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# PHILOSOPHICAL

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## PART I.

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MDCCCIII.

# XII. *Enquiries concerning the Nature of a metallic Substance lately sold in London, as a new Metal, under the Title of Palladium. By* Richard Chenevix, *Esq. F. R. S. and M. R. I. A.*

Read May 12, 1803.

On the 29th of April I learned, by a printed notice* sent to Mr. Knox, that a substance, which was announced as a new metal, was to be sold at Mr. Forster's, in Gerrard-street. The mode adopted to make known a discovery of so much importance, without the name of any creditable person except the vender, appeared to me unusual in science, and was not calculated to inspire confidence. It was therefore with a view to detect what I conceived to be an imposition, that I procured a specimen, and undertook some experiments to learn its properties and nature.

* "Palladium, or new silver, has these properties amongst others that shew it to "be a new noble metal.

"1. It dissolves in pure spirit of nitre, and makes a dark-red solution. 2. Green "vitriol throws it down in the state of a regulus from this solution, as it always does "gold from aqua regia. 3. If you evaporate the solution, you get a red calx that dis- "solves in spirit of salt or other acids. 4. It is thrown down by quicksilver, and by "all the metals but gold, platina, and silver. 5. Its specific gravity by hammering, "was only 11.3; but by flatting, as much as 11.8. 6. In a common fire, the face of "it tarnishes a little, and turns blue, but comes bright again, like other noble metals, "on being stronger heated. 7. The greatest heat of a blacksmith's fire would hardly "melt it; 8. But, if you touch it, while hot, with a small bit of sulphur, it runs as "easily as zinc.

"It is sold only by Mr. Forster, at No. 26, Gerrard-street, Soho, London; in "samples of five shillings, half a guinea, and one guinea each."

I had not proceeded very far, when I perceived that the effects produced by this substance, upon the various tests, were such as could not be referred, *in toto*, to any of the known metallic substances. I immediately returned to Mr. FORSTER, and became possessed of the whole quantity which had been left in his hands for sale. I could not obtain any information as to its natural state, or any trace that might lead to a probable conjecture.

The substance had been worked by art: it had been rolled out in flatting-mills; and was offered for sale in specimens consisting of thin laminæ. The largest of them were about three inches in length, and half an inch in breadth, weighing on the average 25 grs. and were sold for one guinea. The other laminæ were smaller, in proportion to the price.

Subjected to the same treatment as platina, to procure a polished surface, palladium assumed an appearance scarcely to be distinguished from that metal. The laminæ were not very elastic, but were very flexible, and could be bent several times in opposite directions without breaking. The specific gravity, I found to differ not a little from that which is stated in the printed notice, and to vary considerably in different specimens. Some pieces of the substance were as low as 10,972, while others gave 11,482.

The effects of GALVANIC electricity upon palladium, were the same as upon gold and silver. No oxidizement of the substance took place; but oxygen gas was emitted, during the whole time it formed a part of the GALVANIC circle in action.

A lamina of this substance being exposed to the blowpipe, the side removed from the immediate action of the flame became blue; but the temperature at which this colour was produced, exceeded that at which steel begins to lose the tinge it had received at a lower heat.

I exposed palladium, in an open vessel, to a greater degree of heat than that which can melt gold. No oxidizement ensued; and, although the metallic slip was extremely thin, no appearance of fusion took place, even at the edges or corners. Upon increasing the fire considerably, I obtained a melted button; but I cannot estimate the degree at which the fusion was effected.

The button, by this treatment, had lost a little of its absolute weight; but its specific gravity had increased from 10,972 to 11,871. It was of a grayish-white. Its hardness was rather superior to that of wrought iron. By the file, it acquired the colour and brilliancy of platina. It was malleable to a great degree. Its fracture was fibrous, and in diverging striæ, which seemed to be composed of crystals; the surface of the button also, when seen through a lens, appeared to be crystallized.

Palladium very readily combines with sulphur. I exposed a certain quantity of it to a violent heat, without being able to melt it; and, at that elevated temperature, threw some sulphur upon it. It immediately entered into fusion, and remained in that state until the redness of the crucible was hardly visible in the daylight. The increase of weight in the button of the sulphuret, was such as could not indicate with exactness the proportion of sulphur combined with it; and I was so limited in the quantity of palladium I could obtain on any terms, that I thought it prudent to reserve as much as possible for the investigation of more important properties. Sulphuret of palladium is rather whiter than the substance itself, and is extremely brittle.

Palladium, melted in a charcoal crucible, and kept in fusion for fifteen minutes, did not acquire any properties different from those which I have already mentioned, in speaking of the effect of heat upon that substance. Hence we may conclude, that there is not any action between charcoal and palladium.

I put equal parts of palladium and gold into a crucible, for the purpose of forming an alloy. The result, owing to an accident, did not weigh so much as the sum of the quantities employed; therefore, the proportions in this alloy were uncertain. Its colour was gray; its hardness about equal to that of wrought iron. It yielded to the hammer; but was less ductile than each metal separate, and broke by repeated percussions. Its fracture was coarse-grained, and bore marks of crystallization. Its specific gravity was 11,079.

Equal parts of platina and palladium, entered into fusion at a heat not much superior to that which was capable of fusing palladium alone. In colour and hardness, this alloy resembled the former; but it was rather less malleable. Its specific gravity, I found to be 15,141.

Palladium, alloyed with an equal weight of silver, gave a button of the same colour as the preceding alloys. This was harder than silver, but not so hard as wrought iron; and its polished surface was somewhat like platina, but whiter. Its specific gravity was 11, 290.

The alloy of equal parts of palladium and copper was a little more yellow than any of the preceding alloys, and broke more easily. It was harder than wrought iron; and, by the file, assumed rather a leaden colour. Specific gravity 10,392.

Lead increases the fusibility of palladium. An alloy of these metals, but in unknown proportions, was of a gray colour, and its fracture was fine-grained. It was superior to all the former in hardness, but was extremely brittle. I found its specific gravity to be 12,000.

Equal parts of palladium and tin gave a grayish button, inferior in hardness to wrought iron, and extremely brittle. Its fracture was compact and fine-grained. Specific gravity 8,175.

With an equal weight of bismuth, palladium gave a button still more brittle, and nearly as hard as steel. Its colour was gray; but, when reduced to powder, it was much darker. Its specific gravity, I found to be 12,587.

Iron, when alloyed with palladium, tends much to diminish its specific gravity, and renders it brittle. Arsenic increases the fusibility of palladium, and renders it extremely brittle.

From these experiments, we may form the following Table, shewing the difference between the true and the calculated mean of specific gravity in the alloys of palladium.

| | Metals. | Proportion. | Specific gravity by calculation.* | Specific gravity by experiment. | Difference. |
|---|---|---|---|---|---|
| Palladium alloyed with | Gold - | uncertain. | uncertain. | 11,079 | uncertain. |
| | Platina - | equal parts. | 17,241 | 15,141 | — 2,100 |
| | Silver - | equal parts. | 10,996 | 11,290 | + ,294 |
| | Copper - | equal parts. | 10,176 | 10,392 | + ,216 |
| | Lead - | equal parts. | uncertain. | 12,000 | uncertain. |
| | Tin - | equal parts. | 9,340 | 8,175 | — 1,165 |
| | Bismuth | equal parts. | 10,652 | 12,587 | + 1,935 |

* In the specific gravities of the different metals, I have followed the Table given in our best elementary work, Dr. THOMSON's System of Chemistry.

I exposed ten grains of palladium to the action of potash, in fusion, during half an hour. The substance lost its brilliancy, and diminished two grains and a half in weight: these were found in the potash.

The action of soda upon palladium, does not appear to be quite so violent.

Ammonia, allowed to remain for some days upon palladium, acquires a slight bluish tinge, and holds a small portion of oxide of palladium in solution. In all these cases, the action of the alkali is promoted by the contact of the atmospheric air, the oxygen of which combines with the metal, in favour of the affinity the oxide of palladium possesses towards the alkali.

Some of the pieces of palladium were more easily acted upon by the acids than others; and, in general, those of the greatest specific gravity were the least affected. Upon the whole, however, the following statement may be taken as the average of the habitudes of palladium with the acid solvents.

Sulphuric acid, boiled upon palladium, acquires a beautiful red colour, and dissolves a portion of the substance. The action of this acid is not very powerful, and, upon the whole, it cannot be looked upon as a good solvent for palladium.

Nitric acid acts with much greater violence upon palladium. It oxidizes the substance with somewhat more difficulty than it can oxidize silver; and, by dissolving the oxide, forms a very beautiful red solution. If the nitric acid be impregnated with nitrous gas, its action upon palladium is much more rapid.

Muriatic acid, by being boiled upon palladium for a considerable time, acts upon it, and becomes of a beautiful red.

But the true solvent of palladium is nitro-muriatic acid, which attacks it with great violence, and forms a beautiful red solution.

From all these acid solutions of palladium, a precipitate may be produced by the alkalis and earths. These precipitates are, for the most part, of a beautiful orange; are partly redissolved by some of the alkalis; and the supernatant liquor of the precipitate formed by ammonia is sometimes of a fine greenish-blue. Sulphate, nitrate, and muriate, of potash, or of ammonia, produce an orange precipitate in the salts of palladium, as in those of platina, when not in too dilute solution; and the precipitates from the nitrate of palladium are in general of a deeper orange. All the metals, except gold, platina, and silver, cause very copious precipitates in solutions of palladium. Recent muriate of tin produces a dark orange or brown precipitate in neutralised salts of palladium, and is an extremely delicate test. Green sulphate of iron precipitates palladium in the metallic state; and, if the experiment succeed, the precipitate is about equal in weight to the palladium employed. Prussiate of potash causes an olive-coloured precipitate; and water impregnated with sulphuretted hydrogen gas, a dark brown one. Fluoric, arsenic, phosphoric, oxalic, tartaric, citric, and some other acids, together with their salts, precipitate some of the solutions of palladium, and form various combinations with this substance.

Such are the principal characters I have found in palladium, examined as a simple metallic body. It does not appear that, in stating any of its properties, except its specific gravity, the printed notice has been guilty of misrepresentation.

From these experiments, it would be difficult to say of what metal, or of what combination of metals, palladium consists. We could not suppose gold or platina to be an ingredient in it, as it is in some measure acted upon by sulphuric and muriatic acids, and is wholly soluble in nitric acid. Silver is excluded, by the effect of muriatic acid upon its solutions; as is lead, by that of the sulphuric. Tin, antimony, bismuth, or tellurium, would have left an insoluble residuum with nitric acid. No traces could be found of any of the acidifiable metals; and iron was looked for with particular care, but in vain. In a word, the precipitation by the metals, seems to exclude all those of easier oxidability than mercury; and this we should not suppose to be present, as copper is not in the least whitened, when used to precipitate palladium.

The striking similarity of many of the precipitates of palladium with those of platina, induced me to multiply the comparative experiments; and I constantly observed contradictory facts. The specific gravity, easy fusibility, combination with sulphur, precipitation by green sulphate of iron and by prussiate of potash, together with other effects, were such as I could not reconcile to the known characters of platina; unless I could suppose that a substance did exist, which could totally change its physical and chemical properties, or so disguise them as to render them proof against the evidence of chemical reagents.

The lightest of the metals is tellurium; yet, in order to produce an alloy of the specific gravity of palladium, (supposing for a moment the real density of the alloy equal to the calculated mean,) it would require two parts of tellurium and one of platina; and it is highly improbable, that so large a proportion of tellurium could exist in any mass, without being detected. We have been told of very extraordinary anomalies in chemical affinities, by Mr. BERTHOLLET; and Mr. HATCHETT has made us acquainted with some, not less extraordinary, in the properties of alloys. Yet I think we shall cease to wonder at what has been related by these chemists, when we learn that palladium is not, as was shamefully announced, a new simple metal, but an alloy of platina; and that the substance which can thus mask the most characteristic properties of that metal, while it loses the greater number of its own, is mercury.

I confess it was not from an analysis of palladium that I was first led to this result; for I had convinced myself, by synthesis, of its nature, and had formed the substance, before I could devise any probable method of ascertaining its component parts.

In reflecting upon the various modifications which substances undergo when in union with each other, and on the variations produced in the laws of affinity by the intervention of new bodies, I was induced to try whether, by the affinity of platina with some metal easily reduced, it might not happen, that a reduction of both would take place by green sulphate of iron, although no such effect were produced upon each metal when separate. The most likely to succeed, as being most easily reduced, after gold, platina, and silver, was mercury. I poured some solution of green sulphate of iron into a salt of platina, and also into a salt of mercury; no precipitation took place. I united the two liquors; and a precipitate, exactly resembling that which is formed by green sulphate of iron in palladium, was instantly formed. I collected the precipitate, and exposed it to a strong heat; and, after repeated trials, obtained a metallic button, not to be distinguished from palladium.

It certainly is one of the most extraordinary facts respecting alloys, that two metals, by their union with each other, should so lose the characteristic properties of each individually, that neither of them can be immediately detected by the usual methods. Nothing but an affinity of the most powerful order could produce such effects. But, to place the metals under the most favourable circumstances for that affinity to exert its influence, and to promote their union, is not the result of common methods. Among a great number which I have tried, many have failed, and none have been attended with uniform success. I have, however, formed palladium by the immediate union of platina and mercury; and, as whatever may place the apparent capriciousness of this combination in a conspicuous point of view is not devoid of interest, I shall describe the means by which I have attempted to produce it, whether they failed, or were attended with success.

SYNTHETICAL EXPERIMENTS.

*Exper.* 1. It was not till after repeated trials of the mode just mentioned, that I succeeded in forming palladium. In many instances, I obtained a button completely melted, of the specific gravity of 13, and sometimes more; not so easily fused by sulphur as palladium; not soluble in nitric acid; and the absolute weight of which exceeded that of the platina originally employed. But, although this substance was not platina, I could not say it was palladium. The most successful experiment by this method, was attended with the following circumstances. I dissolved one hundred grains of platina in nitro-muriatic acid, and then put in two hundred grains of red oxide of mercury, made by nitric acid; but this not being sufficient to saturate the excess of acid, I continued to add more, until it ceased to be dissolved. On the other hand, I prepared some green sulphate of iron, and poured it into a long-necked matrass. I then poured the mixed solution of platina and mercury into the solution of green sulphate of iron, and heated the whole upon a sand bath. In less than half an hour, a copious precipitate was formed; and the inside of the matrass was lined with a thin metallic coat. The liquor was passed through a filtre, which I had weighed; and the precipitate, after digestion with muriatic acid, was well washed and dried. When I had collected as much of this as I could, there remained upon the filtre 12 grains; besides which, I had collected 264, in all 276. The supernatant liquor still contained a portion of mercury, and about eight grains of platina Therefore, the 276 were composed of 92 of platina, and 184 of mercury. From this it appears, that one hundred grains of platina, can determine the precipitation of near two hundred grains of mercury, by green sulphate of iron; and that, in this proportion, there is a reciprocity of saturation. The 264, collected from the filtre, were exposed to a low red heat, and were reduced to 144. The 12 of the filtre would have given about seven; therefore, the whole would have been 151. The substance was in the form of a fine powder, and had a metallic lustre. It was then put into a charcoal crucible, and fused into a button. This button weighed 128 grains, and, with the quantity left on the filtre, would have weighed 135. In this 135, there were 92 of platina; therefore, it was composed of about two parts of that metal and one of mercury. It was of the specific gravity of 11,2; was wholly soluble in nitric acid; was easily fused by sulphur; was precipitated by green sulphate of iron: in a word, it was not to be distinguished from palladium.

*Exper.* 2. As another mode of forming palladium in the humid way, I put metallic iron into a mixed solution of platina and mercury. Both metals were precipitated; and the precipitate was submitted to the same treatment as in the former case; but the success was not so complete. Iron can precipitate either platina or mercury separately; but green sulphate of iron can perform its function only in favour of the affinity of platina and mercury. Their union is promoted by its action; and the effects are, in all probability, simultaneous. The combination of the metals takes place, if I may be allowed the expression, in their nascent metallic state, and in a fixed proportion of mutual saturation. The union of the two metals, therefore, is in the present experiment less intimate, and the button which results from fusing the precipitate, is of much greater density.

*Exper.* 3. The same process was repeated, only using zinc instead of iron, but the result was not more satisfactory.

*Exper.* 4. I poured some mercury into a solution of platina, and heated them together for some time. A precipitate took place; but, upon fusing it into a button, I did not find it to be palladium.

*Exper.* 5. I dissolved the same quantities of platina and mercury as in *Exper.* 1, in nitro-muriatic acid, and evaporated those solutions together. I then volatilized as much as I could of the mercury, at a red heat. At the end of the operation, I obtained precisely my original quantity of platina, reduced to the metallic state; but not one particle of the mercury remained along with it.

*Exper.* 6 and 7. The same quantities of platina and mercury, dissolved in nitro-muriatic acid, were precipitated by phosphate of ammonia; and the liquor was evaporated. The residuum, in a glassy state, was exposed to a violent heat in a charcoal crucible; and I obtained a melted button, which weighed more than the original quantity of platina, and was of the specific gravity of 14,5. On account of the easy fusibility of phosphuret of platina, I likewise tried to combine it directly with mercury, but could not succeed.

*Exper.* 8. I precipitated a mixed solution of platina and mercury, by a current of sulphuretted hydrogen gas; and reduced the insoluble powder. After many attempts, in which I obtained buttons of the specific gravity of 14,3 and 14,5, I formed a piece weighing 11 grains, of the specific gravity of 11,5. This last was palladium; but I could not ascertain the excess of weight, as a part of the original precipitate had been lost.

*Exper.* 9. I mixed a solution of muriate of platina with prussiate of mercury, and obtained a slight precipitate. The liquor was evaporated, and the whole residuum exposed to a violent heat. This experiment did not succeed. It was not repeated so often as the others; but I have some reason to think it might be attended with success; for I obtained, in one instance, a few very minute grains, that were soluble in nitric acid.

*Exper.* 10. I heated some purified platina, in the form of a very fine powder, with ten times its weight of mercury, and rubbed them together for a long time. The result was, an amalgam of platina. This amalgam, exposed to a violent heat, lost all the mercury it had contained; and the original weight of the platina remained without increase.

*Exper.* 11. The best method of forming an amalgam of platina, is that prescribed by Count MUSSIN PUSHKIN. I dissolved a known quantity of platina in nitro-muriatic acid, precipitated by ammonia, and evaporated the liquor. The residuum was rubbed for a long time with a great quantity of mercury, and then exposed to a violent heat. Many operations failed; in some, I had a button of the specific gravity of 13,2. In one attempt, I succeeded completely: from 30 grs. of platina, treated as above, I obtained a button weighing 43,5, of the specific gravity of 11,736, which had all the properties of palladium.

*Exper.* 12. I fused together, in a charcoal crucible, 100 grs. of platina, 200 of cinnabar, 100 of lime, and 400 of calcined borax; and obtained a button, which weighed more than the platina, and was of the specific gravity of 15,7. It was not soluble in nitric acid; but combined with sulphur, at a red heat.

*Exper.* 13. In some experiments I had made, I found that the furnace in which I formed these alloys, was capable of melting platina, without the assistance of any flux except calcined borax. I therefore urged 100 grs. of platina, at a very strong heat; and, when I judged the fire to have attained its greatest intensity, I poured mercury upon the platina, through a long earthen tube that terminated in the crucible, and immediately withdrew the apparatus from the fire. No sensible union of the metals had taken place; nor had the platina increased in weight.

*Exper.* 14. I put 100 grains of platina into an earthen tube, and placed the tube horizontally in the above furnace. At one end of it was a retort, containing 2lbs. of mercury. When the tube was at its greatest heat, the mercury was made to boil; and the entire quantity passed over the surface of the platina, at that temperature. The experiment lasted one hour and a half; but the metals did not seem to have combined.

*Exper.* 15. Mr. PEPYS was so obliging as to try the effect of his very powerful GALVANIC battery, in forming palladium. A piece of platina-wire was plunged into a bason of mercury, and formed part of a GALVANIC circle. The wire was nearly in fusion; but no combination seemed to take place. The nature of this experiment did not allow of very accurate weighing; but the fused globules of platina did not appear to have acquired the properties that constitute palladium.

Such are the experiments by which I attempted to form palladium. They were chiefly founded upon two principles; disposing affinity, and assimilation. In the one case, I endeavoured to present to the metals that compose it, a substance which, on account of its affinity for some menstruum necessary for their solution, and of their own tendency to combine in the proportions stated in *Exper.* 1, might cause them to unite in the form of an insoluble compound. In the other case, I hoped to assimilate the properties of each, and, by making them something more alike, to place them in the most favourable circumstances for uniting. *Exper.* 1 was founded on the former, and *Exper.* 8 on the latter of these principles.

In many instances, when I did not form palladium, I obtained a metallic button which was not platina; and, when I did so, it always weighed more than the original quantity of platina employed. In repeating *Experiments* 1, 2, 4, 6, 8, 11, and 12, I seldom failed of having such a substance. No effect of this kind took place in any experiment, when mercury was not used along with platina; and the other metals were merely accessaries, in promoting their union and precipitation. This is sufficiently proved, by the uniformity of the results in different processes, whether it was palladium or the substance I now mention which was formed. The chief property which distinguishes the latter substance from platina, is its density. It is not unusual to obtain it of a specific gravity so low as 13; very frequently 15 or 17. In the first experiments, I suspected this lightness to be owing to some air-bubbles; but repeated fusion, and comparative experiments upon platina, soon convinced me of the contrary. The augmentation of weight also, which the platina never fails of acquiring, proves that this metal has combined with some ponderable substance; and, in fact, the result of these operations is, an alloy which is a mean betwixt platina in its pure state and what has been called palladium. It is, consequently, subject to infinite variation. The first effects which mercury produces upon platina are, to render it more fusible, and to diminish its specific gravity. The next new property conferred upon it is, the power of uniting with sulphur; and, lastly, it becomes soluble in nitric acid. It is not however till the specific gravity is below 12, or 12,5 at most, that it has acquired this property; and all these effects follow the direct order of the increase of weight observable in the platina.

It is not very difficult to combine a small quantity of mercury with platina: but, to resolve the problem completely, and to produce an alloy of these metals which shall be of so low a specific gravity as 11,3, and shall be soluble in nitric acid, is not so easily accomplished. From the repeated failures which I have experienced in these operations, I am much inclined to think that the author of palladium has some method of forming it, less subject to error than any I have mentioned. No doubt that perseverance would put us in possession of his secret; but, being prevented by want of leisure from pursuing these researches at present, I have confined myself to establishing the fact, and describing the processes which I have employed.

Having thus acquired a certainty that mercury is a constituent part of palladium, I made some further experiments upon it, with a view to its analysis; but they have not been attended with so much success. It might be expected, from the great number of methods which have failed to form palladium, that many might be found to decompose it when formed. But I have found the converse of such processes as did not succeed in producing palladium, to be ineffectual in destroying the combination.

ANALYTICAL EXPERIMENTS.

*Exper.* 1, 2, and 3. The converse of the synthetical experiments 1, 2, 3, was made, but without any satisfactory result.

*Exper.* 4. The converse of *Exper.* 4 was made without success. I put some mercury into a solution of palladium, and left them together for some time. The precipitate which was formed was palladium, just as it had been used for the operation.

*Exper.* 5. I exposed different pieces of palladium to a very violent heat for two hours. In some, a diminution of absolute weight, with an increase of specific gravity, took place; in others, neither of these effects was produced. The specimens which I had made were chiefly of the latter kind.

*Exper.* 6. Cupellation did not afford any satisfaction respecting the analysis of palladium; but the heat necessary for this purpose is so great, that I could not place great reliance upon this experiment. It is difficult to detach the button from the cupel with accuracy.

*Exper.* 7. I burned some palladium in oxygen gas. A white smoke arose during the combustion, and was deposited upon the sides of the glass jar that contained the gas. But this smoke was palladium, and not the mercury separated from it.

*Exper.* 8. A slip of palladium, which Mr. DAVY had the goodness to expose, in my presence, to the action of the strong GALVANIC batteries of the Royal Institution, burned with a very vivid light, and a white smoke; but no mercury was separated by this operation.

There is not any property of this compound which appears to me so wonderful, as that which is manifested by these experiments. It is a striking proof how unfounded was the opinion of some philosophers, who supposed that the rapidity of combination was a measure of the force of affinity. We do not know of any affinity among chemical bodies which is more powerful than that of platina and mercury appears to be. The obstacles which must be overcome, in order to fix the latter metal, are a proof of this; yet the difficulty of forming this combination to its full extent is extreme. The difference which exists between the compound and its elements, when merely mixed, either in solution or otherwise, cannot be better exemplified than by comparing the result of the 5th synthetical experiment, with the difficulty of expelling mercury from the compound.

I must here observe, that all the analytical experiments, and many others, were made, by way of comparison, upon the palladium I had bought, as well as upon that which I had made. But, although I had myself combined the mercury with the platina, and consequently knew it to be in the compound that resulted, I could not succeed in separating it. Neither did the substance described in a former paragraph, as intermediate between platina and palladium, allow one particle of mercury to escape from it, by any process I have yet been able to devise.

The name of palladium conveys to our mind the idea of something absolute, and therefore incapable of gradation. But gradations in alloys are infinite; and the alloy of platina and mercury is susceptible of infinite variation. Palladium also brings to our recollection a contemptible fraud directed against science: the name, therefore, should not be admitted. I have called it an alloy; for it differs too much from the usual idea we have annexed to the word amalgam, but it accurately corresponds with our notions of the name I have adopted.

The facts which I have related in this Paper, appear at first sight to have no similar examples in chemistry; and may not gain immediate assent from every person. The philosopher, indeed, will feel no humiliation in being forced to correct or to extend his knowledge; and will not altogether disbelieve a fact, because he can adduce no parallel instance, or because it is not in unison with his received opinions. Such conduct would be raising an insurmountable barrier against the progress of science: it would be setting up our own feelings in the place of nature; and attempting to measure what in itself is immeasurable, by the narrow scale of human comprehension.

But let us not confine our view of the facts and principles that have been mentioned, to this single instance. Let us trace them in a more extended circle; and see whether any thing may be found in nature that can apply to the present subject.

The first prejudice, for such I must call it, against the presence of platina in palladium is, the small density of the alloy. And no doubt it is extraordinary, that a metal the specific gravity of which is at least 22, (CHABANEAU says 24,) combined with another the specific gravity of which is nearly 14, should produce a mass of the specific gravity of 10,972; not much more than half of that which calculation would denote, and inferior to either of its elements. In Mr. HATCHETT's Paper upon the Alloys of Gold, to which I always refer with pleasure, we find some extraordinary instances of anomalies in specific gravity, both in excess and diminution upon the calculated mean. His experiments have not been doubted; nor can their accuracy be called in question. The principle of deviation in the true and the calculated mean is therefore admitted. Who then can say where this deviation shall end, or mark out limits to the operations of nature?

But a no less extraordinary instance of irregular density is daily before our eyes; yet it has not so much as attracted our attention. It is true that it is taken from among the gases. But, if we suppose that we have attained accuracy in experiments upon these subjects, I see no reason to refuse their evidence in this instance. The density of oxygen gas, to that of water, is as 1 to 740; and the density of hydrogen gas as 1 to 9792. The mean density of that proportion of oxygen and hydrogen gases which constitutes water, is to that of water as 1 to 2098; or, in other words, water is 2098 times heavier than the mean density of its elements in the gaseous state. But water is only 1200 times heavier than steam, or water in the state of vapour. Therefore, there is a variation in +, of 898, or nearly half, between the density of water and its elements, when both are in the aeriform state. This fact, however, regards bodies only as they remain in the same state, whether of solidity, liquidity, or fluidity. The anomaly is much greater, if we contemplate them as they pass from one of these states to the other. Yet we must not omit the consideration of such a change, in the instance of mercury alloyed with platina; for the former metal, before liquid, becomes solid as it enters into the new combination.

A stronger prejudice will perhaps exist against the fixation of so volatile a substance as mercury. It is certain that the labours of the alchemists have thrown some ridicule upon this subject, as a philosophical pursuit. Men of science have long since declined the research; and it is not probable that we are indebted to experiments undertaken in the true spirit of philosophy, for the present fixation of mercury. But, the same cause which induced us to look upon the project as chimerical, should dispose us to admit it when accomplished. Every chemist well knows, that similar fixations of volatile substances are not uncommon. If an ore containing sulphur, or arsenic, or antimony, be gently roasted, a great part of those volatile bodies is driven off; but, if a fusing heat be suddenly applied, the mass unites in such a manner that a very small share of them escapes. Mr. HATCHETT has instanced an artificial combination of gold and arsenic, from which he could not expel the latter metal, by any degree of heat. Yet arsenic, though less fusible, is not much less volatile than mercury. I will also add a case still more in point; *viz.* the combination of arsenic and platina, which is not to be broken by a fusing heat.

An example of this fact, occurs again in water. The liquefaction or solidification of two gases to produce water, by a loss of caloric, never shocks our mind, because it is familiar to us. We cannot say what loss of caloric may be sustained by mercury, in order to unite with platina; or how far the presence of the latter may contribute to expel caloric from the former. We know too, that at any temperature, without the aid of a combustible body, to act as a reductive, we have not been able to disunite the last portions of oxygen, from the oxides of iron or of manganese. Yet, in the usual method of reducing a metallic oxide, the oxygen is surrounded by a much greater quantity of caloric than is necessary to convert it into gas. Every fixation of a volatile substance is analogous to the present question; and they whose minds have taken alarm from the novelty of the fact, may thus be familiarized with the necessity of admitting it.

But, it may be objected, in the instances of iron or manganese, oxygen is combined with a combustible body, and retained in it by a decided and powerful affinity. There is no reason to suppose that such an affinity may not exist among metals. We have been forced to acknowledge it, in a few cases, among the earths; and, from the profound and sagacious researches of Mr. BERTHOLLET, we have learned many new facts, that promise us a rapid increase of knowledge. I shall beg leave to add a few examples, which are taken from that class of bodies to which the subject of the present Paper belongs, and show that the metals obey the general law of mutual attraction.

EXPERIMENTS TO PROVE AFFINITY AMONG THE METALS.

*Exper.* 1. I dissolved one hundred grains of silver in nitric acid, and precipitated by neutral muriate of platina. The precipitate, well washed and dried, was of a bright straw-colour, and weighed 147 grs. Reduced in a charcoal crucible, it yielded a button weighing 121 grs. and of the specific gravity of 11,6. The difference of weight, between the original hundred grains of silver and the 121, was owing to 21 grains of platina, which had been drawn down in precipitation along with the silver, by an affinity for that metal. This alloy is acted upon by nitric acid, and a great part of the platina is dissolved along with the silver; nor is it very easy to separate them by the common methods.

*Exper.* 2. I dissolved one hundred grains of silver in nitric acid, and added about 1200 of mercury. I poured the mixed solution into a solution of green sulphate of iron, and obtained a very copious precipitate. When washed and dried, it weighed 939, and was a perfect amalgam, in the due proportion of mutual saturation. Its specific gravity was 13,2; but no mercury remained with it after exposure to heat.

*Exper.* 3. I dissolved one hundred grains of gold in nitro-muriatic acid, and added to it about 1200 grains of mercury.

Green sulphate of iron, poured into this mixed solution, caused a precipitate weighing 874. It was in the form of a fine blue powder, not resembling an amalgam, though wholly metallic. Its specific gravity I could not ascertain; but all the mercury was expelled by heat.

The reagents which I used in the following experiments, were recent muriate of tin, and green sulphate of iron. To bring the examples of anomalous precipitations, in mixed solutions of the metals, more clearly into view, it will be necessary to state the action of these salts, upon a solution of each metal when separate.

By recent muriate of tin we have, with a solution of gold, the well known purple of CASSIUS. With platina, the colour of the liquor is much heightened. With mercury, there is a total reduction. With copper, a reduction from the black oxide at 20 *per cent.* of oxygen, to the yellow oxide at 11,5 *per cent.* of oxygen. With arsenic acid, a reduction to the state of white oxide. With silver, with lead, with antimony, no reduction. Green sulphate of iron reduces none of the metallic solutions, except those of gold and of silver.

When mixed solutions of the metals are exposed to the action of recent muriate of tin, or of green sulphate of iron, we have the following results.

*Experiments* 4, 5, 6, 7, and 8. Muriate of tin, poured into a mixed solution of gold and mercury, precipitates both metals together; and there are no traces of the purple. Mixed solutions of gold and antimony, also of gold and arsenic acid, are acted upon in the same manner. Mixed solutions of gold and copper, also of gold and lead, afford results similar to those of each metal when separate.

*Experiments* 9, 10, 11, 12, and 13. With a solution of platina and arsenic acid, muriate of tin gives no precipitate; but the colour of the liquor is more heightened than if the platina had been alone in solution. Platina and antimony give a precipitate by this reagent, after standing some time; but the effect is retarded by the excess of acid in the solution of antimony. Platina and copper, also platina and lead, are acted upon as the separate solutions of these metals. Platina and silver are precipitated together by green sulphate of iron.

*Experiments* 14, 15, 16. Mercury and copper, mercury and lead, also mercury and arsenic, are precipitated in the metallic state by recent muriate of tin.

From these experiments it is evident,

1st. That gold has an affinity for mercury, for antimony, and for arsenic.

2d. That platina has an affinity for silver, for mercury, and for antimony; and that it is influenced by the presence of arsenic.

3d. That silver has an affinity for mercury.

4th. That mercury has an affinity for copper, for lead, and for arsenic.

This series of experiments is not intended as a system of metallic affinities; but as a few facts stated to corroborate an assertion. I am well aware that many others might be noticed; but it is not my intention to enter further into this subject, in the present Paper. The general importance of the principle, and the extensive influence it is likely to have upon chemistry, demand that it should be treated by multiplied researches. The experiments that can elucidate it are of the most delicate nature, and require peculiar care; for they do not always succeed, unless performed under the most favourable circumstances.

When mixed solutions of three or more metals are exposed to the action of recent muriate of tin, or of green sulphate of iron, their action upon each other appears in a much more striking, as also in a much more complicated point of view.

## EXPERIMENTS UPON PLATINA.

I shall now state some experiments which I have had occasion to make upon platina, during the foregoing researches. Very little is known concerning this metal, its oxides, or its salts; and, although I have not had occasion to extend the enquiries very far, yet my experiments may serve to establish a few points.

I dissolved a quantity of purified platina* in nitro-muriatic acid, and precipitated by lime. A great portion of platina remained in the liquor, although I had used an excess of the above earth. I redissolved the precipitate in nitric acid, and evaporated to dryness. The result was, a subnitrate of platina. I then exposed the mass, in a crucible, to a heat capable of expelling the acid altogether; and the oxide remained alone. When this was reddened, at a heat which certainly was not capable of melting silver, the oxide was reduced, and appeared with a metallic lustre. The weight of the various products, in the above experiments, was such as to give the following proportions in the oxide, and the subnitrate of platina.

Yellow oxide of platina is composed of,

| | |
|---|---|
| Platina - - - | 87 |
| Oxygen - - - - | 13 |
| | 100. |

* By purified platina, I have always understood, in this Paper, platina reduced, at a gentle heat, from the salt obtained by pouring a concentrate solution of muriate of ammonia into a concentrate solution of platina.

Subnitrate of platina is composed of,

| | |
|---|---|
| The above oxide of platina - - | 89 |
| Nitric acid and water - - - | 11 |
| | 100. |

But, in the reduction of this oxide of platina, it became of a green colour; and remained during some time in that state. Nitrate of platina sometimes becomes of a pale green at the edges, when evaporated to dryness; and ammonia assumes a green colour when it holds oxide of platina in solution, as we have seen more particularly with palladium. This, therefore, is a second oxide of platina. It contains but seven *per cent.* of oxygen.

I dissolved a known portion of platina in nitro-muriatic acid, and expelled the nitric acid, by pouring in a sufficient quantity of the muriatic; and then evaporated to dryness. By this experiment I learned, that the insoluble muriate of platina is composed of,

| | |
|---|---|
| Yellow oxide of platina - - | 70 |
| Muriatic acid and water - - | 30 |
| | 100. |

I then expelled the muriatic acid by the sulphuric, and evaporated again to dryness. I found the insoluble sulphate of platina to be composed of,

| | |
|---|---|
| Oxide of platina - - - | 54,5 |
| Acid and water - - - - | 45,5 |
| | 100,0. |

By much the most delicate test for platina is muriate of tin. A solution of the former, so pale as hardly to be distinguished from water, assumes a bright red by a single drop of the recent muriatic solution of the latter metal. If mercury be present, the colour is much darker. Recent muriate of tin, poured into a solution of the muriate formed by the red oxide of mercury, converts it into the muriate formed by the less oxygenized acids; but, shortly after, the mercury is reduced to the metallic state. Hence it was, that the alloy of platina and mercury always gave a deeper coloured precipitate than platina, with muriate of tin.

Neither platina nor mercury are precipitated by prussic acid, or by the prussiates. But, if sulphate, nitrate, or muriate of platina be poured into prussiate of mercury, an orange-coloured precipitate is immediately formed; and, in some cases, a mixed solution of platina and mercury gives a similar precipitate by prussic acid alone.

Platina is one of the metals which are precipitated by sulphuretted hydrogen, without the necessity of a double affinity.

The affinities of platina differ much from what is generally stated in the tables. By the few acids I have had occasion to try, oxide of platina is attracted in the following order: sulphuric, oxalic, muriatic, phosphoric, fluoric, arsenic, tartaric, citric, benzoic, nitric, acetic, and boracic.

That sulphuric acid should attract the oxide of platina with greater force than the muriatic, is an unanswerable argument to an opinion which was long supported by many philosophers, and which is not yet altogether abandoned by them. Muriatic acid has been said to contribute to the solution of gold or platina, in nitro-muriatic acid, in the same manner as sulphuric acid is supposed to promote the decomposition of water, during the solution of iron by that acid diluted. The affinity of muriatic acid for the oxide of gold or of platina, has been looked upon as the disposing cause that nitric acid is decomposed by those metals. But it is evident that some other action takes place; for, sulphuric acid, which has a stronger affinity for oxide of platina than muriatic acid, does not in the least promote the decomposition of nitric acid by gold, or by platina.

## CONCLUSION.

The substance which has been treated of in this Paper, must convince us how dangerous it is to form a theory before we are provided with a sufficient number of facts, or to substitute the results of a few observations, for the general laws of nature. If a theory is sometimes useful, as a standard to which we may refer our knowledge, it is at other times prejudicial, by creating an attachment in our minds to preconceived ideas, which have been admitted without inquiring whether from truth or from convenience. We easily correct our judgment as to facts; and the evidence of experiment is equally convincing to all persons. But theories, not admitting of mathematical demonstration, and being but the interpretation of a series of facts, are the creatures of opinion, and are governed by the various impressions made upon every individual. Nature laughs at our speculations; and though from time to time we receive such warnings as should awaken us to a due sense of our limited knowledge, we are presented with an ample compensation, in the extension of our views, and a nearer approach to immutable truth.

The affinities of metals for each other are likely to be of the most extensive influence in chemistry. They will promote scepticism with regard to future discoveries, and throw some doubts upon our present knowledge. Palladium is certainly not less different from the elements that compose it, and from all other metals, than any two can be from each other. Within the last fifteen or twenty years, several new metals and new earths have been made known to the world. The names that support these discoveries are respectable, and the experiments decisive. If we do not give our assent to them, no single proposition in chemistry can for a moment stand. But, whether all these are really simple substances, or compounds not yet resolved into their elements, is what the authors themselves cannot positively assert; nor would it in the least diminish the merit of their observations, if future experiments should prove them to have been mistaken, as to the simplicity of those substances. This remark should not be confined to later discoveries; it may as justly be applied to those earths and metals with which we have been long acquainted.

With regard to the metals, we have seen how little dependance is to be placed on specific gravities. A contrary anomaly to that which operates upon platina and mercury, may take place in others; and they may become as much heavier than the mean, as the former become lighter. In this state of union, they may for a long time appear homogeneous, even by the test of chemical reagents. One of the properties that renders metallic substances so precious is, their easy formation into such instruments as our necessities require. The fragile metals are but of secondary consequence; and, at most, serve to confer on those which are ductile, some quality which adapts them better to particular purposes. It often happens that, by being alloyed, two ductile metals become fragile; but we have no instance of the contrary effect in any high degree. It is therefore more to be supposed that we should look to simplification among the fragile metals; and, even at this early period, it may not be too speculative, to consider the metallic bodies in an order which may bring together those which possess the greatest number of similar characters.

As an instance of this approximation, it may be observed, that nickel and cobalt strongly participate in the properties of copper and iron. The two former metals were long regarded as mixtures; and the doubts of the ancient chemists, who feared to pronounce as to their nature, may still be proved to have more foundation in truth than the assertion of the moderns, who have declared them to be simple. Acted upon by the same menstrua, forming insoluble compounds with the same acids, and soluble alike in other substances, they have but one or two marked properties that lead us to consider them as distinct metals. But palladium has at least five or six characters, as strong as those of any metal whatsoever, that distinguish it, not only from its elements, but also from all other metals.

Among the earths, this approximation is still more apparent. A leading character of these substances is, their tendency to enter into saline combinations, in which they receive new properties, and perform new functions. If we rank them according to this general tendency, we shall have the following order: barytes and strontia; lime and magnesia; glucine and alumina; zircon and silica. And, if we consider them two by two in this order, which is a natural one, we shall bring together precisely those which differ by the smallest number of chemical characters.

This investigation might be pursued still further; but we must wait the result of experiments: a wide field is open for research. In the dark ages of chemistry, the object was, to rival nature; and the substance which the adepts of those days were busied to create, was universally allowed to be simple. In a more enlightened period, we have extended our enquiries, and multiplied the number of the elements. The last task will be to simplify; and, by a closer observation of nature, to learn from what a small store of primitive materials, all that we behold and wonder at was created.