XI. *An Analysis of Sea-Water ; with Observations on the Analysis of Salt-Brines.* By JOHN MURRAY, M. D. F. R. S. E.

(Read 15th April, and 20th May, 1816.)

THE composition of Sea-Water has been variously stated by different chemists, not only with regard to the proportions of the salts which it holds in solution, but with regard even to the ingredients themselves.

According to LAVOISIER, it contains muriate of soda, muriate of magnesia, and muriate of lime, sulphate of soda, sulphate of magnesia, sulphate and carbonate of lime. The proportions he assigns are, in a pound of water, (French weights) 126 grains of muriate of soda, $14\frac{3}{4}$ grains muriate of magnesia, 23 grains muriate of lime mixed with muriate of magnesia, 7 grains of sulphate of soda and sulphate of magnesia, and 8 grains of sulphate and carbonate of lime*.

BERGMAN gives a very different statement. He found only muriate of soda, muriate of magnesia, and sulphate of lime ; the proportions in a Swedish kanne, which is equal to about $6\frac{1}{2}$ English pints, are 2 ounces 433 grains of muriate of soda, 380 grains

* Memoires de l'Academie des Sciences, 1772.

D. The saline matter was digested with 9 ounces of a weaker spirit, composed of 2 of alcohol and 1 of water, heat being applied to it by a sand-bath nearly to ebullition, with frequent agitation; and the liquor having been poured off while hot, 4 ounces more of the same diluted alcohol were added, heated as before, and after it had become clear by subsidence, this liquor was added to the other. The greater part of the saline mass, consisting chiefly of muriate of soda, was thus dissolved.

E. The residue was submitted to the action of successive quantities of a still weaker spirit, composed of 3 of alcohol, and 4 of water, aided by heat, with the view of dissolving the sulphate of magnesia and of soda. A solution was obtained of a strong saline taste.

F. To abstract these salts more completely, the residue was lixiviated with small successive portions of warm water; a solution having a similar taste was obtained.

G. There was left at length a powder, soft, light, tasteless, and insoluble.

It now remained to examine these products more minutely, to determine their nature, and estimate precisely their quantities.

The powder obtained in the first evaporation A, consists, according to LAVOISIER, of sulphate and carbonate of lime. It weighed when dry 25 grains; it was submitted to the action of a very dilute alcohol, acidulated with muriatic acid, which excited effervescence; this being poured off, and the residue being lixiviated, and dried, weighed 22 grains. It was *sulphate of lime*, and absorbed water with avidity, becoming solid and dry. The liquor poured off, afforded by evaporation a saline deliquescent matter, which, heated with sulphuric acid, gave products

products equivalent to 1.7 grains of *carbonate of magnesia*, and 1.2 grain of *carbonate of lime*.

The solution (B) obtained by the action of the stronger alcohol, ought to have contained, according to the results of LAVOISIER'S analysis, muriate of magnesia and muriate of lime. A small portion of it was diluted with distilled water, and a few drops of a solution of oxalate of ammonia were added, but caused no precipitation, nor even any opacity. The liquor, therefore, contained no muriate of lime. It was distilled to dryness. The dry matter deliquesced on exposure to the air; being lixiviated with alcohol, a small portion of muriate of soda remained undissolved, which was added to the solution D. The liquor being evaporated so far as to be of an oily consistence, afforded, on cooling, *muriate of magnesia* in prisms. This, dried until it had no appearance of moisture, weighed 145 grains. Decomposed by sulphuric acid, it afforded 105.9 grains of dry sulphate of magnesia, equivalent to 88.5 of real muriate.

The solution D had a strong saline taste, and, in cooling, had deposited muriate of soda in cubes on the sides of the bottle. A little of it being diluted with distilled water, oxalate of ammonia did not impair the transparency. Carbonate of potash, and muriate of barytes, produced a turbid appearance. The entire liquor was submitted to distillation, until the alcohol was abstracted, and was then evaporated in an open bason, until crystals formed in it while hot. These were cubes of *muriate of soda*, and this salt continued to be afforded by successive evaporations. The last product deliquesced a little on exposure to the air, indicating the presence of muriate of magnesia; and the remaining liquor afforded by evaporation a deliquescent saline mass: both these were washed with repeated portions of alcohol; muriate of magnesia was thus obtained,

D d 2

which

which dried, weighed 17.3 grains, and which, converted into sulphate, gave 12.4 grains, equivalent to 9.7 of real muriate. The matter not dissolved by the alcohol, being dissolved in water, afforded by slow evaporation sulphate of magnesia in prisms, which dried, weighed 6.3 grains. The crystallised muriate of soda, dried at a heat of 200° , weighed 580 grains.

The solution E deposited, on standing after twelve hours, crystals in flat striated prisms, having every appearance of *sulphate of soda*, and which, on more minute examination, were found to be so : freed from sensible moisture, they weighed 18 grains. The liquor diluted with distilled water, was not sensibly affected by oxalate of ammonia ; it became slightly turbid with sub-carbonate of potash, and with muriate of barytes. The alcohol was drawn off by distillation ; being then submitted to evaporation, a crust of muriate of soda formed on the surface, and crystals in cubes were deposited ; additional portions of them were obtained by successive evaporations, and the liquor continued to afford a crust of muriate of soda on its surface, while hot, until it was almost entirely evaporated. A small portion of liquor remained, which, on cooling, afforded prismatic crystals of sulphate of magnesia, which, freed from moisture, weighed 8.9 grains. The muriate of soda dried weighed 170.8 grains.

The first portions of the aqueous solution F had deposited crystals of sulphate of soda on cooling ; and the whole quantity being partially evaporated, yielded an additional portion. The crystals of both, freed from adhering moisture, weighed 44.2 grains. The liquor being farther evaporated, cubes of muriate of soda were formed on the sides of the capsule, while it was warm, and by continuing the evaporation, a quantity of this salt was obtained, which weighed when dry 12.3 grains.

A small portion of liquor remained, which, by farther evaporation, yielded crystals of sulphate of soda to the amount of 6 grains, with crystals of muriate of soda 2 grains.

The portions of muriate of soda obtained in the preceding experiments amounted to 765.1 grains. None of them, however, were perfectly pure. Their solutions became turbid on the addition of sub-carbonate of soda, and of muriate of barytes, indicating the presence of sulphate of magnesia, or of muriate of magnesia and sulphate of soda, and probably indeed of portions of all these. The whole was submitted to the action of highly rectified alcohol for 12 hours, with repeated agitation; the alcohol acquired a bitter taste; being poured off, and distilled, it afforded muriate of magnesia, which, heated with sulphuric acid, gave a product equivalent to 6.2 of real muriate. The residual salt still gave indications of the presence of sulphate of magnesia, by the tests of muriate of barytes and sub-carbonate of soda. The difficulty is so great, of separating a small portion of a salt from a large quantity of another, where the difference in their solubility is not considerable, that instead of attempting to remove the sulphate of magnesia by farther crystallizations, it was decomposed by adding to the solution sub-carbonate of soda; the precipitate was collected, and converted into sulphate of magnesia by the addition of sulphuric acid. This, dried at a low red-heat, weighed 16 grains, equivalent to 33 crystallised. The salt had been previously exposed to a red-heat, when it weighed 744.5 grains. The above quantity of sulphate abstracted from this, leaves as the real quantity of muriate of soda 728.5 grains.

The powder G was soft, light, and tasteless. It weighed when thoroughly dried 7.5 grains. It might be expected to be similar to the powder A, and was therefore subjected to the same treatment. Diluted alcohol, acidulated with muriatic acid,

acid, excited effervescence ; the liquor poured off afforded by evaporation muriates equivalent to 2.8 of *carbonate* of *magnesia*, and 1.3 of *carbonate* of *lime*. And the remaining *sulphate* of *lime* dried weighed 3 grains.

By this analysis, then, the substances obtained from 4 pints of sea-water, and their proportions, are as follow :

Muriate of Soda,	-	-	728.5 grains.
Muriate of Magnesia real,		83.5	
		9.7	
		6.2	
		99.4	99.4
Sulphate of Magnesia crystal-			
lised,	-	6.3	
		8.9	
		33	
		48.2, or real,	23.5
Sulphate of Soda crystallised,		18	
		44.2	
		6	
		68.2, or real,	30.2
Sulphate of Lime, real,		22	
		3	
		25	25
Carbonate of Lime,	-	1.2	
		1.3	
		2.5	2.5
			Carbonate

Carbonate of Magnesia,	1.7	
	2.8	
	4.5	4.5

The two last ingredients might be accidental products, from the decomposition of muriate of magnesia and of lime. Muriate of magnesia is decomposed by heat ; a portion of its acid is expelled ; and the magnesia separated in consequence of this, will absorb carbonic acid, from the current of warm air applied during the evaporation, or from the carbonic acid gas which the sea-water itself contains, and which is not immediately expelled by heat. The small portion of carbonate of lime might be produced in a similar manner, or from the action of the carbonate of magnesia on muriate or sulphate of lime. I accordingly found, in a subsequent analysis, that on adding muriate of barytes to sea-water, no carbonate but only sulphate of barytes is precipitated, which proves that these conclusions are just. For the small portion, therefore, of carbonate of magnesia, the equivalent portion of muriate of magnesia, 4.2, raising it to 103.6, is to be substituted. If the lime which afforded the carbonate existed in the state of sulphate, then the equivalent portion of this 3.4 is to be added to the sulphate actually obtained, making it 28.4. If it existed in the state of muriate of lime, it still would, but for this change, have been converted in the progress of the evaporation into sulphate of lime ; the same substitution, therefore, is in this view equally to be made. With these corrections, and reducing the proportions to a pint, the ingredients and their quantities will be as follow :

Muriate of Soda,	-	182.1 grains.
Muriate of Magnesia,	-	25.9
Sulphate of Soda,	-	7.5
Sulphate of Magnesia,	-	5.9
Sulphate of Lime,	-	7.1
		228.5

The results of the preceding analysis are different from those I had expected to obtain. I had supposed, that in LAVOISIER's method, the sulphate of soda, and muriate of lime, which he stated as ingredients, had been obtained from some peculiarity in the process by which their reciprocal action, and consequent transition into muriate of soda and sulphate of lime had been prevented; and that in the common method of evaporation they are not obtained, because this mutual decomposition takes place. It appears, however, that the results by LAVOISIER's method are different from those he stated, and are such as preclude this view. No muriate of lime is obtained, and sulphate of lime is obtained in considerable quantity; of course, the sulphate of soda, which is also found, cannot be considered as being procured, in consequence of its decomposition by muriate of lime being prevented by any peculiarity in the process, and must therefore be ascribed to some other cause.

Besides the peculiarity in this analysis of sulphate of soda, there is another singularity in the result, that little sulphate of magnesia is procured. This salt, it is well known, is extracted in considerable quantity by the common process of evaporation of sea-water on a large scale, being obtained by boiling down the bittern, while, by this method, little or no sulphate of soda is obtained.

The products of this analysis are thus so different from those usually assigned, and so different from those known to be afforded by the usual process of evaporation, that it became desirable to perform the analysis in the common mode, so as to ascertain the actual results of it with precision, with a view to determine on what these differences depend. This I accordingly executed.

A. Four pints of the same sea-water were submitted to evaporation in a sand-bath, and after the crystallization of the muriate

riate of soda commenced, the liquor was poured off at intervals from the salt deposited, and farther evaporated. This was continued as long as it appeared to afford no other salt on cooling than muriate of soda. The latter products of this salt were less pure than the first, being deliquescent on exposure to a dry atmosphere; they were therefore redissolved in water; by evaporation, the greater part was obtained crystallized, in a purer state, and was added to the other; and the small portion of residual liquor was added to the residual liquor of the evaporated sea-water.

B. By farther evaporation, this liquor afforded crystals in slender prisms, which were permanent in the air, and which were found to be sulphate of magnesia; by repeated evaporations, successive crystallizations of this kind were produced, (small portions of muriate of soda being also obtained, which, after being washed, were added to the salt A); the products of the first crystallizations were nearly pure; those of the latter crystallizations were less distinct in form, and were in part deliquescent.

C. The portion of liquor still remaining was evaporated, until, on cooling, it formed a congeries of slender prisms, which, exposed to the air, deliquesced, and soon passed to a state of perfect solution, a proof of their being principally muriate of magnesia.

The products thus obtained, consisted, first, of muriate of soda A; secondly, of sulphate of magnesia B; and, thirdly, of muriate of magnesia C. These, however, could not be supposed to be pure, and they were, therefore, submitted to farther examination.

D. The muriate of soda A, gave indications of the intermixture of magnesian salts; the solution of a minute portion of it in distilled water becoming turbid on the addition of carbo-

nate of soda. It was also to be presumed, that there would be mixed with it any sulphate or carbonate of lime deposited during the evaporation. It was therefore re-dissolved in water. There remained undissolved a residue, which, when thoroughly dried, weighed 22.6 grains. The salt was again procured by evaporation, but it was still not perfectly pure. Its dilute solution gave a milkiness with carbonate of soda; and oxalate of ammonia and muriate of barytes rendered it turbid, indicating the presence either of a little muriate of lime with sulphate of soda, or magnesia, or of sulphate of lime with a portion of sulphate or muriate of magnesia. The whole was re-dissolved in distilled water, a powder similar in appearance to the insoluble residue of the former solution, remained undissolved, which, when thoroughly dried, weighed 10.3 grains. To the clear solution a portion of alcohol was added, not sufficient to cause any precipitation of muriate of soda; it produced a slight turbid appearance, and after some hours a powder had subsided, which, after being washed with water, was tasteless: it weighed 1.5 grains. The muriate of soda, obtained by evaporation, weighed, when dried, 718 grains. Being still not entirely pure, it was reserved for another operation.

E. The insoluble residues collected in the preceding operations being put together, were submitted to the action of alcohol, acidulated with muriatic acid, to remove any carbonate of lime, or of magnesia. Effervescence was excited; the liquor being poured off, and the insoluble residue of sulphate of lime being washed with a little water, weighed, after exposure to a heat nearly equal to ignition, 26.3 grains. The alcoholic solution, with the addition of the small portion of water with which the sulphate of lime had been washed, afforded, by evaporation, a matter which entered readily into fusion, and which, treated with sulphuric acid, gave 5.6 of sulphate, equivalent

valent to 4.3 of carbonate of magnesia, and 3 of sulphate, equivalent to 2.2 of carbonate of lime. I have already observed, however, that no carbonic acid is detected in sea-water by the test of barytes; these carbonates, therefore, are, as before, to be considered as products of the evaporation, arising from the decomposition of muriate of magnesia, and of muriate or sulphate of lime. The one, but for the decomposition by which it is produced, would have appeared as sulphate of lime; it increases, therefore, the proportion of that ingredient to 29.3 grains. The portion of muriate, equivalent to the other, that is, 4.4 grains, may be added to the quantity of that salt obtained in the subsequent steps of the analysis.

F. The products of the different crystallizations B, consisting chiefly of sulphate of magnesia, with portions of muriate of magnesia, were left exposed to the air for some days, and the liquor formed from them by deliquescence, was poured off occasionally, and added to the solution of muriate of magnesia, C. The residues were then washed with pure alcohol, to abstract more completely any muriate of magnesia. The portions remaining undissolved, were dissolved together in water. By evaporation, they afforded sulphate of magnesia in bevelled prisms; by farther evaporation, muriate of soda in cubes was obtained; and by successive evaporations, there were thus procured sulphate of magnesia in crystals, 46.6 grains; and muriate of soda 39 grains. A small portion of liquor remained, which, containing chiefly muriate of magnesia, was added to the liquor C.

G. This liquor C to which the portion of liquor formed by deliquescence from B, had also been added, was evaporated to dryness. It was then submitted to the action of successive portions of alcohol, employing, first, the alcohol with which the saline matter B had been lixiviated, and afterwards pure al-

cohol. These liquors, poured off from a portion which remained undissolved, were evaporated to dryness ; the dry mass was dissolved in water, and, by a second evaporation, afforded a congeries of prisms of *Muriate of Magnesia*. Dried by a heat of 150° , the weight amounted to 156 grains. Converted into sulphate of magnesia by the addition of sulphuric acid, the product weighed, after being dried at a low red-heat, 99.2 grains, equivalent to 78.4 of real muriate of magnesia.

H. The matter which remained undissolved by the alcohol G was dissolved in distilled water. The solution was evaporated, until, by a farther spontaneous evaporation in a warm apartment, crystals were successively formed ; these were sulphate of magnesia, and, in general, bevelled prisms. The whole freed from moisture weighed 48.6 grains. A small portion of liquor remained, which, when evaporated, gave a deliquescent saline mass : by slow evaporation 2.6 grains of muriate of soda were obtained from it ; the remainder yielded muriate of magnesia equal to 3 grains.

I. The crystals of sulphate of magnesia obtained by the successive evaporations, were not all equally well formed ; and after they had been left exposed to a dry air for some time, some of them became quite efflorescent, while others did not. The former were picked out, and each portion was re-dissolved in water. By a new crystallization, there were thus obtained 72 grains of sulphate of magnesia, and 18.5 of sulphate of soda.

K. The muriate of soda obtained in the preceding steps, amounted in all to 759.6 grains. After exposure to a red-heat, it weighed 752.4 grains. It has already been stated, that it was not perfectly pure ; its solution being rendered milky, both by sub-carbonate of soda and muriate of barytes. The separation of the sulphate of magnesia, which this chiefly indicated,

indicated, was not to be completely looked for by solution and crystallization. Sub-carbonate of soda was therefore added to the solution as long as any precipitation took place ; the precipitate heated with a sufficient proportion of sulphuric acid to redness, gave 16.4 sulphate of magnesia, equivalent to 33.7 of the same salt crystallised. The former quantity abstracted from the weight of the muriate of soda, reduces it to 736 grains.

This analysis, then, affords the following ingredients, and their proportions in their *real* state.

Muriate of Soda,	-	736 grains.
Muriate of Magnesia,	-	85.8
Sulphate of Magnesia,	-	51.2
Sulphate of Soda,	-	8
Sulphate of Lime,	-	29.3

Or, reducing them to a pint of the water;

Muriate of Soda,	-	184 grains.
Muriate of Magnesia,	-	21.5
Sulphate of Magnesia,	-	12.8
Sulphate of Soda,	-	2
Sulphate of Lime,	-	7.3
		227.6

By the two modes of analysis now stated, different results have been obtained. There are common to both as the principal products, Muriate of Soda, and Muriate of Magnesia. But in the one, sulphate of magnesia, with only a small proportion of sulphate of soda, are procured. In the other, sulphate

phate of soda in a much larger quantity, with only an inferior *proportion of sulphate of magnesia, are obtained.* How is this diversity of result to be accounted for?

As the relative quantities of these salts are thus varied, and are indeed nearly altogether dependent on the kind of analysis, it is obvious that one or other of them must be an original ingredient, and the other must be a product of decomposition. If sulphate of magnesia is the original ingredient, then, when it is not obtained, or is obtained only in very inferior quantity, while sulphate of soda is procured in its place, it must be held that it is decomposed; and the only decomposition that can account for these results is that from the mutual action of muriate of soda and sulphate of magnesia, by which, while portions of them are removed, corresponding portions of sulphate of soda and of muriate of magnesia are formed. On the other hand, if sulphate of soda is the original ingredient, then, when it is not obtained, or is obtained only in small quantity, it must be held that it is decomposed; and the only decomposition of it that can here take place, must be from the action of muriate of magnesia, by which, while quantities of both these salts are removed, corresponding quantities of sulphate of magnesia and muriate of soda will be produced.

Of the two analyses, the one in which sulphate of soda principally is obtained, is that in which the solvent action of alcohol is employed; the other, in which there is the mere separation of the salts by evaporation and crystallization, is that which affords scarcely any of it, but in place of it sulphate of magnesia. Now, it is to be observed, that in both of these the preliminary operation of evaporation to dryness is the same. Since sulphate of soda, therefore, is not obtained by this operation, it is obvious, that, even on the assumption of its being the original ingredient of sea-water, it must, in the progress of the

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the evaporation be decomposed by the muriate of magnesia, and converted into the sulphate of magnesia; and hence, in the subsequent solvent action of the alcohol, by which it is obtained, it must be re-formed. And, on the other hand, if sulphate of magnesia is the primary ingredient, and is obtained as such by the evaporation, it remains to be explained, how it is converted in the subsequent solution by the alcohol into sulphate of soda. The whole question, therefore, resolves itself into the nature of the action of the alcohol, producing sulphate of soda; and of this I perceive no other solution than that which I have now to illustrate.

The fact, however it is to be explained, or to be reconciled with the doctrine of chemical attraction giving rise to combinations or decompositions according to the strength with which it is exerted, seems to be established by an induction too strict and extensive to admit of doubt, that these results are often determined by the force of cohesion, in such a manner, that in principles acting on each other, those on which this force operates most powerfully, in relation to the fluid which is the medium of action, are combined together. So much is this the case, that, as BERTHOLLET has justly remarked, we may, from a knowledge of the solubility of the compounds which substances form, predict what combinations will be established when they act on each other; those always combining which form the least soluble compounds. So far the influence of this has been illustrated by this able chemist. But it appears to me to admit of farther extension, so as to afford a solution of the present question.

If the force of cohesion can so far modify chemical attraction, as to establish among compound salts dissolved in any medium, those combinations whence the least soluble compounds are formed, we are entitled, I conceive, to conclude, that

that the reverse of this force, that is, the power of a solvent, may produce the opposite effect, or cause the reverse of these combinations to be established. Suppose muriate of magnesia and sulphate of soda to be dissolved in water, and the solution to be concentrated by evaporation, the combinations of sulphate of magnesia and muriate of soda, being on the whole less soluble in water, this circumstance of inferior solubility, or the force of cohesion thus operating, may determine the formation of these, and, accordingly, their formation is found by experiment to take place. But suppose sulphate of soda and muriate of magnesia to be dissolved by the aid of heat in alcohol so far diluted as to effect their solution, then those combinations will not be established which existed in the watery solution, because, on the whole, sulphate of magnesia, and muriate of soda, are less soluble in alcohol, even in this diluted state, than sulphate of soda and muriate of magnesia. These latter compounds will, therefore, remain undecomposed. But farther, this *may* give rise, or, rather, *must* give rise, in conformity to the principle above stated, to the reverse effect; so that suppose sulphate of magnesia and muriate of soda to be submitted to the action of this diluted alcohol, aided by heat, the solvent power considered, in relation to the reverse combinations, may cause the change in the state of these compounds, and their transition into muriate of magnesia and sulphate of soda.

In the analysis of sea-water, then, by the first of the methods above described, the evaporation may either, if sulphate of magnesia and muriate of soda are the original ingredients, afford them undecomposed in the solid state; or, if muriate of magnesia and sulphate of soda are the ingredients, it may cause, by the influence of the force of cohesion, the formation of sulphate of magnesia and muriate of soda. But when the
solid

solid mass is submitted to the action of alcohol, its operation, as a solvent, may, on the same principle, cause the reverse combinations to take place, of muriate of magnesia and sulphate of soda; the quantity of this sulphate being, of course, equivalent to the quantity of sulphate of magnesia; and the quantity of muriate of magnesia formed, being added to the quantity of that salt which the sea-water contains as a primary ingredient. Thus is explained the diversity of results obtained by the two modes of analysis; and this diversity itself affords an excellent illustration of the change of combination which may be produced in mineral waters by analytic operations, and a very conclusive proof that the substances obtained by the analysis are not always to be regarded as the original ingredients, since here they are varied according to the mode in which the analysis is performed*.

VOL. VIII. P. I.

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LAVOISIER

* The small portion of sulphate of soda obtained with the sulphate of magnesia, in the second analysis, may have been formed by the action of the alcohol, which, though employed much less extensively than in the first, was still introduced to a certain extent. Or it might originate from other circumstances independent of this; for a similar result, I have been informed, sometimes occurs in the large way, sulphate of soda being procured in boiling down the *bittern of sea-water to obtain its sulphate of magnesia*, or in purifying this sulphate. The circumstances on which this depends, it may be difficult to assign with perfect precision; but it probably arises from the relative quantities of the different salts, and their tendency to crystallization, as influenced by the state of concentration, and the temperature. That both of these have a considerable effect on the combinations established in a compound saline solution, has been sufficiently shewn by the experiments of BERTHOLLET and others. A striking proof of it was derived from the very salts which are the subject of the present observations, in a singular case of affinity, first observed by SCHEELÉ, and afterwards confirmed by GRÉN: that of muriate of magnesia and sulphate of soda, which decompose each other in a concentrated solution at a high temperature, producing muriate of soda and sulphate of magnesia; but, at temperatures below 32°, the reverse effect takes place, muriate of soda and sulphate of

LAVOISIER had stated muriate of lime as having been obtained in his analysis, being dissolved with the muriate of magnesia in the alcohol with which the solid matter obtained by evaporation had been lixivated. I found no trace of it; and its presence after the evaporation to dryness, does not seem compatible with that of either sulphate of soda, or of magnesia. Yet if the preceding reasoning be just, it is possible that alcohol, by its solvent action, might cause its reproduction to a certain extent from sulphate of lime. On the other hand, the entire insolubility of sulphate of lime in alcohol, might prevent it from being acted on; this is even more probable; and the result stated of muriate of lime being obtained, is therefore, in all probability, to be ascribed to error, principally perhaps to its not being distinguished sufficiently from muriate of magnesia, the quantity of which is stated by LAVOISIER evidently too low.

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of magnesia re-acting, and being converted into sulphate of soda and muriate of magnesia. This singular case is evidently owing to the relation of the solubility of these salts to temperature. Muriate of soda has its solubility little increased by heat, of course little diminished by cold; sulphate of soda is in this respect precisely the reverse; hence, at an elevated temperature, muriate of soda is the less soluble salt; and this determines its formation and separation from a compound solution, containing its elements; at a low temperature, again, sulphate of soda is the less soluble salt; and this equally determines its formation, of course occasions the reverse decompositions. Now, according to the proportion of saline ingredients, and according to the state of concentration, and the temperature favouring the tendency of certain salts to crystallization more than others; it is easy to conceive, that in a compound solution, different combinations may be established, as these circumstances vary, and thus products may be obtained, under certain conditions, which are not obtained under others. Although sulphate of magnesia, therefore, is usually obtained by evaporation from sea-water, sulphate of soda, at some stages of the operation or under peculiar circumstances, with regard either to relative quantity of the elements, or to temperature, may likewise be formed.

The question now remains for consideration, What is the real composition of sea-water? How far are the salts obtained in either mode of analysis, those which exist originally in solution? This question is evidently to be considered under the same point of view as that which I have illustrated in a former paper, with regard to the change in the state of combination, which may be produced in the saline compounds existing in mineral waters, by the analytic operations to which they are subjected. We have no strict evidence that the binary compounds which are obtained are those which existed in solution, admitting even the principle that binary combinations exist. On the contrary, there is every probability, that the substances obtained are often products of the operation, arising from changes of combination which it established. And this is even placed in a more striking point of view in the present case, as the ingredients obtained are actually different, when different methods of analysis are employed. It is, therefore, necessary to inquire farther what the real composition is.

With regard to the sulphate of lime, which is the first substance separated by the evaporation, the general views I have already stated, give every probability to the conclusion, that it is a product of the operation formed by the action of sulphate of soda or of magnesia during the evaporation, on muriate of lime; that this last salt, therefore, is an ingredient in sea-water; the proportion of it being the quantity equivalent to that of the sulphate of lime which the analysis affords.

The small portions of carbonates of magnesia and lime which are obtained in the evaporation, I have already stated, are evidently accidental products from the decomposition of muriate of magnesia and muriate or sulphate of lime.

The large quantity of muriate of soda leaves no doubt, if binary compounds at all exist in a state of solution, that it is the

chief ingredient in sea-water, though the quantity of it may be affected by the changes which occur from the actions of some of the other salts.

A similar conclusion is to be drawn with regard to the Muriate of Magnesia. Though the proportion of it may be affected by the changes which occur in the analytic operations, still, from the quantity in which it is obtained, a considerable part of it must originally exist.

The principal difficulty is with regard to the sulphate of magnesia, and the sulphate of soda. It has always been supposed, that sulphate of magnesia is an ingredient in sea-water, from its being procured by evaporation ; and it is possible that it may be so. But it is just as possible, *a priori*, that sulphate of soda may be the original ingredient, and that, during the evaporation, the mutual action between it and muriate of magnesia, is favoured by the concentration, whence portions of both are decomposed, and corresponding quantities of sulphate of magnesia and muriate of soda are formed. Nor is there any thing connected with the mere results themselves, which proves which of these views is just.

If the appeal be made to experiment, it is sufficiently established, that sulphate of magnesia may be formed by the action of sulphate of soda on muriate of magnesia. When these two salts are boiled together in solution, a double decomposition takes place at least partially, and portions of sulphate of magnesia and muriate of soda are formed. On the other hand, the reverse combinations may also, according to circumstances, be established. We have seen reason to conclude, that they are so from the agency of alcohol ; and even in an aqueous solution, when certain proportions of the salts are used, they appear, under some circumstances, particularly that of a low temperature, to take place to a certain extent. But still these
facts

facts only shew what decompositions may occur from evaporation or other processes; they do not prove what the actual state of combination is in the original solution.

It is obvious, that this is merely a case belonging to the more general question, What is the state of combination in a compound saline solution, and on what principle can it be determined what are the binary compounds that really exist in it?—a question of considerable importance, but one at the same time of very difficult determination.

When it is admitted that this cannot be inferred with certainty from the actual products of analysis, the next most obvious view is, that it may be inferred from a knowledge of the real forces of affinity, as, according to these, certain binary compounds must be formed; and as the state of the science does not afford any certain estimate of the strength of attraction, the problem, it may be concluded, is at present incapable of being solved.

This conclusion, however, is by no means certain. Attraction is so much modified in its operation by external forces, and combinations are so frequently established from the influence of these, that it is not clear that we should be able to determine what combinations would exist in cases similar to those connected with the present investigation, from a knowledge of the degrees of attraction, were we even in possession of it. It is rather, perhaps, from a knowledge of the influence of these external forces, that an approximation to the solution of the problem is to be attained; and an extension of the principle I have illustrated in the preceding part of this paper, it appears to me may throw some light on the question.

If the force of cohesion has so much power in modifying chemical attraction, as to change its results, and establish combinations independent of the relative degrees of strength with which

which it is exerted ; and if the reverse of cohesion, that is, the power of a solvent, operates in establishing the reverse combinations, as, in considering the agency of alcohol in this analysis, there has appeared sufficient reason to conclude, then it will follow, that, as in a concentrated medium, the least soluble compounds are formed, so in a dilute medium, the more soluble compounds will be established. The power of the solvent is exerted with greatest effect on those which are most soluble ; and hence, if the reverse combinations even existed, this power must change them, and establish the others, precisely as the power of cohesion acts with most energy on those which are least soluble, and thus causes their formation, when it is brought to act with sufficient force. Hence will follow the simple rule by which the state of combination may be determined ; that, in any fluid containing the elements of compound salts, the binary compounds existing in it will be those which are most soluble in that fluid ; and the reverse combinations will only be established by its concentration favouring the influence of cohesion. Thus, if we concentrate a solution containing sulphuric and muriatic acids, soda and lime, we know, that from the influence of cohesion, the binary combinations will be those of sulphuric acid with lime, and of muriatic acid with soda. And on the same principle, we may infer, that in a dilute solution containing these elements, the combinations will, from the influence of the power the reverse of cohesion, that of the solvent action of the liquid, be those of sulphuric acid with soda, and muriatic acid with lime. In a concentrated solution, containing muriatic and sulphuric acids, soda and magnesia, sulphate of magnesia and muriate of soda are formed ; and, on the same principle, in a dilute solution, there must exist sulphate of soda and muriate of magnesia.

This

This principle, if just, is an important one, as enabling us to determine the state of binary combinations in a saline liquor. I add, therefore, one other illustration of the reasoning on which it rests.

Suppose that in a compound saline solution, that is, one containing more than one acid and one base, the acid and the base which have the strongest attraction, are those which are most soluble, or form the most soluble compound; the solvent power of the liquid operating at the same time, will concur with this, and favour their combination; and any other acid and base likewise present, will of course, at the same time, combine. But suppose the more powerful attraction to belong to those which form an insoluble compound, the solvent power counteracts this, and prevents the combination. And the more this power is increased, which is done by increasing the quantity of the solvent, the more will this be counteracted. The reverse combinations will therefore be established by the operation of the opposite affinities. Hence, generally speaking, in a dilute solution, the binary combinations must be those which form the most soluble compounds, and very powerful attractions would be required to counteract this.

Applying this principle to the composition of sea-water, or rather to the question with regard to the sulphate of soda, and sulphate of magnesia, it is obvious, that the former is to be considered as the original ingredient, and the latter as a product of the evaporation; for muriate of magnesia, and sulphate of soda, are, on the whole, more soluble in water than muriate of soda and sulphate of magnesia. On the same principle it follows, still more unequivocally, that the lime exists in the state of muriate of lime, with a portion of sulphate of soda equivalent to the quantity of sulphate of lime which the evaporation affords. The salts, therefore, really existing in seawater,

water, are muriate of soda, muriate of magnesia, muriate of lime, and sulphate of soda. The quantity of muriate of soda is less than what is obtained by evaporation, for a portion of it is formed by the decompositions which occur ; the quantity of muriate of magnesia is larger, as a portion of it is decomposed ; the quantity of muriate of lime is inferred from the quantity of sulphate of lime ; and the quantity of sulphate of soda is determined from the quantities of sulphate of magnesia and sulphate of lime obtained. The proportions may thus be easily assigned. Referring to the preceding analyses, the proportions in a pint, according to this principle, will be the following :

According to the first analysis,

Muriate of Soda,	-	170.2 grains.
———— Magnesia,		30.6
———— Lime,	-	5.8
Sulphate of Soda,	-	21.9
		228.5 grains.

According to the second analysis :

Muriate of Soda,	-	165.2
———— Magnesia,		31.6
———— Lime,	-	5.9
Sulphate of Soda,	-	24.9
		227.6

If the opposite view be adopted, that the sulphate existing in sea-water is not sulphate of soda, but sulphate of magnesia ; then the ingredients and their proportions will be as follow :

According

According to the first analysis,

Muriate of Soda,	-	188.3 grains.
———— Magnesia,		16
———— Lime,	-	5.8
Sulphate of Magnesia,		18.4
		228.5

According to the second analysis,

Muriate of Soda,	-	185.6
———— Magnesia,		15.2
———— Lime,	-	5.9
Sulphate of Magnesia,		20.9
		227.6

But this view rests on no principle, and is, as I have stated, less probable than the other *.

VOL. VIII. P. I.

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The

*There is sometimes obtained in the large way, from the products of the evaporation of sea-water, a triple salt, which has not been noticed by chemists, but which appears to be of definite composition, and is distinguished by peculiar properties,—a Sulphate of Magnesia and Soda. It is formed in purifying the sulphate of magnesia procured by the first evaporation from the bittern of sea-salt. In this process the sulphate, which is impure, both from the intermixture of muriate of soda and muriate of magnesia, and perhaps, also, of sulphate of soda, is dissolved in water, and by evaporation and cooling is obtained crystallised; a fresh quantity of it is added to the residual liquor, and by the necessary evaporation and cooling, a new crystallization is produced; this is repeated for a third or fourth time; and it is in these latter crystallizations that this triple salt is formed, frequently in considerable quantity, and usually at a high temperature, being precipitated even in the boiler. It crystallises in rhombs, at first irregular and semitransparent; but by solution in water, and a second crystallization, is obtained in more regular rhombs, truncated on the acute angles, on the obtuse angles and edges, and on the terminal edges,

The difficulties attending the perfect separation of compound salts from each other, by crystallization, even with the aid

edges, considering the rhomb as a four-sided prism, and transparent. The crystals are permanent in the air; they are soluble in little more than three times their weight of water, at the temperature of 60° ; they do not undergo the watery fusion from heat, but suffer decrepitation. In these properties, this salt differs entirely from sulphate of soda, or sulphate of magnesia.

To determine its composition, 20 grains reduced to powder were exposed to heat, raised gradually nearly to redness; they lost from the escape of water 5.6 grains. The residual powder was dissolved in water, and muriate of barytes was added as long as any precipitation was produced. The precipitate dried at a red heat, weighed 23.9 grains, equivalent to sulphuric acid 8.2 grains. To the clear liquor carbonate of ammonia was added, which did not impair the transparency; phosphoric acid was then dropped in, which produced a copious precipitation. The precipitate, calcined at a red-heat, weighed 5.3 grains, equivalent to 2.1 of magnesia, or 6.4 of sulphate of magnesia; the residual liquor being evaporated to dryness, the dry mass was submitted to heat, gradually raised, as long as any vapours exhaled; it afforded, by solution in water and evaporation, muriate of soda in cubes, which, after exposure to a red heat, weighed 6.4 grains, equivalent to 7.8 grains of sulphate of soda. 100 grains of the salt, therefore, afford of

Sulphate of Magnesia,	-	32 grains.
Soda,	-	39
Water of Crystallization,	-	28
Loss,	-	1
		100

It afforded also a slight trace of muriatic acid; its solution being in a very slight degree rendered turbid by nitrate of silver, probably owing to the intermixture of a little muriate of soda, as an extraneous ingredient. This accounts for the proportion of sulphuric acid, as inferred from the quantities of the bases, being a little larger than that directly obtained by the precipitation by muriate of barytes.

The difference of crystalline form, as well as other differences of properties in the salt from those, either of sulphate of soda or sulphate of magnesia, sufficiently prove that it is not merely an intermixture of the two, but that it is of definite composition. It deserves to be remarked, too, that it has not the same relation to water that either of these salts has, or any mean between

aid of the action of alcohol, either as a solvent or a precipitant, are so great, that analyses executed in this mode can scarcely be perfectly accurate. And as it appears, if the preceding observations are just, that there is no certainty in the conclusion that the products of analysis by evaporation or crystallization are the real ingredients, no peculiar advantage in this respect belongs to this method, and just as much information is obtained by discovering the acids and bases which exist in solution, and then inferring, according to the most probable view, what the states of binary combination are in which they exist. This kind of analysis has the advantage, that it can be executed with much more precision than the other: it is liable to fewer sources of error, and, by finding the quantities, not of the compounds, but of the elements, any error that is introduced is discovered, when the binary compounds are inferred. To ensure accuracy, therefore, it was desirable to apply it to the illustration of the present subject, more especially as the preceding analyses, though they do not differ greatly in the results, still, from these difficulties, do not exactly correspond.

Different methods might be employed. The following is the one I have preferred.

To a pint of sea-water, reduced by evaporation to nearly one-fourth, at which state of concentration no crystallization nor deposition takes place, muriate of barytes was added as long as any precipitation occurred. By a preliminary trial, it

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was

tween them; the quantity of its water of crystallization being considerably less. Its taste is much less disagreeable than that of sulphate of soda or sulphate of magnesia; it might therefore probably be introduced with advantage as a purgative salt, especially as it could be procured at a low price; and from its composition, it would afford a very good substitute for the aperient mineral waters, which usually owe their activity to sulphate of soda and sulphate of magnesia.

was found that the precipitate gives no effervescence with muriatic acid, nor suffers any change. It was therefore sulphate of barytes. Dried by a low red heat, it weighed 43 grains, equivalent to 14.4 *sulphuric acid*.

By this step the whole salts in the sea-water were converted into muriates. It remained to discover and estimate the quantities of their bases.

To the clear liquor, oxalate of ammonia was added as long as any turbid appearance was produced. The precipitate, washed and dried, by a heat of 150° continued for two hours, weighed 8.5 grains. Calcined with a low red-heat, it gave of carbonate of lime 5.2 grains. This, dissolved with strong effervescence in dilute muriatic acid, and the product being heated with sulphuric acid, gave sulphate of lime, which, after exposure to a red-heat, weighed 7 grains, equivalent to 2.9 of pure *lime*.

To the clear liquor warmed, carbonate of ammonia was added, and phosphoric acid was dropped in *; an abundant precipitation took place of phosphate of magnesia and ammonia, and additional portions of the phosphoric acid, with such additions of the carbonate as were necessary to preserve an excess of ammonia in the liquor, were added, as long as any precipitation was produced. The precipitate was converted, by calcination for an hour at a red-heat, into phosphate of magnesia. This weighed 37 grains, equivalent to 14.8 grains of *magnesia*.

The clear liquor was evaporated to dryness, and the dry mass was exposed to a heat gradually raised to redness, to expel the muriate of ammonia formed in the preceding operations.

* I shall have to state in a subsequent paper, the peculiar advantages attending this method of estimating the magnesia.

tions. Muriate of soda remained, which weighed 180.5 grains, equivalent to 96.3 of soda, and 84.2 of muriatic acid.

This gives the quantity of *Soda* contained in the sea-water ; but it does not necessarily give the quantity of muriatic acid ; for if more of this acid be present than what the soda can neutralize, combined with portions of any of the other bases, (and from the former analysis this appears to be the case,) this quantity will be combined with ammonia in the preceding steps of the analysis, and is of course dissipated in the state of muriate of ammonia.

This will appear, and the quantity be discovered by ascertaining what proportion of these bases the quantity of sulphuric acid obtained by the analysis is capable of neutralizing, thus finding if any excess of them remain ; and, from the quantity of this, discovering the quantity of muriatic acid, which would be requisite for saturation, which of course is the quantity lost. 2.9 of lime, the quantity of this earth obtained by the analysis, neutralize 4.1 of sulphuric acid ; this deducted from 14.4, the quantity obtained, leaves 10.3, to neutralize which, 5.1 of magnesia are required ; this deducted from 14.8, the quantity of magnesia, leaves 9.7 of that earth ; to neutralize this, 13.5 of muriatic acid are required ; and this added to the 84.2 in the muriate of soda, gives 97.7 grains as the total quantity of *Muriatic Acid*.

The elements, then, of the salts, in a pint of sea-water, are, by this analysis,

Lime,	-	2.9 grains.
Magnesia,	-	14.8
Soda,	-	96.3
Sulphuric Acid,		14.4
Muriatic Acid,		97.7
		226.1 grains.

The

The proportions of the compound salts may be assigned from these, according to whatever view may appear most probable, of the state of combination in which they exist in sea-water, and thus the results may be compared with those of the former analyses.

Thus, supposing the elements to be combined in the modes in which they are obtained by evaporation, that is, as muriate of soda, muriate of magnesia, sulphate of magnesia, and sulphate of lime; the proportions of these salts in a pint, will be

Muriate of Soda,	-	180.5 grains.
———— Magnesia,	-	23
Sulphate of Magnesia,	-	15.5
———— Lime,	-	7.1
		226.1

Supposing that the lime exists as muriate of lime, (which is the most probable conclusion with regard to it), and farther supposing, that the sulphuric acid exists in the state of sulphate of magnesia, the proportions will be

Muriate of Soda,	-	180.5 grains.
———— Magnesia,	-	18.3
———— Lime,	-	5.7
Sulphate of Magnesia,	-	21.6
		226.1 grains.

Or, lastly, supposing that the sulphuric acid exists in the state of sulphate of soda, the proportions will be

Muriate

Muriate of Soda,	-	159.3 grains.
———— Magnesia,	-	35.5
———— Lime,	-	5.7
Sulphate of Soda,	-	25.6
		————
		226.1 grains.

These proportions differ somewhat, though not very materially, from those found by the other modes of analysis. The principal differences consist in the quantity of magnesia, and of sulphuric acid being rather larger. This is evidently to be ascribed to the modes of detecting sulphuric acid by barytes, and magnesia by phosphoric acid and ammonia, being so perfect, that the entire quantities of them are found ; while, in the other modes, from the difficulty of effecting the entire separation of salts from each other, a small portion of sulphate of magnesia, or of muriate of magnesia and sulphate of soda, had remained with the muriate of soda, and though subcarbonate of soda was employed to decompose them, this decomposition is not altogether perfect. In the mode of analysis, too, by re-agents, the presence of water in the products can be more completely excluded, and to this, probably, is to be ascribed the absolute quantity of saline matter being a little less according to this analysis, than it is in the others*.

Of

* In another analysis of sea-water, in which subcarbonate of ammonia was employed to precipitate the magnesia, a solution of it being added to the water concentrated by evaporation, the clear liquor, after the subsidence of the precipitate being evaporated to dryness, the saline matter being exposed to heat, to dissipate the muriate of ammonia ; being re-dissolved in water, the subcarbonate of ammonia again added, and this repeated for a third, and even a fourth time, the results gave the following proportions of the elements,

Lime,

Of the different views which may be taken of the state of combination of the elements, I have already inferred, that the one which supposes the sulphuric acid to exist in the state of sulphate of soda, is the most probable ; and as the mode of analysis by re-agents is the most accurate, the last table may be considered as that which exhibits the highest approximation to the real composition of sea-water, both with regard to its ingredients, and their proportions.

I had proposed to add a few observations on the analysis of salt brines ; but as they are merely applications of the principles already illustrated, it is sufficient to state them briefly, or to notice those which present rather striking results.

KLAPROTH has given a laborious investigation of the nature of these brines ; in the greater number of them, he states as ingredients, muriate of soda, muriate of magnesia, muriate of lime, and sulphate of lime. It is obvious, that there are no just grounds whence this composition can be inferred ; it is much more probable, that sulphate of soda is the ingredient,
and

Lime	-	-	2.9 grains.
Magnesia,	-	-	13.
Soda,	-	-	97.6
Sulphuric Acid,	-	-	15.2
Muriatic Acid,	-	-	96.9
			225.6 grains.

The principal difference here, is the proportion of magnesia being somewhat smaller, evidently owing to its precipitation by the carbonate of ammonia, even with the aid of the methods employed to promote it, being imperfect.

and that, acting on a portion of the muriate of lime, it forms sulphate of lime.

In other analyses, in those, for example, of the salt brines of Lorraine, by NICHOLAS *, muriate of soda, sulphate of soda, sulphate of lime, muriate of magnesia, and muriate of lime, are enumerated as ingredients. Here it is still more evident, that there is no proof of the previous existence of sulphate of lime; on the contrary, as both muriate of lime and sulphate of soda are present, they must, in the concentration of the liquor by evaporation, form by their mutual action muriate of soda and sulphate of lime; and the quantity therefore of this sulphate which may be obtained, must have this origin.

In general, when muriate of lime and muriate of magnesia are stated as ingredients with sulphate of lime, no sulphate of soda or sulphate of magnesia is found. The reason is obvious, that if either of these salts existed, it would re-act on the muriate of lime, and form sulphate of lime. But when muriate of lime is not found, sulphate of magnesia, or sulphate of soda, is often stated as an ingredient, obviously owing to the circumstance, that although a portion of muriate of lime has been present, so as to form sulphate of lime, there has not been a quantity sufficient to decompose the whole sulphate of soda, or sulphate of magnesia.

A striking example of these facts is to be found in Dr HENRY's analysis of the different varieties of sea and rock salt †. In four varieties of rock-salt, there were found small quantities of muriates of lime and magnesia, with a portion of sulphate of lime, but no sulphate of magnesia; while in the different varieties of sea-salt, British and foreign, there was no appreciable quantity, and in some of them no trace whatever

VOL. VIII. P. I.

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* *Annales de Chimie*, t. 20.

† *Philosophical Transactions*, 1810.

of muriate of lime, but in all of them with sulphate of lime considerable quantities of sulphate of magnesia. In the latter, therefore, the muriate of lime had been converted entirely into sulphate of lime from the excess of sulphate of magnesia; in the former, from the deficiency of the sulphate, a portion of the muriate of lime had remained undecomposed.

A result somewhat similar, and which affords a very direct application of the same principles, is stated by Mr HORNER, in his analysis of the salt-brine at Droitwich, compared with that of Cheshire*. The latter contains a little muriate of lime; the former contains none. But, then, that of Droitwich contains sulphate of soda and sulphate of lime; there is every probability, therefore, that its muriate of lime has been converted into sulphate of lime by the sulphate of soda, which is in excess; while in the Cheshire brine, as there is no sulphate of soda in excess, that is, none after the evaporation, a portion of muriate of lime remains.

There is a singular fact stated by Dr HENRY with regard to what is called *fishery salt*, prepared from salt brine, which seems to admit of explanation only on these views. He found the proportion of sulphate of lime mixed with it to be less, as it was collected at a later period of the evaporation; that drawn from the boiler, after two hours application of the heat, contained in 100 parts 16 of sulphate of lime; that, after 4 hours, contained only 11; and that, after 6 hours, only $3\frac{1}{2}$. Now if the water of this brine held sulphate of lime in solution, the sulphate would begin to be deposited when the quantity of water was diminished to that extent that it was unable to retain the whole dissolved; and, in the progress of the evaporation, would continue to be deposited proportional to this,
to

* *Geological Transactions*, vol. ii.

to the end of it, and the muriate of soda would be deposited in the same manner ; so that the proportion between the two would continue nearly the same. But if the sulphate of lime did not exist in solution, but derives its origin from the action of sulphate of soda on muriate of lime, which these brines contain, this action would take place, when a certain degree of concentration of the liquor had been attained ; the sulphate of lime would then be copiously deposited ; but as the evaporation continued to proceed, its quantity would be diminished, as the quantity either of sulphate of soda, or of muriate of lime, became less ; and its deposition would cease when either of these salts was exhausted.

This is placed in a still clearer light, by an analysis of these brines, after evaporation, to a certain extent, compared with their original composition. A brine from Northwich was found by Dr HENRY to afford, by evaporation, saline matter, which, he inferred, contained in 1000 parts, muriate of lime and muriate of magnesia in nearly equal proportions 5 parts, sulphate of lime 19 parts, muriate of soda 974 parts. But the brine remaining after the separation of all the common salt, which it is thought worth while to extract, afforded saline matter by evaporation, which he found to contain, in 1000 parts, muriate of magnesia 35, muriate of lime 32, sulphate of lime 6, muriate of soda 927. Here, in the progress of the evaporation, the quantity of sulphate of soda, which may be considered as an original ingredient of the brine, had been diminished by the decomposition arising from its action on the muriate of lime. The liquor, therefore, after this, afforded by farther evaporation, along with a large quantity of muriate of lime, a small quantity only of sulphate of lime ; while, if this sulphate had been an original ingredient, it would have continued to be afforded at least in equal proportion.

Something similar to this occurs in the evaporation of seawater. It is, after a certain extent of evaporation, but while a large portion of liquor still remains, that the precipitation of sulphate of lime takes place ; that is, after the concentration is sufficient to favour the mutual action of the sulphate of soda, or sulphate of magnesia, and muriate of lime. After this, the quantity diminishes as the evaporation proceeds, till at last not a trace of it, or of sulphate of lime, remains in the bittern, which consists of muriate of soda, muriate of magnesia, and sulphate of magnesia alone. This curious fact has not been particularly noticed, though it is in consequence of it that magnesia is prepared from bittern on the large scale, perfectly pure.

All these facts seem scarcely to admit of any explanation, but on the view that has been stated, and they afford a strong confirmation of it.

XII.