XIV. *A General Formula for the Analysis of Mineral Waters.*

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(Read June 7. 1816.)

THE analysis of Mineral Waters has always been considered as a difficult operation. Numerous methods are employed to discover their ingredients, and estimate their quantities, many of which are liable to errors. This diversity of method itself is a source of discordant results. And to those not familiar with such researches, it presents the difficulty often of determining what process is best adapted to discover a particular composition. Hence the advantage of a general formula, if this could be given, applicable to the analysis of all waters. The views which have been stated in the papers, connected with this subject, which I have had the honour of submitting to the Society, have suggested a method which appears to me to admit of very general application, and to be simple, not difficult of execution, nor liable to any sources of error but what may be easily obviated. The principles on which this method is founded, and the details of the process itself, form the subject of the following observations.

Two methods of analysis have been employed for discovering the composition of mineral waters,—what may be called

the *direct method*, in which, by evaporation, aided by the subsequent application of solvents, or sometimes by precipitants, certain compound salts are obtained ; and what may be called the *indirect method*, in which, by the use of re-agents, the principles of these salts, that is, the acids and bases of which they are formed are discovered, and their quantities estimated, whence the particular salts, and their proportions, may be inferred.

Chemists have always considered the former of these methods as affording the most certain and essential information : they have not neglected the latter ; but they have usually employed it as subordinate to the other. The salts procured by evaporation, have been uniformly considered as the real ingredients, and nothing more was required, therefore, it was imagined for the accuracy of the analysis, than the obtaining them pure, and estimating their quantities with precision. On the contrary, in obtaining the elements merely, no information, it was believed, was gained with regard to the real composition, for it still remained to be determined, in what mode they were combined, and this, it was supposed, could be inferred only from the compounds actually obtained. This method, therefore, when employed with a view to estimate quantities, has been had recourse to only to obviate particular difficulties attending the execution of the other, or to give greater accuracy to the proportions, or, at farthest, when the composition is very simple, consisting chiefly of one genus of salts.

Another circumstance contributed to lead to a preference of the direct mode of analysis ;—the uncertainty attending the determination of the proportions of the elements of compound salts. This uncertainty was such, that even from the most exact determination of the absolute quantities of the acids and bases existing in a mineral water, it would have been difficult,

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or nearly impracticable, to assign the precise composition, and the real proportions of the compound salts; and hence the necessity of employing the direct method of obtaining them.

The present state of the science leads to other views.

If the conclusion were just, that the salts obtained by evaporation, or any analogous process from a mineral water, are its real ingredients, no doubt could remain of the superiority of the direct method of analysis; and even of the absolute necessity of employing it. But no illustrations, I believe, are required to prove, that this conclusion is not necessarily true. The concentration by the evaporation, must, in many cases, change the state of combination, and the salts obtained are hence frequently products of the operation, not original ingredients. Whether they are so or not, and what the real composition is, are to be determined on other grounds than on their being actually obtained; and no more information is gained, therefore, with regard to that composition, by their being procured, than by their elements being discovered; for when these are known, and their quantities are determined, we can, according to the principle from which the actual modes of combination are inferred, whatever this may be, assign with equal facility the quantities of the binary compounds they form.

The accuracy with which the proportions of the constituent principles of the greater number of the compound salts are now determined, enables us also to do this with as much precision, as by obtaining the compounds themselves. And if any error should exist in the estimation of these proportions, the prosecution of these researches could not fail soon to discover it.

The mode of determining the composition of a mineral water, by discovering the acids and bases which it contains, admits, in general, of greater facility of execution, and more accuracy,

curacy, than the mode of determining it by obtaining insulated the compound salts. Nothing is more difficult than to effect the entire separation of salts by crystallization, aided even by the usual methods of the action of alcohol, either as a solvent or a precipitant, or by the action of water as a solvent at different temperatures; in many cases it cannot be completely attained, and the analysis must be deficient in accuracy. No such difficulty is attached to the other method. The principles being discovered, and their quantities estimated in general from their precipitation in insoluble compounds, their entire separation is easily effected. Nothing is easier, for example, than to estimate the total quantity of sulphuric acid by precipitation by barytes, or of lime by precipitation by oxalic acid. And this method has one peculiar advantage with regard to accuracy, that if any error is committed in the estimation of any of the principles, it is discovered in the subsequent step of inferring the binary combinations, since, if all the elements do not bear that due proportion to each other which is necessary to produce the state of neutralization, the excess or deficiency becomes apparent, and of course the error is detected. The indirect method, then, has every advantage over the other, both in accuracy and facility of execution.

Another advantage is derived from these views, if they are just, that of precluding the discussion of questions which otherwise fall to be considered, and which must often be of difficult determination, if they are even capable of being determined. From the state of combination being liable to be influenced by evaporation, or any other analytic operation by which the salts existing in a mineral water are attempted to be procured, discordant results will often be obtained, according to the methods employed; the proportions at least will be different, and sometimes even products will be found by one method which
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are not by another. In a water which is of complicated composition, this will more peculiarly be the case. The Cheltenham waters, for example, have, in different analyses, afforded results considerably different ; and, on the supposition of the salts procured being the real ingredients, this diversity must be ascribed to inaccuracy, and ample room for discussion, with regard to this is introduced. In like manner, it has often been a subject of controversy, whether sea-water contains sulphate of soda with sulphate of magnesia. All such discussions, however, are superfluous. The salts procured are not necessarily the real ingredients, but in part, at least, are products of the operation, liable, therefore, to be obtained or not, or to be obtained in different proportions, according to the method employed. And all that can be done with precision, is to estimate the elements, and then to exhibit their binary combinations according to whatever may be the most probable view of the real composition.

The process I have to state, conformable to these views, is essentially the same as that which I employed in the analysis of sea-water in a preceding memoir ; and it was the consideration of the advantages belonging to it, that has led me to propose it, with the necessary modifications, as one of general application.

Mineral waters have been arranged under the four classes of Carbonated, Sulphureous, Chalybeate, and Saline. But all of them are either saline, or may be reduced under this division. From waters of the first class, the carbonic acid which is in excess, is expelled by heat, and its quantity is estimated. Sulphuretted hydrogen is in like manner expelled or decomposed. And iron may be detected by its particular tests, and removed by appropriate methods. In all these cases the water remains, with any saline impregnation which it has, and of course is essentially

entially the same in the subsequent steps of its analysis as a water purely saline; the precaution only being observed of these principles being removed, and of no new ingredient being introduced by the methods employed.

The salts usually contained in mineral waters are Carbonates, Sulphates, and Muricates, of Lime, of Magnesia and of Soda. In proceeding to the analysis, a general knowledge is of course first to be gained of the probable composition by the application of the usual tests; the presence of sulphuric and carbonic acids being detected by nitrate of barytes, of muriatic acid by nitrate of silver, of lime by oxalic acid, of magnesia by lime-water or ammonia, and of any alkaline neutral salt by evaporation. It will also be of advantage to obtain the products of evaporation, and ascertain their quantities, without any minute attention to precision, the object being merely, by these previous steps, to facilitate the more accurate analysis.

Supposing this to be done, and supposing the composition of the water to be of the most complicated kind, that is, that by the indications from tests, or by evaporation, it has afforded carbonates, sulphates, and muricates of lime, magnesia and soda, the following is the general process to be followed to ascertain the ingredients, and their proportions.

Reduce the water by evaporation, as far as can be done without occasioning any sensible precipitation or crystallization; this, by the concentration, rendering the operation of the re-agents to be employed more certain and complete. It also removes any free carbonic acid.

Add to the water thus concentrated a saturated solution of muriate of barytes, as long as any precipitation is produced, taking care to avoid adding an excess. By a previous experiment, let it be ascertained whether this precipitate effervesces or not
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with diluted muriatic acid, and whether it is entirely dissolved. If it is, the precipitate is of course carbonate of barytes, the weight of which, when it is dried, gives the quantity of carbonic acid ; 100 grains containing 22 of acid. If it do not effervesce, it is sulphate of barytes, the weight of which, in like manner, gives the quantity of sulphuric acid ; 100 grains, dried at a low red-heat, containing 34 of acid. If it effervesce, and is partially dissolved, it consists both of carbonate and sulphate. To ascertain the proportions of these, let the precipitate be dried at a heat a little inferior to redness, and weighed ; then submit it to the action of dilute muriatic acid ; after this wash it with water, and dry it by a similar heat, its weight will give the quantity of sulphate, and the loss of weight, that of carbonate of barytes.

By this operation the carbonic and sulphuric acids are entirely removed, and the whole salts in the water are converted into muriates. It remains, therefore, first to discover and estimate the quantities of the bases present, and then, to complete the analysis, to find the quantity of muriatic acid originally contained.

Add to the clear liquor a saturated solution of oxalate of ammonia as long as any turbid appearance is produced. The lime will be thrown down in the state of oxalate. The precipitate being washed, may be dried, but as it cannot be exposed to a red-heat without decomposition, it can scarcely be brought to any uniform state of dryness with sufficient accuracy to admit of the quantity of lime being estimated from its weight. It is therefore to be calcined with a low red-heat, by which it is converted into carbonate of lime, 100 grains of which are equivalent to 56 of lime. But as a portion of carbonic acid may be expelled, if the heat is raised too high, or a little water retained if it is not high enough ; it is proper to

convert it into sulphate, by adding sulphuric acid to a slight excess, and then exposing to a full red-heat. The dry sulphate of lime will remain, 100 grains of which contain 41.5 of lime *.

The next step is to precipitate the magnesia. With regard to this there is some difficulty, particularly as connected with the design of the present formula. The principle on which it is founded is, first, to remove all the acids but the muriatic, and, secondly, to remove the bases, or otherwise estimate their quantities. The lime and the magnesia may be removed by precipitation; the soda cannot. The process, therefore, must be so conducted, as to leave it at the end in the state of muriate of soda. Hence it is necessary either to remove any new product introduced in the previous steps of the analysis, or if any such remain, to be able to estimate its quantity with precision. In decomposing the muriate of lime by oxalate of ammonia, muriate of ammonia is substituted, which can be afterwards dissipated by heat. The object, therefore, is to decompose the muriate of magnesia, and remove the magnesia, either by some similar method, or, if not, by some other in which the muriate substituted can be accurately estimated; and to attain one or other of these conditions, gives rise to the difficulty to which I have alluded.

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* The only source of error to which this step of the analysis is liable, is that which will arise if more barytes has been used in the first operation, than was necessary to precipitate the sulphuric and carbonic acids. It will be thrown down in the state of oxalate of barytes, and be converted into carbonate and sulphate, and thus give the apparent proportion of lime too large. This is obviated, of course, by taking care to avoid using an excess of barytes. To render the operation of the oxalate of ammonia as perfect as possible in precipitating the lime, the water should be considerably reduced by evaporation, taking care to avoid any separation of any of its ingredients.

The decomposition of the magnesian salt by ammonia would have the former advantage, as the muriate of ammonia would be expelled at the end of the process by heat ; but this decomposition, it is well known, is only partial. Sub-carbonate of ammonia causes a more abundant precipitation of magnesia, but still its action is likewise partial, a ternary soluble salt being formed after a certain quantity has been added. It seemed probable, that this might be obviated, by adding the sub-carbonate of ammonia as long as it occasioned any precipitation, then evaporating the clear liquor to dryness, expelling the muriate of ammonia, and any excess of ammonia, by heat, re-dissolving, and again adding the sub-carbonate of ammonia to decompose the remaining magnesian salt. Proceeding in this way, I found that a copious precipitation took place on the second addition, and even at the fourth a small quantity of precipitate was thrown down. But the decomposition, after all, was not perfect, for the quantity of magnesia obtained was not equal to what was procured by other methods.

Sub-carbonate of soda or potash has been usually employed to precipitate magnesia from its saline combinations. The precipitation, however, is only partial, unless an excess of the precipitant be employed (and even then, perhaps, is not altogether complete); and as this excess cannot easily be estimated, it introduces a source of error in estimating the quantity of muriate of soda at the end of the operation, against which it is not easy to guard.

The method proposed by Dr WOLLASTON, of precipitating magnesia from its solution, by first adding carbonate of ammonia, and then phosphate of soda, so as to form the insoluble phosphate of ammonia and magnesia, is one much more perfect ; the whole of the magnesia appears to be precipitated, and as a method, therefore, of determining the quantity of this

base, it is probably unexceptionable. It does not, however, altogether accord with the object of the present formula. The soda of the phosphate of soda serves to neutralize the muriatic acid of the muriate of magnesia; a quantity of muriate of soda is of course formed, which remains with the muriate of soda of the water, and the amount of which, therefore, it is necessary to determine with accuracy. This may be done from the quantity of phosphate of magnesia obtained giving the equivalent portion of muriate of soda, either by means of the equivalents of the acids, or of the bases. But still this renders the method somewhat complicated; and it may be liable to some error, if any excess of phosphate of soda be added, which, in order to precipitate the magnesia entirely, it may be difficult to avoid; this excess remaining with the muriate of soda, and rendering the estimate of it incorrect. And independent of these circumstances, it would be preferable to give uniformity to the operation, by employing some method by which the product in this, as well as in the previous steps, is removed, at the end of the analysis, leaving only the muriate of soda.

It seemed probable that this might be attained, by employing phosphoric acid with the carbonate of ammonia, to form the triple phosphate of ammonia and magnesia, such an excess of ammonia being used, as should both be sufficient for the constitution of this compound, and for the neutralization of the muriatic acid of the muriate of magnesia; muriate of ammonia would thus be substituted, the same as in the preceding step of precipitating the lime, which at the end would be expelled by heat, leaving muriate of soda alone. I accordingly found, that when this variation of the process was employed, the clear liquor, after the precipitation, was not affected by the addition either of phosphate of soda with ammonia, or of subcarbonate of soda,—a proof that the separation of the magnesia had

had been complete. To establish its accuracy with more certainty, the following experiments were also made.

Twenty grains of muriate of soda (pure rock-salt), which had been exposed to a red heat, and ten grains of crystallised muriate of magnesia, were dissolved in an ounce of water, at the temperature of 100° . The phosphate of soda and carbonate of ammonia were then employed to precipitate the magnesia in the mode proposed by Dr WOLLASTON, that is, a solution of the ammoniacal carbonate was first added, and afterwards a solution of phosphate of soda, as long as any precipitation was produced, taking care to preserve in the liquor a slight excess of the ammonia. The precipitate being washed and dried, afforded, after exposure to a red heat for an hour, 5.4 grains of phosphate of magnesia, equivalent to 2.15 of magnesia. The clear liquor being evaporated, muriate of soda was obtained, which, after exposure to a red heat, weighed 25.7 grains. Phosphate of magnesia being composed of 39.7 of magnesia, with 60.3 of phosphoric acid, 5.4 grains of it are equivalent to 6.4 grains of muriate of soda, and this deducted from the quantity obtained 25.7, leaves 19.3 as the quantity originally dissolved.

A solution perfectly the same was prepared, and a solution of carbonate of ammonia was added to it as before. A strong solution of phosphoric acid was then dropped in, as long as any precipitation was produced, observing the precaution of having always an excess of ammoniacal carbonate in the liquor. The precipitate being washed and dried, afforded, after exposure to a red heat, 5.5 grains of phosphate of magnesia equivalent to 2.19 of magnesia. The clear liquor being evaporated, and the dry matter being exposed to a heat gradually raised to redness, weighed, when cold, exactly 20 grains.

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In both experiments, the quantity of muriate of soda is accurately obtained, or as nearly so as can be expected. They correspond, too, as nearly as can be looked for, even in a repetition of the same experiment, in the quantity of magnesia which they indicate. To ascertain how far this corresponded with the real quantity, I converted 10 grains of the crystallised muriate of magnesia into sulphate by the addition of sulphuric acid, and exposed it to a low red heat; the product weighed 6.4 grains, equivalent to 2.13 of magnesia. This may be regarded as a perfect coincidence, and as establishing the accuracy of the other results *.

It thus appears, that phosphoric acid with an excess of ammonia may be employed to precipitate magnesia from its saline combinations; and in a process such as the present, it has the advantage, that the muriate of ammonia formed, can be afterwards volatilised by heat, and the quantity of any residual ingredient can of course be easily ascertained. Neutral phosphate of ammonia would also have this advantage; but it does not succeed, phosphate of magnesia not being sufficiently insoluble. On adding a solution of phosphate of ammonia to a solution of sulphate of magnesia, the mixture became turbid in a minute or two, and in a short time a precipitate in crystalline grains formed at the bottom and sides; but it was not considerable, and did not increase. Phosphate of ammonia, however, with an excess of ammonia, or with the previous addition of carbonate of ammonia, may be employed with the same

* According to the result of this last experiment, 100 grains of crystallised muriate of magnesia would give 64 of real sulphate of magnesia, composed of 21.3 of magnesia, and 42.7 of sulphuric acid. This quantity of sulphuric acid is equivalent to 29.4 of muriatic acid. Hence 100 grains of this salt crystallised (in which state its composition, I believe, has not been determined) consist of 21.3 magnesia, 29.4 muriatic acid, and 49.3 of water.

same effect as phosphoric acid. In applying the phosphoric acid to this purpose under any of these forms, it is necessary to be careful that it be entirely free from any impregnation of lime.

There is one other advantage which this method has, that if even a slight excess of phosphoric acid be added, the error it can introduce must be extremely trivial; for the effect of it will be only to decompose a small portion of the original muriate of soda; and as the difference is very inconsiderable in the proportion in which phosphoric and muriatic acids combine with soda, any difference of weight which may arise from this substitution, to any extent to which it can be supposed to happen, may be neglected as of no importance*.

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* For the sake of comparison, and to ascertain the accuracy of different methods, I submitted a similar solution of muriate of magnesia and muriate of soda to analysis by sub-carbonate of ammonia. To the saline liquor, heated to 100°, a solution prepared by dissolving carbonate of ammonia in water of pure ammonia, was added, until it was in excess. A precipitation rather copious took place; the precipitate being collected on a filtre, the clear liquor was evaporated to dryness, and the saline matter was exposed to heat, while any vapours exhaled. Being redissolved, a small portion remained undissolved, and on again adding sub-carbonate of ammonia to the clear liquor, precipitation took place, rather less abundant than at first. This was repeated for a third, and even for a fourth time, after which the liquor was not rendered turbid. Being evaporated, the muriate of soda obtained, after exposure to a red heat, weighed 20.5 grains. The whole precipitate washed, being heated with sulphuric acid, afforded of dry sulphate of magnesia 4.8 grains, a quantity inferior to that obtained by the other methods, evidently owing to the less perfect action of the ammoniacal carbonate as a precipitant. A similar deficiency in the proportion of magnesia was found in the analysis of sea-water by sub-carbonate of ammonia, as has been already stated; while, on the other hand, in its analysis by phosphate of soda and carbonate of ammonia, a larger quantity of muriate of soda was obtained than by the other methods, probably from the difficulty of avoiding an excess of phosphate of soda in precipitating the magnesia.

To apply this method, then, to the present formula; add to the clear liquor poured off after the precipitation of the oxalate of lime, heated to 100° , and, if necessary, reduced by evaporation, a solution of carbonate of ammonia; and immediately drop in a strong solution of phosphoric acid, or phosphate of ammonia, continuing this addition with fresh portions, if necessary, of carbonate of ammonia, so as to preserve an excess of ammonia in the liquor as long as any precipitation is produced. Let the precipitate be washed; when dried by a heat not exceeding 100° , it is the phosphate of ammonia and magnesia containing .019 of this earth; but it is better for the sake of accuracy, to convert it into phosphate of magnesia by calcination for an hour at a red heat: 100 grains, then, contain 40 of magnesia.

Evaporate the liquor remaining after the preceding operations to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it towards the end to redness. The residual matter is muriate of soda, 100 grains of which are equivalent to 53.3 of soda, and 46.7 of muriatic acid. It is not, however, to be considered necessarily as the quantity of muriate of soda contained in the water; for a portion of soda may have been present above that combined with muriatic acid, united, for example, with portions of sulphuric or carbonic acid; and, from the nature of the analysis, this, in the progress of it, or rather in the first step, that of the removal of these acids by the muriate of barytes, would be combined with muriatic acid. It does not, therefore, give the original quantity of that acid; but it gives the quantity of SODA, since no portion of this base has been abstracted, and none introduced.

The quantity of muriatic acid may have been either greater or less than that in the muriate of soda obtained. If the quantity

tity of soda existing in the water exceeded what the proportion of muriatic acid could neutralise, this excess of soda being combined with sulphuric or carbonic acid, then, in the removal of these acids by muriate of barytes, muriatic acid would be substituted, which would remain in the state of muriate of soda ; and if the quantity considered as an original ingredient were estimated from the quantity of this salt obtained, it would be stated too high. Or if, on the other hand, more muriatic acid existed in the water than what the soda present could neutralise, the excess being combined with the other bases, lime or magnesia, then, as in the process by which these earths are precipitated, this portion of the acid would be combined with ammonia, and afterwards dissipated in the state of muriate of ammonia, if the original quantity, were inferred from the weight of the muriate of soda obtained, it would be stated too low.

To find the real quantity, therefore, another step is necessary. The quantities of bases, and of acids procured, (taking the quantity of muriatic acid existing in the muriate of soda obtained), being combined according to the known proportions of their binary combinations, if any portion of muriatic acid has been abstracted, the bases will be in excess, and the quantity of this acid necessary to produce neutralization, will be the quantity lost ; or, on the other hand, if any portion of muriatic acid has been introduced, and remains beyond that originally contained in the water, this quantity will be in excess above what is necessary to produce neutralization. The simple rule, therefore, is to combine the elements obtained by the analysis, in binary combinations, according to the known proportions in which they unite ; the excess or deficiency of muriatic acid will then appear ; and the amount of the excess being subtracted from the quantity of muriatic acid contained

in the muriate of soda obtained, or the amount of the deficit being added to that quantity, the real quantity of MURIATIC ACID will be obtained *.

There is one deficiency, however, in this method. If any error has been introduced in any previous step of the analysis, either in the estimation of the bases or of the acids, this error will be concealed by the kind of compensation that is made for it, by thus adapting the proportion of muriatic acid, to the results such as they are obtained ; and at the same time, an incorrect estimate will be made of the quantity of muriatic acid itself. When any error, therefore, can be supposed to exist, or, independent of this, to ensure perfect accuracy, it may be proper to estimate directly the quantity of muriatic acid in a given portion of the water, by abstracting any sulphuric or carbonic acid by nitrate of barytes, and then precipitating the muriatic acid by nitrate of silver or nitrate of lead. The real quantity will thus be determined with perfect precision, and the result will form a check on the other steps of the analysis, as it will lead to the detection of any error in the estimate of the other ingredients ; for when the quantity is thus found, the quantities of these must bear that proportion to it which will correspond with the state of neutralization.

Thus, by these methods, the different acids, and the different bases are discovered, and their quantities determined. To complete the analysis, it remains to infer the state of combination in which they exist. It will probably be admitted, that this must be done on a different principle from that on which the composition of mineral waters has hitherto been inferred. The compounds which may be obtained by direct analysis, cannot

* The analysis of sea-water in a preceding paper, will afford an illustration of this (page 237.)

cannot be considered as being necessarily the real ingredients, and to state them as such would often convey a wrong idea of the real composition. There are two views according to which the state of combination in a saline solution may be inferred, and in conformity to which, therefore, the composition of a mineral water may be assigned. It may be supposed, that the acids and bases are in simultaneous combinations. Or if they be in binary combinations, the most probable conclusion with regard to this, as I have already endeavoured to shew, (p. 230.) is, that the combinations are those which form the most soluble compounds, their separation in less soluble compounds, on evaporation, arising from the influence of the force of cohesion. In either of these cases, the propriety of first stating as the results of analysis the quantities of acids and bases obtained, is obvious. On the one supposition, that of their existing in simultaneous combination, it is all that is to be done. On the other supposition, the statement affords the grounds on which the proportions of the binary compounds are inferred. And there can be no impropriety in adding the composition conformable to the products of evaporation. The results of the analysis of a mineral water may always be stated, then, in these three modes : *1st*, The quantities of the acids and bases : *2dly*, The quantities of the binary compounds, as inferred from the principle, that the most soluble compounds are the ingredients ; which will have at the same time the advantage of exhibiting the most active composition which can be assigned, and hence of best accounting for any medicinal powers the water may possess : And, *3dly*, The quantities of the binary compounds, such as they are obtained by evaporation, or any other direct analytic operation. The results will thus be presented under every point of view.

It is obvious that the process I have described, adapted to the most complicated composition which usually occurs, is to be modified according to the ingredients. If no lime, for example, is present, then the oxalate of ammonia is not employed ; and in like manner with regard to the others. I have also supposed the usual and obvious precautions to be observed, such as not adding an excess of any of the precipitants, bringing the products to a uniform state of dryness, &c. having mentioned only any source of error less obvious, or peculiar to the process itself.

With regard to other ingredients, either not saline, or more rarely present, it will in general be preferable, when their presence has been indicated by the employment of tests, or by results occurring in the analysis itself, not to combine the investigation to discover them with the general process above described, but to operate on separate portions of the water, and to make the necessary allowance for their quantities in estimating the other ingredients. The quantity of iron, for example, in a given portion of the water, may be found by the most appropriate method. Silica will be discovered by the gelatinous consistence it gives on evaporation, and forming a residue insoluble in acids, but dissolved by a solution of potash. Alumina may be discovered in the preliminary application of tests, by the water giving a precipitate with carbonate of ammonia, which is not soluble, or is only partially soluble in weak distilled vinegar, but is dissolved by boiling in a solution of potash, or by its precipitation from the water sufficiently evaporated by succinate of soda ; or in conducting the process itself, it will remain in solution after the precipitation of the lime by the oxalic acid, and be detected by the turbid appearance produced on the addition of the carbonate of ammonia previous to the addition of the phosphoric acid to discover the
magnesia.

magnesia. Its quantity may then be estimated from its precipitation by carbonate of ammonia, or by other methods usually employed. Silica will also be precipitated in the same stage of the process ; its separation from the alumina may be effected by submitting the precipitates, thoroughly dried, to the action of diluted sulphuric acid. Potash when present, which is very seldom to be looked for, will remain at the end, in the state of muriate of potash. Muriate of platina will detect its presence, and the muriate of potash may be separated by crystallization from the muriate of soda.

THERE is another mode in which part of the analysis may be conducted, which, although perhaps a little less accurate than that which forms the preceding formula, is simple and easy of execution, and which may hence occasionally be admitted as a variation of the process ; the outline of which, therefore, I may briefly state.

The water being partially evaporated, and the sulphuric and carbonic acids, if they are present, being removed by the addition of muriate of barytes, and the conversion of the whole salts into muriates effected in the manner already described ; the liquor may be evaporated to dryness, avoiding an excess of heat, by which the muriate of magnesia, if present, might be decomposed ; then add to the dry mass six times its weight of rectified alcohol (of the specific gravity at least of .835), and agitate them occasionally during twenty-four hours, without applying heat. The muriates of lime and magnesia will thus be dissolved, while any muriate of soda will remain undissolved.

ved. To remove the former more completely, when the solution is poured off, add to the residue about twice its weight of the same alcohol, and allow them to stand for some hours, agitating frequently. And when this liquor is poured off, wash the undissolved matter with a small portion of alcohol, which add to the former liquors.

Although muriate of soda by itself is insoluble, or nearly so, in alcohol of this strength, yet when submitted to its action along with muriate of lime or of magnesia, a little of it is dissolved. To guard against error from this, therefore, evaporate or distil the alcoholic solution to dryness, and submit the dry mass, again, to the action of alcohol in smaller quantity than before; any muriate of soda which had been dissolved will now remain undissolved, and may be added to the other portion; or at least any quantity of it dissolved must be extremely minute. A slight trace of muriate of lime or of magnesia may adhere to the muriate of soda, but when a sufficient quantity of alcohol has been employed, the quantity is scarcely appreciable; and the trivial errors from these two circumstances counteract each other, and so far serve to give the result more nearly accurate.

Evaporate the alcohol of the solution, or draw it off by distillation. To the solid matter add sulphuric acid, so as to expel the whole muriatic acid; and expose the residue to a heat approaching to redness, to remove any excess of sulphuric acid. By lixiviation with a small portion of water, the sulphate of magnesia will be dissolved, the sulphate of lime remaining undissolved, and the quantities of each, after exposure to a low red heat, will give the proportions of lime and magnesia. The quantity of soda will be found from the weight of the muriate of soda heated to redness; and the quantities of the acids will be determined in the same manner as in the general formula.

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This method is equally proper to discover other ingredients which are more rarely present in mineral waters. Thus, alumina will remain in the state of sulphate of alumina along with the sulphate of magnesia, and may be detected by precipitation by bi-carbonate of ammonia. Silica will remain with the muriate of soda after the action of the alcohol, and will be obtained on dissolving that salt in water. And iron will be discovered by the colour it will give to the concentrated liquors, or the dry residues, in one or other of the steps of the operation.

THE general process I have described may be applied to the analysis of earthy minerals. When they are of such a composition as to be dissolved entirely, or nearly so, by an acid, that is, where they consist chiefly of lime, magnesia, and alumina, its direct application is sufficiently obvious; where they require the previous action of an alkali from the predominance of siliceous earth, on this being separated, the excess of alkali may be neutralised by muriatic acid; and the remaining steps of the analysis may be prosecuted, with any modification which the peculiar composition will require. As the quantities of the ingredients are capable of being estimated with so much precision, it may be employed with more peculiar advantage where a small quantity only of the mineral can be submitted to analysis; and when it is employed, such a quantity only, ten grains, for example, ought to be made the subject of experiment.