

An analysis of the Malvern waters / by A. Philips Wilson.

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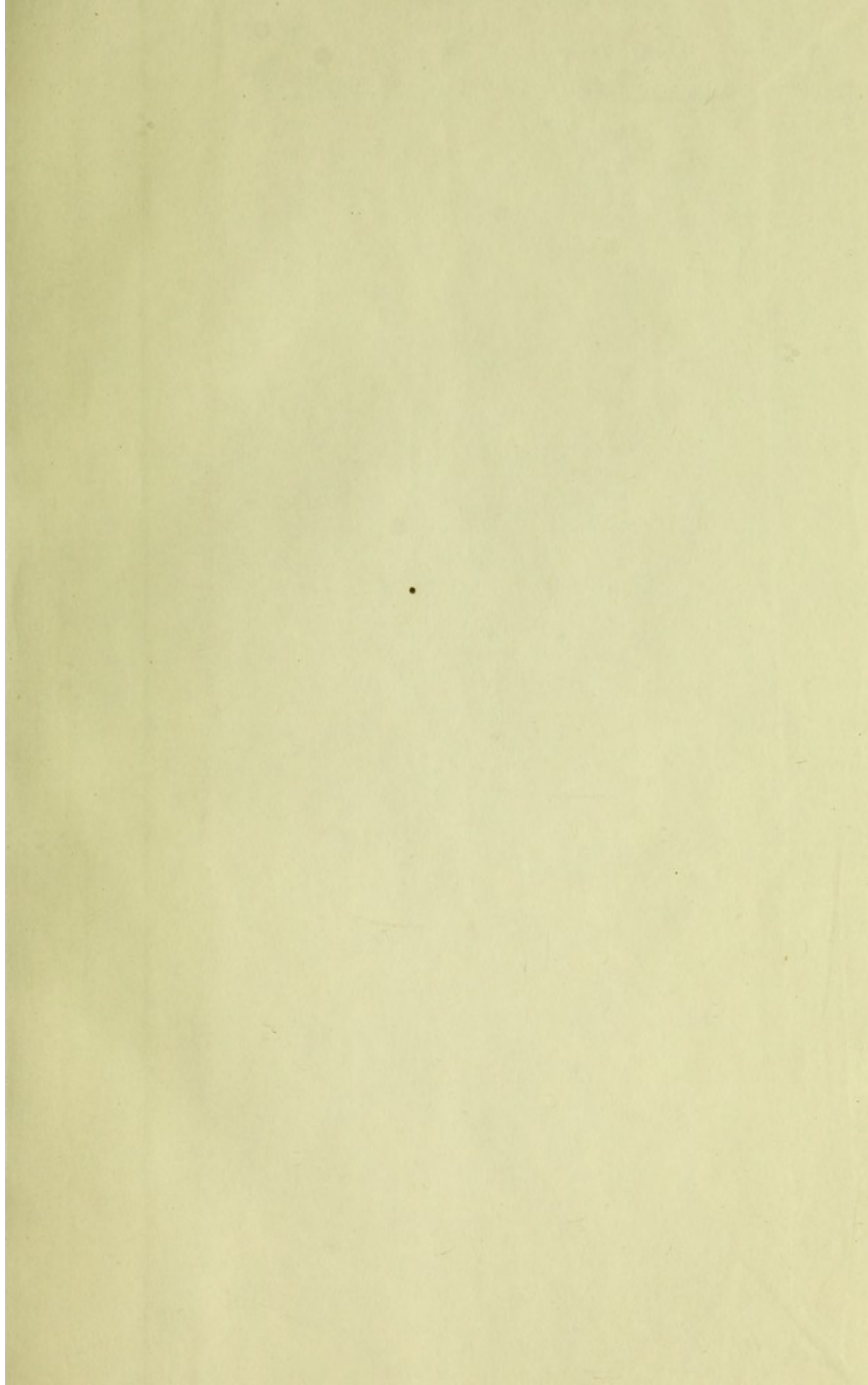


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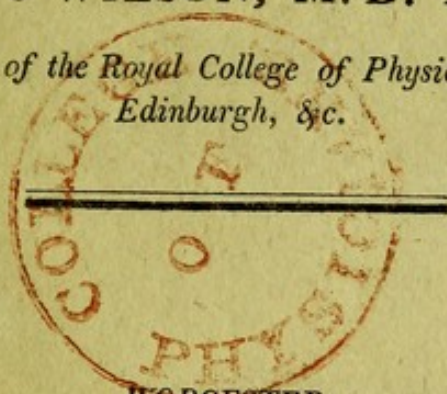
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✓ Philip. (A.P.W)

AN
ANALYSIS
OF THE
MALVERN WATERS.

BY
A. PHILIPS WILSON, M. D. F. R. S. Ed.

*Fellow of the Royal College of Physicians of
Edinburgh, &c.*



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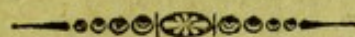
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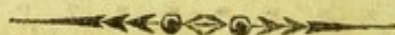
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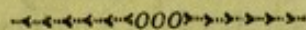
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ERRATA.

- INTRODUCTION—Page x, l. 8, for , read . and l. 9, dele or.
 Page 25, l. 8, for *was* read *were*.
 — 48, l. 10, for *was* read *were*.
 — 58, l. 1, after *contents* insert *of a gallon*.

INTRODUCTION.



THE Malvern waters have long been celebrated for their purity, and to this alone their effects have generally been ascribed. From the following Analysis of these waters, however, it would appear that this opinion is erroneous, and that their good effects, as in the case of other mineral waters, arise chiefly, at least, from the foreign ingredients they contain. This will hardly be doubted if it can be shewn that they contain substances which have long been celebrated medicines in the same diseases in which the effects of the Malvern waters are so strikingly beneficial.

That they contain but a small quantity of such substances is no argument against this opinion. We well know that the effects of medicines are not in proportion to the dose merely, but are influenced by a variety of circumstances, with some of which we seem to be but ill acquainted. How many chalybeate springs, which contain but a small quantity of iron, are more efficacious in restoring vigour than the most powerful artificial chalybeate; yet we know

that the effects of such waters depend on the iron they contain, because, when deprived of it, they lose at the same time their invigorating quality. Whether the same quantity of iron dissolved in the same quantity of pure water, would produce the same good effects, independently of the other ingredients of such waters, we cannot tell. Most probably it would not. But when we reflect on the intimate union which takes place between bodies, when one exists in very great, and the other in very small quantity, of which a thousand instances might be enumerated, we have some reason to suppose that the effects of many mineral waters depend on this intimate union, by which perhaps a greater quantity of the medicine is received into the system, or is received in a state more capable of producing its peculiar effects than when it is taken into the stomach and bowels in a more concentrated form.

To the numerous cases proving the efficacy of the Malvern waters, given by Dr. John Wall,* I might, were it necessary, add some equally striking which have fallen under my own observation.

The complaints in which these waters have been chiefly celebrated are the various forms of

* See seventy-six cases of their efficacy related by Dr. John Wall, in his Medical Tracts, re-published by Dr. Martin Wall in 1780.

Scrophula, Cutaneous diseases of different kinds, and Gravel.

Dr. John and Dr. Martin Wall * are the principal writers on the Malvern waters. It seems to have been the opinion of both, that the effects of these waters are chiefly to be ascribed to their purity. "The efficacy of this water," the former observes, "seems chiefly to arise from
" its great purity, whereby it passes through the
" smallest vessels, and not being loaded with
" any salts or earth, it is capable of dissolving
" more than those waters which are already saturated with them. Its effects externally,
" both in lotion and bathing, may in a great
" measure depend upon the same; since it is
" past all doubt that fluids may enter the body
" this way by the absorbing vessels." † And Dr. Martin Wall, in his Appendix to Dr. John Wall's Observations, remarks, "Its principal virtue

* There are two springs in the Malvern hills which have been celebrated, and are supposed to be of the same nature. The one is called the Holy-well, the other St. Ann's-well. The experiments of both Dr. J. and Dr. M. Wall were made with the water of the former. There are also some chalybeate springs in the neighbourhood of the village of Malvern, the analysis of which I have begun, and shall lay before the public as soon as I have had leisure to finish it. To Dr. Wall's Tracts I refer the reader for an account of the situation of the Malvern springs, and of the nature of the hills from which they issue.

† See the above mentioned Tracts, page 117.

" then

“ then must depend upon its extreme purity,
 “ assisted by the fixed air which it contains.” *

Dr. John Wall, however, was led by several observations to doubt the justice of the popular opinion. “ It has been the opinion of some
 “ persons,” he observes, “ that the water of
 “ the Holy-well is only pure element, devoid
 “ of mineral spirit and almost all other princi-
 “ ples. Indeed were this the case, which for
 “ many reasons I am convinced it is not,
 “ that purity alone would make the spring of
 “ great value.” After a quotation from Hoff-
 man, Dr. Wall continues, “ I have inserted this
 “ quotation from an author of the greatest
 “ eminence, in order to shew what might be
 “ expected from a pure water, and surely no
 “ spring can more justly deserve the title than
 “ this does.† But that there is also a fine subtle
 “ penetrating spirit concealed in these waters,
 “ agreeable to what is mentioned in the fore-
 “ going treatise, is evident from the following
 “ observations. The first of these was commu-
 “ nicated to me by my very ingenious friend,
 “ Dr. Mackenzie, who informed me, that he

* Page 288.

† Dr. Martin Wall, we shall find, has shewn that Dr. John Wall was deceived with respect to the quantity of the foreign contents of this water. It is certain, however, that compared even with the springs in common use, it must be considered a very pure water.

“ knows

“ knows a gentleman in Warwickshire who has
“ a cancerous ulcer in his face, which he uses
“ to bathe every day with Malvern water before
“ he applies his other dressings to it. The wa-
“ ter, when used alone, frequently makes the ulcer
“ smart to a degree, which he is not able to bear
“ till he adds a certain proportion of common
“ water to it; but when the Malvern water is
“ thus diluted with river or other water, he
“ can bear it very well.

“ This remarkable observation has been since
“ confirmed to me by Dr. Turton, a very eminent
“ Physician, of Birmingham, who himself also
“ felt a very sensible effect from this water, dif-
“ ferent from that of a common spring. He
“ has lately had a putrid fever, attended with
“ ulcerations on the throat and tongue, which
“ left the parts very tender: upon washing his
“ mouth with this water, and drinking a glass
“ of it at the spring head, he felt great pain and
“ smarting in all the parts which had been ul-
“ cerated: however he continued to wash his
“ mouth frequently, the uneasiness gradually
“ lessening upon every lotion; and he drank
“ large quantities of the water that whole day.
“ The next morning he found his mouth and
“ throat quite easy and free from any tender-
“ ness, which it had never been before since
“ his illness.”

Before relating my experiments and conclu-
sions,

sions, it will be proper, in order to avoid confusion, to point out those of Dr. John and Dr. Martin Wall, which seem to contradict them, and the circumstances which reconcile these contradictions.

Dr. M. Wall has noticed what appears to be a principal cause of Dr. J. Wall's having obtained so small a residuum from the Malvern water by evaporation, namely, that he performed the evaporation in open vessels. It will appear, from the experiments I shall relate, that some part of the solid contents of this water, if the distillation is not performed very slowly, comes over with the water, even when it is performed, as Dr. M. Wall advises, in a retort and receiver luted together.

Dr. J. Wall was led to believe, that the Malvern waters contain sulphuric acid in a disengaged state. " The water of the Holy-well, " when drank immediately as it comes out of " the hill, leaves a peculiar tartness in the " throat. This is by some likened to the taste " of brags or alum, and is most perceptible to " those who have not been used to the water; " but this taste is soon lost, and the water grows " softer after it has been kept some time, though " the bottles be ever so carefully stopped. With " this water either acids or alkalis mix without " the least alteration in transparency, and without any precipitate or conflict; and yet it " seems

“ seems to contain a concealed acid, because
“ iron laid in the water is corroded; and with a
“ solution of silver, though at first it mixes
“ without any milkiness, yet, by standing some
“ time, the water grows gradually whitish, and
“ then muddy, and of a dirty reddish purple;
“ and at last a powder, of a deep purple colour,
“ is precipitated, which is the effect of the
“ vitriolic acid.”*

Dr. M. Wall attributes this precipitate to carbonat of lime; it seems not, however, to proceed either from this or the sulphuric acid. Dr. M. Wall justly observes, that, if it arose from the presence of sulphuric acid, infusion of litmus and syrup of violets would give evidence of acidity, which they do not. With respect to the carbonat of lime, Dr. M. Wall seems to have been misled by his correspondent, who says, that no turbidness takes place on the addition of a solution of nitrat of silver, after the water has been distilled in close vessels, although acetat of lead occasions a precipitate. I have always found the turbidness to take place on the addition of nitrat of silver, when a precipitate could be obtained by acetat of lead.

Were Dr. M. Wall's explanation just, the turbidness should be prevented by the previous addition of nitrous acid to the water, which is

* See Dr. J. Wall's Tracts, pages 116 and 117.

not the case, unless the water has been distilled. Besides, there is no precipitate on the addition of oxalic acid, whether the water has been distilled or not.

Dr. J. Wall states, as another proof of the existence of a disengaged acid in these waters, that effervescence ensued on mixing the water of the Holy-well with a saturated solution of carbonate of potash. The way in which the experiment was made* sufficiently points out that the appearance of effervescence arose merely from the extrication of air with which all waters are impregnated. A far less quantity of acid than is necessary to occasion any degree of effervescence would affect the above mentioned tests of acidity.

Carbonate of ammonia has also been supposed to exist in the Malvern waters, and one of Dr. M. Wall's correspondents thought he had ascertained its presence, as indeed there was reason to believe, when he found that after distillation this water gives a precipitate with acetate of lead. Dr. M. Wall refers to another experiment of the same correspondent, in which he found that the nitrate of silver occasioned no precipitation nor turbidness in the distilled Malvern water, which Dr. M. Wall justly observes it should have done, had this water contained an alkali; but in

* See Dr. J. Wall's Tracts, page 132.

this experiment there seems to have been some inaccuracy, for, as I have just observed, the Malvern waters, though distilled in close vessels, may still give a precipitate with nitrat of silver, a circumstance which tends to invalidate Dr. M. Wall's explanation of the precipitate from the distilled water by acetat of lead, namely that it arises from the water retaining its carbonic gas after distillation, which we cannot surely suppose. But this explanation is wholly set aside by a circumstance which was overlooked both by Dr. M. Wall and the gentleman he alludes to, namely, that the addition of an acid prevents the precipitate; and this seems to confirm the account of the precipitate given by the latter: we shall find, however, that it is not owing to the presence of carbonat of ammonia, but to a cause which it would oblige me too much to anticipate the Analysis I am about to lay before the reader to consider here.

In the 24th experiment related by Dr. M. Wall, potass gave a precipitate with three quarters of a pint of Malvern water, boiled down to half an ounce; and in experiment 26th, a solution of ammonia gave a precipitate with this water, boiled down in the same manner; and this precipitate being removed by filtration, it became turbid in about a minute after the addition of a few drops of a saturated solution of carbonate of potass. From these experiments,

Dr. M. Wall infers that the Malvern water contains selenite.

This inference seems, on more than one account, to be inadmissible. Had the water contained selenite, it must have been precipitated long before the evaporation was carried to this length. Besides, the presence of some other earthy salt may have occasioned this precipitate, or that with the ammonia may have been produced by carbonat of magnesia, which is not wholly precipitated by boiling till the water is evaporated nearly to dryness.* But this subject I shall have occasion to resume; the precipitate which Dr. M. Wall obtained by potash, after the addition of the ammonia, demands more particular attention in this place.

There can be no doubt, I think, from the following circumstances, that this precipitate proceeded from the impurity of the solution of ammonia which had been employed. Unless this solution is prepared with care, it may contain a small quantity of the lime used for obtaining ammonia from the muriat of ammonia. I repeated Dr. M. Wall's experiment with Malvern water evaporated to less than a twentieth part of its bulk, and a solution of ammonia which I had by me, and found the result as he has stated

* See Mr. Kirwan's Essay on the Analysis of Mineral-Waters, page 200. I have made much use of this excellent Essay, and have followed the plan of analysis recommended in it.

it, a solution of carbonat* of potass giving a precipitate; but when I used a pure solution of ammonia, prepared by Mr. Accum, no precipitate took place on the addition of the solution of carbonat of potass. In the above experiment, as in Dr. M. Wall's, it was not till about a minute after the addition of the potass that the precipitate was fully formed.

It will be necessary to notice several other experiments of Dr. M. Wall, when I come to speak of the subjects to which they relate.

What has just been said respecting the solution of ammonia, was not necessary to demonstrate how requisite it is to have the tests we employ in analysis prepared with the greatest care. All the tests used in the following Analysis, whose specific gravity is mentioned, were prepared by Mr. Accum; the others were prepared by Messrs. Allen and Howard, of Lombard-street, with the exception of a few which I prepared myself, according to the directions given by the most approved writers.

On the manner in which I have employed

* All the potass of commerce is more or less carbonated: Dr. M. Wall used what is called oleum tart. per deliq.

one test, the litmus, of which I have made frequent use, it will be necessary to make some observations. It may be made a test of greater delicacy than it is in the ordinary way of applying it. After making various trials, I thought the following the best way of using it :

Let two crystal basons of the same size, with cylindrical sides and flat bottoms, of at least four inches diameter, be placed on a sheet of white paper, and another sheet of white paper placed behind them, and let the observer stand between them and the quarter from which the light comes, that he may receive the light reflected from behind and below them. Let one of the basons be filled to about one inch in height with the water in which we suspect the presence of an acid, and the same quantity of distilled water be put into the other, and to each let the same number of drops of a strong infusion of litmus be added; let the quantity of litmus be no more than is sufficient to give them the slightest tinge, which shews decidedly the blue colour in the distilled water; by comparing the colour of the water in the two basons, a very small quantity of acid may be detected, especially by a person accustomed to use the test in this way.

Mr. Kirwan says, that with paper stained with litmus (his mode of using this test) he could
not

not discover $\frac{1}{12,000}$ of sulphuric acid. By the foregoing mode of using the litmus, it is rendered many times more sensible, as will appear from the following experiment.

To two ounces of water, sulphuric acid was added in the proportion of 1 to 307200. This was put in one of the basons placed as above; in the other, two ounces of water, which I had previously found did not affect the colour of the litmus. On dropping into both basons the same quantity of infusion of litmus, the colour was sensibly redder in the bason which contained the acid than in the other; the difference was such as could be readily observed by a person accustomed to make such experiments.

When I diluted the acid in the proportion of 1 to 460800, I could not observe the difference of the shade. The specific gravity of the acid employed was 1,85, so that one grain of this acid contained 0,7946 grs. of real acid, as nearly as can be ascertained from Mr. Kirwan's table of the specific gravity of sulphuric acid mixed with different proportions of water.*

* The specific gravity of the acid mentioned in Mr. Kirwan's table, whose specific gravity comes nearest to that I used, and a grain of which contains 0,7946 grs. of real acid, is 1,8542, so that it differs from that I employed only by 0,0042. The circumstance which renders it so difficult to ascertain the quantity of real acid in any mixture of sulphuric acid and water is, that the specific gravity does not increase in the same proportion with the quantity of real acid.

It appears, then, from the foregoing experiment, that 0,7946 grs. of sulphuric acid may be detected by the litmus used as I propose in 307200 grs. of water, so that one grain of real sulphuric acid may be detected by this test in 386597 grs. or 50,33 pints, of water.

It follows from what has been said, that the litmus employed in this way may also be made a very delicate test of alkalis, as litmus reddened by an acid will detect the presence of any quantity of alkali capable of neutralising the acid which changed its colour.

Mr. Kirwan has found 45,2 of real sulphuric acid saturate 54,8 of potash; therefore one grain of this acid saturates 1,2123 grs. of potash; hence 1,2123 grs. of potash may be detected by the litmus in 386597 grs. of water, that is, 1 grain in 318895 grs. or 41,52 pints, of water.

The same chemist has found that 56 grs. of real sulphuric acid saturate 44 grs. of soda, therefore a grain of this acid saturates 0,7857 grs. of soda; hence 0,7857 grs. of soda may be detected by the litmus in 386597 grs. of water, that is, one grain of soda may be detected in 492041 grs. or 64,06 pints, of water.

He has also found that 54,66 grs. of real sulphuric acid saturate 14,24 grs. of ammonia; therefore a grain of this acid saturates 0,2605 grs. of ammonia; hence 0,2605 grs. of
of

of ammonia may be detected by the litmus in 386597 grs. of water, that is, 1 grain of ammonia may be detected in 1484057 grs. or 193,23 pints, of water.*

The litmus used in this way is a much more sensible test of alkalis than the most delicate test of them mentioned by Mr. Kirwan, namely, paper stained with Brazil wood, which detects one grain of carbonat of soda in 9945 grs. or 1,16 pints, of water.

To determine whether the colour of the litmus is restored by fixed alkalis or carbonated earths, we must have recourse to the method employed by Mr. Kirwan for this purpose, in the use of the test just mentioned, evaporating the water to one half of its bulk, which will increase the effect of the litmus, if it arises from a fixed alkali, but diminish or wholly prevent it, if from carbonated earths.


If the presence of ammonia be suspected, the test must of course be applied to the first part of the water which rises in distillation.

To ascertain by the litmus the quantity of carbonat of alkali which exists in water, I have found the following method the most convenient:—Into one of the basons placed as


* Other writers make the foregoing proportions different, but Mr. Kirwan's known accuracy has induced me to adopt his.—When we know the quantity of alkali, it is easy to ascertain what its quantity would be if carbonated, the state in which it always exists in mineral waters.

above put a certain quantity of acid, 0,001 grs. for example, to equal quantities of the water to be analysed and of distilled water add an equal quantity of a strong infusion of litmus; let the former of these be put by small quantities at a time into the bason containing the acid, and the latter by equal quantities into the other bason, till the shade of colour in the two basons is exactly alike; then the nature of the alkali having been previously ascertained, the quantity of water required to saturate the known quantity of acid will, by the above proportions, give the quantity of alkali it contains.

The filtering paper used in the following experiments was white paper deprived of its glue, by Mr. Accum.




AN ANALYSIS, &c.



CHAP. I.

OF THE HOLY-WELL WATER.



IN the following Analysis of the Malvern waters I shall begin with the water of the Holy-well, because it contains a greater quantity of foreign ingredients than that of St. Ann's.

SECT. 1.

Of the Gaseous contents of the Holy-well water.

From the following experiments, Dr. Martin Wall concludes that the Holy-well water contains carbonic gas :

“ Experiment 1. To a glass of the water at
“ the spring head a small quantity of lime water
“ was added : small distinct flocculi formed, and
“ floated throughout, but not numerous.

“ Exper. 2.

“ Exper. 2. A half pint bottle, containing
 “ about $\frac{3}{4}$ of an ounce of clean iron filings,
 “ was filled at the spring head with the water,
 “ sealed up and carried to Worcester: the next
 “ morning some of the water was poured into a
 “ glass without filtering it, and upon the ad-
 “ dition of some infusion of galls the whole
 “ presently became of a fine purple colour,
 “ which it retained some time without turning
 “ black.

“ Exper. 3. A part of the remainder of the
 “ water employed in experiment 2 was filtered;
 “ and, upon adding some infusion of galls, no
 “ change of colour ensued but that which re-
 “ sulted from the dilution of the colour of the
 “ infusion; no purple tinge or shade in the
 “ smallest degree.

“ Exper. 5. A phial, containing about half
 “ an ounce of clean iron filings, was filled with
 “ Malvern water at the spring, sealed up, and
 “ in about ten days it was brought to me at
 “ Oxford, where it was kept near a week longer.
 “ The cork when drawn came out with violence
 “ and noise, as it usually does from the bottles
 “ of Pyrmont and Spa waters; and this violence
 “ was attended with a chalybeate smell. A small
 “ quantity of this water was decanted carefully
 “ through a piece of linen cloth into a glass:
 “ the water thus filtered was not clear, it had a
 “ slight chalybeate taste; and upon adding to it
 “ some

“ some drops of infusion of galls, it assumed a
 “ muddy purplish hue, which colour gradually
 “ subsided to the bottom, and the water above
 “ became clear.

“ Exper. 6. I filtered the remainder of the
 “ water used in experiment 5 through thin
 “ paper, it had a very slight flavour, and
 “ still slighter taste, of iron; it gave no purple
 “ or black colour on the addition of infusion of
 “ galls, but only diluted the yellow colour of
 “ the infusion.

“ It should be remarked that before the phial
 “ of water used in experiments 5 and 6 was
 “ opened, it was obvious that a part of the fil-
 “ ings had suffered a considerable corrosion, and
 “ perhaps a partial solution: the lower part con-
 “ tinued perfectly in a metallic state, but over
 “ it floated a light black powder, which was
 “ nearly in the proportion of one fifth of the
 “ whole.”

1. On repeating the first experiment of Dr.
 M. Wall, I found the result as he has stated
 it. Lime water was mixed with Holy-well water
 in equal quantities at the spring; although the
 transparency was not at first disturbed, in a short
 time they became slightly turbid, and small floc-
 culi were seen floating in the water.

2. Strontian water was mixed with it in equal
 quantities, at the spring. The turbidness now
 appeared

appeared sooner, and increased to such a degree as to give a milky appearance to the water.

3. Barytic water was mixed with it in equal quantities at the spring. The turbidness now appeared still sooner, and the milky appearance of the water became more considerable.

These are precisely the effects which a small quantity of carbonic gas dissolved in water produces, but none of them are decisive of its presence, for many other substances found in mineral waters will give the same appearances with all these tests.

Barytes, Strontian and lime have a stronger affinity for carbonic acid than any of the alkalis, magnesia, alumina, or iron; and, consequently, when the carbonats of any of these exist in mineral waters, Barytes, Strontian and lime will attract the carbonic acid from them. I have found that Barytic and Strontian water occasion a very evident turbidness in water which contains carbonat of Soda in the proportion of 1 grain to 45,000 grs. or near six pints.

Besides these carbonats, the foregoing tests (as Mr. Kirwan observes) give precipitates with various earthy salts, and the mere effect of carbonic gas is not easily distinguished. Barytic water also gives a precipitate with sulphats.

Nor are the experiments with iron filings decisive of the presence of carbonic gas. Although
it

it be found that the Holy-well water becomes more impregnated with iron than pure water, under the same circumstances, would be, it does not follow that it contains carbonic gas; other substances found in mineral waters are capable of dissolving iron.

4. I repeated Dr. M. Wall's experiment. A six ounce bottle, containing above half an ounce of iron filings, was filled at the spring head with Holy-well water, closely corked and sealed. After it had stood above forty-eight hours, it was opened, and some of the water poured out, which gave a purple colour on adding to it a few drops of tincture of galls, but this colour neither disappeared on filtering the water, nor did it subside with the filings. A little of this water was exposed to the air for more than twenty-four hours; at the end of this time the purple colour was as strong as at first.

5. Some Holy-well water was kept exposed to the air for several weeks. It was then mixed with iron filings, allowed to remain exposed to the air, and in about twelve hours filtered. On adding to it a few drops of tincture of galls, it became of a dark purple.

But any water will give the foregoing appearances with iron filings; I have repeated them with distilled water, and found the results the same.

Nor is it difficult to account for the cork of
the

the bottle, in which the iron and water had been kept, coming out with noise, which also happened in my repetition of Dr. M. Wall's experiment.

The black powder which floated over the iron filings is an oxid of iron, which may be formed by allowing iron to lie in any water in the temperature of our summer, and is produced by the decomposition of the water. Its oxygen combines with the iron forming the black powder, while the hydrogen is disengaged in the form of gas: and from this gas it arises that the cork comes out with noise. When considerable heat is applied to water and iron filings, the hydrogen gas is seen to rise in bubbles from the iron, and may be collected; the iron, at the same time, from which it rises, being converted into the black powder mentioned by Dr. M. Wall. In making the experiment, indeed, in the common temperature of our summer, if the vessel is allowed to remain at rest for some time, on shaking it, a great number of air bubbles rise from the filings. More bubbles are formed on again allowing the vessel to remain at rest, and so on, till all the iron is oxidated.

Mr. Kirwan regards the litmus as the only test by which we can ascertain the presence of the carbonic gas in waters. "Waters," he observes, "that contain uncombined fixed air to the amount of $\frac{1}{16}$ of their bulk, or partly com-
bined,

" bined, partly femi-combined and partly un-
 " combined, so that the uncombined part
 " amounts to $\frac{1}{18}$ or more of their bulk, will red-
 " den infusion of litmus.

" To render this test decisive," he observes,
 a little lower, " it is necessary, 1st. That the
 " redness be fugacious, and capable of repeated
 " renovation and evanescence by fresh additions
 " of the mineral water, which distinguishes
 " this air from very dilute solutions of the mi-
 " neral acids; for these also may excite an eva-
 " nescent redness for some time, that is, until
 " the alkali contained in the litmus is saturated,
 " as Bergman has well observed. 2d. That the
 " mineral water should give a precipitate with
 " lime water soluble in the mineral acids with
 " effervescence: this distinguishes fixed air from
 " hepatic air, which also fugaciously reddens
 " infusion of litmus."

6. To the water at the spring, a few drops of
 a strong infusion of litmus was added so as to
 give the whole a slight tinge. The litmus was
 not at all reddened. It had exactly the same ap-
 pearance as if the infusion had been dropped
 into distilled water.

Even the litmus, however, cannot be re-
 garded as a decisive test of the presence of car-
 bonic gas, for as the above-mentioned tests often
 seem to indicate the presence of this gas where
 it does not exist, the litmus sometimes fails to
 indicate

indicate its presence even where the quantity is great ; for I have found that however much the infusion of litmus is reddened by charging it with carbonic gas, its colour is immediately restored by adding to it a small quantity of any of the alkaline carbonats, although they have been perfectly saturated with the carbonic acid. Waters containing such carbonats, therefore, may contain carbonic gas, although they do not redden the infusion of litmus.

It appears then, that we have no test which will in all cases ascertain the presence of carbonic gas in water ; this can only be done, therefore, by separating, by means of a mercurial apparatus, the gaseous contents of the water, and examining their properties when they can no longer be affected by its other contents.

7. Into a glass vessel, connected by means of a glass tube, with such an apparatus, eight ounces of the Holy-well water were put at the spring, the whole contents of the vessel and tube being twelve ounces and three drams. The water was gradually heated, and made to boil for a quarter of an hour, and the air which came over, received in a glass jar graduated to the cubic inch, inverted over the mercury. In order to estimate any loss of air which might take place in the experiment, the fire was removed, that the apparatus might return to the temperature of the air, and the space which the
air

air in the jar occupied, the height of the mercury of the jar above that of the trough, and the height of the barometer and thermometer were noted. Half an ounce of a strong solution of potash, which had been wholly deprived of its carbonic acid by being boiled with lime, was then thrown into the jar; but, although it was strongly agitated with the air in the jar for a considerable length of time, no absorption whatever took place, the surface of the solution of potash remaining exactly at the same point of the scale, attached to the jar, as on its first introduction.

A condensation of the air in the jar necessarily takes place on the introduction of the solution, in consequence of the descent of the mercury, so that the point of the scale occupied by the surface of the solution is higher than that which the surface of the mercury had occupied.

This condensation is easily distinguished from any absorption of the air, because it is proportioned to the increase of atmospherical pressure from the descent of the mercury, and completed at the moment the solution of potash is introduced.

The jar and its contents were then removed into a tub of water, and a quantity of nitrous gas, under the same atmospherical pressure equal in volume to the air which the jar contained, introduced

troduced into it. The nitrous acid was immediately formed, and, on agitation, the water rose to the same point of the scale it occupied before the introduction of the nitrous gas. The whole of the air contained in the jar, therefore, was atmospherical air.

The Holy-well water, then, contains no carbonic gas. The precipitate occasioned by the Barytic, Strontian and lime water consequently arose from some other part of its contents.

SECT 2.

Of the Carbonats contained in the water of the Holy-Well.

8. A dilute infusion of litmus, prepared with filtered rain water, was sensibly reddened by a very small quantity of acetous acid. It was then divided into two equal parts; to the one was added a certain quantity of filtered rain water; to the other the same quantity of the water of the Holy-well, which had been kept several days in a bottle, slightly corked. The latter appeared of a bluer colour than the other. The same quantity of filtered rain water was again added to the first, and of Holy-well water to the other: the difference of colour was then more considerable. This experiment was several times repeated with the same result.

9. Into filtered rain water, and Holy-well water at the spring head, a little of an infusion
of

of litmus, reddened by an acid, was dropped. The Holy-well water soon assumed a bluer colour. Both in this, and the former experiment, I thought the difference of colour continued to become more considerable for several hours, during which I occasionally observed it.

10. Thirty-two ounces of Holy-well water were slowly evaporated to two ounces and a half, with a sand heat, in a glass retort and receiver, put together without luting. When about one half of the water had passed over into the receiver, that in the retort had assumed a milky appearance, which gradually increased, and a white powder was at length deposited, part of which subsided very slowly. This powder was separated by filtering the water, and subjected to the action of diluted muriatic acid. A considerable effervescence took place.

The acid was then separated from the part of the powder which it had not dissolved by filtering; and to this acid a few drops of sulphuric acid (sp. gr. 1,85) were added, without occasioning any precipitate or turbidness. A few drops of alcohol (sp. gr. 0,817) were then added, and the temperature raised to above 130° of Farenheit. It was then set apart for twenty-four hours. At the end of this time a considerable deposition of selenite was formed. This experiment was repeated several times with the same result. From which it appears that

that the powder which occasions the milkiness in this water, when part of it is evaporated, contains carbonat of lime.

11. The first part of the foregoing experiment was repeated; but instead of adding to the filtered acid sulphuric acid and alcohol, a little of a solution of ammonia (sp. gr. 1,26) was dropped into it: a cloud appeared, which was gradually formed into a light white precipitate,* lying near the bottom of the vessel. It appears, from this experiment, that the milky appearance of the water is partly owing to the presence of magnesia.

12. On examining the retorts in which the foregoing distillations were performed, the part which had contained the water was found lined with a thin film. A small quantity of diluted muriatic acid was poured into them. Wherever the acid touched the film, an effervescence ensued. The acid was then filtered. It gave no precipitate with oxalic acid; but, on adding to it the same sulphuric acid used above, (9.) a precipitate was immediately formed, which was much increased on the addition of a few drops of alcohol.

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* See Mr. Kirwan's Treatise on the Analysis of Mineral Waters, p. 93 and 94. When the water is agitated before it is poured out of the retort, so as to bring away with it the powder which has fallen to the bottom, this precipitate is of a brownish colour; for the cause of which see Exper. 15th.

It seems, at first sight, difficult to reconcile these appearances, as the oxalic acid is a more delicate test of lime than the sulphuric; they are readily explained, however, when we know that the presence of a mineral acid will prevent the appearance of a precipitate from the oxalic acid notwithstanding the presence of lime. "Where the mineral acids abound," Mr. Kirwan observes in a Treatise above referred to,* "and are in some measure disengaged from any combination, they either decompose the saccharine acid or dissolve the saccharated lime, if any be formed, and thus prevent, either totally or partially, the appearance of a precipitate, as I have long since observed in analysing stones."

13. To another portion of the diluted acid used in the last experiment, to whose action the film in the retort had been subjected, a few drops of the same solution of ammonia used above (11.) were added; a brownish white fleecy precipitate ensued. The film formed on the retort, then, as well as the powder obtained by filtering, contains both carbonat of lime and carbonat of magnesia.

14. In order to ascertain whether the Holywell water contains iron, a correspondent of Dr. M. Wall added to it at the spring some infusion of galls, and observed no change of colour.

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He then evaporated a pint and a half to three ounces, and found no change of colour on adding to it infusion of galls.

These experiments I have repeated with the tincture of galls with the same result. The Holy-well water, evaporated to less than a 70th part of its bulk, gave no colour either with tincture of galls or prussiat of potash.

Water may contain iron, however, which will elude these means of detecting it. If it contains carbonat of iron in too small quantity to be detected by the tests at the spring, we shall not detect it in the water evaporated to however small a quantity, because the carbonat of iron will be deposited during the evaporation.

15. To ascertain whether the Holy-well water contains any carbonat of iron, a gallon was slowly evaporated to two ounces and a half in a glass retort and receiver, luted together. It was then filtered, and the powder which remained in the filter subjected to the action of diluted muriatic acid. The crust, which adhered to the retort, was also subjected to the action of the same acid. Both these portions of acid were found to contain iron. By the following process any test of iron will readily detect it. Both acids we have seen contain lime. This was separated as in Exper. 10, a precipitate similar to that just described (13.) was then obtained by a solution of Soda, and allowed to subside, and as much

much of the fluid poured off as could be done without disturbing the precipitate: enough of diluted muriatic acid was added to re-dissolve the precipitate. It then gave a deep purple, with tincture of galls; and a copious blue precipitate, with prussiat of potass. * This experiment may be made without separating the lime, which is a tedious process, if ammonia be used instead of Soda; as by the former, the iron may be precipitated, mixed with only a small quantity of magnesia.

The foregoing substances, namely, the lime, magnesia and iron, form the whole of what is taken up by the diluted muriatic acid from the precipitate obtained by evaporating the Holywell water, whether the powder which is found in the remaining water, or the film which adheres to the retort, is subjected to its action; for these are of the same nature.

A residuum is left after the action of the acid, on which I shall soon have occasion to make some observations: we are now to examine

* If prussiat of potass is added to this fluid, as long as any blue precipitate is formed, and this precipitate is separated by filtering, the magnesia alone may then be precipitated by a solution of ammonia. This experiment I have frequently made: when the magnesia is precipitated as above (13.) it is necessarily mixed with the iron. The peculiar appearance of the precipitate sufficiently indicates its presence. It is to be recollected, that the acid contains no other substance which can be precipitated by ammonia but iron and magnesia.

mine the water left in the retort after the distillation.

16. A gallon of Holy-well water was evaporated in a glass retort and receiver, luted together, to two ounces and a half; to which, after it was filtered, a little of a strong solution of ammonia was added. After it had stood for several hours, the bottom of the vessel was covered with a small quantity of a white powder, which, after it had remained for some time exposed to the air, effervesced with acids. The result of this experiment might have been foreseen from what has already been said, as magnesia is not wholly deposited by ebullition till the water is evaporated nearly to dryness.

17. A gallon and a half of Holy-well water were slowly evaporated to fifteen ounces in a glass retort and receiver, luted together. The water remaining in the retort was then filtered, and paper stained with turmeric was dipped into it. In less than a minute, without the assistance of heat, the paper was changed to a reddish brown. From this experiment it appears that the Holy-well water contains a carbonat of fixed alkali; for, according to Mr. Kirwan, the only other substances which could produce this effect are pure alkalis, lime and carbonat of ammonia. The first never exists in mineral waters. If carbonat of ammonia exists in the Holy-well water,
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it must come over into the receiver during distillation. If the effect on the turmeric paper had proceeded from lime, a pellicle would have been formed on the surface of the water remaining in the retort by exposure to air, which was not the case. Uncombined lime, indeed, is very rarely found in mineral waters; and Bergman says, it must be in hot, not in cold mineral waters, that it exists.

18. The presence of a carbonat of fixed alkali in the Holy-well water may be ascertained in another way, equally simple, which at the same time proves that it is chiefly owing to it that this water possesses the power of neutralising acids. This power must arise from the presence of carbonats of some of the earths, or of carbonat of ammonia, or of carbonat of a fixed alkali. If it arises from any of the earthy carbonats, except the carbonat of magnesia, or from carbonat of ammonia, ebullition will wholly destroy it. If from carbonat of magnesia, ebullition, if it increases it at all, will increase it only in a slight degree. It will soon arrive at its maximum; and beyond this, however much the water is evaporated, it will be impossible to increase its power of neutralising acids.

If this power arises from the presence of a carbonat of fixed alkali, it will be increased by evaporation nearly as long as any of the water remains. This is found to be the case with the Holy-well
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water.

water. Evaporating part of the water increases its power of neutralising acids; and however far the evaporation is carried, by carrying it farther, this power is still increased.

The existence of a carbonat of fixed alkali in this water accounts for many observations which have been made respecting it. It is remarked, that clothes may be washed in it with less soap than in any other; and that vessels, which are incrustated by hard water having been boiled in them, are cleaned by boiling in them the Holy-well water.

“ Upon the whole,” Dr. J. Wall observes,*
 “ too much care cannot be taken by those who
 “ send for this water from the well that their
 “ bottles be perfectly clean; since it is known
 “ that this water will dissolve those foulnesses
 “ which common water will not touch.

“ Waters, full of earthy particles, are found
 “ to foul and incrust the vessels in which they
 “ are boiled; as is evident in tea-kettles,
 “ &c. which vessels may again be perfectly
 “ cleaned by boiling some of these pure waters
 “ in them.”

But the effect of the purest water in removing this crust will not be found equal to that of the Holy-well water, and indeed is very trifling, the crust formed being sulphat of lime, which is
 very

* See his Tracts, p. 117.

very insoluble in water, but is readily decomposed by all the alkaline carbonats.

The presence of the alkaline and other carbonats readily accounts for the precipitate obtained by Barytic, Strontian and lime water.

19. Thirty ounces of Holy-well water were slowly evaporated to less than a dram, care being taken to prevent any of the alkaline carbonat from remaining on the sides of the vessel in which the evaporation was performed; a solution of tartareous acid (sp. gr. 1,56) was then added freely, but no deposition of supertartrite of potass ensued; it was then slowly evaporated to dryness, but no supertartrite of potass was formed. The alkaline carbonat which this water contains, therefore, is the carbonat of Soda.

20. In my first distillations of the Holy-well water, the water which passed over into the receiver still gave precipitates with acetat of lead and nitrat of silver, both of which were prevented by the previous addition of an acid to the distilled water. It seemed a fair inference from these circumstances, and indeed Mr. Kirwan, in his Treatise on the Analysis of Mineral Waters considers it as such, that the water contains carbonat of ammonia. This opinion, however, seemed improbable, because the precipitates given by the first part of the water which came over were less copious than those given by the water previous to distillation.

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It was wholly set aside by its being found, in the above distillations, that the water which came over first did not give more copious precipitates than that which came over towards the end of the distillation.

I could only explain the appearance of these precipitates by supposing that a small part of the carbonat of Soda had passed over with the water, from the distillation having been conducted too rapidly, although it had been performed in a very large retort, whose contents were many gallons, and in which I put only a gallon or a gallon and a half.

21. To ascertain the truth of this opinion, a gallon of Holy-well water was distilled to a few ounces in a glass retort and receiver, with a heat below the boiling temperature. The water which came over gave no precipitate either with acetat of lead or nitrat of silver.

22. A small quantity of carbonat of Soda was dissolved in filtered rain water, which, I had previously found, gave no precipitate with either of the foregoing tests. It was distilled in a glass retort and receiver, in a heat which made it boil pretty briskly. The water which came over gave a precipitate with both acetat of lead and nitrat of silver.

23. But the carbonat of Soda is not the only part of the solid contents of the Holy-well water which comes over if the distillation be rapid.

I three

I three times distilled a quart of this water in the same retort and receiver, with different degrees of heat, and found that the powder obtained by filtering the water which remained in the retort, was less in proportion as the distillation had been more rapid. It is on this account that, in the distillations I shall afterwards have occasion to mention, for the purpose of ascertaining the quantities of the different carbonats, the water was not permitted to boil.

24. It is mentioned above (15.) that a residuum is left after the action of the diluted marine acid on the precipitate obtained by distillation. This residuum remains unchanged in the following fluids, although the temperature is gradually increased till they boil: sulphuric acid (sp. gr. 1,85), muriatic acid (sp. gr. 1,12), nitric acid (sp. gr. 1,146), fluoric acid (sp. gr. 1,42), strong solutions of all the alkaline carbonats, a solution of ammonia (sp. gr. 1,26), alcohol (sp. gr. 817).

25. By a strong solution of potash or Soda it is completely dissolved in the common temperature of the air, and very rapidly, if heat is applied.

The fluoric acid seems to act partially on the residuum; but this appearance is deceitful, and proceeds from a circumstance which it will be necessary to explain at length.

In distilling the Holy-well water in glass vessels, an appearance takes place which I was
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at first at a loss to account for. After the distillation has continued for some time, a number of shining particles appear in the water remaining in the retort which sparkle in the sunshine. The agitation of the water in boiling seems necessary to their appearance, for when the distillation is conducted very gently, none of them are found in the water: but after gently pouring out the Malvern water, if any water be strongly agitated in the retort, it is found to contain them; and if the preceding distillation has been long continued, generally in very great quantity. I found that they were insoluble in the sulphuric, muriatic and nitrous acids, also in solutions of the alkaline carbonats; but with the assistance of heat, readily soluble in solutions of potash or Soda. These circumstances rendered it probable that they were silicious, which, together with their brilliancy, suggested the idea of their being fine laminæ separated from the surface of the glass. This induced me to boil the Holy well water in an iron vessel, but however long the boiling was continued, none of the shining particles appeared. When I found that this water contains a carbonat of Soda, it did not seem improbable that, by long boiling, the carbonat, from the affinity of the Soda to glass, might so loosen the surface of the glass that, by the agitation of boiling, small laminæ might be detached from it. This seemed the
more

more probable, as glass is easily dissolved by boiling solutions of pure potash or Soda. I have myself seen the bottom of a glass retort deeply eroded by boiling them in it for a few hours: and it may be observed, that, in this instance, the shining particles appeared in the alkaline solution. Dr. Priestly has shewn indeed that boiling water itself, if long applied, will dissolve glass. In order to ascertain this point, I repeatedly boiled in a Florence flask, for some hours, a weak solution of carbonate of Soda, and found that the same shining particles made their appearance. The surface of the glass seems to be that which is most easily detached; for I found that when a solution of Soda was repeatedly boiled in the same flask, the shining particles, at length, either ceased to appear or appeared in small quantity: but if the flask was so placed that the fluid touched a fresh surface, they then made their appearance as at first.

This appearance seems constantly to attend the solution of glass in a boiling fluid. I have just remarked, that it takes place when a solution of potash or Soda is boiled in it. I have found that boiling the fluoric acid in a glass vessel produces the same effect. The surface of the glass seems loosened by the solvent, and broken off by the agitation of boiling. As these shining particles remain in the filtering paper with the residuum,

residuum, they account for the apparent action of the fluoric acid.

SECT. 3.

Of the Saline contents of the water of the Holy-well.

The only acids, if we except the carbonic gas, which have been found to exist in mineral waters, are the sulphureous, sulphuric, muriatic, nitric and boracic acids.

Of these the sulphuric, muriatic and nitric acids have never been found uncombined in these waters. The sulphuric acid has been found semi-combined. The sulphureous and boracic acids have been found uncombined; they do not, however, exist in this state in the Holy-well water, as appears from the experiments which have been related.

Neither the sulphureous nor boracic acid have been found in a combined state in mineral waters. Mr. Kirwan thinks the former probably exists in this state in some of the hot sulphureous waters. Of the latter he observes,
 “ the boracic acid, uncombined with any basis
 “ has been found in some lakes in Italy. 16
 “ Roz. Journ. and 2 Mem. Dijon, 1784, p. 151.
 “ In a combined state with natron it probably
 “ exists in those lakes of Thebet and Persia,
 “ where tinckal is found; perhaps, also in Hungary,
 “ where lakes abounding in natron occur,
 and

“ and where it does not appear to have been
 “ fought for *

The only acids, therefore, which we are to look for in the Holy-well water, are the sulphuric, muriatic and nitric acids, in a state of combination.

25. A few drops of a solution of nitrat of Barytes was added to the Holy-well water at the spring. No precipitate nor cloud ensued.

26. Thirty ounces of this water were evaporated to two ounces; to which, more acetic acid than was necessary to saturate the basis of the alkaline carbonate it contains, was added. A solution of acetat of Barytes was then dropped into it; a white precipitate immediately ensued.

From these experiments it appears that the Holy-well water contains sulphuric acid, but not in considerable quantity.

27. More nitrous acid was added to some Holy-well water than was sufficient to saturate the bases of the carbonates it contains, and without any previous distillation a solution of nitrat of silver was dropped into it; a cloud immediately appeared. This water, therefore, contains muriatic acid.

28. The muriatic acid may easily be obtained from it in a disengaged state. The water was boiled till the earthy carbonates were precipitated;
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* Mr. Kirwan's Treatise on the Analysis of Mineral Waters, p. 14.

it was then filtered and evaporated to dryness. A white crust remained, which decrepitated with heat, and effervesced with sulphuric acid, the muriatic acid being disengaged in the form of gas.

29. A gallon and a half of this water were evaporated in a glass retort and receiver, luted together, to fifteen ounces. Part of the water which remained in the retort was deprived of its sulphuric acid by dropping into it a solution of acetat of Barytes, and of its muriatic acid by dropping into it a solution of acetat of silver, as long as any precipitate could be obtained, and filtering it. It now contained only acetats and nitrats, if any exist in the Holy-well water. It was then evaporated to dryness, and the acetats dissolved by treating them with alcohol.* No nitric acid was disengaged on treating the residuum with strong sulphuric acid. This water, therefore, contains no nitric acid.

It appears, then, from all that has been said, that the Holy-well water contains the carbonats of Soda, lime, magnesia and iron, and the sulphuric and muriatic acids in a combined state. It remains to be ascertained with what substances these acids are combined.

In order to abridge the labour of analysing mineral waters, Mr. Kirwan gives a table of
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* See Mr. Kirwan's Treatise on the Analysis, &c. p. 128.

incompatible salts. Under the first head he mentions alkaline carbonats as incompatible with earthy or metallic sulphats, muriats or nitrats. To this, however, there is one exception, for he gives three instances in which small quantities of sulphat of lime were found in the same water with alkaline carbonats.

I found that the powder obtained in the distillation just mentioned, in which a gallon and a half was evaporated to fifteen ounces, contained no sulphat of lime.* This, however, is not a fair experiment, as the quantity of carbonat of Soda in a given portion of the water was so increased by the evaporation that, if sulphat of lime does exist in the Holy-well water, it must have been decomposed in this experiment: nor can the experiment be performed in this way satisfactorily; for it is necessary to evaporate a great part of the Holy-well water before a sufficient quantity of the sediment can be procured. I therefore performed the experiment in the following manner.

30. Three pints of it were boiled in a glass retort till some degree of turbidness appeared: it was then filtered, returned to the retort, and evaporated to about five ounces, which was found

* After it had been treated with diluted muriatic acid, it was boiled with a strong solution of carbonat of Soda, and then again subjected to the action of muriatic acid, after being washed to free it from the carbonat of Soda; no effervescence ensued.

found to give as copious a precipitate, with a solution of nitrat of Barytes, as if it had not been filtered. This experiment proves that the alkali acquires no sulphuric acid during evaporation from that part of the contents of the water which is first precipitated by boiling, and consequently that the Holy-well water contains no sulphat of lime.

It appears from what has been said, that the sulphuric and muriatic acids found in this water must be combined with an alkali.

31. Three pints of it were evaporated to about five ounces and a half, in a glass retort and receiver, to which some lime was added, and to the first dram of water which came over after the addition of the lime, a few drops of a solution of acetat of lead were added, without occasioning any cloud or precipitate. The alkali with which the foregoing acids are combined, therefore, is a fixed alkali.

32. Sixty ounces of this water were slowly evaporated, in a glass retort and receiver, to four ounces, which were filtered; and the carbonat of Soda was decomposed and the Soda saturated with acetous acid. A solution of acetat of Barytes was then added as long as any precipitate appeared. After being allowed to stand for some hours, the water was again filtered to separate this precipitate, and evaporated in a temperature below the boiling point

point to a dram and a half. A solution of tartareous acid (sp. gr. 1,56) was then freely added; a deposition of tartrite of Barytes immediately ensued, in consequence of the water containing some acetat of Barytes; but no supertartrite of potass was formed. The water was then slowly evaporated to dryness, without the appearance of any supertartrite of potass. The sulphat therefore is not sulphat of potass.

33. Thirty ounces of this water were slowly evaporated, in a glass retort and receiver, to two ounces, and filtered. The carbonat of Soda, as in the last experiment, was then decomposed, and the Soda saturated with acetic acid. A solution of acetat of silver was then dropped into it, as long as any precipitate appeared; and after being allowed to stand for some hours, it was filtered, and evaporated in a temperature below the boiling point to less than a dram. The same solution of tartareous acid used in the last experiment was then freely added to it: no supertartrite of potass appeared. It was then slowly evaporated to dryness, without any supertartrite of potass being formed. The muriat, therefore, is not muriat of potass.

It follows, from these experiments, that the sulphuric and muriatic acids found in the Holy-well water are combined with Soda.

The

The contents of the water remaining in the retort after partial distillation, then, are sulphat, muriat and carbonat of Soda.

It appears from all that has been said, that the contents of the Holy-well water are the carbonats of Soda, lime, magnesia and iron; the sulphat and muriat of Soda, and the residuum above mentioned (24.)

SECT. 4.

Of the quantity of Carbonats contained in the water of the Holy-well.

To ascertain the quantity of the alkaline carbonats in mineral waters, Mr. Kirwan advises that the alkali should be saturated by diluted sulphuric acid, whose proportion of real acid is known from its specific gravity, the quantity required being noted. This method, however, cannot be employed in the analysis of such waters as that of the Holy-well, because it contains other substances capable of neutralizing acids. To enable us to draw any conclusion from such an experiment in the case before us, all the carbonats, except that of Soda, must be separated from the water; and this difficulty, we shall find, is the cause of another, which it does not seem easy to surmount.

34. Various quantities of Holy-well water, from a quart to a gallon, were evaporated with
a gentle

a gentle heat, in glass retorts and receivers, to a fifteenth or twentieth part of their bulk; they were then filtered, and a strong solution of ammonia being dropped into them, they were allowed to remain at rest from twelve to twenty-four hours: at the end of this time they were again filtered. By these processes they were deprived of all their carbonats, except the carbonat of Soda. They were then boiled for a sufficient length of time to expel the ammonia.

To ascertain what quantity of carbonat of Soda they contained, diluted sulphuric acid, whose quantity of real acid had been ascertained, was added to them, the litmus being used as the test of saturation; but the results of no two of these experiments corresponded, and all of them indicated less carbonat of Soda than, from other experiments, I had reason to believe the water contained. That I might avoid every cause of error, I performed the distillations very slowly, some of them without permitting the water to boil; retorts were used which had never been employed for any other purpose, and which were repeatedly washed with the Holy-well water, and the filtering paper was that mentioned in the Introduction.

With all these precautions, I could arrive at no conclusion respecting the quantity of the alkaline carbonat. The greater the quantity of water, and consequently the larger the vessels employed,

ed, the more dissimilar, in general, was the result. These circumstances can only be attributed to the carbonat having met with more or less acid, notwithstanding the precautions employed, in the tedious process it underwent to prepare it for the sulphuric acid. And although this acid would displace that which the Soda had attracted, the displaced acid would equally with the sulphuric affect the litmus. I found, indeed, that even handling the filtering paper was capable, owing to the acid which escapes by insensible perspiration, of influencing the result of this experiment. After devoting much time to it, I was convinced that no certain conclusion respecting the quantity of the carbonat of Soda could be drawn from it. I therefore had recourse to another method, which may be regarded as decisive, because, in repeating it, the results were found to correspond.

35. Half a grain of carbonat of Soda was dissolved in twelve ounces of distilled water, which were heated to 136° . Paper stained with turmeric was allowed to remain in it for one minute at this temperature. It was not at all reddened. This water was gradually evaporated at a temperature never exceeding 140° . and at short intervals slips of paper stained with turmeric were dipped into it and allowed to remain in it exactly a minute, and as soon as the tinge it gave to the
paper

paper was decidedly red, it was removed from the fire and measured; at this time the temperature was 124° . The quantity of water was found to be nine ounces.

Four ounces of Holy-well water were heated to 136° ; at this temperature it did not affect the colour of paper stained with turmeric, and allowed to remain in it one minute. The evaporation was continued in a temperature never exceeding 140° , and gradually lessened to 124° , the slips of paper being used at short intervals as before. When a decidedly red tinge was observed, on allowing the paper to remain in it for a minute in a temperature of 124° , it was removed from the fire and measured: it was found to have lost just one fourth. From this experiment it is evident the quantity of carbonat of Soda in a gallon of Holy-well water is easily calculated. The result is 5,33 grs.

36. Half a grain of carbonat of Soda was dissolved in eleven ounces of distilled water, and exposed to a temperature of 115° . The paper stained with turmeric was used as before; but I now measured the water as soon as the least discolouration appeared in the paper after it had remained in it for a minute in the above temperature, and found the quantity to be ten ounces and a half.

Four ounces of Holy-well water discoloured the paper, allowed to remain in it for the same
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length of time in the same temperature, when one eighth was evaporated. I was surpris'd, on making the calculation, to find that this experiment gave precisely the same result as the preceding, 5,33 grs. of carbonat of Soda in a gallon, that is, 128 ounces.

In making these experiments the paper must not be allowed to touch the bottom of the vessel, and it must be examined the moment it is taken from the water; else the red tinge will appear sooner than it ought to do, in the former case, from the higher temperature of the bottom of the vessel, and in the latter from the evaporation of part of the water which adheres to the paper by which the alkaline solution which remains on it is rendered stronger. This increase of redness, for some seconds after it is removed from the water, is very observable. The redness does not continue to increase however; and when the paper is dry, unless it has been considerable, it is no longer to be perceived. The red tinge is more readily observed if the wet paper is laid on something white.

37. In order to ascertain the quantity of carbonat of lime which the Holy-well water contains, a gallon, which had been kept only 24 hours, was evaporated in a temperature below the boiling point in a glass retort and receiver, luted together, to two ounces and six drams.

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The distillation occupied between three and four days. The water remaining in the retort was then filtered, and the powder which remained on the filter subjected to the action of diluted muriatic acid; a considerable effervescence ensued. The same portion of acid was repeatedly passed through the paper, and then distilled water passed through it, till the water came away tasteless. The crust on the retort was then in like manner subjected to the repeated action of diluted muriatic acid, and washed repeatedly with small quantities of distilled water, in order to obtain the whole of the acid which had been put into the retort: the diluted acid, and the water with which the powder and crust in the retort had been washed, were put together, and some sulphuric acid (sp. gr. 1,85) was added to them. They were then evaporated to one half at a low temperature, and at that of 135° , alcohol (sp. gr. 817) was repeatedly added to them. They were now placed in a temperature of between 60 and 70° , in which they were allowed to remain for 48 hours. At the end of this time a copious deposition of sulphat of lime had taken place, which was separated from the fluid by filtering, and dried by exposure for many hours to a temperature of about 170° . It was now found to weigh 2,5 grs.

Sulphat of lime (according to Mr. Kirwan) dried in a temperature of 170° , consists of 50,39
acid

acid, 35,23 lime, 14,38 water. It requires a white heat wholly to deprive it of water : 2,5 grs. of fulphat of lime, therefore, contains 0,88 grs. of lime. 100 parts of carbonat of lime (according to Mr. Kirwan) contain 45 of acid and 55 of lime ; therefore, 0,88 grs. of lime give 1,6 of carbonat of lime, the quantity contained in a gallon of Holy-well water.

38. In order to ascertain the quantity of carbonat of magnesia in the Holy-well water, to the water remaining in the retort, in the last experiment, after it was filtered, a strong solution of ammonia was added ; and after it had been allowed to stand for twelve hours, it was agitated in the vessel till all the magnesia that had been deposited was mixed with the water ; it was then filtered to obtain the magnesia, which was dissolved in diluted muriatic acid, and added to the acid from which the fulphat of lime was separated in the last experiment. A solution of Soda was then added to them as long as any precipitate appeared. The magnesia and iron were thus obtained in the form of a reddish brown fleecy precipitate, which was allowed to fall towards the bottom of the vessel, and after pouring off the clear fluid, re-dissolved in a small quantity of diluted muriatic acid. The iron was then precipitated by prussiat of potass ; and in about twelve hours after, removed by filtering. The fluid now contained nothing capable of
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of being precipitated by carbonat of Soda but magnesia. A solution of this carbonat was dropped into it as long as any precipitate appeared, by which the magnesia was obtained in the state in which it exists in the water. It was separated by filtering, and dried in a temperature of 80° for twelve hours, and found to weigh 1,166 grs. but this includes a small quantity of water, for it requires a temperature of 600° to expel from magnesia the whole of its water. Mr. Kirwan has shewn that 100 grs. of carbonat of magnesia dried at 80° contain 45 of magnesia; therefore, 1,166 grs. of carbonat of magnesia dried at 80° contain 0,524 of magnesia. According to the same chemist, 79 grs. of carbonat of magnesia contain 34 of acid; therefore, 0,524 grs. of magnesia give of carbonat of magnesia 0,9199 grs. the quantity contained in a gallon of Holy-well water.

39. In order to ascertain the quantity of carbonat of iron in the Holy-well water, a gallon * was evaporated to dryness in a glass retort and receiver, luted together, in a temperature below the boiling point. The distillation occupied between four and five days. A white crust was left in the part of the retort which the water had occupied. This was submitted to the action of diluted muriatic acid; a strong effervescence

* It was brought from the spring to Worcester, and immediately put into the retort.

vescence ensued. The acid was repeatedly applied to every part of the retort which the water had touched; and after the acid was poured out, the same parts were repeatedly washed with small quantities of distilled water, which were added to the acid; the whole was then filtered. The acid which remained uncombined was neutralised by a strong solution of ammonia; and this solution was added as long as any precipitate appeared. The precipitate was then separated by filtering, and redissolved in diluted muriatic acid: a solution of prussiat of potash was then dropped into it as long as any blue precipitate was formed; and this precipitate, after it had stood about twenty-four hours, was removed by filtering. The paper in which it was obtained had been dried in a temperature of about 70° , and weighed 2 grs. It was again dried in the same temperature, and found to weigh 2,95; 0,95, then, was the weight of the prussiat of iron. This prussiat is composed of equal quantities of oxide of iron and prussian acid. The quantity of oxide of iron obtained from a gallon of Holy-well water, then, is 0,475: 100 parts of carbonat of iron contain 24 of acid and 76 of oxide of iron, so that, 0,475 of oxide gives 0,625 of carbonat of iron, the quantity contained in a gallon of Holy-well water.

In estimating the quantity of iron in mineral waters,

waters, Mr. Kirwan advises us to separate the magnesia, if any exists, from the iron by acetic acid ; but the quantity of both is so small in the present case that I found it impossible to estimate the quantity of iron by this method.

40. Sixty ounces of Holy-well water were kept for a fortnight in a bottle, loosely corked. They were then evaporated, in a glass retort and receiver, to four ounces ; these were filtered, and the powder obtained and the film remaining on the retort were treated with diluted muriatic acid, and the whole of the iron dissolved in the acid obtained in the state of prussiat, as in the last experiment, in a piece of paper weighing gr. 2, and dried in a temperature of about 70° : the paper was again dried in the same temperature, but the weight of the prussiat was so small as not to be indicated by a nice balance. It appears, therefore, that the Holy-well water loses its iron by being kept ; but as it holds no more iron in solution than it can hold independently of the presence of any gas, its iron is lost more slowly than a great portion of the iron of most other chalybeats.

SECT. 5.

Of the quantity of the Saline contents of the water of the Holy-well.

41. To ascertain the quantity of sulphat of Soda in this water, sixty ounces were slowly evaporated in a glass retort and receiver, put together

together without luting, to four ounces. Before it was poured out of the retort it was repeatedly passed over every part of the retort which the water had touched, during the evaporation, that it might take up any of the sulphat of Soda which had been left; it was then filtered, and the carbonat of Soda decomposed, and the Soda saturated with acetous acid. A solution of acetat of Barytes was then added as long as any precipitate appeared: it was allowed to remain at rest above twelve hours. The precipitate was then obtained by filtering through a piece of paper, which weighed 2 grs. and had been dried in a temperature of about 70° , more of the solution of acetat of Barytes was added to the filtered fluid, but no farther precipitate ensued. The paper was again dried in the same temperature; it was now found to weigh 3 grs. The weight of the sulphat of Barytes, therefore, was 1 gr. Mr. Fourcroy has shewn that sulphat of Barytes, whether native or artificial, contains 0,03 of water; to expel the whole of which requires a red heat: a grain of sulphat of Barytes, therefore, wholly deprived of its water, gives 0,97 of real sulphat of Barytes. Now, Mr. Kirwan has shewn that 170 grs. of real sulphat of Barytes indicate 100 grs. of desiccated sulphat of Soda; therefore, 0,97 grs. indicate 0,57 of desiccated sulphat of Soda, or 1,347 of chrySTALLISED sulphat of Soda,

Soda, the quantity which exists in sixty ounces of Holy-well water, which makes 2,896 grs. in a gallon.

42. To ascertain the quantity of muriat of Soda in the Holy-well water, thirty ounces were slowly evaporated in a glass retort and receiver, put together without luting, to two ounces. Before the water was poured out, it was repeatedly applied to every part of the retort which it had touched during the evaporation. It was then filtered, and the Soda saturated with acetous acid, as in the preceding experiment. A solution of the acetat of silver was now dropped into it, as long as any precipitate appeared. It was allowed to remain at rest above twelve hours, and filtered through a piece of paper which had been dried in a temperature of about 70° . and weighed 2 grs. The filtered fluid gave no precipitate on the farther addition of acetat of silver. The paper was again dried in the same temperature, and found to weigh 2,857 grs. 0,857, then, was the weight of the muriat of silver. Mr. Kirwan has shewn that 235 grs. of muriat of silver indicate 100 grs. of muriat of Soda dried at a temperature of 80° . therefore, 0,857 grs. of muriat of silver denote 0,364 of muriat of Soda, the quantity contained in thirty ounces, that is, 1,553 grs. in the gallon.

43. I made several experiments to ascertain the quantity of the residuum, (24,25.) from which it appears that it forms about one-third of the powder obtained by evaporation to about one-twelfth part, besides the film which remains on the retort after the action of the acid, which amounts, perhaps, to about one half as much as the part of the residuum found in the powder. This makes the quantity of residuum in a gallon 1,687 grs.

The contents of a gallon of the Holy-well water, then, are,

Carbonat of Soda	5,33 grs.
Carbonat of lime	1,6
Carbonat of magnesia . .	0,9199
Carbonat of iron	0,625
Sulphat of Soda	2,896
Muriat of Soda	1,553
Residuum	1,687
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CHAP. II.

OF THE WATER OF ST. ANN'S WELL.

IN the Analysis of the water of St. Ann's-well, I shall follow the same plan which was pursued in that of the Holy-well; but as most of the experiments I am about to relate are similar to those which have already been laid before the reader, it will not be necessary to detail them with the same minuteness.

SECT. 1.

Of the Gaseous contents of the water of St. Ann's well.

44. Lime water was mixed with the water of St. Ann's well, in equal quantities, at the spring; but I did not perceive that the transparency was at all disturbed, either at the time of mixing them or for some time after: nor did I perceive any of the flocculi observed when the Holy-well water was mixed with lime water. (1.)

45. Strontian water was mixed with the water of St. Ann's well, in equal quantities, at the spring: in a short time they became turbid, but not to the same degree as the Holy-well water and Strontian water.

45. Barytic water was mixed with it, in equal quantities,

quantities, at the spring: the turbidness became greater than in the last experiment, but not equal to what it was when the Holy-well water was used.

47. To the water at the spring a few drops of a strong solution of litmus were added, so as to give the whole a slight tinge: the litmus was not at all reddened; it had exactly the same appearance as if the infusion had been dropped into distilled water.

48. Into a glass vessel, connected by means of a glass tube with a mercurial apparatus for the purpose of examining the nature of gases, eight ounces of the water of St. Ann's well were put at the spring, the whole contents of the vessel and tube being twelve ounces and three drams. The experiment was conducted precisely in the same way with a similar experiment mentioned above, (7.) and the result was the same: the same solution of potash used in that experiment was introduced into the jar which received the air which had come over from the vessel containing the water; but although it was strongly agitated with it for a considerable length of time, no absorption whatever took place. The jar was removed into a tub of water, and an equal volume of nitrous gas mixed with the air it contained; nitrous acid was formed, and, on agitation, the water rose to the same point of the scale attached to the jar which it had occupied before the introduction of the
nitrous

nitrous gas. The whole of the air contained in the jar, consequently, was atmospherical air.

The water in St. Ann's well, therefore, contains no carbonic gas; the precipitate occasioned by the Barytic and Strontian water, then, must arise from some other part of its contents.

SECT. 2.

Of the carbonats contained in the water of St. Ann's well.

49. A dilute infusion of litmus prepared with filtered rain water was sensibly reddened by a very small quantity of acetous acid; it was then divided into two equal parts; to the one was added a certain quantity of filtered rain water, to the other the same quantity of the water of St. Ann's well, which had been kept for some time. The latter appeared of a bluer colour than the other.

49. Into this water at the spring and filtered rain water, a little of an infusion of litmus, reddened by an acid, was dropped. The water of St. Ann's well soon assumed a bluer colour than the other.

51. Into Holy-well water, and water of St. Ann's well, both at the spring, a little of an infusion of litmus, reddened by an acid, was dropped. The former assumed a bluer colour than the latter. From this experiment it appears, that the water of St. Ann's well does not possess so great a power of neutralizing acids as that of the Holy-well.

52. Three

52. Three pints of the water of St. Ann's well were evaporated in a glass retort and receiver to about four ounces, and filtered to separate the powder which had been deposited: this powder was subjected to the action of diluted muriatic acid: a considerable effervescence ensued. The acid was then filtered, and some strong sulphuric acid was added to it; a cloud appeared, which was much increased on the addition of alcohol. The water of St. Ann's well, therefore, contains carbonat of lime.

53 The acid used in the preceding experiment was filtered, to separate from it the sulphat of lime, and a solution of prussiat of potash was dropped into it; a blue precipitate was immediately formed: from which it appears, that the water of St. Ann's well, like that of the Holy-well, contains iron. This water itself, however, gives no indication of iron, either at the spring or after part of it has been evaporated, however far the evaporation has been carried. (14.)

54. A part of the powder obtained by evaporating two gallons of the water of St. Ann's well to twelve ounces, was subjected to the action of diluted muriatic acid: the acid was then filtered, and a strong solution of ammonia dropped into it: a whitish fleecy precipitate was formed. This water, therefore, also contains carbonat of magnesia.

54. The water which remained in the retort
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in the distillation last mentioned, reddened paper stained with turmeric, indicating the presence of an alkaline carbonat. (17.)

55. The presence of an alkaline carbonat was also proved by finding that when the water was evaporated to a 15th or 16th part, its power of neutralizing acids was greatly increased. (18.)

56. About thirty-five ounces of this water were slowly evaporated to two, in a glass retort and receiver, it was then filtered and evaporated in an open glass vessel, with a temperature below the boiling point, to one dram, care having been taken that no part of the alkaline carbonat should be left on the sides of the retort in which the distillation was performed. A solution of tartareous acid (sp. gr. 1,56) was then freely added, but no precipitation of supertartrite of potash took place. It was then evaporated to dryness, but no supertartrite of potash was deposited. The alkaline carbonat of the water of St. Ann's well, therefore, is the carbonat of Soda.

From the foregoing experiments it appears that the water of St. Ann's well contains all the carbonats found in that of the Holy-well, namely, the carbonats of Soda, lime, magnesia and iron.

57. The film which adheres to the retort is of the same nature with the powder which floats in
the

the water. It was subjected to the same processes as the powder, and yielded lime, magnesia and iron. (12, 13, 15.)

The residuum left by the muriatic acid has the same properties with that obtained from the water of the Holy-well. (25).

SECT. 3.

Of the Saline contents of the water of St. Ann's well.

58. A few drops of a solution of nitrat of Barytes was added to this water at the spring. No precipitate or cloud ensued.

59. Three pints were evaporated in a glass retort to about four ounces, and filtered: to a part of it more nitrous acid was added than was sufficient to saturate the Soda it contained; a solution of nitrat of Barytes was then dropped into it. A white precipitate was immediately formed.

From these experiments it appears, that the water of St. Ann's well contains sulphuric acid, but not in considerable quantity.

60. To two ounces of this water, without previous distillation, more nitrous acid was added than was necessary to saturate the Soda it contains: a solution of nitrat of silver was then dropped into it. A cloud immediately appeared, demonstrating the presence of muriatic acid.

61. A quart of it was evaporated in a glass retort

retort and receiver to about two ounces, and deprived of its fulphuric and muriatic acid by solutions of acetat of Barytes and of acetat of silver. (29.) It was then evaporated to dryness, and the acetats were dissolved by alcohol; fulphuric acid was added to the residuum; but no nitric acid was disengaged. From this experiment it appears that the water of St. Ann's well contains no nitric acid.

This water, therefore, like the Holy-well water contains only the fulphuric and muriatic acids; for it appears from the observations made above, (C. 1. S. 3.) that it is only these, or the nitric acid, that we are to look for in it, since it contains no disengaged acid, which is proved by the experiments related in the last Section. It remains to be ascertained to what basis the foregoing acids are united.

I have already had occasion to observe, that under the first head in Mr. Kirwan's Table of incompatible salts, alkaline carbonats are mentioned as incompatible with earthy or metallic sulphats, muriats, or nitrats. To this we found there is one exception, as small quantities of sulphat of lime sometimes exist in mineral waters with such carbonats. To ascertain whether the water of St. Ann's well contains sulphat of lime, the following experiment was made.

62. Some of this water was boiled till a slight
1
degree

degree of turbidness appeared; it was then filtered, and the evaporation continued till it was reduced to a tenth part. More nitrous acid than was sufficient to saturate the Soda it contained, was then added to it; a solution of nitrat of Barytes was now found to occasion as copious a precipitate from it as if it had not been filtered. No part of the sulphuric acid found in this water after partial evaporation, therefore, is derived from that part of its contents which is first precipitated by boiling. (29, 30.)

It follows, then, from what has been said, that the foregoing acids are combined with an alkali.

63. Thirty-five ounces of this water were evaporated in a glass retort and receiver to two, some lime was then added to it, and to the first half dram which came over after the addition of the lime, a few drops of a solution of acetat of lead were added; no cloud or precipitate ensued. The alkali with which these acids are combined, therefore, is a fixed alkali.

64. Thirty-five ounces of this water were evaporated in a glass retort and receiver to two, and filtered, care being taken to prevent any part of the soluble contents of the water from remaining on the sides of the vessel in which the evaporation was performed; more acetic acid than was sufficient to saturate the Soda contained in it was then added, and a solution of acetat of Barytes

Barytes dropped into it as long as any precipitate appeared. It was again filtered to separate the sulphat of Barytes, and, in an open glass vessel, evaporated in a temperature below the boiling point to one dram. A solution of tartareous acid (sp. gr. 1,56) was now freely added to it; a precipitation of tartrite of Barytes immediately took place, owing to the water containing some acetat of Barytes, but no supertartrite of potass was formed. It was then filtered and evaporated to dryness without the formation of any supertartrite of potass. The alkali combined with the sulphuric acid, therefore, is not potass.

65. Thirty-five ounces of water were evaporated in the same manner to two, and filtered; more acetous acid than was necessary to saturate the Soda it contained was then added to it, and a solution of acetat of silver dropped into it: a copious precipitate appeared. It was again filtered to separate the muriat of silver, and evaporated, as in the last experiment, in an open glass vessel to about one dram; the same solution of tartareous acid was then freely added to it; but no precipitate of supertartrite of potass ensued. It was then evaporated to dryness without any supertartrite of potass being formed. The alkali combined with the muriatic acid, therefore, is not potass.

From all the experiments which have been related in this Chapter, it appears, that the contents,

tents of the water of St. Ann's well are the same as those of the Holy-well water; namely, the carbonats of Soda, lime, magnesia and iron, the sulphat and muriat of Soda, and the residuum, whose properties are mentioned above, (25).

SECT. 4.

Of the quantity of the Carbonats of the water of St. Ann's well.

66. Two ounces of this water were evaporated in a glass retort to one. In a temperature of 124° , paper stained with turneric was allowed to remain in it for a minute. At the end of this time it had a decidedly red tinge.

This experiment was repeated with eight ounces, and with half a gallon of water, and the result still found to be the same.*

* The evaporation in this case was performed in a retort, not in an open vessel, as in a similar experiment related above, (35.) because I found from many trials, that by evaporation for so long a time as was here necessary, in open vessels, even with a very low temperature, a considerable part of the carbonat of Soda was dissipated. We have seen above, (21, 22.) how readily this carbonat rises with the water. The cause of the difference of the result in evaporating in close and open vessels, seems to be, that in the latter case all that rises from the water escapes; in the former only the most volatile parts, the other parts being condensed on the sides of the retort return to the fluid; hence the advantage of distilling in retorts, whose contents are much larger than the quantity of fluid we wish to distill. In this way we may easily account for Dr. J. Wall's having found so little residuum when he evaporated the Holy-well water in an open vessel.

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If these experiments be compared with one related above, (35.) in which half a grain of carbonat of Soda, in nine ounces of water, gave a similar tinge to paper stained with turmeric, the quantity of carbonat of Soda in a gallon of the water of St. Ann's well, will be found to be 3,55 grs.

67. In order to ascertain the quantity of the other carbonats which this water contains, a gallon* was evaporated to dryness in a temperature below the boiling point in a glass retort and receiver, luted together. The distillation occupied between four and five days. A white crust remained in the bottom of the retort, which was subjected to the action of diluted muriatic acid. A considerable effervescence ensued. The acid was repeatedly applied to every part of the retort which the water had touched, and after the acid was poured out the same parts were repeatedly washed with distilled water, that the whole of the acid which had been put into the retort might be obtained. These portions of water were added to the acid, and some sulphuric acid (sp. gr. 1,85) was dropped into them. The whole was then evaporated in a temperature below the boiling point to about one-third, and in that of 135° , alcohol (sp. gr. 0,817) was repeatedly dropped into it. It was now placed in a temperature of about 60° , where

* It was brought from the spring to Worcester, and immediately put into the retort.

it was allowed to remain for forty-eight hours; during this time a deposition of sulphat of lime had taken place, which was separated by filtering through a piece of paper which weighed 2 grs. and had been dried in a temperature of about 60° . It was again dried in the same temperature, and found to weigh 2,55 grs.

We found above, (37.) that 2,5 grs. of sulphat of lime indicate 1,6 grs. of carbonat of lime; 0,55 grs. therefore, indicate 0,352 grs. of carbonat of lime, the quantity in a gallon of the water of St. Ann's well.

68. In order to estimate the quantity of carbonat of magnesia in this water, to the fluid from which the sulphat of lime had been separated in the preceding experiment, prussiat of potass was added as long as any blue precipitate appeared, which, after being allowed to stand for 24 hours, was separated by filtering.

The filtered fluid now contained nothing capable of being precipitated by carbonat of Soda but magnesia; a solution of this carbonat, therefore, was dropped into it as long as any precipitate appeared; the magnesia was thus obtained in the state of a carbonat, in which state it exists in the water. After it had stood above twelve hours, it was separated by filtering through a piece of paper, weighing 2 grs. which had been dried in a temperature of 80° ; the paper was again dried in the same temperature, and found to

to weigh 2,33. But the carbonat of magnesia dried at 80° , we have seen, contains a certain portion of water. It appears from what is said above, (38.) that 1,166 grs. of carbonat of magnesia, dried at 80° , indicate, of real carbonat of magnesia, 0,9199 grs. therefore, 0,33 grs. indicate 0,26 grs. of real carbonat of magnesia, the quantity in a gallon of the water of St. Ann's-well.

69. In order to estimate the quantity of carbonat of iron in the water of St. Ann's well, the precipitate formed by the prussiat of potash, in the preceding experiment, was obtained in a piece of paper which weighed 2 grs. and had been dried in a temperature of about 60° : it was again dried in the same temperature, and found to weigh 2,5 grs.

It was found above, (39.) that 0,95 grs. of prussiat of iron indicate 0,625 of carbonat of iron; therefore, 0,5 grs. of prussiat of iron indicate 0,328 grs. of carbonat of iron, the quantity in a gallon of the water of St. Ann's well.

It is almost superfluous to observe, that the water of St. Ann's well, like that of the Holywell, loses its iron by being kept.

It may be proper to mention, that the foregoing precipitates, and the papers in which they had been obtained, were washed with distilled water before they were dried. If this is not done,

done, some of the other contents of the fluid will adhere to the paper.

SECT. 5.

Of the quantity of the Saline contents of the water of St. Ann's well.

70. In order to estimate the quantity of sulphat of Soda in this water, half a gallon was slowly evaporated to four ounces in a glass retort and receiver. Before it was poured out of the retort, the water was repeatedly applied to every part which it had touched during the evaporation. A sufficient quantity of acetous acid was then added to it to saturate the Soda, and a solution of acetat of Barytes was dropped into it as long as any precipitate appeared. It was allowed to stand above twelve hours, and then filtered through a piece of paper, which had been dried in a temperature of about 60° , and weighed 2 grs. To the filtered fluid, more of the solution of acetat of Barytes was added; but no farther precipitate took place: the paper was again dried in a temperature of about 60° , and found to weigh 2,55 grs. Had a whole gallon of water been used, therefore, the weight would have been 3,1 grs.

It was shewn above, that 1 gr. of sulphat of Barytes, dried in the common temperature of the air, indicates 1,347 grs. of crystallised sulphat

phat of Soda; therefore, 1,1 grs. of sulphat of Barytes indicate 1,48 grs. of sulphat of Soda, the quantity in a gallon of the water of St. Ann's well.

71. In order to ascertain the quantity of muriat of Soda in this water, to the water used in the last experiment, after the sulphat of Barytes was separated by filtering, a solution of acetat of silver was added as long as any precipitate appeared. It was allowed to stand for more than twelve hours, and was then filtered through a piece of paper of the same weight, and which had been dried in the same temperature with that used in the last experiment. It was again dried in this temperature, and found to weigh 3,125 grs. To the filtered water, more acetat of silver was added; but no farther precipitate appeared. Had a whole gallon of water been used, therefore, the quantity of muriat of silver would have been 2,25 grs. It was shewn above, that 0,857 grs. of muriat of silver indicate 0,364 grs. of muriat of Soda; therefore, 2,25 grs. of muriat of silver indicate 0,955 grs. of muriat of Soda, the quantity in a gallon of the water of St. Ann's well.

72. The residuum left after the action of the diluted muriatic acid on the precipitate obtained by evaporation, seems to bear the same proportion to the carbonats as that obtained from the Holy-well water; and, on this supposition, amounts to 0,47 grs.

The following, then, are the contents of the water of St. Ann's well :

Of carbonat of Soda	-	3,55	grs.
Of carbonat of lime,	-	0,352	
Of carbonat of magnesia		0,26	
Of carbonat of iron	-	0,328	
Of fulphat of Soda	-	1,48	
Of muriat of Soda	-	0,955	
Of residuum	- - -	0,47	
			<hr/>
			7,395

CHAP. III.

OF THE MEDICINAL EFFECTS OF THE
MALVERN WATERS.

AS the following observations concern the public at large, equally with the chemist, I shall lay aside the language peculiar to the latter, which may here be done, as the few substances I shall have occasion to mention are such as are commonly known.

The general reader will understand many of the terms used in the preceding Chapters, and have a clearer knowledge of what I am about to say, when the terms carbonic gas and carbonat are explained to him, which may be done in a few words. By carbonic gas, the chemist means fixed air. This air is an acid, which, like every other, has a tendency to unite with certain substances when it is brought into contact with them. When it is united to any other substance, chemists call the compound, a carbonat, as the carbonat of Soda, of iron, &c. *

It

* When it enters into combination, it loses the form of an air, which, however, it immediately assumes if it is displaced by a stronger acid, or any other cause ; hence the effervescence which
ensues

It appears from the foregoing Analysis, that the Malvern waters differ from the other celebrated waters of Britain, and agree with several of those of the continent in containing carbonat of Soda. To the Spa water they bear so striking a resemblance, that the solid contents of these waters differ in little else than the greater proportion in which they exist in the Spa water, as the reader will perceive from the following Table of the solid contents of a gallon of the Malvern and Spa waters. The proportion of the contents of the Spa water is taken from the Analysis of Bergman, reduced to the English measure by Dr. Saunders in his Treatise on Mineral Waters:—

ensues when we mix a solution of carbonat of Soda with lemon juice in making the common saline draught, or drop lemon juice on chalk, which is the carbonat of lime. From the property of being, as it were, fixed in bodies with which it combines, it was in a less perfect state of chemistry, when this property was supposed to be peculiar to it called fixed, or fixable air, chemists do not allow it the name of air or gas, their term for air, except when it exists in an aereform state. The cause of this requisite distinction in chemistry, it is not necessary here to enter on. After the explanation I have given, I shall be allowed in the present Chapter to call it fixed air, whether it exists in the aereform or fixed state.

Soda

	<i>Holywell.</i>	<i>St. Ann's.</i>	<i>Spa.</i>
	GRS.	GRS.	GRS.
Soda, combined with fixed air	5,33	3,55	11,76
Lime, combined with fixed air, <i>i. e.</i> chalk	1,6	0,352	11,76
Magnesia, combined with fixed air,			
<i>i. e.</i> uncalcined magnesia	0,9199	0,26	35,68
Calx of iron, combined with fixed			
air, <i>i. e.</i> ruft of iron	0,625	0,328	5,86 *
Glauber falt	2,896	1,48	
Common falt	1,553	0,955	1,376

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* Dr. Saunders gives the quantity of calx of iron: I here give the quantity of calx saturated with fixed air.

The solid contents of the Malvern and Spa waters, it appears from the foregoing Table, if we except the difference in quantity, differ only in there being no Glauber salt in the Spa water. The Spa water differs also from the Malvern waters in containing a considerable quantity of uncombined fixed air, none of which is contained in the Malvern waters.

How far the effects of the Spa water depend on the presence of the uncombined fixed air we cannot say; we should not be inclined to attribute much of them to this air, because water as much or more charged with it is not found to produce the same effects; but a similar observation applies to every other ingredient of these waters. The effects of mineral waters do not seem to arise from any one of their contents, so much as from the peculiar combination and manner in which they exist in the waters. We cannot infer that all waters having any one ingredient, although their most active ingredient, the same will produce similar effects; but we certainly have reason to expect similar effects from waters, the greater part of whose most active ingredients are the same, and exist in them in the same state. Whether the Malvern waters will be found serviceable in the various cases in which the Spa water is so celebrated, it is impossible to say, as a trial of them in many of these cases has not been made; but that they
are

are calculated to produce similar effects in relaxation of the system, and the various diseases which arise from it, is probable from their effects in scrophulous debility, which are perhaps more beneficial than those of any other mineral water of this country. The smaller quantity of the foreign contents, which, however, is in some measure compensated by the Malvern waters being used in greater quantity than the Spa water, will probably render them less effectual than the latter in many cases; but it is not unlikely that from the same circumstance they may be better adapted to others, and they derive from it no small advantage in being perfectly safe. A trial of them, though often attended with some inconvenience, never produces any serious bad effects.

In estimating the probable virtues of a mineral water, we must not attend so much to the mass of its solid contents as to the activity of these contents. Many waters in common use contain a much larger proportion of solid contents than some of the most powerful mineral waters. Of the ingredients found in mineral waters iron and Soda are among the most active; and the reader will observe from the foregoing table, that the difference of the quantities of these in the Malvern and Spa waters is not so great as of some other of their contents. The solid contents of the Buxton water, though rather

ther more than those of the Holy-well, may almost, perhaps, from the inactivity of their nature and their similitude to the contents of many waters in common use, be overlooked in explaining its effects. Writers have consequently, with great probability, attributed these effects to an air of a peculiar kind which it contains. The effects of the Tunbridge water, on the contrary, are attributed chiefly to its solid contents, although the whole of these, according to Dr. Babington's Analysis, amount only to 5 grs. in a wine gallon; about a third part of the solid contents of the Holy-well water. But one grain is calx of iron.

The sensible effects of the Malvern waters are different in different cases, and they are generally most felt on first using the waters. It is not uncommon for them to produce a degree of nausea, and they often prove aperient, sometimes considerably so; in many cases they produce the opposite effect on the bowels, so that some aperient medicine is necessary. When drank largely, particularly by those who are not accustomed to them, they frequently produce some vertigo, drowsiness, or even pain of the head. In some they produce a degree of feverish heat. I have known many instances in which it was necessary to lay aside the use of them on this account. The most constant of all their
sensible

sensible effects is that of a diuretic, and they seldom fail, after they have been used for some time, to encrease both the spirits and appetite.

To what part of their contents each of these effects are to be ascribed, it is difficult to say positively: many of them seem to arise from the iron they contain. That the increased heat proceeds from this cause cannot, I think, be doubted; and it is remarkable that many of the other effects which have been enumerated, are the same which attend the use of other chalybeates. Many of the effects of the Tunbridge water, for example, although more powerful in proportion as it is a stronger chalybeate, are similar to those just mentioned. It also produces nausea, drowsiness, and vertigo, which, as in the case of the Malvern waters, are most felt on first using it.

Dr. J. Wall's explanation of these effects, though ingenious, can hardly, I think, be admitted. He supposes that they arise from the great purity of this water, in consequence of which it enters the vessels very rapidly, and thus produces a temporary plethora. But it appears from all that has been said, that the Malvern waters, particularly the water of the Holy-well, are by no means so free from foreign contents as has been supposed. Besides, were this explanation just, distilled water ought to produce a greater degree of the same symptoms, which is not found to be the case.

The diuretic effect, probably one of the most beneficial effects of these waters, we cannot hesitate to ascribe to the carbonat of Soda, which has long been used in medicine for the purpose of producing this effect, although in the artificial forms in which it is given, it is seldom so effectual a diuretic as the Malvern waters are. In these it is doubtless assisted by the large quantity of water in which it is taken, probably by some other part of their contents. To this effect, and to the iron which the Malvern waters contain, we may partly ascribe the good appetite and spirits which attend their use. These must in some measure be ascribed to the pleasant situation, and the pure air of the Malvern hills. The quantity of the carbonats of lime and magnesia, and of the salts found in these waters, seems too small to permit us to attribute any of their sensible effects to them. They may perhaps modify the effects of the other ingredients in a way we do not understand.

I had occasion in the Introduction to mention the diseases in which the Malvern waters have been chiefly celebrated, namely, the various forms of scrophula, cutaneous diseases of different kinds, and gravel. In scrophula and cutaneous diseases, Soda and iron have long been celebrated medicines; and on Soda, in some form or other, we chiefly rely for relief in gravel.

The

The Malvern waters seem to be better adapted to the two former cases than to gravel, because they depend more immediately on the fault of the habit in general, in which we find that minute quantities of medicines, given frequently and for a considerable length of time, are often more efficacious than larger doses. Such, however, is the relief often obtained by these waters in gravel, probably in part from their acting merely as a diluent, and in part from the Soda they contain, that Dr. J. Wall thought they possessed the power of dissolving urinary concretions. "It is, perhaps, too much to expect," he observes, "that a formed stone can be dissolved by this water; but that fabulous matter may, I am fully convinced, from the effects I have observed in those who have used it." That it may tend to wash out sand lodged in the kidneys, and to prevent its formation, seems highly probable, and there is reason to believe that it has some degree of the effect of waters more strongly impregnated with Soda, which seem often to allay the irritation occasioned by urinary concretions, even where they have no effect in dissolving them. That a weak chalybeate impregnated with carbonat of Soda, which passes off so freely by the kidneys, should allay a variety of other disorders of the urinary passages, which Dr. J. Wall says he has found it to do, cannot appear surprising.

Wherever

Wherever there are fountains or eruptions, these waters should be used externally as well as internally. Indeed, like many other mineral waters, the Malvern waters were at first only used as an external application. Their good effects, employed in this way, are chiefly to be ascribed to the carbonate of Soda they contain; a simple solution of which, applied externally, has long been used as a remedy in the same diseases.

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