"On the Behaviour of the Becquerel and Röntgen Rays in a Magnetic Field." By the Hon. R. J. STRUTT, B.A., Scholar of Trinity College, Cambridge. Communicated by LORD RAYLEIGH, F.R.S. Received January 9,—Read January 18, 1900.

In the current number of Wiedeman's 'Annalen,' an experiment is described by Giesel showing that the Becquerel rays are deflected in a magnetic field. This result is of great interest, on account of the light which it throws on the nature of the rays. Up to the present, the evidence has tended to show that the Becquerel rays were of the same nature as the Röntgen rays, both being capable of penetrating thin metal sheets, of affecting a photographic plate, and of producing ionisation in the surrounding air. Neither could be refracted or reflected; and so far as has yet appeared, neither could be polarised.

These facts seemed to form a fairly strong body of evidence that the two kinds of radiation were essentially similar. But the announcement of the magnetic deflectibility of the Becquerel rays seems to throw doubt on this conclusion. The Röntgen rays, so far as is known, are quite unaffected by magnetic force. Under these circumstances it seemed worth while to make a new attempt to discover such an effect on the Röntgen rays. This attempt I have carried out. It will be best to say at once that the result is negative.

A focus tube was employed as the source of radiation. It was placed at a distance of about 35 cm. from a powerful electro-magnet, and in such a position that the cathode rays in the tube were parallel to the magnetic force due to the magnet. The line joining the oblique anti-cathode to the centre of the magnetic field lay in the plane of the anti-cathode.

A short distance in front of the magnet a wire was placed at right angles to the direction of the rays, and in the plane of the anti-cathode. It was thus at an angle of about 50° to the magnetic force—the same angle as that between the axis of the cathode stream and the anti-cathode. This wire was used to cast a shadow on a photographic plate placed at a distance of 65 cm. on the other side of the magnet.

An exposure was first made with the magnetic force in one direction. The exposure was then stopped, the field reversed, and another exposure given of course without shifting the plate. If then the rays had been appreciably deflected, the photograph should have shown two shadows, either overlapping, or altogether separated.

The rays casting the shadow were those emitted at a grazing angle from the anti-cathode. The reason for using these very oblique rays was that owing to the foreshortening of the anti-cathode, the source was virtually narrower than it would have been, had rays

been used which left the anti-cathode at a greater angle. Thus sharper shadows were obtained, and a smaller magnetic deflection could have been detected.

The tube was arranged with its cathode stream parallel to the magnetic field, so as to avoid any shifting of the source of radiation when the magnet was reversed, owing to an effect of the magnet on the original cathode beam. Such a shifting would have given rise to a spurious effect. The only objection to this was that the shadow-casting wire had to be obliquely placed so as to be in the plane of the anti-cathode. Thus some sensitiveness was lost.

I shall now give an estimate of the smallest deflectibility which could have been detected. The rays traversed a distance of 65 cm. after leaving the magnetic field.

It was estimated that a lateral displacement of the shadow of the wire by 0·02 cm. could have been detected. But the wire was inclined 50° to the resultant magnetic force. Thus the smallest real displacement that could with certainty be detected was $\frac{0{\cdot}02}{\sin 50}$ cm.

The smallest angular deflection of the rays which could be detected would be, in circular measure,

$$\frac{0{\cdot}02}{65 \sin 50} = 0{\cdot}000405.$$

The length through which the rays were exposed to the magnetic force was 8 cm. If in this distance they were bent through the above angle, the radius of curvature would be

$$r = \frac{8}{0{\cdot}000405} \text{ cm.} = 19{,}800 \text{ cm.}$$

The strength of the magnetic field was determined in the usual manner, by observing the throw of a galvanometer when a small coil of known dimensions connected up with it was suddenly withdrawn from the region between the pole pieces. To reduce the results to absolute measure, the throw due to reversal of an earth-inductor in the same circuit was observed.

In this way the strength of the field was found to be

3270 C.G.S.

It is convenient to exhibit the result by giving the maximum field which the experiments indicate as unable to produce a curvature of radius 1 cm.

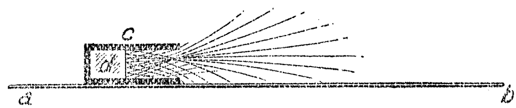
Since a field of 3270 does not produce a curvature of radius less than 19,800 cm., we see that the field required to produce a curvature of radius 1 cm. cannot be less than

$$6{\cdot}5 \times 10^7.$$

Owing to the fact that the magnetic field was *reversed* instead of being merely shut off, the experiment is really of double the sensitiveness indicated above. But, in order to be well on the safe side, it has been thought best to leave this out of account.

For the sake of comparison I have attempted a rough estimate of the amount of the magnetic deflection of the Becquerel rays. The method employed was as follows :—

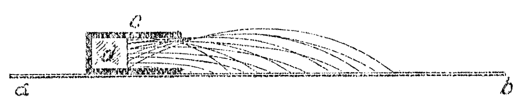
FIG. 1.



A photographic plate, shown in section at *ab*, was laid on the top of the square pole pieces of a magnet, the magnetic force being perpendicular to the plane of the diagram. The plate was covered with thin aluminium foil; *c* is a metal capsule filled with the substance *d*, which emitted the rays.*

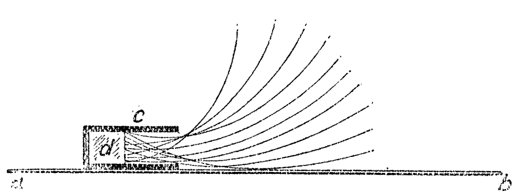
When no magnetic force was acting, the rays were emitted from the capsule as indicated in fig. 1, some of them striking obliquely on the plate. On development after one hour's exposure, a shadow was obtained beginning at the edge of the capsule *c*, and extending a short distance. The effect gradually tailed off, and at a few cm. distance away from *c* it was inappreciable. When the magnetic force was in such a direction as to bend the rays down into the plate (fig. 2), the

FIG. 2.



shadow extended further. When, on the other hand, the magnet was reversed so as to bend the rays away from the plate (fig. 3), the

FIG. 3.

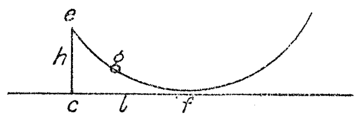


* The substance employed was a preparation from uranium residues, supplied by de Haen, Hamburg.

shadow obtained on development was much shorter, the time of exposure being, of course, in each case the same.

The numerical estimate of the curvature of the rays was obtained from an experiment of the latter kind.

FIG. 4.



Let us suppose that ec (fig. 4) represents in section the front surface of the radiating substance, cf the surface of the photographic plate.

Let f be the place furthest from c at which the darkening on the photographic plate was perceptible. Now the rays which reach furthest are those which proceed from e, the highest point of the radiating surface, as may easily be seen from geometrical considerations. The rays which reach f must consequently proceed from e. Rays proceeding from any lower point of the surface will either be bent up so as never to reach the plate at all, or else they will strike it short of f. The ray which reaches f from e will clearly just graze the surface of the plate at f.

If r be the radius of curvature, h the distance ec, and l the distance cf, then

$$h(2r - h) = l^2, \text{ or } r = \tfrac{1}{2}\left(\frac{l^2}{h} + h\right).$$

If then we measure h, the height of the highest part of the radiating surface above the plate, and l the greatest distance to which the darkening of the plate extends, we have data for determining r.

It must be admitted that the measurement of l involves great uncertainty. The image gradually tails off, and any estimate of its length must to a great extent be arbitrary.

The value of r deduced is more uncertain still, since l^2 is involved in calculating it. But, in spite of these objections, the method may, I think, be relied on to give the order of magnitude of r, and that is all that is required, so far as the conclusions which it is here sought to draw are concerned.

In one experiment, the length l was estimated at 2 cm.; h was 0·8 cm. Thus $r = 3$ cm. approximately.

The strength of the magnetic field, measured as before, was 1680 C.G.S. Thus the field required to produce a curvature of radius 1 cm. is about 5×10^3.

In another experiment, l was 1·8 cm., h was 0·8 cm., and the field 2140. This gives practically the same result as the preceding.

In an experiment described by Professor J. J. Thomson, a beam of cathode rays was bent to a radius of curvature of 9 cm. in a field of 35 units. Thus a field of 315 would have been required to bend it to a radius of 1 cm.

Let us now collect the results obtained, and compare them with this.

The field which would be required to produce a curvature of 1 cm. radius would be

For cathode rays	3×10^2
,, Becquerel rays	5×10^3
,, Röntgen rays not less than	6×10^7.

If the Röntgen rays are magnetically deflected at all, it is by an amount less than a ten-thousandth part of that observed in the case of the Becquerel rays.

The magnetic deflectibility of the Becquerel rays cannot but be considered to be a most characteristic property. And the above result appears to make it tolerably certain that the Röntgen rays do not possess this property. It is to be concluded, therefore, that the Becquerel rays are, after all, essentially different in character from the Röntgen rays.

"An Experimental Investigation of the Thermo-dynamical Properties of Superheated Steam." By JOHN H. GRINDLEY, B.Sc., Wh. Sch., Exhibition (1851) Scholar, late Fellow of the Victoria University. Communicated by Professor OSBORNE REYNOLDS, F.R.S. Received April 21, 1899,—Read January 18, 1900.

(Abstract.)

PART I.—*On the Law of Flow of Saturated Steam through Small Orifices.*

In making experiments on the thermal properties of superheated steam obtained by wiredrawing saturated steam, it is essential that certain laws assumed in theory to govern the flow through the orifice should obtain in practice.

Among these laws the only one on which a difference would be expected to exist between experiment and theory, is the law of adiabatic expansion assumed to hold during the flow.

Since such adiabatical flow is not only assumed, but is indispensable in obtaining temperature results in the wiredrawn steam which will enable deductions to be made by theory of the initial dryness of the steam or its thermal condition after wiredrawing, it was found im-