An essay on the analysis of mineral waters / by Richard Kirwan.

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ESSAY

ON

THE ANALYSIS

OF

MINERAL WATERS.

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INTRODUCTION.

THOUGH all Waters that flow from the earth are properly called Mineral, yet of late this denomination has been specially applied to such waters only as are distinguished by a peculiar colour, taste, smell, or other obvious property, from common spring, lake, river, or other water, fitted for economical uses.

Mineral Waters thus understood, have long attracted the attention of mankind by their medicinal powers. These, indeed, can properly be inferred only from their experienced effects; yet, even with *this* restriction, the knowledge of their contents must be deemed highly important, not only for the purpose of imitating such as are found beneficial, in countries where nature does not afford them, but also for the purpose of discovering the medical powers, and mode of action, of certain ingredients taken in a certain proportion, and a given degree of dilution, with the long train of consequences that may in time be deduced from this knowledge.

There is also another point of view in which an acquaintance with the contents of Mineral Waters must be deemed of some importance; arising from unknown depths, they *alone* announce to us several of the substances therein existing, and frequently the awful operations therein transacted. Thus several valuable ores have been discovered, witness the copper-ores of the county of Wicklow, in this country, and various mines of salt, allum, &c. The Waters of Bath, Aix-la-Chapelle, Carlsbad, and many more, manifest the secret operations of heat at depths hitherto inaccessible, and by the nature of their contents, suggest the causes that most probably maintain it. In Mineral Waters we find many substances dissolved, whose existence in a state of solution hath until of late been thought impossible. Thus the Sprudel springs at Carlsbad, in Bohemia, annually afford 17369 pounds of siliceous earth held in solution; and, though this water also contains fossil alkali, yet that earth does not owe its solubility to this salt, as the alkali is fully aerated. 1 Klapr. 352. To say nothing of the waters of Geyser, in which this earth also abounds in quantities utterly disproportionate to the quantity of alkali also contained in it. Thus, a compound of sulphur and bitumen is found dissolved in the waters of Rensdorf, such as has never been imitated by any process of art. 3 Crell. Beytr. 447.

Struck with the importance of these facts, towards forming sound notions of universal geology, a science intimately connected with the principles of morality and religion, it appeared to me, that a general method of detecting the contents of Mineral Waters was a proper appendage to the methods of distinguishing mineral substances in their solid state, which I had already communicated to the public. The propriety of undertaking this task, will not appear in the least diminished by the consideration that we are already in possession of an inestimable tract on this subject, by the late very excellent Mr. Bergman, when we recollect that his tract was published twenty years ago—that natural knowledge is susceptible of unlimited improvement—that chemical knowledge hath within that period been considerably advanced—and that some substances have since been found to exist in waters, that were not heretofore suspected to exist in them. Some excellent tracts on particular Mineral Waters have also since appeared; among which, that of Mr. Fourcroy, on the Waters of Enghien; several of Mr. Westrumb's; and those of Klaproth, on the Waters of Carlsbad; and of Dr. Black, on the Waters of Iceland, cannot be mentioned with too much praise. In these, some new tests, several improvements in the application of those already known, some in defining the limits of their powers, and methods of determining with precision, in particular cases, the separate quantities of inseparable substances, will be found. Nor should I overlook the merits of our ingenious countrymen, Dr. Garnet and Dr. Pearson, who have in several instances applied with much exactness the Bergmanian method of investigation to the analysis of some English Mineral Waters.

To state, add to, and generalize these improvements, by proposing new tests, and new limitations of the powers of those already known, in cases where none were before determined, or where they were inaccurately assigned; also by substituting more direct methods of investigation to the random methods before employed, and various new modes of estimating the quantity of each of the substances discovered, is the purpose of the following sheets. That I have perfectly succeeded in each particular instance, I shall not pretend, but that the general method here proposed and pursued, deserves attention, I am fully confident; and that its defects, in particular instances, either arising from the nature of the case, or my mistake, may soon be noticed, satisfactorily proved, and, if possible, properly amended or supplied, is my most earnest wish.

It is much to be regretted, that since the death of Bergman, few or none have attended, except Morveau, (who is indeed, himself a host) to the establishment of general principles. What use may be made of some facts, not very numerous, but truly stated, and carefully examined, Lavoisier has happily demonstrated. He did not confine himself to those he himself had discovered, but examined, considered, and repeated those brought to light by Black, Priestley, Cavendish, Bergman, Scheele, Berthollet, and others. The science of nature is undoubtedly infinite, its objects and their relations being so; and therefore in proportion as new facts shall be discovered, several of the principles now received will require restrictions or modifications; and the same may be said of such general theorems as can at any time be formed; yet the formation of these theories should not be too long deferred, otherwise we shall be involved in a labyrinth of particular facts, betwixt which we can trace no connection, nor consequently apply to no useful purpose. Abundance of such facts, hitherto not sufficiently attended to, are to be found in the memoirs of many academies, and in some antient, and many modern works of various intelligent chemists; but to select, under various heads, compare, repeat, and correct where need should be found, and occasionally add to these, can be undertaken and properly executed only by a society of skilful and well-informed persons, instituted for that particular purpose.

The niceties of manipulation, which in these researches are of great consequence, I have mostly omitted, as they may be seen in Mr. Bergman's essay; some farther improvements in the processes of evaporation and filtration are to be found in Dr. Black's analysis of the Mineral Waters of Iceland.

But I have every where mentioned the most material facts relative to the present object, that occur in writings at present little known in this country; though, it is hoped, through the encouragement the Philosophical Journal at present receives, that the works of learned foreigners will no longer remain in obscurity.

CHAP. I.

OF THE SUBSTANCES HITHERTO FOUND IN MINERAL WATERS.

BY *Mineral Waters* we mean such as either by their colour, taste, smell, or specific gravity, discover an unusual impregnation with some mineral substance, or fixed air—yet sea-water is not distinguished by that appellation.

The substances hitherto discovered in Mineral Waters, are either of the class of aerial fluids, or of an acid, alkaline, or earthy nature, or neutral, or semi-neutralized substances, or hepatic, or saponaceous compounds, or extractive matter; this last, however, is rather of vegetable origin.

§. I. OF AERIAL FLUIDS.

1. *Oxygen Air*, first discovered in waters by Scheele. Its proportion is generally inconsiderable.

It has never been found with hepatic air, nor in ferruginous waters, being incompatible with such substances.

Is not it one of its constituents
see Nicholson, Henry &

2. *Mephitic Air*, (the azote of the French) it was first discovered in Buxton Waters by Dr. Pearson, and afterwards in those of Harrowgate by Dr. Garnet, and in those of Lemington Priors by Lambe. 5 Mem. Manchester.

3. *Common Air*, first discovered in waters by Mr. Boyle. Its quantity scarcely exceeds $\frac{1}{18}$ of the bulk of the water.

4. *Fixed Air*, first discovered in Pyrmont Waters, by Dr. Brownrigg. Its proportion is variable. Scarce any water is absolutely free from it. 1 Bergm. p. 85. 100 cubic inches of most waters contain at least one or two of it; but those called *Mineral* generally contain from six to forty. Bergm. on Scheffer, §. 186.

According to Mr. Bergman, 100 cubic inches of Pyrmont Water contain 95 of fixed air; according to Dr. Higgins, about 160; and, according to Mr. Westrumb, 187. 3 Westrumb 159; but 95 Swed. decimal inches = 151 English inches; and all allow that the quantities in any particular spring are variable within certain limits, and frequently much is lost in the carriage. Though, in general, water, at the temperature of 60°. can take little more than its own bulk of fixed air, even by continued agitation; yet, if it contains aerated alkalis, or earths, it can easily retain more, as well as in temperatures some degrees lower. In a combined state, it has been found united to alkalis, barytic, calcareous, magnesian, and alluminous earths, in many waters, and also to iron. Fixed air is incompatible with no other air, except with alkaline air.

5. *Hepatic Air*, or sulphur in an aerial form, first discovered by Scheele. The composition and various states of this air, have lately been explained by the successive investigations of Gingembre, Hassenfraz, Fourcroy, Van Dieman, with his associates, and Berthollet. In general, it consists of inflammable air combined with sulphur; but different proportions of these, constitute species whose properties are very different. In one species they are combined merely to saturation. This I call *sulphurated hydrogen*, HYDROGENE SULPHURÉ of Berthollet. Sulphurated hydrogen, combined with a basis, forms a *hydro sulphuret*, HYDRO SULPHURÉ of Berthollet. It may also be called an *hepatule*, a denomination which will some-

times be found convenient, to distinguish it from the combination of a basis with sulphur singly, which I call an *hepar*.

In the second species, sulphur is combined with hydrogen, beyond the point of saturation; that is to say, there is an excess of sulphur held in solution. This I call *super sulphurated hydrogen*, SOUFFRE HYDROGENÉ of Berthollet. This species combined with a basis, forms a *super sulphurated hydro sulphuret*, SULPHURE HYDROGENÉ of Berthollet. I shall also call it an *hepar*, when that appellation is most convenient, as it sometimes will be found.

Compounds of some or other of these denominations have been found in Mineral Waters.

Hence it is difficult to ascertain the quantity of sulphur contained in hepatic air, hepatules, and hepars, the excess in each being variable.

By my experiments, 100 cubic inches of common hepatic air, that is, super sulphurated hydrogen, weigh at a medium, about 34 grains, the greater part of which is sulphur. Mr. Bergman calculates that quantity of air to contain only 13,3 grains of sulphur. 1 Bergman, 237. If so, it should be much lighter than common air, which is contrary to observation; but the truth is, that Bergman barely mentions the quantity of sulphur remaining after the decomposition of hepatic air by nitrous acid; and this decomposition is never total in any case, and much less in his mode of applying the nitrous acid, because the acid soon becomes too dilute to act on the hydrogen, as is evident by the smell of hepatic waters thus treated, when heated to about 130°. of Fahr. According to Bergman, ibid. 100 cubic inches of water saturated with this air, at temperature 59°. contain about 60 cubic inches of it. However, I found water to take up much more of it, namely, from $\frac{2}{3}$ to $\frac{3}{4}$ of its bulk; and by long continued agitation nearly twice its bulk; and hot water takes up more of it than cold.

6. *Heavy Inflammable Air*, or carbonated hydrogen, is said to exist in some Mineral Waters in Italy. Pure inflammable air has not yet been found in waters. 5 Fourcr. 73.

7. Sulphureous Air, or Vitriolic Air, exhales from some hot waters in Italy, but it

is only the excess that thus exhales; while in the water it is mere sulphureous acid, and as such I shall consider it.

§. 2. ACIDS.

1. *The Sulphureous Acid* has been detected in many hot waters in Italy, in the neighbourhood of volcanos, as I have just mentioned. See Vairo in a note, Scopolis Dictionary, *Acque* 198, and probably also in a state of combination with the substances contained in those waters.

The *Sulphuric*, or Common Vitriolic acid, has not been united barely to water, but it has been found *semi-combined*, or as an *excess* in vitriolic and alluminous water. In a combined state it occurs in various salts, as vitriolated tartarin, Glauber, Epsom, selenite, allum, and vitriol of iron.

2. The *Muriatic Acid* has hitherto occurred only in a state of combination with tartarin, soda, barytic, magnesian, and argillaceous earths, and with iron, and (as suspected) with Manganese. Dr. Withering suspects it to exist uncombined in the waters

of Nevil Holt. See his notes on Bergman's Sciagraph. §. 29.

3. The *Boracic Acid*, uncombined with any basis, has been found in some lakes in Italy. 16 Roz. Journ. and 2 Mem. Dijon, 1784, p. 151.—In a *combined state* with natron, it probably exists in those lakes of Thibet and Persia, where tinckal is found. Perhaps, also, in Hungary, where lakes abounding in natron occur, and where it does not appear to have been sought for.

4. The *Nitrous Acid* in a *combined state*, is said to exist in many springs in the district of Bihor in Hungary. 1 Chem. Ann. 1793, p. 224. These are the only acids either uncombined or combined, which have as yet occurred in Mineral Waters; for though arsenical waters have been mentioned by many, yet there is no authentic account of the existence of any.

§. 3. ALKALIS AND EARTHS, PURE OR AERATED.

1. *Tartarin*, or Vegetable Alkali, has been extracted from a Mineral Water at

Doway. 4 Mem. Scav. Etr. 498, partly, as it would seem, united to a bituminous oil, and partly to fixed air. According to Monnet Traité des Eaux Minerales, p. 165, it exists also in the waters of Aix-la-Chapelle; but Kortum found none.

2. *Natron*, or *Soda*, in an aerated state, is found in numberless springs and lakes.

3. *Aerated Volalkali*, has been discovered in the waters of Rathbone-Place, in London, by Mr. Cavendish. Phil. Trans. 1767; and in some waters in France, by Mr. Malouin. Mem. Paris, 1746.

4. *Lime*, free from all combination, is said to exist in some waters. Scheff. Vorless. §. 188. Bergman, in his note thereon, says it must be in hot, and not in cold Mineral Waters.

Aerated Lime held in solution by an excess of fixed air contained in the water, not combined with the lime, but acting as a menstruum, is commonly found in all waters. The quantity of fixed air required to produce this effect, is generally so much the smaller, as the quantity of water, with respect to the lime, is greater, as the instances which I shall presently adduce sufficiently prove; but some other facts leading thereto must previously be established.

1. Seven hundred grains of water, at the temperature of 60°. may hold in solution about one grain of lime, as Bergman has well observed. Therefore, an ounce of lime-water contains at most about 0,68 of a grain of lime.

2. One hundred grains of quick-lime take up when slacked, and retain when dried in a heat of 600°. 28,7 grains of water. 1 Lavois. p. 196. Therefore, 100 grains of slacked lime so dried, contain 77,62 of lime, and 22,38 of water.

3. Lime precipitated from lime-water by a stream of fixed air, and kept a sufficient time in contact with it, retakes the quantity of fixed air which it had lost, (as appears) very *nearly*, when weighed after desiccation, in a heat of 600°. by Lavoisier's experiments. 1 Lavois. p. 204, 205; and by those of Mr. Cavendish, Phil. Trans. 1766, p. 171, and 1767, p. 101; and those of Jacquin, and 1 Bergman, p. 50; but still more exactly when it is dried in a low red heat; but if dried in a lower heat, or by exposure to the atmosphere, as has been

practised by many, the same quantity of fixed air which it had at first possessed cannot be expected in a given weight of it, as it then retains much water.

4. Aerated lime is itself soluble in an excess of fixed air, as Mr. Cavendish first discovered; and here two questions arise important to subsequent calculations, namely, what quantity of aerated lime can be held in solution by a given volume of water fully aerated; and 2dly, what quantity of aerated lime may be found dissolved in water not fully aerated.

As to the first point, Bergman expressly asserts, that the *cantharus*, or 100 Swedish cubic decimal inches of pure water, or 42250 grains, being saturated with fixed air at the temperature of 50°. that is, containing its own bulk of that air, is able to dissolve 27 grains of aerated lime. See 1 Bergm. 194. 159. 91. 93. and 9. and that smaller proportions of this air dissolve proportionably less. Now, converting these quantities into equivalent English measures and weights, and estimating the weight of fixed air as I have determined it, 159,37 cubic inches of water, or 45352 grains, saturated with fixed air, or containing its own bulk thereof at the temperature of 50°. (and supposing the barometer at 30″) ſhould dissolve 29 grains of aerated lime. Again, Mr. Bergman, p. 26, says, that 1500 parts by weight of fully aerated water dissolve *about* one of aerated lime, which is nearly consistent with his former determination. For, according to him, p. 194, 100 cubic inches of fixed air weigh about 50 grains; then the *cantharus* saturated with this air should weigh 42300 grains Swedish; and if 42300 take up 27 grains, 1500 should take up 0,96.

It appears, however, by other experiments better suited to the processes of nature, that this determination is much too low, or in other words, that fully aerated water can take up a much greater proportion of aerated lime. Mr. Bergman's experiments were made on aerated lime (calcareous spar) artificially pulverised and inserted into aerated water. See 1 Bergman, 26; and no artificial pulverization is sufficiently minute to enable so weak a menstruum to exert its full dissolving power. Hence the experiments of Mr. Cavendish, being made in circumstances more analagous to what passes in nature, are better adapted to the calculation of the power of this menstruum.

Mr. Cavendish found that 17,5 ounces, or 8400 grains of water, not even fully aerated, could hold in solution 7 grains of aerated lime; consequently 1500 grains of such water could hold 1,25 grains of lime. I say, not fully aerated, for of these 17,5 ounces of lime-water, only 11 were aerated, and to these 6,5 of lime-water were added. So that, deeming water to be fully aerated when it contains its own bulk of air, (in temperature 50°.) this water wanted at least $\frac{1}{3}$ of its complement, and probably more; for Mr. Cavendish furnished these 11 ounces with only as much air as it could *conveniently take*; that is, as I understand, without agitation. Phil. Trans. 1767, p. 104.

An experiment of Mr. Berthollet's Mem. Paris, 1780, p. 127, evinces a still greater solubility of aerated lime in fully aerated water. He found that 900 grains of water, impregnated with fixed air by the precipitation of an acid solution of lime, by an aerated alkali, can hold in solution one grain of lime, which is equivalent to 1,8 grains of aerated lime. Therefore 1500 grains of water, thus impregnated, can hold in solution 3 of aerated lime.

In answer to the second question, I say, it appears from various experiments, that, when the proportion of water to that of aerated lime is very considerable, for instance, as 12000 to 1, then the weight of fixed air necessary to keep the lime in solution is about $\frac{1}{2}$ the weight of the aerated lime; and if the proportion of water is still more considerable, a still smaller weight of fixed air is required, so that at last the quantity of water may be so increased that no sensible excess whatsoever shall be required to keep the aerated lime in solution. And, conversely, the smaller the proportion of water is assumed with respect to the aerated lime, the greater must be the excess of fixed air necessary to keep it in solution, within the limits above-mentioned.

And, lastly, if the weight of the fixed air, united to water, exceeds that of the aerated lime, it will dissolve it, let its volume with respect to that of the water be ever so small.

These three positions are proved by the following experiments:

Thus, in Mr. Cavendish's experiment above-mentioned, 8400 grains of water held in solution 7 grains of aerated lime. Here the volume of water exceeds 33 cubic inches, and the quantity of fixed air, he tells us, is only as much as is contained in 14 grains of marble, that is, 5,7 grains in his experiment, being about 12 cubic inches. Here then the volume of air is only about $\frac{1}{3}$ of that of the water, and its weight only $\frac{8}{10}$ of that of the aerated lime, and yet it held it in solution.

Again, the Marquis de Brezé, an Italian nobleman of distinguished chemical ability, found four French pounds, or 96 cubic inches of water, or 36864 grains, to hold in solution 4 grains of aerated lime, though the bulk of fixed air contained in that quantity of water was only 3,5 cubic inches, that is, 2,4 grains, which is only about $\frac{1}{27}$ of the volume of water, and little more than $\frac{1}{2}$ the weight of the aerated lime. Mem. Turin, 1788, p. 95. Nay, Bergman himself found 4,5 grains of aerated lime in 42250 of water, though that water contained only 4 cubic inches, that is, 2 grains (Swedish) of fixed air, which surprised him so much, that he judged they were only mechanically suspended. 1 Bergman, p. 190.

The same fact may be inferred still more directly from the experiments of Mr. Morveau. 1 Mem. Dijon, 1784, p. 86. He found two measures of what he calls good lime-water precipitated by one of water fully aerated, or nearly so, that is, containing about its own bulk of fixed air; but the lime was completely re-dissolved by adding five more measures of the aerated water.

Let us suppose each measure to contain one cubic inch; then two measures of good lime-water will contain $\frac{6}{10}$ of a grain of lime; and this will be precipitated by a measure of aerated water, which contains one inch of fixed air, or 0,465 of a grain, this being nearly the saturating proportion, and thus one grain of aerated lime nearly will be formed; on adding five measures of aerated water, we have one grain of aerated lime dissolved in eight cubic inches of water, or 2025 grains; and yet the water contains less than its own bulk of fixed air, for the excess of this air amounts only to five cubic inches, that contained in the first measure being combined with the lime. Hence it might naturally be expected, that 12 measures of water, half saturated with fixed air, that is, containing only 6 cubic inches of that air, should be required to produce the same effect in re-dissolving the aerated lime; yet he found that 9 measures only were requisite, and these consequently contained but 4,5 of that air. And, for the same reason, it should seem, that 24 measures of water, containing 6 cubic inches of fixed air, should be required to produce the same effect, and yet he found 15 sufficient, which contained only 3,75 cubic inches of fixed air; and instead of 48 measures of aerated water containing 6 cubic inches of fixed air, he found that 24, which contained only 3 of fixed air, were required; from whence it evidently follows, that, as the quantity of water increased, the necessary excess of fixed air to dissolve the aerated lime was continually diminished*. Nay, Maret assures us, that he found 3 grains of aerated lime

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* It is true, I all along supposed English cubic inches and grains; whereas there is not the same proportion between English inches and grains as between French inches and grains; but this does not alter the general conclusion.

dissolved in a *pinte*, or 17950 grains of water, without any excess of fixed air. 2 Mem. Dijon. 1784. p. 157 and 158. Probably the quantity was so small as to escape him. Lastly, Marquis de Brezé found 4 grains of aerated lime (calcareous spar finely pulverized) dissolved by 18 cubic inches of fixed air in 58 cubic inches of water. Mem. Turin, 1788, p. 13. Here the weight of fixed air far exceeds that of the aerated lime; yet, though it was $\frac{2}{3}$ less than the volume of water, it held the aerated lime in solution.

I have dwelt the longer on these circumstances, as I look upon attention to them to be of importance in geological researches, and they have hitherto been overlooked.

5. *Aerated Magnesia* very commonly occurs in Mineral Waters. *Magnesia fully aerated* is of itself soluble in water, without the assistance of superfluous fixed air. According to 1 Bergm. 373, the cantharus, or 42250 grains of water, takes up 47 grains of such magnesia in the temperature of 59°. Consequently 7000 grains of water (an Averdup. pound) may take up 7,786 of this salt. But water fully aerated takes up a still

larger proportion of this magnesia; for, according to 1 Bergman, 373, 7000 grains of such water can take up 58,6 of such magnesia, at the moment of its precipitation, by an aerated alkali.

Common Magnesia is also soluble in fully aerated water in a large proportion. According to 1 Bergman, p. 31, such water may take up $\frac{1}{300}$ of such magnesia, or 7000 grains may take 23,33, when precipitated from an acid by an aerated alkali. Nay, according to Butini, p. 22. such water may, by particular management, take up $\frac{1}{43}$ of its weight of common magnesia. He even found that *pure water* may in a long time dissolve $\frac{1}{377}$ of its weight of magnesia, p. 2. He also remarked, that the society of other salts, as vitriolated, tartarin, Epsom, and common salt, renders aerated magnesia still more soluble, as a higher heat is necessary for its precipitation, p. 93 and 95.

6. *Aerated Argil* is said to have been found in the waters of Avor, in Anjou. 37 Roz. p. 95. Westrumb also found argil in some waters, but in so small a proportion, that I rather think it was mechanically diffused than truly dissolved. Thus he found

but one grain of it in 18 pounds of the waters of Meinberg, but he found 9 grains in 10 pounds of the waters of Pyrmont; in these it appears to have been really dissolved. According to Bergman, 30 grains of argil requires as much fixed air to dissolve them as 150 of magnesia. Vol. I. p. 37. of Morveau's translation. That is, 5 times as much as magnesia.

7. *Siliceous Earth* hath been found dissolved in many waters, particularly the hot or warm; and though these waters often hold an alkali, yet the solution of silex cannot well be attributed to it, as its quantity is either too small for to act on the quantity of silex, as at Geyser, or it is aerated, as at Carlsbad.

8. *Aerated Iron* is found in many Mineral springs. According to 1 Berg. p. 34, water, saturated with fixed air, may take up $\frac{1}{10500}$ of its weight of iron. Or 100 cubic inches of this air may in water take up 4 of iron. Ibid. 174, 222. Yet the waters of Medevi, which he says contain in the cantharus but 6 cubic inches of this air, contain 4 grains of iron. 4 Bergman, p. 351 and 352.

§. 4. NEUTRAL SALTS.

SULPHATS.

1. *Glauber* very frequently occurs in various springs and lakes.

2. *Vitriolated Volalkali*, found in some lakes near volcanoes, 16 Roz. p. 363.

3. *Selenite*, a very general ingredient in most springs.

4. *Epsom* also occurs in many Mineral springs, but far more rarely than selenite.

5. *Vitriolated Argil*, both in the aluminous state, and otherwise, is sometimes met with, though rarely; most commonly it is in the state of acid sulphat, or alum. 5 Fourcroy. 73. see Mem. Paris, 1777, 93, &c.

6. *Vitriol of Iron* is not unfrequent in the springs and lakes of volcanic countries; see Scopoli's Dict. Chym. *Acque*. 201. Lavoisier found it in the waters of Mulino, near Latera. Mem. Paris 1777. p. 93. Dr. Garnet in those of Horley Green, and Mr. Bergman in the waters of Denmark. 1 Bergm. p. 176.

7. *Vitriol of Copper* has been found only in waters issuing from copper mines.

NITRATS.

8. *Nitre*, according to Ruckert, 1 Chy. Ann. 1793. p. 224, is found in several springs and wells in the territory of Bihor in Hungary. Vestiges thereof have also been discovered in some wells in Berlin, 2 Margr. p. 43. and of Upsal. 1 Bergm. and in some salt springs in Germany, as at Nidda near Altendorf. 1 Bergm. Journ. 1792. p. 5.

9. *Nitrated Lime* has also been found in some springs in the sandy Desarts of Arabia. Sprat's History of the Royal Society, 264. and in Berlin. 2 Margr. p. 43.

10. *Nitrated Magnesia* is said to have occurred in some springs. Berg. on Scheffer. §. 188. 2 Anmerk.

MURIATS.

11. *Sylvian* has of late been discovered in some Mineral springs. 2 Crell's Chy. Ann. 1797. 381. 11 Mem. Scav. Etrang. Hist. 101. It has also been noticed by Monnet, Hydrolog. 263.

12. *Common Salt* abounds not only in the sea, but in various lakes, wells, and springs, in moſt countries.

13. *Sal Ammoniac* has been detected in some Mineral lakes in Italy. 16 Rozier's Jour. 362. And also in Siberia. 2 Herman. 346.

14. *Muriated Barytes* is said to have sometimes occurred in Waters. Bergm. Sciagraph. § 58. Scheff. Vorless. § 188. Anmerk.

15. *Muriated Lime* is very generally found in Mineral springs.

16. *Muriated Magnesia* exists not only in the sea, but in many other waters.

17. *Muriated Argil* has been detected in some waters by Dr. Withering. Berg. Sciagr. § 67. p. 31.

18. *Muriated Manganese* is said by Bergman to have occurred in some waters in Sweden. Sciagr. § 74. and has lately been discovered in the waters of Limington Priors by Mr. Lambe. 5 Mem. Manchester.

BORAX OR TINCKAL.

19. This exists in some lakes in Thibet and Persia.

SULPHURETS AND SOAPS.

20. *Sulphurated Alkali*, and *Sulphurated Lime*, have sometimes occured in waters, forming hepatules, but never hepars, as far as I can find; for all the sulphurated waters of which I have met any account are nearly, if not wholly, transparent and colourless. Whereas I found that hepars, whether alkaline or calcareous, when so far diluted as to become nearly colourless, immediately become blue, and then turbid from the precipitation of the sulphur, and in that state ceased to have any action either on nitrated silver or lead, or indeed on any test. To discover any action on tests, these waters must have a pretty strong yellowish green tinge, and of such, though possibly to be met with in lakes near volcanos, I have seen no authentic account. All the sulphurated waters, mentioned by writers on whom we can safely rely, contain either hepatic air or an alkakine or calcareous hepatule, or both. Such waters bear dilution without letting any thing precipitate, and are either transparent and colourless, or nearly so, when fresh drawn from the source, and become turbid

only when exposed for some time to the air.

21. *Bituminated Alkali* has been found in a well near Doway.

BITUMENS, AND VEGETABLE AND ANIMAL EXTRACTIVE MATTER.

22. *Petrol*, floating on Mineral Waters, has often been noticed; and bitumen, but in very minute proportion, has been detected by Westrumb in the waters of Driburgh. 2 Westrumb, 56; and in some of those of Pyrmont. 3 Westrumb, 85, and 152, &c.

23. *Vegetable Extractive* Matter is not, properly speaking, an ingredient in any Mineral Waters, but is often, nevertheless, found in them.

24. *Animal Extractive* Matters occur more rarely. A well infected with it has been lately noticed at Avor in Anjou. 37 Roz. Journ. p. 95.

§. 5. OF ASSOCIATED SALTS.

The following observations are intended merely for geological purposes, to enable us to conjecture from what substances Mineral Springs derive their origin.

1. *Aerated Lime and Selenite* most frequently accompany each other.

2. *Aerated Magnesia* is always accompanied by *Aerated Lime*, but not *vice versa*.

3. *Aerated Soda* is generally accompanied with Glauber and common salt, but not *vice versa*.

4. *Epsom* is most commonly accompanied by Glauber, or Selenite, or both, but not *vice versa*.

5. *Vitriol of Iron and Alum* are commonly associated.

6. *Common Salt*, unless attended with soda, is always so with selenite.

7. *Selenite* is found in most springs, and accompanies all salts, (except soda,) when both are in any notable proportion.

8. *Muriated Magnesia* is most commonly found with common salt, but not *vice versa*; it is also often found with Epsom.

9. *Muriated Lime* is almost always accompanied with common salt. Hence it appears to me that most mineral springs derive their impregnations either from argillites singly, or argillites mixed with sulphur

or pyrites; but I forbear to enlarge. See several probable and ingenious conjectures on this subject in Bergman's Erde kug. Beschreib. §. 75; and 1 Bergm. 207; 3 Bergm. 262—282; and 1 Klaproth, 344. That Epsom and common salt decompose each other, when some degrees under the freezing point, whence Glauber and muriated magnesia originate, has been remarked by Gren, in the fourth volume of his Journal, p. 224. But they re-act on each other in a higher temperature, as I have experienced.

CHAP. II.

OF TESTS.

UNDER this head I shall mention only the most decisive, or those that are necessary in particular cases, or that serve to confirm the inductions drawn from others.

§. I. OF THE GENERAL TESTS OF FIXED AIR, AND OF THE MINERAL ACIDS.

I. FIXED AIR.

This air is found in Mineral Waters in three states; either merely combined, or partly combined and partly semi-combined, or uncombined.

1. *Infusion of Litmus* is not reddened by waters that hold fixed air merely in a state of combination, as in waters that contain soda merely *aerated*, but not super-saturated therewith.

2. *This infusion will be reddened* by waters holding fixed air partly combined and partly semi-combined, if the semi-combined part

amount to $\frac{1}{6}$ of the bulk of the water, and the *redness* will be so much the more distinct, as the bulk of the air approaches more to that of the water, or exceeds it. Thus waters, containing aerated earths or iron, hold fixed air partly combined with the earth, &c. and also some excess, which I look upon as semi-combined, because it enables the water to hold the earths in solution. So the waters of Scydschutz, though they hold both aerated lime and aerated magnesia, and consequently both combined and semi-combined fixed air, yet, as the semi-combined part amounts to only $\frac{1}{10}$ of the bulk of the water, infusion of litmus is not reddened by it. 1 Bergm. p. 190. This infusion is scarcely affected by the waters of Enghien, which contain 6 cubic inches of fixed air in 48 of water, that is, $\frac{1}{8}$, it being semi-combined.

But the waters of Seltzer, that contain $\frac{6}{10}$ of their bulk of semi-combined fixed air, redden this infusion. 1 Bergm. 196. And also the waters of a fountain at Spaw, in which Mr. Bergman found only $\frac{45}{100}$ of their bulk of semi-combined fixed air; most of which must have been semi-combined, judging from the quantity of aerated earths it held in solution.

3. Waters that contain uncombined fixed air to the amount of $\frac{1}{10}$ of their bulk, or partly combined, partly semi-combined, and partly uncombined, so that the uncombined part amounts to $\frac{1}{15}$ or more of their bulk, will *redden* infusion of litmus *.

Thus Bergman found the waters of Medevi to redden this infusion, though they contained but $\frac{1}{10}$ of their bulk of fixed air. 4 Bergm. p. 351. But then this air was wholly uncombined, for it held no aerated earth in solution. So Dr. Garnet found the waters of the Old Spaw at Harrowgate to redden this infusion, though they held but $\frac{1}{14}$ of their bulk of fixed air; but it was mostly uncombined, as it held but 2 grains of aerated iron, for whose solution, in a large quantity of water, a small excess of fixed air is sufficient. If the bulk of the uncombined fixed air exceeds that of the water,

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* These experiments should be made with infusion of Litmus, so far diluted as to be nearly colourless, and in tubes of at most half an inch in diameter; and the mixtures made in the proportion of half of each, more or less, according to the quantity of fixed air.

one cubic inch of it will redden several inches of the infusion. Thus Westrumb found one cubic inch of Pyrmont water, which contained 1,8 times its bulk of fixed air, to redden 55 cubic inches of the blue, but dilute infusion. 3 Westr. p. 34.—Bergman observed, that one cubic inch of water, holding its own bulk of fixed air, reddened 50 inches of the infusion. 1 Bergman, p. 11.

To render this test decisive, it is necessary, 1°. That the *redness* should be *fugacious*; and capable of repeated renovation and evanescence, by fresh additions of the Mineral Water, which distinguishes this air from very dilute solutions of the mineral acids; for these also may excite an evanescent redness for some time, that is, until the alkali contained in the litmus is saturated, as Bergman has well observed. 1 Bergm. p. 12. 2°. That the Mineral Water should give a precipitate with lime-water soluble in the mineral acids with effervescence; this distinguishes fixed air from hepatic air, which also fugaciously reddens infusion of litmus.

Again—*Paper tinged blue by Litmus* is also fugaciously reddened by water impregnated with *more* than its own bulk of fixed air; thus Westrumb found it reddened by Pyrmont water; and Reuss, by the waters of Egra, which contained 1,6 of its bulk of this air. But water that contains only *its own bulk of this air*, *or less*, does not redden this paper, as Bergman observed. 1 Bergm. 13, and 94; but, on the contrary, often renders it *more intensely blue*, as where such water contains an aerated alkali, as Seltzer water, 1 Bergm. 196, or aerated earths. 1 Bergm. 191.

Lastly, where either the infusion, or the paper tinged by it, is reddened by the Mineral Water in its natural state, but not after the water has boiled for a quarter of an hour, or has been considerably evaporated, it is certain that this redness was produced by fixed air, or hepatic air; but the absence of the hepatic smell, and its escape in a much slighter heat, will exclude all suspicion of this last.

Lime-water, duly saturate, and added in sufficient quantity, immediately discovers half a grain of fixed air, or about one cubic inch in 7000 grains of water; that is $\frac{1}{14000}$ part of the whole, 1 Bergm. 161, and 158, and a still smaller proportion after long standing. *Stronthian Lime-water* is a still more delicate test. But as *tests* in examining Mineral Waters, neither of them is *decisive*, as they form precipitates with various earthy salts, and the mere effect of fixed air is not easily distinguished.

2. OF THE MINERAL ACIDS IN GENERAL.

Infusion of litmus (and paper tinged by it) is also a test of Mineral Acids in general existing in waters, either uncombined or semi-combined, that is, exceeding the point of saturation; (the excess entering into a weak combination with the salt, into whose combination it enters;) for, in this case, the redness produced is, at least after a few trials, *permanent*, and commonly much more intense.

But this, like all other tests, has its limits. According to Bergman, paper, tinged by litmus, is *reddened* by being just dipped in the *cantharus* (5,5 English wine pints) of water, containing 12 grains of the strongest vitriolic acid. Now, if by the strongest acid, he means that whose specific gravity is 2,000, then 12 grains of it occupy the space of 6 of water; and as the *cantharus* of pure water weighs 42225 grains, that of water, containing 12 of this acid, must weigh 42255 grains; then this paper thus applied, would discover $\frac{1}{3521}$ part of vitriolic acid in water, and if the paper were long left in it, or the water heated, it is probable it would discover a still minuter portion of this acid, but it certainly would not discover $\frac{1}{12000}$ part. I added 1,38 grains of vitriolic acid, whose specific gravity was 1,844 to 1000 grains of water, and found paper, blued by litmus, sensibly reddened by it: 1,38 grains of this acid contains, by my calculation, 1,08606 of real acid. But when to 7 grains of the dilute acid thus formed, I added 100 grains of water, this mixture did not redden paper tinged by litmus. Several other tests of this acid are more sensible, as will presently be seen.

Ebullition is also a good test of the presence of Mineral Acids, as these are not expelled by it as fixed air is.

HEPATIC AIR.

This air also reddens solutions of litmus, but its most striking and distinctive character is the discoloration of metallic solutions, and particularly those of lead, which it *blackens* sooner or later, according to its quantity. It blackens also the solution of nitrated silver, or precipitates it *brown*, or *reddish* if in minuter quantity; but *extractive matter* also produces this effect. Paper impregnated with a solution of lead, or on which characters are traced with that solution, is *blackened*, or the characters rendered visible. Mercury, or a clean piece of silver, inserted in such water, is also discoloured, or if the impregnation be strong, the silver will be tinged yellowish, or reddish, or bluish, by being simply held over such water, especially when heated. The smell is still a more delicate test. This air is absorbable by lime-water, though many have asserted the contrary, but it does not precipitate the lime; a precipitate does, indeed, ensue, but it is sulphur, and not lime.

HEAVY INFLAMMABLE AIR, OR CARBONATED HYDROGEN.

This air is distinguished by burning, when mixed with common air, without any explosion; it is not absorbable by lime-water, but water over which it is burned precipitates lime-water, as fixed air is produced. It has no peculiar smell.

MEPHITIC AIR, (AZOTIC AIR OF THE FRENCH.)

This air is principally distinguished by negative characters, maintaining its volume mixed with nitrous air, extinguishing flame and life, and not affecting lime-water.

SULPHUREOUS AIR.

This air is distinguished by its peculiar smell; it permanently reddens infusion of litmus, and paper tinged by litmus. It also precipitates lime-water; nay, it may be expelled from the precipitated lime, with effervescence, in a short time after their union.

But if mixed with a *tincture of red roses, reddened by an acid*, it renders this tincture colourless, as I have experienced. No other air produces this change. A mixture of half fixed air with the vitriolic air does not prevent this discoloration. Other effects of this air are more ambiguous. Mr. Fourcroy tells us, that the sulphureous acid does not precipitate muriated barytes, nor nitrated silver, nor mercury. Analy. des Eaux D'Enghien, p. 235. In my experiments, however, I found it to precipitate each of these solutions, and also lime-water. Berthollet, in 2 Annal. Chem. p. 58, tells us, he could form none that did not effect these precipitations, which he attributes to a mixture of sulphuric acid, which he separates by a solution of barytes in the sulphureous acid. I rather think it proceeds from a different degree of oxygenation; that which is most oxygenated, but still sulphureous, effects the above precipitations; that which is less oxygenated does not; but that the acid I employed was truly sulphureous is evident from its destroying the redness of the tincture of roses, which a small quantity of sulphuric acid would restore, if any were mixed with it, and from the low degree of heat in which it was expelled, and also from its assuming an aerial form, which sulphuric acid as such cannot assume. He also observes, that the least oxygenated or most perfect sulphureous acid precipitates the nitrates of silver and mercury. Ibid 60.

Note. The existence of sulphureous air is inconsistent with that of any aerated alkali or earth; if, therefore, these are found in any water, that air must be absent.

OXYGEN AND COMMON AIR.

The usual test of these is nitrous air extracted from dilute nitrous acid, by dissolving copper filings without heat. If equal measures of each air be taken, and the nitrous gradually introduced and shaken over distilled water for five minutes, one measure of the best oxygen air and one of the nitrous will be reduced to 0,03 of a measure; and the most degraded oxygen and nitrous to one measure. The best common air and the nitrous to 1,05 measure, and the worst to 1,4 measure.

§ 2. OF AERATED ALKALIS AND AERATED EARTHS IN GENERAL.

The *Infusion of Turmerick* (Curcuma, terra Merita) which is yellow, is turned *brown* or *reddish brown* by alkalis, whether pure or aerated. Paper stained yellow by it is equally effectual. Per Bergm: 49 grains of crystallized soda in the *cantharus*, that is, 5,5 English wine pints of water render this tincture *brown*, and 30 would *redden* it. Now 49 grains of crystallized soda contain but 18 or 19 of mere aerated soda; therefore, it would discover by *browning* 19 grains of mere aerated soda in 5,5 pints of water, or 3,3 grains in one pint or $\frac{1}{1117}$ part of the weight of water, and a still smaller quantity by *reddening*; but it is sluggish, and requires to be kept sometime in the water, or that the water be warmed.

It is affected by lime-water in the same manner as by alkalis, as I have found. So also by *aerated volalkalis*, according to 1 Bergm. 95. But by these, the change operated is less durable. But it is not affected by aerated earths; and hence some Mineral

Waters give *simultaneous* signs, *both of an alkali and of an acid*; of an alkali, by *browning* paper tinged by turmerick; and of an acid, (namely fixed air) by *reddening* paper tinged by litmus; but this happens only when the water contains a due quantity of alkali and a large excess of fixed air. But *successive* signs of both may be obtained, when the proportion of fixed alkali is small and the water considerably evaporated; for the fixed air would tinge litmus paper red before evaporation, and the turmerick paper would be browned after evaporation. Hence evaporation is often necessary in obtaining a due result from this test. So also to discover *volalkali* by it, a small portion of the water should be distilled off, and the liquor in the receiver essayed.

Tincture of Rhubarb is said to be a still more sensible test of alkalis. 2 Lampadius, p. 79.

Infusion of Brazil Wood, which is red, (Fernambouc of Bergman) or paper stained by it, is still a more sensible test; but it is ambiguous, as it is *blued* both by *alkalis and aerated earths*, and some say also by selenite. It is however easy to distinguish whether the cærulescence proceeds from a fixed alkali or an aerated earth; for, if it proceeds from a fixed alkali, it will be more intense after the water has been evaporated to one half; but if from an earth, it will either disappear if the earth be calcareous, or be much more feeble if an aerated magnesia.

According to Bergman, 10 grains of crystallized soda, (that is 4 grains of mere aerated soda) dissolved in 5,5 pints of pure water, enable the water to give a feeble blue or purple tinge to paper tinged red by Brazil wood, that is $\frac{1}{9945}$ part of the weight of the water.

With respect to *aerated earths*, the power of this test seems at least equally great. Mr. Bergman found it slightly blued by the waters of Upsal, though they contain for the most part but 5,5 grains of aerated lime and half a grain of soda in the *cantharus*; that is, somewhat more than 7 medicinal pounds; and, consequently, less than one grain in the pound. Yet Westrumb did not find this test altered by the waters of Verdener, which contained nearly one grain of aerated lime in the pound, and $\frac{7}{20}$ of selenite, 2 Westrumb, p. 270, and 292; but he found 2 grains of aerated earth in one pound of water to produce the change; 3 Westrumb, p. 144, 152; and with his observation those of Fourcroy concur.

With respect to *Gypsum*, Bergman tells us that he found sea-water to give a slight blue tinge to braziled paper, which he ascribes to aerated magnesia, though the *cantharus* contained but $\frac{1}{8}$ of a grain of it. It is then more natural to ascribe it to selenite, of which the *cantharus* contained 45 grains, and this power Gætling also ascribes to it. Yet I must own that I could not find that one grain of selenite dissolved in 500 of water produced any tint in this paper.

Again—*Paper tinged blue by litmus, and afterwards reddened by distilled vinegar*, or the *infusion* slightly reddened by the vinegar, is also used as a test of alkalis, which, by absorbing the vinegar, restore its original colour. According to Bergman, it will discover 40 grains of crystallized soda (16 of mere aerated soda) in 5,5 pints (the *cantharus)* of water, that is about $\frac{1}{3}$ of a grain in a pint, or $\frac{1}{2438}$ part of the weight of the water. But this test too is ambiguous, as *aerated earths* also restore its blue colour; after ebullition and considerable evaporation, this change is however stronger, if produced by a *fixed alkali*; and weaker or null, if produced by an aerated earth.

Aerated substances in general, whether alkalis, earths, or metals, are also discovered by the affusion of some drops of strong vitriolic acid, which immediately extricates numerous air-bubbles, if the aerated substances be copious, or if there be a large excess of fixed air; but, if the proportion of these substances be very small, the water may retain the air extricated from them. This enables us to form some judgment of their proportion. According to Bergman, 5,5 English pints must excite a visible effervescence with this acid, containing 390 grains of crystallized soda, (156 of the merely aerated.)

Note. Aerated alkalis (unless in very minute proportion) are incompatible with all earthy sulphats, muriats, and nitrats.

§ 3. OF FIXED ALKALIS, SINGLY AND SEVERALLY.

Muriated Magnesia is precipitable *only* by fixed alkalis, for though the alkaline sulphats may (as I think) decompose it, yet they will occasion no precipitate. But this test is best applied after the alkalis have in some measure been *de-aerated* by heat, otherwise the fixed air will hold the magnesia in solution. I prefer this test to Epsom, because Epsom is also decomposable visibly by muriated lime.

If lime or magnesia, in any notable proportion, be found in any water after ebullition, then aerated alkali or volalkali cannot exist in it in any notable proportion. Waters also that contain these alkalis in such proportion, being evaporated to $\frac{1}{8}$ or less, and then mixed with $\frac{1}{20}$ of their weight of sal ammoniac, emit an alkaline smell, at least when gently warmed, if not without heat.

Tartarin is distinguished from natron or soda, by forming, with the nitrous acid, prismatic nitre, and a deliquescent salt with the acetous acid; and, when concentrated, affording a precipitate with the tartaric acid also concentrated, and a soluble salt with the saccharine acid, and a blue glass, when vitrified with the calx of nickel. *Soda*, on the other hand, affords with the nitrous acid, quadrangular nitre; with the vitriolic, an efflorescent salt; with the acetous, a non-deliquescent; with the tartaric, no precipitate; with the calx of nickel, a *brown* glass; with fixed air, an efflorescent and non-deliquescent salt.

§ 4. OF VOLALKALIS SINGLY.

These are discovered, if copious, by the smell; if in small quantity, by adding to the water suspected a portion of lime. But the best method of discovering a small quantity is to distil a portion of the water gently, and then to examine the water in the receiver with the above-mentioned tests; solutions of sublimate, corrosive, and acetited lead, are precipitated *white* by very minute portions of volalkali; but the former is apt to be re-dissolved. I found that one grain of aerated volalkali, containing at the rate of 48 per cent. of fixed air, gave with acetited lead a precipitate which, washed and dried in a heat of 120°, weighed 2,25 grains. See also §. 9.

GENERAL REMARKS.

Any water that precipitates both *muriated or nitrated lime, or muriated or nitrated mag-*

nesia and alum, must contain either a fixed or volatile alkali, free or aerated; if the fixed air be abundant, it may hold the earths for some time dissolved; but, by exposure to the air by heat, or at least by ebullition, this effect will be produced.

§ 5. OF AERATED EARTHS AND METALS MERELY.

All these are precipitated in some measure, if abundant, by exposure to the air under a large surface; but, in all cases, by heat and evaporation. Aerated lime, argil, (and magnesia for the greater part,) and aerated iron, are intirely precipitated by boiling for a quarter of an hour. *Aerated magnesia* is not indeed intirely precipitated until the water that contains it is *wholly* evaporated. But whether it exists in the boiled water may with certainty be inferred, 1st, when any is found in the precipitate given by ebullition, for in that case some still exists in the boiled water. 2nd, If the water contain no aerated alkali, by adding *muriated argil*, for if there be any aerated magnesia in the boiled water, the argil will be precipitated; an effect which no other substance contained in the water, except an alkali, can effect.

§ 6. TO DISCOVER IRON, WHETHER UNITED TO FIXED AIR OR TO A MINERAL ACID.

Tincture of Galls is the general test of iron dissolved in almost any acid. According to Bergman, 3 grains of crystallized *vitriol of iron*; that is, 0,84 of a grain of mere vitriolated iron, or $\frac{1}{24}$ of a grain of mere iron dissolved in 5,5 English wine pints of water, strike a purple in 5 minutes with one drop of this tincture.

Hence it would discover 0,153 of a grain of vitriolated iron in one pint of water, or $\frac{1}{47789}$ part of its weight. Nay, Bishop Watson tells us, that infusion of galls tinged sensibly purple 15 gallons of water, in which only one grain of vitriol of iron was dissolved. 1 Watson, p. 2[illegible]4. Now 15 gallons contain 875000 grains.

Iron dissolved in fixed air is also detected by tincture of galls, and in the same proportion as vitriol of iron; thus Bergman found 3,5 grains of aerated iron, in 5,5 pints of Pyrmont water, to strike a purple with one drop of tincture of galls, 1 Bergm. p. 201 and 203. However, the quantity of iron thus taken up is sometimes so minute, or so imperfectly dissolved, that it immediately falls when exposed to the air; in this case, a piece of the gall-nut should be fastened by a thread to a vessel in which the water is taken up from its source.

If the tincture be sparingly added, and the proportion small, the colour will be *purple*; but, if more copiously added, or the quantity of iron more considerable, *black*.

If the martial water contains an aerated alkali, this tincture will strike a *violet*; if alkalino-neutral salts, a *dark purple*; if earthy salts, a *violet*; if selinite, the precipitate will be *whitish* at first, and afterwards black; and if hepatic air, the tinge will be a *purplish red*. 1 Westr. p. 85, and 2 Chem. Ann. 1793, p. 222. But I suspect that it is rather manganese that gives the purplish red, as it can exist with hepatic air. Note also, that the spirit of wine in the tincture precipitates selenite very readily, and hence the whiteness of the precipitate.

According to Struvius, 1 Mem. Lusanne, 190, muriated iron, if highly oxygenated, is not discoverable by galls. But Westrumb attributes the invisibility of the change produced to an excess of acid which re-dissolves the precipitated iron; this excess, therefore, must be saturated before a change is perceived. 1 Westrumb, p. 86.

According to 2 Chym. Dijon. 333, *iron dissolved in calx, or semi-oxygenated arsenic*, is not discoverable by galls.

Iron dissolved in *mild Volalkali* is at first *whitened*, but finally *blackened*, by tincture of galls. Per Lassone, Mem. Par. 1778, p. 10 and 11.

So, also, iron dissolved in *Caustic fixed Alkalis* (for the mild do not act on it) is precipitated at first *crimson red* by this tincture, but it afterwards *blackens*. Mem. Par. ibid. and Delaval, 39.

By applying this test before and after evaporation, or ebullition, we may know whether the iron is held in solution by fixed air or by a mineral acid; for if it operate its effect *before* the application of heat and *not after*, fixed air is the solvent of iron. If *after* the application of heat, as well as before, then a mineral acid is the solvent. If by heat any calx be precipitated, and yet galls continue to strike a tint, it is probable that the iron is held in solution both by fixed air and a mineral acid; for it scarcely ever happens that the water should be so loaded with vitriol as to deposit any in a slight heat.

Prussian Alkali is also another very sensible test of iron; (for the method of preparing it, and applying it as an instrument of separation, see my Mineralogy, 494): it is also attended with this advantage, that it discovers most other metals by their colours or other incidents, and precipitates nothing else but metallic substances. The only metal precipitated *blue* is iron; Manganese is indeed often precipitated of a *bluish grey*, because it is mostly mixed with iron, but, when free from iron, its precipitate is white.

Note also, that iron held in solution by the *sulphureous Acid* is precipitated *bluish white*, and so it is also though held in solution by any other acid, if the Prussian test be ill prepared, as it then contains sulphureous acid. *Prussiated Lime*, which some use as a test, does not precipitate iron from the sulphureous acid. 2 Ann. Chem. p. 60.

If an alkali exists in the Mineral Water, it will prevent a small portion of iron from striking a *blue* with this test, until it be saturated by an acid, 1 Klapr. p. 330; and consequently this test will not discover iron held in solution by an alkali until this alkali be saturated. Mem. Turin, 1790, p. 393.

According to Struvius, 1 Mem. Laus. p. 99, it does not discover iron held in solution by fixed air; but Bonvoisin remarks, that this defect takes place only where the aerated solution of iron is accompanied also with a large proportion of aerated lime, or aerated magnesia; and that it is in some measure remedied by the addition of a mineral acid, for then a precipitate may be obtained, at least after a few days. Mem. Turin. 1790, p. 393, and 394. That the general rule laid down by Struvius is without foundation is evident from the experiments of Bergman and Westrumb on Pyrmont waters, and of those of the latter on the waters of Driburgh and Meinberg, &c. nay, in these last, he found this test to answer, though the water contained 7 grains in the pound of aerated lime. And I must own, that the appearance of iron after some days is suspicious when an acid has been added, as it might arise from the decomposition of the Prussian alkali itself. Thus Westrumb having added Prussite to water, which had already deposited its aerated iron by long standing exposed to the atmosphere, and also ten drops of strong vitriolic acid, found at last, after alternate additions of each, a precipitate which he attributes to the Prussite, and not to the water. Therefore care must be taken that no more acid be added than is just necessary to saturate the aerated substances and iron.

Note also, that the iron precipitated from fixed air by this test is generally greyish at first, but gradually becomes blue.

According to Bergman, one, or at least two, grains of vitriol of iron, dissolved in 5,5 pints of water, are discoverable by this test. Therefore it would discover above $\frac{1}{30000}$ part of mere iron, in 5,5 pints of water, and after some days it would discover a still smaller proportion.

§. 7. TO DISTINGUISH THE AERATED SUBSTANCES PRECIPITATED BY EBULLITION FOR $\frac{1}{4}$ OF AN HOUR.

These are either aerated lime, or aerated magnesia, or, but more rarely, aerated argil, or aerated iron, very rarely selenite, or two or more, or all of these together.

Let them be treated, when well dried, with a small proportion of dilute marine acid without heat; it will easily dissolve all of them, except the argil and selenite.

To the filtered solution add the tincture of galls; it will discover the iron, if any.

If the solution *contain only calcareous earth*, it will give no precipitate with caustic volalkali, (the phial containing the solution should instantly be closed, lest the volalkali should absorb fixed air,) but will afford a precipitate when vitriolic acid is added, or an aerated alkali. If it contain only *magnesia*, it will give a precipitate with caustic volalkali, and none when treated with vitriolic acid.

If it contain *calcareous earth and magnesia together*, it will give a precipitate, both with caustic volalkali and with vitriolic acid; this latter result is hastened by evaporation, or a slight addition of spirit of wine.

The *Selenite and Argil*, that remain untouched by the marine acid, are distinguished and separated by boiling in a solution of mild soda, which will decompose the selenite, and leave the argil untouched; the resulting calcareous earth may then be dissolved in distilled vinegar, or dilute marine acid, and precipitated by vitriolic acid, or a mild alkali, and the argil will be known by remaining undissolved; for when dry, it is scarcely attacked by any acid in a short time, and when heat is not applied.

Aerated magnesia, iron, and argil, may also be discovered in another manner: let the water, fresh drawn from the spring, be treated with nitrous or muriatic acid to saturation; thus the aerated earths and alkalis, if any, will be converted into nitrats, or muriats. Let the water be then boiled, to expel all remains of fixed air; let lime-water be now added; it will decompose the magnesian salts, as well that formed of the pre-existing vitriolic or marine acids, as of the nitrous or marine superadded, and leave the calcareous untouched. Let this precipitate, not fully dried, be treated with distilled vinegar, it will take up the magnesia, and leave the iron and argil; let the solution be precipitated by a semi-aerated alkali dried and weighed.

Again—Let an equal portion of the water be boiled and evaporated to some degree, and then treated with lime-water as the former portion. Now no magnesia will be precipitated, but that united to a pre-existing mineral acid, and consequently its weight should be smaller; the excess of weight of the former precipitate will therefore prove the existence of aerated magnesia.

§. 8. OF HEPARS AND HEPATULES.

An alkali, containing *hepatic air supersaturated with sulphur*, is what I call an *alkaline hepar*.

An alkali containing *hepatic air barely saturated with sulphur* (that is, containing just so much as constitutes it in the state of hepatic air) is what I call an *alkaline hepatule.*

So if *Lime* be united to *super-saturated hepatic air*, it forms a calcareous *hepar*. But if to *merely saturated hepatic air*, it forms a calcareous *hepatule*.

Hence sulphur may and does exist in two states in Mineral Waters, either united to the water singly in the form of *hepatic air saturated or super-saturated*, or in the state of an *hepatule*, or often in both at the same time, and in the same water; for these states have not as yet been sufficiently attended to. In the state of hepatic air, its tests have been already mentioned.

Waters containing either an *hepar*, *or an hepatule*, retain the sulphureous characters even after long exposure to the atmosphere, ebullition, and considerable evaporation: thus they precipitate the solution of nitrated silver *brown*, or reddish brown, and frequently the solution also of nitrated lead; whereas those that contain *mere hepatic air*, do not, as Fourcroy has well observed. *Eaux d'Enghien*, p. 203 and 208.

Water that contains the *alkaline hepatule singly* may be known by the following characters. 1st, It is transparent and colourless, and bears dilution, and even boiling heat, without losing its transparency. 2ndly, It gives, after bearing a boiling heat, as well as before, a dark brown precipitate, with a solution of nitrated silver, or, if very dilute, a precipitate at first *flesh-coloured*, but which in a few minutes becomes *brown*, and at last almost *black*. 3dly, With a solution of sublimate corrosive, it gives a precipitate partly *reddish*, partly *yellowish*, and partly *black*. 4thly, With nitrated lead it gives a *brown* precipitate. 5thly, With water impregnated with fixed air, or with boracic acid, it gives no cloud, at least in a few hours. 6thly, It has scarce any smell, it slightly reddens paper tinged yellow by turmeric, and gives a faint purple, or dilutes the colour of that stained red by Brazil wood. If much diluted, it may, however, scarcely, if at all alter them.

Calcareous Hepatule bears dilution and heat like the alkaline, and is almost devoid of smell. 2ndly, It does not discolour paper tinged by any of the colorific tests. 3dly, Mixed with water impregnated with fixed air, it affords a cloud in a short time.

4thly, With a few drops of a solution of nitrated silver, it gives a precipitate, first *white*, then *reddish*, and lastly, *black*; these colours appear more or less, or sooner or later, according to its dilution. 5thly, Nitrated lead I did not find altered by it in a short time, but with *acetited* lead it gave soon a *bluish white* precipitate. 6thly, With a few drops of solution of sublimate corrosive it gives a *white* precipitate with a slight tinge of *red*, particularly if the hepatulized water be hot; this clearly distinguishes it from alkaline hepatules. 7thly, Some mercury thrown into this hepatule was not blackened until after three days. 8thly, With solution of nitrated mercury it gives a *yellowish*, or if hot, a *brown* precipitate.

Note. If waters containing either of these hepatules, contain also hepatic air, it is plain their characters must be altered and modified by this last; therefore, to discover them, the hepatic air should first be expelled by heat, and exposure to the atmosphere.

§ 9. OF VITRIOLIC ACID AND SULPHATS.

The tests of the vitriolic acid in particular, are *muriated*, *nitrated*, or *acetited barytes*; nitrated or acetited *lead*; nitrated *mercury*; nitrated, muriated, or acetited *stronthian*; nitrated, muriated, or acetited *lime*.

The powers of most of these tests I have particularly examined, and shall here relate the results of my experiments, and also those of Bergman and of a few other analysts.

1. I found *muriated barytes* (or rather its solution) to produce a very sensible precipitate in water that contained but $\frac{1}{910256}$ of its weight of real vitriolic acid. And in another experiment, I found it affected by a proportion of acid still much smaller. None of the other tests were affected by this proportion of acid. The specific gravity of the solution of muriated barytes was 1,1144.

2. *Acetited lead* gave an immediate but slight precipitate with water that contained $\frac{1}{70990}$ of its weight of real vitriolic acid, but *nitrated lead* was not affected by it, not even in 24 hours, nor was *nitrated* or *muriated* stronthian, nor the other tests. The spe-

cific gravity of the solution of acetited lead was 1,1180, and that of the nitrated lead was 1,1. Paper stained by litmus lost its colour, but was scarcely reddened.

3. *Nitrated lead*, and also *nitrated* and *muriated stronthian* (and also *acetited stronthian*, but much more imperfectly and slowly) produced a cloud in water which contained but $\frac{1}{1000}$ of real vitriolic acid, and they would certainly detect even a much smaller proportion. But neither *nitrated mercury* nor nitrated or muriated or acetited *lime* were affected by this proportion in 24 hours. Paper stained by litmus was very sensibly reddened.

Hence by the successive application of these tests, we may determine pretty nearly the proportion of vitriolic acid in waters that contain it singly and unsaturate, and *vice versa*; by its means we may also form some conjecture of the proportion of the substances which it detects.

These tests must certainly act more or less vigorously according to their degree of dilution. Acetited lead is more sensible than the nitrated, not only from the weaker affinity of the acetous acid, but also because it holds much more of the calx of lead in solution. Care must be taken that it be not in such a state as to be precipitated by mere water.

According to Bergman, a few drops of a solution of muriated barytes immediately detect the acid contained in 12 grains of recently crystallized glauber dissolved in 5,5 English wine pints of water, forming a cloud or white streaks. And three grains after a few minutes, or one grain after 2 or 3 hours. Now 12 grains of crystallized glauber contained 2,83 of real vitriolic acid by my calculation; therefore, a pint of water should contain little more than half a grain of real acid; of course this test immediately discovers about $\frac{1}{14622}$ of combined vitriolic acid, or $\frac{1}{81233}$ in 2 or 3 hours. Hence we see this test discovers much less of the combined than of the uncombined acid, and perhaps its affinities to different bases may thus be measured. By means of this test, Dr. Black discovered 1,28 parts of desiccated glauber in 10,000 of Rykum water.

I have also made a series of experiments to determine the powers of the different tests of vitriolic acid, in detecting this acid in a state of combination and in a given quantity of water, viz. in one grain of each of the following salts. Vitriolated tartarin, desiccated glauber, desiccated Epsom, selenite, desiccated allum, desiccated vitriols of iron and zinc, each dissolved in 1000 *grains of water*.

1. The solution of *vitriolated tartarin*, essayed with *muriated barytes* instantly gave a cloud, and so it did with *acetited and nitrated lead*, but the former was much denser; and also with *nitrated stronthian* after a few seconds, and more quickly with *muriated stronthian*; *nitrated silver* also gave a slight cloud. But *nitrated mercury*, or *nitrated* or *muriated* or *acetited lime* made no alteration in 24 hours.

Note. Portions of the solutions of the vitriolic salts were put into different tubes and essayed with, sometimes a few drops, and, when necessary, with nearly an equal volume of each of the tests essayed. The temperature was 64° or 66°.

2. *Glauber*, its solution in 1000 grains of water was instantly clouded by a few drops of *muriated barytes* and *nitrated lead*, or

nitrated stronthian after a few seconds. But the other tests did not affect it even in 24 hours, nor did nitrated silver disturb it, until somewhat more than one grain of desiccated glauber was inserted into 1000 of water.

3. *Selenite*; its solution in 1000 grains of water was instantly clouded by *acetited lead*, but not by *nitrated lead* nor by *nitrated stronthian*, until after a few seconds. Nitrated silver gave also a slight bluish cloud. The weaker precipitants I forebore trying. Bergman found that muriated barytes discovered 7 grains of selenite in 42253 of water, that is about $\frac{1}{6}$ of a grain in 1000 of water, but then it required 24 hours, 1 Bergman, p. 161.

4. *Epsom*; its solution in 1000 grains of water was instantly clouded by *nitrated lead*, and also by *nitrated* and *muriated stronthian* after a few seconds, and by *nitrated silver* very slightly in 2 hours; but nitrated lime* had no effect in 24 hours. A decomposition did not even happen as we shall presently see. It would appear by Dr. Garnet's ex-

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* Fourcroy also remarked, that muriated lime could not discover one grain of Epsom in 4000 of water. *Analyse des eaux d'Enghien*, p. 205 and 206.

periments on Harrowgate water, that muriated barytes discovered in a gallon of water 10,5 grains of Epsom (that is, 5 of desiccated) in half an hour, but then the precipitation was assisted by the 24 grains of aerated earth, which that water also contained.

5. *Alum*; its solution in 1000 grains of water was immediately clouded by *nitrated lead*, and by *nitrated stronthian* after 1 hour; with *nitrated lime* no cloud was produced in 24 hours; with *nitrated silver*, it gave a slight bluish cloud.

6. Vitriol of iron dissolved as the above salts, with *nitrated barytes*, *and acetited lead*, gave an immediate precipitate; but with *nitrated lead* only after 2 hours. With *muriated stronthian* after a few seconds; with *nitrated stronthian* more slowly, with *acetited stronthian* only after 2 hours, by *nitrated lime* it was not disturbed.

7. *Vitriol of Zinc* also dissolved in 1000 parts water is instantly detected by the solution of *nitrated lead*, more *slowly* by that of *nitrated stronthian*, but soon by *muriated stronthian*. Neither nitrated *lime* nor *silver* disturbed it in 24 hours.

Hence we see, 1°. The vitriolic tests ranged in the order of their powers, and beginning with the most powerful, are muriated barytes, acetited lead, nitrated lead, muriated stronthian, nitrated stronthian, nitrated silver, nitrated mercury, nitrated, muriated, or acetited lime. Barytic and stronthian lime waters may also be used, and are very powerful, but I have not compared them.

2°. The barytic and saturnine solutions would undoubtedly detect the vitriolic acid in much smaller quantities of the above neutral salts, than one part in 1000 of water, as the experiments of Bergman above mentioned, and those which I shall presently adduce sufficiently prove. But the slow precipitation of selenitic waters shews, that to detect small quantities the water should previously be much evaporated.

As the energy of the weaker tests might be quickened by heat, and their decomposition, if any happened, might be rendered visible by spirit of wine; I repeated the experiments on the neutral salts essayed by these tests, with attention to these circumstances.

Vitriolated Tartarin; the solution of one grain in 1000 of water, was essayed by *ni-*

trated mercury, and the next day the mixture was slightly heated, and spirit of wine, whose specific gravity was 0,835 was added, in a few minutes an incipient precipitation appeared of a yellowish colour. Spirit of wine and heat produced also a precipitation when *nitrated lime* was added, and let to stand for 24 hour; but then the precipitate was vitriolated tartarin and not selenite; so that here no decomposition took place. This appeared by adding strong vitriolic acid, for then a copious selenitic precipitate appeared.

Glauber; a similar solution treated in the same manner with nitrated mercury and nitrated lime afforded the same results. No decomposition took place in 24 hours of the nitrated lime.

Selenite; *nitrated Mercury* offerded a copious yellow precipitate as soon as spirit of wine was added.

Epsom; a similar solution exhibited with *nitrated mercury* a copious yellow precipitate as soon as spirit of wine was added. *Nitrated lime* also when spirit of wine was added seemed to afford a precipitate, but did not, for it was Epsom that was precipitated.

Alum; a similar solution discovered a slight precipitate, when *nitrated mercury* and spirit of wine were added; but with *nitrated lime*, only a minute cloud.

Hence *nitrated mercury* is a valuable test, particularly when vitriolated earths are concerned, as by its yellow colour it prevents ambiguities.

I next proceeded to try the power of the weaker tests on vitriolic salts, when contained in a larger proportion in their respective solutions, viz. *one grain of each salt in* 500 *of water*, and found that neither *nitrated mercury*, nor *nitrated lime*, occasioned any precipitation in such solutions of *vitriolated tartarin*, *Glauber*, *Epsom*, or *alum*, when spirit of wine was not applied, not even after 24 hours.

Nay, those tests produced no precipitate, even in 24 hours, in solutions of the above-mentioned sulphats, that contained 2 *grains of each in* 500 *of water*, though there was a decomposition in most cases, as appeared on adding spirit of wine, and heating the mixture. Thus a solution of *vitriolated tartarin*, 2 grains in 500 of water essayed with *nitrated mercury* and spirit of wine, 0,835 and heat, gave a copious yellow precipitate. Treated with *nitrated lime* and heated for one hour to 150° on then adding the above spirit of wine gave a precipitate, which was selenite for the supernatent liquor, gave no precipitate when treated with *muriated barytes.*

Glauber, dissolved in the same manner and treated as above, with the same precipitants, gave a similar precipitate but less copious.

Epsom and *Alum* afforded in a similar treatment the same results, except that allum and nitrated lime exhibited a pellicle before the spirit of wine was added.

Note. The water could have been but inconsiderably diminished by heat, as the tubes that contained the solutions were long and not above 2 or 3 tenths of an inch in diameter. No precipitate appeared in any of these solutions, until spirit of wine was added, except that of alum just mentioned.

In applying muriated barytes or nitrous or acetited lead to Mineral waters, which usually contain a variety of salts, certain precautions must be used to prevent ambiguities. Thus muriated barytes is also precipitated by *aerated alkalis* and *aerated earths* which seize its acid, as well as by sulphats or sulphites whose acid seizes its basis. It is true, that the genuine cause is easily discovered, for the precipitate formed by aerated alkalis or earths, is an *aerated barytes* which is easily *soluble* in the nitrous or marine acids, whereas the precipitate formed by the vitriolic acid is *insoluble*. But it is better to avoid any such ambiguity, which is easily effected, by saturating the alkalis or earths by marine acid, previous to the application of the *muriated barytes*. This improvement was first suggested by Westrumb. If a nitrated or acetited test be employed, the previous saturation should be affected by a similar acid as is evident. If an alkali and an alkaline sulphat be both contained in the water, Dr. Black remarked that the sulphat is first attacked by this test. Geyser, 5, unless enough be added to act on both, or the alkali much more copious.

Note also, that if the solution of muriated barytes be not sufficiently dilute, and it be dropt into a saturate solution, a precipitate will appear though there be no vitriolic acid, but in such case the precipitate will be dissolved by adding more water, or heating the mixture.

There is also another ambiguity in the application of this test, not sufficiently noticed because it does not often occur. *Barytic solutions* are also precipitable *by the boracic acid*, which has been found in Mineral Water, as Maret has observed, 2 Mem. Dijon, 1784, p. 154, and the precipitate is also insoluble. He also found that though this acid also precipitates *acetited lead*, yet the precipitate which it affords is re-dissoluble in nitrous acid, whereas that formed by the vitriolic acid is not. These experiments I have repeated, and found the same results. The nitrous acid I employed to re-dissolve the precipitate was of the specific gravity 1,3. a weaker does not succeed so well or soon. Nay, I found that nitrous acid 1,416 dissolves vitriolated lead, therefore to prevent all ambiguity *nitrated* or *muriated stronthian* should be applied, for the boracic acid does not precipitate these, nor does it *nitrated* or *muriated lime*, if free from any vitriolic taint. I have reason to suspect that in the Mineral Water of Cherchiaio, examined by Maret, there was a slight quantity of sulphureous acid.

Hepars and *Hepatules*, whether calcareous or alkaline, also precipitate barytic solutions, nay even water strongly impregnated with hepatic air produces the same effect in some degree, when *acetited barytes* is employed, but the *muriatic* and *nitrated* solutions are precipitated *brown*, only by vitriolic salts when due precautions are taken, as above mentioned. This cause of ambiguity is commonly discoverable by the smell, and barytic solutions are useful in discovering the sulphureous impregnation, applying them to the water before and after de-aeration and de-sulphuration.

Acetited Lead. This test is liable to some fallacies which I shall here mention, and the means of preventing them. 1. It is often, at least when old, precipitable by *pure water*. This is remedied by adding more distilled vinegar, or adding water until a precipitate no longer appears. 2. It is also precipitable by *aerated alkalis and earths*; this is remedied by previously saturating the water with acetous acid. 3. It is precipitable in some measure by *muriated salts*; this cannot be remedied, but the part so precipitated may be detected and separated, as it is soluble in distilled vinegar, which vitriol of lead is not. 4. It is precipitable by the boracic acid, but this precipitate is soluble in nitrous acid 1,373 (or a stronger,) to which *vitriol* of lead does not yield. 5. It is precipitable *black* by hepatic water, and often by hepatules; but the cause is easily distinguished, and the precipitate is also soluble in the acetous acid. But *note*, if the water be sulphureous, the precipitate will be black, though proceeding from the vitriolic acid. 6. It is precipitable by aerated iron; this, therefore, should first be separated; the precipitate it gives is soluble in nitrous acid.

It may be inferred from Dr. Black's experiments on Geyser waters, p. 5, that when soda and glauber are both found in a mineral water, and acetited lead dropped into that water, it will preferably be decomposed by the soda, though its quantity be one half smaller than that of the glauber; yet, perhaps, this is owing to another cause which I shall mention in the sequel.

As to its power, Bergman observed that this test discovers 115 grains of crystallized glauber in 42250 of water; that is about 55 of fully desiccated glauber, or about 13 grains in 10000. I found it to discover a much smaller proportion. Much depends of the specific gravity, that is the saturation of the saturnine test.

Nitrated Lead is also a test of vitriolic acid, inferior in power to the last; its indications are liable to the same fallacies, as they are remedied in the same manner, *mutatis mutandis*.

§ 10. OF MURIATIC ACID, COMBINED OR UMCOMBINED.

The solution of nitrated silver is the most delicate test of this acid; but its precipitation may also arise from other causes which I shall here state, and the means of either preventing their operation, or at least of tracing it to its genuine source. 1. This solution is precipitable by *aerated alkalis or earths*; but this may be prevented by previously saturating them with nitrous acid, besides, the calx of silver precipitated by them is soluble in nitrous or even acetous acid, which solubility muriated silver does not possess. 2ndly, This solution is precipitable by sulphats or sulphites, but this may be prevented by previously decomposing those salts by nitrated or acetited barytes, after which the solution of silver may be safely applied. 3dly, It is also precipitable by *hepatic air* or *hepatules*, and the precipitate is then coloured reddish, or brown, or black, or it is at first white, and speedily becomes brown or black; this happens if sulphur be contained in the water, though the precipitate should arise either from the vitriolic or marine acids, or any other cause; but when these acids are not concerned, the precipitate is soluble in the nitrous acid, and thus all ambiguity ceases. 4thly, It is precipitable by *extractive* or *bituminous matter*, as the hydrogen of this matter decomposes the nitrous acid; but in this case also the precipitate is discoloured and is soluble in the nitrous acid, so that no deception can arise.

The power of this test is very great. According to Mr. Bergman, one grain of common salt dissolved in 42250 of water is discovered by producing white streaks on pouring in only one drop of this test. Therefore it discovers common salt, or any other muriated salt, when it constitutes only $\frac{1}{42250}$ part of the whole. But a grain of common salt contains only 0,39 of a grain of real acid, therefore it discovers 0,39 of a grain of combined muriatic acid in 42250 grains of water, or $\frac{1}{108333}$ part of its weight. And after standing some time it would discover much less.

Its power of detecting vitriolic acid is much less extensive, as Mr. Bergman and Dr. Black have observed (Geyser, p. 31.) and may be seen by my own experiments above related.

Note, It should be saturated or even super-saturated with nitrous acid and sufficiently dilute.

Acetited Silver. This is a precipitant of marine acid as powerful as the former, which I find necessary on some occasions. I prepare it by Margraf's method. 1 Margr. p. 116, (French) it crystallizes as Margraf asserts, though Monnet denies it, *Dissolution des Metaux*, p. 168. I found the saturate solution filtered while hot, to form very speedily acicular crystals. Monnet failed probably from having evaporated the solution.

It is subject to the same deceptions as the nitrous solution, but they are detected and remedied in the same manner.

Note also, that with nitrated lime or magnesia it gives a slight cloud, but this proceeds from an exceeding small proportion of marine acid always found in calcareous earths, and often in magnesia, for the precipitate is insoluble in nitrous acid, and when filtered off, no new precipitation takes place on the addition of the acetited silver.

Vitriol of Silver. This test of marine acid was first proposed by Westrumb. To prepare it he dissolves one part vitriol of silver in 110 parts of water. It should certainly be sufficiently dilute, as vitriol of silver is in some measure, when saturate, precipitable by pure water.

As the muriatic acid has a stronger affinity to silver than the vitriolic, muriats decompose this vitriol just as they do nitrated silver, and it has this advantage, that it is not precipitable by sulphats also, as nitrated silver is, but still it is subject to the ambiguity arising from its precipitability by aerated alkalis and earths. This he proposes to prevent by previously saturating these by nitrous acid, but unfortunately nitrated earths, particularly the calcareous, are precipitable by vitriolated silver; nay I found that even nitrated magnesia occasions a precipitate with this salt. Hence, unless we are sure of the absence of aerated earths, this test cannot be fully relied on.

§ II. OF THE UNCOMBINED BORACIC ACID.

Acetited Lead, is the true test of this acid when disengaged from every basis. But as this test may also be acted on by aerated alkalis and earths, and by sulphats and muriats, some precautions must be used to be enabled to trace the precipitate to the boracic acid singly. Therefore,

1. The alkalis and earths may be saturated with acetous acid, (distilled vinegar) yet I am inclined to think, that this precaution is unnecessary, as the boracic acid should unite these, and thus no excess of acid should appear.

2. The sulphats should be decomposed by acetited stronthian, and the muriats by acetited silver, for neither of these are decomposed by the pure boracic acid. Then these being filtered off, acetited lead will precipitate the boracic acid, and the precipitate is soluble in nitrous acid whose specific gravity is 1,3.

OF BORAX.

The waters in which this salt is found have never yet been analysed; as it is difficultly soluble, it is probable they contain no large proportion of it, except $\frac{1}{30}$ be reckoned such. It also is incompatible with earthy and metallic salts, except those formed by fixed air, but the mineral alkali may, and probably does co-exist with it. It may therefore be discovered by saturating both with vitriolic acid, and then distilling the compound in a heat gradually raised so as to redden the bottom of the retort. Some boracic acid will thus sublime in the neck of the retort in the form of shining particles.

As natron is much more soluble than borax, it is probable they may be separated by evaporation and crystallization, the borax crystallizing much sooner, and in the same manner it may be separated from glauber and common salt.

I dissolved aerated soda and saturated it with distilled vinegar, so that it no longer affected sublimate corrosive. I mixed it with a solution of borax, and it immediately precipitated sublimate corrosive of a brick red.

§ 12. OF SULPHUREOUS ACID UNCOMBINED.

This may be discovered by the smell, also by gentle distillation into a receiver in which a few ounces of water should be put and kept cool. This water impregnated with this acid will discolour litmus, destroy the redness of tincture of roses tinged red by an acid, and precipitate muriated barytes, &c.

§. 13. OF NITROUS ACID COMBINED.

As there is no particular precipitant of this acid, it is discovered only by the properties of the salts which it forms, of which I shall presently treat.

§. 14. OF EARTHS COMBINED WITH THE MINERAL ACIDS IN GENERAL.

Fixed Alkalis, whether caustic or semi-aerated, and *semi-aerated volalkalis*, serve as general tests of earths combined with the mineral acids and dissolved in water. *Of earths dissolved by fixed air*, I have already treated, and here suppose them separated by heat as already mentioned. Aerated magnesia is the only one that in some measure escapes, and this may be discovered by muriated argil. Fully aerated alkalis are not so fitly applied, as the fixed air evolved from them when they unite to the mineral acids that were previously united to the earths, often keep the earths in solution. Also, if the earthy salts be contained in the waters only in a small proportion, they in many cases evade the detecting power of alkalis, as will hereafter be shewn.

§. 15. OF BARYTIC EARTH.

Vitriolic Acid much diluted, immediately detects this earth, which is said to have been found in waters united to the marine acid.

Lime, united to the nitrous or muriatic acid, can alone cause any doubt with relation to the precipitate; but if the proportion of water be abundant, the selenite thus formed appears very slowly, or not at all, and when precipitated, it is dissoluble in 700 times its weight of water, or less; whereas Baroselenite requires 40000 times its weight of water to re-dissolve it. Besides a solution of selenite, itself precipitates muriated barytes.

If barytic earth be found, no sulphat need be sought for, as they cannot co-exist in the same water.

§. 16. OF CALCAREOUS EARTH.

If this earth were uncombined, fixed air would certainly be the best test of it, but when *combined*, as it has almost ever been found in waters, *saccharine* or as some call it, *oxalic* acid, is its most delicate test.

As this acid however acts and is acted upon by other substances, certain circumstances must be attended to before the existence of calcareous earth can with certainty be inferred or denied, from the appearance or non-appearance of a precipitate, when this acid is employed. Thus,

1. Where the mineral acids abound, and are in some measure disengaged from any combination, they either decompose the saccharine acid, or dissolve the saccharated lime, if any be formed, and thus prevent, either totally or partially, the appearance of a precipitate, as I have long since experienced in analyzing stones, and have mentioned in the first edition of my Mineralogy, in 1784. This has also been noticed by Westrumb, 3 Westr. 332. And it occurs principally where *nitrated* lime is concerned, as Mr. Bergman himself, the inventor of this test, has observed; for having attempted the precipitation of nitrated lime by the saccharine acid, he found that, though the solution, after the addition of this acid,

really contained 119 grains of saccharated lime, yet only 72 were immediately precipitated, the remaining 47 continuing dissolved until the liquor was evaporated, 1 Bergm. p. 262. Hence, also, it is proper that the saccharine acid should be well purified (by a second crystallization) from all remains of nitrous acid that may adhere to it when first formed.

2. This acid precipitates barytic earth from the muriatic acid with which it is said to have been found combined in some Mineral Waters. But this inconvenience, which seldom occurs, is easily prevented by previously adding the dilute vitriolic acid, which frees the water very soon of barytic earth, if any be contained in it.

3. This acid precipitates *magnesia*, even from the vitriolic acid, but then it acts sluggishly; in solutions containing much more Epsom than any natural water ever contains, this precipitation takes place very slowly, demanding from 2 to 15 hours; whereas, calcareous earth is immediately precipitated by it, though only two grains of it, or less, should be contained in 7000 of

water. Besides, if by other tests the existence of magnesia is disproved, then there can be no objection to this test.

The *power* of this test, by the testimony of all analysts, is very extensive. According to Bergman, one grain of the concrete acid of the size of a pin's head, discovers one grain of pure lime in 42250 of water, by forming a grey cloud, and a precipitate is deposited at least in 24 hours. Fourcroy found this acid in a state of solution to discover immediately about 2 grains of calcareous earth united to different acids in 9216 of water, or more exactly $\frac{1}{4213}$ of the whole. The specific gravity of the saccharated solution he employed was 1,020. By applying it before and after considerable evaporation or continued ebullition of the Mineral Water, it shews whether the lime was held in solution by fixed air, or by a mineral acid, or partly by both. For, if the lime were held in solution by fixed air only, it would be precipitated by continued ebullition or partial evaporation; and consequently this test could precipitate none; but if it were dissolved in a mineral acid, this test would cause a precipitate both before and after partial evaporation or ebullition; and if the precipitation proceeded partly from lime united to fixed air, and partly to a mineral acid, the quantity of the precipitate formed by this test before evaporation or ebullition, would exceed that formed after evaporation.

The presence of an alkali, though barely aerated, in a Mineral Water, does not disturb the operation of this test, either on lime or magnesia, as it is more strongly attracted by either of these earths than by an alkali.

Caustic tartarin has also been applied as a test of this earth when held in solution by fixed air; as by taking up part of the air, it precipitates the earth, and this precipitate is effervescent, which distinguishes it from earths held in solution by common acids. Per 1 Bergm. p. 196. This alkali would detect 17 grains of the aerated earth in 42250 of water; but it is not a test sufficiently discriminative, as it precipitates many other substances.

Vitriolic Acid is another useful test of calcareous earth, when this earth is united either to fixed air, or to the *nitrous*, *muriatic*, or *sulphureous* acids. But its power is not extensive; for the resulting selenite is itself soluble in 500 parts water, and if an excess of acid supervene, in much less. Hence it slowly precipitates lime from lime-water, as one ounce of this seldom contains more than 0,68 of a grain of lime, which when the vitriolic acid is added, makes no more than 1,7 of a grain of mere selenite*, most of which remains in solution; but, if the lime be united either to the nitrous or muriatic acids, it may exist dissolved in a far smaller proportion of water; but these acids being expelled by the vitriolic, render the resulting gypsum much more soluble, so that, unless the lime amounts to 3 or more grains in 1000 of water, no precipitate will appear: this, however, is much helped by adding spirit of wine. I found that one grain of selenite in 1000 of water immediately formed a cloud on adding spirit of wine, whose specific gravity was 0,834 or 0,848, but not when the specific gravity of the

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* By mere selenite, I mean selenite considered abstractly from the water of crystallization, to which, when dissolved, it is not united, as I shall prove in the sequel.

spirit of wine was 0,900, until the mixture was heated.

If muriated barytes and muriated lime should both occur, and both be precipitated by the vitriolic acid, still the superior solubility of that part of the precipitate which consists of vitriolated lime would immediately discover this earth. Moreover, a solution of selenite itself would precipitate the muriated barytes, as already observed.

§. 17. MAGNESIA.

Caustic Volalkali and Lime-water are the only *general* tests of this earth, as they precipitate it from all acids; the first partially, the second totally; yet their indications are somewhat ambiguous, as they both precipitate *argil* also. I shall treat first of volalkali.

1. *Caustic Volalkali* should be applied with diffidence when *aerated magnesia* is reasonably suspected to exist in the solution; for in such case the volalkali will become aerated, and, when it is so, it precipitates lime from any acid, as well as magnesia or argil. Now aerated magnesia is reasonably

suspected, whenever aerated magnesia is deposited by evaporation or ebullition of the Mineral Water. This inconvenience is remedied by saturating the water with muriatic or nitrous acid, which expels the fixed air, and the liquor should be boiled to free it intirely; then the caustic volalkali can precipitate only magnesia or argil. To separate these, my method is to draw off the supernatent water by a syphon or syringe, (the precipitate being too small for filtration) wash the precipitate repeatedly, re-dissolve it in nitrous or marine acid, and again precipitate with a mild alkali; dry it in a heat of 90°. or 100°. and then expose it to the action of dilute vitriolic or marine acid. The magnesia is thus quickly dissolved, and the argil, if any, scarcely touched. The reason of proceeding thus is, that the magnesia, precipitated by caustic volalkali, is itself de-aerated, and in that state not easily dissolved in any acid, much less by distilled vinegar the solvent usually recommended as having but little action on argil. By the second precipitation it becomes aerated, and easily soluble; besides, distilled vinegar cannot penetrate into argil; and thus, if the magnesia be in a small proportion, much of it will escape its action.

2. *Lime-water.* This test is still more deceptive than the last; for it not only precipitates both magnesia and argil, as the last, but is itself precipitable by fixed air and vitriolic acid. The effect of fixed air is prevented by saturating the water with nitrous acid, and that of the vitriolic acid by expelling it by means of nitrated barytes, previous to the application of lime-water; this will then precipitate only magnesia or argil, or both, which are to be essayed or separated as just mentioned[*].

Besides these general tests, there are others applicable in particular cases, as will hereafter be shewn.

§. 18. OF ARGIL.

Caustic Volalkali and *Lime-water* are also the general tests of argil. How the ambiguities arising from their double power, as well as from fixed air and vitriolic acid, are

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[*] In the 22 Ann. Chym. p. 219, it is said, that lime-water does not decompose muriated magnesia, yet I have never failed of producing a precipitate.

prevented, and how each of these earths are distinguished and separated, I have shewn in the last section.

There are also other tests of this earth suited to particular combinations, as will soon be shewn.

§. 19. OF SILICEOUS EARTH.

The general method of discovering this earth is to evaporate a large quantity of water nearly to dryness, then to supersaturate and re-dissolve all that may have been precipitated by adding a sufficiency of nitrous or vitriolic acids, and then evaporate to dryness. If then the dry mass be once more re-dissolved in water and filtered, the siliceous earth will remain on the filter. It is distinguished by its insolubility in most acids, and its vitrescibility with two parts soda.

OF SECONDARY TESTS.

Besides the general tests of acids, and of their bases, mentioned in the foregoing sections, there are others of particular combinations of many of them, applicable on particular occasions, and with particular circumstances, these I shall call *secondary tests.* The quantity of each salt in a given quantity of the Mineral Water, found by these tests, should be noted.

OF VITRIOLIC SALTS.

§. 20. OF VITRIOLATED TARTARIN AND GLAUBER.

Nitrated Lime is a good test of both these salts with the following precautions. 1st, Let the water be cleared of *volalkali*, if any be suspected, by gentle and partial distillation. 2dly, Let it be evaporated to one half, and freed from all suspicion of Epsom or alum, by treating it with *lime water*; thus all other vitriolic salts will be converted into selenite.

3dly, Let the selenite be expelled by evaporation to a few ounces, and the addition of a few drops of spirit of wine and saccharine acid.

4thly, To the filtered residuum then add a strong solution of nitrated lime, if the alkaline sulphats exist in the quantity of 8 grains in 1000 of the liquor, a precipitate will speedily appear. If the sulphats be contained only in the quantity of 4 grains in 1000 of the liquor, nitrated lime will discover this also, if spirit of wine be added, and the liquor slightly heated, at least after 24 hours. The discovery of still smaller quantities, indeed of the smallest, may be obtained by using nitrated barytes instead of nitrated lime, after the previous preparation just mentioned.

Having thus ascertained the existence of an alkaline sulphat, to distinguish whether the basis be *tartarin* or *soda* let an equal quantity of the water be treated in the manner aforesaid; but instead of nitrated lime, let *acetited barytes* be employed, and the precipitate being filtered off, an acetited alkali will be found in the filtered liquor. Let this be evaporated to dryness, and treated with spirit of wine 0,835, to separate it from other salts that may accompany it. The alcoholic solution, filtered off and evaporated to dryness, will exhibit the acetous salt; which, if its basis be *tartarin*, will deliquesce by exposure to the atmosphere; but if soda, it will rather effloresce.

The power of spirit of wine, in precipitating these salts, and particularly glauber, is not great; a solution of one grain of vitriolated tartarin in 1000 of water was clouded (where the liquors touched) by spirit of wine, whose specific gravity was 0,817, and a precipitate appeared in three days. But a similar solution of glauber was less affected, and the slight precipitate formed, vanished on agitation. But a solution of one grain of vitriolated tartarin in 500 of water was not altered by spirit of wine 0,834 after 24 hours, nor was a solution of 2 grains of desiccated glauber in 500 of water, in my experiments.

Note. Both these salts are incompatible with the existence of either nitrated or muriated lime, and also with nitrated or muriated magnesia, except one or other of the antagonists be in a very minute proportion in 7000 grains of the water. *Note also*, both the sulphats may be decomposed by barytic lime water even added to excess, and afterwards the excess precipitated by fixed air and the alkalis saturated therewith, then on evaporation both alkalis will be obtained. This is Vanquelin's method.

§. 21. OF SELENITE.

Evaporation and *Spirit of Wine* are the best tests of this *salinescent* substance.

By *evaporation to a few ounces* it will be deposited if contained in the proportion of 4 grains in a 1000 of the evaporated liquor, if in a still smaller proportion, the liquor should be treated with spirit of wine; its *peculiar solubility*, when thus obtained single, the proporties of its solution in 500 parts water, which affords a precipitate both with muriated barytes and acid of sugar, and with a solution of aerated magnesia, and with spirit of wine, set its nature beyond all doubt.

I found *spirit of wine*, whose specific gravity was only 0,848 to produce a cloud instantaneously, in a solution of one grain of selenite in 1000 of water, a still more dephlegmated spirit would discover a still smaller quantity of it. Spirit of wine, whose specific gravity was 0,900, also produced a cloud in the solution when heated. No other salt is so sensible to its power.*

Alkalis are frequently used as tests of earthy salts, and with respect to their power of precipitating earthy sulphats, I have made some experiments which I shall mention under the head of each.

1st, *Caustic tartarin* does not precipitate selenite even in 24 hours, when contained only in the proportion of one grain in a 1000 of water. Hence 7 grains of selenite in a pint of water will elude its action; (care should be taken when the genuine effect of caustic fixed alkalis is explored, that the water should contain no fixed air, else the alkali would take it up and then act as aerated alkali,) but it will immediately precipitate a solution that contains one grain of selenite in 500 of water, and consequently 14 grains in about a pint of water. But common *semi-aerated tartarin* (salt of tartar) or *crystallized soda* even effloresced, or *aerated volalkali*, immediately form a precipitate in water that contains selenite

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* I believe solutions of it may be so proportioned as to become tests of the degrees of strength of spirit of wine or brandies.

in the proportion of $\frac{1}{1000}$, and certainly even in a much smaller proportion at least in 24 hours, or a few days.

According to 1 Bergman, p. 161 and 157, fixed alkalis discovers $\frac{1}{3280}$ of selenite, this seems the limit of their powers; consequently they would not discover one grain in a pint of water. *Muriated barytes*, according to Bergman, detects 7 grains of selenite in 42230 of water in 24 hours, or about $\frac{1}{6033}$ part of the whole. Ibid.

Selenite is incompatible with no salt found in Mineral waters, except alkalis, and aerated magnesia, and muriated barytes.

§. 22. ALUM.

Aerated Lime is a good test of this substance, for with alum it gives a precipitate, and with no other salt except *muriated barytes*, and *vitriolated metals*. The ambiguities arising from these collateral powers of this test rarely occur, and are easily prevented. That arising from *muriated barytes* is prevented by a few drops of dilute vitriolic acid, which will detect and precipitate the barytic earth if any be; and in such case we may be sure that neither alum nor any other sulphat exists in the water. If a *vitriolated metal* exists in the water, it is easily discovered by the colour of the precipitate and also by prussite, which removes it. After which this test will decompose and precipitate the argil from alum. Aerated magnesia produces the same effect.

Mr. Bergman, to effect this separation, uses chalk well purified, finely pulverised and applied to the water evaporated to a few ounces and strongly heated, 4 Bergm. p. 150. in note. I have found the solution of lime in fixed air dropped into a solution of alum to produce a precipitate very readily. It is true, the precipitate was mostly gypsum, for much of the argil was kept in solution by the fixed air. To apply this experiment to Mineral Waters, containing alum, immersed in abundance of water, we must recollect that gypsum is soluble in 500 times its weight of water; and that, consequently, none can be precipitated unless the quantity of water be diminished by evaporation. But the argil may singly be precipitated if the fixed air that holds it in solution be expelled by heat, even though the mass of water be not much reduced. Remark also, that any water that produces a precipitate with both muriated lime, aerated lime, and muriated magnesia, must contain alum.

The power of *caustic alkalis* to discover this salt is exceeding weak, caustic tartarin did not discover one grain of alum dissolved in 1000 of water, not even after 24 hours; nor even one grain in 500 of water, and scarcely 4 grains in 500 of water; caustic volalkali was still less effective.

Aerated alkalis are more powerful; common *salt of tartar* produced a cloud in a solution of alum, containing but one grain of desiccated alum, (equal nearly two of crystallized) in 1000 of water after a few seconds. But *crystallized soda* produced none even in 24 hours. Nor did *mild volalkali* until the water was heated, then floculi appeared. Nay *crystallized soda* did not precipitate a solution containing one grain of desiccated alum in 500 of water, even after resting 24 hours; but it did when the solution contained 2 grains of such alum in 500 of water. *Mild vol-*

alkali instantly produced a cloud in water, 500 grains of which contained one of such alum.

To distinguish alum from mere vitriolated argil, is not always easy. If indeed on the addition of a few drops of caustic volalkali, argil be precipitated, we may be sure that either alum or muriated argil exists in the water; and in §. 30, a method will be seen of distinguishing these; but, if by the addition of a few drops of the volalkali or caustic tartarin, no precipitation follows, this may proceed either from an excess of vitriolic acid accompaning the alum, or from an existing mere vitriolated argil into which those alkalis enter, forming that triple salt which we call alum. The only method of discriminating these cases that at present occurs to me is this, let the excess of acid be absorbed by tartarin, and then let all the earthy salts be precipitated by lime water, and the existence of an alkaline sulphat investigated as in §. 20. If any alkali be thus discovered, then alum exists in the water; but, if none be thus found, the vitriolated tartarin remains with the argil which detains it, and consequently only vitriolated argil, and not alum, existed in the water. This conclusion may be confirmed by making the same experiment with soda instead of tartarin, for as this does not enter into the composition of any alum the sulphat it forms will be detected as in §. 20 in all cases. Hence if both sulphats are detected, alum exists in the water, but if that of soda only is detected, then we may be certain that it is only vitriolated argil that exists in the water.

Spirit of wine, unless very strong, has no extensive power of precipitating alum; spirit of wine 0,834 does not precipitate desiccated alum from water, 500 grains of which contain 2 grains of it, unless the mixture be slightly heated; but with this circumstance one grain of it in 500 of water may be discovered by affording a cloud, which disappears on agitation. In this case I added to the solution three times its bulk of the spirit of wine.

Alum is incompatible with alkalis, muriated barytes, the nitrats and muriats of lime, and aerated lime and magnesia, unless minute quantities of one or other, or of both the antagonists, be present.

§. 23. EPSOM.

The Hepatule of Stronthian[*] is a good test of Epsom when *alum* either does not exist in the water or is eliminated by aerated lime, as mentioned in the last section; for with no other earthy salt does this hepatule give an immediate precipitation, not even with muriated magnesia, or muriated barytes. It will indeed give a precipitate with selenite, but only after standing 24 hours. It is also requisite in order to attribute its effect singly to Epsom, that the water should contain no excess of acid, not even of fixed air, nor any metallic salt. The solution of Epsom I used in this experiment contained but one grain of this salt (which had been desiccated) in 500 of water.

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[*] The hepatule of stronthian I employed was formed by adding 5 measures of hepatic air, (expelled from an alkaline hepar by marine acid without the assistance of heat) to two measures of stronthian lime water; the first 4 measures caused a considerable precipitate. The liquor when clear was filtered off.

Muriated lime, is a good test of Epsom when aerated alkalis and alkaline sulphats are absent, more especially when neither muriated magnesia, nor aerated lime, produce a precipitate, for then alum and vitriolated and muriated argil, and uncombined vitriolic acid, must be absent.

The power of *alkalis* in detecting the magnesia contained in this salt is very different from that which they exercise over other earths; for caustic alkalis are much more powerful than the aerated.—Thus I found *caustic tartarin* to form *immediately* a blue cloud in a solution of one grain of desiccated Epsom in 1000 of water, and so also did *caustic volalkali*, and consequently they would discover a still smaller quantity after some hours.

But *crystallized soda*, *semi-aerated tartarin*, *mild volalkali*, and a mixture of half mild and half caustic alkali produced no cloud in 24 hours; as, if there was a decomposition, the fixed air kept the magnesia in solution. Nay, *semi-aerated tartarin* produced no cloud in a solution of Epsom that contained 2 grains (equal to four grains crystallized) in 500 of water, in 24 hours, nor did mild volalkili; though, if the liquors had been heated much, they probably would.

Hence if *selenite* and *Epsom* co-exist in the same waters, though in unequal proportion, that is, though the quantity of selenite be much smaller, yet on adding a mild alkali in so small a proportion as not to act strongly on both, it is the selenite that will be first acted upon, and mild calx precipitated.

So also if *selenite* and *alum* co-exist in the same water, aud be treated in the same manner, the selenite will be first acted upon.

So also if *Epsom* and *alum* co-exist in the same water, and are treated with mild alkalis as above, argil be the earth first precipitated.

If *selenite Epsom* and *alum* co-exist in the same water and a mild alkali be cautiously applied to precipitate them, the *selenite* will be the first acted on, next the *alum*, and last of all the *Epsom*. But if *caustic volalkali* be employed, the Epsom will first be acted on, then the alum, and the selenite not at all.

Note, by mild alkalis I mean *semi-aerated*, for the fully aerated, particularly if tartarin, or volalkali, may hold small quantities of either lime or argil in solution, more or less according to the circumstances mentioned Chap. 1, § 3, and always magnesia.

Fourcroy dissolved 6 grains of allum and 6 grains of Epsom, each in 2304 of water, and treated each solution with caustic volalkali. The magnesia was immediately precipitated, but the argil only after 20 minutes. Here 1000 grains of each solution held 2,6 of each salt. 5 Fourcroy, p. 97, his experiments on nitrated and muriated magnesia and argil exhibited results similar to the above.

The power of *spirit of wine* in precipitating Epsom is not considerable, a solution of one grain of disiccated Epsom in 1000 of water was not precipitated nor clouded even in 24 hours, by spirit of wine whose specific gravity was 0,817. Nor was one grain in 500 of water by spirit of wine 0,834 in 24 hours, though thrice the volume of the solution was added; but when the solution contained 2 grains of the Epsom, though no cloud at first appeared, a precipitate was found after 24 hours.

Hence *selenite and Epsom* may well be separated by spirit of wine 0,834 or even a weaker, even if both should be precipitated, their different solubility in water will sufficiently distinguish them. So also may selenite from other salts, the metallic excepted.

Epsom is incompatible with alkalis, muriated barytes, and nitrated or muriated lime, but not with aerated lime.

VITRIOL OF IRON.

The best method perhaps of detecting this vitriol in water, is to *heat it* in a vessel presenting a large surface, and leave it exposed to the air for a few days, thus the vitriol will be decomposed.

Spirit of Wine also precipitates this vitriol when in its usual state, and thus its union with the *vitriolic acid* may be demonstrated for it does not precipitate muriated iron; and thus also if both co-exist in the water they may be separated. If the iron be *super-oxyginated*, forming what formerly was called *dephlogisticated vitriol of iron*, it may be discovered by digesting the water containing it over earth of alum in a vessel slightly closed, as this earth easily decomposes the super-oxygenated vitriol of iron, but the duly oxygenated, only after long coction, and in proportion as it thus becomes super-oxygenated. However, I am inclined to think that such vitriol is scarce ever found naturally in waters; that which resulted in some experiments, was, I am inclined to believe, formed in the operations to which the water was subjected. But if it really exists naturally, it will be discovered by the just mentioned test.

Spirit of wine, whose specific gravity was 0,817, I found to precipitate one grain of crystallized vitriol of iron in 24 hours, though this viriolic solution held only one grain of it in 1000 of water. If therefore the liquor, after the precipitation of vitriol of iron by this spirit, still affords strong signs of iron, and gives no barytic precipitate when treated with muriated barytes, we may conclude it to have contained both *vitriolated and muriated iron*.

When spirit of wine has produced a precipitate, this precipitate should be thrown on a filter, and washed with cold water, and then examined by pouring warm water on it while on the filter, the liquor that then passes will contain the vitriol dissolved, easily discoverable by tincture of galls, or prussite.

Vitriol of iron is incompatible with alkalis, muriated barytes, and aerated earths.

OF MURIATS.

§. 25. COMMON SALT AND SYLVIAN.

1. Let the vitriolic salts, if any be contained in the water, be expelled by *spirit of wine* 0,817, and what this does not expel, by *nitrated barytes*. Thus nothing but nitrats and muriats can remain in the water.

2. Let such of them as may consist of nitrated and muriated *earths*, be decomposed by treating them with dilute vitriolic acid, and heating the liquor to expel the dislodged nitrous and marine acids, as long as any excess of acid can be discovered by the colorific tests.

3. Let the violated earths thus formed, be expelled by spirit of wine as above. Thus the *whole of the selenite* and most of the Epsom will be eliminated. What may remain of Epsom may be expelled by barytic lime water gradually added. The magnesia or argil thus deprived of an acid basis must also fall, or be separated by filtration, and the muriated barytes thus formed must be expelled by vitriolic acid, and then the muriatic acid may be expelled by ebullition.

4. The liquor can now contain only *alkaline* nitrats and muriats. To decompose the last, let them be treated with *acetited silver*, as long as any precipitate appears. Thus, acetited soda or tartarin will be substituted to common salt and sylvian.

5. To separate these from nitre and nitrated soda, if any be; evaporate the filtered solution to dryness, and treat the dry saline mass with spirit of wine 0,817 or 0,835, (the strongest is the best,) for 24 hours, in a heat not exceeding 60°. The acetited salts will thus be taken up, and on evaporating the solution, deposited; the acetited tartarin will be discovered by

deliquescence, and the acetited soda by efflorescence. Or if a fuller proof be required, let both be heated to redness in a silver crucible until the acetous acid is expelled, and let the alkaline mass then remaining be dissolved in the smallest quantity of warm water, and to this solution add a few drops of the tartaric acid as long as it affords a precipitate. Thus the tartarin, if any be, will be discovered.

Common salt is *incompatible* with no salt found in mineral waters, but sylvian is incompatible with glauber, nitrated lime, and, if I mistake not, with nitrated magnesia and nitrated soda.

Spirit of Wine 0,834 effected no precipitation of common salt nor of sylvian in solutions that contained respectively one grain of each in 500 of water, nor did spirit of wine 0,817 in solutions of one grain of these salts in 1000 of water.

§. 26. OF MURIATED VOLALKALI.

1. To discover this salt, all the sulphats contained in the Mineral Water should be precipitated by acetited barytes.

2. The solution thus freed from sulphats should be evaporated to dryness; the dry mass can then consist only of acetites, and alkaline muriats, as earthy muriats and nitrats are incompatible with all sulphats, except with selenite, or unless the earthy muriats and nitrats have for their basis the same species of earth as the earthy sulphats, (as nitrated and muriated magnesia and Epsom, and muriated argil and alum,) however *small quantities* of one or of several incompatible salts may subsist together, as we shall see in the third chapter. But the earthy muriats that can here be found, which may be in large proportion if the water be free from alkaline sulphats, are no impediment to the discovery here sought, as they are all soluble in spirit of wine.

3. Let the dry saline mass be treated with spirit of wine, 0,817, in the temperature of 60°. for 24 hours, it will dissolve all, except the alkaline muriats, among which the muriated volalkali will also remain. This residuum then distilled with quick-lime will emit the volalkali, which, passing into the receiver, will precipitate

the solutions of iron, or alum, or lead, previously placed therein.

Muriated volalkali is incompatible with alkalis, and, if I mistake not, with glauber, and nitrated lime.

§. 27. MURIATED BARYTES.

Vitriolic Acid is a sufficient test of this salt, as no other barytic combination has yet been found in any mineral water. It produces a precipitate insoluble in 10000 times its weight of water. If on adding muriated barytes a precipitate appears, this salt cannot be found in the water, as that would prove the existence of some other vitriolic salt, with which the co-existence of this is incompatible. It is also incompatible with aerated alkalis and aerated earths, unless one or other of the antagonists be in a very minute proportion. According to 1 Bergman, p. 125, spirit of wine dissolves muriated barytes; but Scheele contradicts it, and so also do my experiments.

§ 28. MURIATED LIME.

1. Free the water of selenite, the only sulphat fully compatible with muriated lime, by gentle evaporation to a few ounces and addition of spirit of wine 0,817, and afterwards of the minutest vitriolic taint by *nitrated* barytes. After this treatment the solution can retain only muriats, and perhaps nitrats, among which that arising from the use of nitrated barytes must be enumerated, which can only form nitre or nitrated soda, or both in very minute quantities. If the proportion of nitrated barytes employed be large before it has attained its full effect, then we may be sure that the quantity of muriated lime in a pint of the water must be very minute, otherwise it would not escape decomposition by the alkaline and magnesian sulphats, if any be. So if the water be manifestly alkaline, or contain a large proportion of aerated magnesia, it can of necessity contain only a small quantity of muriated lime, as both these substances decompose this salt.

2. Evaporate the filtered solution to dryness, and treat the residuary mass with spirit of wine, 0,817; this will dissolve the calcareous and magnesian muriats, (and also nitrats if any,) and muriated argil, *leaving* the barytic, and nitrats formed in decomposing the sulphats, if any were, and also the alkaline muriats which might be contained in the water originally, *behind*.

3. This alcoholic solution is then to be evaporated to dryness, and the residuum re-dissolved in water.* In this solution we are to seek for muriated lime, by trying, first, if it be *possible* it should be contained in it, and secondly, whether it be *certainly* contained in it. The possibility of its being contained in it is established by finding in a proportion of it the *muriatic acid*, by means of nitrated silver, and *calcareous earth* by means of the saccharine or vitriolic acids, or any earthy sulphat. But, to attain a full certainty, we must either *disprove* the existence of the nitrous acid, or, if this be found, also that of magnesia, or, at least, (if magnesia and nitrous

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* This I shall in future call a *Conversion* of an alcoholic into an aqueous solution.

acid be found,) we must shew that the muriatic acid is united to the lime; for, if the nitrous acid and magnesia exist in the water, then it is *possible* that the muriatic acid should have been united to the magnesia, and that the lime, (detected by its proper tests,) had been united to the nitrous acid. It is true, that the existence of nitrous acid in Mineral Waters is not *probable*, but still it may be suspected, as it has been found united to lime in the waters of Vaugirard by Fourcroy.

To prove, therefore, that the muriatic acid is united to lime, four methods occur: the first consists in shewing, that no other earth exists in the solution, and if this succeeds it is sufficient. For this purpose let a portion of the solution be essayed with aerated lime; this will precipitate the argil, if muriated argil exists in the water, but not muriated or nitrated magnesia. And if argil be not found, (or if found, it being filtered off,) let the solution be treated with perfectly caustic volalkali, which will precipitate magnesia, if nitrated or muriated magnesia exists in it. If neither of these earths be found, it is plain, that the muriatic acid must be united to lime, and even if argil, and not magnesia be found, still the existence of muriated lime is proved, as nitrated argil has not yet been discovered in any mineral water.

But if magnesia be found, three other methods occur of discovering whether the lime be united or not to the muriatic acid; the first is to precipitate the lime by gradual additions of the of the dilute vitriolic acid, as long as any precipitate appears, and the addition of a small quantity of spirit of wine, 0,834, or even a weaker and gentle heat. Thus both the vitriolic acid and the lime will be eliminated from the filtered solution, and the acid to which the lime was first united, will remain disengaged in the liquor, and consequently is capable of passing over when the liquor is distilled. If then the liquor be gently distilled, and received in a small quantity of water placed in the receiver, the acid previously united to the lime will pass into it. . If the water in the receiver precipitates nitrated silver, we may be sure it was the muriatic acid that was united to the lime; if it does not, and yet discovers signs of acidity by the colorific tests, we may be certain that the lime was originally united to nitrous acid, and consequently the muriatic to magnesia.

The second method of discovering muriated lime, consists in decomposing the muriated earth by *acetited silver*; thus the earth which was united to the muriatic acid, will be united to the acetous, then evaporating the solution to dryness, and treating the dry mass with spirit of wine, 0,817, or even 0,834; the acetited lime, if it be found, will for a long time evade the action of the alcohol, but nitrated lime and muriated magnesia very soon yield to it.

The third method of discovering muriated lime requires also that the solution should be evaporated to dryness, and gradually heated to incandescence for an hour (more or less, according to the quantity) under a large surface, and then exposed for some hours to the open air in a cool place. If the saline mass contained nitrated lime and muriated magnesia, both these salts will be decomposed by the heat given, and the earths only will remain; but if it consisted of muriated lime and nitrated magnesia, this last will be decomposed, and the muriated lime alone will remain undecomposed and attract moisture from the atmosphere, and can be dissolved in spirit of wine, &c.

This salt is incompatible with any notable proportion of aerated alkalis, or aerated magnesia, and with all sulphats except selenite; and, if I mistake not, with nitrated soda.

§. 29. MURIATED MAGNESIA.

To save trouble, it may be proper to remark at the outset, that aerated alkalis and alkaline sulphats are incompatible, if in notable proportion with a notable proportion of this salt, yet small proportions may co-exist. If therefore a notable proportion of the former be found in the preceding experiments, only a small proportion of this last can be expected; but it is compatible both with selinite and Epsom.

To evince the presence of this salt, let the sulphats the water may contain be decomposed by *nitrated barytes*; thus nitrats and muriats can only remain in it.

2. Let the solution be then evaporated to dryness, and the dry mass treated with

spirit of wine, 0,817. Thus the alkaline nitrats and muriats will be excluded from the alcoholic solution, and only the nitrats of lime and magnesia, and the muriats of lime, magnesia, and argil, can possibly be comprehended in it. Let then the alcoholic solution be converted into an aqueous one.

3. We are now to try whether *magnesia* does really exist in this solution; and for this purpose let a portion of it be essayed with *aerated lime*; this will precipitate argil, if any be contained in the solution, but not lime or magnesia, and the argil (if found) being filtered off, let the same portion of the solution be treated with perfectly caustic volalkali; this will precipitate magnesia, if any be in the solution.

4. The existence of muriatic acid is next to be explored in the same portion of the solution by nitrated silver; for if this acid be not found, all farther research for muriated magnesia is evidently at an end.

5. If the muriatic acid be found, then it is incumbent on us to shew that it is united to magnesia. There are two ways of shewing this, according to the circumstances of the case: the first consists in shewing

that the solution contains no other earth but magnesia; for this purpose, let another portion of the solution be treated with vitriolic acid and spirit of wine, as in the last section. If no precipitate appears, and if no argil has been found in the former trial, then it is plain that magnesia is the only earth contained in the solution, and consequently that muriated magnesia exists in it, and perhaps also nitrated magnesia; for these two salts may co-exist.

The second way of shewing the existence of muriated magnesia must be resorted to in more complicated circumstances, namely, when in the preceding trials, not only argil, but also lime has been found in the solution; for then both muriatic acid and magnesia might exist in the solution without contracting an union with each other, as the magnesia may have been united to the nitrous acid, and the lime and argil to the muriatic; or the nitrous may be united to both the lime and the magnesia, and the muriatic acid only to the argil, or the magnesia may be united partly to the nitrous, and partly to the marine acid. In this case, therefore, we must first eliminate the lime by the vitriolic acid, and also the acid it was united to by distillation, as in the last section; after which we must precipitate also the magnesia by the saccharine acid, and the addition of spirit of wine; in the interval of a few days it will be wholly deposited, then by distillation, the acid it was united to will be found in the receiver. If it be the *marine*, then muriated magnesia existed in the solution; if it be an aqua regia (which may be found by its action on leaf gold, or regulus of antimony, or affording with tartarin both nitre and sylvian) then the magnesia was united to both the muriatic and nitrous acids; but, if the nitrous singly, then muriatic magnesia did not exist in the water.

§. 30. MURIATED ARGIL AND MURIATED IRON.

These salts are a so incompatible with aerated lime, and aerated magnesia, and aerated alkalis, except either these or the muriated argil be held in a very minute proportion.

To discover them, the aerated alkalis, if any be, should be saturated with nitrous acid, and the sulphats decomposed by nitrated barytes; and these being filtered of a portion of the water, should be treated with aerated lime, which will precipitate both the muriated argil and muriated iron, if any be, and no other salt.

Note, however, that a doubt may arise if iron be found, whether it were not the remains of vitriolated iron, which would be held in solution by the nitrous acid employed in decomposing that vitriol by nitrated barytes? To dissipate that doubt, the water should be boiled after the nitrated barytes had performed its office; for by ebullition in open vessels the nitrated iron, if any, would be precipitated, and the iron afterwards expelled by aerated lime, must be deemed to proceed from muriated iron. Moreover, if the iron be muriated, it will give no precipitate with muriated barytes.

§. 31. MURIATED MANGANESE.

Muriated manganese is generally accompanied by muriated iron, and is separated from all other concomitant salts except muriated argil, by aerated lime, after the previous treatment mentioned in the last section.

The precipitate thus obtained, should be dissolved while yet moist, in the muriatic acid, and the solution treated with tartarised tartarin, which, according to Hermstadt, precipitates muriated manganese, but not muriated iron. See the 2nd vol. of my Mineralogy, p. 461.

§. 32. OF NITRATS.

NITRE, AND NITRATED SODA.

To discover these salts without crystallization, precipitate all the sulphats by *acetited barytes*, and all the muriats by *acetited silver*; thus no other salts but *acetites* and *nitrats* can remain.

2. Evaporate the whole to dryness, and treat the saline mass with spirit of wine, 0,817; it will take up all the acetites, except a portion of the acetited lime, and leave the alkaline nitrats.

3. Filter off the undissolved nitrats, and wash them with spirit of wine, 0,850, or a weaker, and re-dissolve them in water.

4. Let the aqueous solution be treated with aerated magnesia, this will precipitate the nitrated lime.

5. To get rid of the nitrated magnesia formed by the last treatment, evaporate the whole once more to dryness, and on the dried mass pour spirit of wine 0,817, this will take up the nitrated magnesia, and leave the alkaline nitrats untouched.

§. 33. NITRATED LIME.

This salt is incompatible not only with aerated alkalis, aerated magnesia and argil, and all sulphats except selenite, but also with sylvian, which it invisibly decomposes. It is evident therefore that a notable proportion of any of the antagonists renders every proportion but the smallest of the other impossible.

To discover this salt, the water should be evaporated considerably, yet not too much, in order to deposit the greater part at least of the selenite it may contain, and then should be treated while yet warm with spirit of wine 0,817 to free it from other sulphats also. The evaporation should not be carried too far, least the sulphats and nitrated lime should decompose each other when approximated.

2. The sulphats filtered off and the alcohol expelled by heat, a portion of the liquor should be essayed for lime by the saccharine acid, and if this be discovered we must proceed farther.

3. We must decompose the muriats by acetited silver, which will free it not only from marine acid, but also from all remains of sulphats if any were still retained, and hence a small excess of it should be added.

4. The filtered solution can now retain only acetites and nitrated lime, and must be evaporated to dryness, and the dry saline mass again treated with spirit of wine 0,817 which will take up all the acetites, except acetited lime, which would result from muriated lime, and also contain the nitrated lime, if any be.

5. The alcoholic solution should then be converted into an aqueous solution, the vitriolic acid will prove or disprove the existence of the nitrated lime, as no other calcareous salt can exist in it.—Instead of the process No. 4, the acetites

and nitrated lime may also be treated with the semi-aerated tartarin, which will precipitate the basis of the acetites, and also that of the nitrated lime, and the filtered liquor being evaporated to dryness, and the dry mass treated with spirit of wine 0,817, the acetited tartarin will be re-dissolved, and the *nitre* remain untouched.

§. 34. NITRATED MAGNESIA.

This salt is incompatible with alkalis and all sulphats (except Epsom and selenite) which it invisibly decomposes, and also with sylvian and muriated barytes, therefore this salt must be in a very minute proportion where any of its antagonists abound, and *vice versa*.

1. To evince its presence, the water must therefore be freed from sulphats and un-neutralised alkali, by a few drops of marine acid, moderate evaporation, and spirit of wine as mentioned in the last section, and also from all that may have escaped this last agent, and also from muriats, by the application of *acetited silver*.

2. The filtered solution being now evaporated to dryness, the residuary saline mass will yield to spirit of wine 0,817, all the acetites and other salts, except nitrated lime, if any were. The spirit of wine will consequently take up nitrated magnesia, if the water originally contained any.

3. Now to discover the nitrated magnesia, we must convert the alcoholic solution into an aqueous solution, and treat the aqueous solution with *caustic tartarin*; this will precipitate all the earthy acetites, and also the nitrated magnesia, forming acetited tartarin with the former, and nitre with the latter.

4. The earths being filtered off, the aqueous solution is again to be evaporated to dryness, and the residuum treated with spirit of wine 0,817, which will take up the alkaline acetites, and leaving the nitre untouched, will thus demonstrate the original presence of nitrated magnesia.

If nitrated lime does not exist in the water, the application of acetited silver is still necessary to destroy the alkaline muriats, which otherwise would be found with the newly produced nitre.

§. 35. BITUMINATED ALKALIS.

This mineral soap (unless existing in a very minute proportion) is incompatible with all earthy sulphats, muriats, and nitrats.

If in a notable proportion, it affects the *colorific tests* as aerated alkalis do. *Strong acids* dropped into waters that contain it produce a coagulum, which is often re-dissolved by adding more of the water, namely, when the alkali is so abundant that it can take up more bitumen than is naturally united to it. Alkalis do not affect it, but re-dissolve the coagulum if any were formed by acids. *Sal ammoniac* is decomposed by it, and the volalkaline smell evidently perceived if the water be heated, or the volalkali will be found if distilled.

If the water coagulated by acids be filtered off, a viscous substance remains on the filter, which is inflammable and soluble in alkalis, and thus its bituminous nature is evinced.

§. 36. EXTRACTIVE MATTER.

Mr. Westrumb has furnished us with a test of this substance, for which none was before known. He tells us, that a solution of *nitrated silver* applied to water, out of which all muriatic and vitriolic acid has previously been expelled by nitrated lead, will be precipitated *brown* by extractive matter; and that three grains of this precipitate denote one grain of extractive matter, 3 Westrumb, p. 57.

The usual method of obtaining it, is to evaporate the water to dryness, and then treat the residue with spirit of wine, in which it seems this matter is soluble; then to evaporate the alcoholic solution to dryness, and moisten the dry mass with muriatic or dilute vitriolic acid, and then again to dry it perfectly, and once more re-dissolve it in spirit of wine and filter the solution, the extractive matter will then remain on the filter.

So also that part of the saline mass which the alcohol had at first left undissolved, being again dissolved in water, and the solution evaporated to dryness, and again treated with alcohol, will yield somewhat more to it, which treated as already mentioned, will leave somewhat more of extractive matter on the filter. It tastes bitterish, and seldom exceeds half a grain in 7000 grains of water.

This matter is sometimes separated without the intervention of vitriolic acid, by merely throwing the alcoholic solution into twice its weight of water, Westrumb, *saline Pyrmont*, p. 50.

§. 37. ANIMAL EXTRACTIVE MATTER.

This singular substance, of which I met no distinct account, but in the 37th volume of the *Journal de Physique*, for July, 1790, p. 87, is found in the fountain of Avor, in Anjou, in great abundance, and was discovered by Mr. Ducloseau; the smell and taste of this water are exceeding disagreable until it has been a long time exposed to the air, it then putrifies; but after a few days, particularly if much agitated, it becomes much purer. The animal extract which it contains is in a great measure soluble in spirit of wine, but much escapes its action, and emits a most infectious smell on evaporating it. I find no other description of it.

CHAP. III.

OF INCOMPATIBLE SALTS.

I ONCE thought the labour of analysing Mineral waters might be much abridged, by observing, when certain species of salts were discovered in it, what other species would be decomposed by that or those already discovered, and consequently could not (I thought) be supposed to co-exist with them, and of course needed not to be sought for. But I soon found both my own experiments, and by the observations of the most accurate analysts, that when both species of antagonist salts, if I may so call them, are *very* far from the point of saturation in a given solution, they may co-exist in it. The requisite distance from the point of saturation is various in various species of salts; the observations I have made on it I shall mention, after producing some examples of the co-existence of these seemingly incompatible ingredients.

1st, Mr. Cavendish, on analysing the waters of Rathbone-place;* found that a pint, or 7315 grains of this water held about 0,9 of a grain of aerated volalkali, and 1,2 grains of selenite. Now these two salts, if in sufficient quantity, would decompose each other, for though the inverse also happens, (for aerated lime decomposes ammoniacal salts,) yet it is only with the assistance of heat; in the temperature of the atmosphere it does not. I have observed in § 21, of the last chapter, that a drop of the solution of aerated volalkali instantly decomposes a solution containing $\frac{1}{1000}$ of selenite.

2dly, Mr. Bergman tells us he sometimes found one grain of selenite in a *kan* of Spaw water, which nevertheless contained 8,5 of crystallized Mineral alkali (or rather about 4 of mere aerated) and expresses some surprise at this occurrence, and attributes their inactivity to their great rarity.†

3dly, Dr. Garnet found in the wine gallon of the sulphur water at Harrowgate,

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* Phil. Trans. 1767, p. 107.

† 1 Bergm. p. 211.

13 grains of muriated lime, and 10,5 of crystallized Epsom (or rather 5 of mere Epsom, as I shall presently shew) and these salts may well co-exist in that proportion in so large a quantity of water, at least 58400 grains. Then a pint would hold 1,6 grains of muriated lime, and 0,6 of a grain of mere Epsom. In § 9, of the last chap. I have shewn that nitrated lime did not *discover* one grain of mere Epsom in 1000 grains of water in 24 hours; and *Fourcroy* observed, that muriated lime did not discover one grain of Epsom in 4000 of water, nor did even a decomposition happen in my experiments.

4thly, Tingry found one grain of soda and 5,4 of selenite in 10 pounds of the water of Amphion, 3 Mem. Laus. p. 59.

5thly, Westrumb found 0,06 of a grain of muriated lime, and 0,93 of a grain of magnesia to co-exist in a pound of water with 11,7 of crystallized (or rather 6 of mere) glauber, 1 Chy. Ann. 1788, p. 129.

6thly, Accum found 1,04 of a grain of muriated lime, and 13,8 of crystallized (or about 7 of mere) glauber in one pound of water, 5 Crell Beytr. p. 465.

7thly, Cornette found 6 grains of muriated lime and 6 of glauber to retain their transparency in one pound of water, Mem. Paris, 1778, p. 345. This indeed is not conclusive, for still there might have been a decomposition; but in the water of Salins, he proves that glauber and muriated lime co-exist until heated. Ibid, p. 342.

8. Maret found that 94 grains of boracic acid did not unite to 3 of aerated lime, though both were contained together in 4 ounces of water, 2 Mem. Dijon. 1784, p. 156.

9. Bergman found half a grain of muriated lime, and half a grain of glauber, in a *kan* of the waters of Odin in Upsal, and also 1,5 grains of aerated soda, 1 Berg. p. 157.

As these examples appear to me abundantly sufficient to prove that many salts, which are incompatible when in considerable proportion, may nevertheless co-exist when in a very minute proportion to the quantity of water that contains them. I shall not trouble the reader with a repetition of other instances related in the ninth §. of the last chapter.

Bergman ascribes the inactivity of the divellent powers in these cases to the rarity of the particles that possess them, within a given space; this is indeed the *circumstance* in which the activity of these powers ceases, but does not appear to me to be the *cause* of this cessation. However rare the antagonist particles may be, they are equally numerous within a given space, let the proportion of their mass be what it may. It is only the *magnitude* of the particles that can be supposed different when their proportion is different. Thus the number of particles of an ounce of salt within 10 cubic inches of water, in which it is supposed dissolved, is equally great as it is within that same space, when that weight of salt is dissolved in 1000 cubic inches of water; it is only the magnitude of the particles that is different. Now the diminution of magnitude in other cases, rather promotes than obstructs the exertion of attractive powers, as the surfaces of the attracting particles by which they come in contact with each other are thereby increased; therefore the diminution of magnitude, merely as such, cannot be the cause of this inactivity. It must consequently be rather attributed to the *resistance* of the particles of water to that *motion* and *separation* from each other, which the action of the devellent powers of the saline particles would necessarily induce; just as the particles of leaf-gold float on water, when the difference of the specific gravity of gold and water is compensated or overcome by the resistance of the particles of water to their division. So in this case the force of the devellent powers is resisted and overcome by the attractive power of the particles of water to each other. And hence when this resistence is diminished by heat, a decomposition often takes place, which otherwise would not, see Mem. Par. 1778, p. 342. Hence the greater the attractive power of the antagonist particles to each other, the greater must be their rarity before its activity can be counterbalanced by the resistance of the particles of water. Thus we have seen that the attraction of barytic earth and of calces of lead to vitriolic acid, and of calces of silver to marine acid, and of gallic acid to calces of iron, and of lime to fixed air being exceeding strong, they will act on each other, though their masses be to that of water, only as 1 to 80000 or 100000. And thus a scale of attractive powers may perhaps one day be formed.

The following list exhibits most of the incompatible salts that need here be noticed.

1. Aerated alkalis—and earthy or metallic sulphats, muriats, or nitrats.
2. Uncombined vitriolic acid—and earthy nitrats, or muriats, or aerated earths, &c.
3. Alkaline sulphats—and earthy nitrats, or muriats.
4. Glauber—and sylvian.
5. Vitriolated tartarin—and nitrated soda.
6. Vitriolated volalkali—and nitre (Quere?) and sylvian.
7. Epsom—and nitrated lime or muriated lime.
8. Alum—and nitrated lime or magnesia, or muriated ditto.
9. Nitrated lime—and sylvian, sal ammoniac, muriated barytes, and muriated magnesia.
10. Nitrated magnesia—and sylvian and muriated barytes.
11. Muriated magnesia—and nitrated soda, and nitrated lime.

CHAP. IV.

OF THE EXTERNAL OR PHYSICAL PROPERTIES OF MINERAL WATERS.

The properties of waters as far as they relate to the senses, that is their colour, transparency, smell, taste, and the inferences to be drawn from them, being noticed and satisfactorily deduced by Bergman, need not here be mentioned. The temperature and situation of the springs should also be carefully observed as they may lead to geological discoveries, the quantity of water that flows from them in a given time is also to be remarked; as a calculation of the quantity of some useful substance that may be extracted from them may be grounded thereon.

But of all the physical properties of Mineral Waters, the most important, with respect to their analysis, is their *specific gravity*, on this therefore I shall make some remarks.

Though the lightest waters are *generally* the most pure, yet this happens only when they are also void of smell and taste, for hepatic waters are often specifically lighter than the purest distilled water. Thus *Andrea* found the water of the sulphureous spring of *Limmer* lighter than distilled water, 2 Crell. Beytr. p. 207; as did *Brockman* that of *Rensdorf*, 3 Crell. Beytr. p. 461. This water it is true is also bituminous.

The heaviest water of which I met any account, is that of the lake Asphalt or *Dead Sea*. Lavoisier found it 1,2403, and that it contained 44,4 per cent. of saline matter, of which 6,25 parts were common salt, and 38,15 were muriated lime and muriated magnesia, Mem. Par. 1778, p. 69. The lightest is that of the fountain of Envie, near *Turin*, its specific gravity is 1,0000. It contains no fixed air, and 8 pounds of it contain about 0,5 of a grain of aerated lime, Mem. Turin, 1788, p. 84. The specific gravity of waters that abound in fixed air, is very difficultly obtained, as they constantly emit bubbles. It should not be attempted, unless in temperatures below 50°. as even the weakly impregnated often sparkle at 60°. According to Bergman, water fully saturated with fixed air at the temperature of 36°. weighs 0,0015 more than distilled water.

There is a method of conjecturing the quantity of salt in 1000 parts of a saline solution whose specific gravity is known, which, however inaccurate, is yet useful in many cases as the error does not exceed 1 or 2 per cent. and sometimes not even equal 1 per cent. It consists simply in substracting 1000 from the given specific gravity expressed in *whole* numbers, and multiplying the product into 1,4. It gives the weight of the salts in their most desiccated state, and consequently freed from their water of crystallization. The weight of fixed air must be also included; thus a solution of common salt having its specific gravity 1,079. I find its difference with 1000 is $\begin{array}{r}1079\\ -1000\\ \hline =\cdot\cdot 79\end{array}$ and $79 \times 1{,}4 = 110{,}6$ then 1000 grains, &c. of such solution contain 110,6 of common salt; and in effect, Brisson found a solution of 2 ounces of salt in 16 of water to have its specific gravity 1,079; here 18 ounces of the solution held 2 of salt, now as 18. 2 :: 1000. 111.

Again, Brisson found a solution of 6 ounces of salt in 16 of water to have its specific gravity 1,2038. This solution must therefore have weighed 22 ounces. Therefore 1000 grains of it should contain 272,2 and $\begin{array}{r}1203\\ -1000\\ \hline =203\end{array}$ and 203 x 1,4 = 284. The error here is 1,2 per cent.

Brisson found a solution of 2 ounces of nitre in 16 of water to have its specific gravity 1,0702, then if 18 ounces contain 2 of salt, 1000 should contain 111. The difference in this case is 70,2, which multiplied into 1,4 gives 98,28, the error is not 1,3 per cent.

In his table we also find that a solution of 2 parts glauber in 16 parts water, had its specific gravity 1,0438; consequently 1000 parts of the solution would contain 111. The difference here is 43,8, which multiplied into 1,4, gives 61,32; and in effect, glauber contains about half its weight of water of crystallization, in which case 111 would be reduced to 55,5, and when he dissolved 4 parts glauber in 16 of water, he found the specific gravity of the solution 1,079; and if 20 contain 4, 1000 should contain 200. The difference is 79, which multiplied into 1,4 = 110,6, which expresses the weight of the desiccated salt with little error. I have compared, in the same manner, the specific gravities and weights of the solutions of soda, vitriols of iron, copper, and zinc, and find the errors in computing from this rule, equally inconsiderable.*

I have also examined and compared the proportions of common salt in several of the solutions of that salt of which the specific gravity is given in the Phil. Trans. for the year 1770, p. 349, and found the quantities given by the above rule to-

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* I cannot however find this correspondence betwixt the specific gravities of the waters analyzed by Mr. Bergman, and the weight of the contents he attributes to the waters he analyzed. Hence I believe he must have been deceived. Thus, to the waters of Selzer, he attributes the specific gravity 1,0027 taken at 59°. of Fahr. yet Brisson in temperature 61°. Fahr. found it 1,0035. So Bergman states the specific gravity of the waters of Denmark at 1,026, and its contents, when crystallized, at 32,75 grains; and yet to the water of Selzer, whose specific gravity he states at 1,0027, he attributes 180 grains of crystallized contents, and 30 of fixed air.

lerably near the truth. I selected this salt as the proportion of it taken up by water in temperatures between 46°. and 55°. differ insensibly from those taken up at temperature 60°. or 61°. It must however be remembered that the salt there employed contained some portion of muriated magnesia, otherwise one part of salt could not be held in solution by two of water, which occasions in some instances, namely, when the proportion of salt is considerable, a deviation of about 2 per cent. from the rule.

I must also remark that the specific gravity of salts in their concrete state, must always be lower than that which the saline particles possess when dissolved; because in their concrete state numberless vacuities intercede between the saline particles, which in a great measure vanish or subsist no longer, when the particles are severed from each other, as they are when in a state of solution; moreover the more dilute the solution is, the more minutely must these particles be divided, and consequently retain fewer vacuities, and consequently must be specifically heavier.

Hence it is that salts, before solution, elevate water to a much greater height than after solution, as Dr. Watson has observed, p. 331; and thus found that vitriolated tartarin, whose specific gravity before solution, was 2,636, had, when dissolved, its specific gravity raised to 5,272, though the cause of this phænomenon did not then occur to him.

CHAP V.

OF THE STATE OF SALTS IN MINERAL WATERS.

TO be enabled to judge of the quantity or proportion of the salts detected in Mineral Waters, we must ascertain their weight when dry, and in a concrete form. Now many of them and those too the commonest in Mineral Waters, as soda, Glauber, Epsom, may exist in a concrete form in two states; namely, furnished with, or intirely deprived of their water of crystallization, the absence or presence of which produces a difference, amounting to one half their weight or more; when deprived of this water, they exist in their mere *simple* saline state; when furnished with it, in their *crystallized* state.

There is no question, but their weight should be taken in that state, whatever it be, in which they are judged to exist in Mineral Waters; and what appears to me very surprising, most analysts have hitherto considered them as existing in those waters in a crystallized state.

Thus Bergman, vol. I, p. 122. expressly decides that their quantity is to be estimated by their weight in their crystallized state; "for," adds he, "in that state they exist in "waters." And Fourcroy, in his Analysis of the waters of Enghien, p. 294, computing the quantity of neutral salts he detected in them, tells us we must consider these salts as contained therein, in their crystallized state. "For," says he, "they are "capable of being crystallized, and when "naturally dissolved, they necessarily contain that quantity of water to which they "adhere with more force than to that "which holds them dissolved." This estimation is also less subject to error. And again, p. 301, "Neutral salts must be "estimated in their state of crystallization, "for it is only thus that their quantities "can be exactly appretiated; in effect, "crystallization is a constant uniform "state, which, when regular, always re- "requires in each neutral salt the same "quantity of neutral salt, and the same

" quantity of water and saline matter, and " is not subject to error. Moreover, salts " dissolved in Mineral Waters ought to " be considered as retaining their water " of crystallization." Led by these authorities, or persuaded by these reasons, most analysts have adopted this mode of estimation.

It must however be owned, even at first sight, that this mode of estimation appears very unnatural. The virtue and powers of Mineral Waters, whether medical or chymical, reside entirely and solely in the mere saline parts; for in salts actually crystallized, the water of crystallization, though in a solid state, is as devoid of power (except as far as relates to the production of cold) as any other water, insomuch, that in calculating the results of the union of such salt with any other substance, the water of crystallization is no farther considered than as it contributes to the dilution of the saline part, as is evident when it is employed either as a saturant, a precipitant, or a flux. On a more attentive view, the fallacy of this mode of estimation will appear still more clearly. When a salt is actually dissolved, there is no pretence for distinguishing any part of the water it is dissolved in, as water of crystallization, as in fact there is no crystallization. The only difference betwixt water of crystallization and other water, is the difference of states, the one being solid and the other liquid; but when salts are dissolved, all is liquid, this difference then exists no longer. The difference of states arises from the substraction of caloric, but when crystallized salts are dissolved, the watery part (as well as the saline part) recovers its caloric or latent heat, and thus produces cold; consequently it is then in the same state as other water; a sure proof of this is, that it is only in their crystallized state that salts produce cold during their solution, whilst several of them when dissolved in their desiccated state, produce heat; and, on the contrary, those that produce cold during their solution, produce heat, or give out caloric in the moment of their crystallization, which evidently shews they were not deprived of their caloric, nor consequently in a crystallized state in the water. It is true nevertheless, that all saline solutions contain less specific heat than pure water; but this arises solely from the saline part, which contains less caloric than water, and therefore the aggregate of both must contain less. The assertion that salts are more attached to any portion of the water in which they are dissolved than to another portion of the same water, is destitute of foundation; tests shew that every integrant part of a saline solution is equally impregnated.

Farther—if salts existed in waters in their crystallized state, as Mr. Bergman asserts, or attached to their water of crystallization, then it would follow, that solutions of equal quantities of two salts whose specific gravities in their crystallized state are equal, in equal quantities of water, should equally raise the specific gravity of the portions of water in which they are dissolved, though one of those salts should possess a large portion of water of crystallization, and the other scarce any. Yet hydrostatic experiments clearly prove that the contrary happens; and that of salts that contain much water of crystallization, nearly twice as much is requisite to produce a specific gravity equally high as of a salt which contains little or no water of crystallization.

Thus Brisson, having dissolved two parts of common salt in 16 of water, in the temperature of 61°. found the specific gravity of the solution to be 1,079; but the solution of the same quantity of Glauber's salt in the same quantity of water had its specific gravity 1,043. Nay, it required 4 parts Glauber to produce the same specific gravity (very nearly) as was produced by only two of common salt, namely, 1,0795; and yet in their crystallized state, the specific gravity of Glauber is rather higher than that of common salt; for that of common salt by Fahrenheit's experiment is 2,125, and that of Glauber by Friend's experiment 2,132, and by Muschenbroeck's 2,246. Therefore the water of crystallization adds nothing to the specific gravity of any solution, nor to any other effect produced by it, and therefore its distinct existence as such, or in a different state from other parts of the water, is perfectly imaginary. Hence it is that the difference of elevation produced in water before and after solution is much greater in solutions of salts that contain little or no water of crystallization, as vitriolated tartarin, common salt, calcined vitriol, &c. than in solutions of salts that contain much water of crystallization; because in these the mere watery part contributes little to this effect. Thus, in those of vitriolated tartarin and calcined vitriol it amounted to $\frac{1}{2}$, and in that of common salt to $\frac{10}{27}$, but in that of Glauber it amounted only to $\frac{1}{7}$, in green vitriol to $\frac{3}{16}$, as Dr. Watson observed, Phil. Trans. 1770, p. 331 and 332.

Nor can it be said that the state of crystallization should be chosen as most favourable to the exact estimation of the weight of salts; for, not to mention that many salts very commonly found in Mineral Waters are scarce even to be obtained in a crystallized state, as muriated lime, and muriated magnesia, it is certain, 1. That small quantities of any salt are difficultly crystallized into forms by which they can be distinguished *. 2dly, That the mother liquor always retains some portion. 3dly, That the crystals themselves retain part of

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* Journal des Mines, N. XXVII. p. 203.

the mother liquor. 4thly, That the quantity of the water of crystallization is itself variable, according to the state of the atmosphere †. 5thly, That many salts, such as soda and common salt, Glauber and soda, Glauber and Epsom, &c. cannot be perfectly separated by crystallization, nor consequently their weight duly ascertained.

Hence, if neutral salts even existed in their crystallized state in water, yet this mode of estimating their weight must be deemed the least accurate, and the weight of their simple saline part should otherwise be investigated.

I know of only one exception, and that is vitriol of iron; for though this does not exist in a crystallized state in water, yet neither does it exist in the de-aqueated state in which we can procure it, as in the heat applied to strip it of its water it attracts more oxygen than when in solution it possessed.

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† Westrumb, the most experienced hydro-analyst in Europe, says, that it requires the greatest skill to obtain salt, furnished with the due quantity of water of crystallization. 2 Westrumb. 2 Heft. p. 45.

PART II.

OF THE ANALYSIS OF MINERAL WATERS.

CHAP. I.

OF THE COMMON METHOD.

THE Analysis of Mineral Waters comprehends three branches of inquiry; viz. 1st, The determination of the different species of salts contained in the Mineral Waters. 2dly, The estimation of the quantity of each in a given quantity of the water, either by weight, as in pounds, or by measure, as in a gallon, quart, &c. And, lastly, The determination of the species and quantity of elastic fluids contained in a free and uncombined state.

The determination of the species of salts has hitherto been attempted, partly by inferences from the results of tests, and partly by their actual exhibition, some in a crystallized and some in a desiccated form, being obtained by evaporation to dryness, and separated from each other by the skilful application of spirit of wine of different densities, and of water successively applied in unequal quantities and of unequal temperatures to the dry saline mass, with various incidental solutions and precipitations; and lastly, by the solution and precipitation of the aerated earths, or ascertaining the indissolubility of such as are insoluble.

I shall now state my objections to each of these modes of investigation, as commonly practised.

§. 1. OF TESTS.

Tests as commonly applied, are generally allowed to afford only *conjectural*, not *demonstrative* inferences even of the *species* of salts contained in Mineral Waters, at least in the cases that most frequently occur. Thus Fourcroy, one of the most skilful and experienced hydro-analysts of modern times, speaking of the water of Vaugirard, tells us, that, "tests announce "the presence of sulphuric acid, lime,

" magnesia, &c. in that water; but that " these indications are far from affording " us a satisfactory knowledge of the prin- " ciples contained in it, of which *evapo-* " *ration* alone conveys a certain and exact " account." *Analyse des Eaux d'Enghien*, p. 371.

Gioenetti, in his celebrated analysis of the water of St. Vincent, after relating the results of the application of a few tests, concludes by telling us he will pursue this inquiry no farther; " for though tests are " not without their use, yet *no certain* " conclusion can be drawn from them." *Analyse des Eaux de St. Vincent*, 31.

Bergman also, to whom this mode of inquiry is so much indebted, admits that it does not always afford grounds for an *accurate decision*, particularly where *quantities* are concerned; yet he foresaw that even in this respect much might be effected, though until then they never had been employed with that view, 1 Bergm. 89. His prediction has lately been fully verified by Dr. Black and Mr. Klaproth, and in some measure by Hassenfraz.

Fourcroy has well explained the source of the insufficiency and inaccuracy of tests: "They announce, it is true, some earthy "or alkaline bases, others of them acids, "and others also metals; yet they do not "always inform us with what acid this or "that basis is united, nor consequently the "true nature of the matters contained in "the waters. It is true, that the knowledge of double elective attractions throws "in many instances, much light on the "subject, yet in many cases much uncertainty still remains; as when the vitriolic "acid is united both to lime and to magnesia, and the muriatic to magnesia; or "when the muriatic acid is united to lime "and magnesia, and the vitriolic to lime. "Of these combinations tests give us no "information." *Analyse des Eaux d'Enghien*, p. 69 and 70.

It must however be allowed, that in some cases the constituent specific ingredients have been inferred from the indications of tests, with great sagacity and ingenuity, by some German chemists, particularly Gren, Westrumb, and Reuss. But cases occur that evade detection in the usual mode of applying them. Thus, in the waters of Bilberger both Epsom and muriated magnesia exist, as Gren *conjectured*, but without any proof derived from the tests he applied, for the muriatic acid, without contradicting any of them, might have been united solely to an alkali, 1 Crell, Beytr. 3 stuck, p. 69.

The usual method of applying tests is similar to that of sending out adventurers to an unknown country to try what discoveries they can make, hence their indications are vague and unconnected.—Whereas if they were limited to some particular object, and so combined and arranged as to prove or disprove its existence, their indications might be rendered certain and precise; and such information I have already shewn them capable of conveying, when employed with single and definite views.

§. 2. OF EVAPORATION.

As the mode of investigating the contents of Mineral waters by tests, as commonly employed, is frequently incapable of discovering either various species, or quantities, so the pursuit of either object of inquiry by evaporation, and the train of operations that succeed it, is not only on many occasions vain and fruitless, but even fallacious and inaccurate.

The fallacies to which evaporation gives rise have been noticed by Mr. Fourcroy, ever since the year 1788, and some of them he has indeed happily obviated.— Thus he has shewn that when hepatized waters are evaporated to dryness, the sulphur re-acts on the aerated lime contained very frequently in those waters, and converts it into an hepar, and when spirit of wine is afterwards applied, the hepar is dissolved by it, and consequently the aerated lime can at no period of the analysis be discovered. But when the spirit of wine that contains this hepar is again evaporated to dryness, the sulphur is converted partly into sulphuric and partly into sulphureous acid, and thus a selenite is formed, and if the water contained muriated magnesia, Epsom will also be formed, and thus the original ingredients are completely metamorphosed and disguised, *Analyse de l'Eau d'Enghien*, p. 270 and 325.

In addition to this observation, grounded on experiments, which he purposely instituted to verify them, I shall farther remark, that Mineral waters frequently contain incompatible salts as already stated, one or other of which is indeed in an inconsiderable proportion, but when by close evaporation they are brought together in an inconsiderable space, they decompose each other, and thus salts are exhibited which the water did not originally contain.

Again, the usual practice is to weigh the saline mass left after evaporation, before and after treating it with spirit of wine, in order to judge by the loss of weight how much of it had been taken up by the spirit, see 1 Bergm. p. 181, 5 Fourcroy, p. 127, and 1 Westrumb, 2 heft, p. 119, and 120. Now it is easily seen that the difference of weights can decide nothing in this case, unless the degree of desiccation before and after the treatment with spirit of wine, be exactly the same, which can never be expected to happen, not only because the same degree of heat cannot be exactly attained, nor the saline mass exposed under exactly the same surface, but also, because the salts that remain after the action of the spirit of wine retain water much less powerfully than those which the saline mass contained, before it was exposed to that menstruum. Nor can this inconvenience be remedied by weighing the contents of the spirituous menstruum after its evaporation, for these will be often found to weigh more than the spirit had really taken up, because it deposits its contents in a crystallized state which nevertheless it had taken up deprived of their water of crystallization; and this is particularly observable where muriated magnesia is concerned, as Fourcroy has well remarked, *Analyse d'Enghien*, p. 284. The various losses of weight above-mentioned have also been noticed by him, ibid. 282, and by Westrumb, 2 Westr. 2 heft, p. 43, and cannot have escaped any experimenter. The process that next succeeds the treatment with spirit of wine, namely, the solution of the more soluble salts, by adding to the dry residuum eight times its weight of cold water, and separating them from each other by crystallization as recommended, 1 Bergm. p. 122, and 126, is still more grossly defective, and incapable of answering the end proposed in a great variety of cases, not only from the inverted order of solubility, when the least soluble are also in the least quantity, but also from the avowed impossibility of an exact separation of many species of salts by this method. Thus, it is well known that common salt and soda, common salt and glauber, common salt and Epsom, glauber and soda, glauber and Epsom, muriated lime and muriated magnesia, nay, not even nitre and common salt can be exactly separated by crystallization; and hence in all these cases the most skilful and experienced analysts have of late been necessitated to have recourse to estimate their qantities by calculation. As the methods they have devised are curious and instructive, I shall here briefly relate them.

1. *Common salt and soda*, both being crystallized and exactly weighed, Bergman*

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* 1 Bergm. p. 132.

requires that the soda be saturated with dilute vitriolic acid, and the quantity of this acid employed, noted. Then that the same weight of the same dilute acid should be saturated also with crystallized soda, the weight of which must be the same as that of the soda mixed with the common salt, and this weight being substracted from that of the aggregate of both, gives that of the common salt. Here it is supposed that the crystallized soda in both cases contains the same quantities both of water and fixed air, if not, the quantities of real alkali will undoubtedly be equal, but those of each alkali in its crystallized state (which is that which Bergman seeks) unequal.

Gioannetti* in this case saturated the compound mass of both (after weighing it) with distilled vinegar, and then separates the acetited soda with spirit of wine, and thus obtains the common salt single. The alcohol must indeed be highly rectified not to attack the common salt also, as will soon be seen.

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* Analyse de St. Vincent, p. 36, 37.

The Marquis de Brezé* in a similar case re-dissolved the compound of both salts, and treated the solution with a solution of nitrated silver as long as a precipitate appeared, and then treating the precipitate with nitrous acid, estimated the weight of the common salt by that of the muriated silver, as that alone remained undissolved by the nitrous acid added. But he supposes that 135 grains of muriated silver indicate 65,35 of crystallized common salt, which is not exact.

2. *Common Salt and Glauber*; if the quantity of common salt exceeds or equals that of the glauber, Westrumb† separates them, first by obtaining much of the common salt by crystallization, and then adding dilute spirit of wine, he obtains nearly the whole of the glauber, after which the remainder of the common salt is obtained by evaporation. But if the quantity of glauber be predominant, he separates it intirely by spirit of wine. This application of spirit of

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* Mem. Turin, 1788, p. 60.

† 1 Westr. Abhandl. p. 290. 2 Westr. Kleine, Abhandl. 2 heft, p. 87, and 88.

wine I consider as a great improvement of the halurgic art, for which we are indebted to Mr. Westrumb.

3. *Soda, Common Salt and Glauber*; Klaproth estimates the quantities in a mixed solution of all three in the following manner, which is by far the most exact. 1. He saturates the soda with dilute vitriolic acid (382 grains of which he previously found requisite to saturate 100 of desiccated soda, and to afford therewith 132,5 grains desiccated glauber) then, (knowing that 100 grains of desiccated glauber would, when treated with acetited barytes, afford 168 of desiccated baroselenite) he estimated the whole quantity of glauber from the quantity of baroselenite which it afforded when treated with acetited barytes, from which he substracted first, the weight of glauber formed by the addition of the vitriolic acid, of which, as already said, 382 grains afford 132,5 of desiccated glauber, the remainder then was the glauber originally contained in the solution, and the quantity of factitious glauber being known, that of the soda was also discovered, as 132,5 grains of desiccated glauber corresponded

with, and was afforded by the saturation of 100 grains of desiccated soda. Lastly, the solution now containing only acetited soda and common salt, he estimated the quantity of this last, by decomposing it with nitrated silver, having shewn that 233,5 grains of muriated silver well dried corresponded with and proceeded from the decomposition of 100 grains of pure common salt, dried by exposure to the atmosphere, 1 Klapr. p. 333 and 334.

On comparing the quantities of these salts obtained by *Gren*, in the ancient method, (crystallization) with those obtained by Reuss, by Klaproth's method, from the waters of Egra, which differ but little in different seasons, I find the difference to amount to 6 per cent. with respect to the common salt; 11 per cent. with respect to glauber; and 17 per cent. with respect to soda; Gren moreover observed that 91 grains of common salt, and 46 of soda, could not be separated by crystallization, 2 Chy. Ann, 1785, p. 333.

4. *Common Salt and Epsom.* Fourcroy separated and estimated them after weighing the aggregate of both, by decomposing the Epsom by lime water, and thus con-

verting it into selenite, of which he easily freed the solution by evaporation, and this being filtered off, the solution afforded the common salt singly, whose weight being substracted from the aggregate, gave that of the Epsom originally contained in the water, *Analyse de l'Eeau d'Enghien*, p. 288. He tells us that the solution, though consisting of 432 grains when evaporated for thé purpose of obtaining the common salt, retained no selenite (as he found by the barytic test) which otherwise might be suspected; Westrumb would probably have separated the Epsom by spirit of wine, which is certainly the quickest method.

5. *Glauber and Epsom.* Bergman, after noticing that their crystals often much resemble each other (but that those of the former are commonly larger and more depressed) as both are bitter and subject to efflorescence, yet easily distinguishable by adding lime water, tells us he determines the quantity of each, when both are mixed, by weighing and then dissolving the aggregate of both, after which he decomposes the Epsom by soda, and by adding vitriolic acid to the precipi-

tated magnesia recomposes Epsom, the weight of which he substracts from that of the aggregate, the remainder gives the weight of the glauber originally contained in the aggregate, 1 Bergm. p. 128 and 129. He adds, that the weight of the Epsom might also be inferred from that of the precipitated magnesia, (which shews that great man had the method of estimation I employ already in contemplation.) In this case however it would be better to precipitate the magnesia by lime water, as then it would be obtained free from fixed air; there is no danger that selenite would be precipitated with it, as the abundance of water would keep the selenite in solution, and to obtain the whole of the magnesia, the solution should be heated to 180°. If the quantity of Epsom were very small, there would be an obsolute necessity of recurring to this mode of estimation. Westrumb observed that 65 grains of Epsom and 300 of glauber could not be separated by crystallization, 2 Westr. p. 45, and 46.

6. *Muriated Lime and Muriated Magnesia.* To separate and estimate each of

these, Klaproth first weighs the aggregate, then precipitates the warm solution of both by soda, then super-saturates the precipitate with vitriolic acid, continuing the heat for some time, (I suppose, to be certain that the calcareous earth was wholly taken up, and to expel the fixed air,) after which he saturates the excess of acid by aerated lime. The selenite thus formed he filters off, then evaporates gently to rid the solution of any remaining selenite, the solution then containing nothing but Epsom, he crystallizes by exposure to the air, re-dissolves the crystals, decomposes the Epsom by soda, and dissolves the precipitated magnesia in muriatic acid, evaporates to dryness and substracts its weight from the original aggregate, and thus obtains the weight of both the ingredients, 1 Klapr. p. 360. Dr. Garnet, in his Analysis of the sulphur water of Harrowgate, p. 44, applied also the vitriolic acid to separate these muriats; the selenite thus formed he separated, and estimated the quantity of lime it contained and the quantity of muriated lime that quantity would form, by Bergman's computation, and substracting this from the original aggregate, found the weight of the muriated magnesia.

Westrumb separated these salts, after weighing the desiccated aggregate, by adding lime water, whose proportion of lime he had previously ascertained. Thus he obtained the magnesia unaerated, this he dissolved in muriatic acid, evaporated the solution to dryness, and substracted the weight from that of the aggregate. Fourcroy employed nearly a similar proprocess, *Analyse d'Enghien*, p. 374.

7. *Common Salt*, *Muriated Lime*, *and Muriated Magnesia*; Gioannetti, to estimate these, after weighing the aggregate, precipitated the muriated earths by semi-aerated tartarin, separated them from each other by vitriolic acid, the selenite and Epsom he easily obtained apart, and decomposed each by semi-aerated tartarin. To each of the earths he attributed its own weight of muriatic acid according, as he says, to Baume's computation, and substracted the joint weights from the aggregate, and thus obtained that of the common salt, Gioannetti, p. 97.

CHAP. II.

THE Analysis of a Mineral Water embraces, as I have already noticed, two objects; the discovery of the different species of ingredients contained in it, and the determination of the weight of each. How the species are discovered, I have already set forth in the chapter *on Tests.* The quantities of solid ingredients I determine, in most instances, by *estimation*, as being the least laborious, in many cases equally, and in many the most exact. This estimation is founded for the most part on my own experiments, confirmed by those of the most eminent analysts, as I have shewn in a paper presented two years ago to the Royal Irish Academy, and now published. The salts I consider in their desiccated state, for the reasons given in the fifth chapter of the first part. I now proceed to state the order in which the several particulars of the process should be conducted, according to the method I here propose.

§. I. TO DETERMINE THE EXISTENCE AND QUANTITY OF THE AERIAL FLUIDS.

The first step I would take after examining the physical properties of Mineral Water, would be to examine the existence and quantity of the aerial fluids they may contain. How the existence of each species is detected I have already shewn.

¶ I. OF FIXED AIR.

Fixed air may exist in a Mineral Water, either pure and unmixed with any other species of air, or mixed with common air, mephitic air, or oxygen air, or with sulphureous air, or with hepatic air.

OF FIXED AIR, PURE, OR MIXED WITH ATMOSPHERIC, OXYGEN, OR MEPHITIC AIRS, AND UNCOMBINED.

1. Let a retort or body furnished with a long bent neck or tube, whose capacity is known, be filled to $\frac{2}{3}$ of its cubic contents with the water whose aerial contents are to

be examined and connected (in the well-known manner) with a mercurial apparatus, containing a jar also accurately divided into cubic inches and tenths of a cubic inch, and let its contents be equal or nearly equal to those of the retort, or body and bent tube.

2. Let the water be heated to ebullition for a quarter of an hour.

3. When all is cool, let the mercury within and without the jar be brought, if possible, to a level; if not, let the number of cubic inches it contains be found, with the temperature and the barometrical height, and noted.

4. This being done, let a solution of caustic tartarin be gradually introduced into the jar, and the jar shaken therewith gently until the fixed air is absorbed, and note the number of inches thus absorbed*, and their proportion to the whole quantity.

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* I prefer caustic tartarin to lime-water, because its solution contains more tartarin than lime-water does of lime (if the bulks of both solutions be equal;) and therefore absorbs fixed air much more quickly; and if the absorption be much delayed, there is some danger that the barometrical height and temperature may change, which would produce an alteration in the bulk

5. The next step is to find the whole quantity of air in cubic inches, under the given barometrical height and the given temperature. Here two cases may arise; either the mercury within and without the jar is brought to a level, or it is not; if it be, then no calculation is requisite, the number of inches corresponding with the actual barometrical height and temperature being then truly expressed. But if the mercury within and without the jar cannot be brought to a level, then the number of inches corresponding with the given pressure of the atmosphere and temperature must be sought by calculation. To understand which it is requisite to ob-

of the residuary air, and thus the quantity absorbed would be rendered doubtful. Some advise, in order to hasten the absorption, that the jar should be transferred into a tub of lime-water, and shaken therein; but to say nothing of the enormous quantity of lime-water requisite, some common air is by agitation expelled from the lime-water, and unites to the residuary air unabsorbed, and renders its quantity doubtful; the temperature is also frequently different from that of the mercury; and if the air within and without the jar be not on a level, the quantity of residuary air must be calculated anew.

serve, that, when any part of the jar is filled with mercury and air, and the mercury is above the level of that contained in the tub, the air always occupies a greater space than it would if the mercury within and without the jar was upon a level; because the weight of the atmosphere is not intirely counterbalanced by the elasticity of the air within the jar; but part of it is counterbalanced by the weight of the mercury within the jar that rises above the level of that without the jar, therefore the air within is not so much compressed as it would be if acted upon by the whole weight of the atmosphere. Hence, to find the space it would occupy if subject to the whole pressure of the atmosphere, institute this proportion. As the actual height of the barometer in inches and parts of an inch is to the same height, less the number of inches of mercury in the jar :: so is the number of inches, &c. occupied by the air in the jar, to the number it would occupy if subject to the whole pressure of the atmosphere.

Thus, supposing the barometer to stand at 30 inches, and that the mercury in the jar occupies 8 inches, and that the air occupies 7 inches; then, if the air was subject to the whole pressure of the atmosphere, it would occupy but 5,1.

For, as 30. 30—8 (=22) so are 7 to 5,1.

If water be used instead of mercury, then 13,6 inches of water in the jar are equal to one of mercury, and one inch of water is equal to 0,075 of an inch of mercury, a quantity which in most cases may be neglected.

We are next to find the number of inches of fixed air which are supposed to have been absorbed, and this also must be found by calculation, if the mercury within and without the jar cannot be brought to a level; for the number of inches absorbed must be deduced by substracting those that remain; but, as the mercury will rise still higher within the tube after the absorption, the true remaining height cannot be found without calculation, for the reasons already given.

Thus in the example already given, the barometer being at 30 inches, if the mercury within the jar occupies after the absorption of the fixed air, 10 inches, and the air 5 inches, then, as $30 . \overline{30-10}\ (=20)$ :: so are 5 to 3,3; then, $\overline{5{,}1-3{,}3}=1{,}8$, is the quantity of fixed air absorbed*.

The space occupied by the air under the given pressure of the atmosphere being thus found, we next proceed to examine the *weight* of the fixed air absorbed, at the given barometrical height and the given temperature. The quantity or weight of air in a given space is influenced

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* These calculations are founded on the supposition that each space of the solid contents of the jar (which is found by the weight of water it contains, viz. 253,18 or 253,2 grains) is also one linear inch in height. But, if the jar be not accurately cylindrical, or if the linear inch of the graduated space exceeds the number of cubic inches contained in that space, then the numbers above found, by calculation, must be diminished in the same proportion. Thus, if the linear height be 15 inches, but, from the narrowness of the jar, the cubic contents are only 12, then the number 5,1 above found must be diminished in the proportion of 15 to 12. Thus, as 15 . 12 :: 5,1 . 4,08. But if from the breadth of the jar the number of cubic inches in the graduated space exceeds the number of linear inches of height, then the numbers found by calculation must be increased in the same proportion. Thus, if the height be 12 inches, but the number of cubic inches 15; then, as 12 . 15 :: 5,1 . 6,37.

by two causes, its pressure and its temperature; the effect of each of these we now examine, and, 1st, The weight of air in a *given* temperature is *directly* as its pressure, but its pressure is given by the barometrical height; so that its weight in a given temperature at one barometrical height being known, the weight it would have at any other barometrical height and in the *same* temperature may also be known. Now I have found that 100 cubic inches of common air, at the temperature of 60°. weigh 30,929 grains; therefore, if the barometer were 29,5, and the temperature also 60°. then 100 cubic inches of common air would weigh 30,414; for, as 30 . 29,5 :: 30,929 . 30,414.

But, 2*dly*, If the temperature be above or below 60°. the weight of air of the same volume is diminished in the first case, and increased in the second case, by each degree above or below 60°.; and hence a certain proportion must be *substracted* from the volume in the first case, to reduce it to the bulk the same weight would have at 60°. and *added* in the second case, let the height of the barometer be what it may[*].

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[*] Phil. Trans. 1777, p. 566.

According to General Roy, Phil. Trans. 1777, p. 704, 1000 inches of air gain 2,52 by each degree of heat between 32°. and 82°. that is, nearly $\frac{1}{400}$ of the whole, by each of the 50°. comprehended between 32°. and 82°.

According to Sir George Shuckburg, ibid. p. 563, 1000 parts of common air gain 2,48 by each degree between 32°. and 71°. which agrees very nearly with the former statement; so that we may take $\frac{1}{400}$ as the mean increase for each degree from 32°. to 72°. inclusive.

According to the experiments of Mr. Prieur de Vernois, 1 Ann. Chym. p. 299, common air is dilated $\frac{1}{12,67}$ by the 45°. Fahrenheit of heat, between 32°. and 77°. and consequently $\frac{1}{570}$ by each degree of heat.

But, as the conclusions of General Roy and Sir George Shuckburg are grounded not only on manometrical, but on a variety of barometrical observations, and differ little from each other, I shall here follow them.

Then the proportion to be added, if the heat of the air be below 60°. or substracted, if the heat be above 60°. in order to reduce it to the bulk it would have if its temperature was 60°. is $\frac{1}{400}$ for each degree below or above 60°.

Thus, to reduce 100 cubic inches of air, thermometer 50°. to the bulk it would have, therm. 60°. I say, $\frac{100}{400}=,25$, and $,25 \times 10 =$ 2,5; then 2,5 must be added to 100; then 102,5 is the bulk which 100 cubic inches of air would occupy if its temperature was 60°. and the barometer not altered.

3. The volume of air at 60°. being thus found, and supposing the barometer at 30″. then to find the weight of that volume of air, I say, if 100 inches, barometer 30″. and thermometer 60°. weigh 30,929 grains, n inches of air will weigh x, and $x = \frac{30{,}929}{100}n$, and x being found and $= a$, then, 4thly, To find the weight that number of inches would have *at any other* (m) *barometrical height*, and temperature 60°. I say, as 30″, a gr. :: m . x gr. and $x = \frac{am}{30}$.

EXAMPLE,

Suppose you want the weight of 100 cubic inches of common air, therm. 50°, barom. 29″,5. First find the volume this number of inches would occupy, barom. 30″. and therm. 60°. by the third rule; the expansion would be $\frac{100,00}{400}$ = ,25 for each degree, and consequently for 10°. it is ,25 x 10 = 2,5; then this bulk of air would be 102,5. Then, by the third rule, I say, if 100 cubic inches of air, therm. 60°. and barom. 30″. weigh 30,929 grains, 102,5 cubic inches should weigh 31,702 grains. But the barometer stands at 29,5 inches; therefore, by the fourth rule, the weight should be 31,173; for, as 30″ . 31,702 grains :: 29,5″ . 31,173 grains. Thus, the weight of 100 cubic inches of air at 50°. is found, since it is the same as that of 102,5 at 60°. the mass not being altered by that supposition.

To avoid the trouble of this calculation, I have subjoined a table of the length in feet of a column of air of the temperatures and pressions that most usually occur in making experiments, (viz. for each degree of heat between 40°. and 74°. and each tenth of barometrical height between 29″. and 30″,3) whose area of the base is one inch, and which weighs 344,32 grains, from Sir George Shuckburg's observations; these lengths, multiplied into 12, give the number of cubic inches that weigh 344,32 grains; hence, by the rule of proportion, the weight of any other number of inches, within the aforesaid limits of pression and temperature, are immediately found.

Thus, if it be required to know the weight of 100 cubic inches of common air, thermom. 50°. barom. 29″,5, I find by inspection that the length of a column of air of the above weight, so circumstanced, is 92,19 feet, and 92,19 x 12 = 1106,28 cubic inches; and if 1106,28 cubic inches weigh 344,32 grains, 100 cubic inches should weigh 31,124 grains, which differs inconsiderably from the former calculation.

So also the *weight* of common air in any particular case being known, to find what number of cubic inches it would amount to under a given barometrical height, and in a given temperature, is very easy by the use of the above-mentioned table. For the length in feet of a column of air so circumstanced, whose basis is one square inch, and which weighs 344,32 grains, is found in that table. Then, as 344,32 is to that number of feet multiplied into 12 :: so is the given weight of air to the number of cubic inches it amounts to.

The weight of a given number of inches of common air, under a certain pression and of a given temperature, being found, the weight of the same number of inches of *fixed air* so circumstanced, may be found pretty nearly; as, in most experiments hitherto made, it was found to be to that of common air as 3 to 2.

The weight of the fixed air being known, its volume in inches may also be found; for it is to that of an equal weight of common air as 2 to 3 nearly, under the same pression and of the same temperature. Thus the weight of 100 cubic inches of common air being 30,929 grains, barom. 30″. therm. 60°. the volume of 30,929 grains of fixed air is 66,67, for as 3 . 2 :: 100 . 66,67.

After the absorption of the fixed air, some common air remains, and to judge of its quantity, that arising from the part of the retort or body left empty must be substracted; to judge of its goodness, the nitrous test is to be applied.

I forbear enlarging on the method, as it is now well known. Care must be taken that the water within and without the jar, (for these experiments should be made over water,) be upon a level that the quantities of air may be exactly found, else recourse must be had to the calculation already mentioned; the nitrous air should be distilled from silver, and extracted without heat by an acid as dilute as can be made to act on it.

The proportions of each air I employ in this case is one measure of nitrous and one of the air to be tried. If the residuum exceeds 1,4 measures, then it is bad common air, and if it amount to much more, then it is *mephitic* air diluted by the common air of the vessels. But, if the residuum be less than one measure, then the air so tried is oxygen air, and so much the purer as the residuum is smaller, but this also is diluted by the air of the vessel.

In 1779, Gieannotti, in his Analysis of the Water of St. Vincent, suggested another method of discovering the weight of uncombined fixed air in Mineral Waters which he thought more accurate than tracing its weight from its volume, and which has since been recommended by many. It consists in adding a sufficiency of lime water to the Mineral Water before ebullition and after ebullition, and weighing the precipitated lime in both cases; the precipitate in the first case, that is before ebullition, he thinks proceeds both from the uncombined and combined fixed air; but the precipitate, after ebullition, proceeds only from the combined. Therefore, substracting the weight of this latter precipitate from that of the former, the remainder gives the weight of the precipitate arising from the uncombined fixed air singly, and this weight being had, he deduces the quantity of fixed air contained in it from Jacquin's experiment, according to which aerated lime thus formed and dried by exposure to the air, contains 40,6 per cent. of fixed air.

This method is indeed ingenious, but highly fallacious, for it is grounded on the supposition that the precipitate in all cases consists of aerated lime singly, since it is by the different weights of this precipitate, before and after ebullition, that the quantity of fixed air is traced. But it is not true that the precipitate in every case consists singly of aerated lime, for lime water precipitates also aerated magnesia by taking up its excess of fixed air which kept it in solution, and also magnesia in an unaerated state, if any Epsom or muriated magnesia existed in the water, and also argil if there were alum; and also aerated iron, and also part of the gypsum formed by the decomposition of Epsom, if any Epsom were in the water. Nay, also, it precipitates the aerated lime that may have been in the water, and thus the first precipitate, before ebullition, will consist of the aerated lime deposited by the lime water, and also of that pre-contained in the Mineral Water. Thus the second precipitate, viz. that formed after ebullition, will not contain the whole of the combined fixed air (as this method supposes) that was contained in the first precipitate; consequently the remainder left after substraction will be greater than it would be if the whole quantity of the combined fixed air, taken up before ebullition, were substracted; therefore the true weight of the precipitate, proceeding from the uncombined fixed air singly, cannot be found by this method, when aerated lime pre-exists in the Mineral Water, unless after ebullition the weight of aerated lime deposited be known.

In the analysis of the water of St. Vincent, these causes of error did not indeed occur, as it did not contain aerated iron or any earthy salts; but, in other cases, they have frequently occurred, as may be seen 2 Westr. 2 heft. 38.

¶ II. TO SEPARATE AND ESTIMATE FIXED AND SULPHUREOUS AIRS.

Let both airs be extracted from the water in a pneumatic mercurial apparatus in the manner already mentioned, and let both be absorbed by caustic tartarin. To effect this absorption and preserve the alkali, the air, after estimating its bulk, should be introduced into a bottle filled with tartarin, and standing in a bason also containing caustic or semi-caustic tartarin.

When the air is absorbed, let the tartarin be gently evaporated to dryness, and left exposed to the atmosphere for a few days; the part that has taken up sulphureous air will be converted into vitriolated tartarin, or sulphat of tartarin, which may be separated from the carbonat by adding dilute marine acid as long as any effervescence appears, and then filtering the solution; 100 grains of vitriolated tartarin contain 45 of sulphuric acid, and 45 of this acid contain 15 of sulphur, which, when combined with 15 of oxygen, would give 30 of sulphureous air, which barom. 30″. and therm. 60°. would form about 42,72 cubic inches.

The quantity of sulphureous air may also be estimated very nearly by the cautious and gradual addition of hepatic air, as this air and the sulphureous, are on mixture in equal quantities, almost entirely converted into sulphur, as I have shewn in the Phil. Trans. 1786, the remainder being only $\frac{3}{11}$ths of both airs, the fixed air remains unaltered, and its quantity may therefore be estimated by transferring it to another jar, and absorbing it by caustic tartarin, as above.

The quantity of this air may also be discovered by the weight of vitriolated silver or mercury which it precipitates from the nitrated solution of silver.

¶ III. TO SEPARATE AND ESTIMATE FIXED AND HEPATIC AIRS.

1st, Expel both airs by heat, and receive them in a jar over mercury. Thus the whole of the fixed air, and *part* of the hepatic, will be obtained.

2dly, Carry the jar into a tub of warm water, to get rid of any mercury that may adhere to it, and immediately after into a tub filled with moderately strong nitrous acid. The hepatic air will immediately be absorbed, and the fixed air remain single.

3dly, Transfer this air into a bottle filled with hot water, and thence pass it into a jar filled with mercury, and estimate its quantity by absorbing it with caustic tartarin, as above.

It is not possible to separate fixed and hepatic air by lime water, as this water absorbs both (as the Marquis de Brezé observed, Mem. Turin, 1788, p. 45, and 2 Westr. 111 and 112, and my own experiments prove.)

¶ IV. TO ESTIMATE HEPATIC AIR.

Introduce two pounds, or a quart of hepatic water into a jar or bottle, so as to fill ¾ of its capacity, and place it in a tub filled with common water. Into this bottle introduce a few cubic inches of nitrous air, it will immediately be decomposed, and after some time, the water will become turbid; continue letting up nitrous air as long as the redness of its mixture with common air evinces its decomposition; this done, turn up the mouth of the jar or bottle, and blow out the residuary air. If the hepatic smell continues in the water, repeat the addition of nitrous air as above, until the smell is destroyed. The hepatic air being thus decomposed, and the sulphureous ingredient rendered visible, add a few drops of nitrous acid to prevent the precipitation of the earths, and let the water be heated to 150°. of Fahren. for half an hour and then filtered; the excess of weight, which the dried filter will gain over its original weight, will discover the weight of the sulphur contained in the water.

One hundred cubic inches of hepatic air contain about 30 grains of sulphur, the remainder being inflammable air and water. According to Bergm. 8 grains of sulphur are equivalent to 60 Swedish Inches = 95,62 English; if so, hepatic air should be much lighter than common air, whereas it is evidently heavier; hence one grain of sulphur denotes 3,33 cubic inches of hepatic air.

All other methods of estimating the quantity of hepatic air are insecure. Thus, for instance, it cannot be wholly separated by pneumatic distillation, neither over water, as this absorbs it, nor over mercury, as this partially decomposes it, as I have experienced, and Fourcroy *Analyse des Eaux d'Enghien*, p. 319, and 320, and 5 Fourcroy, 123, and the whole of it is never expelled, not even by ebullition, 1 Bergm. p. 246, and 247. Nor does the affusion of highly mephitized nitrous acid perfectly precipitate it, it soon becomes too dilute, as Berthollett has well observed, New Roz. Tom. 3, p. 444, (unless presented in the manner above-mentioned) and much exhales.

Nor is precipitation by the *sulphureous acid* a proper method of estimating its quantity, as the precipitate consists of the sulphur contained in that acid, as well as of that contained in the Mineral water.

The *oxy-muriatic acid* also precipitates sulphur from sulphurated waters, but then the smallest excess of it oxygenates the sulphur, and converts it into a sulphureous acid.

§. 2. TO ESTIMATE THE SOLID AND LIQUID INGREDIENTS.

Having determined the quantity and species of elastic fluids, in a given weight or measure of a Mineral water, the next step I should take would be to determine the quantity of the *aerated* substances contained in it, for this purpose, if the water be *sulphurated*, it should first be deprived of its sulphur, either by exposure to the air under a large surface for 5 or 6 days, if only a few pounds be examined, or 18 or 20 days if the quantity be large; or by the gradual addition of litharge, as long as any hepatic smell remains; both methods Fourcroy tells us he found equally efficacious; but the last is much more expeditious, *Analyse de l'Eeau d'Enghien*, p. 279, 280, and 158. After which the water is to be filtered and boiled for half an hour, to deprive it, if possible, intirely of earthy or metallic carbonats. When litharge is not used, the carbonats are to be taken up by muriatic acid, separated from the sulphur by filtration, and investigated and estimated as will presently be shewn.

If the water to be examined be not *sulphureous*, but simply *aerated*, a portion of it is to be taken fresh from the spring, (not less than 7000 grains, but it will be better to take 14000 or more) and let to boil for at least a quarter of an hour, then exposed to the air, set to cool, and filtered as in the former case. Nay, though the water should give no sign of fixed air, it should be treated in the same manner, for sometimes the quantity of this air is so small as not to be discoverable by pneumatic distillation. If the water contains *volalkali*, how this is to be estimated I have already shewn, part 1, chap 1, §. 4. Then another portion of it is to be freed from this and from fixed air by ebullition as above, and the deposit filtered off.

TO ESTIMATE EACH OF THE AERATED SUBSTANCES.

The aerated ingredients may be either *aerated lime*, *aerated magnesia*, *aerated argil*, or *aerated iron*, all which are deposited by ebullition, and the manner of discerning each has been shewn in part 1, chap. 2 §. 7; all being dissolved in the muriatic acid, except argil, and perhaps selenite.—This solution filtered will also leave sulphur on the filter, if any were held in the water.

1. If the muriatic solution be found to contain calcareous earth *singly*, or any other aerated ingredient *singly*, let the solution be precipitated by aerated soda to saturation, and then boiled; each ingredient will thus be had in an aerated state as it existed in the water, the calcareous earth should then be dried in a dark red heat, the magnesia in a heat of 600°, and the iron in a heat of about 80°, and immediately weighed.

2. If iron be among the ingredients thus held in the muriatic solution, let it be precipitated by caustic volalkali, adding it only as long as a reddish precipitate is perceived; a little of magnesia, if any be, may be thus precipitated, but on heating the precipitate exposed to the air for some time, in a heat of about 200°, and then treating it with distilled vinegar, added repeatedly and in small quantities, as long as by alkaline tests it is found to contain any, the magnesia will be taken up, and the calx of iron left single. If there be no magnesia, the iron singly will be precipitated; the iron thus obtained is to be re-dissolved in marine acid, and precipitated by an aerated alkali gently dried and weighed.

3. The acetited magnesia (if any) is next to be precipitated and estimated as above.

4. The muriatic solution thus freed from iron, and from part of the magnesia, (if it contained any) is next to be resorted to. If it contains lime *singly* or magnesia *singly*, these are to be precipitated and estimated as in No. 1, adding to the weight of the

magnesia that also separated from the distilled vinegar.

5. If it contains lime and magnesia, these are to be separated by adding moderately strong vitriolic acid, as long as any precipitate appears, then heating the solution slightly, and adding spirit of wine; the selenite thus precipitated being filtered off and heated gradually to redness for half an hour, will thus be desiccated, and of this 100 grains contain 38,81 of lime, which if aerated would form 70 of desiccated aerated lime. The magnesia may now be precipitated from the muriatic solution by semi-aerated soda, dried and weighed as above.

But the whole of the aerated magnesia is not precipitated by ebullition, to obtain the remainder, the boiled water must be evaporated nearly to dryness; thus the aerated magnesia and selenite will be deposited, and by successively adding distilled water boiling, and in large quantity, the selenite and other ingredients will be re-dissolved, and the magnesia remain single, and being collected may then be dried and weighed. Or the deposited magnesia and selenite may be separated by distilled vinegar, which will take up the magnesia and leave the selenite. The acetited magnesia to be separated as above.

Lastly, the aerated argil and selenite should be estimated by weighing both when dried in a red heat, and noting the weight. Then decomposing the selenite by throwing it into a solution of soda heated to 180°; and saturating the soda, if there be an excess of it, with marine acid, least it should have taken up any argil, and making the solution boil for a quarter of an hour to expel the fixed air. Thus the argil and calcareous earth will be precipitated, and being dried, the mild lime may be separated by distilled vinegar, the argil will thus be left single; and being washed, dried and heated to redness, its weight will be found, which, substracted from the weight of the aggregate of argil and selenite, will give the weight of the selenite also. If the weight of lime and magnesia, or lime and argil, be very small, the following method of estimating their respective quantities may be thought more eligible. 1. Let the mixed solution be evaporated to dryness and weighed, then let both be re-dissolved in marine acid, and the *magnesia* be precipitated by lime water, and the precipitate dried and weighed; and let the weight thus found, be substracted from the joint weight before found, the remainder gives the weight of the *lime*, but the weights thus found are the weights of the earths in a *de-aerated state*; to find their weight in the aerated state in which they exist in the water, we must remark, that 55 grains of *lime* make, when fully aerated, 100 of aerated lime.

And 45 grains of *magnesia* would make, if fully aerated and dried at 80°, about 100 of aerated magnesia, but then it includes water also.

And 23 grains *argil* make up when fully aerated, 100 of aerated argil by Bergman's calculation, 1 Bergm. p. 37, Morveau's translation.

Argil and lime are separated by lime water and estimated in the same manner.

Examination of the Water de-aerated *and deprived of aerated substances by ebullition.*

It is not precisely the water that was already under examination to obtain its aerial contents, that should now be employed; for its quantity may be too small for the succeeding examination, but any other portion of the same water, deprived of its air, and of whatever aerated substances it may contain, by long continued ebullition and subsequent filtration. The quantity that should be thus employed should be according to the specific gravity it now possesses. The *smaller* the specific gravity the greater should be the quantity employed,. and *vice versa.* If the specific gravity amount to 1,01 or more, then it will be sufficient to examine 7000 grains of it; but if the specific gravity of the water amounts to 1,001 or less, 70000 grains, that is, 10 avoirdupois pounds at least, should be employed.

Previous to any attempt to estimate the quantities of ingredients contained in water thus prepared, it is necessary to determine the nature of those ingredients by the tests mentioned in the last chapter, as the methods of detecting the quantities of each must in many cases differ, when the constituent principles of the mineral waters are different. Hence the *investigation* of *all* the ingredients contained in the water to be examined should precede the *estimation* of *any* of them.

1. If the water contains an excess of vitriolic or sulphureous acid, (or of muriatic acid, as Dr. Withering thinks it sometimes does,) or an aerated alkali, which in many respects acts as a mere alkali; the next step to be taken is to estimate this excess in the *first case*, or the quantity of the latter in the *second case*.

Note, however, that water that contains an excess of sulphureous acid never contains, as I believe, fixed air, or any aerated substance, and therefore need not be boiled.

FIRST CASE.

2. Saturate the excess of sulphureous or vitriolic acid, by adding barytic

lime water, until the water is neutralized. The weight of the precipitate after ignition will give that of the excess of vitriolic acid, as 100 parts of baroselenite contain 33 of real vitriolic acid.

3. Again, saturate the excess of *marine
acid*, also by the addition of barytic
lime water, until neutralization
be obtained. Then precipitate the
barytic earth by the gradual addition
of dilute vitriolic acid, as long as any
precipitate appears, the weight of the
precipitate after ignition gives that of
4. the barytic earth employed, as 100
grains of baroselenite contain 66 of
barytic earth, and the weight of the
barytic earth gives that of the muriatic
5. acid which it had saturated, as 100
grains of barytic earth take up 31,8 of
real marine acid.

SECOND CASE.

6. Saturate the aerated alkali by dilute vitriolic acid, whose proportion of real acid is foreknown from its specific

gravity, (or by a previous experiment on the quantity of alkali, a certain quantity of it can saturate,) and note the quantity of it that is employed to procure neutralization, and the quantity of real acid contained in the quantity so employed, then precipitate the whole quantity of vitriolic acid contained in the water, by the addition of barytic lime water, the whole of this acid will be contained in the
7. precipitated baroselenite, of which, after ignition, 100 grains contain 33
8. of real vitriolic acid. If the quantity of real acid thus found *exceeds* the quantity contained in the dilute acid employed in saturating the alkali, then the *excess* proceeds from some alkaline sulphat pre-existing in the water, but as much as is equal to the quantity contained in the added acid, must have been employed in saturating the aerated alkali. Now the *species* of alkali being known, its quantity may be determined, the quantity of real acid necessary to saturate it being thus discovered; for 100 grains of real

9. vitriolic acid saturate 121,48 of tartarin, and 78,32 of soda.

The method of estimating the aerated volalkali has already been given, p. 34.

TO ESTIMATE THE QUANTITY OF BORACIC ACID.

10. The excess of acid in a mineral water sometimes, though very rarely, proceeds from this acid; if it be discovered, it should be precipitated by acetited lead, the precipitate digested in a heat of 200°, in a sufficiency of vitriolic acid 1,2 or 1,3 for an hour or more; thus the acid will unite to the lead. This solution should be then evaporated to almost perfect dryness, and the mass thus formed treated successively with 10 or 12 times its weight of spirit of wine, 850 or 870, until a portion of it no longer burns with a green flame. The solution thus effected being distilled or evaporated, will leave the boracic acid, which may then, or after desiccation, be weighed.

11. The next step to be taken (and in many cases the first, namely, when no excess of a mineral acid or of an alkali is found in the water) is to discover the species of *earths* it may contain; and this point being ascertained, to discover the species of *mineral acids* it may also contain, and by the result of these experiments, the progress of the succeeding investigation is to be regulated. Thus the presence or absence of earths in general is discovered by the appearance or non-appearance of a precipitate on adding a semi-aerated alkali.

If *Barytic Earth* be found, *no sulphat* need be sought for.

If *no Calcareous Earth* be found, no *calcareous sulphat*, *nitrat*, *or muriat*, can be expected.

If *no Magnesia be* found, neither a *magnesian sulphat*, *nitrat*, *or muriat*, can exist in the water.

If *no Argil* be found, then *vitriolated and muriated argil* must be absent.

If no *Metal* be found, then it is plain that no metallic sulphats or muriats need be sought for.

The next object of research, in the order of investigation, is the nature and species of the *acids*, united to some basis in the de-aerated or boiled water.

If no *vitriolic acid* be found, neither can any *sulphat*.

If no *muriatic acid* be found, neither can any *muriat*.

Thus the plan of investigation is narrowed, the objects of research being diminished in number, as no mineral water contains all the ingredients that have been found in different sources; hence I now proceed to the method of estimation of those that may, by any possibility, occur according to the present state of our knowledge.

ESTIMATION OF SULPHATS, OF GLAUBER, AND VITRIOLATED TARTARIN.

12. Glauber, which is by far the commonest of the two, has its weight very exactly indicated by that of the baroselenite, which it yields on the application of the solution of nitrated barytes, in the circumstances men-

tioned § 20, Part I. Chap. 2, as 170 grains of ignited baroselenite betoken 100 grains of desiccated Glauber, or 238 of crystallized Glauber.

13. And 136,36 grains of baroselente indicate 100 of dry vitriolated tartarin.

14. And if, to distinguish whether it were Glauber or vitriolated tartarin that was decomposed, acetited barytes be employed, then the acetited alkali in the solution from which the baroselenite is filtered off, being treated with tartaric acid, will deposit super-tartaricated tartarin (cream of tartar) of which, when dried in a moderate heat, 100 grains will denote 41,8 of vitriolated tartarin, according to the account of its constitution, 3 Bergm. p. 368.

OF SELENITE.

15. Let the aerated magnesia that may still remain in the boiled water be saturated with nitrous acid, then the quantity of selenite is most advantageously determined by weighing after just desiccation, that obtained by eva-

poration to a few ounces, and the addition of a few drops of spirit of wine to the evaporating liquor; spirit of wine will precipitate it, when added in a quantity that would not affect any other sulphat.

OF ALUM.

17. Let the mineral water be evaporated to one half, and then when cold add to it a solution of aerated lime, it will, after ignition and resting for a few days in a well closed vessel, precipitate the argil; this addition should be repeated until no farther precipitation appears. After which, the liquor should be heated to 200°. and a few grains of pure aerated lime added to it, and kept in that heat for half an hour, then suffered to cool and set aside until the liquor is nearly clear, and then filtered off; the precipitate dried should then be treated with distilled vinegar to take up the superfluity of calcareous earth, if too much of that earth had been added; and if none be

found, the operation should be repeated, least enough had not been added. The argil thus freed from the aerated lime is then to be heated to incandescence

18. for half an hour; 12 grains of the argil thus desiccated, denote the existence of as much alum as would, when crystallized, weigh 100 grains, or when desiccated nearly 49.

19. *Note* 1, If no calcareous earth be contained in the water, then aerated magnesia might as well be applied as a precipitant, and rather better, as there would be no danger of gypsum's forming an union with the argil thus separated.

20. *Note* 2, If muriated argil be also found in the water by the previous investigation, (a case that seldom happens) then the water should be evaporated to dryness, and the muriated argil separated by spirit of wine ,834 or ,848, and the dry mass, re-dissolved in a sufficiency of water and treated as above.

OF EPSOM.

21. The methods of estimating the quantity of Epsom, must vary in their application to waters differently constituted, and in this respect many associations may arise, the existence of each of which is deduced from the previous general investigation; for 1. Epsom may be accompanied with selenite, alum, or Glauber, or a metallic sulphat. 2. It may be accompanied with selenite or alum, without Glauber; or 3. It may exist unassociated with any other sulphat. Again, in each of these cases, other *possible* associations must also be attended to.

22. Thus 1. If it be accompanied with *selenite singly*, then it may also be attended with muriated magnesia, and muriated argil. In this case, the best method of detecting its quantity, is to precipitate the selenite by the gradual addition of a solution of magnesia in fixed air, agitating both in a close vessel, and then letting them rest for a few days; for thus the calcareous earth

singly will be precipitated, and if any still remain, it will be discovered and precipitated by heating the filtered water to 200°. and gradually adding pulverized aerated magnesia. It is true, the muriated argil, if any, and which very rarely occurs, may thus be also precipitated; but this is easily separated from the aerated lime. The
23. aerated lime is now to be heated to ignition and weighed, and from its weight (or otherwise) the quantity of lime it contains is inferred, as 100 grains ignited aerated lime contains 55 grains of lime, and the quantity of lime being known, the quan-
24. tity of selenite it was derived from may also be deduced, as 100 grains selenite, heated to incandescence, contain 41 of lime.

25. Then the quantity of Epsom is discovered by precipitating the vitriolic acid from the water by any barytic solution in acids, and from the weight of the ignited baroselenite, deducing the quantity of this acid as above shewn, No. 2, and this quantity being

known, we may find how much of it
26. entered into the composition of the selenite, as 100 grains selenite heated to incandescence contain 59 of vitriolic acid, the remainder entered into the composition of the original Epsom, whose quantity is thence estimated, as
27. 63,32 grains of vitriolic acid form 100 of desiccated Epsom.

28. 2. If it be accompanied by *Glauber singly*, without any other sulphat, then no earthy nitrat or muriat can be suspected in the water; and therefore it may be estimated by precipitating its earth by semi-aerated soda. This earth, dried and heated to ignition for an hour, will be freed from water and fixed air, and then its weight
29. will give that of the Epsom, from whose decomposition it proceeded, as 36,68 grains of such magnesia proceed from and denote 100 of desiccated Epsom; or the magnesia may be precipitated in an unaerated state by lime-water, as already mentioned; particularly if it be in a very small quantity.

30. 3. If it be accompanied with *selenite* and *Glauber*, and with no other sulphat, neither then can any other earthy nitrat or muriat exist in the water, and therefore it may be estimated by decomposing both it and the selenite by semi-aerated soda, which will precipitate both the calcareous and magnesian earths. The precipitated earths filtered off, washed and dried, should then be re-dissolved in dilute vitriolic acid in a boiling heat, and the solution evaporated to dryness; the dried mass pulverized, should then be treated with twice its weight of cold water, which will take up the regenerated Epsom, and leave the selenite. Lastly, the solution of Epsom evaporated to dryness in a heat of 400°. and weighed, will present the quantity of that salt contained in the water,

31. 4. If it be accompanied with *alum* singly, neither then can any earthy nitrat or muriat, except muriated argil, be found in the water; and if, by the previous investigation, muriated argil be found, it will be proper to separate

it by evaporation to dryness, and the application of spirit of wine, ,835 or ,848; and this being separated, the dried mass is to be dissolved in a sufficient quantity of water, and the Epsom and alum decomposed by a semi-aerated alkali in a boiling heat; the earths thus precipitated, being well dried and pulverized, are to be separated by distilled vinegar, which will take up the magnesia, from which it is again to be precipitated, dried, ignited, and weighed, and the weight of desiccated Epsom, into whose composition it enters, deduced, as in the second case.

§2. 5. If it be accompanied with *alum* and *Glauber*, the estimation of its quantity is obtained as in the last case.

§3. 6. If it be accompanied with *selenite* and *alum*, or with *selenite*, *alum*, and *Glauber*, here also no earthy nitrat or muriat can interfere, except muriated argil, which if it be found, must be separated as in the fourth case. Then the three sulphats are to be decomposed by semi-aerated soda; the earths when well dried to be treated with dilute muriatic acid, which will speedily take up the magnesian and calcareous, and leave the argil. The muriatic solution is then to be treated once more with semi-aerated soda, and boiled to expel all the fixed air. The precipitated earths well washed, should then be treated with dilute vitriolic acid, as mentioned in the third case, and the Epsom extracted and estimated as there shewn.

34. 7. If it be accompanied with *vitriol of iron* singly, that is, without any other sulphat, or with *vitriol of iron and Glauber*, and no other sulphat, in this case also, earthy nitrats or muriats cannot be found in the water; let one or two pounds of the water be exposed to the air for one or two days, and then boiled in open vessels, and while boiling, let a few grains of pure argil be thrown into it, and the ebullition continued for half an hour, and when cold and clear, let it be examined by the tincture of galls, to see whether any iron still remains; if any does, let

the process be repeated; if no iron be found, then Epsom and Glauber only remain in the water; consequently the Epsom is to be decomposed, and its quantity estimated as in the second case. We need not suspect a mixture of alum, as the vitriolated argil thus formed, can have no excess of acid, and remains insoluble; it is even proper to add an excess of argil.

35. 8. In every other case in which vitriol of iron is associated with Epsom, the vitriol of iron is to be decomposed, and separated as just mentioned; and this being separated, every case is reducible to some or other of the preceding.

36. 9. *Note.* That if the selenite be previously separated, as mentioned under the head of that salt, some of the cases here mentioned will be rendered more simple, and the estimation of the Epsom easier.

37. 10. If the Epsom be accompanied *with no other sulphat*, then muriated magnesia and muriated argil may co-exist with it, as in the first case. The

quantity of Epsom is then to be estimated from the quantity of vitriolic acid contained in the baroselenite formed by precipitating it by muriated barytes, as shewn in the first case.

VITRIOL OF IRON.

38. Vitriol of iron may be accompanied either by selenite, or by Epsom, or by alum, or by Glauber, or any two or more of them, or by all four, and also by muriated argil, which in most cases is previously to be separated by evaporation to dryness, and the application of spirit of wine; the spirituous solution evaporated to dryness, will deposit this muriat, which may then be weighed.

Hence eleven cases arise.

39. 1. If it be accompanied by *selenite singly*, that is, with no other sulphat, still no earthy nitrat, muriat, or carbonat, can co-exist with it, except muriated argil; in this case, the vitriol is to be precipitated by the gradual affusion of caustic volalkali,

which will also decompose the muriated argil. This precipitation being completed and filtered off, the selenite may then be precipitated by mild vol-alkali, and the calcareous earth washed, dried, ignited, and weighed, and from its weight the quantity of lime it contains deduced, (as in No. 23). This being done, the vitriolated ammoniac thus formed is to be decomposed by any barytic solution; and from the weight of the ignited baroselenite, the quantity of vitriolic acid deduced; thus the quantity of it taken up by the lime is discovered as in (No. 26,) the remainder must have entered into the
40. composition of vitriol of iron, of which 100 grains in its most de-aqueated state contain nearly 42 of real acid, or, if crystallized, 26.

41. 2. If it be accompanied by *Epsom singly*, it is to be precipitated by the addition of aerated lime to the water heated, as long as any reddish precipitate is perceived. Thus the calx of iron will be precipitated, but the

Epsom will remain*; but for greater caution, somewhat more aerated lime should be added than is necessary to saturation, and the liquor should boil a quarter of an hour: when all is cool, the liquor should be poured off, washed with cold water, and the gypsum newly-formed, re-dissolved in hot-water; the superfluous aerated lime and calx of iron will thus remain undissolved; and then the selenitic solution should again be precipitated by aerated soda and boiled. The precipitate heated to ignition, and weighed, will exhibit the quantity of aerated lime really employed in decomposing the
42. vitriol of iron; as 33 grains perfectly aerated lime take up the acid of 100 of crystallized vitriol of iron, and thus the weight of this last is discovered.

43. 3. If it be accompanied by *alum singly*, then both are to be decomposed by a solution of muriated barytes, the

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[*] Aerated lime precipitates both vitriols of all metals, and also alum. See 1 Bergm. p. 132, 319, 334; and 4 Bergm. p. 148.

weight of the ignited baroselenite will
give the quantity of vitriolic acid con-
tained in both, as shewn No. 2; after
which an equal quantity of the
Mineral Water is to have its vitriol
decomposed by exposure to the air, and
the addition of pure argil, as in No. 34,
taking care not to add too much, the
supernatent liquor (to which the wash-
ings of the precipitate must be added)
will contain the alum singly which
should be precipitated by volalkali in a
boiling heat; the earth thus precipi-
tated, dried, and heated to incandes-
cence, will denote the quantity of
alum it proceeded from, as in No. 18 is
44. shewn. And as 100 grains of crys-
tallized alum contain about 20 of
vitriolic acid, we see how much of
the vitriolic acid contained in the
baroselenite belonged to the alum.
The remainder of this acid must,
therefore have belonged to the vitriol,
and this remainder being known, we
know the quantity of the vitriol,
46. as 26 grains real vitriolic acid enter

into the composition of 100 grains of crystallized vitriol of iron.

47. 4. If it be accompanied by *Glauber* or *vitriolated tartarin*, and no other sulphat, let it be decomposed by an alkali, the extent of whose power in saturating vitriolic acid is already known, and let the quantity of this acid thence inferred be noted; then let an equal quantity of the water be treated with a solution of muriated barytes; and thus the whole quantity of vitriolic acid contained in both salts will be extracted, from which, that found by the last experiment to belong to the vitriol of iron is to be substracted, the remainder belongs to the Glauber or vitriolated tartarin, as the case may be, and thus the quantity
48. of both may be traced, as 100 grains of ignited baroselenite contain 33 of vitriolic acid, and 26 grains of vitriolic acid denote 100 of crystallized vitriol of iron, and 45 grains of vitriolic acid denote 100 of vitriolated tartarin, and 56 grains of this acid betoken 100 of fully desiccated Glauber.

49. *Note.* In the second experiment the precipitated baroselenite should be digested in marine acid before it be dried, to take up any calx of iron that may adhere to it.

50. 5. If it be accompanied by *selenite* and *Epsom*, and no other sulphat, let the vitriol be decomposed as in No. 34, by pure argil; an excess of it cannot here produce any inconvenience. Thus the water will contain only selenite
51. and Epsom. These, in this case, may be separated from each other by evaporation to dryness, and the gradual affusion of cold water to the dry mass as long as by the test of caustic volalkali it is perceived to contain mag-
52. nesia. The selenite is now to be redissolved in hot water, and decomposed by the addition of a solution of semiaerated tartarin, the extent of whose power to saturate vitriolic acid is known by a previous experiment. Thus the quantity of acid belonging to the selenite is discovered, and its quantity traced, as 59 grains of vitriolic acid enter into the composition of 100

53. of selenite heated to incandescence. Then the solution of Epsom is also to be decomposed by semi-aerated tartarin, whose saturating power has been determined as before, and thence the quantity of vitriolic acid in the Epsom discovered; and thus also the quantity of Epsom, as 63,32 grains of vitriolic acid enter into the composition of 100 grains of fully desiccated Epsom.

54. Lastly, an equal quantity of the Mineral Water is then to be treated with a solution of muriated barytes, to extract the whole quantity of vitriolic acid contained in the three salts, and deducting the shares found to appertain to the selenite and Epsom, the remainder belongs to the vitriol of iron, whose quantity is thence inferred, as in No. 48.

55. 6. If it be accompanied by *selenite* and *alum*, and no other sulphat, let it be decomposed by pure argil, as in No. 34, taking care not to add an excess of argil; thus the selenite and alum will remain alone in the solution.

56. Let the alum be decomposed by caustic

volalkali, (in a well closed vessel) the extent of whose power of saturating vitriolic acid is already determined; then let the vitriolated volalkali thus formed, and the selenite also, be decomposed by muriated barytes; thus the quantity of vitriolic acid contained in both is discovered, as in No. 48, from which, that belonging to the alum, known by the weight of volalkali requisite to precipitate its earth, is to be substracted. The remainder is then to be attributed to the selenite; thus the quantities of both salts may
57. be traced by No. 44 and 52. This being done, an equal quantity of the water is to be decomposed by a solution of muriated barytes, the precipitate will ascertain the acid of the three sulphats from which the portion belonging to the selenite and alum is to be substracted, the remainder belongs to the vitriol of iron, whose quantity is thus discovered, as 26 grains vitriolic acid denote 100 of crystallized vitriol, as already said.

58. 7. If it be accompanied by *selenite* and *Glauber* and no other sulphat, let the vitriol be decomposed by pure argil, as in No. 34. Then the *selenite* and *Glauber* only will remain in the
59. solution; decompose the selenite by a solution of semi-aerated soda, the extent of whose power in saturating vitriolic acid is foreknown and noted; thus the quantity of acid contained in the selenite will be detected, and thence the quantity of selenite traced
60. as in No. 52. Then decompose both the newly formed and original Glauber by muriated barytes, thus the quantity of acid in both is discovered, as shewn in No. 48, whence substracting the quantity already found to belong to, the selenite, the remainder belongs to and denotes the quantity of Glauber as shewn No. 48.

61. Now take an equal quantity of the Mineral Water, and decompose the three sulphats by muriated barytes; from the quantity of acid discovered by this compound, substract the portion belonging to the selenite and Glauber,

the remainder denotes that belonging to the vitriol, whose quantity is thus traced, as in No. 57. The selenite and Glauber, after the separation of the vitriol, may also be separated by evaporation, desiccation, and solution of the Glauber in a small proportion of water, as is evident.

62. 8. If it be accompanied by *selenite*, *Epsom* and *alum*, let the vitriol be decomposed, as in No. 34, by argil, taking care not to add too much.—
63. Then the water will contain only *selenite*, *Epsom*, and *alum*; to separate and estimate each, let all three be precipitated by semi-aerated soda, and the solution boiled; the precipitate washed, dried, and pulverized, should be treated with dilute marine acid, which will take up the aerated lime and magnesia and leave the argil.— The lime and magnesia are then to be precipitated once more by aerated soda, the solution boiled, and the precipitate re-dissolved in dilute vitriolic acid in a boiling heat, and treated as in No. 30. Thus both the selenite

and Epsom will be obtained in specie, but *note*, the selenite should be heated to incandescence before its weight be taken.

64. Now to estimate the alum, let a portion of the water equal to the last, be deprived of its vitriol, as the last had been, by decomposition, and then let the three other salts be deprived of vitriolic acid, by a solution of muriated barytes, and from the quantity of acid which the baroselenite thus formed exhibits after ignition, let the quantity that enters into the selenite and Epsom be substracted; the remainder enters into the composition of the alum, whose weight is thus traced, as 20 grains vitriolic acid form 100 of crystallized, and 49 of desiccated alum.

65. Lastly the quantity of vitriol is detected by precipitating an equal portion of the water, with a solution of muriated barytes; for deducting from the quantity of vitriolic acid, which the ignited baroselenite exhibits, the portion belonging to the selenite, Epsom, and alum, the remainder

states that which entered into the vitriol, and thence the quantity of this vitriol is deduced; 26 grains of the acid giving 100 of crystallized vitriol of iron.

66. 9. If it be accompanied with *selenite*, *Epsom*, *alum*, and *Glauber*, free the water from two of the earthy salts, and also from the vitriol, by decomposing them with lime water, or by digestion on lime. Thus selenite and Glauber will alone remain; free the water from selenite by evaporation to dryness, and re-dissolve the Glauber by cold water. Thus the Glauber alone will be obtained, and by evaporating its solution to dryness in a heat of 400°, and weighing, its quantity in that state will be found and should be noted, and the quantity of its acid
67. thence deduced, as 100 parts of desiccated Glauber contain 56 of acid.—
68. This being done, we next take an equal quantity of the water and deprive it of vitriolic acid by muriated barytes, whose weight after ignition will give the whole quantity of acid

contained in the 5 sulphats, from which that belonging to the Glauber being deducted, the remainder belongs to the vitriol, selenite, Epsom, and alum.

69. Then take another equal quantity of the water, and deprive it of the vitriol by ebullition and exposure to the air and digestion on pure argil, as long as the water gives an ochrey precipitate with caustic volalkali; the supernatent liquor will then contain only selenite, Epsom, alum, and

70. Glauber. Decompose these four by muriated barytes, the ignited baroselenite will give the quantity of vitriolic acid contained in all four, which being substracted from the quantity found in the five (No. 68) gives as a remainder, that contained in the vitriol of iron, whence its quantity is deduced.

71. And again substracting from the quantity of acid found in the four sulphats that portion which belongs to the Glauber, we obtain in the remainder the portion belonging to the selenite,

72. Epsom, and alum. Then take a double portion of the Mineral Water, deprive

it of its vitriol, as in No. 69, divide the supernatent liquor into two portions, each of which will contain the same quantity of selenite, Epsom, and alum, as the portions of the
73. mineral water already examined. From one portion precipitate the argil by aerated lime in a boiling heat, which should continue to be added until there is an excess of it, which will be known by treating the precipitate with distilled vinegar. Thus the supernatent liquor will contain only the original and newly formed selenite, and Epsom, and Glauber; the selenite is easily separated by evaporating the whole to dryness, and re-dissolving the Glauber and Epsom in a moderate quantity of
74. cold water. Then precipitating the vitriolic acid from both these salts by muriated barytes; the ignited baroselenite will discover the quantity taken from both; from which that belonging to the Glauber being substracted, the remainder gives that belonging to the Epsom, whence the quantity of Epsom may be deduced, as 63,32 grains of the

acid enters into the composition of 100 of desiccated Epsom.

75. We now take the second portion of the de-vitriolated water, and strip it of argil, and of most of the magnesia by caustic volalkali, and the precipitate being filtered off, the water will contain only selenite, Glauber, and vitriolated volalkali, and perhaps some undecomposed Epsom. Of these three last we strip it, by evaporation to dryness, and the affusion of cold water; thus the selenite will remain single, and being heated to incandescence, its weight will be found, and from its weight let its quantity of acid be deduced, as 100 grains of selenite, heated to incandescence, contain 59 of acid. Then de-

76. ducting from the quantity of acid found in the three earthy sulphats, No. 71, the portion found in the Epsom, No. 74, and that now found in the selenite, the remainder will state the portion of acid belonging to the alum, and hence the quantity of the alum is traced, as 20 grains of acid belong to 49 of fully desiccated alum.

77. 10. If it be accompanied with *Epsom* and *alum* and no other sulphat, let the water be treated with muriated barytes, and thus the quantity of vitriolic acid contained in all three will be found as already often shewn. Let another equal portion of the water be de-vitriolated by exposure to the air, heat, and the addition of argil, as in No. 69.

78. Let the supernatent water, containing then only Epsom and alum, be treated with muriated barytes. The baroselenite thus formed, will give the quantity of vitriolic acid contained in these two salts, and substracting this quantity from that found in the three salts, No. 77, we have in the remainder that contained in the vitriol of iron, whose quantity is thus found, as 26 grains of acid enter into the composition of 100 grains of crystallized vitriol of iron.

79. Then let another equal portion of the mineral water be de-vitriolated as before, and from the supernatent liquor let the alum be precipitated by aerated

lime, digesting in a strong heat, and adding even an excess of the aerated lime. Thus the alum will be decomposed. Let the supernatent liquor be now evaporated to dryness, and the dry mass treated with cold water; this will take up the Epsom, and the solution being filtered off, and evaporated to dryness, will give the weight of desiccated Epsom; its quantity of acid may thence be deduced, and this being substracted from that found in the Epsom and alum jointly, No. 78, gives that belonging to the alum singly, whence its quantity may be inferred, as 20 grains of vitriolic acid enter into the composition of 49 of desiccated alum.

80. 11. If it be accompanied with *Epsom*, *alum*, and *Glauber* only, decompose a certain portion of the water by muriated barytes, the baroselenite will exhibit the quantity of acid contained in the four salts.

81. Then take a triple portion of the water, and strip it of vitriol as in No. 77, divide it into three equal parts, and

examine the quantity of acid in the three sulphats that remain in one portion of the water, by muriated barytes, and substracting the acid thus found from the quantity contained in the four, you obtain that contained in the vitriol of iron, whence the quantity of *vitriol* is
82. deduced, as in No. 78. This being done, decompose the Epsom and alum contained in the other equal portion of water, by the gradual addition of quick lime in a digesting heat, until it ceases to give a precipitate on being dropped into an aerated alkali, then evaporate the whole to dryness, and extract the Glauber by cold water.

83. The solution of Glauber evaporated to dryness, and the dry mass heated to 400°. will state the weight of the desiccated *Glauber*, and thence the quantity of acid it contains is deduced, as 100 grains of desiccated Glauber contain 56 of acid; and deducting this quantity of acid, from that contained in the three sulphats, No. 81, we have the quantity contained in the *Epsom* and
84. *alum*. Then taking the third equal

portion of the water that had been devitriolized, precipitate the alum by aerated lime in a digesting heat, adding even an excess of the aerated lime, then extract the *Epsom* and *Glauber* by the gra-
85. dual affusion of cold water. From this solution, precipitate the vitriolic acid contained in both by muriated barytes, and from the quantity of acid given by the baroselenite thus formed, substract that already found in the Glauber, No. 83, the remainder states the quantity belonging to the *desiccated Epsom* singly, whose quantity is thus detected, as 63,32 grains of vitriolic acid denote 100 of desiccated Epsom.

Lastly, substract the quantity of acid found in the *Epsom* and *Glauber* jointly from the quantity found in the Epsom, Glauber, and alum, No. 81, the remainder exhibits that belonging to the *alum*, whose quantity is thus made apparent, as 20 grains vitriolic acid belong to 49 of desiccated alum.

Note. These processes are not so tedious as they may appear on the reading, as several of them may be carried on at once.

OF MURIATS.

SYLVIAN AND COMMON SALT, AND OTHER MURIATS.

86. Sylvian and common salt may either exist singly, or they may accompany each other, and in both cases may be accompanied by aerated alkalis, or sulphats, or earthy muriats, or the three last only; hence ten cases may occur.

87 1. If *either of these salts exist singly in water*, that is, accompanied by no other salt, (a case which indeed scarce ever occurs,) it may be estimated by precipitating its acid by nitrated silver, as 100 grains of the muriated silver thus obtained, heated somewhat below ignition, denote 16,54 of marine acid.

88. And if the muriated silver be derived from sylvian, 36 grains of marine acid denote 100 of sylvian, or more shortly 217,65 of the muriated silver denote 100 of sylvian.

89. Or if the muriated silver proceed from common salt, 38,88 grains of the marine acid contained in it denote 100 of common salt; or more shortly, 235

grains of the muriated silvér denote 100 of common salt; but the simplest and easiest way is to evaporate to dryness.

90. 2. If *these salts accompany each other*, unaccompanied by any other, they are separated and distinguished by the application of acetited silver and tartaric acid, as shewn in §. 25, No. 4, and above in No. 14.

91 If common salt be accompanied with *aerated alkalis*, fixed or volatile, in any notable proportion, then all earthy salts must be absent, and the aerated volalkali must be expelled by distillation, and estimated as already mentioned, Part I. Chap. 2, §. 4, p. 51, or if no fixed aerated alkali accompany it, it may be saturated by vitriolic acid; the quantity of acid applied, discovered by barytic lime water, and from the quantity of vitriolic acid thus found, the quantity of the volalkaline basis indicated, as 100 parts vitriolic acid take up about 26 of real caustic volalkali.

92. If it be accompanied with *aerated soda or tartarin*, saturate these with

vitriolic acid, whose power of saturating soda or tartarin has already been determined and noted. This gives the

93. quantity of either.—82,5 grains of real vitriolic acid denote 100 of mere *tartarin*, and 127,7 grains of real vitriolic acid betoken 100 grains of *mere soda.*

94. Then precipitating the marine acid from the sylvian or common salt, by a solution of vitriol of silver, the weight of the muriated silver dried as before mentioned, gives the weight of the sylvian or common salt, as in No. 88 and 89.

95. 3. If the common salt, &c. be accompanied with *aerated soda and Glauber*, saturate the soda with vitriolic acid as in No. 92, and precipitate both the newly formed and original Glauber with acetited barytes, the weight of the ignited baroselenite will give the quantity of acid contained in *both*, as already seen, No. 2. whence substracting the weight of the added acid, the remainder gives the weight of that contained in the original Glauber, as 56 grains of real

acid betoken 100 of desiccated Glauber. Then decompose the common salt by nitrated silver, and estimate as in No. 94.

96. 4. If it be accompanied with *muriated volalkali* singly, and no other salt, decompose the ammoniac by barytic lime water, and then after ebullition to expel the caustic volalkali, expel the barytic earth by dilute vitriolic acid, until neutralization is obtained, then expel the disengaged muriatic acid by ebullition, until the water ceases to discolour colorific tests, or at least is saturated by a known quantity of soda, the baroselenite thus obtained, gives the quantity of barytic earth employed in saturating the marine acid, as 100 grains of ignited baroselenite contain 66 of earth, and the quantity of earth thus found, gives the quantity of acid contained in the sal ammoniac; as 100 grains of barytic earth saturate, and therefore denote 31,8 of muriatic acid; and the quantity of this acid thus discovered, indicates the weight of sal ammoniac, as 42,75 grains of muriatic acid enter into the

composition of 100 of sal ammoniac in the state it is in when sublimed.

97. The quantity of the sal ammoniac may also be determined, by evaporating that of the common salt now remaining in the water to perfect dryness, and deducting from its weight that newly formed, by the addition of the soda, of which 53 grains give 100 of common salt. This newly formed common salt contains the acid that existed in the sal ammoniac, which is thus discovered, as 100 grains of common salt contain 38,88 of acid; the remainder left by the substraction of the newly formed common salt gives the weight of that originally contained in the water. *Note*, Vauquelin has shewn in 13 Ann. Chy. p. 94, by a very curious experiment, that common salt and sal ammoniac, in a saturate solution, do not well stand together, the common salt excluding the sal ammoniac. Whence many important consequences are deducible.

98. 5. If it be accompanied with *muriated volalkali and any sulphat*, (Glauber I

think is incompatible with sal ammoniac) and no other salt, let the *sulphats* be first removed by evaporation, (and precipitation by spirit of wine if numerous) and then the muriatic solution being filtered off, let the sulphats (except selenite) be re-dissolved in water, and each estimated as shewn from No. 12 to No. 85.

99. If the muriatic solution still retains any sulphat (which will be discovered by exploring a portion of it by soda and muriated barytes) let it be precipitated by acetited barytes, or if an earthy salt, by barytic lime water; this water, it is true, will decompose both the sulphats and the sal-ammoniac, and also the earths united to the vitriolic acid, but as much of it as acted on the sal-ammoniac will remain in solution, and may afterwards be separated by dilute vitriolic acid, and will serve to estimate the quantity of the sal-ammoniac as shewn in No. 96. And as much of it, as proceeded from the action, of the vitriolic acid contained in the sulphats, will remain an

insoluble precipitate; and the earths it proceeded from and precipitated with it, being re-dissolved by digestion in marine acid, will, by separating each, discover the sulphat they proceeded from, and by their weight indicate that of each sulphat, into whose composition they entered.

100. The muriatic solution after the expulsion of the barytic earth should then have its disengaged muriatic acid expelled or saturated as in No. 96, and the quantity of common salt estimated as in No. 97.

101. 6. If the common salt, &c. be accompanied with sulphats only, and no other muriat, the sulphats are to be separated and estimated, as also the common salt, as in the last case.

102. 7. If the common salt be accompanied with earthy or metallic muriats only, as *muriated lime*, *magnesia or argil*, *and muriated iron*, these may be precipitated by barytic lime water, and each earth, &c. washed but not dried, re-dissolved by digestion in muriatic acid. If only one of these

muriated earths be found, saturating the excess of acid with a known quantity of an earth of the same species, and evaporating the solution to dryness, and deducting from the weight thus found that of the muriated salt formed by the earth added.

103. Thus 50 grains of lime form 100 of *muriated lime* heated to redness,
104. 31 grains of magnesia form 100 of *muriated magnesia* heated to 140°, and
105. according to Richter 21,8 grains of *argil*, give 100 of muriated argil so far evaporated as to be sensibly dry.

106. If it be accompanied by *muriated lime and muriated magnesia*, and no other salt, these earths are to be precipitated by barytic lime water, as in the former case, and re-dissolved in marine acid, the quantity of the calcareous earth is discovered by precipitating it by vitriolic acid, as 100 grains of selenite heated to incandescence give 41 of calcareous earth, and this being found, the quantity of muriated lime is found by No. 103.

107. The muriated magnesia now remains

single, and adding a known weight of magnesia to absorb the excess of acid, it is to be evaporated and estimated as in No. 102 and 104.

108. If it be accompanied by *muriated lime and muriated argil* only, these are separated and estimated in the same manner as No. 106, 107, 105, or the argil by caustic, and the lime by mild volalkali.

109. If it be accompanied with *muriated magnesia and muriated argil* only, both are to be precipitated by barytic lime water, the precipitated earths should be thrown into a bottle of water impregnated with fixed air and kept therein with frequent agitation for two days, thus both earths will take up fixed air, and the magnesia become more soluble. The water is then to be evaporated to dryness in a heat of 140°, the dry mass to be pulverized and exposed to the action of dilute marine acid, which will readily take up the magnesia and leave the argil. The muriated solution being then evaporated to dryness in a heat of

140°, will state the quantity of muriated magnesia, and the argil dried at 140°, will exhibit the quantity united to the muriatic acid in the water whence the quantity of the compound it formed is deduced, as in No. 105.

110. Lastly, the barytic solution containing also the common salt is to be decomposed by adding a few drops of vitriolic acid, thus the marine acid it contained will be left single, and may be expelled by heat or saturated with soda, whose power of saturating marine acid is foreknown,

111. 53 grains of mere soda forming, when united to muriatic acid, 100 of common salt; and evaporating the whole to dryness, and substracting the common salt formed by this addition, we obtain that of the pre-existing

112. common salt. The quantity of marine acid contained in the earthy salts is also thus found, as it is contained in the newly formed common salt of which 100 grains contain 38,88 of real marine acid, and thus any

errors in the estimation of the earthy salt may be corrected.

113. 8. If common salt be accompanied by any *alkaline sulphat in a notable proportion*, then it cannot be attended with any *earthy muriat in a notable proportion*, and *vice versa*, if it be attended with earthy muriats in a notable proportion, it cannot contain *glauber*, &c. in a notable proportion. But inconsiderable proportions of each of these antagonist salts may co-exist as already seen; if therefore the co-existence of these antagonists be found by tests, the proportion of each to the whole quantity of water should be determined by some experiment before we proceed to an ulterior estimation, and this may be effected during the general investigation by tests, as already mentioned. Hence three cases may arise,

114. for 1. If the *alkaline sulphat* be in a notable proportion, (as three grains in 1000,) then the water should be evaporated to dryness, and the dry mass exposed to the action of

spirit of wine ,817 which will take
up the earthy muriats singly and leave
the sulphats and common salt, which
should be re-dissolved in a sufficiency
of water, or at least all of them
except the selenite; from this solution
the common salt should be preciptated
by vitriol of silver, the
muriated silver dried as already mentioned
gives the weight of the common
115. salt as in No. 89. And 100
grains of common salt, which is
thus converted into Glauber, would
give 120 nearly of desiccated Glauber,
and the quantity thus formed is consequently
to be substracted from the
quantity of Glauber found in the sub-
116. sequent investigation. This being
done, the sulphats are to be estimated,
117. as already shewn at large. Lastly,
the spirituous solution is to be evaporated
to dryness, the dry mass re-dissolved
in water, and the muriats it
contains, estimated as in No. 102, 109.

118. But 2dly, If the *muriated lime or
muriated magnesia*, be in notable proportion,
then the proportion of the

alkaline sulphat must be inconsiderable. And if unaccompanied with any other sulphat, it may be estimated by precipitation of its acid by muriated barytes, as already often seen, and the quantity of common salt thus formed discovered, and substracted from that originally contained in the
119. water, as 100 grains of desiccated Glauber thus converted into common salt would give 82,8 of common salt.

120. And 3dly, If both the *alkaline sulphat* and the *earthy muriats* be each in an inconsiderable proportion, it will be proper to evaporate the whole to some degree, and separate the sulphats by affusion of spirit of wine, ,817, and pouring off the residuary liquor, evaporate it to dryness, and dissolve the earthy muriats by spirit of wine ,817, the common salt will remain undissolved, and perhaps some remains of the sulphats, which will be easily discovered on redissolving it.

121. Lastly, If the common salt be attended with only so inconsiderable a quantity of sulphats, as that these

should not be precipitable by spirit of wine, but with a considerable quantity of earthy muriats, these last should be taken up by spirit of wine, re-dissolved in water, and precipitated by desiccated Glauber; thus common salt and selenite, or Epsom, or vitriolated argil, or two or more of them will be formed, which are easily separated or estimated by the rules already given.

Note. Whenever spirit of wine is employed to extract the earthy muriats, it scarce ever takes them up totally if entangled with salts, on which it does not act; therefore, in such case, cold water in small quantity should, after the spirit, be applied to the residuum, and what the water takes up after a few minutes, should again be evaporated to dryness, and again treated with spirit of wine.

122. 9. *Common Salt*, *Selenite* and *muriated Lime*, *muriated Magnesia*, and *muriated Argil*, are compatible with each other. And in this case the water being evaporated to a considerable degree, (the

degree depends on its specific gravity) should be treated with muriated barytes. The baroselenite will discover the quantity of acid contained in the selenite, as shewn No. 52; and the quantity of selenite being known, the quantity of lime which it contained, and now remaining in the liquor, is inferred; as 100 grains of selenite in the state of dryness to which it is reduced by incandescence contain 41 of lime, which quantity of lime is afterwards to be deducted from that resulting from the muriated lime originally contained in the water.

123. This being done, the muriated earths are to be precipitated by barytic lime-water, and the precipitates treated and estimated as shewn, No. 102 and 112.

124. Lastly, the common salt will be had by evaporation to dryness, from whose weight that formed by the soda added, as seen No. 110 and 111, is to be substracted.

125. 10. *Common Salt*, *Selenite*, *Epsom*, *muriated Magnesia*, and *muriated Argil*,

are also compatible with each other. In this case, take two equal portions of the water, and from the one precipitate the selenite, or rather its earth, by aerated magnesia and heat, as in No. 22, which will precipitate also the argil from the muriated argil; separate these, and find the quantity of lime, and from this deduce the quantity of *selenite* by the rules already seen.

126. Then decompose the newly-formed and original Epsom by muriated barytes; this will discover the weight of vitriolic acid contained both in the selenite and in the *Epsom*, from which, substracting that contained in the selenite, we have that belonging to the Epsom, from which the quantity of *Epsom* is to be inferred.

127. Then precipitate from the second portion of water the Epsom, muriated magnesia, and argil, by common lime-water and heat, in close vessels; treat the precipitate as in No. 109, and from the argil deduce the weight of muriated argil as there shewn, and

from the weight of the magnesia (deducting that belonging to the Epsom) estimate that of the *muriated magnesia*, as 31 grains of magnesia heated to 140°. denote 100 of muriated Epsom duly dried.

128. Lastly, Precipitate both the original and newly-formed selenite by barytic lime-water and heat, thus the lime will remain in the water; precipitate this by fixed air, filter the solution, and evaporate to dryness; thus the common salt will be obtained.

11. Earthy muriats unaccompanied with common salt, scarce ever occur; if such be, the estimation may be made as in the above cases.

NITRATS.

NITRE.

129. *Nitre* may co-exist with all *sulphats*, and with all *muriats* that are compatible with each other; in this case, the best method of estimating its

quantity is, after sufficient evaporation to precipitate the sulphats by acetited barytes, and the muriats by acetited silver; thus all these salts are rendered soluble in spirit of wine ,817, (being converted into *acetites)* when evaporated to dryness; then re-dissolving the residuum in water, the nitre may be obtained single and
130. crystallized. Its quantity being thus found, another portion of the water should be examined as if it did not exist in it. If it be found with
131. *soda*, as it is said to have been, this should first be saturated with vitriolic, or some other mineral acid whose power of saturation is known, and then the process to be continued as above.

132. 2. If it be accompanied with *common salt*, *nitrated Lime*, and *muriated Lime*, as it generally is, or with *muriated Magnesia*, the best method of separation is to take up the earthy nitrats and muriats by spirit of wine ,817; these being separated, re-dissolve the dry residuum in water, and

separate the nitre and common salt by acetited silver, thus the quantity of common salt is determined. The
133. acetited soda being then removed by spirit of wine, the nitre will remain single; the spirituous solution is next to be evaporated to dryness, and the residuum re-dissolved. The weight
134. of the *muriated magnesia* is estimated by precipitation by nitrated silver, as 100 grains of this contain 16,54 of acid; and 100 grains of muriated magnesia duly desiccated, contain 34,6 of acid; or if de-aqueated, 100 grains of it would contain 48 of acid; and thus it should be considered.

135. And the weight of the *nitrated lime* is obtained by precipitating the lime by vitriolic acid, and estimating the weight of the lime by that of the selenite, as often mentioned, and 35 grains of lime enter into the composition of 100 grains of nitrated lime thoroughly de-aqueated. The weight of the acid and lime may also be obtained by precipitating the ni-

trated lime by tartarin, or by vitriolated tartarin; thus nitre and selenite are both obtained, and 100 grains of nitre duly desiccated contain 44 of nitrous acid.

OF THE DEPURATION AND AUGMENTATION OF COMMON SALT, CONTAINED IN BRINE WATERS.

This object being nearly connected with that of the present treatise, and of importance to manufactures of salt, I shall here give the ingenious method lately proposed by Mr. Gren, in the fourth volume of his Journal; an *abridgment* of it has also been published by Mr. Nicholson, in the second volume of his Journal, taken from an obscure account in the *Annales de Chymie.*

Mr. Gren's method is founded on the following experiments:

1. If 60 grains of slacked lime be dissolved in as much muriatic acid as is requisite to saturation, and 120 of desiccated Glauber in a sufficiency of water, and both solutions mixed and agitated, these salts will decompose each other, and selenite and common

salt be formed. (*Note, however*, that the lime in this experiment was somewhat aerated and contained water, otherwise it would require for its saturation more vitriolic acid than is contained in 120 grains of desiccated Glauber.)

2. Let 240 grains of aerated magnesia be dissolved to saturation in muriatic acid, and the solution diluted; to which add 150 grains of slacked lime diluted with water, and 240 of dry effloresced Glauber, and let them be agitated; after some time, and frequent agitation, the lime decomposes the muriated magnesia, but the muriated lime thus formed, is in its turn immediately decomposed by the Glauber, and common salt and selenite formed; thus the magnesia is left single, and most of the selenite, as being little soluble falls with it, and both may be filtered off. The theory of this operation is not rightly given by Mr. Gren; for, according to him, the lime decomposes the Glauber, (which is not true in temperatures below 200°.) and then the alkali of the Glauber decomposes the muriated magnesia; the former statement seems therefore more just.

Hence improvements may be made in the five following cases:

1. If the brine contains *common Salt* and *muriated Lime* only, in such case the addition of Glauber is necessary, as more common salt is produced and also selenite, which being scarcely soluble, scarce any remains in the solution, but is deposited and forms what is called *schlott*.

2. If the brine contain besides *common Salt*, also *Glauber* and *muriated Magnesia*, in such case, lime only need be added, as muriated lime will be formed, which is decomposed by the Glauber, and thus selenite and pure magnesia precipitated. Yet I am of opinion that Glauber and muriated magnesia cannot stand together in the same water unless in inconsiderable proportions. See the direct experiments of Cornnette, Mem. Par. 1778, p. 338. And in such proportions even muriated lime and Glauber may co-exist, as I have already shewn; and see Mem. Par. 1778, p. 342. However, if the muriated magnesia be in considerable proportion, and that of Glauber inconsiderable, the addition of lime is useful.

3. If the brine contain *common Salt, Epsom,* and *muriated Magnesia* only, then an addition of both Glauber and lime will be proper; the lime is wanting to decompose the Epsom, and the Glauber and lime are wanting to decompose the muriated magnesia, and prevent the permanent existence of muriated lime, which would be as hurtful as the muriated magnesia.

4. If the brine contain only *common Salt, muriated Lime,* and *muriated Magnesia,* here also both lime and Glauber must be added; the lime to decompose the muriated magnesia, and the Glauber to decompose the muriated lime thus formed, and convert it into selenite. Glauber alone would, indeed, decompose both the muriats, but then Epsom would be formed, which is difficultly separated from common salt.

5. If the brine contain *common Salt, Epsom, muriated Magnesia, and Glauber,* then the addition of lime only would be sufficient, if the Glauber were in sufficient proportion, otherwise some should be added.

To these we may add the case in which *common Salt and Epsom* only are found, and then the addition of lime singly is useful; and the case in which *common Salt and an aerated Alkali* are found, in which case the mixture of other brine containing earthy muriats or sea-water is proper.

CHAP. III.

OF THE USE OF SPIRIT OF WINE IN THE ANALYSIS OF MINERAL WATERS.

Spirit of wine is employed in the analysis of Mineral Waters, as a *precipitant* of some salts, and as a solvent of salts of another sort.

Its use as a *precipitant* seems to have been accidently discovered by Mr. *Boulduc*, Mem. Par. 1726, p. 458, in 8vo. To eight parts of the Mineral Water of Passy he added eight of spirit of wine, and found it to precipitate selenite immediately. Then pouring the clear liquor into another vessel he added five parts more of the spirit of wine, and soon after found Glauber also precipitated and crystallized, and then passing the clear liquor into another vessel he added five parts more of the spirit, and found common salt also deposited. He also informs us that the spirit of wine should be well rectified.

In this account two points remain undetermined; namely, 1st, the relative proportions of the salt and water to each other, on which the spirit of wine can exert its precipitating power, as the water may certainly be in so large a proportion with respect either to the selenite or Glauber as to elude the power of spirit of wine, added in the quantities here mentioned, and the common salt may still more easily be retained. 2dly, the degree of rectification of the spirit of wine is not ascertained.

To obtain therefore a more precise knowledge of each of these particulars, I made solutions of one grain of the following salts in distinct portions of water, taking of each salt one grain, and of water 1000 grains, in each proportion. Of some salts I found it necessary to take solutions of one grain in 500 of water, and in some cases two grains in 500. The salts were vitriolated tartarin, Glauber, Epsom, selenite, alum, sylvian, common salt, nitre and muriated argil. The Glauber, Epsom, alum and nitre were desiccated.

To precipitate the salts from these solutions I employed spirit of wine, of different degrees of rectification, their specific gravities being at 60° 0,817, 0,834, 0,848, 0,900, seldom employing the stronger, when a weaker was found adequate to the effect.

The volume of spirit employed was various, generally however equal to that of the saline solution, except I found less sufficient; sometimes triple the volume of the solution was applied, its temperature generally about 60°. when higher it is mentioned, gentle heat strongly promoting precipitation.

The results of most of these experiments have already been mentioned, but it must be more satisfactory to see them presented in one view.

Moreover, to find the correspondence between the weight of *Glauber* precipitated by spirit of wine, and that which was contained in the solution, to 50 grains of a solution of Glauber, which contained 9,225 grains of Glauber. I added 2,5 times its bulk of spirit of wine 0,817 the precipitate, which immediately was formed, consisted of 7,13 grains, and in time, the remainder would undoubtedly be separated.

Hence we see, 1st, that *selenite* may be compleatly precipitated from water, that contains it in the proportion of $\frac{1}{1000}$, or even less, by any spirit of wine, whose specific gravity is below 0,850. And so may the *alkaline sulphats*, but slowly, by spirit of wine ,817. And thus these salts may be estimated and separated from each other without evaporation.

2. That the *alkaline sulphats* must be in a greater proportion than $\frac{1}{240}$ to be precipitated by spirit of wine, whose specific gravity is 0,834 or above it.

3. That *alum* must be in greater proportion than $\frac{1}{300}$ to be precipitated by spirit of wine 0,834, unless triple the volume of the solution, and also heat be applied.

Opposite to page 266.

PRECIPITATION,
BY
SPIRIT OF WINE.

Saline Solutions, 1 gr. in 1000 water.	,900	,848	,834	,817.
Vitriolated tartarin	0. in 24 hours, nor when heated to 120°.	0. in 24 hours	0. in 24 hours, tho' in triple quantity	1. in 3 days, a commencing precipitation was soon visible.
Glauber -	0. - - - -	0. - - -	0. tho' triple the volume added and heated	scarcely 1 in 3 days, tho' some soon visible.
Epsom -	0. - - - -	0. - - -	0. tho' treated as above	a cloud, but no precipitate in 3 days.
Selenite -	0. until heated	1. instantly	1. instantly	1. instantly.
Alum -	0.	0.		
Vitriol of iron crystallized -	0. - - - -	0. - - -	a yellowish powder in 3 days	an immediate cloud and yellowish powder in 3 days. So also it did in a solution of 1 grain in 2000 of water.
Nitre -	- - - - -	- - - -	- - - - - - - -	no cloud in 3 days.
Sylvian -	0. - - - -	0. - - -	0. - - - - - - -	no cloud in 3 days.
Common salt -	0. - - - -	0. - - -	0. - - - - - - -	no cloud in 3 days.
Muriated argil, a saturate solution -	- - - - -	- - - -	- - - - - - - -	an instant cloud, but no deposit in 3 days.
Muriated barytes	- - - - -	- - - -	- - - - - - - -	a slight cloud, but scarce any deposit in 3 days.
Muriated strothian, a saturate solution	- - - - -	- - - -	- - - - - - - -	a slight precipitate in 3 days.
Aerated lime in solution -	- - - - -	- - - -	- - - - - - - -	instant cloud; in 24 hours deposited in grains.
Aerated magnesia in solution -	- - - - -	- - - -	- - - - - - - -	instant cloud, in 24 hours a flocculent precipitate.

4. That *Epsom* must be in greater proportion than $\frac{1}{240}$ to be immediately precipitated by spirit of wine 0,834.

Westrumb tells us (on the Brine of Pyrmont, p. 30.) that an *equal* volume of alcohol precipitated 16 grains of *aerated lime*, *aerated magnesia*, *and selenite*, from one pound of the mineral water, which is nearly the whole of what it contained, for one pound contains (Ibid 46.) 5,4 grains of aerated lime, 3,4 of aerated magnesia, and 7 of selenite = 15,8 grains.* That *five times* the bulk of the alcohol to one pound of the water precipitated, about 4 grains of *Glauber*, of which the pound contains 15,4. That *nine* times the bulk of the alcohol to one of water, could precipitate scarce any common salt, of which the pound nevertheless contains 70 grains.

OF SPIRIT OF WINE AS A SOLVENT.

Spirit of wine, as a solvent, was first applied to the Analysis of Mineral Waters by the illustrious Laviosier. Mem. Par. 1772, p.

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* *Note*. On comparing the contents of the pound, with those of 100 cubic inches, (see his first table,) and observing that his cubic inch contains 395 grains, Ibid, p. 35, it seems the pound of Pyrmont contains but 3278,5 grains.

333, in 8vo. Led to this application by the experiments of Maquer, 3 Mem. Turin, 1762, 1765, on the solubility of different salts in spirit of wine. Maquer's experiments were made with spirit of wine, whose specific gravity appears to have been 0,8437 in the temperature of 54°,5 of Fahr. and would be ,840 in the temperature of 60°.

Maquer added to each of the salts, whose solubility he tried 288 grains of this spirit of wine; the salts he employed, were previously deprived of their water of crystalization, and perfectly desiccated. He made the spirit boil, filtered it while boiling, and evaporating the filtered liquor to dryness, from the weight of the residuum, inferred the quantity of each salt the spirit had dissolved.

The salts he thus essayed, and which relate to our present purpose, were vitriolated tartarin, Glauber, vitriolated vol-alkali, selenite, vitriol of iron, vitriol of copper, nitre, common salt, sylvian, nitrated lime, muriated lime, and muriated iron. He found that the above-mentioned *sulphats* were scarce at all affected even by the boiling spirits. 2. That only 4 grains of *nitre* were thus dissolved. 3. That 288 of *nitrated lime* were thus taken up. 4. That scarce any *common salt* could thus be dissolved. 5. That 5 grains of *sylvian* were taken up by the spirit. 6. That 288 grains of *muriated lime* were held in solution. 7. That 36 grains of *muriated iron* yielded to the spirit.

It is plain, however, that this method of essaying the solubility of salts was very inaccurate, for much of the spirit must have evaporated in the heat thus applied, and in cooling during filtration, some of the salts must have crystallized and remained in the filter. The spirit of wine employed by Lavoisier was of the same sort as that used by Maquer. This he mixed with water in eight different proportions, and in each he examined the solubility of the salts usually found in Mineral Waters, both in heat and in cold; the results of his experiments were, 1, That muriated and nitrated lime were easily dissolved by the spirit of wine singly. 2dly, But that the unmixed spirit did not dissolve either *aerated Soda*, *Glauber*, *Epsom*, *common Salt*, nor even *muriated Magnesia*, but only deprived Glauber of its water of crystallization. 3dly, That a mixture of two parts of spirit of win and one of water dissolved a considerable proportion of common salt with the assistance of heat, without depositing it when cold. Now the specific gravity of this mixed spirit containing $\frac{1}{3}$ of its weight of water, must have been at least 0,900 in the temperature of 60°.; for Brisson found the specific gravity of spirit of wine which at 61°. was 0,837, to be when mixed with water in the proportion of 11 of the spirit to 5 of water to be 0,9075. (See his tables.) 4thly, He observed that Glauber could not be dissolved in cold by any mixture in which the quantity of the spirit exceeded that of water, though it might in the heat of ebullition, but that it totally crystallized in cooling, especially if the mixture contained two parts of the spirit to one of the salt. 5thly, That Epsom was somewhat less soluble.

Though these results are valuable, yet still it is to be regretted that this great philosopher did not live to perfect what still remained to be ascertained, the precise quantities of each salt taken up by the spirits in each circumstance.

In 1777, Wenzel published also a series of experiments on the solubility of different salts in what he calls the *best* spirit of wine, whose specific gravity he has unfortunately neglected to mention; yet as he compares them with those of Maquer, there is reason to think that his spirit was nearly of the same strength. Of this spirit he took 240 grains, and an equal weight of the more soluble salts deprived of their water of crystallization; but to dissolve the less soluble he employed 480 of the spirit, and in most cases a strong heat in a water bath. He found *vitriolated tartarin*, *Glauber*, *selenite*, *alum*, the *vitriols of iron*, *copper*, and *zinc*, *common salt*, and *borax*, insoluble.

The salts he found most soluble, and that relate to the present subject, were muriated argil, magnesia, and iron, as exhibited in the following series, together with the heat employed when expressed by him:

Spirit of wine, 240 grains dissolved.		
Of muriated argil . .	240 grs.	at 54°,5 Fahr.
muriated magnesia .	1313	. . 180°.
muriated iron . .	240	. . 180°.
muriated lime . .	240	. in a boiling heat

Of nitrated magnesia	694	at 180°.
boracic acid	48	in a boiling heat.
sal-ammoniac	17	in ditto.
nitre	5	in ditto.
sylvian	5	in ditto.

According to 1 Bergman, p. 108, 100 grains of alcohol (whose specific gravity he has not here determined, but in his notes on Sheffer, § 210, he states it at ,820,) dissolves at 59°. Fahr.; of *nitrated lime*, or *muriated magnesia*, 14,3 grains; of *muriated lime*, 12 grains; of *nitrated magnesia*, 10 grains. He applies the alcohol only for some hours, ibid. 122; but p. 136, he says, 100 parts alcohol would dissolve 20 of muriated magnesia.

Dr. Withering, in a table of the solubility of different salts in alcohol extracted chiefly from Maquer, tells us (Phil. Trans. 1783, p. 336) that he found Epsom soluble, but aerated tartarin and soda insoluble. But neither is the quantity of the salts dissolved, nor the temperature, nor the specific gravity of the alcohol mentioned, nor its quantity or the time during which it is to act.

According to Westrumb, even *common Salt*, and *Epsom*, nay, even *Glauber*, are in some slight degree soluble in spirit of wine, (of which he does not define the specific gravity) 3 Westr. p. 79 and 80. He exposes the salts to its action, without applying heat, for 24 hours, 1 Westr. p. 120; and remarks that this slight solubility of the common salt is very convenient, as it serves to separate that salt from sulphats, for if the spirit takes any portion of these, that portion will be deposited on letting the solution rest for a few days, or at least on evaporating the spirituous solution to dryness, and treating the residuum with alcohol, with two parts of which one of water, is mixed; he tells us the common salt is taken up, and the sulphats (at least the selenite) remain undissolved.

The solubility of *common Salt* in alcohol was also remarked by *Fourcroy*, *Analyse des Eaux d'Enghien*, p. 285 and 373. The quantity of spirit he employed in the experiment was 5760 grains; its specific gravity, he tells us, was 39°. by the areometer, in the temperature of 15°. of Reaum, or 65°,75 Fahr. which, by Mr. Nicholson's calculation, 1 Phil. Journ. p. 39, amounts to the specific gravity ,822; and this, by Dr. Blagden's table, Phil. Trans. 1792, would be 0,825 at 60°. of Fahr.; the quantity of common salt dissolved was 22 grains, that is, 0,38 per cent.

I now proceed to state my own experiments on the solubility of different salts in spirits of wine of different specific gravities, namely, 0,817, 0,834, 0,848, and 0,900. I commonly employed 200 grains, sometimes 100, and sometimes 120 grains; but the centisimal proportion is in every case here given. The temperature was generally 60°. by day, and at most in some cases, 70°. but at night generally from 50°. to 57°. the time generally 24 hours, when longer it is mentioned.

TABLE of the Solubility of the following Salts in 100 Grains of Spirit of Wine, of different Densities.

	SPIRIT OF WINE.				
Salts.	0,900.	0,872.	0,848.	0,834.	0,817.
	Grs.	Grs.	Grs.	Grs.	Grs.
Glauber - -	0. - - -	0. - - -	0. - - -	0. - - -	0.
Epsom - -	1. in two days. - -	1. in 3 days, temp. from 55°. to 70°.	0. - - -	0. - - -	0.
Nitre - -	2,76. in 3 days, temp. from 55°. to 70°.	1. in 3 days, temp. from 55°. to 70°.	0. - - -	0. - - -	0.
Nitrated Soda -	10,5. temperature from 50 . to 70 . - -	6. temp. from 64°. to 80°. - - -	- - - -	0,38. temp. from 50°. to 67°. - -	0.
Sylvian - -	4,62. temperature from 50 . to 67°. - -	1,66. temp. from 64°. to 80°. - - -	- - - -	0,38. temp. from 55°. to 70°. - -	0.
Common salt -	5,8. temperature from 50 . to 70 .	3,67. in 3 days, from 55°. to 70°. - -	- - - -	0,5. temp. from 50°. to 67 . - -	
Sal-ammoniac -	6,5. from 55°. to 67 . 7,5. heated to 80°.	4,75. temp. from 55°. to 80°. - -	- - - -	1,5. temp. from 55°. to 70 . - -	
Muriated magnesia, dried at 120°. -	21,25. - - -	- - - -	23,75. - - -	36,25. - - -	50.
Muriated Barytes -	1. temp. from 45 . to 55 . - - -	- - - -	0,29. - - -	0,185. - - -	0,09.
Ditto, crystallized -	1,56. - - -	- - - -	0,43. - - -	0,32. - - -	0,06. in 3 days.
Acetited lime -	2,4. in 3 days, temp. 60. - - - -	- - - -	4,12. - - -	4,75. - -	4,88.

Opposite to page 274, and after No. 1.

PRECIPITATION,

by

SPIRIT OF WINE,

Saline Solutions, 2 gr. in 1000 of water.	,900	,848	,834	,817
Vitriolated tartarin	o. - - - -	o. - - -	o. in 24 hours.	
Glauber -	o. - - - -	o. - - -	o. in 24 hours.	
Epsom -	o. - - - -	o. - - -	o. in 24 hours, though triple the quantity was added.	
Selenite -	2. triple the quantity was added, soon clouded, in 24 hours deposited	2. instant cloud	2.	
Alum -	o. - - - -	o. - - -	1. when triple, the volume was added and heat applied.	
Vitriol of iron				
Nitre				
Common salt	o. - - - -	o. - - -	no cloud in 24 hours.	
Sylvian -	o. - - - -	o. - - -	o. in 24 hours.	
Saline solutions, 2 gr. in 500 of water				
Glauber -	o. - - - -	o. - - -	a cloud, but no deposit after agitation in 24 hours.	
Epsom -	o. - - - -	o. - - -	after 24 hours, a deposit.	
Ditto, crystallized	o. - - - -	o. - - -	no cloud in 6 days.	
Alum -	- - - - -	- - - -	no instant cloud, but there was when heat was applied.	
Saturate solution of crystallized Epsom, or 12,5 grains in 50 water		instantly coagulated.	as the former.	instantly coagulated, and could not be dried on a filter.

REMARKS.

It is rather odd that *acetited Lime* should be less soluble in water than in the strongest alcohol.

Of *muriated Magnesia*, some had been dried in a heat of 400°.; and this was less soluble in spirit of wine 0,848 than that which had been dried at 120°.; it did not draw moisture until after eight or ten days. As Lavoisier states it as insoluble, and Bergman ascribes to it different degrees of solubility, it is plain that these differences are owing to its retaining or losing more or less acid during desiccation.

Bergm. p. 125, reckons *muriated Barytes* among the salts soluble in alcohol. Yet Scheele on Manganese, § 32, denies this, and with him my experiments agree, and *Westrumb* and *Vauquelin*, *Journal des Mines*, No. 29, p. 363.

According to Westrumb, *Alkaline Muriats* become more soluble in alcohol when accompanied with earthy muriats; this Vauquelin denies, *Journ. des Mines*, *No.* 29, *Pluviose Ann.* V. p. 26 and with reason, as common salt precipitates some of them from a saturate solution in the water.

TABLES.

TABLE I. Of the quantities of real acid in acid liquors of different specific gravities.

II. Of the quantities of acid absorbed by various bases.

III. Of the quantities of each bases absorbed by acids.

IV. Of the proportion of ingredients in neutral salts.

V. Of the length in feet of a column of air, &c. in temperatures of from 40°. to 73°. and under different barometrical heights of from 29′. to 30,2.

Opposite p. 276.

TABLE I.

OF the Quantity of Real Acid in 100 Parts of Vitriolic, Nitrous, and Marine Acid Liquors of different Densities, at the Temperature of 60°.

In *Vitriolic Acid* of different Densities, at the Temperature of 60°.				In *Nitrous Acid* of different Densities, at the Temperature of 60°.				In *Marine Acid* of different Densities, at the Temperature of 60°.	
100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.
2,0000	89,29	1,4666	44,64	1,5543	73,54	1,3364	41,91	1,196	25,28
1,9859	88,39	1,4427	43,75	1,5295	69,86	1,3315	41,18	1,191	24,76
1,9719	87,50	1,4189	42,86	1,5183	69,12	1,3264	40,44	1,187	24,25
1,9579	86,61	1,4099	41,96+	1,5070	68,39	1,3212	39,71	1,183	23,73
1,9439	85,71	1,4010	41,07	1,4957	67,65	1,3160	38,97	1,179	23,22
1,9299	84,82	1,3875	40,18	1,4844	66,92	1,3108	38,34	1,175	22,70
1,9168	83,93	1,3768*	39,28	1,4731	66,18	1,3056	37,50	1,171	22,18
1,9041	83,04+	1,3663	38,39	1,4719	65,45	1,3004	36,77	1,167	21,67
1,8914	82,14	1,3586	37,50	1,4707	64,71	1,2911	36,03	1,163	21,15
1,8787	81,25	1,3473	36,60	1,4695	63,98+	1,2812	35,30+	1,159	20,64
2,8660	80,36	1,3360	35,71	1,4683	63,24	1,2795	34,56	1,155	20,12
1,8542	79,46	1,3254	34,82	1,4671	62,51	1,2779	33,82	1,151	19,60
1,8424	78,57	1,3149	33,93	1,4640	61,77	1,2687	33,09	1,147	19,09
1,8306	77,68	1,3102	33,03	1,4611	61,03	1,2586	32,35	1,1414	18,57
1,8188	76,79+	1,3056	32,14	1,4582	60,30	1,2400	31,62	1,1396	18,06
1,8070	75,89	1,2951	31,25	1,4553	59,56	1,2464	30,88	1,1358	17,54
1,7959	75,—	1,2847	30,35	1,4524	58,83	1,2419	30,15	1,1320	17,02
1,7849	74,11	1,2757	29,46	1,4471	58,09	1,2374	29,41	1,1282	16,51
1,7738	73,22	1,2668	28,57	1,4422	57,36	1,2291	28,68	1,1244	15,99
1,7629	72,32	1,2589	27,68+	1,4373	56,62	1,2209	27,94	1,1206	15,48
1,7519	71,43	1,2510	26,78	1,4324	55,89	1,2180	27,21+	1,1168	14,96
1,7416	70,54+	1,2415	25,89	1,4275	55,15	1,2152	26,47	1,1120	14,44
1,7312	69,64	1,2320	25,—	1,4222	54,12+	1,2033	25,74+	1,1078	13,93
1,7208	68,75	1,2210	24,10	1,4171	53,68	1,2015	25,00	1,1036	13,41
1,7104	67,86	1,2101	23,21	1,4120	52,94	1,1963	24,26	1,0984	12,90
1,7000	66,96	1,2009	22,32	1,4069	52,21	1,1911	23,53	1,0942	12,38
1,6899	66,07	1,1918	21,43+	1,4018	51,47	1,1845	22,79	1,0910	11,86
1,6800	65,18	1,1836	20,53	1,3975	50,74	1,1779	22,06	1,0868	11,35
1,6701	64,28	1,1746	19,64	1,3925	50,00	1,1704	21,32	1,0826	10,83
1,6602	63,39	1,1678	18,75	1,3875	49,27	1,1639	20,59	1,0784	10,32
1,6503	62,50	1,1614	17,85	1,3825	48,53	1,1581	19,85	1,0742	9,80
1,6407	61,61	1,1531	16,96	1,3775	47,80	1,1524	19,12	1,0630	8,25
1,6312	60,71	1,1398	16,07	1,3721	47,06	1,1421	18,48	1,0345	5,16
1,6217	59,82	1,1309	15,18+	1,3671	46,33	1,1319	17,65+	1,0169	2,58
1,6122	58,93	1,1208	14,28	1,3621	45,59	1,1284	16,91		
1,6027	58,03	1,1129	13,39	1,3571	44,86+	1,1241	16,17		
1,5932	57,14	1,1011	12,50	1,3521	44,12	1,1165	15,44		
1,5840	56,25	1,0955	11,60	1,3468	43,38	1,1111	14,70		
1,5748	55,36+	1,0896	10,71	1,3417	42,65	1,1040	13,27		
1,5656	54,46	1,0833	9,80						
1,5564	53,57	1,0780	8,93+						
1,5473	52,68	1,0725	8,03						
1,5385	51,78	1,0666	7,14						
1,5292	50,89	1,0610	6,25						
1,5202	50,00	1,0555	5,35						
1,5112	49,11+	1,0492	4,46						
1,5022	48,21	1,0450	3,57						
1,4933	47,32	1,0396	2,67						
1,4844	46,43	1,0343	1,78						
1,4755	45,53								

The Numbers above the Lines drawn acroſs the Tables of vitriolic and nitrous Acids were found by Experiments; thoſe under the Lines only by Analogy.

The Affinity of vitriolic Acid to Water decreases in the Ratio of the Square of the Quantity of Water united to it. 23 Ann. Chy. 196 and 197.

And ſo I believe it does to all other Substances; it is the *mean* Affinity that is commonly given.

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* The Sp. Gravity was 1,3741 in the former Table.

Note. The standard Quantities of *Vitriolic* Acid were reduced to *Real* by multiplying them into 0,8929. of the *Nitrous*, by multiplying them into 0,7354, and the *Marine* by multiplying them into 0,516, for the Reasons mentioned in my last Paper.

TABLE II. Of the Quantity of real Acid taken up by mere Alkalis and Earths.

100 parts.	Vitriolic.	Nitrous.	Marine.	Fixed air.
Tartarin -	82,48	84,96	56,3	105, almost.
Soda - - -	127,68	135,71	73,41	66,8.
Volalkali -	383,8	247,82	171,	Variable.
Barytes -	50,	56,	31,8	282,
Stronthian -	72,41	85,56	46,	43,2
Lime - -	143,	179,5	84,488	81,81.
Magnesia -	172,64	210,	111,35	200, Fourcroy.
Argil -	150,9	- -	- -	335, nearly Bergm.

TABLE III. Of the Quantity of Alkalis and Earths taken up by 100 Parts of real Vitriolic, Nitrous, Muriatic, and Carbonic Acids, saturated.

100 parts.	Tartarin.	Soda.	Volalkali.	Barytes.	Stronthian.	Lime.	Magnesia.
Vitriolic -	121,48	78,32	26,05	200,	138,	70,	57,92
Nitrous - -	117,7	73,43	40,35	178,12	116,86	55,7	47,64
Muriatic -	177,6	136,2	58,48	314,46	216,21	118,3	89,8
Carbonic -	95,1	149,6	- -	354,5	231,+	122,	50,

TABLE IV. Of the Proportion of Ingredients in the following Saline Compounds.

100 parts *Carbonic.*	Basis.	Acid.	Water.	State.
Aerated Tartarin	41,	43,	16,	Crystallized.
Common Salt of Tartarin or Pearl Ash	60,	30,	6,	Dry.
Aerated Soda	21,58	14,42	64,	Fully crystallized.
Do.	59,86	40,05	- - -	Desiccated.
Aerated Barytes	78,	22,	- - -	Natural or ignited.
Aerated Stronthian	69,5	30,	- - -	Natural or ignited.
Aerated Lime	55,	45,	- - -	Natural if pure, or artificial ignited.
Aerated Magnesia	25,	50,	25,	Crystallized.
Common Magnesia	45,	34,	21,	Dried at 80°.
Aerated Volalkali	In the ratio of 6 of Salt to 13 fixed Air			
Vitriolic.				
Vitriolated Tartarin	54,8	45,2	- - -	Dry.
Glauber	18,48	23,52	58,	Fully crystallized.
Do.	44,	56,	- - -	Desiccated at 700°.
Vitriolated Volalkali	14,24	54,66	31,1	
Baroselenite	66,66	33,33	- - -	Natural and pure, artificial ignited.
Vitriolated Stronthian	58,	42,	- - -	Natural and pure, artificial ignited.
Selenite	32,	46,	22,	Dried at 66°.
Do.	35,23	50,39	14,38	Dried at 170°.
Do.	38,81	55,84	5,35	Ignited.
Do.	41,	59,	- - -	Incandescent.
Epsom	17,	29,35	53,65	Fully crystallized.
Do.	36,68	63,32	- - -	Desiccated.
Alum	12, ignited	17,66	51, of Crystal + 19,24 in the Earth	Crystallized.
Do.	63,75	36,25	- - -	Desiccated at 700.
Vitriols				
Of Iron	28, ♆ of ♂ = 12, Metal	26,'	38, + 8 of Composition	Crystallized.
Do.	45,	41,93	13,07	Calcined to Redness.
Lead	75, Calx = 71 Metal	23,37	1,63	
Copper	40, Calx = 30 Metal	31,	29,	
Zinc	40, Calx = 30 Metal	20,5	39,	

100 Parts *Nitrous.*	Basis.	Acid.	Water.	State.
Nitre	51,8	44,	4,2 of Composition	Dried at 70°.
Nitrated Soda	40,58	53,21	6,21 of Composition	Dried at 400°.
Do.	42,34	57,55	- - -	Ignited.
Nitrated Vol-alkali	23,	57,	20,	
Nitrated Barytes	57,	32,	11,	Crystallized.
Nitrated Stronthian	36,21	31,07	32,72	Crystallized.
Nitrated Lime	32,	57,44	10,56	Well dried, that is in Air.
Nitrated Magnesia	22,	46,	22,	Crystallized.
Muriatic.				
Muriated Tartarin	64,	36,	- - -	Dried at 80°.
Common Salt	53,	47, aqueous, 38,88 real	- - -	Dried at 80°.
Sal Ammoniac	- -	- - -	- - -	Crystallized.
Do.	25,	42,75	32,25	Sublimed.
Muriated Barytes	64,	20,	16,	Crystallized.
Do.	76,2	23,8	- - -	Desiccated.
Muriated Stronthian	40,	18,	42,	Crystallized.
Do.	69,	31,	- - -	Desiccated.
Muriated Lime	50,	42,	8,	Red hot.
Muriated Magnesia	31,07	34,59	34,34	Sensibly dry.
Muriated Silver	75,	16,54	8,46 Oxygen	Dried at 130°.
Muriated Lead	81,77 ♆ ♄	18,23	In the Calx	Crystallized.
Do.	83, ♆ of ♄	17,	- - -	Desiccated.

TABLE V.

OF the Length of a Column of Air, whose Basis is 1 Square Inch, which weighs as much as $\frac{1}{10}$ of a Cubic Inch of Mercury; that is, 344,32 Grains, at different Temperatures and different Heights of the Barometer.

BAROMETER.

Tempe-rature.	29,	29,1	29,2	29,3	29,4	29,5	29,6	29,7	29,8	29,9	30,	30,1	30,2
40°	91,6	91,28	90,96	90,65	90,35	90,	89,74	89,43	89,13	88,83	88,54	88,24	87,95
41	91,81	91,49	91,18	90,87	90,56	90,25	89,94	89,64	89,34	89,04	88,75	88,45	88,16
42	92,02	91,71	91,39	91,08	90,77	90,46	90,16	89,85	89,55	89,25	88,96	88,66	88,37
43	92,23	91,91	91,60	91,29	90,94	90,67	90,36	90,06	89,75	89,45	89,16	88,86	88,56
44	92,46	92,14	91,82	91,51	91,20	90,89	90,58	90,28	89,97	89,67	89,38	89,08	88,78
45	92,68	92,37	92,05	91,74	91,42	91,11	90,81	90,50	90,20	89,89	89,60	89,32	89,00
46	92,91	92,59	92,28	91,96	91,65	91,34	91,03	90,72	90,42	90,12	89,82	89,52	89,22
47	93,13	92,81	92,49	92,18	91,86	91,55	91,24	90,94	90,63	90,33	90,03	89,73	89,43
48	93,35	93,03	92,71	92,39	92,04	91,76	91,45	91,15	90,84	90,54	90,24	89,94	89,64
49	93,56	93,24	92,92	92,61	92,29	91,98	91,67	91,36	91,05	90,75	90,45	90,14	89,83
50	93,75	93,46	93,14	92,82	92,57	92,19	91,85	91,57	91,26	90,96	90,66	90,32	90,06
51	94,01	93,69	93,36	93,05	92,73	92,42	92,10	91,79	91,48	91,18	90,88	90,57	90,27
52	94,24	93,91	93,59	93,27	92,95	92,64	92,33	92,02	91,71	91,40	91,10	90,79	90,49
53	94,45	94,13	93,81	93,49	93,17	92,85	92,54	92,23	91,92	91,61	91,52	91,00	90,70
54	94,67	94,35	94,02	93,70	93,38	93,07	92,75	92,44	92,13	91,82	91,62	91,21	90,91
55	94.88	94,55	94,23	93,91	93,59	93,27	92,95	92,64	92,33	92,02	91,72	91,41	91,11
56	95,08	94,76	94,43	94,11	93,79	93,47	93,16	92,84	92,53	92,22	91,92	91,61	91,31
57	95,29	94,96	94,64	94,32	94,00	93,68	93,36	93,05	92,73	92,42	92,12	91,81	91,50
58	95,52	95,19	94,87	94,54	94,22	93,90	93,58	93,27	92,95	92,64	92,34	92,03	91,72
59	95,74	95,41	95,08	94,76	94,43	94,11	93,80	93,48	93,17	92,92	92,55	92,24	91,93
60	95,96	95,63	95,31	94,98	94,66	94,34	94,02	93,70	93,39	93,08	92,77	92,46	92,15
61	96,18	95,85	95,52	95,20	94,87	94,55	94,23	93,91	93,60	93,29	92,98	92,67	92,36
62	96,40	96,07	95,74	95,41	95,09	94,76	94,45	94,13	93,78	93,50	93,19	92,88	92,57
63	96,64	96,30	95,97	95,65	95,32	95,00	94,68	94,36	94,04	93,73	93.42	93.10	92,80
64	96,84	96,54	96,18	95,85	95,53	95,20	94,81	94,60	94,24	93,93	93,62	93,30	93,00
65	97,03	96,72	96,39	96,06	95,73	95,44	95,08	94,76	94,44	94,13	93,82	93,50	93,19
66	97,28	96,94	96,61	96,28	95,95	95,63	95,31	94,98	94,67	94,35	94,04	93,72	93,41
67	97,50	97,16	96,83	96,50	96,17	95,84	95,52	95,20	94,88	94,56	94,25	93,93	93,62
68	97,72	97,39	97,05	96,72	96,39	96,07	95,74	95,42	95,10	94,78	94,47	94,15	93,84
69	97,94	97,60	97,27	96,94	96,61	96,28	95,92	95,63	95,31	94,99	94,68	94,36	94,05
70	98,14	97,81	97,47	97,14	96,81	96,48	96,16	95 83	95,51	95,19	94.88	94,56	94,25
71	98,37	98,04	97,70	97,37	97,04	96,71	96,38	96,06	95,73	95,41	95,10	94,78	94,47
72	98,59	98,25	97,92	97,58	97,25	96,92	96,59	96,27	95,94	95,62	95,31	94,99	94,67
73	98,80	98,46	98,10	97,79	97,45	97,12	96,80	96,47	96,14	95,82	95,51	95,19	94,87

APPENDIX.

SINCE the conclusion of the above treatise, I made several experiments with various saline solutions, whose results appeared to me new and surprizing. Mr. Hatchett had the goodness to repeat them before me with the same success. I was induced to make them by reading of some in a paper of Quatre Mer de Dijonval in Rozier's Journal. I think it necessary to publish them here to prevent the false inductions these results would otherwise naturally lead to.

Mixtures of solutions.	Results.
Barytic lime-water and Common lime-water.	An immediate precipitation; the solutions were saturate, but the result was the same when both were previously diluted. The precipitate was not re-dissolved on adding marine acid, at least not immediately.
Stronthian lime-water and Common lime-water.	No precipitate.

Mixtures of solutions.	Results.
Barytic lime-water and Stronthian lime-water	No precipitate; but on adding a few drops of common lime-water a turbidity was immediately perceived.
Muriated barytes and Muriated lime.	A precipitate which was not dissolved on adding nitrous acid, but rather increased.
Muriated barytes and Nitrated lime.	A precipitate after agitation. This was re-dissolved on adding more water.
Nitrated barytes and Muriated lime.	A cloud, which was not re-dissolved on adding more water, but was by strong nitrous acid.
Nitrated barytes and Nitrated lime.	A precipitate when agitated, but re-dissolved by adding more water.
Muriated barytes and Muriated magnesia.	A dense cloud or precipitate, which was not re-dissolved on adding more water.
Muriated barytes and Nitrated magnesia.	A cloud, not re-dissolved by adding more water, but was so by strong nitrous acid.
Nitrated barytes and Muriated magnesia.	A cloud, not re-dissolved by water, but was by strong nitrous acid.
Nitrated barytes and Nitrated magnesia.	On agitation, gave a cloud; not re-dissolved by the addition of water, nor soon by strong nitrous acid.
Muriated barytes and Muriated stronthian.	No precipitate.

Mixtures of solutions.	Results.
Nitrated barytes and Nitrated stronthian.	No precipitate until agitated, but on adding more water all was re-dissolved.
Nitrated barytes and Muriated stronthian.	No precipitate.
Muriated stronthian and Nitrated magnesia.	A cloud, not re-dissolved by the addition of water.
Muriated stronthian and Muriated magnesia.	No cloud.
Nitrated stronthian and Nitrated magnesia.	No cloud.
Nitrated stronthian and Muriated magnesia.	No cloud.
Muriated stronthian and Nitrated lime.	No precipitate, or cloud.
Nuriated stronthian and Muriated lime.	No precipitate.
Nitrated stronthian and Nitrated lime.	No precipitate.

FINIS.

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14 58

8

$x^3 - 41)x = -120$

16

7 32

2

8 64

2

9 128

2

10 256

2

11 512

2

12 1024

2

13 2048

12 1 4 0-6

20
7 80