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There is a kind of tradition that paraffin-wax is a perfect safeguard against moisture; as a matter of fact it is highly absorbent. The wax on the bobbins returned from the tropics is completely choked with moisture. Shellac, or the old-fashioned sealing-wax varnish, resists much better. There is no evidence to show that ebonite is harmful to german-silver or platinoid, but it may be well to keep the metal out of actual contact with ebonite.

Can metallurgists tell us the difference, in constitution and structure, between a german-silver wire that decays in four weeks, and another that under similar conditions never fails? Or, what is even more important, can they make us platinoid that shall never fail? If they cannot, it becomes necessary to surrender those cheaper and better electrical materials, and fall back upon the more expensive alloys, beginning at platinum-silver. If sufficient time and means were at the disposal of metallurgists they might discover the secret of permanence in alloys. Germany, with the advantages of a National Laboratory, has already attacked the question, and "manganin" is the result. Its adoption there as a satisfactory alloy is directly due to work done upon it by the Reichsanstalt. But it has yet to be proved that manganin will endure the conditions imposed by the tropics. Moreover, the doubt arises as to whether it is desirable to obtain from abroad material that ought to be produced by our own country. British cable-manufacturers are already importing thousands of tons annually of sheathing-wire from Germany; and it seems probable that, for the want of a National Laboratory, instrument-makers will now get their resistance-wire from that same adventurous foreign source.

XVI. *Analogy between the Cathodic Rays and those of Röntgen.*
By Prof. A. BATTELLI, of the Pisa University.*

IN the 'Electrician' of the 8th of January, 1897, Prof. Silvanus Thompson describes a very simple experiment which induces him to admit that there exists within Crookes's tubes a special kind of rays, which differ from the cathode rays and from those of Röntgen. He observes that on bringing a magnet near the focus-tube, as was already known, the fluorescence on the side of the tube facing the small reflectors *changes* its position; whereas, on the other hand, if a fluorescent plate be placed before the tube, the luminous stain on it does not shift its position through the effect of the magnet.

* Communicated by the Author.

From this he concludes that there must exist internally the above-said special rays (those deviated through the effect of the magnet), which, according to the author, are of a different nature not only from those of Röntgen but also from the cathode rays, only as they do not follow the regular laws of reflexion.

Now Thompson's experiment as regards the rays emanating from the focus-tube is perfectly similar to what I had already had occasion to observe in 1896 in conjunction with Prof. Garbasso* respecting the cathode rays. We were thereby led to admit, as most probable, that the Röntgen and cathodic rays were of an identical nature, with this difference, however, that the first only constitute a part of the latter.

It seems to me that Thompson's experiment may agree with this hypothesis without the necessity of recurring to a third species of rays of a different nature. In fact, reflexion of cathodic rays cannot be spoken of, if we admit that when they strike against any kind of fluorescent plate they are converted into other sorts of radiation. Whilst on the other hand, if such reflexion be admitted it cannot indeed be said that in its complex action it follows the laws of regular reflexion. We can instead observe in the focus-tubes other facts which I shall forthwith describe, and which are more in harmony with our hypothesis than with Prof. Thompson's.

For the study of these facts I have made use of "focus-" tubes or bulbs, in the inside of which we could place, in various positions, photographic films covered with black paper impenetrable to light, folded (as I had done in preceding experiments) round small metallic cylinders.

The bulbs were of spherical form (fig. 1); from the horizontal tubes A and B penetrated the anode and cathode, from the vertical tube C a small glass rod supporting the small reflector.

Through the same tube C one of the small photographic cylinders projected into the spherical bulb; and through the other vertical tube D one or more similar cylinders were introduced into the bulb.

The reflector and the small cylinders were supported by appropriate framing joined to the respective supports by means of small hinges, so that one could easily give to the reflector and to the cylinders any desired position and inclination.

* A. Battelli, "Ricerche sulle azioni fotografiche nell'interno dei tubi di scarica," *N. Cimento*, ser. 4, vol. iii. p. 193 (1896); A. Battelli ed A. Garbasso, "Raggi catodici e raggi X," tom. cit. p. 289 (1896); A. Battelli ed A. Garbasso, "Azioni dei raggi catodici sopra conduttori isolati," *ibid.* vol. iv. p. 129 (1896).

Finally, the tube D was kept in permanent communication with the air-pump.

Fig. 1.

By means of this arrangement the conditions of the apparatus could rapidly be changed, and on the other hand the closure of the tube C and the communication of the tube D with the air-pump were established in a perfect manner and with much rapidity, by means of joints surrounded with mercury, as indicated in the figure. With these tubes I performed the following series of experiments:—

1st Experiment.—The small reflector was a plate of platinum, and besides the two small cylinders *c* and *c'* situated in front and at the back of the same small reflector, other three were placed in front laterally to *c* distributed at equal intervals between *c* and the surface of the reflector, all at nearly the same distance from the point struck by the small pencil of cathodic rays. The experiment was conducted under the influence of both high and medium rarefaction, and an impression was invariably obtained on all the films placed in front of the platinum reflector, which impression gradually diminished in strength from the film *c* towards the one placed in the plane of the reflector*. In this last

* Whenever I speak of a photographic impression on a film placed in front or at the back of the reflector of a focus-tube, I mean to indicate the impression on that part of the film that was facing the reflector, because in any other part of the same film the impression was always very faint or small.

impression a sharp demarcation is generally observed between the part acted upon (corresponding to the region above the reflector) and the part which remained unaltered (corresponding to the region beneath).

Observing then the interior of the bulb, one could easily perceive, so long as the rarefaction was not very high, the luminous pencil of the reflected cathodic rays forming with the reflector an angle, which, by the way, could not be reckoned as equal to that of the incident pencil; but meanwhile the fluorescence, though slight, spread over all the inner side of the tube placed above the plane of the reflector.

Whilst by degrees the rarefaction was gradually being increased, the reflected pencil of rays became less and less distinct; and near the surface of the reflector there could then be noted, especially by means of an opaque surface provided with a small opening, a feeble halo (rays expanding in all directions), whilst the demarcation-line between the inner and outer part of the tube grew more and more distinct.

2nd Experiment.—The cathode of the bulb used in this experiment was a plane disk, and the reflector had a spherical surface. The luminous cathodic rays striking on the spherical reflector were not reflected in a convergent pencil, but in a diminishing and rather divergent one, which, as the rarefaction increased, reduced itself into a halo near the surface, with an aspect not very dissimilar to the one it assumed when the reflector was formed by a plane surface.

Besides this the fluorescence expanded on the inner sides of the tube in a manner similar to the case of a plane reflector with a line of demarcation corresponding to the edge of the spherical reflector.

These first two experiments prove that it is quite out of the question to speak of a completely regular reflexion of the cathodic rays.

3rd Experiment.—On the direction taken by the small luminous pencil of the cathodic rays, reflected by the ordinary reflector of the focus-bulb, a second plane reflector was placed with an inclination of about 45° to the pencil.

This second reflector sent back the rays that fell on it in a less condensed pencil than when these same rays reached it, but yet its action was similar to that of the first reflector, with this difference, that the halo round its surface had a certain preponderance over the short reflected pencil, which appeared faint and fading, and was often invisible.

4th Experiment.—In the bulb of fig. 1 instead of the photographic cylinder *c*, a spherical reflector *S'* was placed with its axis in a horizontal position, and the cylinder *c'* was

fixed in the posterior part of the tube, but high up in front of the spherical reflector S' and at some distance from the axis of this same reflector.

The cathodic rays reflected by the plane reflector on the spherical one S' , were by this thrown back with the same luminous appearances as surrounded the spherical reflector exposed to the direct cathodic rays in the 2nd experiment; but the small pencil which showed sufficiently in said 2nd experiment was scarcely visible in front of S' and could only be followed up to a very limited distance from the reflector.

The photographic cylinder received then a much more vivid impression on the part facing the reflector than on any other portion of it.

The two experiments, 3rd and 4th, show that the cathode rays reflected by the reflector of a focus-tube can subsequently undergo a new anomalous reflexion similar to the first reflexion of the same rays.

5th Experiment.—In this experiment two bulbs of equal size, with the reflector and the small cylinder disposed as in fig. 1, were placed in simultaneous communication with the air-pump.

In the first bulb, however, the reflector was a sheet of platinum of the thickness of $\frac{1}{10}$ of a millimetre, and in the second bulb a sheet of aluminium of the same thickness.

The electrical discharge was sent alternately in the two bulbs minute after minute.

On the two films which faced respectively the two reflectors, strong impressions were always received and of the same intensity. To a feeble impression obtained at the back of the sheet of aluminium, no impression whatever corresponded on the film placed at the back of the sheet of platinum. But to a sufficiently marked impression on the first, a very feeble impression showed on the second.

6th Experiment.—The same arrangement was maintained as in the preceding experiment; but in the first bulb the reflector was now of aluminium of the thickness of $\frac{6}{10}$ of a millimetre, and in the second the reflector was also of aluminium, but of the thickness of but $\frac{1}{10}$ of a millimetre.

The impressions on the films in front were, as usual, of the same intensity. And as for the posterior films, a stronger impression was obtained on the one situated behind the thinner sheet.

7th Experiment.—The same disposition as in the preceding experiment. The reflector of one of the bulbs was of black paper of the thickness of $\frac{8}{10}$ of a millimetre, and that of the other was a sheet of aluminium of the same thickness.

The impression on the photographic cylinder in front of the sheet of aluminium was very slightly more intense than on the cylinder placed in front of the sheet of black paper. Whereas in the cylinder placed behind the first reflector the impression appeared sensibly weaker than that at the back of the second.

8th Experiment.—Still the same arrangement as in the preceding experiments. The reflector of one of the bulbs was of sheet aluminium of $\frac{1}{10}$ of a millimetre, and the other was also of sheet aluminium of $\frac{3}{1000}$ to $\frac{4}{1000}$ of a millimetre.

The electrical discharge was sent alternately in the two bulbs with intervals of two seconds each time.

Of the films in front, the one that was the more strongly acted on was the one facing the thicker sheet, and the reverse effect was obtained on the films on the back.

Besides this, the two impressions in front and behind the very thin sheet of aluminium were very nearly of the same intensity. And, lastly, at the back of the thin sheet the usual shadow projected in the focus-tube by the reflector was no longer discernible.

Shortly after the action of the bulb, the sheet of aluminium was pierced through by the cathode rays, but we still had sufficient time to complete the experiment.

The same experiment with similar results was performed with two bulbs, the first of which had as reflector a sheet of black paper of the thickness of $\frac{8}{100}$ of a millimetre, and the other a small sheet of black paper even thinner than $\frac{1}{100}$ of a millimetre.

9th Experiment.—In one of the bulbs, with the preceding arrangement, a reflector of black wave-paper was placed of the thinness of less than $\frac{1}{100}$ of a millimetre, and in the other a reflector of sheet platinum covered with the same thin wave paper.

In front of the two surfaces facing the cathode an impression was received slightly more intense on the film facing the sheet of platinum, whereas in front of the opposed surfaces a much stronger impression was naturally received on the other film belonging to the sheet of the thin wave paper.

The experiments from 5th to 9th included prove, not only that the photographic action on the sheet struck by cathodic rays is much more intense on the side facing the cathode than on the contrary one (which was already known), but they demonstrate, moreover, that the agent to which such an effect is due is the more fully transmitted from the first face to the second the thinner the stratum is which is to be penetrated, and the less dense the substance.

This last fact would prove in harmony with the hypothesis that the photographic action is due to the cathodic rays themselves forced back by the obstacle or piercing through it.

And next, what could not easily be foreseen, is the other conclusion suggested by these experiments, namely, that the action of the surface facing the cathode is the more feeble the less the thickness of the sheet. It would be difficult to place this result in harmony with the hypothesis that the Röntgen rays emanating from any substance whatever are generated by the cathodic rays which strike that same substance.

10th Experiment.—Two bulbs of equal size were placed simultaneously in communication with the air-pump, each bulb containing the platinum reflector, and also several photographic cylinders disposed as in the 1st experiment.

One of these reflectors was, however, surrounded by a spherical covering of thin black wove paper of the thinness of $\frac{2}{1000}$ of a millimetre. This covering had a small aperture in front of the cathode, through which the small pencil of cathodic rays penetrated so as to strike direct on the reflector.

The results obtained with both bulbs were identical, with, perhaps, a very slight difference in the intensity of the impression. Besides which, in the bulb with the spherical covering of black thin wove-paper the fluorescence on the inner side of the tube was not altered in its distribution nor sensibly so in its intensity; similarly, the shadow projected by the reflector on the aforesaid inner side of the tube remained unaltered.

Therefore an object surrounding the reflector does not in the least way cause any deviation in the action which may be obtained within the tube through the effect of the cathodic rays reflected by the reflector itself.

11th Experiment.—Two bulbs were used in this experiment prepared in the same way as in the first, both having a reflector of aluminium of from three to four thousandth parts of a millimetre in thickness. To one of these an electromagnet was applied behind the reflector in such a way that the luminous mark, which was visible in the direction of the incidental cathodic pencil, should strongly shift its position.

In the photographic cylinders placed behind the two reflectors, impressions were obtained of very nearly the same intensity.

I then placed, in the next experiment, two more photographic cylinders respectively behind the two small reflectors, but in a lateral position. So soon as the first bulb was excited I rapidly pushed, by means of the electromagnet, the centre of the luminous mark at the back on the line which joined the reflector to the small cylinder.

In this manner I only obtained a very slight variation in the photographic impression.

This experiment goes to prove that the radiation emanating from the posterior surface of a sheet struck by the cathodic rays, acts in the same manner as the radiation emitted by the front surface of the sheet. This shows that the power, observed by Thompson as possessed by the rays emanating from the reflector of a focus-tube, could also be noted in the rays emanating from the anticathodic surface of an ordinary Crookes's tube, if this surface be sufficiently thin.

12th Experiment.—In a bulb similar to that of fig. 1 the two photographic cylinders were composed, each of them, of three small cylinders placed in a line and respectively covered with black paper, with a sheet of aluminium and one of platinum, all of the thickness of $\frac{8}{100}$ of a millimetre.

In the small cylinder covered with aluminium an impression was obtained weaker than the one noted in the small cylinder covered with paper; and on the small cylinder covered with platinum, a still weaker one than on the one covered with aluminium, both in front and at the back of the reflector.

13th Experiment.—Three small cylinders prepared respectively in the same manner as in the 12th experiment were placed at the same moment on the direct line followed by the cathodic rays in an ordinary Crookes's tube.

The same results were obtained as in the preceding experiment with the same relations between the respective photographic impressions.

Fig. 2.

14th Experiment.—For this experiment a bulb was constructed slightly differing from the preceding ones. This also was spherical, and the two electrodes entered it through the two horizontal tubes A and B (fig. 2), and the reflector

penetrated in it likewise through the vertical tube C. But on the part of the bulb facing the said reflector was soldered a large tube M closed by a bimetallic disk, composed, namely, half of an aluminium sheet of the thickness of *half a millimetre*, and the other half also of a sheet of aluminium of the thickness of *one millimetre*. On the diameter along which the two sheets fitted together a thick sheet of zinc was soldered perpendicularly to the plane of the disk.

In front of both the two sheets that formed the disk a small photographic cylinder was placed, on the extremities of which two figures were respectively fixed; one made with the thinner aluminium sheet ($\frac{1}{2}$ millimetre) and the other with the thicker sheet (1 millimetre).

Naturally the two sides of the cylindrical surfaces, wherein the figures showed, were turned towards the disk.

In the region of the film which stood opposite the two thin sheets (the thin disk and figure of the thin sheet) a strong impression was received; whereas on the points placed in a line with the two thicker sheets a rather feeble one was obtained. But the parts where the figure of the thin sheet fronted the thicker half-disk were impressed in an equal degree to the parts placed under the figure of the thicker sheet and the thinner half-disk.

The same results were obtained when the tube M of the bulb was closed by disks formed (*a*) half of aluminium and half of glass of the same thickness, (*b*) consisting half of magnesium and half of glass still of the same thickness.

I also tried to use aluminium and zinc; but the difference between the impressions derived from the rays emanating from both the one and the other metal (of equal thickness) was so great that no decisive result was obtainable.

15th Experiment.—The preceding experiment was repeated, the cathodic rays striking directly on the metallic disk.

The result was the same.

These four last experiments show at any rate very approximately that the transparencies of those substances which are photographically efficacious for the cathodic rays and the Röntgen rays have the same value.

Conclusions.

From the bulk of the experiments above described it seems to me that the following deductions can principally be drawn:—

(*a*) It cannot be asserted that the cathodic rays are reflected, as a whole, according to the laws of regular reflexion.

(*b*) The rays thrown back from the reflector of a focus-tube

we may confidently assume to possess the same properties as the direct cathodic rays.

(c) The rays emanating from the posterior part of a very thin sheet, the anterior part of which is struck by the cathodic rays, also possess the same properties as these.

(d) A pencil of cathodic rays appears as made up of various rays of different natures. When they strike on a substance of a very small thickness they seem to possess the power of passing through it, but in the same way as if they passed through a filter, which would allow a passage more or less easy to some of them than to the others.

XVII. *A Theory of the Connexion between Cathode and Röntgen Rays.* By J. J. THOMSON, M.A., F.R.S., Cavendish Professor of Experimental Physics, Cambridge*.

A MOVING electrified particle is surrounded by a magnetic field, the lines of magnetic force being circles having the line of motion of the particle for axis. If the particle be suddenly stopped, there will, in consequence of electromagnetic induction, be no instantaneous change in the magnetic field; the induction gives rise to a magnetic field, which for a moment compensates for that destroyed by the stopping of the particle. The new field thus introduced is not, however, in equilibrium, but moves off through the dielectric as an electric pulse. In this paper we calculate the magnetic force and electric intensity carried by the pulse to any point in the dielectric.

The distribution of magnetic force and electric intensity around the moving particle depends greatly on the velocity of the particle, if this velocity is so small that the square of its ratio to the velocity of light can be neglected, then the electric intensity is symmetrically distributed round the particle, and at a distance r from it is equal to e/r^2 , where e is the charge on the particle; the lines of magnetic force are circles with the line of motion of the particle for axis; the magnitude of the magnetic force at a point P is $w \sin \theta / r^2$, where w is the velocity of the particle, and θ the angle a radius from the particle to P makes with the direction of motion.

When, however, the velocity of the particle is so great that we can no longer neglect the square of its ratio to the velocity of light, the distribution of electric intensity is no longer uniform, the electric intensity, along with the magnetic force, tends to concentrate in the equatorial plane, that is, the

* Communicated by the Author.