

Received December 11, 1766.

XI. *Experiments on Rathbone-Place Water :*
By the Hon. Henry Cavendish, F. R. S.

Read Feb. 19, 1767. **D**R. Lucas has given a short examination of this water in the first part of his treatise of waters. It is the produce of a large spring at the end of Rathbone-place, and used a few years ago to be raised by an engine for supplying part of the town. The engine is now destroyed ; but there is a pump, nearly in the same situation, which yields the same kind of water. It is the water of this pump, which was used in these experiments.

Most waters, though ever so transparent, contain some calcareous earth, which is separated from them by boiling, and which seems to be dissolved in them without being neutralized by any acid, and may therefore not improperly be called their unneutralized earth. The following experiments were made chiefly with a view of enquiring into the cause of the suspension of this earth, for which purpose this water seemed well adapted ; as it contains more unneutralized earth than most others.

These experiments were made towards the latter end of September 1765, after a very dry summer ; whereby the water was most likely more impregnated with saline and other matters than it usually is.

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The water, at the time I used it, looked rather foul to the eye. On exposing some of it for a few days to the open air, a scurf was formed on its surface, which was nothing else but some of the unneutralized earth separated from the water. On dropping into it a solution of corrosive sublimate, it grew cloudy in a few seconds; it quickly became opaque, and let fall a sediment. This is a property, which I believe does not take place, in any considerable degree, in most of the London waters.

EXPERIMENT I.

494 ounces of this water were distilled in a copper still, till about 150 oz. were drawn off. A good deal of earth was precipitated during the distillation, which being collected and dried, weighed 271 grains. It proved to be entirely a calcareous earth, except a small part, which was magnesia. This I found in the following manner. A little of this earth, being mixed with spirit of salt, dissolved entirely; which shews it to consist solely of an absorbent earth, but does not shew whether it is a calcareous earth or magnesia. The remainder was saturated with oil of vitriol: a great deal of matter remained undissolved, which, as the earth was shewn to be entirely of the absorbent kind, must have been selenite, or a calcareous earth saturated with the oil of vitriol. The clear liquor strained from off the selenite yielded on evaporation only eighteen grains of solid matter, which proved to be Epsom salt; so that all the earth, except that contained in the eighteen grains of Epsom salt, must have been of the calcareous kind. That contained in the Epsom salt is well known to be magnesia.

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The water remaining after distillation, and from which the earth was separated, was evaporated, first in a silver pan, and afterwards in a glass cup, till it was reduced to about three ounces. Not the least earth was precipitated during the evaporation, till it was reduced to a small quantity; there then fell 39 grains, which were entirely selenite: so that all the unneutralized earth in the water was separated during the distillation. The liquor thus evaporated was of a reddish colour, like an infusion of foot.

Many waters contain a good deal of neutral salt composed of the nitrous acid united to a calcareous earth; the most convenient way of ascertaining the quantity of which, is to drop a solution of fixed alkali into the evaporated water, till all the earth is precipitated; whereby this salt is changed into true nitre, and is capable of being crystallized. For this reason, some fixed alkali was dropt into the evaporated water till it made no farther precipitation. The earth precipitated thereby weighed thirty-six grains, and was entirely magnesia. The liquor was then farther evaporated, but no nitre could be made to shoot: being then evaporated to dryness, it weighed 256 grains. It gave not the least signs of containing any nitrous salt, either by putting some of it upon lighted charcoal, or by making a match with a solution of it, but appeared to be a mixture of sea salt and vitriolated tartar, or some other salt composed of the vitriolic acid. As I have heard of no other London water, that has been examined with this view, but what has been found to contain a considerable proportion of nitrous salt, it seems very remarkable that this should be intirely destitute of it. I now proceed

proceed to the experiments made on the distilled water.

The distilled water, especially that part of it which came over first, became opaque, and let fall a precipitate, on dropping into it a solution of sugar of lead. It also became opaque by the addition of corrosive sublimate, much in the same manner that the plain water did before distillation.

It was found, by dropping into it a little acid of vitriol and committing it to evaporation, to contain a small quantity of volatile alkali; as it left four grains of a brownish salt, which being re-dissolved in water, yielded a smell of volatile alkali on the addition of lime. It is doubtless this volatile alkali, which is the cause of the precipitate, which the distilled water makes with sugar of lead and corrosive sublimate.

What first suggested to me that the distilled water contained a volatile alkali, was the distilling some of it over again in a retort; whereby the first runnings were so much impregnated with volatile alkali, as to turn paper dyed with the juice of blue flowers, to a green colour, and in some measure to yield a smell of volatile alkali.

In the foregoing experiment, the salt procured from the distilled water was perfectly neutral; so that the quantity of acid employed was certainly not more than sufficient to saturate the alkali, but it may very likely have been less; as in that case the superfluous volatile alkali would have flown off in the evaporation. The following experiment shews pretty nearly the quantity of volatile alkali in the distilled water.

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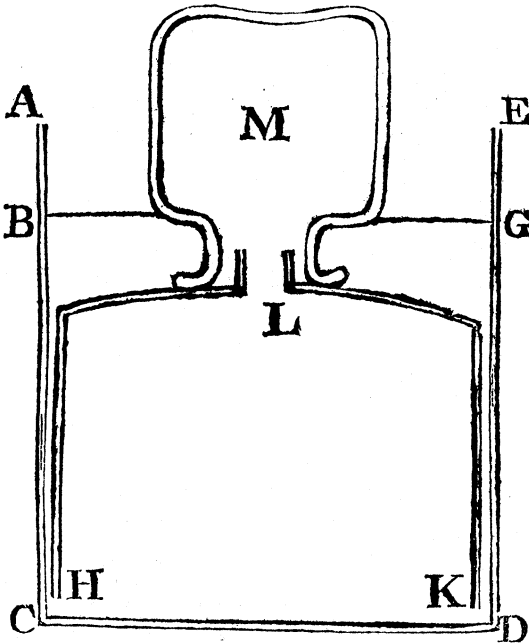
EXPERIMENT II.

1128 ounces of Rathbone-place water were distilled in the same manner as the former. The distilled water was divided into two parcels, that parcel which came over first weighing 121 ounces, the other 146. A preparatory experiment was first made, in order to form a judgement of the comparative strength of each parcel, and also of the quantity of acid which it would require to saturate them. This was done by dropping sugar of lead into each parcel till it ceased to make a precipitate. It was judged from hence that the first parcel contained about $2\frac{1}{2}$ times as much volatile alcali as an equal quantity of the second. Into 30 ounces of the first parcel, mixed with as much of the second, was then put 43 grains of oil of vitriol, which was supposed to be about $\frac{1}{2}$ more than sufficient to saturate the alcali therein. The mixture was then evaporated. When reduced to a small quantity, it was found to be rather acid: sixteen grains of volatile sal ammoniac were therefore added, which seemed nearly sufficient to neutralize it. Being then evaporated to dryness, it left sixty-six grains of a brownish salt, which dissolved readily in water, leaving only a trifling quantity of brown sediment. A little of this salt was found to make no precipitate on the addition of fixed alcali, and the remainder, being boiled with lime, was converted into selenite; a sure sign that the salt was merely vitriolic ammoniacal salt. The volatile alkaline salt contained in sixty-six grains of vitriolic ammoniacal salt is $58\frac{1}{2}$ grains; from whence deducting sixteen grains, the weight of the volatile sal ammoniac added, it appears that the distilled
water

water used in this experiment contains $42\frac{1}{2}$ grains of volatile salt; and therefore the whole quantity of volatile salt driven over by distillation seems to be about sixty-eight grains, which, as the second parcel was so much weaker than the first, is probably nearly the whole volatile alkali contained in the water.

EXPERIMENT III.

Dr. Brownrig, in a paper printed in the Philosophical Transactions, for the year 1765, shews that a great deal of fixed air is contained in Spa water. This induced me to try whether I could not find any in that of Rathbone-place; which I did by means of the contrivance represented in the drawing.



ACDE represents a tin pan, filled with Rathbone-place water as high as BG. HKL is another tin pan, within the first, in the manner of an inverted funnel, and made in such a manner as to leave as little room as possible between that and the sides of the outward vessel. M represents a bottle, full of the same water, inverted over the mouth of the funnel. By this means, as fast as the air is disengaged by heat from the water within the funnel, it must necessarily rise up into the bottle. The Rathbone-place water, put into the vessel, weighed 411 ounces, the funnel held 353 ounces. A bottle full of water being inverted over the mouth of the funnel, as in the figure, the water was heated, and kept boiling about $\frac{1}{4}$ of an hour. As soon as one bottle was filled with air, it was removed by putting a small ladle under its mouth, while under water, and set with its mouth immersed in the same manner in another vessel of water, taking care not to suffer any communication between the included air and the outward air during the removal. At the same time, another bottle full of water was inverted over the mouth of the funnel, in the same manner as the former. It was not easy telling how much air was discharged from the water; as the air in the bottles, when first removed, was hot and expanded; and, before I could be sure it was cold, there was some of it absorbed by the water: but there seemed to be above 75 ounce measures discharged, scarce twenty of which arose before the water began to boil. The water continued discharging air after the experiment was discontinued. In about a day's time, much the greatest part of the air was absorbed, scarce sixteen ounce measures remaining. That which was absorbed appeared to be fixed air, as the water which had absorbed

absorbed it made a precipitate with lime-water. But, in order to absorb all the fixed air more perfectly, the air which remained not absorbed was transferred into another bottle of water, in the manner described in my first paper on factitious air, page 142 of the preceding volume. This bottle was then set with its mouth immersed in a bottle of sope-leys; after which, by shaking the bottle, the sope-leys was mixed with the included water; whereby the air in the bottle was brought in contact with the sope-leys, which is well known to absorb fixed air very readily. By this means the air was reduced to $8\frac{3}{4}$ ounce measures. A small vial being filled with equal quantities of this and inflammable air, and a piece of lighted paper applied to its mouth, it went off with as loud a bounce, as when the same vial was filled with equal quantities of common air and inflammable air. The specific gravity of the remainder was tried by a bladder, in the manner described in the above-mentioned paper; as well as could be judged from so small a quantity, it was just the same as that of common air. From these two circumstances, I think we may fairly conclude that this unabsorbed part was intirely common air; consequently the air discharged from the Rathbone-place water consisted of $8\frac{3}{4}$ ounces of common air and about 66 of fixed air. The air which was discharged before the water began to boil contained much more common air, than that which was discharged afterwards; that which was discharged towards the latter end seeming to contain scarce any but fixed air.

As so much fixed air is discharged from this water by boiling, it seemed reasonable to suppose, that the distilled water should contain fixed air. I accordingly found it to make a precipitate with lime-water.

EXPERIMENT IV.

The following experiment shews that the fixed air was not generated during the boiling, but was contained in the water before. Into 30 ounces of Rathbone-place water was poured some lime-water, which immediately made a precipitate. More lime-water was added, till it ceased to make any farther precipitate. It required $20\frac{1}{4}$ ounces. The precipitated earth being dried weighed 39 grains.

The unneutralized earth contained in 30 ounces of Rathbone-place water is $16\frac{1}{2}$ grains, and the earth contained in $20\frac{1}{4}$ ounces of lime-water (as was found by precipitating the earth by volatile sal ammoniac) is 21 grains. Therefore the earth precipitated from the mixture of Rathbone-place water, and lime-water, is about equal to the sum of the weights, of the earth contained in the lime-water, and of the unneutralized earth in the Rathbone-place water; and consequently all the unneutralized earth seems to be precipitated from Rathbone-place water by the addition of a proper quantity of lime-water. But a more convincing proof that this is the case, is that the clear liquor, after the precipitate had subsided, did not deposit any earth on boiling, or become in the least cloudy on the addition of fixed alkali; whereas Rathbone-place water in its natural state becomes opake thereby. It might perhaps be expected, that the clear liquor should still make a precipitate on the addition of fixed alkali, though the unneutralized earth is precipitated; as in all probability there is still a good deal of earth remaining in it in a neutralized state. The reason why it does not, seems to be, that the remaining earth is most likely intirely magnesia; and Epſom salt,

salt, when dissolved in a great quantity of water, does not make any precipitate on the addition of fixed alkali.

There is great reason to suppose that the earth precipitated on mixing the Rathbone-place water and lime-water, was very nearly saturated with fixed air, i. e. that it contained very near as much fixed air, as is naturally contained in the same quantity of calcareous earth. If so, 30 ounces of Rathbone-place water contain as much fixed air as 39 grains of calcareous earth; whereas the unneutralized earth, in that quantity of water, is only $16\frac{1}{2}$ grains; so that Rathbone place water contains near $2\frac{1}{3}$ times as much fixed air as is sufficient to saturate the unneutralized earth in it.

It seems likely from hence, that the suspension of the earth in the Rathbone-place water, is owing merely to its being united to more than its natural proportion of fixed air; as we have shewn that this earth is actually united to more than double its natural proportion of fixed air, and also that it is immediately precipitated, either by driving off the superfluous fixed air by heat, or absorbing it by the addition of a proper quantity of lime water.

Calcareous earths, in their natural state, i. e. saturated with fixed air, are totally insoluble in water; but the same earths, entirely deprived of their fixed air, i. e. converted into lime, are in some measure soluble in it; for lime-water is nothing more than a solution of a small quantity of lime in water. It is very remarkable, therefore, that calcareous earths should also be rendered soluble in water, by furnishing them with more than their natural proportion of fixed air, i. e. that they should be rendered soluble, both by depriving them of their fixed air,
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and by furnishing them with more than their natural quantity of it. Yet, strange as this may appear, the following experiments, I think, shew plainly that it is the real case.

EXPERIMENT V.

In order to see whether I could suspend a calcareous earth in water, by furnishing it with more than its natural proportion of fixed air, I took 30 ounces of rain water, and divided it into two parts: into one part I put as much spirit of salt, as would dissolve $30 \frac{3}{10}$ grains of calcareous earth, and as much of a saturated solution of chalk, in spirit of salt, as contained 20 grains of calcareous earth: into the other part I put as much fixed alkali, as was equivalent to $46 \frac{8}{10}$ grains of calcareous earth, i. e. which would saturate as much acid. This alkali was known to contain as much fixed air as 39 grains of calcareous earth. The whole was then mixed together and the bottle immediately stopped. The alkali was before said to be equivalent to $46 \frac{8}{10}$ grains of calcareous earth, and was, therefore, sufficient to saturate all the spirit of salt, and also to decompose as much of the solution of chalk as contains $16 \frac{1}{2}$ grains of earth. This mixture, therefore, supposing I made no mistake in my calculation, contained $16 \frac{1}{2}$ grains of unneutralized earth, with as much fixed air as is contained in 39 grains of calcareous earth; which is the quantity which was found to be in the same quantity of Rathbone place water. The mixture became turbid on first mixing, but the earth was quickly re-dissolved on shaking, so that the liquor became almost transparent. After standing some time, a slight sediment fell to the bottom, leaving the liquor perfectly transparent.

transparent. The mixture was kept three or four days stopped up, during which time it remained perfectly clear, without depositing any more sediment. The clear liquor was then poured off from the sediment, and boiled for a few minutes, in a Florence flask; it grew turbid before it began to boil, and discharged a good deal of air; some earth was precipitated during boiling, which being dried weighed 13 grains.

This shews that there was really, at least 13 grains of earth suspended in this mixture, without being neutralized by any acid; the suspension of which could be owing only to its being united to more than its natural proportion of fixed air. But, as a further proof of this, I made the following experiment.

EXPERIMENT VI.

I took the same quantities of rain water, solution of chalk, spirit of salt, and fixed alkali, as in the last experiment, but mixed them in a different order. The fixed alkali was first dropped into the spirit of salt, and when the effervescence was over, was diluted with $\frac{1}{2}$ the rain water. The solution of chalk was then diluted with the remainder of the rain water, the whole mixed together, and the bottle immediately stopped, and shook vehemently. A precipitate was immediately formed on mixing, which could not be re-dissolved on shaking.

It must be observed, that, in the first of the two foregoing experiments, all the fixed air contained in the alkali was retained in the mixture, none being lost by effervescence; whereas, in the last experiment, the greatest part of the fixed air was dissipated in the effervescence; no more being retained than
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what was contained in that portion of the fixed alkali, which was not neutralized by the acid; and consequently the unneutralized earth, in the mixture, contained not much more fixed air than what was sufficient to saturate it. As the latter of these mixtures differed no otherwise from the former, than that it contained less fixed air; the suspension of the earth in the former must necessarily be owing to the fixed air.

In the two foregoing experiments the water contained, besides the unneutralized earth, and fixed air, some sal sylvii, and a little solution of chalk in the marine acid; which, it may be supposed, contributed to the suspension of the earth: but the following experiment shews that a calcareous earth may be suspended in water, without the addition of any other substance than fixed air.

EXPERIMENT VII.

A bottle full of rain water was inverted into a vessel of rain water, and some fixed air forced up into the bottle, at different times, till the water had absorbed as much fixed air as it would readily do; 11 ounces of this water were mixed with $6\frac{1}{4}$ of lime water. The mixture became turbid on first mixing, but quickly recovered its transparency, on shaking, and has remained so for upwards for a year.

This mixture contains 7 grains of calcareous earth; and, from a subsequent experiment, I guess it to contain as much fixed air, as there is in 14 grains of calcareous earth.

EXPERIMENT VIII.

Least it should be supposed, that the reason why the earth was not precipitated in the foregoing experi-

ment, was, that it was not furnished with a sufficient quantity of fixed air, the following mixture was made, which contains the same proportion of earth as the former, but a less proportion of fixed air: $4\frac{3}{4}$ ounces of the above-mentioned water, containing fixed air, were diluted with $6\frac{1}{4}$ of rain water, and then mixed with $6\frac{1}{2}$ ounces of limewater. A precipitate was immediately made on mixing, which could not be re-dissolved on shaking.

EXPERIMENT IX.

I made some experiments to find whether the unneutralized earth could be precipitated from other London waters, by the addition of lime water, as well as from Rathbone-place water. It is necessary for this purpose, that the quantity of lime water should be adjusted very exactly; for, if it is too little, it does not precipitate all the unneutralized earth; if it is too great, some of the earth in the lime water remains suspended. For this reason, as I found it almost impossible to adjust the quantity with sufficient exactness, I added such a quantity of lime water, as I was well assured, was more than sufficient to precipitate the whole of the unneutralized earth; and when the precipitate was subsided, decanted off the clear liquor, and exposed it to the open air, till all the lime remaining in the water was precipitated, by attracting fixed air from the atmosphere. The clear liquor was then decanted and evaporated, which is much the most exact way I know of seeing whether any unneutralized earth remains suspended in the water. The result of the experiments was as follows:

200 ounces of water, from a pump in Marlborough-street, were mixed with 38 ounces of lime water. The earth precipitated thereby weighed 38 grains. The clear liquor, exposed to the air, and evaporated in a silver pan till it was reduced to 6 or 7 ounces, deposited no more than 2 or 3 grains of unneutralized earth.

A like quantity of the same pump water, evaporated by itself without the addition of lime water, deposited about 19 grains of unneutralized earth.

200 ounces of water, from a pump in Hanover-square, being mixed with 67 ounces of lime water, the precipitate weighed 93 grains. The clear liquor, treated in the same way as the former, deposited about 2 grains of earth. 200 ounces of the same water, evaporated by itself, deposited 28 grains of earth.

The same quantity of water from a pump in St. Martin's church-yard, being mixed with 82 ounces of lime water, the precipitate weighed 108 grains. The clear liquor deposited scarce any unneutralized earth on evaporation.

The same quantity of water, evaporated by itself, yielded 45 grains of unneutralized earth.

The way, by which I found the quantity of unneutralized earth deposited on evaporation, was, after having decanted the clear liquor, and washed the residuum with rain water, to pour a little spirit of salt into the silver pan, which dissolves all the calcareous earth, but does not corrode the silver. Then, having separated the solution from the insoluble matter, the earth was precipitated by fixed alkali.

In this way of finding the quantity of unneutralized earth, care must be taken to add very little more acid

acid than is necessary to dissolve the unneutralized earth, and to use as little water in washing out the solution as possible; for otherwise a good deal of the selenite, which is deposited in the evaporation of most water, will be dissolved; the earth of which will be precipitated by the fixed alkali, and by that means make the quantity of unneutralized earth appear greater than it really is.

It appears from these experiments, that the unneutralized earth is entirely precipitated from these three waters, by the addition of a proper quantity of lime water; as the trifling quantity found to be deposited, on the evaporation of two of them, most likely proceeded only from not exposing the water to the air, long enough for all the lime to be precipitated. So that I think it seems reasonable to conclude, that the unneutralized earth, in all waters, is suspended merely by being united to more than its natural proportion of fixed air.

To return to Rathbone-place water; it appears from the foregoing experiments, that one pint of it, or 7315 grains, contains, first, as much volatile alkali as is equivalent to about $\frac{9}{10}$ grains of volatile sal ammoniac: secondly, $8\frac{4}{10}$ grains of unneutralized earth, a very small part of which is magnesia, the rest a calcareous earth: thirdly, as much fixed air, including that in the unneutralized earth, as is contained in $19\frac{8}{10}$ grains of calcareous earth: fourthly, $1\frac{2}{10}$ of selenite: fifthly, $7\frac{9}{10}$ of a mixture of sea salt, and Epsom salt; and the whole solid contents of 1 pint of the water is $17\frac{1}{2}$ grains.

One pint of water, from the pump in Marlborough-street, contains $1\frac{4}{10}$ grains of unneutralized

earth, and as much fixed air as is contained in $2 \frac{2}{10}$ grains of calcareous earth.

The same quantity of water, from the pump in Hanover-square, contains $2 \frac{1}{10}$ grains of unneutralized earth, with as much fixed air as is contained in $7 \frac{2}{10}$ of earth.

The same quantity of water, from St. Martin's Church-yard, contains $3 \frac{4}{10}$ grains of unneutralized earth, with as much fixed air as is contained in $8 \frac{2}{10}$ of earth.

Received November 18, 1766.

XII. *Description of a Meteor seen at Oxford, October 12, 1766. In a Letter to Charles Morton, M. D. Sec. R. S. from the Rev. John Swinton, B. D. F. R. S. Member of the Academy degli Apatisti at Florence, and of the Etruscan Academy of Cortona in Tuscany.*

Dear Sir,

Read Feb. 26, 1767. **T**HE Reverend Dr. Sharp coming into Christ-Church common-room out of the great quadrangle, on Saturday, October 12, 1765, about 8^h 30' P. M. informed the company there, that he had seen some remarkable *Auroræ Boreales* a few minutes before. But, as such phænomena