



# XXX. On the new metals, lanthanum and didymium, which are associated with cerium; and on erbium and terbium, new metals associated with yttria

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[THIRD SERIES.]

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XXX. *On the new metals, Lanthanium and Didymium, which are associated with Cerium; and on Erbium and Terbium, new metals associated with Yttria.* By Professor C. G. MOSANDER\*.

ALTHOUGH in consequence of the imperfect nature of the results which were obtained from my researches on cerium and lanthanium I had no intention of making any communication on the subject on the present occasion, yet after hearing the interesting statement of Professor Scheerer, it appeared to me that it might be useful to make known more generally some particulars which arose during my labours, and principally because this advantage may result, that other chemists, after becoming acquainted with what I am about to state, may possibly be spared the loss of valuable time which might otherwise have been fruitlessly expended.

When sixteen years since I made some experiments upon cerium, several circumstances occurred which led me to the supposition that oxide of cerium was accompanied by some other oxide, which, however, I did not succeed in separating, and want of materials prevented me from then prosecuting the inquiry. A few years since, having procured a quantity of cerite and cerine, I prepared from thence the double salt of sulphate of the oxide of cerium with sulphate of potash, which salt was washed with a solution of sulphate of potash, until the passing fluid gave no trace of precipitate with caustic ammonia or carbonate of soda. I believed that in this manner I could obtain a pure salt free from all foreign substances.

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The double salt was afterwards decomposed in the moist way with carbonate of soda, and with the carbonate of protoxide of cerium thus obtained, all the preparations have been made which will be now mentioned.

After a long examination of various salts of protoxide of cerium, I did not succeed in detecting a salt principally consisting of the supposed new oxide, the presence of which, however, appeared more and more probable in the course of the experiments. As it was known that cerium gives two oxides, I considered it probable that if hydrate of protoxide of cerium mixed with water was exposed to the effect of chlorine, peroxide of cerium would be formed while the more electro-positive metallic oxide would be dissolved in the fluid, and it was in this manner that I succeeded to my satisfaction. When the chlorine was introduced into the fluid, the appearance of the hydrate of protoxide of cerium began soon to change, the volume diminished, and a heavy, bright, yellow, or rather orange-yellow coloured powder fell to the bottom. If, after the chlorine no longer appears to cause any change, the fluid is filtered, a colourless solution, with the strong odour of hypochlorous acid, is obtained, from which, with hydrate of potash in excess, a precipitate is deposited, which collected on a filter, is white, or approaching violet. This precipitate begins soon, however, to grow yellow in contact with the air. If the precipitate be again mixed with water and chlorine introduced, the greater part is dissolved, while a new portion of the yellow-coloured oxide is formed, and remains undissolved. The filtered solution forms a precipitate again with caustic potash, which is treated as before with chlorine, and this is repeated five or six times, when, finally, hydrate of potash precipitates from the solution an oxide which does not become in the least yellow by exposure to the air, and which suspended in water, is completely dissolved by the introduction of chlorine without leaving a trace of undissolved yellow oxide. It was to this oxide, not capable of being more oxidized either by the air or chlorine, that I gave the name of oxide of Lanthanium, after the production of which, and a nearer acquaintance with its properties, another and simpler method was employed to obtain it. The strong basic qualities of the new oxide afforded an easy means of separating it from oxide of cerium, by treating the red-brown oxide which is obtained when the so-called nitrate of protoxide of cerium is heated with nitric acid diluted with 75 to 100 parts of water. An acid thus diluted leaves the greater part of the red-brown oxide undissolved, and from the solution thus obtained the oxide of lanthanium was derived which was employed by me in the experiments that I made in the beginning of the year 1839.

Some of the results which I obtained unfortunately became known to the public. When we find the oxide of a body hitherto unknown, nothing, generally speaking, is easier than the determination of the qualities of the body, and I therefore expected to be able to give a complete account of my experiments in a very short time, but on this point I was much deceived. That which, in the first place, gives any value to chemical investigation, is the certainty that the object investigated is pure, that is to say, free from foreign substances. I had not made much progress in the details of my inquiry, when it appeared that what I at first considered to be pure oxide of lanthanum, was, in point of fact, a mixture of the new oxide with a number of other substances, so that in the course of the experiments I succeeded in separating no less than seven different substances, one after the other. The first, to my great surprise, was lime, in no considerable quantity; and I have found that sulphate of lime and sulphate of potash forms a double salt sparingly soluble. Afterwards the following oxides were successively separated, and by the application of different means, namely, oxide of iron in large quantities, of copper, tin, nickel, cerium, and something resembling uranium, &c.; but even the oxide which remained after the separation of all these substances, left me in nearly the same position which I held at the commencement of the researches, so that, although at the end of the year 1839 I had already been fortunate enough to obtain oxide of lanthanum tolerably pure, it was not until the beginning of the following year that I was able, with any facility, to obtain a larger quantity of it; but, notwithstanding all my efforts, I have not yet succeeded in discovering any method of separating, with any degree of analytical accuracy, lanthanum from cerium, &c.

Oxide of lanthanum, as pure as I have hitherto been able to obtain it, possesses the following properties:—It is of a light salmon colour, or nearly white, but not in the least reddish or brown, and retains its appearance unchanged when heated either in open or close vessels at a red or white heat: the slight colour seems to proceed from a small remnant of some foreign substance. The oxide, although just previously ignited to a white heat, soon changes its appearance in water, becomes snow-white, more bulky, and after twenty-four hours in the ordinary temperature of the air, becomes changed to a hydrate easily suspended in water. With boiling water this change takes place very quickly, and begins immediately; the newly heated oxide as well as the hydrate immediately restores the blue colour to moist reddened litmus paper. Oxide of lanthanum is easily dissolved by acids even much diluted. Salts,

when they are formed by the combination of the oxide of lanthanum with uncoloured acids, are absolutely colourless, as well as the most concentrated solutions of the same. Salts of lanthanum have a sweet, slightly astringent taste, and the solution of them can be completely separated from oxide of lanthanum by the addition of sulphate of potash in sufficient quantity, because the double salt formed by sulphate of oxide of lanthanum and sulphate of potash is quite insoluble in a solution saturated with sulphate of potash. The atomic weight of oxide of lanthanum, as it has hitherto appeared in most instances, has oscillated about 680, a number which, however, possesses no scientific value, when, as I have already remarked, an absolutely pure oxide has not yet been obtained.

Of the salts produced, I will only briefly describe a few of the most characteristic. Sulphate of oxide of lanthanum crystallizes in small six-sided prisms terminated by six-sided pyramids, containing three atoms of water of crystallization. This salt has the same property as sulphate of yttria, thorina, and other oxides of the same class, namely, being much less soluble in warm than in cold water. At  $73^{\circ}\cdot 4$  Fahr. one part of anhydrous sulphate of oxide of lanthanum requires  $42\frac{1}{2}$  parts of water to be dissolved, but of boiling water one part of the same salt requires about 115 parts.

The crystals are very slowly dissolved, but the anhydrous salt is immediately dissolved. The anhydrous salt develops much heat when mixed with a little cold water, and the salt then forms a crystalline crust, which afterwards is very slowly dissolved. If powdered sulphate of oxide of lanthanum be thrown into water whose temperature is  $35^{\circ}\cdot 6$  or  $37^{\circ}\cdot 4$  Fahr., and kept stirring, and with the precaution that the liquid, which besides should be cooled from the outside, never attains a higher temperature than  $55^{\circ}\cdot 4$  Fahr., one part of sulphate of oxide of lanthanum may be dissolved in less than six parts of water, and the solution preserved unchanged for weeks, in closed vessels, and within the stated limits of temperature; but if the liquid be gradually heated, then before the temperature has reached  $86^{\circ}$  Fahr., a number of crystalline groups composed of small needles radiating from a common centre begin to deposit, and when once this crystallization has commenced it cannot be checked, however rapidly we may cool the liquid. With regard to the number and form of the deposited groups, the originally clear liquid is changed in a few minutes to a thin pap. If during the dissolution of the salt according to the manner stated, a part of the liquid acquires a higher temperature through the heat that is developed by the union of the salt with water, the crystallization

of a part of the salt immediately begins, and after that has once begun the phenomenon continues even with so low a degree of heat as  $55^{\circ}\cdot4$  to  $57^{\circ}\cdot2$  Fahr. less, until the solution only contains  $\frac{2}{7}$ ths of its weight of anhydrous salt. The salt which has thus been deposited contains the same quantity of water as that which is formed during the evaporation, as well under  $55^{\circ}\cdot4$  Fahr. as with  $212^{\circ}$  Fahr. If sulphate of oxide of lanthanum be kept at a white heat for an hour, it loses the half of its sulphuric acid, and the basic salt which is produced is insoluble in water.

Nitrate of oxide of lanthanum is a salt easily soluble in water or alcohol, and from an evaporated solution of the consistency of thin syrup, it crystallizes in large prismatic crystals, which rapidly deliquesce in damp air. If the solution be evaporated with a heat of  $86^{\circ}$  Fahr. and above, an opaque milk-white mass is obtained. If the salt be cautiously heated so that all the water is expelled, then by care with a higher degree of temperature, the anhydrous salt may be melted without decomposition, and after cooling it resembles a colourless glass, but with the least inattention respecting the temperature, a part of the nitric acid is expelled, and the melted mass is a mixture of neutral and basic salt, which stiffens to a snow-white opaque mass, which a moment after solidification has the remarkable quality of falling asunder into a voluminous white powder, with such violence, accompanied by a sort of slight detonation, that parts of it are thrown about to the distance of several inches.

Oxide of lanthanum has a particular tendency to form basic salts, and only such are precipitated with caustic ammonia; let this be added in as great an excess as may be, when also it occurs that the combination with some organic acids, such as tartaric acid, is dissolved in an excess of ammonia. Several of the basic salts, for example, basic nitrate of oxide of lanthanum, and basic chloride of lanthanum, are marked by the quality that they cannot be washed upon a filter with water, which runs through of a milky colour, until no part of the precipitate remains upon the filter, and if the liquid be boiled with the precipitate which has been obtained, the whole runs immediately through the filter. If the precipitate be allowed to remain a few days wet upon the filter, it becomes changed into a neutral salt which is dissolved in the water, and carbonate of oxide of lanthanum, which remains upon the filter.

With regard to cerium, my investigations are as imperfect in their results as those upon lanthanum; I will, however, make mention of some facts which may prove interesting for the present.

The reddish-brown powder which remains after the extraction of oxide of lanthanum with dilute nitric acid, is a mixture of the oxide of cerium with oxide of lanthanum, together with all the above-named accompanying substances. I have not been able to find any good method of obtaining pure oxide of cerium; the salts of protoxide of cerium are like those of oxide of lanthanum, perfectly colourless, and with sulphate of potash the protoxide of cerium is precipitated completely from the solution. If hydrate of protoxide of cerium, precipitated by caustic potash, be collected on a filter, it immediately begins to grow yellow, and after the oxidation has proceeded as much as possible in this manner in the air, there remains after drying, opaque light yellow lumps, which contain water; this being expelled by heat, leaves so-called oxide of cerium, which has not the least trace of brown, but after an hour's heating at a white heat, has a slight tinge of red. If the oxide of cerium formed in the manner stated has the slightest tinge of brown, or becomes dark after drying or heating, it proceeds from foreign substances. This yellow oxide, however, always contains protoxide of cerium, and I have not succeeded in obtaining oxide of cerium free from protoxide. The bright yellow oxide which is formed when hydrate of protoxide of cerium, either alone or mixed with hydrate of oxide of lanthanum, &c., is exposed to the action of chlorine, contains not only chlorine but even protoxide of cerium. If nitrate of protoxide of cerium be heated, a light yellow powder is obtained, from which much salt of protoxide of cerium may be extracted with nitric acid, and if this solution be again evaporated, and the dried mass heated, salt of protoxide of cerium is again obtained, and this continues even after the operation has been five times repeated. What I call oxide of cerium is, therefore, really a combination of oxide of cerium with protoxide. The ignited oxide of cerium is scarcely affected by boiling concentrated muriatic acid, still less by other weaker acids; the hydrate, on the other hand, is easily dissolved in muriatic acid, with the development of chlorine, but even after a long boiling the solution retains a yellow colour. Scarcely a trace of the hydrate of oxide of cerium is dissolved by weaker diluted acids, but it assumes a darker yellow colour, and combines with a portion of the acid employed. In the solutions of carbonated alkalies, particularly carbonate of ammonia, the hydrate of oxide of cerium is dissolved in large quantities, and the solution assumes a bright yellow colour. Peroxide of cerium in solutions which are heated to boiling, is immediately reduced by oxalic acid to protoxide of cerium, while carbonic acid is developed. By

means of warm concentrated sulphuric acid, the ignited oxide of cerium is immediately rendered soluble, in consequence of combining with the acid. Neutral sulphate of oxide of cerium is, when dry, a beautiful yellow, becomes by heating orange yellow, with a higher degree of temperature almost cinnabar red, but after cooling the bright yellow colour returns. The salt is soluble in a small quantity of water, but if the solution be heated to boiling, the greater part of the salt is deposited in the form of a tough, soft, semi-transparent, and very viscid mass. If the concentrated solution, which is red yellow, be diluted, it becomes lighter yellow, but begins immediately to grow turbid, depositing a sulphur-yellow powder, which is a basic salt requiring 2500 parts of water for its solution. With sulphate of potash, sulphate of oxide of cerium gives a beautiful yellow salt, which is altogether insoluble in a saturated solution of sulphate of potash, but the double salt cannot be dissolved in water without being decomposed and a basic salt precipitated. Notwithstanding the oxide of cerium is nearly insoluble in diluted acids, it must be remembered that intimately mixed with other easily soluble oxides, it readily passes into solution: sulphuret of cerium is of a dark brown-red colour.

The oxide of lanthanum which was first obtained by me was of a brown colour, but after having been heated to a white heat, became a dirty white; by heating in hydrogen it also lost its brown colour, although a scarcely perceptible loss of weight arose therefrom: by heating in the air, the brown colour returned.

This circumstance, together with several other phænomena which presented themselves during the examination of the properties of oxide of lanthanum, caused me to presume that the oxide of lanthanum which had been obtained was still accompanied by some unknown oxides, and it was in the beginning of 1840 that I succeeded in freeing lanthanum from that very substance which caused the brown colour. To the radical of this new oxide, I gave the name of *Didymium* (from the Greek word *δίδυμος*, whose plural *δίδυμοι* signifies twins), because it was discovered in conjunction with oxide of lanthanum. It is the oxide of didymium that gives to the salts of lanthanum and cerium the amethyst colour which is attributed to these salts; also the brown colour which the oxides of the same metals assume when heated to a red heat in contact with the air. Notwithstanding all possible care, I have not yet succeeded in obtaining the oxide in a state of purity; and I have only arrived so far as to ascertain that a constant compound with sulphuric acid can be produced by



different means, but from the quantity of water of crystallization, and other circumstances, the conclusion may be drawn that the salt is really a double salt, although I cannot at present say whether the other accompanying oxide is oxide of lanthanum, or some other. That which I now thus briefly describe as oxide of didymium is the basis in combination with sulphuric acid in that salt whose properties I will now communicate, as well as a method of obtaining it. The sulphate of oxide of didymium, prepared in different ways, is much more soluble in water than the sulphate of oxide of lanthanum. This circumstance induced me to try whether by treating the mixture of the anhydrous salts in great excess with water in small proportions, solutions could not be obtained, which, in the order they had been procured, should be richer in salts, and particularly in sulphate of oxide of didymium, while, on the contrary, what remained undissolved, should be nearly pure sulphate of oxide of lanthanum; but after having examined five successive saturated solutions, obtained from the same mixture of anhydrous salts, it was found that one part of anhydrous salt had in the first experiment been dissolved in 7.64 parts of water; in the 2nd experiment in 8.48 parts; in the 3rd experiment in 7.8 parts; in the 4th experiment in 5 parts, and in the 6th experiment in 7.44 parts of water. These remarkable proportions of salt dissolved I thus explained: during the dissimilar degrees of temperature which accidentally arise under the development of heat which takes place when, by the addition of water to the anhydrous salt, this takes up water of crystallization, salts containing unlike portions of water of crystallization, and of unlike solubility had been formed, and it was for the purpose of ascertaining the correctness of this supposition that I afterwards prepared the solution of the salts in the manner which I have already stated in describing the sulphate of oxide of lanthanum, the dissimilar solubility of which salt with different degrees of heat was in this manner discovered. If therefore the mixed salts, with a temperature which should not exceed  $48^{\circ}2$  Fahr., be dissolved in 6 parts of water, and the solution thus obtained afterwards heated to  $104^{\circ}$  Fahr., a quantity of light amethyst-coloured salt of lanthanum is deposited, which, by a repetition of the same treatment, after ten to fifteen operations, becomes colourless and nearly pure. The amethyst-coloured solution separated from the salt of lanthanum is evaporated to dryness, and the salt is freed from water; it is again dissolved in the before-mentioned manner, but the solution is now heated to  $122^{\circ}$  Fahr., and filtered after no more salt is deposited. The solution, now

red, is diluted with an equal weight of water, acidulated with a portion of sulphuric acid, and is evaporated in a warm place. Several kinds of crystals are now formed, many of which assume a larger size, and fall to the bottom; when only a sixth part of the liquid, which is generally yellow, remains, it is poured off, the salt crust which lies at the bottom is separated, and the collection of crystals is shaken in boiling water, which is suddenly poured off; when a number of smaller prismatic crystals accompany it. The remaining large red crystals are again dissolved in water, the solution is acidulated with sulphuric acid, evaporated in the before-named manner, and the large red crystals taken separately, when it will be found on a nearer examination that they form a mixture of two kinds: the one, which appear in the form of long, narrow rhomboidal prisms, is taken out, and the remaining large red crystals with many planes, which, according to Wallmark's measurement, appear to belong to the triklinometric system, form the salt which I call sulphate of oxide of didymium. From a solution of a salt of didymium hydrate of oxide of didymium is precipitated with hydrate of potash in excess, and collected on a filter; it has a bluish-violet colour, absorbs during washing carbonic acid from the air, and the residuum, for the most part formed of carbonate of oxide of didymium, is, after drying, light reddish violet. If this be heated to redness, the water passes off and carbonic acid is easily expelled. The oxide produced in this manner is obtained in the form of small lumps, dark brown on the surface, sometimes light brown in the fracture, of a resinous lustre, sometimes nearly black, with the lustre and appearance of dark orthite, at the same time particles are obtained of all the most dissimilar colours, so that they represent together a pattern map of all the most dissimilar kinds which are obtained of the mineral orthite, from the light red brown to the nearly black. The powder becomes light brown. If this oxide be heated to a white heat, it assumes a dirty white colour approaching gray green. Oxide of didymium is a weaker basis than oxide of lanthanum: it has no alkaline reaction, and appears not to absorb water after having been heated. It is, however, tolerably easily dissolved even in diluted acids, and the brown oxide with a development of gas. It is insoluble in carbonate of ammonia; its salts are amethyst-red, as well as the solutions of the salt, which forms no precipitate with hydrosulphuret of ammonia, unless a large quantity be added, or the liquid be heated, when the sulphuretted hydrogen is developed, and a basic salt precipitated having a slight tint of red. If the oxide be dissolved in phosphoric

salt by means of the blowpipe, the bead becomes amethyst-coloured with great tendency to violet, exactly as with a trace of titanitic acid after reduction.

Oxide of didymium heated upon platina foil with carbonate of soda, melts to a gray-white mass. With regard to the salts of didymium, I shall briefly describe those which are analogous to the before-mentioned salts of lanthanum and cerium, and must at the same time mention that the basic salt of didymium which is precipitated by caustic ammonia, can be washed without passing through the filter.

The mode in which sulphate of oxide of didymium is obtained, as well as its appearance, has been already stated; this salt is readily soluble in water at the ordinary temperature of the air, although the crystals are very slowly dissolved. The anhydrous salt is at once dissolved, if before the solution it is not suffered to combine with water of crystallization. Should this occur in such a manner that the anhydrous salt is covered over (*öfver gjutes*) with a little water, the mass becomes heated, and a hard salt crust is formed, which must be reduced to powder before it can be quickly dissolved. At the ordinary temperature of the air, one part of anhydrous sulphate of oxide of didymium requires five parts of water for solution. This solution begins at  $127^{\circ}4$  Fahr. to deposit crystals, the number of which increases in the same degree as the temperature increases, so that the boiled solution contains only one part of anhydrous salt to 50.5 parts of water; at a low red heat an inconsiderable quantity of sulphuric acid goes off, but after an hour's exposure to a white heat, the salt loses two-thirds of its acid. With sulphate of potash, sulphate of oxide of didymium gives an amethyst-coloured double salt, which is completely insoluble in a saturated solution of sulphate of potash.

Nitrate of oxide of didymium is very soluble in water, crystallizes with difficulty; the solution evaporated to thin syrup, has a beautiful red colour, which seen in a certain direction approaches blue. If the salt be evaporated to dryness in a warm place, and heated to melting, which cannot be effected without a great portion of the nitric acid being decomposed, a red fluid is obtained, which, cooled and solidified, does not fall to powder with violence, like the corresponding salt of lanthanum, but retains its form.

I must not omit to mention on this occasion, that amongst the many other bodies which in the course of these researches I was obliged to examine, yttria also presented itself, and I have found that this earth, free from foreign substances, is perfectly colourless, and gives perfectly colourless salts: that the

amethyst colour which the salts generally present comes from didymium, I will not, however, maintain.

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*Addendum, July 1843.*

*On Yttria, Terbium and Erbium.*

I published last summer a short notice of yttria, concerning which earth the following facts subsequently discovered merit attention. When I stated on the former occasion that pure yttria, as well as the salts of that base with a colourless acid, are colourless, my experiments had only gone so far as to show that all the yttria which I could procure for examination might with ease be separated into two portions, the one a stronger and colourless base, the other a weaker, which, in proportion as it was free from yttria, acquired a more intense yellow colour on being submitted to heat, and with acids gave salts of a reddish colour. I continued my examination during the following autumn and winter, and thereby was not only enabled to confirm the correctness of my former observations, but made the unexpected discovery that, as was the case with oxide of cerium, what chemists have hitherto considered as yttria, does not consist of one oxide only, but is for the most part to be regarded as a mixture of at least three, of which two appear to be new and hitherto unknown, all possessing the greater number of their chemical characters in common, for which reason chemists have so readily overlooked their real differences.

The characters which are peculiar to these oxides, and distinguish them from all others are,—1st, that although powerful salt bases, all more so than glucina, they are insoluble in water and in caustic alkalies, but on the other hand soluble, even after having been exposed to a strong heat, in a boiling solution of carbonate of soda, although after a few days the greater part separates from its solution in the form of a double salt; 2ndly, that combined with carbonic acid, they are largely soluble in a cold solution of carbonate of ammonia, and that when such solution is saturated with them, a double salt of carbonate of ammonia and the above carbonates immediately begins to separate, and that in such quantity, that after a few hours very little oxide remains in solution; which explains the observations of several chemists, that, as they express themselves, yttria sometimes dissolves freely, sometimes scarcely at all, in carbonate of ammonia: further, that the salts of these oxides have a sweet taste, and that the sulphates dissolve with more difficulty in warm than in cold water, without its following that they form double salts with

sulphate of potash, which are insoluble in a saturated solution of the latter.

If the name of yttria be reserved for the strongest of these bases, and the next in order receives the name of oxide of terbium, while the weakest be called oxide of erbium, we find the following characteristic differences distinguishing the three substances:—The nitrate of yttria is extremely deliquescent, so much so that if a small portion of a solution of that salt be left for weeks in a warm place, the salt produced will not be free from humidity. The solution of nitrate of oxide of terbium, which is of a pale reddish colour, soon evaporates, leaving a radiated crystalline mass, which does not change in air unless it be very damp. The crystals of sulphate of yttria are colourless, and remain clear and transparent for weeks in air at a temperature varying from 86° Fahr. to 158° Fahr., while a solution of sulphate of oxide of terbium yields by evaporation, at a low temperature, a salt which immediately effloresces to a white powder. Oxide of terbium, the salts of which are of a reddish colour, appears, when pure, to be devoid of colour, like yttria. Oxide of erbium differs from the two former in its property of becoming of a dark orange yellow colour when heated in contact with air, which colour it is again deprived of, with a trifling loss of weight, by heating it in hydrogen gas; and it is to the presence of oxide of erbium that yttria owes its yellow colour, when prepared as hitherto directed: and it is moreover probable, that in all those cases where a colourless yttria has been supposed to have been obtained, the presumed yttria has consisted for the most part of glucina, at least before it was known how to separate the last earth completely.

The sulphate and nitrate of the oxide of erbium are devoid of colour, although the solution of the oxide in acids is sometimes yellow, and the sulphate does not effloresce.

These and a number of other less remarkable differences between the three oxides, appear to me to place beyond a doubt that what we have hitherto obtained and described as yttria, is neither more nor less than a mixture of these three bases, at least such is the case with yttria prepared from gadolinite, cerine, cerite, and orthite, but as I have not yet had the good fortune to discover any tolerably easy or certain mode of obtaining the one or the other oxide chemically pure, I shall confine myself for the present to this short statement of facts.

I proceed to make known two easy methods by which chemists may prove the correctness of the above statements. If caustic ammonia in small quantities at a time be added to a solution of ordinary yttria in muriatic acid, and the preci-

pitae following each addition be washed and dried apart, we obtain basic salts, of which the last precipitated are colourless, and contain yttria only. Going backwards in reverse order from these last, we find the precipitates becoming nearly transparent, reddish, and containing more and more oxide of terbium, while the first precipitates contain the greatest proportion of oxide of erbium, mixed with oxide of terbium and yttria. If a solution of ordinary yttria in nitric acid be treated in the same manner, and the several precipitates be heated separately, the first precipitate will give a dark yellow oxide, the colour of each succeeding one will be paler and paler, till at last a white oxide will be obtained, consisting chiefly of yttria, with a trifling quantity of oxide of terbium. In making these experiments it is of importance that the yttria be free from iron, uranium, &c., a matter of considerable difficulty. It is therefore better to commence precipitating with a weak solution of hydrosulphuret of ammonia, and when the precipitate has no longer a shade of bluish green, then to apply the caustic ammonia as described. A better method in general is to add a portion of free acid to a solution of yttria, and then to drop in a solution of binoxalate of potash, continually stirring till the precipitate no longer redissolves. In a couple of hours a precipitate will form, which is to be separated, and the remaining solution treated as above described, and that as long as any precipitate is formed. If the remaining fluid be then neutralized with an alkali, a small quantity of nearly pure oxalate of yttria is obtained. Of the precipitates the first obtained are most crystalline, and fall quickly, the last more pulverulent, sinking slowly. The former contain most oxide of erbium, mixed with oxide of terbium and yttria; the next contain less oxide of erbium, more of terbium and yttria; while the latter contain more and more yttria, mixed with oxide of terbium. The first precipitates are always reddish, and the last colourless. If a mixture of the oxalates of these bases be treated with a very diluted acid, we obtain first a salt containing mostly yttria, then one richer in oxide of terbium, and the remainder contains principally oxide of erbium. I have even once succeeded in obtaining a double salt of sulphate of potash and sulphate of oxide of erbium (which is with difficulty dissolved in a saturated solution of sulphate of potash), by treating a somewhat concentrated solution of the nitrates of oxide of terbium and erbium with an excess of sulphate of potash.

That much time and labour have been employed in arriving even at the results which I have hitherto obtained, will be evident from the little I have been enabled to make known,

particularly when it is considered that one or two grains of yttria have often been divided into nearly a hundred precipitates, which have been individually examined; but I live in hopes that the knowledge already obtained will soon enable me to publish a more complete account of my investigations.

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XXXI. *Experiments on the mutual relations of Electricity, Light, and Heat.* By ELIAS WARTMANN, Professor of Physics in the Academy of Lausanne.

1. *On the relations which connect Light with Electricity, when one of the two fluids produces chemical action\*.*

THE experiments of Scheele, of Ritter, of Seebeck and of Talbot on the chloride of silver, those of Wollaston on gum guaiacum, of Sir J. Herschel on the precipitation of chloride of platinum by water, and lastly, the beautiful discoveries of M. Daguerre, have placed beyond doubt the existence of a particular influence of light which has been attributed, perhaps without sufficient proofs, and by analogy, to a chemical power supposed to reside in it. On the other hand, a numerous train of electro-chemical labours from the beginning of the present century have proved, that chemical and electrical actions always accompany each other, and are, so to speak, consolidated together and mutually answerable for each other. Chemical action therefore forms a plain on which light and electricity meet. What analogies and what dissimilarities do they there present? Does one of the fluids act in the same manner in the presence or in the absence of the other? Does light become electricity, or does it disengage it when it acts chemically? Here are different questions which have hardly been touched upon. Without pretending to reply to them in a decisive manner, I have endeavoured to procure some data at least with respect to them, and such has been the aim of the following researches.

I at first sought to discover what influence electricity already produced might have on a chemical action operated simultaneously by light; for this purpose the Daguerreotype appeared to me the most convenient and at the same time the most delicate instrument. A proof was obtained after an exposure for

\* [From the *Archives de l'Electricité.*] The lines which follow this title form the second part of a memoir communicated to the Society of Physics and Natural History of Geneva on the 1st of July, 1841. The title of this memoir was, "Experimental Researches on the Imponderable Fluids." The part which I now publish treats of matters in the order of the day, and which are not without some connection with the fact mentioned at the end of the preceding article. The same work had been communicated to the Society of the Natural Sciences of the Vaudois (*Verhandlungen der Schweiz. naturforsch. Gesellschaft bei ihrer Versammlung in Zurich, 1841, p. 272*).