

habitants of the Nicobar Islands, a subject to which he has paid much attention. As the result of his visit and investigations last year he concludes that there is an element of Papuan origin among the people of the interior, and that this is strongly mixed with another not curly-haired race. It is true, then, as has been suggested, that there is a curly-haired race in the interior of Great Nicobar, but whether the Andaman Negrito and this tribe are related is very doubtful. Mr. Roepstorff hopes that future researches may enable him to settle the matter.

It is asserted in Algiers that a letter from Itarem, Chief of the Hoggar Tuaregs, has been intercepted, taking credit to himself for the massacre of Col. Flatters' expedition. This is the man who sent two of his relatives to Col. Flatters as a sign of goodwill, with which that officer professed himself so well satisfied.

The *Times* correspondent states that it is announced by Dr. Nachtigal that the first diet of German geographers will be held at Berlin on June 7 and 8.

ON DISCONTINUOUS PHOSPHORESCENT SPECTRA IN HIGH VACUA¹

IN a paper which I had the honour of presenting to the Royal Society in March, 1879,² I drew attention to the fact that many substances when in high vacua and submitted to the molecular discharge by means of an induction coil, emitted phosphorescent light; and I especially mentioned the phosphorescent sulphides, the diamond, the ruby, and various other forms of alumina, crystalline and amorphous.

Pure alumina chemically prepared has very strong phosphorescence. Sulphate of alumina is dissolved in water, and to it is added an excess of solution of ammonia. The precipitated hydrate of alumina is filtered, washed, ignited, and tested in the molecular stream. It phosphoresces of the same crimson colour, and gives the same spectrum as the ruby.

Alumina in the form of ruby glows with a full rich red colour, and when examined in the spectroscopie the emitted light is seen to be discontinuous. There is a faint continuous spectrum ending in the red somewhere near the line B; then a black space, and next an intensely brilliant and sharp red line, to which nearly the whole of the intensity of the coloured glow is due. The wavelength of this red line, which appears characteristic of this form of alumina is, as near as I can measure, λ 689.5 m.m. This line coincides with the one described by E. Becquerel as being the most brilliant of the lines in the spectrum of the light of alumina in its various forms, when glowing in the phosphoroscope.

This coincidence is of considerable interest, as it shows a relation between the action of molecular impact and of sunlight in producing luminosity. The phosphorescence induced in a crystal of ruby by the molecular discharge is not superficial, but the light comes from the interior of the crystal, and is profoundly modified according as its direction of vibration corresponds or makes an angle with the axis of the crystal, being quenched in certain directions by a Nicol prism.

Sunlight falling on the ruby crystal produces the same optical phenomena. The light is internally emitted, and on analysis by a prism is seen to consist essentially of the one brilliant crimson line, λ 689.5. This fact may account for the extraordinary brilliancy of the ruby, which makes it so highly prized as a gem. The sun not merely renders the red-coloured stone visible, as it would a piece of coral, but it excites the crystal to phosphorescence, and causes it to glow with a luminous internal light, the energy of which is not diffused over a broad portion of the spectrum, but is chiefly concentrated into one wave-length.

The crimson glow of alumina remains visible some time after the current ceases to pass. When the residual glow has ceased, it can be revived by heating slightly with a spirit-lamp.

After long experimenting with chemically pure alumina precipitated from the sulphate as above described, a curious phenomenon takes place. When sealed up in the vacuum two years ago it was snow white; but after being frequently submitted to the molecular discharge for the purpose of exhibiting its brilliant phosphorescence, it gradually assumes a pink tinge, and on examination in sunlight a trace of the alumina line can be

detected. The repeated molecular excitation is slowly causing the amorphous powder to assume a crystalline form.

Under some circumstances alumina glows with a green colour. Ammonia in large excess was added to a dilute solution of alum. The strong ammoniacal solution filtered from the precipitated alumina was now boiled. The alumina which the excess of ammonia had dissolved was thereby precipitated. This was filtered off, ignited, and tested in the molecular discharge. It gave no red light whatever, but phosphoresced of a pale green, and on examination with a prism the light showed no lines, but only a concentration of light in the green.

Two earthen crucibles were tightly packed, the one with sulphate of alumina, the other with acetate of alumina. They were then exposed, side by side, to the most intense heat of a wind furnace—a heat little short of the melting-point of platinum.¹ The resulting aluminas were then tested in the molecular stream.

The alumina from the sulphate gave the crimson glow and spectrum line.

The alumina from the acetate gave no red glow or line, but a pale green phosphorescence.

In my examination of rubies, many pounds of which have passed through my apparatus, I have been fortunate enough to meet with one solitary crystal, not to the eye different from others, which emits a green light when tested in the molecular stream. All others act as I may call normally. The spectrum of this green-glowing crystal shows, however, a trace of the red line, and on keeping the discharge acting on it for a few minutes the green phosphorescence grows fainter and a red tinge is developed, the spectrum line in the red becoming more distinct.

Besides the ruby, other native forms of crystallised alumina phosphoresce. Thus corundum glows with a pink colour. The sapphire appears to be made up of the red-glow and the green-glow alumina. Some fine crystals of sapphire shine with alternate bands of red and green, arranged in layers perpendicular to the axis. Unfortunately it is impossible to prepare a tube for exhibition containing this variety of sapphire, as it is constantly evolving gas from the numerous fissures and cavities which abound in this mineral.

The red glow of alumina is chiefly characteristic of this earth in a free state. Few of its compounds, except Spinel (aluminate of magnesium), either natural or artificial, show it in any marked degree. All the artificially crystallised aluminas give a strong red glow and spectrum line. An artificially crystallised aluminium and barium fluoride phosphoresces with a blue colour, but shows the red alumina line in the spectrum. Spinel glows red, and gives the red line almost as strong as the ruby.

The mineral Spodumene (an aluminium and lithium silicate) phosphoresces very brilliantly with a rich golden yellow colour, but shows no spectrum line, only a strong concentration of light in the orange and yellow. A phosphorescing crystal of Spodumene has all the internal light cut off with a Nicol prism, when the long axes of the Nicol and the crystal are parallel.

It became of interest to see if the other earths would show phosphorescent properties similar to those of alumina, and especially if any of them would give a discontinuous spectrum; considerable interest attaching to a solid body whose molecules vibrate in a few directions only, giving rise to spectrum lines or bands on a dark background.

Glucina, prepared with great care, is found to phosphoresce with a bright blue colour, but no lines can be detected in the spectrum, only a concentration of light in the blue.

The rare mineral phenakite (aluminate of glucinum), sometimes used as a gem, phosphoresces blue like pure glucina, no trace of the alumina line being found in its spectrum. This mineral shows a residual glow after the current is turned off.

Thorina has very little, if any phosphorescence. This earth is however remarkable for its very strong attraction for the residual gas in the vacuum tube. On putting thorina in a tube furnished with well-insulated poles whose ends are about a millimetre apart in the centre, and heating strongly during exhaustion, the earth on cooling absorbs the residual gas with such avidity that the tube becomes non-conducting, the spark preferring to pass several inches in air rather than strike across the space of a millimetre separating the two poles. It is probable that this strong attraction for gas is connected with the great density of the earth thorina (sp. gr. = 9.4).

Zirconia gives a very brilliant phosphorescence, approaching

¹ Paper read before the Royal Society, May 19, by William Crookes, F.R.S.

² *Phil. Trans.* Part 2, 1879, p. 660.

¹ This operation was kindly performed for me by Messrs. Johnson and Matthey.

in intensity that of sulphide of calcium. The colour is pale bluish green, becoming whiter as the intensity of the discharge increases: no lines are seen in its spectrum.

Lanthana precipitated as hydrate and ignited shows no phosphorescence. After it has been heated for some time before the blowpipe it phosphoresces of a rich brown.

Didymia, from the ignition of the hydrate, has scarcely any phosphorescence; what little there is appears to give a continuous spectrum with a broad black band in the yellow-green. On examining the light reflected from this earth when illuminated by day or artificial light, the same black band is seen, and with a narrow slit and sunlight the band is resolved into a series of fine lines, occupying the position of the broadest group of absorption lines in the transmission spectrum of didymium salts.

Yttria shows a dull greenish light, giving a continuous spectrum.

Erbia phosphoresces with a yellowish colour, and gives a continuous spectrum, with the two sharp black bands so characteristic of this earth cutting through the green at λ 520 and 523. These lines are easily seen in the light reflected from erbia when illuminated by daylight. It is well known that solid erbia heated in a flame glows with a green light, and gives a spectrum which chiefly consists of two bright green lines in the same place as the dark lines seen by reflected light.

A curious phenomenon is presented by erbia when the spark passes over it at a high exhaustion. The particles of earth which have accidentally covered the poles are shot off with great velocity, forming brightly luminous lines, and striking on the sides of the tube, rebound, remaining red hot for an appreciable time after they have lost their velocity. They form a very good visible illustration of radiant matter.

Titanic acid phosphoresces dark brown, with gold spots in places.

Stannic acid gives no phosphorescence.

Chromic, ferric, and ceric oxides do not appreciably phosphoresce.

Magnesia phosphoresces with a pink opalescent colour, and shows no spectrum lines.

Baryta (anhydrous) scarcely phosphoresces at all. Hydrated baryta, on the contrary, shines with a bright orange-yellow light, but shows no discontinuity of spectrum; only a concentration in the yellow-orange.

Strontia (hydrated) phosphoresces with a beautiful deep blue colour, and when examined in the spectroscope the emitted light shows a greatly increased intensity at the blue and violet end, without any lines or bands.

Lime phosphoresces of a bright orange-yellow colour, changing to opal blue in patches where the molecular discharge raises the temperature. In the focus of a concave pole the lime becomes red- and white-hot, giving out much light. This earth commences to phosphoresce more than 5 millims. below the vacuum, and continues to grow brighter as long as the electricity is able to pass through the tube. On stopping the discharge there is a decided residual glow. No lines are seen in the spectrum of the light.

Calcium carbonate (calcite) shows a strong phosphorescence, which begins to appear at a comparatively low exhaustion (5 m.m.). The interior of the crystal shines of a bright straw colour, and the ordinary and extraordinary rays are luminous with oppositely polarised light. Calcite shows the residual glow longer than any substance I have as yet experimented with. After the current has been turned off, the crystals shine in the dark with a yellow light for more than a minute.

Calcium phosphate generally gives an orange-yellow phosphorescence and a continuous spectrum. Sometimes, however, a yellow-green band is seen superposed on the spectrum.

Potash phosphoresces faintly of a blue colour. The spectrum shows a concentration at the blue end, but the light is too faint to enable lines, if any, to be detected.

Soda phosphoresces faintly yellow, and gives the yellow line in the spectrum.

Lithium carbonate gives a faint red phosphorescence. Examined in the spectroscope, the red, orange, and blue lithium lines are seen.

I have already said that the diamond phosphoresces with great brilliancy. In this respect perfectly clear and colourless stones "of the first water" are not the most striking, and they generally glow of a blue colour. Diamonds which in sunlight have a slight fluorescence, disappearing when yellow glass is inter-

posed, generally phosphoresce stronger than others, and the emitted light is of a pale yellowish green colour.

Most diamonds which emit a very strong yellowish light in the molecular discharge give a continuous spectrum, having bright lines across it in the green and blue. A faint green line is seen at about λ 537; at λ 513 a bright greenish blue line is seen, and a bright blue line at λ 503, a darkish space separating the last two lines.

Diamonds which phosphoresce red generally show the yellow sodium line superposed on a continuous spectrum.

There is great difference in the degree of exhaustion at which various substances begin to phosphoresce. Some refuse to glow until the exhaustion is so great that the vacuum is nearly non-conducting, whilst others commence to become luminous when the gauge is 5 or 10 millimetres below the barometric level. The majority of bodies, however, do not phosphoresce till they are well within the negative dark space.

During the analysis of some minerals containing the rarer earths experimented on, certain anomalies have been met with, which seem to indicate the possible presence of other unknown elements awaiting detection. On several occasions an earthy precipitate has come down where, chemically speaking, no such body was expected; or, by fractional precipitation and solution from a supposed simple earth something has separated which in its chemical characters was not quite identical with the larger portion; or, the chemical characteristics of an earth have agreed fairly well with those assigned to it in books, but it deviated in some physical peculiarity. It has been my practice to submit all these anomalous bodies to molecular bombardment, and I have had the satisfaction of discovering a class of earthy bodies which, whilst they phosphoresce strongly, also give spectra of remarkable beauty.

The spectrum seen most frequently is given by a pale yellowish coloured earth. It consists of a red, orange, citron, and green band, nearly equidistant, the citron being broader than the others and very bright. Then comes a faint blue, and lastly two very strong blue violet bands. These bands, when seen at their best, are on a perfectly black background; but the parent earth gives a continuous spectrum, and it is only occasionally, and as it were by accident, that I have so entirely separated it from the anomalous earth as to see the bands in their full purity. Another earthy body gives a spectrum similar to that just described, but wanting the red, and having a double orange and double citron band. A third gives a similar spectrum, but with a yellow line interposed between the double orange and the double citron, and having two narrow green lines.

At present I do not wish to say more than that I have strong indications that one, or perhaps several, new elements are here giving signs of their existence. The quantities I have to work upon are very small, and when each step in the chemical operation has to be checked by an appeal to the vacuum-tube and to the induction-coil the progress is tediously slow. In the thallium research it only occupied a few minutes to take a portion of a precipitate on a platinum loop, introduce it into a spirit-flame, and look in the spectroscope for the green line. In that way the chemical behaviour of the new element with reagents could be ascertained with rapidity, and a scheme could be promptly devised for its separation from accompanying impurities. Here however the case is different: to perform a spectrum test, the body under examination must be put in a tube and exhausted to a very high point before the spectroscope can be brought to bear on it. Instead of two minutes, half a day is occupied in each operation, and the tentative gropings in the dark, unavoidable in such researches, must be extended over a long period of time.

The chemist must also be on his guard against certain pitfalls which catch the unwary. I allude to the profound modification which the presence of fluorine, phosphorus, boron, &c., causes in the chemical reactions of many elements, and to the interfering action of a large quantity of one body on the chemical properties of another which may be present in small quantities.

The fact of giving a discontinuous phosphorescent spectrum is in itself quite insufficient to establish the existence of a new body. At present it can only be employed as a useful test to supplement chemical research. When, however, I find that the same spectrum-forming earthy body can always be obtained by submitting the mineral to a certain chemical treatment; when the chemical actions which have separated this anomalous earth are such that only a limited number of elements can possibly be present; when I find it impossible to produce a substance giving

