



V. On hyperphosphorescence

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μ_{∞} directly but makes interpolations, using the temperature-coefficients which have been determined a good distance from 0° , and so runs into the danger of introducing errors into the calculated degrees of dissociation greater than the differences he has to determine. His results (at 0°) deviate from Prof. Ostwald's (at 25°) in some cases irregularly by several per cent., and his investigations are limited to three acids and two salts. For this reason the investigation of the matter remains as desirable as it was before.

Christ Church, Oxford,
May 1896.

V. On *Hyperphosphorescence*.

By SILVANUS P. THOMPSON, D.Sc., F.R.S.*

THE recent researches of H. Becquerel† on the emission by compounds of uranium and by metallic uranium of invisible radiations which very closely resemble those discovered by Wiedemann‡ and by Röntgen§, and which yet unquestionably consist of transverse vibrations, are of so great importance that any experiments upon the same line, however incomplete, are of interest to physicists.

In January last the writer and his assistant Mr. Miles Walker were repeating Röntgen's now familiar experiments on the production of photographic shadows by the emanations from Crookes's tubes, and were casting about for means to shorten the long exposures then necessary, when the idea occurred to them which has independently suggested itself to many other experimenters, namely that of employing fluorescent substances in contact with the photographic film to hasten the photographic action by the emission of rays of a visible sort when stimulated by the x -rays. Accordingly, having prepared sheets of paper or of aluminium covered with fluorescent material, they tried the effect of inserting them in some cases below the glass plate, in other cases above the glass plate with the fluorescent surface next the film, and in yet other cases above the plate but with the fluorescent surface outside. The materials so tried were sulphide of calcium, finely powdered fluor-spar, sulphide of zinc (natural blende), sulphate of zinc (artificial), fluoride of uranium and ammonium, and sundry platino-cyanides.

* Communicated by the Author.

† *Comptes Rendus*, cxxii. pp. 559, 790, &c.

‡ *Zeitschrift für Elektrochemie*, ii. p. 159 (Aug. 1895).

§ *Sitzungsberichte der Würzburger Physik-med. Gesellschaft*, 1895.

When sheets of paper or aluminium covered with these were placed face down upon the sensitive film, so that the x -rays were compelled to pass first through them, some results were obtained tending to show that the method might have some advantages : but the resulting negatives were always patchy and irregular. The most striking effect, however, was quite unexpected. Care had been taken to keep these prepared sheets of fluorescent material in the dark for a sufficiently long time for all visible phosphorescence or persistent fluorescence to disappear. This, in the case of the sulphide of calcium, required many hours. The powdered fluor was also heated beforehand. Nevertheless, though no visible phosphorescence was present, the sensitive films were fogged by rays emitted from these materials. Fluor-spar and the platino-cyanides did not produce any noticeable fogging, however. Even after being kept six weeks in darkness the sulphide of calcium is very active in the emission of rays that will affect a photographic plate.

While these experiments were in progress other experiments were begun to ascertain if from any other sources, such as sunlight or the light of the arc lamp, any rays could be obtained having, like the x -rays, the power of penetrating opaque bodies. From the arc lamp, with an exposure of about two hours, shadows of pieces of metal were obtained on a photographic plate through a piece of pine-wood several millimetres thick ; but aluminium was found to be totally opaque to everything radiated from the arc and to sunlight.

While the experiments on fogging were still in hand there was published the observation of M. Henry on the effect of sulphide of zinc in apparently augmenting the transparency of aluminium to x -rays ; an observation which had an obvious bearing on that which was under investigation. A number of small portions of the fluorescent substances with which we were experimenting were then placed upon the front of a sheet of aluminium about 0.5 millimetre thick, behind which was a gelatino-bromide plate (a Cadett's "lightning" plate) ; and these were left for several days upon the sill of a window facing south to receive so much sunlight (several hours as it happened) as penetrates in February into a back street in the heart of London. On developing the plate it was found that behind those spots where portions of uranium nitrate and uranium ammonium fluoride had been placed, photographic action had taken place through the aluminium sheet. No very distinct effect had been produced by the other substances. On communicating these observations to Sir G. G. Stokes he drew the writer's attention to the similar obser-

variations of M. Becquerel with respect to uranium salts, observations which have since been so remarkably extended. While agreeing with the Röntgen rays in the property of penetrating aluminium, zinc, and other opaque materials, and in exercising photographic actions, the Becquerel rays differ in the circumstance that they can be refracted and polarized. Whatever the Röntgen rays may eventually prove to be, the Becquerel rays consist of transverse waves of an exceedingly high ultra-violet order.

The circumstance that the strongest fluorescent effects are found in the compounds of two metals having such heavy atomic weights as platinum and uranium, when correlated with the other circumstance that the absorbing power towards x -rays is greatest in elements of the greatest atomic weights, naturally suggests a new application of the law of reciprocity between emission and absorption. If that law can hold good in the phenomena of the Röntgen rays, or of the closely-related Becquerel rays, one would argue that the best substances to employ as emitters of such radiations would be those substances which absorb them most freely. Now the property of emitting Röntgen rays has been observed in many substances, but always under the stimulation of the cathodic discharge. In Röntgen's original research glass was the radiator. Porter and Jackson independently found platinum-foil to be superior. Roiti has found porcelain and mica also to serve. The writer has observed Röntgen rays to be emitted from the following substances exposed to cathode discharges:—calc-spar, apatite, rubies, sapphires, diamonds, uranium glass, scheelite, tourmaline, a phosphorescent enamel containing 60 per cent. of sulphide of calcium, sulphide of zinc (hexagonal blende), zinc, aluminium, copper, iron, magnesium, and platinum. Of the metals in the above list, iron and platinum appeared to work better than copper, aluminium, or magnesium. The low melting-points of the last two render them unsuitable. Metallic uranium would have been tried had it been possible* to obtain a specimen; but all inquiries in London proved fruitless. Of the other substances named, the phosphorescent materials seemed to have some advantages over ordinary glass, but they are not so convenient to manage as the metals. Apatite was tried because, consisting as it does chiefly of phosphate of lime, it was thought that the x -rays emitted from its surface could be more certainly

* [While these lines have been going through the press, a specimen of metallic uranium has been given me by Mr. C. Vautin. It emits x -rays freely under the cathode discharge.—S. P. T.]

absorbed by bone than are the x -rays emitted from denser materials such as platinum.

At an early stage of these investigations the use of a fluorescent screen revealed the fact that the relative transparency of flesh and bone differed with different materials used as emitters, and depended also upon the degree of exhaustion. The necessary inference that the x -rays are not all of one kind, but are heterogeneous, was announced by the writer about the same time* that the same conclusion was drawn by MM. Benoit† and Hurmuzescu from other causes. To the rays emitted from apatite, bone was indeed found to be more opaque than to those emitted from platinum. But apatite, when subjected to the kathode discharge, continues to give out gases which after a very few seconds spoil the vacuum; and the tube containing apatite as an anti-kathode could not, consequently, be used except attached to the pump. Glass was found to be more transparent to x -rays emitted from platinum than to x -rays emitted in the same tube from glass.

The extraordinary property exhibited by the uranium compounds of emitting a persistent invisible radiation that will pass through aluminium and produce photographic action would suggest that these rays are identical with Röntgen's, were it not that Becquerel's success in reflecting, refracting, and polarizing them proves that they are more akin to ultra-violet light. The latter does not indeed penetrate aluminium: but it has long been known that ultra-violet rays penetrate films of silver which though thin are thick enough to reflect all visible kinds of light. It would seem to be proved, then, that Becquerel's rays differ from the known ultra-violet in degree rather than in kind, being rays of higher frequency and shorter wave-length. That their properties are intermediate between those of ultra-violet and of the Röntgen rays furnishes a strong presumption that the latter also differ only in degree, and are an extreme species of ultra-violet light. It should not be forgotten that so far back as 1857 M. Niépce de Saint Victor observed many cases in which an object, an engraving on paper or a figured piece of porcelain or marble, immediately after exposure to sunlight, was found capable of giving a photographic impression to a sheet of paper prepared with chloride of silver, with which it was placed in contact. He even used, after exposure to light, cardboard imbibed with salts of uranium or with tartaric acid, and found such to be capable of emitting rays that were photographically active. There was no attempt made, how-

* *Comptes Rendus*, cxxii. p. 807.

† *Ibid.* cxxii. p. 779.

ever, to investigate the possibility of transmitting these invisible radiations through opaque bodies.

The phenomenon of persistent emission of these invisible rays by the uranium compounds long after any electrical or luminous stimulus has ceased to be applied would seem, therefore, to bear the same relation to the transient emission of them in the Crookes tube as the persistent emission of visible light by phosphorescent bodies does to the transient emission of light by fluorescent bodies. Hence the writer ventures to give to the new phenomenon thus independently observed by M. Becquerel and by himself the name of *hyper-phosphorescence*. A hyper-phosphorescent body is one which, after due stimulus, exhibits a persistent emission of invisible rays not included in the hitherto recognized spectrum.

June 6, 1896.

VI. *On the Magnetic Field due to an Elliptical Current at a point in its plane within it.* By J. VIRIAMU JONES, M.A., B.Sc., F.R.S., Principal and Professor of Physics in the University College of S. Wales and Monmouthshire, Cardiff*.

§ 1. **I**N a communication presented to Section A of the British Association† at Oxford in 1894, giving an account of measurements made to determine the value of the International Ohm in absolute measure by the method of Lorenz, I referred to a small error consequent on the fact that my standard coil is wound on a cylinder, the section of which at right angles to the generating lines is not a circle but an ellipse of small excentricity.

In considering the effect of this ellipticity on the value of the resistance calculated from the observations, it must be noted that the ordinary formula implies that the coil is circular. This formula is

$$R = Mn,$$

where R = the resistance in absolute measure,

M = the coefficient of mutual induction of the standard coil and disk circumference,

n = the number of revolutions of the disk per second.

But we are primarily concerned with the balance of the electromotive force between the ends of the resistance when

* Communicated by the Physical Society: read May 22, 1896.

† Report of Electric Standards Committee, Appendix II., Brit. Ass. Report, 1894.