LXVIII. *The Effect of an Electric Current on the Photoelectric Effect.*

To the Editors of the Philosophical Magazine.

GENTLEMEN,—

IN the August number of the Philosophical Magazine Dr. Frank Horton has criticised a paper of mine on the photo-electric emission from bismuth, published in the June number. He ascribes my results to the emission of gas by portions of the apparatus when slightly heated by the current passed through the bismuth, and the subsequent production of radiation and ionization in that gas by the photo-electrons.

I have definite experimental evidence against this explanation.

1. On one occasion a small heating-coil was placed beneath the bismuth plate and was found to produce no change in the photo-electric emission for the small rise of temperature which it produced. This observation was not repeated and is, therefore, given little weight.

2. The early part of the experiment was carried out with only −4 volts instead of the −14 volts which was used later to obtain the saturation current. The rise in the photo-electric current was just as evident at the low voltage as at the high.

3. The effect of the emission of gas should be just as evident if the photo-electric current from the electrode is measured. This control experiment was carried out with both plates and films of bismuth by placing the plate at +14 volts. Though very large currents were passed through the bismuth, the only change in the current from the electrode was a small decrease. If gas emission were the controlling factor, this experiment would have shown rises corresponding to those observed in the original experiment.

I am, Gentlemen,
Yours faithfully,
ALLEN G. SHENSTONE.

Emmanuel College,
Cambridge,
8th August, 1921.

LXIX. *Attempts to Detect the Presence of Neutrons in a Discharge Tube.* By J. L. GLASSON, *M.A.**

1. INTRODUCTORY.—The possibility of the existence of a substance of zero nuclear charge was first mooted by Sir Ernest Rutherford in the Bakerian Lecture for 1920 (Proc. Roy. Soc. vol. xcvii. A, p. 396). The existence of

* Communicated by Prof. Sir E. Rutherford, F.R.S.

such a particle seems a logical extension of present-day views of nuclear structure. The helium nucleus, for instance, is believed to consist of four hydrogen nuclei with two binding electrons. It is still an open question whether this synthesis has yet been effected under the conditions prevailing in the ordinary discharge-tube. But if it occurs it is probable that other intermediate products are also formed, one of the most likely possibilities being the formation of a neutral nucleus containing one hydrogen nucleus and one electron. In the ordinary atom of hydrogen we have a single electron separated from the nucleus by a distance of the order of 10^{-8} cm. It is here contemplated that a more intimate union of the two is possible, such as would be obtained if the electron fell into the nucleus, so that the separation became of nuclear instead of atomic dimensions. Such a particle, to which the name *neutron* has been given by Prof. Rutherford, would have novel and important properties. It would, for instance, greatly simplify our ideas as to how the nuclei of the heavy elements are built up. This building-up process is apparently at work in the evolution of stellar systems from the nebular state. It is, however, difficult to see how an additional positively charged hydrogen or helium nucleus could penetrate into the nucleus of a heavy atom. In the case of Radium C, an α particle is ejected from the nucleus with a speed equivalent to a fall through several million volts, and a speed of this order would be necessary to secure its entrance into the nucleus against the repulsion of the existent positive charge. On the other hand, the entrance of a neutral particle would be much more easily effected, and the subsequent expulsion of the negative electron would achieve the necessary increment of nuclear charge.

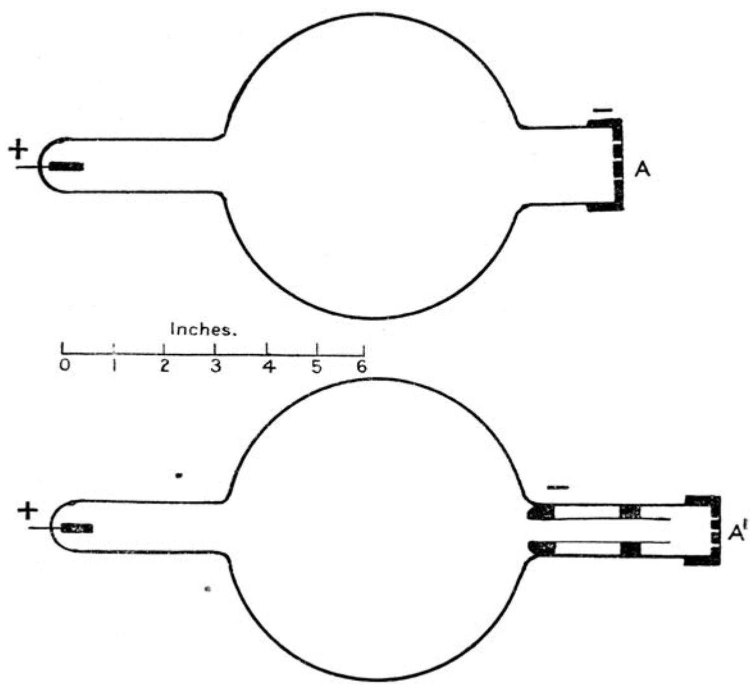
In a search for such particles, the most likely place for their existence seems to be amongst the positive rays in a hydrogen discharge-tube. There is in such a tube a plentiful supply both of free hydrogen nuclei and of electrons. If the hydrogen nucleus in its passage through the residual gas acquired a neutralizing electron in the manner above mentioned, the neutron would, owing to the much greater momentum of the positive nucleus, continue its course with the positive rays with practically unchanged velocity, just as ordinary neutral hydrogen atoms have been shown to do by Sir J. J. Thomson.

The detection of such high-speed neutrons would be extremely difficult, and none of the arrangements hitherto adopted in dealing with positive rays seems likely to reveal their presence. Owing to the large energy of formation it is likely that they would be extremely stable, and owing to their small size and restricted external field they would be extremely penetrating. They would, in fact, resemble closely the neutral pairs by which Sir William Bragg proposed at one time to explain the nature of X and γ rays. It is likely, however, that if a close collision with a heavy nucleus occurred, there would be a disruption or re-arrangement of the neutron or of the heavy nucleus, or of both with the accompaniment of local ionization. In the experimental work attempts have been made to secure this effect by allowing the rays to fall on mercury and lead atoms.

2. Experimental.—The arrangements naturally divide themselves into two parts: (*a*) for production, and (*b*) for detection.

The tubes used for (*a*) have been of the two forms shown in the figure.

Fig. 1.



In the first pattern the window A itself served as the cathode. In the second the cathode was of aluminium provided with a large central tube down which the positive rays were shot on to the window. The windows A and A′ were both made of brass with numerous perforations over which a thin sheet of aluminium foil was waxed on. The effective area of the aluminium window was $2\frac{1}{2}$ sq. cm. for A, and ·6 sq. cm. for A′, the thickness of the foil being ·001 cm. in each case. The tubes were exhausted by a Gaede rotary mercury pump. In preliminary experiments a willemite screen placed at A and A′ showed that at suitable pressures a good beam of positive rays was obtained. As a rule, hydrogen was used in the tubes, and in many cases a steady flow of hydrogen was maintained by the usual capillary tube method. Experiments with air were also made. The tube was run by a 10-inch Cox coil with hammer break.

(*b*) The detection.—Three experimental arrangements were used. In the first an ionization chamber filled with mercury vapour was used. The vessel itself was a cylindrical iron pot, one of the flat faces being provided with a thin mica window for the admission of the ionizing rays. The outside of the vessel was wound with German-silver heating coils embedded in alundum cement. The floor of the vessel was covered with mercury, and by raising the temperature to the boiling-point of mercury a large partial pressure of mercury vapour was obtained. The iron electrode was insulated by a quartz tube at the end of a long cylindrical neck. The quartz insulation was waxed into the neck and kept cool by a water-jacket. The electrode was connected to a Wilson electroscope which served to measure the ionization current through the vessel. Using a very strong source of γ rays, a saturation current was obtained about six times greater than that obtainable when the vessel was filled with air at the same temperature. So far, however, it has not been found possible to obtain great sensitiveness with the arrangement. The rapid ebullition of the mercury produces a considerable development of electricity within the chamber, probably of frictional origin. In view of the interest which the mercury vapour ionization chamber would possess in X-ray work, further experiments with it are being undertaken.

For the present purpose, I used also a second arrangement which allowed of greater sensibility, at any rate as far as γ rays are concerned. This was an ordinary α-ray electroscope with thick lead lining provided with a thin window either of lead or of platinum. The window of the electroscope was placed close up against the window of the positive ray tube.

Finally, a zinc-sulphide screen, such as is used for the detection of α particles, was also used; it was placed close against the window of the tube and examined through a microscope of wide aperture.

4. Results.—The tube was run in all stages of hardness from an alternative spark-gap of less than a millimetre

between 1 cm. balls up to an alternative spark-gap of 5 cm., giving a range of from 2000 up to 50,000 volts across the tube. At the higher voltages a fair amount of ionizing radiation was emitted from the window. By absorption in lead and platinum screens this was found to have an absorbability corresponding to the X rays to be expected from such a tube. Although very long runs were made with the tube, no evidence was obtained, by any of the three methods, of a radiation capable of penetrating ·005 cm. of lead. The present experiments, therefore, have not given any evidence of the existence of particles of the nature anticipated.

In conclusion, I desire to express my sincere thanks to Sir Ernest Rutherford, to whom, as is obvious, this work owes its inspiration.

Cavendish Laboratory, Cambridge.
July 1921.

LXX. *Notices respecting New Books.*

The Formation of Images by Optical Instruments. (Edited by M. Von Rohr, translated by R. Kanthack.) Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office, 1920. 45*s*. net.

THIS work, which can be obtained from any of the branches of H.M. Stationery Office, continues the services of the Research Department to Optical Science, which they began, on the side of publication, with a translation of Gleichen's work. The present work has long been the standard one throughout the complete domain of Geometrical Optics in its more complete aspect, and the only one which gave a really satisfactory account, within the limits of present knowledge, of the aberrations of optical systems as they present themselves to the practical designer as well as to the theorist. The translation is done with great care and not too literally, so that the meaning of the original is never ambiguous. Much improvement on the original has been introduced by change of symbols in certain instances, in accord with more familiar English usage.

As readers will be aware, the original consists of separate chapters of different authorship, each author being an expert; together with a general introduction regarding the history of the conception of the work, written by Czapski. This valuable historical document is also translated.

The Editorial Committee has clearly exercised great care in every particular, and the Department is to be congratulated on the completion of a very significant contribution to the advance of Optical Science and of its corresponding industry in this country. This work, now available in our own language, should have the effect of turning the attention of students much more definitely to the possibilities of this subject than previous works have done. It is produced in an excellent form by H.M. Stationery Office.