

consequently the angles $AE B$ and $CF D$ are equal. That is, the angle subtended by the distance of the centers of the segments from the distance of the focus of parallel rays is equal to the angle subtended by the distance between the objects A and B from the end of the telescope.

XXVIII. *A Letter to Sir Peter Thompson; Knt: F. R. S. containing Experiments on the Copper Springs in Wicklow in Ireland, and Observations thereon, by John Bond, M. D.*

S I R,

Read May 10,
1753.

YOU may remember I had the honour of spending an evening with you in June last, and happen'd to mention a spring in the county of Wicklow in Ireland, which was supposed to have the surprising quality of changing iron into copper. But your constant love of truth, and strong aversion to vulgar errors, made you doubt the fact, which, at that time, I could only affirm on the report, which prevailed among the curious in that country. You then proposed several judicious queries, and seemed desirous of being further informed concerning it, which raised my curiosity to take the first opportunity of inquiring more particularly into the foundation of that marvellous account.

Having soon afterwards occasion to go to Dublin, I went to the spring, which is from thence about thirty-eight miles, and made several experiments on the
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the water ; the result of which I beg leave to present you with, hoping it may afford you some satisfaction in explaining that process, of which you so justly doubted the account given by some credulous authors, who mistook it for a real transmutation ; a ridiculous doctrine, which destroys the essential qualities of bodies, which were impressed by the Great Creator on all material substances, in order to distinguish them from each other, and therefore are intransmutable.

As the history of this discovery has already been accurately related, in several papers read before the Royal Society, of which you have the honour of being a worthy member, I shall endeavour to avoid repetition, and confine myself to the chemical analysis of the water, which, I am told, has been hitherto omitted.

This water flows from a rich copper mine, and is of a sharp acid taste, and light-blue colour. It is received and collected in pits, wherein iron bars are put, which, after lying in the water about three months, are intirely consumed, and at the bottom of the pits, a quantity of copper, greater than that of the iron is found, in the form of coarse sand. This fact is confirmed by profitable experiments, often repeated since the discovery, the honour of which is due to Mr. Matthew Johnston, a worthy old gentleman, and one of the proprietors of the mine, who first proposed this method of collecting the copper.

As this effect is certainly produced by some active principle in the water, I shall first inquire, what this principle is, and mention particularly the experiments, which I made with this view, that you may the better judge of the inferences deduced from them.

Experiment 1.

Into some of this water, taken out of the stream above the pits where the iron bars are placed, I pour'd a solution of an alkaline salt, which rais'd a strong effervescence, and precipitated a large quantity of a dark brown substance.

Corollary. This experiment shew'd, that the water contain'd a strong acid, with a solution of the substance precipitated.

Experiment 2.

I put some aqua-fortis, or spirit of nitre, into some water taken out of the same place; and observed, that the strong acid immediately destroy'd the blue colour.

Corollary. From this experiment we may conclude, that the substance, which was precipitated by the alkali in the first experiment, was so perfectly dissolved by the acid spirit in the second, as to transmit all the rays of light.

Experiment 3.

Some small iron nails put into this water were in four minutes so closely cover'd with some substance of a copper colour, that, with a magnifier of half an inch focus, I could not discern the iron through it. In that time the nails gained four grains. The water had the same effect on silver and tin, but not on gold.

Corollary. The colour and increase of weight were owing to the adhesion of the particles of the matter dissolved in the water by an acid, that could not penetrate gold.

Experiment

Experiment 4.

In order to determine the quantity and quality of the matter in the water, I put two drachms of small iron nails into three ounces of it, and let them stand twenty-four hours; then examin'd, and found the surface of the water cover'd with a thick scum, like that of a chalybeat Spa. It lost the blue colour, and sharp vitriolic taste. It was quite transparent, and at the bottom there was a quantity of a brown ponderous powder, which, when dried, weigh'd 14 grains. This powder, melted without any flux, produced 12 grains of pure copper. The nails lost 8 grains in the water, and were, in several places, cover'd with a solid lamina of pure copper. The water, in which the nails lay, after being filtrated and evaporated, afforded a green vitriol, which in every respect resembled *sal Martis*, and produced the same effects, when dissolved, and mix'd with any astringent tincture.

Experiment 5.

From the spring-water treated in the same manner, I obtain'd a blue vitriol, the basis of which is copper.

From all these experiments it appears, that a mineral acid is the active quality in this water; which being diffused thro' the copper ore, unites itself with that metal, and forms a vitriol, which is dissolved by the water, and remains suspended in it, till it meets with iron in the pits, by which this acid is more strongly attracted than by the copper, therefore

fore it quits the copper, corrodes the iron, and changes it into a vitriol, which is again dissolv'd, and carried off in the stream continually flowing from the pits; whilst the copper, deserted by the acid, falls, by its specific gravity, to the bottom of the pits.

By this account it is evident, that this admirable process is a simple precipitation of the copper, by means of the iron. Hence it has been improperly called a transmutation of iron into copper. But, lest any difficulty should still remain, concerning the consumption of the large quantities of iron put into the pits, I shall add the following observations, to shew, that it is dissolved and carried off in the water.

Observation 1. The water in the pits is cover'd with a thick scum, occasion'd by the air-bubbles constantly rising, and bursting on the surface; which is an evident sign of the solution of the iron.

Obs. 2. The iron is gradually consum'd in the pits, and abounds with irregular depressions, like old iron: a strong symptom of its being corroded by an acid.

Obs. 3. The chanel of the stream running from the pits is furr'd with red oker, which, after being roasted in a strong fire, was attracted by the magnet. As this oker is only found in the stream below the pits, it appears to be part of the iron dissolv'd in the water.

Obs. 4. The quantity of copper found in the pits, after the iron disappears, is generally greater than that of the iron when first put in: for the proprietors assured me, that sometimes a ton of iron will produce, or rather precipitate, a ton and half of copper.

This fact alone would be sufficient to prove, that the iron is not converted into copper; since, according to Sir Isaac Newton's table, the specific gravity of copper is to that of iron as 9000 to 7644.

When I was at this spring in August last, it ran at the rate of 12 ounces every second; and by putting iron into the water of the stream running from the pits, I found, that every ounce contained three grains of copper. Hence by calculation it appears, that 129600 grains of copper are carried off every minute, and consequently 124100 pounds Troy weight in a year; supposing the quantity and quality of the water to continue the same.

Hence we may easily account for the death of the fish, and other phænomena in the river, which receives this vitriolic stream.

In a hot sunny day, when the water is exhaled, the heaps of mold, raised out of the ore-pits, are covered with a vitriolic efflorescence: hence, in rainy weather, the water appears like a strong solution of verdegrise.

Whoever is desirous to imitate the process carried on in these pits, may readily gratify his curiosity, by putting pieces of iron into strong solutions of vitriol.

It is a common experiment, to tinge polish'd iron, by rubbing it with Roman vitriol; which depends on the cause before-mention'd; viz. the acid in the vitriol penetrates the iron, and leaves the copper on the surface. This experiment is also taken notice of by that excellent chemist, and celebrated philosopher, Mr. Boyle, who calls it a *sympathetic precipitation*, in his *Essay on specific Medicines*.

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As soon as the attraction between the copper and the acid ceases, the mutual attraction between the minute particles of the metal prevails, so as to form large solid masses at the bottom of the pits, nineteen twentieths of which are pure copper. These solid masses are partly occasion'd by the pressure of the incumbent heap of granulated copper, constantly increasing.

Hence we see, that the art of assaying, or separating metals from their ores, chiefly consists in evaporating an acid, which prevents the mutual attraction of the metallic particles: for when the acid is driven off by the violence of fire, the particles fall into their proper sphere of attraction, and assume a solid form.

From what has been offer'd on the theory of this admirable process, several practical hints may be taken to render such springs more profitable; and perhaps an easier method may be discover'd of separating copper from its ore, by precipitation, than by calcination. But such improvements I refer to those more conversant in the practice of metallurgy.

Having, I hope, given a satisfactory account of the effects of this water on iron, and proved, that it is owing to a strong mineral acid, which it contains, I should next inquire into the source of this acid; but am anticipated in that conjectural research by many inquisitive gentlemen, who have penetrated deeper into the bowels of the earth, and discover'd, or rather taken for granted, a vague acid, which, they say, is diffused thro' the whole mineral kingdom, and being united with different mineral substances, forms vitriols of different kinds. This hypothesis appears the more

probable, since it is allow'd by modern chemists, that all acid spirits, tho' extracted from different minerals, produce the same effects, and consequently are of the same nature, the spirit of sea salt only excepted, which alone dissolves gold.

Since vast quantities of sulphur are found in this mine, mix'd with the copper-ore, it is probable, that the acid of the sulphur is attracted by the copper, and formed into a vitriol, which is afterwards dissolved by the water.

A farther inquiry into the origin of this acid, I leave to those curious gentlemen, who have solv'd the phenomena of volcano's, earthquakes, hot-springs, &c. from its effects.

The ingenious Dr. Robinson has lately illustrated this doctrine of acids *, by proving, that an acid and light are the same thing: for he infers, from Sir Isaac Newton's philosophy, that whatever attracts, or is much attracted, is light: therefore an acid is light.

This spring perhaps is as remarkable for its medicinal as its metallic qualities. Tho' physicians generally reckon copper taken internally poisonous, yet the miners and other people drink this water frequently, without any ill consequences. It purges and vomits severely, and is become their specific in several diseases, particularly in cutaneous eruptions, arising either from an alkaline acrimony in the blood, which stimulates the sensible extremities of the cutaneous arteries, and occasions a pustule, or from the irritation of insects lodg'd in the skin; both which causes may be removed

* See his Essay on the Operations of Medicines.

removed by the strong acid in this water. It is an excellent detergent for scorbutic ulcers, as Hoffman justly observes. It has already perform'd several remarkable cures of this kind. I have often recommended it in such cases with success, join'd with proper internal medicines; for I am no friend to specifics.

How far the success of practice of the miners, who drink it frequently, may be depended on, longer experience must determine. Certainly, a great allowance must be made for the strength of their constitutions, and the insensibility of their nerves, constantly exposed to the noxious steams of damp pits. I never ventur'd to prescribe it internally; and as the *materia medica* affords vomits and purges of a more innocent kind, I think it in that respect unnecessary. I have reason to imagine, from the effects, which this water had on some earth-worms, that it is a very powerful anthelmintic, if cautiously given.

Some fresh filings of iron, put in this water, soon precipitate all the copper, and make it a strong and agreeable chalybeat. Hence it may be us'd as a substitute to Spa-water, whose virtue depends on the iron. Some prepared filings of iron remain'd eight days in this water; without producing the least alteration. Hence it appears, that this medicine can have but a weak effect, if any at all, in absorbing acids in the first passages.

Thus having communicated all, that at present occur'd to me, relating to this spring; if these observations render the history of it more perfect, and in the least contribute to gratify that laudable curiosity, which you always shew, in removing prejudices, rectifying

redifying mistakes, and encouraging every branch of useful knowlege, I shall think my time well employ'd in this inquiry, which had its rise from your instructive conversation. I am, with the highest respect,

S I R,

London, April 15,
1753.

Your most obedient, and
most humble servant,

John Bond.

XXIX. *A Letter from Dr. Bevis to Mr. James Short, F. R. S. concerning Mr. Gascoigne's Invention of the Micrometer.*

Dear Sir,

Read May 17,
1753.

ALTHOUGH Mr. Townley, in his letter to Dr. Croon, printed in the *Philosophical Transactions*, N^o 25, p. 457, has sufficiently made appear, that the invention of the micrometer was Mr. Gascoigne's, and that he applied it to measuring small angles in the heavens, and for settling the moon's parallax, long before Messieurs Auzout and Picard thought of any such matters; yet are the French astronomers at every turn for giving it to these their countrymen, without so much as once mentioning the name of Mr. Gascoigne.

No sooner had the late Dr. Derham restor'd the application of telescopic sights to quadrants to its true author Mr. Gascoigne, than M. de la Hire, who never made the doctor any reply on that head, took occasion,