and this is the case in Pyrmont water; the phlogisticated, as well as the common vitriolic acid, separates the aerial acid from magnesia.—All this hypothesis,

hypothesis, therefore, falls to the ground, being void of foundation;—and Pyrmont water, exposed to the air, grows turbid, and loses its virtue, not on account of any transposition of its principles, but on account of the departure of the volatile menstruum.

In the dry way, vitriolic acid with phlogiston, generates sulphur; but whence can so much phlogiston be joined with the vitriolated magnesia in Pyrmont water?—if the separated iron still remains mixed with it, the difficulty is easily removed, as this metal, when slightly calcined, still retains much phlogiston: if, after the removal of the iron, sulphur is produced, the cause of this phænomenon, being obscure, should be examined in the country where the water is produced.

§ XIX. *The Preparation of artificial medicated Waters in Sweden.*

In the year 1770, being attacked by a severe hæmorrhoidal colic, I was obliged to take above eighty bottles of foreign medicated waters. By these the symptoms, which were attended with excruciating pain, were somewhat mitigated; in the mean time I examined the nature and principles of these waters with the greatest attention, as I most earnestly wished to be able to imitate them perfectly; for besides their extreme dearness in this country, in the beginning of spring, when

not only diseases, the foundations of which have been laid during the severity of the winter, prevail very much, but my complaints are also particularly troublesome, these waters cannot be had fresh and good at any price.—I soon reaped the wished-for fruit of my labours, for in the year following I substituted the artificial to the natural waters, and not only used them myself with signal advantage, but gave them to many of my friends with the like success. All that time I used the method above described for impregnating water with fixed air; but, in the year 1773, I learned Dr Priestly's method, which, with a little alteration, I have since continued to practise.—The same year, in a short Treatise on the Aerial Acid, which the Royal Academy of Sciences at Stockholm inserted in their Acts, I mentioned in a cursory way that I had for some time prepared for myself and some of my friends artificial medicated waters, entirely resembling the natural waters, both in flavour and virtue.—The celebrated Baer, who then lived at Paris, took that opportunity of writing to my friend Mr Wargentin, requesting me to describe the method I pursued.—This I complied with, by sending a Treatise on that subject to the Royal Academy of Sciences at Stockholm in 1774, which they inserted in their Acts for the following year.

From the very nature of the thing it must be obvious, that an invention of this kind, however
useful,

useful, cannot possibly be universally pleasing.—Many who are incapable of ascertaining or judging of the truth, will distrust it, not without reason, on account of its novelty;—many contend, that to imitate nature is impossible, without considering, that when the component parts are thoroughly known, the success of the process cannot in any degree depend upon the hand which combines them.—Some who prescribe, and others who sell the foreign waters, condemn the artificial, for obvious reasons; and not a few are urged by motives too trivial to be detailed. Besides, the negligence of inexperienced operators or impure materials, may easily defeat the whole operation. The water itself, if it has any offensive taste, will retain it after the process, and by that means bring the invention into disrepute. Those that are prepared in the very best manner, nay, the natural waters themselves, grow vapid on the addition of a small quantity of mineral alkali, though they still retain useful properties, only the pungency of the aerial acid is in this case repressed.

All these obstacles, however, have not prevented the preparation and successful use of artificial medicated waters, even in the most distant provinces of Sweden; and the use of such waters has prevailed generally, although I only proposed them in cases of necessity, where the natural waters could not be had: and even those who at first

could not patiently hear them mentioned, now make use of them, and highly commend them.

In general they produce the same good effects as the natural waters, and in some instances even seem to excel them: my own health, though not perfectly established, has, from the sole use of them, been restored beyond expectation. Every year, about the middle of winter, the beginning of summer, and in autumn, I use about seven kannes in the space of three weeks, and that in the following manner:—I first drink a few kannes of Seltzer water, I then use the Spa, which, with respect to the uncombined alkali, most nearly resembles the Seltzer, and I always finish with the Pyrmont; I take no more than the third part of a kanne every day, as, by the experience of several years, I have found that a larger quantity is disagreeable to my stomach.

I have also seen, with great pleasure, many other complaints either entirely removed, or at least alleviated, by these means. A circumstance, which afforded me singular pleasure, as I had very anxiously wished to succeed in this experiment:—a boy of seven years old, at Upsal, had for some time been afflicted by a violent gout, which had baffled all remedy; in the year 1775, he used for a month the Seltzer water, prepared for him by his father, according to my instructions, and soon recovered perfect health, which he enjoys to this day.

A young gentleman, a student, about 23 years old, was so afflicted by the gout, that he could not, even by the help of a stick, move from one seat to another: he began the use of the artificial waters, first Seltzer, then Pyrmont, and recovered in the space of one month.

Besides, the intermittent fevers, which for some time past were epidemic in Sweden, were so obstinate, that they refused to yield either to Peruvian bark, or the other usual remedies, but were soon removed by the artificial waters, particularly Seltzer, unless the cure was impeded by errors in diet.

I pass over innumerable other examples, which, indeed, encrease daily, and would require a particular description; but I cannot avoid here mentioning a singular phænomenon:—the hæmorrhoids, with which I am afflicted, break spontaneously, while I am in health, generally every 20th day, but only discharge a few drops; they are, however, often stopped, especially at the approach of cold weather, and then occasion a number of distressing symptoms: to remedy these I find nothing so effectual as drinking the artificial Seltzer water; and in the course of eight years, during which I have been using it, it never failed me once; the effect is, to open the hæmorrhoids within six days, sometimes on the third or fourth, upon which I immediately find relief.—I leave to the skilful in medicine the explanation

of this phænomenon, which I have observed not only in myself, but in many others affected in the same way, to whom I recommended it to pay some attention to this circumstance. Now, as the same effect in this case follows the use of the natural and the artificial Seltzer water, I cannot doubt of their identity, any more than of that of the others.

DIS.

DISSERTATION VII.

OF THE

ARTIFICIAL PREPARATION

OF

HOT MEDICATED WATERS.

§ I. *Different Species of Hot Waters.*

THE benign care of our All-wise Creator has not only provided for man's use cold medicated waters, but many hot medicinal springs are found in various parts of our globe; and as the use of the former is found not to be restricted, but extensive and widely diversified, so in like manner the latter are endowed with a great number of useful properties. Some of these hot waters seem to possess no remarkable virtue with regard to the human body, while others quickly dispel a variety of diseases in a very singular and extraordinary

extraordinary manner. Water does not seem capable of producing any notable effect upon the human body of itself; to this end it appears indispensably necessary that it should be impregnated with a certain subtile and elastic aura, which, when extricated in the primæ viæ, is not only of itself able to effect salutary changes, but also so acuates, strengthens, and as it were vivifies the heterogeneous matters contained in the water, that they can penetrate to parts they otherwise could not reach, and possess powers which alone they could never exert. That the aerial acid performs this office in the cold medicated waters is, I imagine, established beyond doubt in the foregoing Treatise;—it remains now to be examined, whether the same fluid is contained in the hot waters, or whether they are assisted by an elastic fluid of another kind.

When we examine the medicinal hot waters in general, we find a remarkable difference obvious to the senses: for some, such as the Caroline baths in Bohemia, do not strike the smell in any particular manner, and seem not to exhale any thing more than a moist and suffocating vapour; others, such as those of Aix, disperse far and wide a most subtile, ungrateful, fœtid odour, resembling that of putrid eggs, or more exactly that which is emitted by a solution of saline hepar, especially upon the addition of an acid. The former most certainly derive their efficacy from the aerial acid,
and

and are therefore justly called aerated; but the latter are of a very different nature, and may, from their hepatic smell, not improperly be called hepatifated. The nature and properties of both must be accurately examined, if we expect to attain any thing like exactness in the imitation of them. They both contain a principle so volatile that they lose their chief virtue upon barely growing cold; so that by no means yet known can they be transported into foreign countries, still retaining their virtue. This circumstance has prevented me from examining these hot waters myself: but so much as will be sufficient for our present purpose is to be found accurately investigated, and clearly related, by the industry of others.

§ II. *Hot Aerated Waters.*

That the Caroline waters, and others of the same sort, abound with aerial acid, may be inferred from their taste, and the quantity of bubbles which is occasioned by agitating them: but other and more obvious criteria shew this evidently to be the case. This water tinges tincture of turnsole with a fugitive redness, and precipitates lime-water; circumstances which, though singly ambiguous, yet jointly are perfectly valid; —they are ambiguous singly, because it is thought that other acids, besides the aerial, may occasion

occasion a fugitive redness (*a*); and the precipitation of lime-water is also occasioned by an aerated alkali, which is supposed, according to the laws of attraction, to yield its aerial acid to the pure lime, which therefore becomes aerated, and (*b*) precipitates; but when these two circumstances are taken together, they produce full conviction: for the aerated alkali (*c*) cannot exist in water together with any acid, except the aerial; besides, the air contained in these waters, when collected, not only produces the above-mentioned effects, but also suffocates animals, and is absorbed by water, which thence becomes aerated. Indeed, the whole neighbourhood of these waters abounds so much with aerial acid, which breaks out in many places, that the rain and snow-water, from lying in cavities of the ground for a short time, often acquire a grateful pungent acidity.

These waters, upon cooling, separate both lime and iron, after the manner of Pyrmont water, but much more quickly. We cannot wonder at the fugitive nature of the virtues of these waters, when we consider how very volatile the aerial acid is, even when lodged in cold water, and how much its volatility is increased by heat.

The existence of aerated hot waters being esta-

(*a*) On Aerial Acid, § vi.

(*b*) Ibid. § xx. B.

(*c*) Analysis of Waters, § viii. n.

blished, we now go on to the other species, the elastic fluid of which, though easily dissipated, yet in fixity very much exceeds the aerial acid.

§ III. *Hot hepatifated Waters.*

The hot hepatifated waters, although they may be aerated, and actually often are so (as for instance those of Aix) may yet be easily distinguished from the hot aerated waters, by the general tenor of their character, and their disagreeable smell: they have the smell of *hepar sulphuris*, and blacken silver, nay, a genuine sulphur is deposited along the channels through which they pass; and yet the most accurate analysis has not been able hitherto to discover in the water the most minute particle, either of *hepar* or of sulphur—but chymistry is able to unfold this mystery: for the saline *hepar sulphuris*, upon the addition of a more powerful acid, generates a species of air, which we may call hepatic air, if with Dr Priestly we give the name of air to every elastic fluid not condensable by cold. Waters impregnated with this kind of air resemble the hot hepatifated waters: the hepatic air, it is true, contains a sulphur, but so expanded and subtilized as to escape the sight, and put on the appearance of common air. A change such as this can only be effected by the action of agents at once the most subtile and the most efficacious, and such are phlogiston

phlogiston and the matter of heat. I know that many philosophers of the first rank are of opinion, that the phænomena of fire and heat are to be explained upon the supposition of intestine motion in bodies; but, upon considering the whole attentively, I am firmly persuaded, and I believe the same is the case with others, that heat arises from the action of a distinct and peculiar substance, which is distributed through the whole corporeal world, and that in a twofold state: for, first, we consider this matter as free, when, in form of an elastic fluid continually tending to an equilibrium, it pervades all bodies dense as well as rare. This, in proportion to its quantity, excites different degrees of heat in animals, dilates and disposes all bodies to fluidity, according to certain circumstances—thus platina, in order to be fused, requires it very highly concentrated, other metals less so; and mercury a quantity so small that it is almost always present in the atmosphere; I say, almost always, as some late observations in Siberia shew that there mercury has been sometimes congealed by natural cold:—whether there can exist any such state as that of perfect privation of heat, or absolute cold, is yet unknown. In such a state (supposing any such to exist) if I mistake not, the aerial acid itself must be congealed, as fluidity appears to depend totally upon heat.

The matter of heat, like all other material substances, is subjected to the law of attraction, and
hence

hence proceeds its state of union with other bodies, a state which inevitably occasions many alterations in its nature and properties. By this tie some of its properties are obscured, nay entirely obliterated, and new ones, before unknown, are produced; and in the same manner as an acid, when saturated with an alkali, cannot be distinguished either by precipitation, by its taste, or by any other of its original properties, so the matter of heat loses, together with its liberty, its chief property, viz. that of producing sensible heat;—this power must, however, be considered as repressed only, not destroyed; for it is again restored in full vigour, when the bond of union which repressed it is broken. This may very clearly be illustrated by the example of water, which by a moderate privation of heat is converted into ice: now, if water heated to a determinate degree be poured on snow, we can, from the known heat of the two ingredients, easily determine what that of the mixture ought to be; but in the present instance, a deficiency is always observed; that is, the heat of the mixture proves to be always less by about 72° , than by calculation it ought to be. The reason seems to be this:—the heat of the water penetrates the snow quickly, expands and separates the small particles, and changes it from a solid to a fluid form: thus the disunited particles have their surfaces much encreased. Now, water attracts the matter of heat, and that the more
largely

largely in proportion to the surface of contact; and such parts of it as it touches very closely, it powerfully retains, and renders latent, so that it can no longer occasion sensible heat; and hence the deficiency of 72° . This saturating portion of heat it does not lose, except at the very point of congelation; which being then set free, occasions a small rise of the thermometer, although it is quickly and irregularly attracted on account of the deficiency of the surrounding matter. As the degree of cold in the adjoining air increases, and as, on account of its elastic nature, it constantly tends to an equilibrium, it at length is so much rarified, that the saturating portion alone remains to prevent the contact of the watery particles; and when that also is taken away, all the mobility of the particles totally ceases. Undoubtedly all substances which are fusible in fire fix a certain quantity of heat (the degree of which is yet undetermined) in the very instant when their particles acquire the due degree of mobility. On the other hand, while the temperature of the water is increasing, the increased quantity of heat increases the distance of the minute particles, and generates elastic vapours: at length, when the heat arrives to the boiling point, the watery particles are so expanded and changed, that their surfaces, being wonderfully increased, are enabled to receive and fix a far greater quantity of heat than before;—and hence

arises

arises the cold, or diminution of heat, occasioned by evaporation.

Bodies which contain the matter of heat fixed, when put into menstrua fitted for dissolving them, generate a degree of heat, greater or less, according to the quantity of latent heat set at liberty by the more powerful attraction of the menstruum. Lime, newly burned and put into water, generates a remarkable degree of heat, because a great part of the heat which had been fixed by the calcareous earth is set at liberty by means of the water, which is more powerfully attracted by it. That portion of the matter of heat which still remains in flaked lime may be disengaged by an acid; and hence, from an equal quantity of lime a greater degree of heat is generated with acids than with water, as the former set the whole of the matter of heat at liberty, the latter only a part.—I have spoken briefly, and in a cursory way, of these matters, in order to illustrate several things in the foregoing pages, and that what follows may be the better understood. We do not here consider the composition of the matter of heat; it is sufficient for us that it may be fixed, and again set at liberty.

Let us now return to the hepatic air, which consists of sulphur united to the matter of heat by means of phlogiston. As the demonstration of this analysis occurs hereafter, I pass it over in this place. The hepatic air is decomposed in the at-

mosphere by means of pure air, which attracts phlogiston so greedily, that it is able to separate it from the nitrous acid itself: this is the cause of the sulphureous crusts which are to be seen at Aix; for the connecting medium (the phlogiston) being separated above the surface of the water, the whole compound is dissolved, and the disengaged particles of sulphur adhere to the surrounding bodies.

Water combines with this hepatic air, and, when impregnated with it, possesses the genuine properties of hepatifated waters, as readily appears upon comparison. But in order to discover how much of its virtues depend upon this air alone, and how much upon grosser materials, we should examine distilled water saturated with hepatic vapour.—In a moderate heat, a kanne of distilled water takes up about sixty cubic inches of hepatic air, which, when decomposed by nitrous acid, yield eight grains of sulphur: the matter of heat which remains disengaged among the particles of the water, is more and more diminished.

§ 1v. *Distilled Water saturated with hepatic Air.*

In the following section we shall explain how water may be saturated with hepatic air. For the present,

sent, we suppose the water to be cool, and fully saturated.

(A) It has a most offensive hepatic smell, when set in a broad open vessel; in 24 hours it blackens silver; an effect which, as the vapour is dissipated in this case but slowly, it does not produce in less than the space of some weeks, when set to stand in an open bottle. This effect may be instantly repressed by nitrous acid.

The taste is strong, somewhat sweetish, not unlike that of putrid eggs, but more disagreeable.

It preserves its clearness entirely, if the water be newly distilled, so as not to have time to absorb aerial acid from the atmosphere.

(B) Tincture and paper of turnsole grow but little red, unless the water be impregnated with washed hepatic air.

Paper of fernambucum suffers no change.

(C) No change is occasioned by acids, unless such as possess the singular property of attracting phlogiston, even in water; one of these is the nitrous acid highly concentrated.—When this is dropped in, the smell is instantly suppressed, the water grows turbid, and a white subtile powder very slowly subsides: this powder, collected and dried, is found to be pure genuine sulphur. The phlogiston being taken away by the acid, the bond of union between the sulphur and the matter of heat is broken; the hepatic air is therefore decomposed, and the sulphur appears in its ordinary

form. That the nitrous acid attracts phlogiston, even in a liquid, is obvious from the artifice made use of by some to make vitriolic acid, when black, clear again,—they add a small quantity of nitre, which is speedily decomposed, and the colouring phlogiston destroyed by the disengaged nitrous acid.

Upon pouring into the impregnated water a few drops of nitrous acid, the fætor is instantly stopped, but in a few minutes it again returns; and this happens repeatedly; so that a quadrant of water requires 200 drops to destroy completely all its hepatic air. When the water contains also a fixed alkali, the acid has but little effect, so long as that is disengaged; but after it is saturated, the hepatic air begins to be decomposed; the reason is clear:—the alkali seizes the acid as soon as it is dropped in, and represses its activity; hence we easily see how sulphur may be precipitated from the Aix waters, which no one, so far as I know, has hitherto effected.

Acid of vitriol, and the other common acids, have no effect.

Dephlogisticated marine acid precipitates the sulphur.

(D) Alkalis cause no change.

(E) Nitrated silver occasions a congrumation, which soon changes to a brown colour.—In this case the acid and the metallic base seem to be loaded with phlogiston, by which they are both rendered

dered insoluble : there is no doubt but a sulphur also adheres to the metal.—Silver, in its metallic state, grows black in this water.

(F) Nitrated mercury, made without heat, occasions a brown precipitate ; that made with heat, a white one. The difference seems to arise hence, that in the latter case the base is so far dephlogistified, that the phlogiston remaining is insufficient for communicating colour to the precipitate.—Mercury, in its metallic state, exposed to hepatic air, grows black, like silver.

(G) Corrosive sublimate is also precipitated white, for the above-mentioned reason.

(H) Acetated lead is precipitated black.—Vinegar does not promote the decomposition of hepatic air : hence, therefore, appears the action of the metallic base alone ;—yet polished lead, exposed to hepatic air, does not grow black, but only brown. The same is true of iron : copper grows black ; but tin, bismuth, antimony, and zinc, are not changed.

(I) Solution of vitriol of zinc occasions a little turbidness, and yields a white sediment ; that of copper occasions a yellowish brown hue, and slowly deposits a sediment of the same colour ; that of iron grows black :—the hepatic smell is soon dissipated, if the proportion of the liquors be properly adjusted.

(K) A grain of white arsenic put into the water grows yellow by degrees, and at length acquires

the properties of orpiment. The same thing happens to a solution of arsenic in water.

(L) Hepatified water, in which filings of iron have been kept for some days in a well-closed vessel, grows purple with tincture of galls;—if the iron be dissolved by an acid, the colour approaches more to violet. This is the reason why, with the same quantity of tincture of galls, different appearances take place: besides, we must observe, that water impregnated with iron by means of hepatic air, is not at all rendered turbid by phlogisticated alkali; and if a small quantity of vitriol of iron be afterwards added, this produces a sediment at first ash-coloured, the upper surface of which grows by degrees (but very slowly) of a pale blue, and after some days grows quite black. If hepatified martial water grows immediately blue on the addition of phlogisticated alkali, this is a sure sign of the presence of an acid menstruum. These circumstances should be carefully observed in the examination of waters.

§ v. *Method of preparing hot medicated Waters.*

In the preparation of hot medicated waters, several circumstances are to be attended to:—First, the waters must be impregnated with elastic fluid; then the grosser materials, which distinguish the different species, are to be dissolved; and,

and, finally, the water to be heated without any loss of its virtue. — We shall speak of all these in order.

(A) The elastic fluid to be employed is either aerial acid or hepatic air, according as the water is required aerated or hepatifated. The former is obtained by a process already sufficiently described; the latter is had in the same way, with the difference of a few circumstances now to be mentioned.

In the place of chalk, we are to employ an hepar sulphuris, made of equal weights of sulphur and pot-ashes together, and melted in a crucible: the hepar is to be reduced to a powder before it is put into the vessel, as otherwise the saturating acid will generate upon the surface a vitriolated vegetable alkali, which is not soluble in a small quantity of water; and this crust, surrounding the internal parts, will prevent the acid from reaching them.—A mass made of three parts of iron filings melted, with two of sulphur, answers the same end, even better than the former.

An inverted bottle, half-filled with water, is to be set to collect the extricated elastic fluid: the water cannot take up so much of hepatic air as it does of aerial acid;—if the water is to be aerated at the same time, $\frac{1}{8}$ or $\frac{1}{4}$ of chalk may be added to the hepar. When, upon agitating the bottle, the hepatic air is no longer diminished, the water is saturated.

The vapour being extremely offensive, and unfriendly to respiration, the operator should be so situated, that a stream of air may carry off the noxious vapour from him.

(B) If particular waters are to be imitated, for instance, the Caroline or the Aix waters above mentioned, the quantity and quality of their several contents must be determined. The Caroline waters contain, in a kanne,

	grains.
of aerated lime - - -	24
of vitriolated mineral alkali - - -	240
of sea-salt - - -	32
of dried mineral alkali - - -	68

together with an admixture of iron. A kanne of Aix water, taken from the Emperor's bath, contains,

	grains.
of aerated lime, - - -	27
of sea-salt, - - -	29
of mineral alkali, - - -	70

It is only the aerated lime that indicates the presence of aerial acid in the Aix waters.

These heterogeneous matters, except the aerated lime (which ought by all means to be left out) are of very easy solution; they need not therefore be added

added to the water, until it is to be drank: the proper quantities of these may be put into the vessel out of which the water is to be drank, and are soon taken up by the warm fluid.

If any one, however, insists upon the aerated lime, the water must first be saturated with aerial acid, and the lime dissolved by its means, in the cold, as before described; the water is then to be impregnated with hepatic air; and in this case some filings of iron should be added; but if the lime be omitted, the filings put in during the warming of the water will give it a sufficient impregnation.

(c) In order to make the aerated or hepatifated water warm, without loss of virtue, we must employ a vessel closely shut, such as Papin's digester;—the copper ones described by Mr Wilcke are best fitted for this purpose: one of those should be taken, which can just hold the requisite quantity of water: the aerated or hepatifated water being put into this, and well closed up, is to be suspended in a common pot in a water-bath; and the water in the greater vessel, being gradually heated, communicates the requisite degree of heat to the digester.

Although cold aerated water is highly medicinal, as experience evinces; and although the same is unquestionably true of cold hepatifated water (§ VI.); yet it is very probable that heat, by increasing their volatility, renders them more subtile and penetrating,

penetrating, and of consequence more efficacious in certain cases. We are not yet certain what degree of heat is most effectual: the Caroline waters raise the Swedish thermometer to 73° , the Aix waters to 62° ; an heat which appears too great for internal use, as the hand can scarcely bear water heated to 50° : but this question is not to our present purpose, it is sufficient that the water can receive the necessary degree of heat, without loss of virtue.

The saline matters should not be put into the digester, as many of them act upon the metal, but the iron may safely be used; and thus it communicates a chalybeate impregnation.

That a glass may be occasionally filled without the loss of any of the volatile parts, a small stopper must be fitted to the upper part of the digester, by opening which the warm water may be poured out, and yet the mass remain closely shut up.

For the purposes of bathing, larger quantities are necessary; in this intention the Caroline waters (for what reason I know not) are out of use. The waters of Aix are often employed; and a large quantity of water may be easily impregnated with hepatic air, by means of a flexible tube conveying the air to the bottom; and this operation may without inconvenience be continued, even while the patient sits in the bath; but the process should be so conducted as to affect respiration as little as may be.

§ VI. *Appendix, concerning cold hepatifated Waters.*

Cold martial waters, when fresh, almost always have an hepatic smell, especially when a little shaken in a closed bottle, yet in general the impregnation is so slight that it goes off in a few moments; but I have lately learned that the hepatic impregnation, in some instances, is more complete. Mr Alstroemerer sent me 12 kannes of Medway water, requesting me to examine their contents. These acidulous waters are situated at Medway, in Ostro Gothland, and have been celebrated for wonderful cures, from the most remote periods of time: the celebrated U. Hierne discovered them in the year 1677, from which time they have been much frequented every year, and with considerable advantage; yet their true nature and properties are but little known.—The following experiments will tend to throw light upon this subject.

This water, when brought to Upsal, is found to have lost its volatile principles, but Dr P. Dubb examined it at the very fountain, by the means above described:—he obtained from every kanne 13 cubic inches of an elastic fluid, which distinctly reddened tincture of turnsole, and therefore undoubtedly was aerial acid. That it also contains some hepatic air, will clearly appear from what follows;

follows; but these 13 cubic inches, having been collected by means of water, do not indicate the true quantity; and I doubt not but that, if they had been collected by mercury, they would amount to 30 at least.

In the Medway water there cannot be any pure air, as that is inconsistent with a martial solution; but the hepatic air remained in the residuum of $10\frac{1}{2}$ kannes, reduced by evaporation, at the very fount, to nearly 2 quadrants: this appears manifestly, for the bottle in which the liquid residuum was put, when opened, struck the nose with an offensive hepatic odour; and a portion of this liquor, upon the addition of a few drops of concentrated nitrous acid, grew white and turbid, and in 24 hours deposited a very subtile sulphureous powder:—in this case then, we have a cold hepatifated water, which retains that fetid principle so tenaciously, that notwithstanding continued boiling, and the agitation of a long journey, it yet retained a considerable portion of the volatile aura.

In order to discover the fixed principles, I first employed precipitants; but I must observe, that the water sent to me was somewhat yellow, very faintly indeed, yet sensibly so, especially when compared with common water: in the liquid residuum, that colour was more conspicuous, and the residuum itself nearly turbid,

In

In taste and smell it resembled pure water, but the liquid residuum gave slight tokens of iron and of an hepar.

Papers tinged with turnsole or Brazil wood discovered nothing; hence it would appear that there is no prevalence either of acid or alkali.

Phlogisticated alkali caused no change either in the water or in the liquid residuum; and this was the case at the very fountain (§ IV. 1).

Tincture of galls also had no effect on the water, but with the residuum formed a dilute purple colour, which yet was somewhat changed by the yellowish brown of the water itself.

Acid of sugar did not occasion a turbidness in the water, until after the space of 24 hours; but with the residuum immediately formed a saccharated lime.

Aerated fixed alkali does not make the water turbid, but it instantly acts upon the residuum; the precipitate was white, and of a calcareous nature.

Salited terra ponderosa did not precipitate anything, even in the residuum; there is of course no vitriolic acid present.

A small piece of alum was decomposed after some hours, which is no doubt occasioned by a salited lime, mixed with the alum.—Hepatic air does not act at all upon solution of pure alum.

A solution of nitrated silver renders the water somewhat turbid; but in the residuum it occasions

a complete milkiness, tinged lightly brown by the hepatic air;—there is present, therefore, a marine acid.

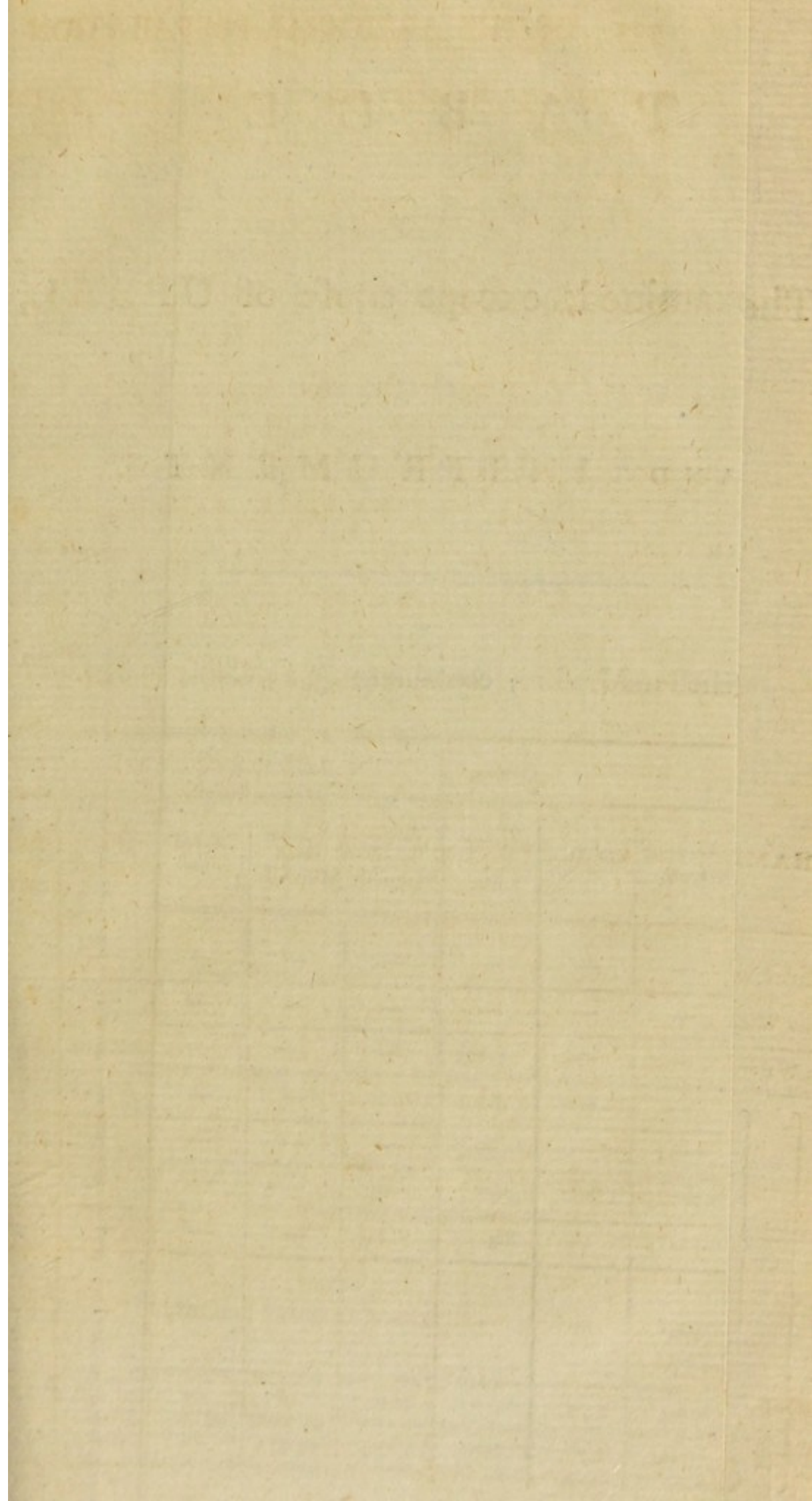
Nitrated mercury, prepared without heat, as also acetated lead, exhibit the very same appearances as nitrated silver.

Corrosive sublimate has no effect.

These experiments detect nothing but a small portion of salited lime, except the admixture of iron, which the tincture of galls shews.

I evaporated half a quadrant of the liquid residuum to dryness, but found only 5 grains of a brown powder, which grew a little moist in the air, yet only a grain or two of it was soluble in water; so that the greatest part of this was a calcined iron. Water poured upon the dry residuum grows brown, an appearance occasioned by a mucilaginous extract; for, evaporating again to dryness, it exhibits a brown matter, which grows white by burning. Since, then, $10\frac{1}{2}$ kannes yielded two quadrants of this liquid residuum, it appears, that we should allow about two grains to each kanne; for the salited lime amounts scarcely to half a grain: I have also observed a few particles of sea-salt.

The dry residuum which, according to Dr Dubb's experiments, is obtained from each kanne by boiling for an hour, weighs 2,75 grains, which seems to be purely martial; and it is to be observed,



S Y N O P T I C A L T A B L E

O F A L L

The SUBSTANCES contained in the several WATERS examined, except those of UPSAL,
REDUCED TO
ENGLISH WEIGHTS, MEASURES, AND INSTRUMENTS.

Substances contained in the Pint, Winchester Measure, containing 35.25 Cubic Inches.

Physical Qualities.				Cubic Inches.			Grains.													
NAMES of the WATERS.				Tempe- rature.	Weight.	Specific Gravity.	Pure Air.	Aerial Acid.	Hepatic Air.	Aerated Lime.	Aerated Magnesia	Aerated Min.Alk.	Aerated Iron.	Sulphur.	Vitrio- lated Lime.	Vitrio- lated Magnesia	Vitrio- lated Min.Alk.	Salited Lime.	Salited Magnesia	Salited Min.Alk.
					Grains.															
Distilled Water, — — —				—	8923.8961	1.0000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Snow Water, — — —				—	8924.7884	1.0001	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sea Water, at the Depth of 60 Fathom,				—	9193.7956	1.0289	—	—	—	—	—	—	—	—	9.801	—	—	—	82.7640	303.3914
Mineral Waters.	Cold.	Aerated.	Seydfchutz, —	—	8977.4393	1.0060	0.4356	0.8712	—	0.9801	2.7225	—	—	—	5.336	187.0991	—	—	4.73714	—
			Seltzer, —	—	8948.9905	1.0027	0.2178	13.068	—	3.38114	6.3251	5.2272	—	—	—	—	—	—	—	13.7491
			Spa, —	—	8932.8199	1.0010	—	9.801	—	1.8513	4.356	1.8513	0.70785	—	—	—	—	—	—	0.2178
			Pymont, —	—	8950.1335	1.0024	—	19.602	—	4.356	9.801	—	0.70785	—	8.3853	5.445	—	—	—	1.5246
		Aerated and Hepatic.	Medway, —	—	—	—	—	6.534	8.712	—	—	—	0.92565	—	—	—	—	0.1089	—	—
	Hot.		Hepatic.	Aix la Chapelle, —	142°	—	—	—	—	13.068	5.9806	—	15.246	—	1.7424	—	—	—	—	—
		Caroline, —		164°	—	—	—	—	—	13.068	5.2272	—	14.8104	—	1.7424	—	—	52.272	—	—

observed, that part of it is magnetical;—this property is, beyond doubt, communicated by the hepatic air.

We conclude, therefore, that a kanne of fresh Medway water contains.

	grains.
of iron, partly dissolved in hepatic air,	
and partly in aerial acid, -	$4\frac{1}{4}$
of falited lime, - - -	$\frac{1}{2}$
	<hr/>
	$4\frac{3}{4}$

	cubic inches.
of aerial acid, nearly -	30
of hepatic air, at least -	40

The sea-salt and mucilaginous extract, are of so little weight, that they may in this computation be neglected.

This water must necessarily be very efficacious: for, 1st, it contains united two principles, one of which gives virtue to the hot, the other to the cold medicated waters: 2d, it contains nothing noxious.—We know that many waters, even the so much celebrated Pyrmont, are loaded with aerated lime and gypsum, substances which are by no means friendly to the human system; and the experience of a whole century abundantly confirms

confirms this opinion of the virtue of the Medway waters, which we have deduced from analysis.

How this water may be imitated, is easily seen from what has been already said.

DISSERTATION VIII.

OF THE

ACID OF SUGAR.

§ I. *Method of obtaining the Acid of Sugar
in a separate State.*

SUGAR being justly considered as an essential salt, it will readily be granted, that it contains an acid;—this acid may be separated, and exhibited in a crystalline form, by the following process:—

(A) Let one ounce of the purest sugar, in powder, be mixed, in a tubulated retort, with three ounces of strong nitrous acid, whose specific gravity is nearly 1, 567.

(B) When the solution is completed, and the most phlogisticated part of the nitrous acid has flown off, let a receiver be luted on, and the so-

lution gently boiled;—in this process an immense quantity of nitrous air is discharged (*a*).

(*c*) When the liquor acquires a dark brown colour, let three ounces more of nitrous acid be poured on, and the boiling continued until the coloured and smoking acid has entirely disappeared.

(*d*) Let the liquor in the receiver be then poured into a larger vessel; and, upon cooling, small quadrilateral prismatic crystals are found adhering together at an angle generally of about 45° : these, collected and dried on bibulous paper, weigh 109 grains.

(*e*) The remaining lixivium, boiled again in the same retorts with two ounces of nitrous acid until the red vapours begin to disappear, upon cooling, as before, affords 43 grains of saline aciculæ.

(*f*) If to the viscid glutinous liquor which remains, there be added, at different times, small quantities of nitrous acid, amounting in all to two ounces; by boiling, and evaporating to dryness, a saline mass is at length formed, brown, glutinous, and deliquescent, which, when perfect-

(*a*) In order to procure this acid, common aqua fortis will serve just as well as the strongest nitrous acid; and any glass, thin enough to bear a moderate heat, will do just as well as a retort. Nothing can be more easy than the process for obtaining the acid of sugar. B.

ly dried, weighs half a drachm; but in depuration nearly half of this weight is lost.

(G) The crystals obtained in the manner above described, are to be depurated by repeated solution and crystallization, an operation which is particularly necessary to the portion got, as described in F. The last lixivium F, digested with nitrous acid, and evaporated to dryness by the sun's heat, exhibits prisms similar to those mentioned in D and E; so that this affords a method of abridging the number of depurations.

(H) To obtain, therefore, one part of this salt, there are required 3 of sugar, and 30 of nitrous acid; so that it may be reckoned among the most expensive salts hitherto known. It must be particularly observed, that a much smaller quantity of crystals will be obtained, if the boiling be continued ever so little beyond the proper time.

(I) The acid thus obtained I call *acid of sugar*; not because it is procurable from that substance only, but because sugar affords it more pure, and in greater quantity, than any other matter hitherto tried. Thus 100 parts of gum arabic, treated as above, with 900 of nitrous acid, at the beginning of the boiling foam violently, and upon cooling, yield scarce more than 21 of saccharine acid, prismatically crystallized; but at the same time the solution, even to the last, separates a saccharated lime (§ VI), which, when collected, weighs 11, and contains about 5 of
U 2 the

the acid of sugar: 8 parts of highly rectified spirit of wine, with 24 of nitrous acid, yield 3 of saccharine acid, but for the most part in a squamous form, and loaded with much moisture; besides, honey, and whatever substance contains sugar, in the same way produces the same acid; and although acid of tartar, dissolved and boiled in nitrous acid, in the same manner, yields a salt somewhat similar to this, both in taste and squamous crystallization, yet it is of a whiter colour; and, besides, is unchangeable in the fire, yielding only a coal as before.

In another Dissertation it will be shewn, that the acid of sugar occurs also in the animal kingdom; and that it, together with a gluten, constitutes the calculi of the kidneys and bladder (*b*).

§ II. *Properties which the Acid of Sugar possesses in common with other Acids.*

This salt possesses many properties, some peculiar to itself, some common to it with the other

(*b*) This has not yet been made to appear; and it is certain that this acid, if it be present at all, is not the only one contained in calculi, for phosphorus has been obtained from them by distillation with inflammable substances. The acid of sugar is present in a vast variety of different animal and vegetable substances; it exists in great quantities in gall-nuts and wool; at least it is obtained from them, when treated with nitrous acid. Mr Morveau conjectures plausibly, that it has for its basis a subtile oil.

acids,

acids, though differing more or less in degree: and these we are now to consider.

(A) The crystals have an exceeding pungent taste;—but a solution of these, when sufficiently diluted, excites a very agreeable sensation on the tongue. Twenty grains communicate a sensible acidity to a kanne of water.

(B) It makes red all the blue vegetable juices, except that of indigo. A single grain, dissolved in four ounces of water, instantly makes red the blue paper used for covering sugar-loaves, which is not affected by the weaker acids; and 12 grains, dissolved in a kanne of water, produce the same effect upon paper tinged with turnsole.

(C) It attacks alkalis, earths, and fundry metals, and dissolves them with effervescence, if they be united with aerial acid. These combinations, which serve to distinguish this evidently from all other acids, will be described in § III.—XXIV.

(D) Distilled water, when boiling, dissolves its own weight of the crystals. In an heat of 15° , it dissolves only half that quantity; and, although the solution appears at first a little turbid, it soon recovers a perfect transparency: the specific gravity of this last solution, when saturated, is 1,0593. The vapours which break forth during the boiling of the former solution do not contain any acid; and the liquor, as it grows gradually cold, deposits a great quantity of crystals, many of which exhibit prisms diverging from a point.

Each of these has four sides obliquely situated, as in the spar; the alternate sides narrower, of which two quadrilateral planes, generally unequal, meet together like a roof, constituting an apex at one or both extremities. Sometimes the prisms occur so short as entirely to resemble the spathaceous cubes, with acute angles, truncated in a parallel direction; so that hence we may easily judge of their primitive form.

Sometimes the prism is rectangular, and the planes of the apex equal: the figure of the apex too is varied by planes rising from the angles of the prisms. If, during the deposition, the vessel be stirred, or if the quantity of dissolved matter be insufficient, the prisms become irregular, and truncated, with five or six sides.

(E) These crystals do not refuse to unite with other acids. Concentrated vitriolic acid, seizing the oily matter, grows brown; and, in the end, totally consumes the crystals, especially on boiling; but when diluted, although it dissolves the crystals readily, yet it yields them up again, but in the form of aciculæ; a change which this acid is wont to induce also upon other salts. The nitrous acid greedily takes up the acid of sugar, and, upon boiling, grows yellow; upon cooling; it again separates crystals, but they are generally irregular. If the solution be often repeated, with the assistance of heat, the saccharine acid is totally destroyed; and at length no crystals appear.

The

The marine acid and vinegar dissolve these crystals very completely, but they yield them again totally unchanged both as to their shape and nature.

(F) 100 parts of spirit of wine, on boiling, take up nearly 56 of this acid; but in a moderate heat not above 40. This solution grows a little turbid, and deposits a mucous sediment, scarcely equal to $\frac{1}{40}$ of the acid; on cooling, squamous crystals are formed; these are irregular, have a fragrant smell, and, on drying, grow white. In order to determine the effect of this acid in forming an ether, two drachms of the crystals, dissolved in as much spirit of wine, (of the specific gravity 0,8581) were boiled over a slow fire in a small retort; as soon as oily striæ began to arise another receiver was luted on, and half a drachm, which was contained in the former receiver, was found to be nothing but the spirit deprived of its superfluous phlegm; that which came over along with the striæ, weighed only a few grains more than the former liquor, this was an acid, and, upon evaporation, yielded a crystallized saccharine acid; upon the addition of lime water, a saccharated lime fell to the bottom, and on the top there floated a thin stratum of ether, holding, in a blue solution, a calx of copper and of gold (the last, probably, alloyed with copper). This liquor, if it may be properly called an ether, differs much from the common ether; for it is not inflammable, except when hot; nor does it burn with a

white, but with a blue flame, only white on the surface; and, finally, the fragrancy of its smell is but weak; perhaps if the experiment was made with a larger quantity, it would succeed better: after the striæ had ceased, there came over a drachm of an acid liquor, which precipitated lime-water, and on evaporation yielded a crystalline acid of sugar; there came over, also, about half a drachm of an heavier oil: the residuum consisted of crystallized saccharine acid, and weighed 29 grains; this residuum, which had but little empyreuma, again treated the same way with two drachms of spirit of wine, yielded a few oily striæ, and a small quantity of oil: the black residuum, which weighed near 12 grains, exhibited brown crystals; and in the fire sent forth a white and pungent smoke.

(G) Vitriolic ether dissolves the crystallized acid of sugar, but with difficulty.

(H) The saccharine acid unites with the oils both essential and expressed, but separates again on proper evaporation: in a more violent heat, also, it separates, by rising above the surface.

(I) In an heat exceeding 15° , the crystals are gradually covered with a white opaque crust; and at length, entirely splitting into a white powder, lose about $\frac{3}{10}$ of their weight; which loss is quickly recovered in a moist air: the crystals, when old, are covered with a loose down, such as appears upon lutes during distillation; but is in no respect different from the saccharine acid itself.

In low close distilling vessels, with a gentle fire,
the

the water of the crystals first comes over (which forms about $\frac{3}{10}$ of the whole) and the acid is fused. When the heat is intense, it soon liquefies, and upon boiling grows brown; a little phlegm comes over into the receiver, an acid powder effloresces upon the luting of the receiver, and a white saline crust sublimes, nay, when the fire is vehement, some of it is forced over into the receiver; but the greater part is destroyed, leaving in the retort a brown or grey matter, equal to nearly $\frac{1}{30}$ of the crystals; this has an empyreumatic smell, makes concentrated vitriolic acid brown, and nitrous acid yellow, but is dissolved in marine acid, without inducing any change of colour. This residuum, exposed to the fire in an open vessel, flies off, leaving nothing in the glass but a white spot. The acid of sugar, when sublimed, easily puts on a crystalline form, and seems to have undergone no change, except that it is rendered extremely pure, being deprived of so much of its oil as it can lose without being itself destroyed. In the receiver is found an acid liquor, which precipitates lime-water, and also exhibits the properties of saccharine acid, but does not easily crystallize: a prodigious quantity of elastic vapour is generated, which, upon separating the vessels, is found to be of an highly pungent and empyreumatic smell;—this vapour, collected during distillation, amounts to nearly 100 cubic inches in every half ounce of the crystals, and consists one half of aerial acid, which

which may easily be separated by lime-water, the other half is inflammable air, and burns with a blue flame (*b*).

Acid of sugar which has been once sublimed, when again subjected to the same operation, sends forth a white smoke; this, collected in a receiver, exhibits, upon cooling, an acid liquor, of a water-green colour, which is not crystallizable: on the sides and neck of the retort, also, some of the acid is found sublimed, and scarcely changed; the residuum is grey.

Upon subliming a third time, the receiver was burst by the elastic vapour: nevertheless a minute portion of an acid liquor was collected, which, upon evaporating to dryness, left a small residuum: the residuum in the retort was hoary. The changes now described are brought about more speedily by means of heat in open vessels: the smoke arising is offensive to the nostrils and the lungs, and the residuum is of a whiter colour; in this case there occur no vestiges of a coal, a

(*b*) M. Morveau observes, that the Abbé Fontana's analysis of this acid is considerably different. He does not estimate the aerial acid at above a third: and the inflammable air seemed to him to be mixed with common air. He affirms, that an ounce of the crystals yielded 432 cubic inches of these elastic fluids, a quantity nearly double to that assigned by Professor Bergman. M. Morveau attributes this difference to the different means which he supposes these two illustrious philosophers employed to convert the acid into elastic fluid. B.

circumstance

circumstance which clearly distinguishes the acid of tartar from that of sugar.

§ III. *Saccharated vegetable Alkali.*

The acid of sugar, exactly saturated with vegetable alkali, does not yield crystals without difficulty—but if either the acid or the alkali be a little predominant, crystals are easily obtained: two parts of alkali, fully aerated, combined with one of saccharine acid, being skilfully evaporated, afford beautiful prisms, nearly of the same form with those of the acid itself: these crystals heighten the blue colour of paper tinged with turnsole; but if boiled in the tincture of turnsole, or in syrup of violets, they change the colour to a red: they dissolve easily in water; but with difficulty in spirit of wine; they undergo spontaneous calcination in heat: the saccharine acid is separated from the crystals by lime, terra ponderosa, or magnesia, when pure; the acids of vitriol, of nitre, of salt, of fluor, of arsenic, and of phosphorus, also induce a change, by attracting the alkaline base.—Acetated and formicated vegetable alkali are decomposed by acid of sugar: but it is fire alone that can perfectly expel the saccharine acid from any base. In discovering lime in any manner, lodged in waters, the saccharated vegetable alkali is preferable to any substance hitherto known, as it attracts lime most powerfully, and is able to disengage.

disengage it from any other acid : it forms, with the lime, a salt, very difficult of solution, which therefore falls to the bottom in the form of a white powder (§ VI.). Although this effect may be produced by the acid alone, yet the double (c) affinity accelerates the operation, at least never impedes it.

§ IV. *Saccharated mineral Alkali.*

Two parts of newly crystallized mineral alkali, combined with one of saccharine acid, form a salt very difficult of solution, which is partly separated during the operation, but what remains after evaporation yields crystalline grains : these crystals dissolve perfectly in warm water, but not in spirit of wine ; they do not change the tincture of turnsole, but make syrup of violets green : the same earths, and the same acids, decompose this and the former salt ; and, besides, the mineral alkali is expelled by the vegetable.

§ V. *Saccharated volatile Alkali.*

One part of saccharine acid takes up six of pure volatile alkali (distilled from one of sal ammoniac, four of quick lime, and three of water). This combination being slowly evaporated, yields qua-

(c) See Treatise on Elective Attractions.

drangular prisms, generally diverging from a number of points. These crystals not only redden tincture of turnsole, but also syrup of violets; they split in heat, losing about $\frac{1}{6}$ of their weight: this loss takes place in the saccharated volatile alkali more slowly than in the acid of sugar itself: water readily dissolves these crystals; spirit of wine does not: upon distillation, they yield first a concrete volatile alkali, then somewhat of a saccharated volatile alkali.—The coally residuum indicates a decomposition, and consequently the disengagement of aerial acid, and the cause of the concretion of the volatile alkali;—this union is decomposed by fixed alkalis, and by the earths and acids which decompose the former, (§ III, and IV.).

§ VI. *Saccharated Lime.*

82 parts of saccharine acid take up 100 of pel-
lucid calcareous spar, but not immediately, be-
cause the surface, when saturated with the acid,
prevents the access of the acid to the internal nu-
cleus. Nitrated lime is completely precipitated
by acid of sugar in the form of a white powder,
not soluble in water; of 119 parts by weight of
this powder, 72 fall to the bottom, and 47 appear
upon evaporation: hence it appears, that 100
parts contain, of acid 48, of pure lime 46, and
of water 6; so that not only the presence of lime
in

in water is discovered by acid of sugar, but even its quantity may, without difficulty, be ascertained.

The saccharine acid attracts lime with such force, that it separates it from every other : this combination, therefore, cannot be decomposed by any acid, alkali, or earth, hitherto known, and can only be decomposed by fire (*e*).

Hence also we understand the necessity of lime-water in the purification of sugar. For the juice of the cane contains a superabundance of acid, which prevents the dry concretion ; and even if to pure sugar dissolved in water be added the saccharine acid, it will not form crystalline grains. Now, nothing more powerfully attracts this acid than lime ; and when united with it, it is insoluble, and either falls to the bottom, or floats in the scum : lime-water, therefore, affords the most complete means of effecting the crystallization, as it removes the impediment, and, besides, may easily be added in any proportion, without communicating

(*e*) This test, however, is not so perfect as *terra ponderosa* for detecting vitriolic acid. Bergman himself (*Obs. on Calculus*) has pointed out one case in which it fails ; and there are certainly others in which it acts more slowly than could be wished, as on strong solutions of lime in acids ; and others, again, in which its action is prevented by causes that have not accurately been assigned. I have frequently found it capricious ; for so my ignorance obliges me to express myself.

any heterogeneous matter. Many persons have thought that a portion of the lime remains mixed with the sugar; but if the purification be properly conducted, the nature of the ingredients, the circumstances of the operation, and, finally, the most accurate analysis, abundantly shew, that there is not the smallest trace of lime remaining:—good sugar dissolves totally in distilled water; which could not possibly be the case if there was present any lime, either crude or united with the saccharine acid, as either of these substances, whether alone or mixed with sugar, is utterly insoluble in water. The vegetable alkali does indeed absorb the acid of sugar, but forms with it a salt not very difficult of solution, (§ III.); and, besides, a caustic lixivium, if used in too great quantity, will dissolve a portion of the sugar. In saccharated lime, the earthy basis predominates; for, when boiled with syrup of violets, it strikes a green colour (*f*).

§ VII.

(*f*) “Physicians are sometimes heard to say, that the use of sugar may be hurtful, on account of the lime used in refining it. But such must belong to the class, unhappily too numerous, whom interest prompts to contend, that chymistry is of no service in the practice of medicine.

“We have here also a striking proof of the influence of chymistry in the improvement of the arts. The author’s discovery cannot fail to illustrate the process for refining sugars: it had been suspected that the lime attracted some unctuous substance, or an acid. But this was mere conjecture;

§ VII. *Saccharated Terra Ponderosa.*

Acid of sugar, saturated with terra ponderosa, quickly deposits pellucid angular crystals, scarcely soluble in water; boiled in distilled water, they split, and yield an opaque powder; but on cooling, the small portion which is dissolved again concretes into crystals, containing a superabundant acid; for this combination never crystallizes, unless the acid be predominant. Now, the hot water takes the superabundant acid from the greatest part, and therefore renders it insoluble, no more acid remaining than what is necessary to saturation;—they scarcely dissolve in spirit of wine;—they yield their menstruum to lime. Saccharated terra ponderosa, put into a lixivium of pure vegetable alkali, is covered with an opaque crust, and at length falls into a powder: the alkali is found united with the superabundant acid.

jecture; and it will be easy (now the object to be accomplished, and the manner of action of the matters employed, are known) to improve the mode of proceeding. The lime, I should suppose, serves to separate not only the superabundant acid furnished from the cane, but that also which is developed by the action of fire, or by an incipient spontaneous fermentation of the essential salt: for, independently of the loss in coarse sugars, that which has been long kept in a damp place has been observed to turn yellow and viscid (*gras*); infomuch that it became necessary to refine it again.”—Morveau.

§ VIII. *Saccharated Magnesia.*

The acid of sugar dissolves magnesia, and forms a middle salt, in the form of a white powder, which is not soluble either in water or spirit of wine, unless the acid be superabundant. 100 parts of this salt contain 35 of pure magnesia, and of acid and water about 65: the fluor acid is the only one which decomposes this salt; it is also decomposed by lime and terra ponderosa: pure magnesia separates the saccharine acid from alkaline salts.

§ IX. *Saccharated Clay.*

42 parts of earth of alum, well washed, are dissolved by digestion in 53 of acid of sugar. This solution, on evaporation, does not produce crystals, but a yellowish pellucid mass, of a sweet yet astringent taste. This, when dry, deliquesces in a moist air, and gains $\frac{2}{3}$ of its weight: it reddens tincture of turnsole, but not syrup of violets; it dissolves sparingly in spirit of wine; in the fire it swells, the acid flies off, and leaves behind a brown earth.—100 parts contain about 44 of earth, and 56 of acid and water. The vitriolic, nitrous, and marine acids, the alkaline salts, terra ponderosa, lime, and magnesia, all decompose saccharated clay. Iron also is attacked by a solution of this salt; and

the iron separates, united with the saccharine acid, (§ XVI.).

Alum is not decomposed by acid of sugar ; neither does nitrated or salited clay yield their base to it.

§ X. *Saccharated Gold.*

The acid of sugar does not act upon gold while in solution ; yet if it be precipitated by a fixed alkali, and well washed, this acid blackens, but scarcely dissolves it.

§ XI. *Saccharated Platina.*

Platina is not dissolved, unless precipitated by an alkali. Now, the vegetable alkali partly unites with the dissolved platina, forming a salt very difficult of solution ; which therefore, upon the addition of the alkali, falls to the bottom like a precipitate, although in reality it contains aqua regia, or at least marine acid ; therefore, to avoid confusion, I make use of platina precipitated by a mineral alkali, and well washed. I know some expert chymists assert, that this noble metal does not yield to mineral alkali ; but the contrary is easily shewn.—Of this we have treated elsewhere at large ; therefore we return to the solution made by acid of sugar : this is yellow, and yields yellow crystals.

§ XII. *Saccharated Silver.*

Acid of sugar dissolves silver precipitated by a fixed alkali but sparingly, and does not attack the metal itself. This combination is most conveniently obtained from a saturated solution of silver in nitrous acid. The silver, upon the addition of acid of sugar, precipitates in the form of a white powder, which, when washed, does not change even the tincture of turnsole; scarcely dissolves in water, much less in spirit of wine; yet is soluble in nitrous acid, and grows black by the rays of the sun. Acid of sugar also decomposes vitriol of silver, but not saluted silver, so far as I have hitherto been able to determine with certainty.

§ XIII. *Saccharated Mercury.*

Mercury, like the former metals, is not acted upon by acid of sugar, unless it be partly deprived of its phlogiston; but in that state it is dissolved, forming a powdery white salt, which is not soluble in water, unless the acid predominates, and grows black when exposed to the sun. The same salt may be had from mercury dissolved in nitrous or marine acid, by the addition of acid of sugar, which immediately occasions a precipitation. Corrosive sublimate, by this method,

yields a fine powder, but slowly, and in very small quantity, which does not grow black in the light.

§ XIV. *Saccharated Lead.*

Lead, digested with acid of sugar, is corroded, but scarcely dissolved, unless it be calcined, especially by precipitation with an alkali. This solution, when approaching to saturation, is made turbid by saline grains, which separate and fall to the bottom. The same happens upon adding acid of sugar to solution of lead, in nitrous acid, marine acid, or vinegar: these crystals contain about 55 parts of lead in 100; they do not dissolve in spirit of wine, and scarcely in water, unless it be sharpened by an acid. A solution of vitriolated lead is not precipitated by the saccharine acid.

§ XV. *Saccharated Copper.*

Acid of sugar attacks copper, even in its metallic state; but with greater ease if it has been dissolved and precipitated by an alkali. Both solutions form a powder of a dilute blue colour, which, unless the acid predominates, is scarcely soluble in water: 21 parts of copper require 29 of acid. Copper is precipitated by saccharine acid, from its solution in vitriolic, nitrous, or marine acid. The colour of a solution of this salt is

a mixture of blue and green, the copper deposits upon zinc or iron. The acid of sugar decomposes acetated copper so completely, that the concentrated vinegar may be separately collected, only a little adulterated with copper.

§ XVI. *Saccharated Iron.*

The acid of sugar attacks iron with an effervescence, which is occasioned by the extrication of phlogiston (*g*). The solution has an astringent sweetness; and, when made without heat, exhibits prismatic crystals of a greenish yellow colour, easily soluble in water, possessing a superabundance of acid, and yet splitting in heat. In 100 parts there are 55 of acid, and 45 of iron. The acid being expelled by fire, there remains a ferruginous mass marked with greenish squa-

(*g*) “ I do not believe that the separation alone of phlogiston can occasion a sensible effervescence. This phenomenon takes place in the solution of metals, in proportion to the decomposition of the acid, at least a partial decomposition; whence an elastic fluid is produced, which unites with phlogiston, and becomes inflammable air.” Morveau. — Mr Kirwan would explain this appearance by saying, that the acid, in dissolving the metal, gives out fire to the phlogiston, which enables it to assume an aerial form; and if it should at last be proved, that inflammable air is one of the states of phlogiston, this must be accepted as the true theory. B.

mulæ on the surface, but the nucleus verges to a brown

Calx of iron is also dissolved; but on digesting both it and the foregoing solution, they yield nothing but a yellow powder, such as is precipitated from green vitriol by acid of sugar, and is also had in the preparation of the saccharine acid, when the nitrous acid employed abounds with iron. This powder is almost insoluble in water, but on boiling separates an ochre.

§ XVII. *Saccharated Tin.*

Tin, by the assistance of heat, is blackened by the acid of sugar, and at length covered by an hoary powder: the solution emits elastic vapours, possesses an austere taste, and exhibits prismatic crystals; but when quickly evaporated to dryness, nothing remains but a corneous mass, which being dissolved, on the addition of an alkali yields a copious precipitate. The calx of tin is also easily dissolved, and both the combinations make tincture of turnsole red.

§ XVIII. *Saccharated Bismuth.*

The regulus of bismuth is somewhat corroded by acid of sugar; but the calx only is dissolved.—This salt is powdery and white, and scarce soluble in water: the metal constitutes one half of its weight.

If to a solution of nitrated bismuth be added the saccharine acid, in the space of an hour polygonal transparent grains concrete at the bottom of the vessel, which have the same properties as the above-mentioned powder, nor do they occasion opacity in water, like the crystals of nitrated bismuth.

§ XIX. *Saccharated Nickel.*

The regulus of nickel, digested in acid of sugar, is covered with a greenish white crust, and at length all splits into a powder of the same colour; the green calx also assumes the same colour, even without heat.—This combination contains twice as much acid as metal. The saccharine acid precipitates a powder of the same kind from nickel dissolved in vitriolic, nitrous, or marine acids: this salt is dissolved in water in small quantity, and assumes a yellow colour, scarce tinged with green; and the crystals are of the same colour.

§ XX. *Saccharated Arsenic.*

Arsenic in a reguline state is scarcely dissolved by digestion, but white arsenic is easily taken up without heat; on evaporation it exhibits prismatic crystals, which, melting with a gentle heat, emit the superabundant acid, and shoot into elegant ramifications; these easily dissolve in water, and

in spirit of wine make tincture of turnsole red; are sublimed by a gentle fire, but destroyed by a stronger; the saccharine acid first flying off, and then the white arsenic, with a smell of garlick.

§ XXI. *Saccharated Cobalt.*

Acid of sugar attacks cobalt, either with or without heat, and converts it into a powder of a dilute rose-colour. The solution is more yellow, and exhibits crystals of the like colour, abounding in acid, and therefore easily soluble; but the rose-coloured powder, which does not change turnsole, is scarcely soluble in water. The acid of sugar, in a moderate heat, takes up more than an equal weight of precipitated cobalt: on the addition of common salt this solution yields a sympathetic ink.

The saccharine acid separates cobalt from all acids yet known, and forms the above-mentioned powder.

§ XXII. *Saccharated Zinc.*

Regulus of zinc effervesces violently with saccharine acid, and is soon covered with a white powder: this, in 100, contains 75 of metal, and is not soluble in water, unless when the acid predominates: the calx yields a similar powder, and on the addition of acid of sugar to solutions of zinc, in vitriolic, nitrous, or marine acids, a similar powder is obtained.

§ XXIII. *Saccharated Antimony.*

Regulus of antimony grows black in digestion with saccharine acid, but the calx and the glass are dissolved, though slowly.—The solution, in which the acid is always predominant, exhibits crystalline grains, which are scarcely soluble in water. The acid of sugar precipitates similar grains from acetated glass of antimony, but not from the butter; yet it takes antimony from the vitriolic acid.

§ XXIV. *Saccharated Manganese.*

Magnesia nigra effervesces with acid of sugar, even without heat; but the saturated solution deposits a white powder scarcely soluble in water, unless the acid be superabundant. This salt grows black in the fire, but again, upon the affusion of acid, is turned to a milky powder, such as is precipitated (mixed with some crystalline grains) upon the addition of saccharine acid, from the solutions of manganese in vitriolic, nitrous, or marine acids.

§ XXV. *Elective Attractions of Acid of Sugar.*

From the preceding experiments it appears, that the elective attractions of acid of sugar are as follow,

follow, viz. Lime claims the first place (§ VI.); terra ponderosa the second (VII.); then magnesia (VIII.); vegetable alkali (III.); mineral alkali (IV.); volatile alkali (V.); and lastly, clay (IX.). With regard to other acids, the saccharine acid yields alkalis to vitriolic, nitrous, and marine acids, arsenical acid, acid of fluor, and phosphoric acids (III.); it yields lime to none (VI.); terra ponderosa, to vitriolic acid (VII.); magnesia, to the fluor acid (VIII.); clay, to vitriolic, nitrous, and marine acids (IX.); silver (XII.) and antimony (XXIII.) to marine acid; lead (XIV.) and perhaps tin (XVII.) to the vitriolic; but mercury (XIII.), copper (XV.), iron (XVI.), bismuth (XVIII.), nickel (XIX.), cobalt (XXI.), zinc (XXII.), and manganese (XXIV.), to none, so far as is yet known. As to the metals, though they are set down by all in the table of simple elective attractions, their forces being determined by precipitation; yet, properly speaking, they do not belong to that place, as these precipitations are in fact performed by means of a double elective attraction.—If, however, any one wishes to keep them in that place, he may take it for granted that they preserve nearly the same order, whatever menstruum they are dissolved in.

§ XXVI. *Whether Saccharine Acid owes its Origin to the nitrous.*

Hitherto we have considered the properties of the acid of sugar; it now remains to say something of its origin: and here a question first occurs, whether it be truly and perfectly inherent in the sugar, or whether it be generated during the boiling, by the adventitious nitrous acid? I do not deny but that, at first sight, the nitrous acid appears to contribute something to the generation of this acid, as all attempts to generate it without the assistance of that acid have hitherto failed. I once thought, that the nitrous acid, being very greedy of phlogiston, is by that means able, during the process, to spoil the saponaceous mass of sugar so far of its inflammable principle that it can at length give out its saline principle alone; yet I never could accomplish this end, either by distillation of sugar, or detonation with nitre; by digestion or decoction with vitriolic or dephlogisticated marine acid; nor finally by manganese: however, although the experiments hitherto tried have proved fruitless, we are not authorised to conclude that there is no possible means of extracting the acid of sugar without the help of nitrous acid; at least, it cannot be proved by any probable, much less conclusive argument, that nitrous acid enters into the composition of the acid of sugar.

sugar.—Sugar is either spontaneously or artificially separated from certain vegetable juices, and is therefore considered as an essential salt: now all such salts, as we know, possess acids peculiar to themselves; it will therefore hardly be denied that the same is the case with respect to sugar, though we were ignorant of any other proofs. In common sugar, the superabundant acid is carried off in such a manner during the preparation, as to escape the notice of our senses: nevertheless those conversant in chymistry can entertain no doubt concerning that which remains (*h*).

We conclude then that an acid does exist in sugar: it remains to enquire, whether this be altered by the nitrous acid.

If we examine the operation with all due attention, we shall find that nitrous acid has suffered no other change than the following: it grows red, being loaded with phlogiston, it becomes more volatile and more weak, and a part of it assumes the nature and properties of that elastic fluid now distinguished by the name of nitrous air: again, nothing more is required than that the essential acid entangled in the oily part be set at liberty, and this is obtained in an highly active state, (§ 1. G), although still loaded with so great a quantity of phlogiston as to exhibit crystals, while other acids, being deprived of that principle, are

(*h*) The acid of refined sugar is developed so as to make a sensible impression on the teeth. Morveau,

always

always fluid; and this solid state is competent to saccharine acid, even when further deprived of phlogiston (§ III. 1.) (i).

If we consider the nature of the acid of sugar, we shall find that it does not resemble the nitrous

(i) If it be in general true, that the concrete state of the acids is owing to phlogiston alone, neither the sedative nor the phosphoric acid, in a glassy state, nor that of arsenic, can be free from it; yet the two last form with it solid sulphur, as well as the vitriolic; and the solidity is probably owing to the same combination. On the other hand, a fluid form is essential to marine acid not dephlogisticated; vinegar, though loaded with unctuous matter, cannot be obtained concrete; nitrous acid is changed by phlogiston into gas, and the volatile vitriolic acid preserves its fluidity. It appears indeed, that these last-mentioned combinations are modified by air, which causes the difference between sulphur and the sulphureous acid;—but these observations ought not the less to guard us against generalizing the principle. The analogy observed by the author may be very just, when considered with respect to some particular phenomena; and it is very possible that the fluid vitriolic acid may harbour as much phlogiston as crystals of the saccharine acid before calcination: the more or less destructibility of a compound does not always indicate the proportion of the constituent parts: lastly, the fluidity of acid is a real state of fusion, like that of mercury; this idea, which I had not considered (l. c.) but with respect to its connection with the general system of the properties of bodies, is confirmed by the fine experiments of the Duke d'Ayen, on the congelation of the vitriolic acid in a temperature 15 degrees below the freezing point [2° or 3° below 0 of Fahrenheit's scale.]

Morveau.

acid

acid in any other instance than those properties which are common to all acids: besides, it expels the nitrous acid from lime, terra ponderosa, magnesia, and metals (§ xxv.); yielding to the other acids nothing but alkalis (§ III.). While the nitrous acid produces salts, either deliquescent or easily soluble, acid of sugar yields such as are scarcely soluble in water (§ VI. VIII. XII. XV. XVI. XIX. XXI.). Alkalis, when nitrated, detonate with ignited phlogiston; but, when saccharated, shew not the least signs of deflagration, which they evidently do upon the addition of the smallest particle of nitrous acid. The nitrous acid corrodes tin and antimony, but scarcely dissolves them, while acid of sugar readily acts upon them: phlogisticated nitrous acid, united with vegetable fixed alkali, deliquesces, does not form crystals, and is readily expelled by vinegar, or even by acid of sugar, still more loaded with phlogiston: all which circumstances by no means take place with respect to the fixed vegetable alkali united with acid of sugar. Many other dissimilarities will occur upon comparison, so that these acids are of a nature not only unlike, but in many instances diametrically opposite. If any will attribute all the difference to phlogiston, I will not deny, that that subtle principle forms a wonderful source of difference; but the differences which take place here can by no means be attributed to this when properly examined. The nitrous acid
is

is weakened, and made far more volatile, by union with the phlogiston; the acid of sugar much more fixed, even when loaded with so great a quantity as to be crystallizable;—it almost everywhere expels the strongest nitrous acid, as experiments shew; besides, the phlogisticated nitrous acid produces, with the very same matters, compounds totally different from those with acid of sugar. Nothing can be judged from circumstances which are unknown, forged, or at best possible—and among all the facts yet known, concerning the acid of sugar, we can find no signs of its being derived from the nitrous acid.

However, let us enquire more deeply; let us principally consult nature, not indifferently and slightly, supplying the deficiencies with fiction, but candidly and properly, by apt and accurate experiments, otherwise her answers, like those of the oracles of old, will be either delusive or ambiguous.

But, by whatever means the acid of sugar is produced, it must be considered as distinct and different from all others, being always essentially and specifically the same. Its singular properties, some of which are of considerable use in chymistry, shew that it deserves the most particular attention: from the time of Stahl, many considered the nitrous and marine acids as generated from the vitriolic; but if all confiding in this theory (which yet is contradicted by daily observation) had

had neglected the examination of those acids, considering them as subordinate and derivative, we should be to this day ignorant of many singular facts, which by degrees were discovered, principally because many considered these acids as distinct and separate substances (*k*).

DIS-

(*k*) To the history of the Acid of Sugar, accident, and the enquiries of later chymists, enable me to make addition.—Professor Murray, of Gottingen, has affirmed, that Mr Schrikel has obtained it by repeated distillations and congelation, without using any nitrous acid. M. Morveau, from whom I learn this, adds nothing further concerning the process. Was it in this case procured by distilling sugar with the black calx of manganese, or the calx of lead, substances which attract the inflammable principle with considerable force? yet the author failed, as he did also in attempting to dephlogisticate the saccharine acid by means of the dephlogisticated muriatic acid. The experiments, however, mentioned by Professor Murray, furnish an irrefragable argument of the essential difference between the nitrous acid, and that of sugar. Though the author's reasoning, by every unprejudiced person, will be thought to prove this abundantly, there are some chymists of note, and teachers of chymistry, who maintain, that the saccharine acid is nothing but nitrous sulphur.

“The Abbe Fontana has obtained an acid perfectly like that of sugar, and saccharine substances, from all the gums and resins.” (Journ. Phys. tom. xii. p. 182. and tom. xiii. p. 23.). Morveau.

I have heard that it has been procured from oils; but the most interesting discovery of this sort was made by the celebrated Mr Watt of Birmingham:—he was, I understand

derstand, making some experiments relative to ink, when he observed a number of bodies floating in the fluid, which had the shape of crystals of the saccharine acid, and upon examination were found to be really such: he found, by adding nitrous acid to galls, and conducting the process in the way recommended by Professor Bergman, that these astringent bodies contain the acid of sugar in greater abundance than the substance from which it derives its name.—I cannot be certain that these circumstances took place exactly as I describe them, but I have reason to suppose that this account is near the truth. B. The acid yielded by an infusion of galls, or by distilling them, according to a late discovery of Scheel's, is probably only a modification of the saccharine acid.

As to what is said concerning acid of sugar, procured by distillation and congelation, Dr Murray, or Mr Moreau, must have mistaken the matter, Mr Schrickel did obtain an acid, by distillation, but very different from Bergman's, as may be seen in a paper of Crell's, among Mr Scheel's Essays. To obtain acid of sugar, without vital air, or nitrous acid, would be a fact of great importance in the present state of chemical theory.

DISSERTATION IX.

OF THE

PREPARATION OF ALUM.

§ 1. *Various Uses of Alum.*

NATURE produces but a very small quantity of native alum; and this is mixed with heterogeneous matters, or effloresces in various forms upon ores during calcination; but rarely occurs crystallized. In this latter state it is reported to be found in Egypt, Sardinia, Spain, Bohemia, and other places; I have sometimes seen it generated in the aluminous schist of Lapland and West Gothland, by a spontaneous decomposition of the ore; besides, it is found dissolved in the aerial waters: it is found, but very rarely, in fountains, and in hot medicated waters. —After having considered the various uses of this salt,

salt, we shall examine at what time it first began to be artificially prepared.

In the dispensatories, alum enters many preparations, liquors, collyria, gargles, plaisters, boluses, pills, powders, and others: by its mild acidity it coagulates milk; and it, besides, possesses a remarkable astringent power.

In the arts also, and the œconomy of private life, the use of this salt is very frequent; it is added to tallow to make candles hard. The printers cushions are rubbed with burnt alum that the ink may stick; and for the same reason the instruments used for printing linen. Wood sufficiently soaked in alum does not easily take fire: the same is true of paper impregnated with it; which, for that reason, is very proper to keep gun-powder, as it also excludes the moisture of the air. Paper impregnated with alum is useful in whitening silver and silvering brass without heat; it is useful, added to milk, which does not easily separate its butter; in the conglutinating of several substances; in making the pyrophorus; in tanning; and many other manufactures.

In the art of dying it is particularly useful, in the preparation of the matters to be dyed; for by cleansing and opening the pores upon the surface by a gentle corrosion, it both renders the substance fit for receiving the colouring particles (by which the alum is generally decomposed) and at the same time makes the colour fixed.

It constitutes the basis of crayons, which generally consist of the earth of alum, finely powdered and tinged for the purpose. This it is which, in the preparation of Prussian blue, prevents the basis of the martial vitriol, which is soluble in acids, from being precipitated by the superfluous alkali; that is, the alkali not saturated with the colouring matter. As this basis adheres more strongly to the vitriolic acid than the clay does; and as, by the mixture of its yellowness, it would form a green, the very white earth of alum also, according to its quantity, dilutes the darker colours, even black itself, and produces infinite degrees of intensity. It is unnecessary to say more of its useful qualities.

§ 11. *Brief History of the Preparation of Alum.*

The *στυπτηρία* of the Greek, and the *alumen* of the Romans, was a native substance, and differed much from the salt which now goes by those names. The varieties of alum mentioned by Dioscorides refer to stalactites, which contained very little, if any, alum; and that completely enveloped by a vitriolic matter. The descriptions of Pliny are still more difficult to be understood, as he had not seen the substances, the description of which he undertakes, but merely transcribed from the writings of others.

The factitious salt, which is now called alum,
was

was first discovered in the eastern countries ; but when, where, and by what means, is unknown. On account of its similitude in astringency, and its use in the arts of tanning and dying, the new salt has retained the old name, which was afterwards called *misy. fory. calcanthum*, or shoe-maker's black.

Among the most early works established for the preparation of alum, we may justly number that of Roccho, a city of Syria, now called Edeffa ;—hence the appellation of Roch alum, a name which is generally so ill understood, that many to this day imagine that it is the same as rock-alum. In the neighbourhood of Constantinople there were many alum-works, as also at Phocæa Nova, now called Foya Nova, not far distant from Smyrna. The Italians hired and made use of many of these ; but about the middle of the 15th century, they introduced the art into their own country, and that with the greater earnestness, as the use of the salt became more frequent, and occasioned the drawing large sums of money out of the country.

Bartholomew Perdix, or Pernix, a merchant of Genoa, who had often been at Rocha, discovered the matrix of alum in the island of Ischia, about the year 1459, and established a manufactory there ; at the same time John de Castro, who had visited the manufactories at Constantinople, discovered a matrix at Tolfa, by means of the *ilex aquifolium*, which he had also observed to grow in

the adjacent mountains of Turkey; and his opinion was confirmed by the taste of the stones. The attempts made by the Genoese at Viterbium and at Volaterre, succeeded extremely well: the preparation of it in Italy soon increased wonderfully fast; and the industry of the natives was much stimulated by an edict of Pope Pius II. prohibiting the use of oriental alum, and appropriating the revenue arising from that made in Italy to carrying on the war against the Turks.

But the art was not confined to Italy: in the 16th century a manufactory was established at Alcamaron in Spain, in the neighbourhood of Carthagera, which still subsists.

There were many manufactories in Germany in 1544, of which that at Schwemsel in Misnia still remains. Long since, in the time of Agricola, alum was boiled at Commotau in Bohemia.

The first manufactory in England was established in the reign of Elizabeth, at Gisborough, by one Thomas Chaloner.

The art of preparing alum made its way into Sweden very late; and although we have now no less than seven manufactories, not one of them was founded before the 17th century.

The most ancient, established in Scania at Andrarus in 1637, had twenty-two single, or twelve double boilers. (We shall see hereafter what is meant by double and single boilers). In this place the stratum of aluminous schist is very deep, being

ing upwards of 360 feet; but all the boilers are not used every year. In the year 1765, 2,735 ton of alum were manufactured; in 1766, 3,099; in 1767, 2,423; and in 1768, 1,427.—A ton of alum weighs 344 lb.

At Lofver, near Calmaria, in Smoland, another manufactory was built in the year 1721; there were employed in this, besides one boiler for purification, only four double boilers, although the patent allowed five; much inconvenience being occasioned by bringing the mineral from Ocland, and by the scarcity of wood. In 1765, there were made 1,020 ton; in 1766, 926; and in 1767, 800;—the average for ten years was 1,000 ton.

In West Gothland there are four; the first at Mulltorp, near the town of Schæfde; this has only two single boilers, and the ore is in the neighbourhood. In 1765 there were made 90 ton; in 1766 no more than 71.

At about half a mile's distance from Oltorp, in the district of Dimbo, a patent was granted in 1726, for three single boilers; in 1765 were made 157 ton; in 1766, 300.

A third at Kasvelas obtained, in 1748, a patent for two single boilers; to which, in 1765, were added two more;—the ore is distant a quarter of a mile. This produced, in 1765, 312 ton; and in 1766, 293.

A fourth at Hænsfæter in Kinekulle, obtained a

right of two single boilers in 1766;—the ore is found in the neighbourhood.

The greatest manufactory was established at Garphyttan, in Nericia, in the year 1766, with a privilege of ten single boilers, which was increased to thirty in 1769. Here, while the matrix is burned, the boiling is performed by means of a peculiar construction of the furnaces; and whether we consider this manufactory with respect to the greatness of the works, the convenience of the apparatus, or the goodness of the alum (which even excels the Roman), we must acknowledge that it is beyond comparison superior to them all.

The district of Ljung, in Ostro Gothland, has had for many years a privilege of boiling alum; but the work has not yet been set on foot.

Every thirtieth ton goes to the royal revenue.

A single boiler is $5\frac{1}{2}$ feet in breadth, 11 in length, and in depth at the front 3, at the rear $2\frac{1}{2}$, and contains 1,663 kannes, and 6 quadrants. The double boiler is of the same depth and length, but is ten feet broad, and contains 3,025 kannes.

§ III. *Proximate Principles of Pure Alum.*

(A) Alum is an imperfect middle salt, consisting of vitriolic acid and pure clay; it takes up a considerable quantity of water in crystallization; and, if the process be not interrupted, yields octaedral

taedral crystals, which are transparent and colourless as water.

(B) The acid is a little superabundant, so as to redden the tincture, and even the paper of turnsole. This excess of the acid is essential; for, upon taking it away, all the taste, all the solubility, and all the original properties of the salt, are lost (*a*).

The proportion of the principles is ascertained in the following manner:—the water is expelled by a gentle heat; the remaining mass grows opaque,

(*a*) M. Morveau will not admit a superabundance of acid in alum: he thinks it would be necessarily separated by edulcoration and crystallization, when it is no longer held by its affinity with the earthy base, or the salt itself, when it is formed. He thinks, that the change of blue vegetable juices to red is not an unequivocal proof of the presence of an uncombined acid, an opinion which Mr Kirwan has also adopted. In the present case it should be remembered, that we have certain proof that a portion of vitriolic acid adheres to the clay less tenaciously than the remainder. If a piece of iron be put into a solution of this earthy salt, it will attract this portion of acid, and the vitriolated clay will fall down insoluble. Now we may presume, that this loosely adhering acid produces the change on blue vegetable juices;—the same thing is true of phosphorated calcareous earth. A solution of this salt will yield the superabundant acid to a base which attracts it with far less power, and then the middle salt will be precipitated insoluble; so that, in both these cases, a quantity of acid above that which is required to attain the precise point of saturation, is necessary to solution and crystallization. B.

swells,

swells, foams, and at length remains quiet, spongy, and friable. The quantity of earthy basis may be determined by precipitation with fixed or volatile alkali. In this way, 100 parts of crystallized alum are found to contain 38 of vitriolic acid, 18 of clay, and 44 of water: let it be observed, however, that the earthy precipitate is not totally deprived of its acid; for when the alkali is added, the superabundant acid is first taken up, and thus a great part precipitates, its acid being diminished, but not quite abstracted; and hence the precipitate, by the assistance of fire, partly decomposes several salts; and long continued digestion in an alkaline lixivium, is necessary to separate all the acid.

(c) Chymists have differed in opinion concerning the nature and proper name of the earth of alum. Messrs Geoffroy and Hellot first extracted it from common clay; Dr Pott did the same, but seems to consider it rather as a production than a separation: at length the celebrated Margraaf, by experiments which deserve well to be attended to, demonstrated that all clay upon the surface of the earth consisted invariably of two principles mechanically mixed, one of which forms the genuine earth of alum, which is perfectly different from calcareous, gypseous, or metallic earths, and from magnesia. I am not certain whether this may be derived from the calcareous earth: to determine this point I have made a great number of experiments

ments of different sorts, but have not thence been able even to form a conjecture. Vague similitudes in certain properties are never sufficient to determine a person who earnestly seeks for truth, and is not shackled by hypothesis.—Since then the earth of alum is found to possess different properties from other earths, it ought to be distinguished from them; and, supposing it in reality derived from the calcareous or any other known earth, yet it requires the addition or abstraction of some other principle; for the bare change of magnitude or figure in the particles will never account for so great a difference; and therefore the primitive and derivative earths (supposing them to be so) must be considered as distinct and separate.

Besides, as an equal quantity of the earth of alum may be extracted from a given common clay, by means of different acids, it must be only mixed with these clays; for if it was generated by the menstrua during the operation, it would no doubt vary both in quantity and quality, according to the differences of the menstrua: but the most accurate experiments prove the contrary, as they always procure the earth of alum the same in quantity and quality, and the very same residuum; and synthesis, in this case, produces full conviction: for if the earth of alum, and a due proportion of siliceous earth finely powdered, be added together, they regenerate common clay.

It may be asked, why the base of alum is considered as a pure clay?—The answer is, That earth which is called clay is chiefly distinguished by its tenacious and plastic quality when moistened, by its cracking when dried, and finally by its acquiring a flinty hardness in the fire. Now, as these specific properties do not depend upon the filiceous particles, (which are not capable of being either softened or hardened), but solely upon the earth of alum, it appears most evident, that the filiceous particles might be absent, and the argillaceous nature remain; and that therefore the residuum is that which constitutes the argillaceous nature. Pure clay, it is true, may occur in the bowels of the earth, but very rarely free from all filiceous particles; and the variety in the proportion of this latter shew plainly, that its presence is only accidental: for the pure clay is very subtilely divided, and very readily mixes with and adheres to heterogeneous matters, as will readily appear upon examination; yet it is remarkable for the intensity of its properties. Thus common clay often contains $\frac{1}{2}$, or even $\frac{3}{4}$ and upwards, of filiceous matter; yet the small portion of pure clay which is present is able to impress its own character, and communicate its own qualities, to the whole mass, so completely that no one can doubt of its argillaceous nature. By common consent, that earth which, by mechanical washing, without the addition of an acid, deposits upwards

of 70 lb. in 100 of filiceous matter, is called clay. Now, it is evident that this foreign substance, by the largeness of its quantity, must temper the qualities of the pure clay. The argillaceous earth contracts by heat very much, even to half its bulk: hence, if it be used for cieling or plaistering, it necessarily cracks, and separates from the walls, when a sufficient degree of heat takes place; nor can it adhere to them, unless when fused, an operation which pure clay cannot be made to undergo, even in the focus of a concave mirror; but the addition of filiceous earth restrains the propensity to contraction in the whole mass, so that it remains of due dimension; and this property is well known to builders, who constantly avail themselves of it (*b*). He who attempts to make well depurated earth of alum fusible, by mixing it with

(*b*) “Clay so much burned as to strike fire produces the same effect as flint; which proves, either that flint serves like any other matter not capable of contracting, or that by burning clay approaches the nature of flint: it certainly undergoes a considerable change in the fire, as it loses the property of being diffusible in water. Such facts, known only by means of manufactures, afford very little insight into nature, till chymistry has examined them carefully.” Morveau.—That clay does not change its nature by being burned, appears evidently from an experiment with which M. de Morveau was seemingly unacquainted:—if hardened clay, such as cannot be treated with water, be dissolved in vitriolic acid, and then precipitated, it regains its former properties, and may be diluted by water. B.

common

common clay, either confounds the clays with others, containing not a particle of clay, or has never made the experiment.—The same is true of other pretended qualities :—alum swells, pure clay does not—the earth of alum, deprived of all its acid, and the precipitating alkali adhering to it, does not fuse with calcareous earth, without the addition of a flinty matter, as the celebrated Macquer has shown ; but we must take care that the calcareous earth contains no flinty matter, which sometimes happens ; for in this case the experiment will fail, because the smallest particle of flint communicates a degree of fusibility to the two ingredients.

(D) 100 parts of crystallized alum requires, in a mean heat, 1,412 of distilled water to dissolve them, but of boiling water only 75 ; so that a kanne of water, in a moderate heat, takes up 2,992 grains of alum, and by a boiling heat 56,333.—This solution has a sweetish astringent taste.

The specific gravity of alum, computed from the increase of bulk, or of distilled water into which it is put, is 2,071, if the air-bubbles produced during the solution be removed ; but if they are taken into the computation, 1,757. This air is not taken away by the air-pump ; but if heat be applied during the solution, it flies off, and upon examination is found to contain nothing but aerial acid.

§ IV. *Aluminous Ores.*

The ores from which alum is artificially prepared are of two kinds; the one contains the alum already formed, the other its proximate principles, which unite on roasting. These must be considered separately;—and we shall first examine the latter species, as being best known, and most frequently met with.

(A) The aluminous schist is nothing more than an argillaceous schist impregnated with a dried petroleum, and thereby rendered black. The oil is easily extracted by distillation: if, by means of menstrua, we analyse it entirely, many ingredients appear; namely, an argillaceous martial substance, often amounting to $\frac{3}{4}$; a siliceous, forming $\frac{1}{6}$; and generally also a small portion of calcareous earth and magnesia; the rest is all pyritous.

During the roasting, the bituminous part is expelled, and the pyritous decomposed; so that a part of the acid adheres to the iron, and the rest to the pure clay: hence are produced at once alum and green vitriol; and if there be present any calcareous earth, or magnesia, they are vitriolated.

Nothing saline is extracted by water from the schist before the roasting, though it be well powdered; nor can the taste discover any vestiges of

a saline matter : hence also it appears to be generated during the operation ; and for that purpose nothing seems to be necessary but the presence of a pyrites ; this sometimes shews visible nuclei of different sizes, but is generally dispersed through the whole mass, in the form of very minute particles : the goodness, therefore, of the ore, is to be estimated by the suitable quantity and equal distribution of the pyrites.

That which contains the pyrites so copiously that it is visible, is rejected, there being too much iron in it—in the mean time, the most dense and ponderous is most esteemed ; the weight manifestly discovering a pyrites, without which no alum is obtained. In this point there generally occurs a considerable difference, which arises, doubtless, from the unequal distribution of the pyrites : hence a stratum adjoining to one of the best kind, is often of little or no value. The ore which produces less than 4 lb. in 100 does not, with us, pay the expence of the process.

Sometimes this ore produces salts without the application of fire ; but we must observe, that in this case it is never found, but has undergone more or less of a spontaneous calcination.

A small piece exposed to fire upon a coal with a blow-pipe, often decrepitates ; but when once made thoroughly hot, it smokes, with a bituminous smell, and easily melts :—with mineral alkali it effervesces violently, and is divided, but not entirely
ly

ly dissolved: it is taken up (though slowly) by the microcosmic salt; but more quickly by borax: these phænomena are easily explained from its composition.

This ore is sometimes found naturally divided, and heaped together, under the forms of grains, or of coarse powder; but it agrees with the former in nature and properties.

(B) The other species of ore, which not only contains the proximate principles, but contains them united, is only found in volcanic countries; such is that which is employed at Tolfa, near Cincelles, for boiling that species of alum which is called Roman alum;—it is probable that this had been long hardened by the subterraneous fire, and penetrated and whitened by the vapour of the phlogisticated vitriolic acid (c): a stony mass, with veins of quartz, and extremely hard, is also found in that country; that which is void of flavour very rarely produces alum upon elixation.

It sometimes, though rarely, contains calcareous particles. I have several pieces, weighing in the whole at least half a pound, in which there is not the slightest trace of any thing calcareous;—upon burning, it does not exhibit the least resemblance to lime; for it neither generates heat with water, nor falls into a powder, but only

(c) De Productio Ignis subterranei.

cracks so much as to assist the efflorescence and ex-
 lixation.

When examined by the blow-pipe, it does not
 flow of itself; with the mineral alkali, at first it
 shews a momentary effervescence, but is not divi-
 ded, much less dissolved; with borax and microcos-
 mic salt, it effervesces, and is at length all taken
 up, exactly in the same manner as burned alum.
 These phænomena abundantly shew, that the alum
 is ready formed, but enveloped in a large quan-
 tity of clay. This mineral, therefore, reduced
 to a subtile powder, and treated in the usual way
 with vitriolic acid, is almost all converted into
 alum, which could not be the case with calca-
 reous earth.—I found that the small portion which
 remains is more frequently siliceous than gyp-
 seous (*d*).

At Solfatara, near Naples, the old lava is at
 present whitened by the phlogisticated vitriolic a-
 cid, the clay is changed into alum, the mass efflo-
 resces, and is resolved into a white earth, from
 which a saline matter is extracted by water. I
 examined 100 of the white earth, and found in it

(*d*) “According to Mr Monnet, it does not contain
 alum perfectly formed; but is a combination of nearly e-
 qual parts of clay and sulphur, which is reduced to alum
 during calcination, by exposure to air. He likewise found
 a little martial earth, to which he ascribes the reddish co-
 lour of the alum, and a little vegetable alkali.” (*Journal*
Physique, Supplement, p. 338.) Morveau.

8 lb.

8 lb. of perfect alum, besides 4 of pure clay, and the residue was siliceous: but this proportion must be variable, as rain dissolves and carries off the salt; so that the proportion of siliceous matter continually encreases, and perhaps in some parts the alum is entirely washed away.

(c) There are found also other varieties of aluminous ores. In Hassia and Bohemia, this salt is obtained from wood impregnated with bitumen. At Helsingborg, in Scania, a turf is found, consisting of the roots of vegetables, mixed with nuts, straw, and leaves, often covered with a thin pyritous cuticle, which, when elixated, yields alum; nay, the sulphureous pyrites is generally mixed with an argillaceous matter, which may be separated by menstrua. To that at Dylta, in Nericia, when sulphur is first obtained by distillation from the pyrites, and afterwards from the residuum exposed to the air, till it effloresces, a green vitriol is elixated; at length, from the magistral lixivium alum may be obtained: for the vitriol being separated by crystallization, there remains alum, together with vitriol so much dephlogisticated, that it cannot concreate; the base of this, therefore, was separated by the alkaline lixivium; and the solution, properly evaporated, yielded alum.

§ v. *The Preparation of Alum includes a Number of Operations.*

After the foregoing observations, we shall be able the more easily to understand the different circumstances necessary for the preparation of alum. The mechanical parts of the process I pass over, as not immediately belonging to our subject. The first chymical operation which occurs is one of the chief; namely, the preparation by which the matrix is either made aluminous, or at least fit for elixation: the next is, the extraction of the alum by water, then the crystallization, and finally the depuration; unless all the operations be performed both with skill and accuracy, the alum obtained will be deficient either in quantity or quality: we shall therefore examine them all separately, and, by diving as far as possible into the nature of them, discover the circumstances necessary to be attended to.

§ VI. *The Calcination and Roasting of the Ore.*

The bituminous ore, in its found and natural state, contains indeed the vitriolic acid, and the argillaceous matter, but not yet combined. In order that the pyrites may yield its acid for that end, it is necessary that it should be destroyed;
and

and this may be effected, either by a slow spontaneous calcination, or by roasting; which last requires less time.

(A) The destruction of the pyrites its necessary, that its sulphur may be deprived of phlogiston; for when that is dissipated, the vitriolic acid being set at liberty, attacks partly the iron, partly the clay: the vitriol generated is so far deprived of its phlogiston by age, that clay is able to take away the menstruum from the iron (x. B), but pyrites suffers no such change, so long as it remains dry, and shut up from the access of free air;—the conditions then necessary to spontaneous calcination are easily found to be the following:

1st, The ore ought to be of a loose texture, that it may be penetrated by the air, and the moisture: the Swedish ores, on account of their hardness, can scarcely be treated in this way, unless they be first pulverized, which occasions too much trouble: but the earthy ores are not only unfit for this purpose, but for roasting, as they extinguish the fire.

2dly, That there be a determinate access of moisture and air, for too much or too little is injurious;—too much water deluges the mass, and excludes the air; too little, besides being insufficient in quantity, acts more slowly; and upon these circumstances depends the proper adjustment of the size of the heaps: a moderate access of air is most proper, as too great a one dries too

fast ; experience only can determine what is fitting upon different occasions.

3dly, The bottom on which the ore is laid for spontaneous calcination should be of clay, or at least so compact as that water can hardly penetrate it, and besides surrounded with a trench to receive the rain-water, when superabundant ; the sides and bottom of this trench must be so constructed that they will not suffer the elixated saline matters to pass off ; —if the ore be set to calcine in a house, the last caution is unnecessary. As the nature of the ores, and local circumstances, are liable to much variation, general rules cannot be established, but the operator must be determined *pro re natâ* ; and in this, whoever understands the nature of the materials, and of the operation, will find no difficulty.

(B) The roasting is effected in a much shorter time, by means of fire. This is generally practised in Sweden, and is performed in the following manner : —small pieces of the black schist are strewed upon a layer of burning sticks, to the thickness of half a foot ; when the sticks are consumed these are covered, nearly to the same thickness, with pieces before burned, and four times elixated : thus strata are alternately laid of such a thickness, and at such intervals of time, that the fire may continue, and the whole mass grow hot and smoke, but not break out into flame ; the upper strata may sometimes be increased to a double

double thickness, on account of the long continuance of the fire;—when about 8 strata are laid, another row is placed parallel and contiguous to the first; when this is finished, a third; and so on, until the heap is of a proper size—it rarely consists of more than 10 rows. The ore, when only once roasted, contains still so much phlogiston, that water acts but little upon it; but when two or three times exposed to the fire, it yields its principles more freely;—nay, the roasting may be repeated to advantage, until the whole is reduced to powder. The bitumen sustains the fire, and it is for this reason that we use alternate layers of the crude schist; and for the same reason, in rainy weather, the strata of unburned schist should be thicker. An heap 20 feet broad at the base, 2 feet at the top, and consisting of 26 rows, is finished in two or three weeks, but requires two or three months to be well burned, and three weeks to cool;—the greater pyritous nuclei explode like bombs.

By a moderate and somewhat smothered fire, the sulphur of the pyrites is slowly consumed, and the phlogisticated acid, penetrating the mass, is fixed; after which the remaining phlogiston is gradually dissipated. The chief artifice is moderating the heat so as to avoid with safety the two extremes; namely, lest, on the one hand, the ore be either insufficiently or too slowly prepared by a weak heat; and on the other, lest either the ne-

cessary acid be dissipated by too intense a fire, or the pieces of schist melt and vitrify. The scoriæ cannot be penetrated by water, and are therefore rejected as useless; these are occasioned either by violent winds, or a strong heat, too much closed; for holes must be opened in the red strata, that the fire may reach to the black stratum which is to be laid on.

At Garphyttan a new method is employed, depending upon a peculiar construction of the furnaces, invented by the celebrated Rinman. — There the ore itself is set on fire, and when burned is boiled, and yields alum in the same manner as when burned in the usual way: I have not yet had an opportunity of comparing the salts produced by these two methods; — it appears probable that more of the acid is dissipated by the open flame: however, although less salt be obtained in the last way, yet, with respect to fuel and labour, there will be a considerable saving. — The heaps are thus formed: — first the schist, burning from the furnace, is laid to the depth of four feet; if the fire be slow, wood is added; then a thin stratum of elixated schist; the third consists of schist not burned; and the fourth of elixated schist, a foot and a half thick; after that the burning schist; and so on as before.

It must be confessed, that the conveniencies in this process are somewhat balanced by inconveniencies; for so great a quantity of schist is requisite

site to sustain the flame, that it cannot all be elixated: hence, so long as this method is employed, we have an heap, which can never be used, perpetually accumulating.

In some foreign manufactories fire is first employed, and afterwards spontaneous calcination: it is impossible to determine generally which is the best method, as that entirely depends upon the nature of the ore, and other circumstances.

(c) As to the hard ores which contain no bitumen (such as those of Tolfa) these are burned upon wood for some hours, like lime-stones, until by cracking they grow pervious to water, and effloresce. As soon as the flame grows white, and the smell of phlogisticated vitriolic acid appears, the fire is extinguished. When the ore grows cold those particles which were nearest to the fire are placed outermost, and those which had been outermost, within; and the fire is again lighted. It is better to burn too little than too much, lest the vitriolic acid be expelled: the ore is sufficiently burned when it can be broken by the hands.—The ore is then heaped up near certain trenches, and is watered about five times a day, and particularly when the sun shines clear; a continued rain and cloudy sky ruin the operation. When the ore can be reduced to a paste in the hand, it is fit for boiling (a).

The

(a) The accounts differ. Mazeas says, that water is poured on the burnt ore 14 days (*Scav. Etrang. t. v.*)

Fougeroux,

The powdery ore sometimes requires no preparation, yet at the manufactories of Puteoli they frequently enrich it in this manner:—they heap up the larger pieces, where the vapours of phlogisticated vitriolic acid break forth, and when well penetrated with this, they yield a larger quantity of alum.

§ VII. *Elixation of the Ore.*

(A) The ore, enriched with alum, and made pervious to water, is boiled, and that in various ways at different places.—At Puteoli it is performed in the most commodious manner: a leaden cauldron, buried in the ground, is filled with the ore (which is often dug out to make room for the cauldron) and water being poured on, it soon becomes well impregnated with alum by the heat of the sun, which here arises to 46° (b). At Tolfa the calcined ore is thrown into the cauldron, and boiled.

(B) In ours, and many foreign manufactories, a cold elixation is performed. I shall give some account of the method which was used at Gar-

Fougeroux, whom I have generally followed, says 40 (*Mem. Paris*, 1766); Angersten, 14, and at most 20. So also with respect to the time of burning, Ferber says it is 3 hours, Fougeroux 12; and he mentions that it is repeated. Ferber speaks of urine and chalk being added, &c. Perhaps the process was different at different times.

(b) Nollet *Mem. Paris*, 1750.

phyttan,

phyttan, in the year 1772:—the receptacles destined for this purpose were made of hewn stone, and the joints closed by some fit cement (in other places they are wooden vessels); every set consisted of four square receptacles disposed in a square, round a fifth, which was deeper than the rest; the first receptacle is filled with roasted schist, and (water being poured on it) lies for 24 hours; the water is then drawn off by a pipe into the fifth, from thence into the second, containing schist not yet washed; from that, in like manner, after 24 hours, through the fifth into the third, and so into the fourth; the lixivium then is conveyed to and let to stand in the fifth; and finally, from thence is drawn off into a vessel appropriated to its reception:—thus the schist is washed with fresh water four successive times.

In other places (and originally at Garphyttan) the water first passes over the schist that has been already washed three times for six hours, then that which has been twice washed, next what has been once washed, and lastly, the ore that has been just roasted. The persons who superintend these manufactories think that the alum, which the water first passing over the new burnt schist takes up, perishes if it be again poured on that previously elixated.—This phænomenon, if it be true, is worthy of attention; but I have not had an opportunity of examining it.

(c) Care should be taken to save fuel as much as possible; it is therefore of great moment to have the lixivium, before boiling, richly impregnated with alum; for the more rich it is when poured into the boiler, the sooner it is crystallized: it should not therefore be put into the boilers until saturated when cold. This saturation is neglected in some places, where every thing is transacted without deviating from the manner first used; in other places the taste is employed as a criterion; but those who examine more accurately, make use of a balance in this manner:—the weight of water which fills a small glass bottle is divided into 64 parts, each of which is called a *panning*; and the quantity by which the same bottle, full of lixivium, exceeds it when filled with water, is supposed to indicate the quantity of salt dissolved: and thence they form their judgment (c).

This method, properly corrected, is sufficiently accurate.—The division into parts is arbitrary; but the most commodious division with respect to the weights in use, and the calculation, ought to be chosen: I shall therefore give some general formulæ:—let the capacity of the bottle expressed in cubic inches be m ; n the number of parts into which it is thought proper to divide it: let a cubic inch of distilled water weigh 422,5 grains; then

(c) Act. Stockholm, 1743.

the

the weight of one panning will $= 422,5 \frac{m}{n}$; that of the whole capacity filled with water $422,5 m$; that of alum of the same bulk as a panning $= 874,9 \frac{m}{n}$: when the lixivium which fills the bottle is $= 422,5 m + 422,5 \frac{m}{n}$, it is then immediately concluded that the quantity with which the water is loaded is $= 422,5 \frac{m}{n}$; but erroneously, for recent experiments shew, that salts dissolved always (*d*) increase in bulk; and if this be always done in the same proportion, and the whole increment be set down aluminous, $422,5 \frac{m}{n} + 452,4 \frac{m}{n} = 874,9 \frac{m}{n}$, will express the true quantity dissolved. And in general if *p* denotes the number of pannings found in the scales, the alum contained in the bottle will be $874,9 \frac{mp}{n}$, and in the kanne $87,490 \frac{p}{n}$.

But to return to the common practice:—the persons who superintend the works contend, that the cold lixivium ought to be made no richer than when the superpondium is equal 45 pannings, which, according to our computation, shews the water to be loaded with $\frac{1}{5,7}$ of its own weight. They assert, that if the superpondium amounts to 6 pannings, which is $\frac{1}{4,8}$, the crystals are deposited. These propositions cannot hold equally good during the whole time that the work is going on, as

(*d*) R. Watfon. Phil. Transf. 1770.

the temperature of the atmosphere varies much during that time. We shewed before that distilled water, in a moderate heat, takes up about $\frac{1}{14}$ of its own weight, which, upon computation $= 2\frac{1}{2}$ pannings, therefore $\frac{1}{5.7}$ cannot be taken up, unless in a heat more than moderate. But we must observe, that in the bituminous minerals, besides the alum, there is always vitriol of iron, which is more soluble; there is also sometimes vitriolated magnesia; and besides, the more subtile earthy particles, mixed mechanically during the operation, remain long suspended, unless the lixivium be filtered.

The water is generally impregnated by a sufficient quantity of the prepared ore: it seems probable that more would be obtained by hot than by cold water; but this is denied by those who daily attend these operations (*e*).

(D) From what has been said it appears that the gradual operation, as it is called, can hardly be used to advantage in the alum works, as, of all the contents of the lixivium, alum is the most difficult of solution.

Congelation is here of no use; for water saturated with alum freezes almost as readily as simple water: and all other salts prevent congelation more than alum.

(*e*) M. Morveau wonders that an aerometer is not employed, in order to determine the concentration of the ley. B.

In rainy weather the lixivium ought to be well covered; but I do not find in any manufactory provision made for this accident.

§ VIII. *Decoction of the Lixivium to Crystallization.*

Let us now suppose the first spring boiling beginning: the fresh lixivium, of a proper strength, is brought from the pits, through canals made for the purpose, to the house destined for the boiling; there it is put into a leaden boiler; at the back of this is placed a receptacle, out of which the loss sustained by evaporation is continually supplied; so that by this artifice the surface of the lixivium in the boiler neither rises nor falls, but continues at the same height.

Some take the floating of a newly laid egg as a token of boiling being finished.—The specific gravity of such an egg is about 1,081; but in a few days, especially in warm weather, it suffers a considerable change:—but supposing its specific gravity constant, yet a considerable difference will occur, unless the magnitude of the part above the water be ascertained.

Others drop a small quantity on a plate, and observe whether it crystallizes on cooling.

Finally, others weigh the lixivium in the bottle above mentioned, and consider the boiling finished, if the increment of weight be equal to 20 pannings;

pannings; that is (according to our computation) if the water be loaded with $\frac{1}{169}$ its own weight. Now we saw that it could take up above $\frac{1}{3}$ its own weight (§ II.) that is, nearly equal to 27 pannings; but the lixivium cannot be so much loaded, as it must be depurated by standing quiet, before any crystals form (*f*).

The lixivium, sufficiently concentrated by evaporation, flows through channels into coolers,

(*f*) Nothing would be more advantageous for judging with precision concerning the degree of boiling which the leys have undergone, than the aerometer. This instrument should be made of metal, that it might be less liable to be broken; it should have sufficient ballast, that it might sink into the liquor, and stand upright; and after having once marked upon the stem the degree at which it stands in a ley sufficiently concentrated, it might be hit again with certainty, and the slightest inspection would be sufficient. I contrived such an one six or seven years ago for a sugar refinery; a process in which the degree of boiling is still more important. This was determined before by putting a drop of the liquor upon the nail, and drawing it out into a filament, to expose it more completely to the contact of the air; inasmuch that the moisture, heat, and agitation of the atmosphere, besides other accidental circumstances, concurred to render this sign very equivocal. The conductor of the work assured me, that this instrument had been very useful to him; and I know that it was afterwards introduced into other refineries. M. Baumé had before advised the use of it, in order to judge of the inspissation of syrups (*El. de Pharmacie*, p. 555.). Morveau.

where

where, in about an hour, it is freed, by deposition, from the grosser heterogeneous particles; it is then put into either stone or wooden receptacles. In eight or ten days the lixivium, commonly called magistral water, flows into another vessel, leaving behind a number of crystals, generally small and impure, which incrust the bottom and sides of the vessel. These are collected, and washed from the impurities which adhere externally, with cold water: the impurities remaining in the reservoir after washing, are kept by themselves.

(B) The washed crystals are put into the boiler used for depuration, and are dissolved in a quantity of water so small that it may, when boiling, be able to take up all the salt, and be sufficiently loaded with it: the lixivium is then poured out into a great tub, which holds the same quantity as the boiler does. After 16 or 18 days the hoops of the tub are loosed, and the aluminous mass is bound with an iron ring: after 28 days the residuum of the solution is let out through a hole, and collected in a trench; the aluminous mass, then dried, is called depurated alum, and amounts, at Garphyttan, to 26 tons.

(c) Let us now look to the boiler emptied for the first crystallization. This is directly filled two thirds with the magistral lixivium, which is brought to the boiling point; and as soon as it arrives at that, the empty third is loaded with the crude lixivium, with which also the waste of evaporation is continually supplied. The boiling being finish-

ed, a certain quantity of aluminous impurities is added, after the solution of which, by continual agitation, the lixivium is let out as before. The first boiling in the spring, is performed with the crude lixivium alone; the rest in the way above described.

As to the time required for crystallization, it may without doubt be shortened, especially when the surface is small with respect to the mass, as is the case in our manufactories; for the reservoirs used in the first crystallization are deep and very narrow at the top, and the same is the case to this day in the second crystallization. The heat of the mass, therefore, being reduced to the temperature of the surrounding atmosphere, the evaporation, and of consequence the deposition, is very slow, except when the weather is exceeding warm, and besides the doors and windows so disposed that a current of air continually runs along the surface. The case is quite different in small experiments, especially in conical glasses, where the surface is very large with respect to the mass. In Italy conical reservoirs are used, and indeed with the greatest propriety.

(D) In order to obtain the alum more pure at the second crystallization, in some places additions are employed, such as alkalis, lime, or urine; for the experience of many years has shewn, that the lixivium sometimes acquires such a consistence, that it both crystallizes with difficulty, and produces impure crystals: pot-ashes, particularly, were
used

used to prevent this inconvenience, because the acid is superabundant. Pot-ashes and lime, either burnt or crude, absorb the acid; and, if added in proper proportion, diminish the quantity of heterogeneous noxious matter, by precipitating them: this will appear clearly, from considering the nature of the lixivium; but urine has no effect, except in so far as it contains volatile alkali. It is not to be denied, that new salts are in this case mixed; namely, vitriolated vegetable alkali, or others, according to the nature of the additament; these are undoubtedly more harmless than those which are taken away, but yet are not to be sold for alum.

(E) The Roman alum has been considered as the best sort: at Brunswick some time since they began to manufacture a species of alum, which, if we give credit to report, may properly be substituted for the Roman. I have examined this alum chymically, and found it mixed with cobalt (f). I have no doubt but the ore of cobalt roasted, is mixed with the lixivium; for in that case the disengaged acid attacks the metallic calx, and forms a rose-coloured solution, which gives a tinge to the crystals. This alum, dissolved in water, yields, upon adding a fixed alkali, an urinous salt; with phlogisticated alkali, discovers iron, but not cobalt; which last is manifested by the violet colour, on fusing the precipitated base with borax: — it is

(f) I see that Erxleben has observed this in his Essays.

distinguished from the Roman alum by its crystals, which are all tinged, acerb, and less acid than the Roman. A crystal of Roman alum exposed to heat by the blow-pipe, soon grows opaque, swells, and foams, but a spongy, immoveable, white mass soon appears; whereas the Brunswick swells less, hardly foams, but melts, and at last grows green; besides, from the very beginning, it sends forth copiously an arsenical smoke.

I do not deny that I have sometimes got a green glass from the rose-coloured base of alum, which would indicate the presence of cobalt, if it always happened; but after once finding it, I have tried 100 times again to no purpose: what this colouring principle is, is still doubtful; but we know for certain that the goodness of the alum does not depend upon it.—I have not yet had an opportunity of examining the use of Brunswick alum in dying (*g*).

(*F*) At Tolfa the lixivium, agitated in a vessel,

(*g*) I have already mentioned Mr Monnet's conjecture concerning the cause of the reddish colour of Roman alum. By analysing the beautiful red selenite from Montalier in Franche Comté, which is crystallized in shining lamellæ, and from which I have obtained iron in its complete state, I am convinced, not only that this metal can communicate all the shades of this colour, but also that it adheres very tenaciously to vitriolic earthy salts; for, after boiling this selenite in distilled water, and filtering the solution, a deposition, having a slight tinge of this kind, took place as the liquor cooled. Morveau.

is inspissated by boiling for 24 hours (*h*); this being done, the fire is extinguished, the earthy parts are taken away by instruments provided for the purpose, and the liquor, after being cleared by subsidence, is let out by a cock into a receptacle made of oak; there it crystallizes for 14 days; it is then let off into shallower receptacles, where it deposits more crystals; and, finally, is let out in the magistral trench. In this process no depuration is effected by crystallizing; and therefore the Roman alum contains in 100 lb. upwards of 5 lb. of a rose coloured earth:—100 of the ore never yields 2 lb. of alum.

The magistral lixivium appears unctuous, and difficultly forms crystals; yet, in broad and shallow vessels, it yields genuine alum, although a slow spontaneous evaporation is necessary.

At Puteoli the lixivium digested by the solar heat forms at length on the surface crystals, which, being collected in a conical stone receptacle, are again dissolved in warm water; and there, the evaporation going on by the natural heat, more pure crystals are formed: in this case the ore yields more than 40 lb. of alum in 100, but generally mixed with iron.

(*h*) Travellers do not agree concerning the metal of which the boiler is made. Angersten says that the bottom is of copper, and the sides of stone, Ferber mentions copper only, Fougereux says the bottom is of lead, Mazzeas, that the boiler is of lead.

§ IX.

In order to discover the differences of the several lixivia more accurately, I began by examining the three principal; these are, that which is made of the roasted ore, saturated with salt in the cold, and which is called the crude lixivium; that lixivium which remains after the second crystallization of the alum; and, finally, the last lixivium, which is commonly called magistral. These lixivia must necessarily differ more or less in different places, according to the nature of the ore employed, and the varieties of the operation: and even supposing the ore to be the same, and equally roasted, yet the first is the richer, from the greater heat of the atmosphere; the second, through the whole year suffers the smallest variation; and the last the greatest, as being from the beginning of spring till late in autumn, continually loaded with foreign matters; therefore, although a great variety necessarily occurs, yet it will be useful to consider a set of experiments which were made upon lixivium got at Garphyttan in the month of September 1776, and carried well corked to Upsal.

(A) The specific gravity of the crude lixivium, in a moderate heat, was to that of distilled water as 245 to 215: this specific gravity indicates 9 pannings.

At

At the bottom of the bottle was collected a yellowish powder; the lixivium was yellow, a little greenish, had an aluminous taste, but somewhat austere and earthy. Paper tinged with turnsole grew red when wetted with this lixivium; but the deep blue paper used for sugar was not changed.

Phlogisticated alkali immediately precipitated a Prussian blue, in the proportion of 930 grains to the kanne: this indicates nearly 809 grains of vitriol.

Fixed alkali, dropped in by degrees, precipitated first a ferruginous yellowish powder, then a white one; but that which falls on the addition of a few of the first drops, is by degrees again dissolved; hence we may judge of the superabundance of acid;—how great that superabundance is, we shall see in the sequel:—the acid of sugar occasioned no change.

In this lixivium there are present vitriol, alum, and vitriolated magnesia; salts which are not separable from one another, but with great difficulty. I first tried to effect this separation by spontaneous evaporation; when this can be done, distinct crystals generally appear (a very long time is indeed requisite); and, in the mean time, the atoms which float in the atmosphere mix with the liquor; but to avoid these inconveniencies, I use broad vessels, which expose a large surface to the air; and as evaporation proceeds, *ceteris paribus*, in proportion

portion to the surface, the delay is much diminished. In order to exclude dust, a very thin silk, or a large glass bell, may be put over the liquor: by this method I obtained from a kanne of the lixivium 1,933 grains of crystallized alum, and of a shapeless acid saline mass, 5,790 grains; these were dried upon bibulous paper;—even the crystals themselves, upon the addition of phlogisticated alkali, yielded Prussian blue; I therefore tried another method of separating the salts, and that with better success:—

I first precipitated the iron with phlogisticated alkali, then the earthy part with fixed alkali, in order to take up the superabundant acid; I again dissolved this earth, when washed, in vitriolic acid, the gypsum remained at the bottom; I weighed the liquor, filtered, crystallized, and dried; I totally destroyed the aluminous part of the salt remaining, by chalk; and, finally, filtered and crystallized the liquor which remained; this produced nothing but vitriolated magnesia.

I determined the quantity of superabundant acid in the following manner: I added small pieces of crystallized sal sodæ, these soon grew red from the precipitated iron, but were soon dissolved: I continued to add the alkali, until some remained undissolved; at the same time I saturated a known weight of that vitriolic acid, commonly called oil of vitriol, with the same alkali, and
hence

hence learned to compare the superabundance with the quantity of this oil.

These experiments shewed that there were, in each kanne of the crude lixivium, 15 grains of gypsum, 3,889 of vitriolated magnesia, 2,933 of alum, 809 of martial vitriol, and so much disengaged acid as was equal to 72 grains of common oil of vitriol.

The vitriol of iron which appears here is of a peculiar nature, for the lixivium does not deposit an ochre on boiling, or on spontaneous evaporation to dryness, but holds its colour perfect; yet that it contains iron very much dephlogisticated, is easily gathered from the ferruginous colour of the martial precipitate, occasioned by a fixed alkali: the case is very different with a solution of common vitriol.

§ x.

From the preceding paragraph, it evidently appears, that there is present in the lixivium a greater quantity of acid than is necessary for the formation of alum. The question is, whether this impedes the crystallization, or promotes it? Many, among whom is the celebrated Margraaf, assert the former; but an experiment published in 1744, by Mr Baron, suggested the latter opinion to some.—The experiment is this: concentrated vitriolic acid, added in large quantity to a solution
of

of alum, precipitates the alum, by seizing the water; which being quickly crystallized in this intensely acid solution, frequently exhibits crystalline spiculæ, or needles diverging from a point, like stars. This, in the same circumstances, happens to many salts: — highly concentrated vitriolic acid is able to take away from alum not only the water of solution, but the water of crystallization. Let a transparent piece of alum be put into such an acid, and in a few minutes it will be found to grow white and opaque: thus we have what may be called alum calcined by the humid way; and this phænomenon is a test of the perfect concentration of vitriolic acid.

But in the present case there is no question of so great a quantity of acid as is able to take away from the salt its dissolving water: the most highly concentrated vitriolic acid seems to be saturated with about double its weight of water (at least it attracts no more from the atmosphere): but we are now enquiring concerning a quantity which has united to it far more than twice its weight of water, which therefore must adhere but loosely, as being superabundant.

Every day's experience shews that vitriolated vegetable alkali and gypsum are more copiously dissolved, if the water be sharpened by a small portion of vitriolic acid; nay, the nitrous acid has the same effect; and in general this holds good of
all

all salts hitherto known, excepting only tartarized tartar, and those which agree with it in qualities; for this salt, when the proportion of acid is encreased, degenerates into tartar, which is far more difficult of solution. It would be scarce worth while to demonstrate that alum agrees with the other salts in this respect, were it not that it has been called in question.—What follows, will, I hope, elucidate that matter sufficiently (*i*).

(A) I chose 12 glasses of a conical figure, as nearly similar and equal as possible; to the first, I did not add any vitriolic acid; in the second, I put 4 drops; in the third, 6; and so on, as the following table shews; where the column marked *number of glasses* shews the number of drops put into each—(100 drops weigh about 113 grains). This being done, an equal measure of a solution of alum filtered, was put into each glass:—I employed Roman alum, and therefore filtering was necessary, to separate the earthy part. The glasses were set in a place where the thermometer stood during the whole experiment (which lasted 25 days) between 6° and 10°: after the 1st, 2d, 6th, and 25th days, whatever was found crystallized was taken off with a silver spoon, and dried for 10 hours, upon a bibulous paper folded, and was then weighed. In order to avoid fractions, I express

(*i*) See the Stockholm Transactions, in which I first published these experiments.

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the weights in docimaſtic pounds, 400 of which are equal to 215 grains.

Number of glaſſes.	After 1ſt day.	After 2d day.	After 6th day.	After 25th day.	Sum total.
0	50	5	3	18	= 76lb.
4	39	13	2	17	= 75
6	38	$11\frac{1}{2}$	2	18	= $69\frac{1}{2}$
8	30	14	$1\frac{1}{2}$	16	= $61\frac{1}{2}$
12	30	13	1	17	= 61
16	20	19	1	18	= 58
20	20	$16\frac{1}{2}$	1	20	= $57\frac{1}{2}$
24	14	22	1	20	= 57
30	14	22	1	20	= 57
40	15	$18\frac{1}{2}$	1	23	= $57\frac{1}{2}$
50	12	23	$\frac{1}{2}$	23	= $58\frac{1}{2}$
100	16	25	$\frac{1}{2}$	24	= $65\frac{1}{2}$

(B) I repeated the experiment, only making uſe of five glaſſes; into each I put one half the meaſure of filtered ſolution of alum, and the number of drops of the acid indicated in the firſt column beneath: 100 drops now weighed about $92\frac{1}{2}$ grains. The experiment took up 23 days; at the end of which time all the moiſture in the firſt glaſs had evaporated.—The temperature was between 15° and 20° .

Number

Num- ber of glasses.	After 1st day.	7 days.	12.	23.	Total.
0	199	30 grs.	44lb.	56lb.	= 329lb.
25	190	21	52	64	= 327
50	172	29	53	66	= 320
75	166	17	52	67	= 302
100	163	26	50	58	= 297

Hence it easily appears, that the smallest addition of acid impedes the crystallization. A comparison of the 3d, 4th, and 5th column, will indeed shew many irregularities, which may be exhibited by a curve, by erecting, perpendicular to the axis, ordinates proportioned to the number in each column, and by taking the abscissæ proportional to the numbers in the first column. These irregularities can hardly depend entirely on the inequality of the cups; but undoubtedly they depend, at least in part, upon the different relative proportions of the alum, water, and acid; besides, a perfect equality cannot be preserved in a number of drops: but this does not affect the general conclusion; for if by accident, where the difference is small, 4 should = 6 in weight, this will not happen where the difference is greater, without remarkable negligence.

Besides, I took as much care as possible that the solution poured into the last glass should be as warm as that in the first. If any variation happened

pened here, it must have arisen from the latter glasses being richer than the former, on account of the contraction of bulk by cooling.

That the evaporation should proceed sensibly during the whole time of the process, the broad surfaces give reason to expect; and all the phenomena demonstrate that it was so. It is otherwise in the manufactories (§ VIII. c).

(c) To avoid the exception arising from the inequality of the drops, I made the experiment in the following manner:—I dissolved 215 grains of pure alum in distilled water, in a small cucurbit, and evaporated over the fire until the surface of the liquor corresponded with two opposite marks on the narrow neck, which, according to former experiments, indicated that the warm solution was fit for crystallization; I therefore poured it out into a glass: in the same cucurbit, after washing it, I again dissolved and evaporated 215 grains, with the addition of 24 grains and an half of concentrated vitriolic acid. This solution was poured out into a glass similar and equal to the former. I repeated the experiment a third time, with no other alteration than the addition of 53 grains of vitriolic acid. The glasses were then all set close together, in a place the temperature of which was 10° . After 56 hours, I collected the crystals, and left them untouched for 12 hours, upon bibulous paper, many times doubled. At the expiration of that time I found the weight of crystals

itals obtained from the first cup to be $155\frac{3}{4}$, from the second 130, and from the third only $100\frac{1}{4}$.

(D) The last objection is, that the vitriolic acid attracts water very strongly; and therefore no other way impedes crystallization, than by taking away the water necessary for the solution. The question is not at present in what manner the vitriolic acid acts; and therefore, without giving up my thesis, I might allow this conjecture to be right. But I took that opportunity of examining into its truth: for this purpose, I provided two equal and similar bottles, A and B; into each I put eight ounces of distilled water, and into B only I put $50\frac{1}{2}$ grains of vitriolic acid: I afterwards added to each equal portions of powdered alum, and immediately closed them both well. As long as none remained undissolved, I continued to add more alum, and did not cease, until a portion remained for some days, which the liquor was incapable of dissolving. Equal portions of the salt were always more quickly dissolved in B than in A. The water in A dissolved only $339\frac{1}{2}$; that in B 373, and $80\frac{1}{2}$ more upon the further addition of $134\frac{1}{2}$ of vitriolic acid.

Since, then, the solution is as it were in the inverse ratio of crystallization; and as no difference in evaporation could take place the bottles being nearly full, placed near one another, and well stoppered; I conclude, that the acid of itself encreases the

the solubility, or, which is the same thing, impedes the crystallization.

§ XI.

After having shewn, by many experiments, that the crystallization is impeded by the superabundant acid, the question now is concerning the most commodious method of detaching that superfluity.

(A) Alkaline substances, saline or earthy, are no doubt capable of suppressing it, but these superadd a salt of another kind. It sometimes happens, that alum does not yield firm crystals, a fact first observed by M. Margraaf, who also shewed, that this inconvenience arose from a small quantity of vegetable alkali. I know that, without any addition, complete crystals may be obtained; but for the most part, unless the evaporation be carried on extremely slow, the great portion which remains after the deposition of a few perfect crystals is nothing but a saline magma. It is remarkable that this impediment to crystallization is equally well removed by volatile alkali, but not by mineral alkali, or by lime (and this points out the resemblance between vegetable and volatile alkali, as also between mineral alkali and lime, a resemblance which we shall see elsewhere (k): not only

(k) Dissertation on Platina, vol. ii.

the common, but even the Roman alum, when precipitated by a volatile alkali, yields a liquor which not only contains an ammoniacal salt, but frequently a vitriolated vegetable alkali; which latter may be had alone, the former being separated by sublimation. The presence of this alkali is owing either to the clay itself being adulterated with the residuum of putrified vegetables, or from ashes, either added on purpose, or accidentally mixed, during the calcination and roasting. In the mean time, it is certain that alum and vitriolated vegetable alkali easily unite, and thus a triple salt is formed: the alum, deprived of this addition, is unfit for making the pyrophyrus, which may be easily tried; for the aluminous magma which refuses to crystallize distinctly, yields, when treated in the usual way, not a particle of pyrophyrus; whereas it yields an excellent one, upon the addition (l) of a small quantity of vegetable alkali (m).

(l) Vid. Scheele on Fire.

(m) It is difficult to imagine how this alkali contributes to the production of pyrophorus, more especially since M. Proust has shewn, that it may be obtained without alum, and even without vitriolic acid; that the residuum of saccharum saturni, after distillation, crystals of verdigrease, and several other metallic salts, are true pyrophori; in a word, that almost every substance which leaves, after its decomposition, a coally matter, simply divided by an earth, or a metallic calx, has the same property (*Journ. Phys.* 1778, *Suppl.* p. 432). Morveau. See Priestly, vol. iii. and iv. Appendix.

These circumstances suggest a suspicion, that vegetable alkali is necessary for the perfection of alum; and that therefore all perfect alum should be considered as a triple salt; but this conjecture is not well founded, as the same perfection may be obtained by the volatile alkali, and a spontaneous evaporation. However, I do not suppose the addition of vegetable alkali improper, provided it be pure; for if impure it is more noxious than useful. The whole of the superabundant acid, however, must by no means be saturated with alkali, as the alum would in that case be too much mixed with a foreign salt, and the operation be rendered expensive, without gaining any advantage.—Urine ought to be avoided, partly on account of the heterogeneous matters which it contains, partly on account of the volatile alkali, which communicates to alum properties that render it unfit for the purposes of dying.

(B) But as a pure clay constitutes the basis of alum, the superabundant acid cannot by any other means be more conveniently repressed than by this earth: which, at the same time that it prevents the noxious superabundance, increases the quantity of alum. I am very much surpris'd that so excellent and obvious a remedy has never been proposed by any person, at least so far as I know.

In order to ascertain what was to be expected from this, I instituted several experiments, by which the truth of the above assertion was sufficiently

ciently evinced. It will be sufficient to relate two:—I employed a magistral lixivium, in which the excess of acid was nearly in quantity as described (§ IX. c.); to a kanne of this I added two drachms of pure clay, reduced to a fine powder, and moistened with a few drops of water: I then applied the heat of ebullition, which I continued for ten minutes; when all was cold I separated the clay that remained, and upon washing and drying I found that $25\frac{1}{2}$ grains were dissolved; which indicates an increase of alum of 141 grains (§ III. B.). At another time I employed gentle boiling for half an hour, by which 75 grains were taken up, so that 416 grains of alum were produced; hence a single boiler would produce 1,400 ounces.

I entertain no doubt, therefore, but that the addition of clay is extremely useful; and this should be done at the very first, when the lixivium is put into the boiler; a clay free from lime is necessary, as this last would produce gypsum; it must also be free from any thing vitriolic. In general the quantity is to be regulated by the quantity of superabundant acid; and we must consider that the earth of alum frequently constitutes only one fourth of argillaceous earth. A few trials will, in the present case, be sufficient to direct us.

§ XII.

Many circumstances relating to the method of obtaining alum pure have been mentioned in the foregoing section, where we treated of repressing the superabundant acid.

Alum, as it is commonly made, although depurated by a second crystallization, yet is almost always found contaminated with dephlogisticated vitriol; hence it grows yellow by age, and when dissolved in water deposits ochre. This, in many of the arts, is equally useful with pure alum; it is even so in dying, when dark colours only are wanted, which frequently require green vitriol: but when the more lively colours are sought, every thing martial must be avoided, as it always obscures them more or less. In such cases the Roman alum is employed: it is therefore required to discover a method by which the common alum may be so depurated as to equal the Roman in goodness. The common ore, indeed, always contains more or less martial, which even actually enters the lixivium; notwithstanding this, however, we must not despair (*i*).

(*i*) "The preference given by dyers to Roman alum does not appear to me a sufficient reason for concluding that it is not coloured by iron. It is certain, that the red felenite above mentioned does not any more shew signs of martial earth, in consequence of the addition of tincture of galls, and Prussian alkali, although it contains iron enough to be reduced." Morveau.

(A) Alum,

(A) Alum, made without the addition of the magistral lixivium, both as to purity and efficacy, rivals the Roman alum, and often excels it. The crude lixivium, indeed, contains vitriol, but in such quantity that it is entirely separated by the second crystallization: for the alum made in this way does not shew the smallest sign of iron, either with tincture of galls or phlogisticated alkali; besides, by the second crystallization all the earthy parts are separated, which earthy parts always adhere to the Roman. By my advice, this method was pursued in two of our manufactories, and an alum prepared superior to the Roman.

The reason is plain, for the noxious heterogeneous matters at first remain in the magistral lixivium; now, as two thirds of this continually enter the following decoctions, these matters are continually accumulating, insomuch that the alum being in the first crystallization overwhelmed with these, can be but imperfectly freed in the second; nay, a third or a fourth are sometimes necessary, to form as good alum as is had without the addition of the magistral lixivium by means of two. How absurd this continual addition of the magistral lixivium is, will sufficiently appear from its nature, and will be demonstrated more at large in the following paragraph.

(B) If the lixivium abounds with dephlogisticated vitriol, (which is easily discovered by the red colour, and the continual deposition of ochre) this

is destroyed by the addition of clay : and let not this be thought contradictory to the general laws of attraction. It is indeed true that iron, put into a solution of alum, is dissolved, and precipitates the earthy base of the alum : as also that, when vitriol and alum are both in the same solution, if an alkali be added gradually, and without agitation, the white argillaceous earth will be first precipitated, and afterwards the greenish martial earth. But this is only true of iron in a metallic state, or but little dephlogisticated ; for if the inflammable principle be any further diminished, the efficacy of attraction is thereby so much weakened, that the iron, being now calcined, will yield the vitriolic acid to pure clay. The truth of this assertion may be proved many different ways : thus, let a portion of alum be dissolved in a lixivium of highly dephlogisticated vitriol ; let an alkali be then added, and ochre will be precipitated first, and not until after it clay ; besides, if clay be added to such a lixivium, and boiled, alum is formed ; and, provided there be a sufficient quantity of clay, the whole of the vitriolic salt will be destroyed.

Those who are fond of wonderful transmutations, and accordingly see them in every thing, will in this instance rather say, that the martial is commuted into an argillaceous earth : they add, to finish the demonstration, that the salt elixated from colcothar of vitriol not only (like alum) refuses to crystallize without the addition of a little vegetable

getable alkali, but also yields transparent crystals, which resemble alum in the astringency of their taste.

These phænomena are true, but the conclusion deduced from them is erroneous. The more frequently vitriol of Mars is dissolved, and again crystallized, the more it is deprived of its green colour, and at length it totally loses it; hence the watery colour of the salt obtained from colcothar: the taste is astringent, like that of vitriol, but with some small difference, the metallic base being here deprived very much of its phlogiston: besides, that the salt got from colcothar most commonly does not contain a particle of alum, there is no doubt; for every common vitriol owes its origin to pyrites, which is rarely without some clay; therefore we have no occasion for a metamorphosis to account for the production of alum: but that vitriol, which is formed of iron and pure vitriolic acid, never shews the smallest vestige of alum; and the colcothar salt obtained from such vitriol, upon the addition of a fixed alkali, deposits nothing but an ochre; but with a phlogisticated alkali the whole base is converted into a Prussian blue.

From all this it evidently follows, that an aluminous lixivium, which is only contaminated by dephlogisticated vitriol, may be at once enriched and depurated, by the addition of pure clay free from vitriolic matters.

(c) A lixivium containing perfect vitriol cannot be freed from it to any purpose, either by clay or alkali; for the former effects no decomposition, unless in so far as the vitriol is dephlogisticated by long boiling: the latter, although it can destroy all the vitriol, yet it cannot effect this, so long as any alum remains, which yields its acid more readily.

§ XIII.

In applying the magistral lixivium to use, we must take notice of many varieties, the chief of which depend upon the admixture of a vitriolic salt, as this renders the alum unfit for certain purposes; and, if the quantity be large, renders it unapt to crystallize. However, we must also take into the account vitriolated magnesia, which not unfrequently is found mixed with it.

(A) A magistral lixivium containing alum alone, is scarcely found any where, except at Tolfa. Mr Fougereux de Bondaroi observes, that this, exposed very much to the air in broad shallow vessels, by degrees, though slowly, yields genuine alum, in the same way as clay artificially combined with vitriolic acid, which, though in the usual way it only affords incoherent crystals, affords very complete ones by a slow spontaneous exsiccation. I have not yet been able to discover the reason of this phenomenon; but in the foregoing

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pages I have mentioned, that this disposition to crystallize may be induced by the addition of a little vegetable or volatile alkali, but not by the mineral alkali, or lime (§ XI. A).

In the magistral lixivium there sometimes occurs a species of fat, as is judged not so much from its viscid appearance (which may be occasioned by the quantity of the matters dissolved) but from its nature and properties; for a saturated solution of alum, in the same manner as other salts, if kept long, or boiled in a glass vessel, communicates to the glass the property of repelling water, as if it had been smeared with oil, and wiped with a cloth. So long, therefore, as we know no other bodies but oils which communicate this property, we must conclude, that something at least analogous to oil is in the lixivium.

(B) The lixivium containing perfect vitriol, so long as it is rich in alum, may be employed, as it usually is, but only for the preparation of common alum; whereas, if the vitriolic salt abounds, it must either be crystallized into a vitriol, or else be so destroyed as to produce alum, which may be done in the following way:—let the lixivium be reduced to a tenacious mass with clay, and formed into cakes, and these be exposed in an house to the open air; by these means the phlogiston, which is powerfully attracted by pure air, is by degrees separated from the iron, while the acid, by its stronger attraction, takes up the clay:
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the calcination is accelerated by fire, but it must be cautiously employed, lest the acid should be expelled: the lixivium is thus treated to much more advantage than by continued boiling, particularly when it contains but little alum (*k*), as is the case in our manufactories about the end of the summer, as the noxious foreign matters are increased on every boiling.

(c) The lixivium, containing dephlogisticated vitriol, may be advantageously treated, by adding clay during the boiling: the reason has been already explained (§ x. B), so that we need not dwell upon it here.

(D) The lixivium containing perfect vitriol, and vitriolated magnesia, is the most common in our manufactories; this may be employed in the ordinary way for the preparation of common alum, in the beginning of summer, and so long as the heterogeneous matters have not accumulated too much; but when that takes place, it is proper to separate the vitriolated magnesia; for this purpose it is necessary to decompose the vitriol, and also the alum, for they cannot be separated by crystallization (§ ix.); this is best done by a calcareous powder, which must be unburnt, as, if burnt, it would also decompose the vitriolated magnesia: this powder is to be added by degrees, lest the effervescence should occasion the mass to swell over

(*k*) Vid. Monnet sur l'Alunation.

the sides of the vessel: a just proportion removes the salts, by the assistance of agitation and heat; phlogisticated alkali will readily shew whether there is any thing martial remaining. In the place of the decomposed salts there remains gypsum, but only a very small portion of it remains in the lixivium; for, on account of the deficiency of menstruum, the greatest part falls to the bottom along with the ochre and clay. As soon as the liquor has subsided and grown clear, it must be carefully decanted into another vessel, and evaporated until a drop let fall upon a cold substance shews crystals in a few minutes; it is then to be removed from the fire, and, on cooling, it produces vitriolated magnesia.

If in our manufactories all the magistral lixivium which is unfit for making alum was treated in this manner, we should undoubtedly obtain as much Epsom salt as is consumed in all Sweden: this salt is now imported; whereas, if at the same time this and other means were used, we might be able to export to all Europe.

It is evident that this lixivium may also, by the methods above described, be employed for the artificial preparation of the matrix of alum.

(E) The magistral lixivium has always a superabundance of acid: we found in one kanne nearly five ounces; so that in a single boiler there are nearly 250 lb.: but vitriol, when well dephlogisticated, retains its acid so loosely, that it may easily
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be separated by fire. I do not doubt, therefore, but that such a lixivium, if its surface be first increased by pouring over an heap of sticks, and afterwards collected, might be advantageously subjected to distillation.

(F) Finally, the ochre, which separates either spontaneously or upon the addition of an alkali, may be made, by various methods of preparing it, to afford various pigments;—it is enough here to throw this out as a hint.

§ XIV.

From what has been said, I believe it will plainly appear, that if the operations were conducted with skill and prudence in our manufactories, we should have, at the ordinary expence, alum better in quality, and a larger quantity. I flatter myself, that in foregoing sections I have pointed out the means of obtaining this end. As to the forms of furnaces, and other contrivances for more commodiously conducting the operations, I pass them over, as belonging rather to mechanics than chymistry, although these two frequently lend one another mutual assistance.

DISSERTATION X.

OF

ANTIMONIATED TARTAR.

§ 1. *Medicines should be prescribed in such a Way, that each shall always possess the same Virtues.*

IN prescribing medicines, or in composing dispensatories, nothing is more necessary than that both the materials and method of preparation be so chosen as to be exactly alike in all cases and situations: for if the officinal preparations be not directed to be made in such a manner, that they can never, under the same name, possess different virtues and properties; or if the process be so ordered, that, notwithstanding all possible care in the repetition of it, it cannot to a certainty be performed in the same way, it plainly appears, that

that medicines of very different qualities may be produced by the same formula, and that not only in different shops, but in one and the same. The danger hence arising is indeed but small, when the less powerful preparations only are subject to this inconvenience; but from what follows, it will appear, that this is often the case with those which are possessed of considerable activity.

For example, let us suppose an emetic, or a purgative made by the same formula, and, nevertheless, that the medicine does not always produce the effect desired, that it at one time has little or no effect, at another acts most violently; in this case, beyond doubt, the life of the patient is endangered, the credit of the physician injured, and preparations which, if rightly adjusted, would be of the most material advantage, fall gradually into disrepute, and at length into total disuse.

All these inconveniencies are found to take place in many officinal preparations, particularly those of metals, many of which, though known by the same name, are in degree of efficacy entirely unlike.

§ II. *Antimonial Emetics.*

From the most remote times antimonials were known to possess an emetic quality: this property

perty they exert only when dissolved; but in general they can undergo solution within the body as well as without; for, in the primæ viæ, there are sometimes humours endowed with the property of dissolving this semi-metal; and on this account antimonials were formerly given in the form of powder. But as it is plainly impossible for us to determine, *a priori*, either the quantity or quality of this menstruum, it follows, that from variation in it, either of quantity or quality, the dose must be uncertain, and the effect extremely dubious. Examples are to be met with, of some persons who could swallow considerable quantities of the regulus, without any inconvenience, which would be highly dangerous to persons who are subject to acidity. At present, the mercurius vitæ, the hepar antimonii, and pulverized glass of antimony, are much in use, because these substances contain the regulus, reduced by solution to a saline nature; they therefore may be given with much more safety, and, being always the same, act more powerfully and certainly. Tartar has been almost always in use, as a solvent for this metal; and the salt arising from this composition has been called *tartar emetic* (*a*), from its operation; and *stibiased tartar*, from its composition.

(*a*) Mynsicht first introduced this preparation in 1631. He employed the crocus metallorum; Zwelfer, the glass of antimony; and Lemery, the hepar.

I prefer, however, the name of antimoniated tartar, as antimony is at present a more popular name for this mineral than stibium: and this preparation of antimony I design to examine in the following pages.

§ III. *Different Methods of Preparation.*

Upon turning over the most celebrated dispensaries, we find a wonderful difference in the methods of preparing this salt; all, except the old dispensatory of Stockholm, which mixes with it a lixivious salt, prescribe the crystals, or cream of tartar, as the menstruum; but differ with respect to the matter to be dissolved.

The crocus metallorum is directed by the new Vienna dispensatory (*b*), by the new Utrecht (*c*), the Wirtemberg (*d*), the Edinburgh (*e*), Bornsfo Brandenburg (*f*), the London (*g*), and some others; but the Edinburgh and the Brandenburg admit the use of the glass of antimony, which is the basis employed by the old Stockholm (*h*) and the Ratisbon (*i*); but the Paris dispensatory (*k*) orders it with an equal part of the hepar, not freed from the scorixæ. The Pharm. Bateana (*l*) em-

(*b*) An. Dom. 1734.

(*c*) 1749.

(*d*) 1750.

(*e*) 1756.

(*f*) 1758.

(*g*) 1758.

(*h*) 1686.

(*i*) 1727.

(*k*) 1738.

(*l*) 1688.

employs the flowers of antimony. As to the proportions, the Ratisbon, Vienna, Utrecht, Wirtemberg, London, and Brandenburg, employ an equal weight (*m*) of tartar and of the metallic matter; the Edinburgh and Paris double that quantity: there is also a difference with respect to the quantity of water. In the Vienna and Edinburgh dispensaries, 12 parts of water are ordered to one of tartar; 6 in the Wirtemberg; and in the rest, so much as is sufficient for solution. The mixture, being digested for a day or two, is boiled until the tartar is completely dissolved, according to the instructions of the Brandenburg dispensatory, and most others; but the Paris directs, in express words, 12 hours, the Edinburgh 10, and the London half an hour. After filtration, the Ratisbon and London require crystallization; the rest evaporation to dryness. In the old Stockholm dispensatory, one ounce of glass of antimony is deflagrated with two drachms of crude nitre; one drachm of alkali of tartar, and nine ounces of pure water, are then added; the whole is boiled to dryness in an iron pot, the mass reduced to powder; warm water is poured on; it is filtered; and, being evaporated to dryness, is strongly heated on an unburned brick.

The above will be sufficient to shew the disagreement of the dispensaries: indeed, to com-

(*m*) Vid. Dispens.

pare the differences minutely, would exceed the bounds of such a Treatise as this. We may, however, observe another method formerly in use, for the purpose of exciting vomiting, which is in itself sufficiently commodious, if it were sufficiently exact :—wine was set to stand for a night, in a cup made of regulus of antimony and tin; or else balls of this metal, which were called perpetual pills, were steeped in wine for a certain number of hours. What judgement is to be formed of these contrivances, the following experiments will shew : when we consider the disagreements above mentioned, and others that might be adduced, we shall cease to wonder at the uncertain effect of emetic tartar.

Upon accurate examination, we shall see that the weaker of these preparations contains scarcely five hundredths of the metal, while the stronger have upwards of 0,24. Hence, then, appears the necessity of determining the basis and the menstruum in such a manner, by accurate experiment, that this medicine may always possess the same properties, and the same degree of strength.

§ IV. *The Base to be chosen.*

The hepar, the crocus metallorum, and the glass of antimony, are the substances generally made use of as the basis of tartar emetic. We must

must first inquire, whether these three, prepared according to the usual formula, actually contain the same quantity of phlogiston; for, according to the variation of that principle, a greater or smaller portion of the metallic regulus will be dissolved in the same quantity of menstruum; and of course the emetic power will vary. That hepar which is prepared with a larger proportion of nitre, necessarily loses more of its phlogiston than that in the preparation of which less nitre has been employed; and even although an equal quantity of nitre and antimony be (as is usually the case) employed for this purpose, it still depends upon other circumstances, whether the reguline part be acted upon at all, and in what degree. The deflagration is performed, either by throwing the nitre and antimony into a hot crucible, or by setting fire to the mixture in a cold mortar: in the former case, the sulphur is more quickly destroyed, and flies off; so that the metal is of course more completely deprived of its phlogiston, than in the latter, where no fusion takes place; and there is no external operation of fire: hence the hepar made in the latter way is red, that produced by the former method rather yellow. But though the process were universally conducted in a crucible, it is impossible at all times to apply the very same degree of fire; nor can the difference of degrees be possibly ascertained: so that, from this circumstance alone, the products must differ

essentially ; add to which, that the nitre and crude antimony cannot be mixed together so evenly, but that in one part the nitre will prevail, in another the antimony ; and hence also a variation in the product must necessarily take place ;—and the natural consequence of this variation is, that the regulus is scarce ever acted upon twice in exactly the same manner.

All the above-mentioned differences arising in the preparation of hepar, affect in the very same manner the production of the crocus metallorum ; the latter being no other than the residuum of the former, insoluble in water. Besides, another variation in this preparation may arise from the difference of accuracy in washing ; for, on this account, more or less remains, which, by encreasing the weight, and absorbing the acid, not only weakens the strength of the menstruum, but prevents the same weight of it from containing always the same quantity of antimony.

Glass of antimony is obtained from the fused calx of this metal. Now, as the regulus, the crude antimony, and other preparations, may each be calcined by means of fire ; and as all these, according to circumstances, and the nature of the preparation, lose phlogiston in different degrees, it follows inevitably, that the glasses made of the calx must differ much from each other.

But, suppose the crude antimony always used
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for this purpose, as many direct it to be, yet even in this case we cannot be sure that the same force of fire has been employed; and as that varies, the calx may sometimes be so far deprived of phlogiston, as to be vitrified with great difficulty, and sometimes retain so large a portion of the inflammable principle as to resemble the hepar in fusion, rather than the glass; and between these two extremes there are innumerable intermediate degrees. When we consider every thing attentively, we shall cease to wonder at the different degrees of transparency, and the different colours of the glass.

Hence we may conclude, that neither the hepar, the crocus, nor the glass, can supply a base for emetic tartar, which will be always similar to itself; and therefore, that they are to be avoided, if a more proper substance can be found.

It may perhaps be thought, that the regulus is preferable to those substances which are most in use; but even if we were in possession of a sure method of regulating the fire in the preparation of the regulus, so that it shall always be of the same nature; and although we also had a sure and commodious method of measuring the solvent power of the menstruum, yet it remains to be determined by experiment, whether antimony, in its reguline state, can communicate an emetic quality to acid liquors.

Boiling vinegar indeed attacks it; but for the acid of tartar, see § VI. A. VII. A. Many persons extol the virtues of wine which has lain in a cup of the regulus, and had the powdered regulus steeped in it for 24 hours; but in this instance an error may readily conceal the truth: for minute particles of the powdered regulus may, on account of its micaceous texture, be easily suspended in the liquor, and therefore may be sometimes swallowed: besides the regulus when, either by means of too much fire, it is externally deprived of a portion of its phlogiston, or mixed, either internally or externally, with an hepar, it may communicate to wine an emetic quality, although the reguline part itself contributes nothing to it. In order to obtain a decisive conclusion, the regulus should be often well fused with a fixed alkali, and then well washed with vinegar; besides, the wine which is decanted off should be filtered through paper;—this I never had an opportunity of trying more than twice. I steeped the regulus, eliquated according to the London dispensatory, divided into small pieces, and well washed in Rhenish wine, and kept the bottle closed in a moderate heat for six days: the wine, after filtration, did not shew the slightest token of an emetic virtue.

Of all the antimonials none deserve so much attention as the powder of Algaroth, which was some time since thought well adapted to this purpose

pose (n).—The following experiments will serve to shew its nature more completely. It is obvious, that if 3 parts of crude antimony, and 4 of corrosive sublimate, be mixed together, by means of heat, and a double elective attraction, a double exchange will take place; for in the corrosive sublimate there is calcined mercury, and in the crude antimony the regulus combined with sulphur: during the operation the antimony yields its phlogiston to the calcined mercury, which thereby becomes quicksilver, and in its turn yields its marine acid to the antimonial calx. This compound passes over into the recipient, under the name of butter of antimony; and if at length the heat be much increased, cinnabar is formed, consisting of the sulphur of the crude antimony united with the mercury. We must take particular notice that neither the regulus of antimony, nor of any other metal, can be taken up by acids, until it is to a certain degree deprived of its phlogiston; and that degree is various in various cases, as I have elsewhere demonstrated (o).

Butter of antimony, dropped into water, is instantly decomposed; the water seizes the greater part of the marine acid, and the deserted metal falls to the bottom in the form of a white pow-

(n) By Macquer.

(o) De Attr. Elect.

der: this powder was formerly known by a number of singular names, to which it had little claim; but is now generally called powder of Algaroth, in honour of Vittorio Algarotti, an Italian physician, who has been very lavish in praise of it.

In this operation the antimony is constantly acted upon in the same manner by the marine acid, and consequently always loses an equal quantity of its phlogiston, which is a circumstance very much to our purpose. How well soever this precipitate be washed, tho' with warm water, yet still a small quantity of the acid adheres, as appears from hence, that upon distillation a small portion of butter of antimony comes over into the recipient; but the acid admixture may be avoided by saturating it gradually with *oleum tartari per deliquium*; for in this case the more minute and white particles fall to the bottom, which can only be had by washing with an alkali. This is indeed more soluble than the former obtained by water, but supposes a complete decomposition, which yet is not always obtained; at least there is in this case room for fraud, as this method is more expensive and more troublesome.

The precipitate obtained by water, although less in quantity, is yet perfectly soluble, and therefore I prefer it, as being less liable to variation; and we should not, without urgent necessity, confide in the fidelity of the operator.

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The argentine flowers are justly enumerated among the best preparations of antimony; but the preparation of these, although more difficult, yet forms a less certain base for emetic tartar than the powder of Algaroth does.

§ v. *The proper Menstruum.*

From the time that this medicine first became known, to the present day, tartar has been almost every where, and at all times, used for the menstruum (*p*); however, as this salt is not a pure acid, but, as chymical analysis and synthesis shew, a sort of tartarized tartar, with a determinate superabundance of acid, it is to be considered that we are not yet certain whether the superabundant acid alone acts, or whether the other ingredients contribute any thing.—I am now to relate the experiments which I made to determine that point.

§ vi. *Power of the Acid of Tartar.*

The first trials were made with pure acid (*q*) of tartar, of which the specific gravity was to that of distilled water, as 1,230 to 1000.

(*p*) The old Stockholm Pharmacopœia, after Zwelfer, uses alkali.

(*q*) Retz has described, in the Stock. Transf. the method of obtaining the pure acid of tartar.

(A) The

(A) The following experiments were made with regulus of antimony, prepared according to the London dispensatory, and reduced to a very subtile powder. One part of this was boiled for twenty minutes in a phial, with 25 of the above-mentioned acid, then filtered, and set in a cold place; it was afterwards further evaporated, when a salt concreted in the form of crusts and furrowed pieces, which in the fire exhibited the same properties as crystallized tartar, without any visible antimonial smoke. For the better understanding of this, we must explain the peculiarities of this acid when exposed to fire upon charcoal, by means of the blow-pipe.

The crystals of this acid, which are formed by slow evaporation, resemble thin transparent lamellæ, irregularly situated in a way which is called cellular by mineralogists. As soon as the external fluctuating part of the flame reaches the crystals, they immediately liquify, and form a mass pellucid like water; this, when exposed to the blue conical nucleus of the flame, foams with a loud noise; and after the expulsion of the water grows black, sends forth first a smoke, then a blue flame, and leaves a quantity of spongy scorix; which diminishing more and more by the extremity of heat, at length become entirely white: this residuum easily dissolves in acids, and changes the blue juices of vegetables green, in the same manner as alkalis do; and this is also the case

case with those parts which have not been tried upon the cod. From an attentive consideration of these circumstances, it appears that this acid has but little effect upon the metal in its reguline state; and the powder collected upon the filter, not being diminished in weight, confirms this opinion.

(B) Hepar of antimony, prepared with an equal quantity of nitre, was put to the proof with the same quantity of acid, and in the same manner, except that it was only boiled fifteen minutes; but the residuum was the very same with that described in the last experiment, both with respect to crystallization and habit with regard to fire, with this single difference, that the residuum on the coal is of a reddish brown.

(C) One part of crocus metallorum was boiled in six of the acid, diluted with water, for the purpose of evaporation; this, when filtered, after fourteen days deposited a saline radiated mass, which gave out somewhat of an antimonial fume, when exposed to the blow-pipe.

(D) One part of glass of antimony boiled for 30 minutes with 25 parts of acid, filtered and evaporated, separated, on the surface of the liquor in the vessel, small crystalline grains; but all the rest grew gradually hard, and formed a gelatinous mass much resembling cherry-tree gum.

This, when exposed to the fire, exhibited, besides the phenomena of acid of tartar, not only

an intense antimonial smoke, but several metallic grains. The gelatinous matter, and the crystalline, possessed the same properties.

(E) One part of diaphoretic antimony, boiled 30 minutes with 25 of acid, and treated as the above solutions, yielded at length a white saline matter, which, exposed to flame, sends forth a little antimonial fume; and the residuum is of a brownish colour.

(F) One part of materia perlata, boiled 15 minutes with 30 parts of acid, yielded a saline crust, which, exposed to heat, produced an antimonial fume, and a yellowish brown porous substance.

(G) One part of powder of Algaroth was boiled 30 minutes with 9 parts of acid, and then filtered.

This solution, in a digesting heat, became all gelatinous; but afterwards, in a cold place, by means of an air somewhat moist, became elegantly streaked by various rays and branches. This gelatinous matter, when exposed to flame, swells violently, and yields a copious antimonial fume, but no metallic grains.

At another time, one part of the same powder, precipitated by water, was boiled for an hour with 5 parts of acid; this was dissolved without any residuum; and, on slow evaporation, yields irregular crystals.

(H) Although in the foregoing solutions the acid abounded very much, a good deal of the metal

metal remained undissolved, notwithstanding the boiling: I attempted to saturate the powder of Algaroth;—for this purpose one part of the powder was boiled two hours with three of acid, when there was no longer any residuum; notwithstanding which, the solution retained an acid taste, and changed the blue juices of vegetables to a red.

These experiments shew plainly, that the acid of tartar alone has scarce any power in dissolving this semi-metal, so long as this last possesses its full proportion of the inflammable principle; but that, in proportion as this principle is diminished, the metal is more fitted for solution: this, however, is to be understood within certain limits; for although diaphoretic antimony, beyond doubt, contains less phlogiston than the glass, yet no considerable difference takes place between them with respect to solubility.

§ VII. *Antimonials dissolved by tartarized Tartar.*

Tartarized tartar being a neutral salt, it does not at first appear probable, that it can possess the property of dissolving metals and other substances; yet the following experiments prove that it actually does possess such a property.

(A) One part of the regulus was boiled 40 minutes with 8 parts of tartarized tartar dissolved in
pure

pure water, and after filtration was set in a cool place; a congeries of numerous crystals was soon formed at the bottom; a piece of this, exposed to the fire, swelled and grew black; its former colour changed to a white; at length the whole mass was absorbed by the charcoal, in the same manner as happens to crude tartar; and this occurs without the slightest vestige of antimony.

(B) One part of liver of antimony, treated in the same manner with tartarized tartar for 30 minutes, produced the same phenomena as (A) above.

(C) One part of crocus metallorum boiled two hours with 8 of the same salt, give tokens of antimony, but very obscure.

(D) One part of glass of antimony, boiled 45 minutes, with 8 of the salt, separated, upon evaporation, a substance composed of saline spiculæ; which, when exposed to flame, swelled much, and yielded many reguline grains.

(E) Diaphoretic antimony, subjected in the same proportions to the experiment for 35 minutes, exhibited, upon crystallization, the same phenomena as in (C).

(F) One part of powder of Algaroth, boiled 20 minutes, with 5 of the salt, and filtered, yielded crystals of two different sorts, one of which consisted of complete tetraëda, and, exposed to flame, yielded a great number of metallic grains; the other resembled saline spiculæ, and seemed to be

be no other than crude tartar; and this being with difficulty separated from the former, sometimes exhibited marks of antimony.

In another experiment, two parts and a half of tartarized tartar were saturated by half an hour's boiling with one of Algaroth, and formed a brownish red solution, which gave a slight red tinge to tincture of turnsole, and evaporated to dryness, exhibited crystalline grains, amounting to three parts and an half.

Hence it is sufficiently evident, that tartarized tartar can actually dissolve antimony, although that salt had been purposely prepared in such a manner that the alkali should prevail, to avoid deception from superabundant acid; besides, the extraordinary agreement of this with the acid of tartar, appears from hence, that both menstrua act either not at all, or a little, or much, upon the very same preparations.

§ VIII. *Antimonials dissolved by Cream of Tartar.*

The different strength of the tartareous acid, and of tartarized tartar, being examined, we might in some measure judge from thence, of the efficacy of tartar which is composed of these two; but any reasoning of that kind, not confirmed by experiment, must be fallacious.

(A) Two parts of liver of antimony, boiled
with

with one of tartar, after the crystals that first formed, yielded nothing but an insipid saline gum.

(B) One part of crocus metallorum, boiled with eight of tartar, cemented into a gummy substance of a brownish yellow colour.

(C) One part of glass of antimony requires at least three of tartar; if it then be dissolved by boiling, it will yield crystals.

(D) Three parts of diaphoretic antimony, made of regulus, united by boiling with two parts of tartar, on evaporation yielded at first some crystals, the residuum was a gum, which, when well dried, did not attract moisture.

(E) Tartar scarcely acts upon materia perlata.

(F) Two parts of Algaroth's powder obtained by water, require seventy of tartar; if there be more of the menstruum, and the proper quantity of water, dissipated by evaporation, the superabundant tartar concretes, containing no more antimony than that which is held by the water of the crystals: this combination reddens turnsole; on evaporation it first deposits crystals, and then exhibits a clear jelly; a large quantity of water gradually decomposes it by separating the antimonial calx.

(G) Two parts of the argentine flowers, boiled with one of tartar, yield crystals, but no gum: the crystals amount to about one fifth of the weight of the antimony.

(H) Bezoar

(H) Bezoar mineral is not dissolved; but antimony, dissolved in a proper aqua regia, and precipitated by fixed alkali, is readily acted upon, and forms crystals.

In general, to expedite the solution of antimonials, we may use partly a fixed alkali, and partly borax.

Argentine flowers fused with one half of mineral alkali, run together into a yellow mass, covered with a green crust: three parts of this, reduced to powder, are dissolved by one of tartar, and the whole mass becomes gummy.

If one part of tartar be added to one half of sedative salt, three parts of this combination take up one of glass of antimony, and form a gum, which, being carefully dried, splits into a yellow powder, which is said to excel common emetic tartar, both in virtue and solubility: but tartar is not by this artifice rendered more capable of dissolving either regulus, crude antimony, or argentine flowers, than the tartar alone is.

Borax first calcined, and melted with an equal quantity of crocus metallorum, forms a mass of an hepatic colour, five parts of which, mixed with eight of tartar, dissolved in water, instantly generate a colour like that of kermes mineral, and leave no more than two parts undissolved, which also resemble the kermes: by evaporation we get a red gummy salt.

Tartarized borax attacks crude antimony, forming a transparent gummy salt of an amber colour, one part of which unites with eight parts of tartar, and holds them dissolved.

§ IX. *Preparation of an antimonial Emetic, which may be depended upon.*

The foregoing experiments furnish us with two methods of preparing an emetic of determined efficacy.

Let powder of Algaroth be used as the basis, as it always contains an equal quantity of phlogiston, which is of great consequence (§ v.); and let that separated by water be chosen, as it is more certain than that which is obtained by means of alkali (§ iv.) The presence of marine acid is of no consequence, provided the quantity be always the same;—and let the menstruum be either cream of tartar or tartarised tartar: either of the salts, thus prepared, will afford an antimonial medicine for the shops, of a constant and determined degree of efficacy; but as they differ in their own nature, and in the quantity of matter which they take up, their effects must differ, at least in degree. I here only mean to investigate the method of preparing medicines which shall always possess the same degree of power; and this end is obtained by both these operations. It belongs to the practitioner to determine the use of these, and to discover

to cover whether there be so great a difference between them, that it is necessary to be provided with both; or whether one of them may not answer the purpose, by varying the dose. In the mean time, I subjoin the method of properly preparing the two; and first of

Antimoniated tartar:—let five ounces of cream of tartar, reduced to powder, and two drachms and an half of powder of Algaroth, precipitated by warm water, washed, and dried, be gently boiled in a glass vessel for half an hour, in half a kanne of water; this being done, there generally remains a small quantity of a blackish mercurial powder. I do not saturate the tartar completely, as, in that case, some of the solution turns to a gelatinous matter, and the salt resulting, being long suspended in the water, is more easily decomposed, which occasions considerable inconvenience in practice (§ VIII. F.): besides, the weight of a weaker medicine being greater, its quantity may be ascertained with more accuracy; and it may be taken at different times, without any danger: let the filtered solution be evaporated in an open vessel (not metallic) till a pellicle appears; let it then be kept in a digesting heat till crystals form, which must be taken away by degrees, and dried on moistened bibulous paper;—all the clear crystals are equal in weight to the tartar employed: the more purely saline crusts adhering to the sides of the vessel, amounting to

D d 2

about

about half an ounce, are to be well washed off with cold water, and kept by themselves—the last red and thick lixivium must be thrown away.

Tartarized tartar antimoniated :—let ten ounces of tartarized tartar, and three drachms of Algaroth's powder, prepared as in the last process, be boiled in a glass vessel for half an hour, with one-fourth of a kanne of water: let the solution be filtered, evaporate the brownish red lixivium till a pellicle appears, expose it then to a digesting heat, and crystals will separate by degrees; these must be dried upon wet bibulous paper:—when collected they only equal half the weight of the menstruum; the saline crusts, which may be purified by washing, scarcely exceed one tenth of the tartarized tartar—the rest, together with the dark red lixivium, should be thrown away.

§ x. *Properties of antimoniated Tartar.*

The emetic salt, prepared after the manner now described (unless the natural coalescence of the particles be somehow interrupted) is of an octaedral figure, the pyramids somewhat more elongated than those of alum; the crystals are colourless as water, and either wholly, or for the most part, transparent: the antimony constitutes about a third of their weight; they neither crack in the air, nor attract moisture; but, when old, assume an opaque whiteness: exposed to flame with the
blow-

blow-pipe, they decrepitate, burn, emit an antimonial fume, and leave upon the coal some metallic grains.

In a moderate heat (150°) distilled water dissolves about $\frac{1}{80}$ its own weight, or nearly three grains, in half an ounce; and that without any alteration, either in colour or clearness. Tincture of turnsole is scarcely reddened by the solution; alkalis, whether fixed or volatile, caustic or mild, precipitate it; the subtile snowy powder which separates adheres very strongly to the glass vessels in which the operation is performed.

In the first lixivium (§ IX.) a remarkable difference is observed with respect to this precipitant: for if it be entirely pure or caustic, a white, subtile, and very spongy powder is separated, which subsiding, remains unchanged; but if the alkali be mild, after a few hours the precipitate begins to concrete in the form of radii diverging from different points, resembling those figures by which sculptors imitate the sun: but if the solution containing those radiating masses be exposed to an heat of 30° , within a quarter of an hour the figures disappear, and nothing remains but a shapeless powder.

That which is precipitated by common fixed alkali after washing, being exposed to flame, betrays scarcely any antimony: it leaves a white spongy mass which is totally soluble in marine acid, but is so far from being dissolved by vitriolic acid,

that, by that acid, it is precipitated from the marine.

A like precipitate is obtained by means of common volatile alkali: but that which is obtained by caustic volatile alkali does not exhibit these figures; gives out scarce any smoke when exposed to flame; and forms an ash-coloured, fusible, but fixed glass: lime-water also precipitates it, but the precipitate is again dissolved, upon agitation, unless a sufficient quantity of lime water had been added at first;—in this precipitation too the figures appear.

By concentrated vitriolic acid a large quantity of white matter is thrown down, which again disappears on agitation; if collected, washed, and exposed to flame it first grows brown, and concretes into little masses, which afterwards give out an antimonial fume, and are consumed.

Hepar sulphuris, dropped into the saline solution, produces a sulphur auratum.

The reddish yellow colour of this lixivium depends upon iron, as is easily shewn by phlogisticated alkali, which immediately generates Prussian blue.

§ XI. *Properties of tartarized Tartar antimoniated.*

Tartarized tartar, stibiated, forms rarely tetrahedral, but generally octahedral crystals, if suffered
to

to crystallize freely; of these some are pellucid, and void of all colour, others have a little opake whiteness; the habits of the crystals, both in the air and fire, are the same with those of the antimoniated tartar: the metal forms about one-fifth of their weight. Distilled water, in a moderate heat, takes up nearly $\frac{1}{40}$ its own weight, that is five grains in half an ounce, and still retains its colour and clearness; it shews some faint signs of a superabundant acid; the alkalis and vitriolic acid produce the same phenomena as we described in the former section; with this difference, that they are produced more sparingly and slowly, and that the figures there mentioned do not in this case occur.

The solution of the first boiling is of a brownish red, and the magistral lixivium still more so: for experiment sake, a little distilled pure vinegar was poured in, and afterwards a single drop of phlogisticated lixivium, and in an instant the blue colour appeared: the iron then, in this case, is present without an acid; for, to decompose the phlogisticated alkali, a double elective attraction is required. Many of the last lixivia, which are red, and do not readily form crystals, doubtless owe their properties to dephlogisticated iron.

Whence, in the present case, this metal can come, is not at present very clear: the ashes are indeed boiled to dryness in an iron pot; but the

cream of tartar is purified in brass vessels : besides, the white alkali of tartar, when boiled in a glass vessel with powder of Algaroth, gave also a brownish red-coloured tinge.

DIS-

DISSERTATION XI.

O F

M A G N E S I A.

§ I. *Brief History of Magnesia.*

AT the beginning of the present century, a certain canon regular sold, at Rome, a sort of powder, under the title of magnesia alba, or Count Palma's powder, which he asserted to be a panacea : but the preparation of it was solicitously concealed as a profound secret, until Mich. Bernh. Valentini, in the year 1707 (a), disclosed the method of preparing it, by calcination, from the last lixivium of nitre. Two years after, Joh. Hadr.

(a) In a dissertation printed at Gieffa. In his *Praxis Medica*, he calls this earth the *laxativum polychrestum*.

Slevoght (*b*) taught another and more easy method of procuring it, by precipitation. After this, in 1717, Lancisi (*c*) wrote upon this subject; as also did Fred. Hoffman (*d*), and other moderns. From that time the use of this powder has very much increased, and it is now introduced into most dispensaries.

Many considered this powder as calcareous earth, as they were not acquainted with any other which effervesced with acids, and, above all, because they neglected all further examination.—However, F. Hoffman observed, that it differed from the earth prepared from crabs eyes, shells of oysters, and eggs, in this particular, that all these, united with vitriolic acid, afford an insipid salt; whereas magnesia produces one intensely bitter. At length the nature and properties of magnesia were completely elucidated by two of the most celebrated chymists of the present age; I mean Dr Black, of Edinburgh, who published his experiments in 1755 (*e*), and the Principal of the academy at Berlin, A. S. Margraaf, who published his in 1759, *as it should seem*, entirely ignorant of Dr Black's Essays (*f*). Both these gentlemen have examined the nature of this earth with the

(*b*) In a dissertation printed at Jena, 1709.

(*c*) Annot. in Mercati Metalloth.

(*d*) Obs. Physico-chem.

(*e*) Edinburgh Essays.

(*f*) Mem. Berlin.

utmost accuracy and diligence ; and have most evidently shewn, that it differs altogether from lime : but, contented with discovering its properties and distinguishing characteristics, they pass over its genesis, as not being yet ascertained by undoubted experiments. It is certain that the genesis and reciprocal transmutations of bodies are subjects so deep, that nothing concerning them should be determined from a slight similitude, or rude and imperfect experiments ; these being matters which are only to be established by the agreement of the most accurate analysis and synthesis. If we were at liberty to adapt observations, experiments, and the very nature of things, to preconceived theories, there would soon be an end to all the excellence and certainty of natural philosophy, and that science would be entirely overturned.

I shall, for the sake of connection, briefly relate the discoveries of these two very expert chymists ; but my chief labour shall be employed concerning those circumstances which they have either omitted, or touched upon but slightly.

§ II. *Preparation of Magnesia.*

This powder may be prepared in many different ways ; the most pure is that precipitated from Epsom salt : scarcely more than half the weight of alkali of tartar is requisite ; but as that salt is expensive,

five, pot-ashes are generally used : however, as these are commonly mixed with vitriolated tartar, and with filiceous earth, nearly an equal quantity is necessary : both the salts should be dissolved in at least a double quantity of pure water ; after filtration, they are to be mixed and boiled, then set to stand at rest, until a powder precipitates ; the clear water is then poured off, and fresh warm water added ; this again is to be poured off, and the operation repeated, until the precipitate is freed from all the heterogeneous matter, which can be washed away by water : finally, the whole residuum is to be dried upon a filter or a cloth.

100 parts of Epsom salt produce about 42 of aerated magnesia ; but only 25 of magnesia which does not effervesce with acids : this difference depends upon the precipitating alkali, as it is saturated with or deprived of aerial acid. In the former case, 58 parts of alkali are requisite ; in the latter, about 45 ;—the filtered liquor yields about 32 of vitriolated vegetable alkali.

The rationale of the operation is this :—the double portion of water, added to the two salts to be mixed, is not only sufficient to dissolve them, but also the vitriolated alkali which is generated by the mixture. The vitriolic acid of the Epsom salt attacks the alkali, and expels the aerial acid, if any be present, which unites intimately with the deserted magnesia : but the boiling prevents the
magnesia

magnesia from being dissolved in the water, by a superabundance of the aerial acid. By calculation, 58 parts of alkali of tartar contain about 13 of aerial acid; $10\frac{1}{2}$ of which are just sufficient to saturate 19 of pure magnesia; $2\frac{1}{2}$, therefore, are left to unite with the water: if this be equal or superior to 1,388 parts, (for, in a moderate heat, water can take up at least 0,0018 of its own weight), when thus saturated with aerial acid, therefore, it can take up nearly $\frac{1}{5}$ of the precipitate, (§ IV.): the menstruum, therefore, which diminishes the quantity of the mass required, being volatile, must be expelled by heat. At first sight, it cannot but appear very singular, that so much alkali is necessary to effect a complete precipitation; while, at the same time, not above 30 parts of vitriolated tartar are obtained, which contain at most but 17 parts of pure alkali: but we must in general take notice, that, to effect a complete decomposition, the quantity of a precipitant which would be sufficient to saturate the matter in a disengaged state, is by no means sufficient; triple, quadruple, nay sometimes sextuple the quantity, being necessary: besides, the alkali, which in this case is superabundant, renders the vitriolated tartar more soluble; so that the whole does not easily crystallize.

The last lixivia of nitre, and of common salt, which refuse to crystallize, contain magnesia, dissolved in nitrous or marine acid; and the magne-

fia is collected by precipitation, evaporation to dryness, and calcination: if it is obtained from nitrous acid, it is called magnesia of nitre, to which the name of pulvis fentinelli was formerly given;—that which is got from marine acid is called magnesia of common salt: the former always abounds in heterogeneous matter, particularly with lime; hence the nitrous lixivium yields more than four times the weight of powder which is obtained from the marine lixivium (*g*). The magnesia obtained by precipitation is very different from that obtained by calcination; as this latter can scarcely be entirely freed from marine acid; and besides we shall see hereafter the effect of the fire (§ III.).

§ III. *Pure Magnesia.*

Common magnesia, after having been exposed to a white heat, does not effervesce with any acid:

(*g*) 1 lb. of a nitrous ley affords, according to Spielman, 4 oz. of magnesia, by calcination, and 5 by precipitation. Margraaf, out of 1 lb. of marine ley, obtained 1 oz. $1\frac{1}{2}$ drachm, and 10 grains, by alkali of tartar, and by volatile alkali 1 oz.: when volatile alkali is used, a salt, consisting of three ingredients, is found in the liquor, viz. of magnesia, volatile alkali, and vitriolic acid, which cannot be separated by crystallization.—Hoffman, in the last ley of the salt-works at Hall, found magnesia.

the aerial acid being expelled by the fire. If the operation be properly conducted, 100 parts of magnesia will lose 55 of their weight: this loss is occasioned by the expulsion both of the water and the aerial acid. If the heat be violent, and long continued, a greater loss of weight is found to take place, as the violence of the fire is capable of dissipating some even of the fixed parts.

After proper calcination, I call the magnesia pure, because it is freed from water and aerial acid: but it can scarcely be obtained perfectly pure, except by means of the volatile alkali: for the fixed alkalis, when used as precipitants, adulterate the magnesia, frequently with lime, but always with siliceous earth; with which the alkali of tartar is found loaded, unless when crystallized: the mineral alkali, when properly reduced to crystals, is likewise free from siliceous earth. Calcined magnesia dissolves in all the acids but slowly, and without effervescence; and in this state requires about the same quantity of acid to saturate it as before the calcination; and forms, with the acids, the very same middle salts: it does not grow sensibly warm with water, nor does it dissolve in it like lime; it is therefore a true earth, so far as can be collected from experiments hitherto made.

100 parts of pure magnesia, steeped in water, after drying are found to have increased in weight more than 18; whereas 100 of magnesia, saturated

ted with aerial acid, take up 66 (§ iv.). The pure magnesia does not effervesce in acids, but in great length of time, in the open air, it recovers this property by attracting aerial acid from the atmosphere : why it dissolves so very slowly in acids we shall see in § XIX.

Pure magnesia cannot deprive any alkali, except the volatile, of its aerial acid, as acids have a stronger affinity to them than to magnesia. It does not precipitate lime-water, but it precipitates all metals, not excepting platina, from their solution in acids with it : nitrated silver yields a black precipitate, and corrosive sublimate one obscurely red. It also decomposes ammoniacal salts, but slowly ; so that at first there is scarce any perceptible odour ; but if the mixture be sufficiently moistened, and kept 24 hours in a close corked bottle, when the bottle is opened the volatile alkaline smell will be observed very unequivocally.

Magnesia exposed for a long time to a very intense heat, begins to coalesce, and shew signs of fusion, particularly the magnesia which is obtained from the lixivium by calcination. It flows easily with borax, or with the microcosmic salts : with equal parts of flint and borax it assumes the form of a beautiful glass like the topaz : with equal parts of flint and mineral fluor, a glass is produced of the colour of the chrysolite fused : with an equal weight of fluor mineral, it penetrates and dissolves the crucible.

Magnesia

Magnesia, mixed almost in any proportion with lime, pure clay, and flint, flows in the fire; and, with a quadruple proportion of green glass, forms a mass like porcelain, which gives fire with steel. —Even an equal weight of flint, of quick lime, of terra ponderosa, of glass, of lead, of alkali of tartar, and finally of vitriolated tartar, will not flow alone with magnesia; but common clay runs with it into an hard mass.

Glass cemented in magnesia resembles porcelain (*h*).

§ IV. *Aerated Magnesia.*

That magnesia which is saturated with aerial acid I call aerated magnesia, because it contains that acid which abounds in the atmospheric air: such is that which is precipitated by a crystallized fixed alkali (§ II.); this effervesces in acids, and by a slow saturation loses 0,25 of its weight; the

(*h*) M. Morveau here relates an experiment, in which he exposed magnesia, and at the same time calcareous earth, to a violent heat: the former shewed no signs of fusion, nor did it even adhere to the crucible; the calcareous earth was fused along with part of the bottom of the crucible. He had before asserted that magnesia was one of the most fusible earths *per se*, and promoted very much the fusion of other earths;—an opinion he now retracts. Macquer and d'Arcet had before shewn the refractoriness of this earth. B.

substance, of which the expulsion occasions this loss, being collected by a proper apparatus, and examined, is found to possess all the qualities of aerial acid. Hence it follows, that 100 parts of aerated magnesia contain 25 of that acid, 30 of water, and 45 of an earthy matter distinct from all others hitherto known (§ III. and XIX.). Magnesia, fully aerated, contains 30 lb. in 100 of aerial acid: it is therefore in reality a medial earthy salt, of which (when completely crystallized) a kanne of distilled water, in a moderate heat, takes up 47 grains. Water saturated with aerial acid dissolves a far greater quantity, even so far as an ounce and a quarter; provided the water, loaded with abundance of the acid, meets the magnesia minutely divided, as in the moment of precipitation, as it is in that state more exposed to the action of the surrounding menstruum. A solution of this sort in the open air is gradually deprived of its superabundant acid, which flies off, and thence a portion of magnesia, which had been dissolved, must separate; this takes place first upon the surface, as it is there the volatile menstruum first begins to be deficient. The pellicle which is formed, on examination is found to possess the properties not of lime, but of magnesia.

Evaporation being conducted leisurely, crystals also appear, partly consisting of pellucid grains, partly of fasciculi of rays diverging from the same point

point (i). Distilled water, aerated, and saturated with magnesia, exhibits the following properties with precipitants.

(A) It makes paper weakly tinged with turnsole more distinctly blue; paper stained red by Brazil wood it makes blue; and induces a light brown upon the yellow of turmeric: so that at first we should ascribe these changes to an alkaline mixture, which adhered in the precipitation, and had eluded the washing; but this suspicion soon falls to the ground, if we employ magnesia precipitated with volatile alkali, as this alkali produces the same changes of colour; but we must observe these changes quickly disappear, together with the volatile substance which has occasioned them; whereas those made by magnesia, although precipitated by this alkali, are permanent; they therefore depend upon the earth alone.

(B) Upon the addition of acids, innumerable bubbles, extremely thin, float on the surface; these are occasioned by the aerial expelled by the stronger acids.

(C) Aerated fixed alkali occasions no change, unless the quantity of water be insufficient for dissolving the magnesia and the alkali both together; in which case the former is separated: but if a pure caustic alkali be employed in proper quantity, the earth is immediately precipitated pure, i. e.

(i) Tab. 1. fig. 8.

incapable of effervescing with acids (§ III.). These alkalis are therefore capable of separating aerial acid from magnesia.

Lime (which in its peculiar properties bears some analogy to fixed alkalis) in this case has the very same effects as fixed alkali; when saturated with aerial acid it occasions no change, but lime-water or quick lime precipitates the magnesia pure.

The aerial acid adheres more readily to magnesia than to the volatile alkali; for if the former, when caustic, be added to the latter, and kept in a close vessel for some days, at length the alkali is found caustic, and the magnesia will effervesce with acids. Another experiment seems indeed to overturn this; for magnesia dissolved in water by means of aerial acid, is precipitated by pure volatile alkali: but it is to be observed, that here the precipitate effervesces with acids, so that the alkali has taken away none but the superabundant aerial acid; and the portion of magnesia, which was only held dissolved by the superabundance, necessarily falls to the bottom.

(D) All the middle salts, whether earthy or metallic, are precipitated by aerated magnesia, and that by means of a double elective attraction, as pure magnesia has not that effect. By this method lime and terra ponderosa, dissolved in other acids, are thrown down; for while their menstrua seize the magnesia they themselves fall to the bottom, united with the aerial acid, as appears from the

the increase of their weight, and their property of effervescing with acids.

The precipitates occasioned by pure magnesia gain no increase of weight, and, if they be metallic, assume colours different from those of the precipitates occasioned by aerated magnesia: the latter separates corrosive sublimate of a darker colour, but after a few hours the colour of both precipitates is a reddish ash-colour.

If to aerated magnesia, dissolved in water, be added a solution of corrosive sublimate, the mixture grows a little milky, and by degrees deposits a quantity of white sediment; then by little and little, first upon the surface, and afterwards at the bottom, thin blackish crystals concrete, composed of mercurius dulcis, and calx of mercury partly aerated.

The smallest drop of solution of mercury, in boiling nitrous acid, is instantly and copiously thrown down of a brownish yellow colour, by water loaded with magnesia, by means of aerial acid: but the solution of the same metal, made in the cold, yields a white powder, which, after a few days, grows greyish; this happens because the metal has lost little of its phlogiston.

§ v. *Vitriolated Magnesia.*

Vitriolated magnesia is called English salt, Epsom salt, Seydlitz or Seydschutz salt, deriving a

name from the place whence it comes; but these all differ very little from each other, except in the proportion of salited magnesia which they contain mixed with them. On account of its taste it is vulgarly called bitter purging salt; but it is with more propriety called, from its nature, vitriolated magnesia, especially when it is free from heterogeneous matters:—in crystallizing, it exhibits quadrangular prisms, with pyramidal apices, which are also quadrangular.

This salt is so easily soluble, that a kanne of distilled water, in a moderate heat, can take up $70\frac{1}{2}$ ounces, but by boiling 140, before a pellicle appears; yet this last solution, when exposed to cold, concretes totally.—The bulk of the water is increased about 0,45, by the addition of the salt, and the heat of boiling; a circumstance which ought to be taken particular notice of in determining the quantity of it; for in general the quantity of water is determined by the measure of the solution, which is always fallacious. If regular crystals are required, the evaporation must only be continued until a drop let fall on a cold surface concretes in a few minutes.

This salt, exposed to a dry air, first loses its transparency, and at length falls into a white powder: by complete calcination all the water of crystallization flies away; this water forms nearly one half of the whole, amounting to 0,48: hence therefore it appears, that 100 parts contain 19 of
pure

pure magnesia, 33 of vitriolic acid, and 48 of water (§ III).

Fixed alkali quickly precipitates it, as well as the volatile alkali when aerated, nay even that which is commonly considered as pure. This last case seems to indicate a doubt with respect to the degree of affinity:—as pure magnesia, added to a solution of that salt which is called secret ammoniac, and kept for some days in a bottle closely stopped, discovers, upon opening the bottle, a distinct odour of volatile alkali: this precipitation may be attributed to other causes. Thus the volatile alkali can scarcely be procured perfectly pure, being either adulterated with water or aerial acid: besides, the purest, when exposed ever so little to the open air, or to air newly expelled from the lungs, instantly attracts a portion of that acid; and thus, by a double elective attraction, acquires the property of being decomposed: yet the precipitate occasioned by the volatile alkali generally exhibits, on solution, very slight marks of effervescence: this the love of truth obliges me to confess; so that if this precipitation be owing to the aerial acid, it is evident that a much smaller quantity of it suffices for this purpose than for saturation: but these causes are accidental; there is one, however, which is constant, *v. g.* the volatile alkali is very strongly united with magnesia and vitriolic acid; now in this triple salt the acid, formerly entirely attached to the magnesia, must

be divided in a certain ratio between the two; and hence the magnesia, which does not enter into this new union, is separated, and falls to the bottom.

Lime-water separates magnesia from the vitriolic acid, although crude or aerated lime has no effect; hence it evidently appears how much the efficacy of this substance is affected merely by an union with aerial acid.

The acid of sugar, added in proper quantity, takes away the whole earthy basis from the vitriolic acid, and precipitates it to the bottom in the form of a white powder, especially if the solution be inspissated by gentle evaporation; for otherwise, by means of the superabundant acid, the greater part is held suspended.

In the same manner the vitriolic (which in power of attraction is among the strongest) yields magnesia to the fluor acid: at first a very small sediment falls, but during evaporation the fluored magnesia by degrees appears; in this case, however, heat must be carefully avoided, as by it the more volatile of the menstrua are much weakened. The vitriolic acid is also expelled by the acid of phosphorus, at least when the watery part is sufficiently diminished by evaporation; spirit of wine coagulates the mixture in the same manner as it does with phosphorated magnesia.

Rectified spirit of wine does not take up vitriolated magnesia, which may by it, therefore, be separated

separated from water. In proportion as the solution is more saturated, and the spirit more pure, the coagulation happens more quickly; so that in a few minutes the whole mixture will concrete into a solid mass.

The Seydlitz, Seydschutz, or Epsom salts (*k*) are got by evaporation from the water of fountains, in the places from whence they borrow their names. These waters contain other substances, and from hence, exclusive of the difference in exsiccation, the salts vary; hence the Seydlitz salt scarcely attracts moisture from the air. The Epsom or English salt is prepared from sea-water, after the crystallizations of the common salt, by boiling, and by adding colcothar of vitriol, which contains a portion of acid; this acid, quitting the iron, unites with the magnesia, and produces a crystallizable bitter salt. That which comes to us under the form of crystalline aciculæ contains so much salited magnesia, either united with the water of crystallization or adhering externally, that it easily deliquesces by the moisture of the

(*k*) The Epsom salt was first noticed by Grew in 1675; but as only a much smaller quantity than was used could be got from springs, chymists anxiously sought for an artificial mode of composing it. Hankwitz prepared it at London, from common salt, or the last ley of this and calcined vitriol, Eph. N. C. cent. 3. and 4. Others found it in different springs: Bertrams, in those at Creutzburg; Gehrardten in those at Oberneusultz, &c.

air. The crystals of this salt are sometimes so large that they are sold for Glauber's salt; and on the other hand, in France, Glauber's salt, being reduced to small spiculæ, by agitating it during the crystallization, is sold for Epsom salt.

These frauds are indeed of little consequence, yet they throw a veil over the truth, and are not easily discovered. Thus, lime water does not precipitate genuine Glauber's salt; but Epsom salt instantly yields up its acid to the lime, and a selenites, together with the deserted magnesia, falls to the bottom.

Vitriolated magnesia does not give up its acid on distillation.

Phlogisticated vitriolic acid also dissolves magnesia; but the middle salt, arising from this combination, is easily distinguished from Epsom salt by its taste; it also yields smaller crystals, and, upon the addition of any acid, even vinegar, it gives out a pungent and suffocating vapour: it is separated from water by spirit of wine, although, by the accession of phlogiston, it should seem to approach nearer to that inflammable menstruum.

§ VI. *Nitrated Magnesia.*

The nitrous acid, saturated with magnesia, after proper evaporation, yields prismatic, quadrangular, spathous crystals, without apices; these possess an acrid, and, at the same time, an exceeding

ceeding bitter taste, and easily deliquesce in the air: if paper be moistened with a dilute solution of it, after drying, it burns with a green flame; which colour aqua fortis alone, in the same way, frequently exhibits.

The acids of fluor, of sugar, of phosphorus, and vitriol, take away magnesia from the nitrous, a circumstance which yet escapes observation, for these new combinations are soluble in nitrous acid; they may, however, be brought into view either by evaporation, or by dropping in highly rectified spirit of wine, as this, by absorbing the water, precipitates the salts.

Nitrated magnesia yields its acid on distillation; it dissolves completely in spirit of wine: in this case, however, its flame is not green, but becomes larger and more vivid than before.

Phlogisticated nitrous acid saturated with magnesia, betrays itself by its taste, and, on the addition of any, even the vegetable acid, by its smell; but these principles are scarcely separated by the phlogisticated vitriolic acid; at least the addition of rectified spirit of wine occasions no coagulation (*l*).

(*l*) "Lime-water decomposes nitrated magnesia. In a memoir on the treatment of the mother leys of nitre, I have pointed out this process as very advantageous, not only for completing the analysis of them, but also for separating magnesia from calcareous earth, at small expence."

Morveau.

§ VII. *Salited Magnesia.*

Magnesia, dissolved in marine acid, has an exceeding bitter taste, and cannot be crystallized, unless, after being much inspissated by heat, it be exposed suddenly to extreme cold; but the aciculæ which concrete upon this occasion soon deliquesce by the moisture of the atmosphere. While the marine acid dissolves magnesia, its transparency is somewhat obscured; and when the saturation is finished, the solution quickly concretes into a jelly of a watery colour; which, if diluted while warm, yields spongy masses, not soluble even in marine acid: a jelly of this sort is produced by the acids of nitre, of ants, of vinegar, and others, but does not appear in the filtered solutions; for the moisture being in a great measure dissipated, these yield a viscid matter like gum, which, when well washed, is found to be siliceous (§ xv.) owing to the impurity of the precipitating alkali.

If aerated magnesia be employed, the aerial acid which is separated is partly absorbed by the water, which, by this means, takes up a portion of the magnesia without any other assistance: hence, when the solution is finished, it changes vegetable colours like an alkali (§ 1 v. A.); which is true not only of the solution made by marine acid, but of all others, unless the acid solvent be superabundant.

superabundant. If, therefore, an exact saturation be required, it is more easily had by pure magnesia; for if aerated, in order to answer the end, an accuracy extremely troublesome is requisite; for either the superfluous aerial acid must be expelled, or the saturation must be determined by repeated trials.

Salited magnesia dissolves in spirit of wine, and is subject to the same laws of affinity as the nitrated, except that this is soluble in nitrous acid; for on adding that acid, and evaporating, nitrated magnesia is formed; besides, the acid of ants unites intimately with salited magnesia, forming a crystallizable salt compounded of three ingredients: this combination yields its acid to a distilling heat.

§ VIII. *Fluorated Magnesia.*

The fluor acid (*m*) at first violently attacks magnesia; but as the saturation approaches, certain particles, almost insoluble, are separated; and at length, when the saturation is complete, the water, which hardly dissolves the fluorated magnesia, lets fall at once all that the superabundant acid had taken up.

(*m*) This acid was described by its experienced inventor Mr Scheele, in the Stockholm Transf. for 1771.

That

That portion which can be dissolved by means of abundance of acid, on spontaneous evaporation concretes above the liquor to the sides of the vessel, in the form of a transparent mucilage, marked with long and very slender crystalline threads; but at the bottom we find spathose crystals, which, though not easily dissolved, are yet not entirely rejected by spirit of wine. Their form is hexangular prisms, ending in a low pyramid composed of three rhombi.

Neither vitriolic, nor any other acid, decomposes fluorated magnesia by the humid way: this combination, when alone, and pure, does not yield its acid in the most intense heat of distillation.

§ IX. *Arsenicated Magnesia.*

The acid of arsenic (*n*), united to saturation with magnesia, is with much difficulty soluble in water; and therefore, like the former combination, the whole subsides, and is again dissolved, if superabundance of acid be added: upon evaporation it then yields no crystals, but a viscid mass like gum, which is not precipitated by spirit of wine; yet it is worth observing, that the acid of arsenic, added to acetated magnesia, which like-

(*n*) This acid will be soon described by Mr Scheele, in the Stockholm Transf. See Diff. XXI. vol. ii.

wise forms nothing but a viscid mass (§ XIII.) produces elegant prismatic crystals, which may be called solar, as many of them diverge like rays from a point; the reason is doubtless this:—the acid of arsenic, unless when superabundant, cannot suspend the magnesia, but all superfluous acid impedes crystallization; now the acetic acid dissolves the arsenicated magnesia, and suffers it to concrete into crystals by a slow evaporation; and the same thing takes place, if the acetic acid be expelled from the magnesia by the acid of arsenic: these crystals, in a long continued heat, calcine so far as to grow opaque and white. What has been now said of vinegar holds with respect to nitrous acid, marine, and the acid of ants; by all which arsenicated magnesia is not decomposed, but dissolved, and yields solar crystals: this seems to afford a method of crystallizing salts which are difficultly soluble (§ X. XV.); viz. let the water be sharpened with some suitable acid, which will not alter the salt required (o).

The

(o) This process opens a new field for observations; it will be useful on many occasions: but I doubt whether a pure salt can be by these means obtained; the supposition appears repugnant to the general and constant laws of solution; for a crystallizing body always, of necessity, retains a portion of the dissolving fluid; this, in the salts, is called the water of crystallization: and if vinegar here performs the office of water must not the salt retain the vinegar of crystallization? This case is different from the precipitation

The fluor acid, the acid of sugar, of phosphorus, and vitriol, separate magnesia from the acid of arsenic; but the acid of tartar, united with arsenicated magnesia, is generally found to compose a triple salt.

This salt is not decomposed by fire, unless with the addition of phlogiston; in which case the acid intimately united with it generates a regulus.

§ x. *Boraxated Magnesia.*

The saline substance which in borax is united to the mineral alkali, and is called the sedative salt by Homberg, shews, upon examination, un-

precipitation of salts by spirit of wine, which is only a sudden absorption of the water, and requires that the salt should not be soluble in the added liquid: on the contrary, we are forced to admit a real affinity of the fluid with the salt, a gradual approximation not of the salt only, but of the integrant parts of the solution itself, in consequence of the evaporation of the superabundant portion of the solvent; it is therefore impossible that this adhesion of the principles should cease suddenly, without any new cause supervening; or that the salt, thus abandoned, should assume a regular form. To object the uniformity of crystals produced in this manner in different acids, is in vain: that the two principles constantly existing in these combinations should, with respect to crystallization, be endowed with properties that a third cannot destroy, is, I think, much more probable; it is certainly not without example, even in the simple salts. Morveau.

doubted

doubted though weak marks of an acid nature, it even attacks some metals, &c.

If magnesia be put into a solution of this, it will be dissolved, though very slowly, on account of the weakness of the menstruum. On evaporation irregular crystalline grains appear: the principle of connection in these being very weak, they may be separated in the humid way by other acids; even spirit of wine separates them, but takes up a part of the acid: vinegar and acid of ants dissolve this salt entirely; and, when the moisture is dissipated, it appears in the form of spiculæ, on which others stand at right angles: it flows in the fire, and that without any decomposition; nay, the acid of borax expels from magnesia, by the assistance of heat, all the acids which are volatilized by heat.

§ XI. *Saccharated Magnesia.*

The peculiar acid which resides in sugar has already been described, together with the best method of obtaining it pure: this dissolves magnesia, and holds a great quantity of it suspended; but when saturated, it falls to the bottom, refusing to unite with water, which has already been observed in other instances (§ VIII. IX.): it is scarcely soluble in spirit of wine.

The fluor acid alone is capable of taking magnesia from acid of sugar by the humid way.

This salt, when ignited, sends forth all its acid;

nor does it shew any vestiges of a coal, as the tartarified magnesia does, as we shall see in the following section.

§ XII. *Tartarified Magnesia.*

The genuine (*p*) acid of tartar takes up magnesia in the very same way as the former acid; and the portion which is suspended by a superabundant acid falls by evaporation in polygonal transparent grains, resembling short hexangular prisms truncated at both ends, and more or less irregular: spirit of wine with difficulty attacks this salt; and therefore, when added to a solution of it in water, immediately throws down crystalline grains.

The acids of fluor, sugar, phosphorus, vitriol, nitre, and salt, decompose tartarified magnesia.

This salt readily melts in the fire, boils, swells, and yields a coal, which, when burned, at length leaves the magnesia free.

§ XIII. *Acetated Magnesia.*

Vinegar, though loaded to saturation with magnesia, yet dissolves readily in water: however evaporation be conducted, no crystals are obtained; but at length a viscid deliquescent mass appears,

(*p*) See the Stockholm Transf. for 1770.

which parts with the vinegar on distillation. Spirit of wine may be completely mixed with this saline liquor.

All the acids, except phlogisticated vitriolic and nitrous acids, and the aerial acid, decompose acetated magnesia.

§ XIV. *Formicated Magnesia.*

The acid of ants, when saturated with magnesia, quits the water, and falls to the bottom: this is again soluble in superabundant acid, and deposits crystals upon evaporation, which are very difficultly soluble in water, are void of taste, do not melt in the fire, but swell and decrepitate a little, soon grow black, and split at length into a white powder, which effervesces with acids; because the acid of ants, when it is destroyed, yields aerial acid to the magnesia: the figure of the crystals is hemispheric, the cutting plane being oblique, a little concave, polished, with striæ (which are scarce distinguishable by a glass) diverging from a center very like the tubercles of liverwort: hence the acid of ants is readily distinguished from vinegar, to which, in other respects, it is very like; it, as well as phlogisticated vitriolic and nitrous acid, takes away magnesia from the acid of ants: one half the weight of this salt is magnesia; one part of it requires thirteen of water to dissolve it

in a moderate heat : spirit of wine does not take it up (q).

§ xv. *Phosphorated Magnesia.*

The acid of phosphorus takes up magnesia almost in the same way as the former; but that which is taken up by a superabundant acid, as soon as evaporation begins, yields crystalline grains, which are somewhat larger in acetated magnesia when the acid of phosphorus has been previously added; and that for the reason assigned (§ ix.); at length, however, the whole liquor falls into a viscid mass.

By the humid way the acid of phosphorus takes away magnesia from all the acids, except the fluor acid and acid of sugar—by the dry way all the volatile acids are expelled.

A solution of phosphorated magnesia grows cloudy upon the addition of spirit of wine; but when the spirit is dissipated by evaporation, the clouds again disappear.

In general, it is proper to observe, that solutions of common magnesia, in all the acids, are of an opal colour, occasioned by filiceous atoms which remain upon the filter; but, when

(q) If the smallest quantity of calcareous earth be mixed with magnesia, sparry crystals are formed, which effloresce in the air. See J. Afzelius on the Acid of Ants.

that

that operation is neglected, fall by degrees to the bottom, and concrete into a gelatinous mass (§ III.).

§ XVI. *Whether Magnesia be soluble in alkaline Salts.*

Some bodies are of such a nature, that they possess an attraction both for acids and alkaline menstrua. Among these it will be sufficient to mention copper, which is dissolved, not only by acids, but by alkali, especially the volatile, which forms with this metal a crystallizable salt; it has been properly enough doubted, whether magnesia was one of this kind of bodies. Margraaf, in the precipitation of magnesia, cautions us against the use of too much alkali, particularly the mineral and volatile, as these again diminish the quantity of precipitate which had been before thrown down: with that noble candour with which this illustrious man always relates his experiments, he confesses, at the same time, that he could not effect a direct solution, although some bubbles appeared, which seemed to indicate some kind of action in the menstruum. In this very business all my labour, too, was in vain; but we now know that the earth, after having been thrown down, may again disappear by another medium, viz. aerial acid (§ II.). To this, therefore, and not to the sole action of the alkali, are we to attribute this phenomenon; especially

as the circumstances attending it agree exactly with the nature of the alkalis; for, in the same weight, volatile alkali contains more aerial acid than the fixed mineral; and the vegetable least of all (r).

§ XVII. *Magnesia dissolves Sulphur.*

Magnesia attacks sulphur both by the dry and the humid way; but the connection of these substances is so loose, that they soon separate in the open air. Let $\frac{2}{3}$ of a bottle, containing a pound, be filled with distilled water; let a handful of magnesia, and as much flower of sulphur, be put in; let the air included above the liquor be rarefied by heat, and the bottle then shut close; let it be then kept in balneo mariæ for some hours; and, after cooling sufficiently, when the orifice is opened, a manifest hepatic odour strikes the nostrils; but the water itself, when filtered, yields, with a lixivium of fixed alkali, a sediment, which is soluble in acids. With solution of silver, it grows black and turbid; as also with saccharum saturni: on spontaneous evaporation, the bottom of the vessel is, at length, found covered with a pellicle, interspersed with crystalline aciculæ, which dissolve with effervescence in acids, except a greyish powder, which, thrown on live coals, gives out a ful-

(r) See Dissertation I. § viii.

phureous smell, but no flame; which undoubtedly arises from hence, that the sulphur is impure, being enveloped with saline particles.

§ XVIII. *Elective Attractions of Magnesia.*

The phænomena above related, point out the following order of elective attractions, in the humid way, viz. first fluor acid (§ x.—xv.); acid of sugar (viii. xi. xv.); phosphoric acid (xi. xv. v.); vitriolic acid (xv. v. ix.); arsenical acid (ix. v. vi.); nitrous acid (ix. vi. vii.); marine acid (vi. vii. xii.); acid of tartar (vii. xii. x.); acid of ants (x. xiv. xiii.); acetous acid (xiv. xiii. vi.); acid of borax (xii. x. xiv.); phlogisticated vitriolic acid (vi. v.); phlogisticated nitrous acid (xiii. vi. v.); aerial acid (iv.); water (iii.); and sulphur (xvii.).

In the dry way, the order is different; for in this the more fixed, though weaker acid, by means of the heat, overpowers the volatile, tho' stronger. Let m denote any substance attracted by two menstrea; the stronger, in a moderate heat, by the elective attraction A , the weaker by the elective attraction a ; let us then suppose the first more volatile in the fire, and denote its nifus to rise by v , and the nifus of the other by v : it now appears, that m is attracted by a force $= A - a$; but let the heat be continually increased, and this force will be continually changed. Now,

since v increases more than v , at length $A - a$ will be $= v - v$; but when the fire is further increased, the equilibrium will be destroyed, and the menstruum, which was before weaker, will prevail. The case will be more simple, if we suppose the weaker menstruum entirely fixed, that is $v = 0$. In the Treatise on Elective Attraction, we shall examine more minutely how fire encreases the volatility of bodies.

Hence the acids which are fixed, such as those of phosphorus, arsenic, and borax, are found to prevail over all others; and from experiments the foregoing table is to be altered in the following manner, viz. acid of phosphorus, of arsenic, of borax, vitriolic acid, acid of sugar, nitrous acid, marine acid, acid of fluor, of ants, of vinegar, phlogisticated vitriolic and nitrous acids, and, last, aerial acid. The acid of tartar has no place here, as it is destroyed by a sufficient degree of fire.

§ XIX. *Magnesia differs from Lime.*

Magnesia and lime agree in this respect, that they both dissolve in acids, with effervescence; yet terra ponderosa and aerated alkaline salts possess the very same property; a circumstance which indicates no more than the presence of aerial acid in all of them. But if they are examined more closely, we shall find a remarkable dissimilitude; the

the particulars of which we shall briefly relate, that the true nature of magnesia may be better and more distinctly known.

Water takes up aerated magnesia (not aerated lime). Magnesia, after a sufficient calcination, is rendered insoluble, (lime soluble). Pure magnesia makes none but the volatile alkali caustic, (lime imparts causticity also to fixed alkali). Magnesia, when saturated with vitriolic acid, constitutes a bitter salt, soluble in about an equal weight of water, (lime yields a selenite almost insipid, one part of which requires more than 400 of water). Magnesia, with nitrous acid, produces a crystallizable salt, (nitrated lime can scarcely be brought to crystallize). Magnesia, with marine acid, forms a liquor, which, on distillation, easily loses the menstruum, (lime does not). Magnesia, with vinegar, refuses to crystallize, (lime exhibits several singular vegetations). Magnesia is not thrown down from other acids by vitriolic acid, (lime produces gypsum, which instantly falls to the bottom). Magnesia attracts the fluor acid, in preference to all others, then the acid of sugar, and the rest as above described, (lime effects the same menstrua in a very different order). There are many other circumstances already mentioned, which, compared with the known properties of lime, will evidently shew the difference.

So great and so constant is the difference, that these substances ought no more to be confounded.

As

As the magnesia obtained from the nitrous lixivium is almost always mixed with lime, in accurate examination this impure earth should not be employed: whoever wishes, then, to examine the true nature of magnesia, should employ the base of the sal amarus, as that, if rightly prepared, will never deceive him.

But it has been suggested, that magnesia is lime altered, putting on, *pro re nata*, now the shape of lime, now entirely putting it off; it is scarcely possible, that the same substance should acquire properties so different: in the mean time, while we are only speaking of possibility, we can say no more than that, as yet, chymistry labours under so great imperfection, that it cannot, *a priori*, determine whether or not the powers of nature be sufficient to effect such a metamorphosis; but we must not, from a bare or distant possibility, believe the real existence of transformation.

The expert are not disturbed by vague assertions. Accurate experiments, both analytic and synthetic, and these accurately employed, at all times and in all places afford the same results: the vitriolic acid, saturated with lime, produces gypsum; with magnesia the sal amarus, and that constantly. In order to obtain gypsum from lime-water, we need no other artifice than a perfect saturation: if the acid menstruum is superabundant, gypsum is indeed produced, but so much penetrated

netrated by the acid, as to deliquiate in the air, to preserve its polish long in the fire, and to flow very readily; but if this acid be superfluous, or saturated or separated by means of spirit of wine, a true gypsum appears; which will hereafter be seen, when we examine lime. Varieties, occasioned by the abundance or deficiency of a proximate principle, cannot properly be called transmutations;—the vitriolic acid remains truly and totally, in itself, unchanged; the same may be said of lime; although, according to the variety of quantity in each, they may both be varied three different ways: for either they are both saturated, or the acid abounds, or it is deficient; in each of these cases a true gypsum is produced; but in the second case it is loaded with a disengaged acid; in the third, with a lime not dissolved; and hence its nature and properties must be more or less obscured: that this is the case is evident; and besides, these two principles may be again separated in all respects the same as they had been before their union; a circumstance which does not agree with a real transmutation; at least, if the meaning of that word be extended so far, it will apply to all the neutral and middle salts.

At the time when men were ignorant of the true preparation of Epsom salt, various opinions were entertained upon that subject; and among others, it was thought, that lime, first dissolved in marine acid, then precipitated by vitriolic acid, filtered,

filtered, and evaporated to a pellicle, would yield true Epfom falt. But whoever tries the experiment will soon find, that the precipitate first thrown down, and the aciculæ after, when washed in spirit of wine, are no other than perfect gypfum: this, on account of its being but just made, and therefore not yet deprived of the adhering liquor, has a taste acid, and somewhat bitter, partly occasioned by the marine acid still disengaged, and partly from the lime: but if, by means of filtration through paper, or, which is better, by spirit of wine, it be deprived of its liquor, it shews all the properties of genuine gypfum, unless magnesia be mixed with the lime, as we shall afterwards see (§ xx.). In this case, therefore, there is no real transmutation; which, if it took place, would undoubtedly prevent the production of the smallest particle of vitriolated magnesia.

Nor shall we succeed better, if, according to the directions of others, lime precipitated from nitrous or marine acid be moistened, and afterwards exposed to calcination, with ever so great caution: certainly, by this method, nothing more can be had than lime more or less impregnated with the acid, in proportion as the degree of heat has been less or greater.

Magnesia, precipitated by an alkaline salt from lixivium of nitre, is readily dissolved in vitriolic acid, yielding that salt which goes by the name
of

of Epsom salt ; but that which is got by evaporation and calcination neither effervesces, nor seems to be diminished in that menstruum.—Hence magnesia is supposed to be transformed into lime by means of fire ; but the true reason of the phenomenon is very different :—the acid attacks calcined magnesia, indeed, but very slowly ; for the part of the menstruum which lies next round it, becoming specifically heavier, sinks to the bottom, preventing the access of the disengaged acid ; by degrees, however, the acid penetrates ; so that if a sufficient quantity be added, it will at length take up the whole of the magnesia, which is not the case with lime : an intestine motion of the liquor accelerates all solutions ; and hence it is that aerated magnesia quickly vanishes ; for the aerial acid, being expelled by the stronger acid, breaks forth in innumerable bubbles, which agitate and displace the several particles, so that the acid is perpetually in contact with the magnesia : for the same reason calcined lime and terra ponderosa are dissolved more slowly than when they are aerated.

Others contend that magnesia is generated from clay, by means of vitriolic acid ; and this I will readily grant to be the case, provided any one can shew a method by which pure clay can be thus changed ;—conjectures and opinions should depend upon or be formed by experiments. With vitriolic acid they obtain from common clay the
earth

earth of alum, which being afterwards mechanically and carefully mixed with filiceous earth, again regenerates common clay (s). From what has been said it appears, that magnesia is an earth distinct from all others, whether simple or compound we will not take upon us to decide; the same is also true of lime: but as in all the experiments hitherto instituted they preserve constant properties, and are never decomposed, they ought to be reckoned among the simple bodies, until a faithful analysis, confirmed by a proper synthesis, reveal their origin. That man will certainly deserve well of the science of chymistry who shall shew, not by forged opinions, but by undoubted experiments (which, at all times and in all places, will stand the most rigorous test) that magnesia owes its origin to lime or clay.

§ XX. *In what State Magnesia occurs upon the Surface of the Earth.*

Magnesia is less common than other primitive earths; or, to speak more properly, it is so mixed

(s) See Margraaf, vol. ii. p. 49. he concludes "this earth is neither calcareous nor aluminous;"—p. 10. and 11. he says, "the objections of a certain chymist on this subject are so trifling, that to answer them would be loss of time: I shall only say, that clay may be recomposed just the same as before, by putting together its constituent parts; wherefore no transmutation is produced by the vitriolic acid, nor any new substance produced during the operation."

with

with other matters, that it can neither be immediately distinguished, nor often freed from heterogeneous matters, without the help of acid menstrua. Magnesia, as well as clay, is an exceeding fine light and spongy earth, and therefore the very purest of them, buried in the earth, must necessarily be soon mixed with heterogeneous particles. Magnesia, lime, terra ponderosa, clay, and flint, if reduced to a fine powder, and ground together, along with water, cannot afterwards be separated from each other but by fit menstrua. It would however be highly absurd to deny that these substances are contained in their perfect state in the mixture; and to assert, that they are produced by the action of acids.

All these (except the last, which refuses to unite with ordinary acids) though dissolved and precipitated 30 times, were yet found absolutely unchanged: the only variety which occurred was with respect to the three first, which appeared caustic or mild, according as the precipitating alkali had been either aerated or pure: besides, not one of these five earths could, by means of any menstruum hitherto tried, be actually transmuted into another; so that, consistently with the rules of right reasoning, we cannot deny the existence of magnesia, although it is often so enveloped in heterogeneous matter that it cannot be extricated without the help of acid menstrua. In many bitter waters we find magnesia combined with vitriolic acid;

acid; and the celebrated Monnet has lately discovered a schist which, when roasted and elixated, yields a true *sal amarus*, such as occurs in our aluminous schist (*t*), though in small quantity.

At the silver mine of Salberg, upon the surface of the great masses which are annually heaped up for the purpose of separating the ore by washing, is found a crust which, when examined, is often found to contain 65 lb. in the cwt, of *sal amarus*; for the matrix consists of calcareous earth, which, besides siliceous atoms, contains magnesia sometimes mixed; but there are also present grains of pyrites, which, by spontaneous calcination, form with the calcareous earth gypsum, and with the magnesia *sal amarus*.

It is found united with nitrous acid in all nitrous earth, and with marine acid in great quantity in salt springs, and in the water of the ocean; and it is this which occasions the disagreeable bitter taste.

It is found in the very same state in which we have it in the shops, in various mineral waters, as Pyrmont, Spa, and Seltzer, destitute of every acid except the aerial.—Let me ask, what acid it is that forms it in this case; as we see it can be separated merely by evaporation?

Mixed with certain clays, with lime, and siliceous powder, it forms a singular variety of marl.

(*t*) Diff. IX. of the Preparation of Alum.

It

It is found in the terra lemnia, combined with clay, flint, and martial earth; it also enters into the composition of various stones; with flint it is united in the flintite and serpentinum; with flint and lime in asbestos; with flint and clay in mica.—It is also hidden in calcareous stones which have been long buried in the sea, consisting of impalpable particles; and in many others not yet sufficiently examined.

Garnets alone never form entire mountains; yet we cannot from thence doubt of their existence.—The same may be said of pure quartz, and others.

Therefore, although no one has yet seen thick strata, or huge heaps of magnesia, yet it is formed in a perfect state upon the surface of the earth; and the chymical analysis of earths and stones discovers it, partly mixed mechanically with other matters, partly dissolved;—neither its quantity nor bulk can change the nature of the thing itself: we are forced to give up such transmutations, as not only being fallacious, and not founded upon sufficient experiments, but as contradicting each other:—for some pretend that magnesia is produced from lime, others from clay, a third from the earth of alum, and, what is observable, that this may be done by the vitriolic acid. But we are not enquiring what may possibly be done, being intent on discovering what plain experiments shew to have been actually done.

§ XXI. *The Uses of Magnesia.*

Magnesia has hitherto been only used in the apothecary's shop; and it acts in a different way, according as it is crude, or calcined, or combined with an acid:—when crude it destroys acidities in the *primæ viæ*, but at the same time giving out its aerial acid, occasions in some persons considerable inconveniencies (*v*). It accelerates the putrefaction of flesh more than chalk, crabs claws, or the other testaceous powders; but retards that of the bile (*u*).

Half the dose of calcined magnesia equally opens the bowels, and destroys acidity, and that without any inconvenience. It not only preserves flesh long, but in a singular manner restores bile already corrupted: taken in equal proportions, with camphor, opium, guaiacum, storax, mastic, assafoetida, myrrh, scammony, and other gum-resins or pure resins, and triturated with water, it yields very useful tinctures; for upon filtration they appear clear and saturated, without any thing caustic, as calcined magnesia refuses to dissolve:

(*v*) Quandoque flatulentias et morificationes in imo ventris relinquit, si frequentius in usum trahitur, primaque regio, progignendis corrosivis succis, ut in hypochondriacis fieri solet, exposita est.

(*u*) Henry on Magnesia.

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but these tinctures must be only made when wanted.

Every one knows the cathartic use of vitriolated magnesia.

The use of magnesia in rural œconomy must be left to the examination of manures.

END OF THE FIRST VOLUME.

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every one knows the character of of a isolated
The use of history in rural economy must be
to the examination of manures.

END OF THE FIRST VOLUME

To be placed at the End of Vol. I. with the Plates.

COMPARATIVE VIEW of the FRENCH and SWEDISH THERMOMETERS
with that of FAHRENHEIT.

Plate	heli.	Secd.	Ill.
213			100
208			100
204		1090	
200		95	
196			
193			90
188			
184		1030	85
180			
176			
172			80
168			
164		1090	75
160			
156			70
153			
148			65
144		1000	
140			
136			60
132			
128			55
124		1090	
120			
116			50
112			
108			45
104		1010	
100			40
96			
92		1090	35
88			
84			30
80			
76			25
72		1030	
68			20
64			
60			15
56		1090	
52			10
48			
44			5
40			
36			0
32		1000	
28			
24			
20			5
16		990	
12			10
8			
4			15
0			

