unmistakable bands in a single photograph taken with an aluminium radiator.

The complete investigation will probably show the different β -ray spectra to be extremely complex, and the question of their connexion with the corresponding complexity of the X-ray spectra is of the greatest theoretical importance, calling for closer examination of both the X ray and the excited β -ray spectra of the elements. It will be observed that the iron line (1) corresponds to a wave-length only 2 per cent. greater than the value 1.946×10^{-8} cm. given by Moseley* for the α line of iron, and the line (2) of lead to a wave-length greater by 1 per cent. than that of the α line of nickel (1.662×10^{-8} cm.). These differences are no greater than can be accounted for by uncertainties in the numerical constants involved: also, on account of the faintness of the photographic impression, it is difficult to measure very accurately the radius of curvature of the path of the excited β rays, and any percentage error introduced here is doubled in the calculation of the energy. The evidence, therefore, so far as our experiments go, indicates the production of excited β rays characteristic both of the anticathode and of the radiator. Whether the complete β -ray spectra can be connected with the X-ray spectra on the simple quantum theory, or whether the latter will have to be modified to bring the spectra into line, is a question to be solved by further experiment.

In conclusion we have much pleasure in thanking Sir Ernest Rutherford for suggesting this experiment, and for his advice throughout the course of the work.

Physical Laboratories,
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July 1st, 1914.

XXXIV. *Spectrum of the β Rays excited by γ Rays.* By
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IT is well known that the primary β radiation emitted by the great majority of radioactive substances contains a number of groups of rays expelled with definite velocities. When the β rays are analysed by their passage through a magnetic field, and received on a photographic plate, they

* Moseley, *Phil. Mag.* xxvi. p. 1024 (1913).

† Communicated by the Authors.

give a veritable spectrum, consisting of a number of well-marked bands. In a previous paper*, Rutherford and Robinson have analysed in some detail the magnetic spectra of the β rays of both radium B and radium C, and have measured the velocities and energies of a large number of groups from each element.

It is also well known that the γ rays of radium B and C in passing through matter give rise to high-speed β rays. The penetrating power of these rays has been examined by the electrical method, and has been shown to correspond approximately with that of the primary β rays from the same radioactive substance. It is of great importance to determine accurately the distribution of velocities of these excited β rays, and to trace their connexion, if any, with the primary β rays emitted by the radioactive substance.

For this purpose, we have made a number of experiments by a method similar to that described in the paper mentioned above. The diagram, fig. 1, is reproduced from that paper.

Fig. 1.

The whole apparatus is placed in a uniform magnetic field between the pole-pieces of a large electromagnet. The β rays issuing from the radioactive source S describe

* Rutherford and Robinson, *Phil. Mag.* xxvi. p. 717 (1913).

circular orbits, and after passing through a wide slit fall on the photographic plate PP. The great advantage of this method is that the β rays in a comparatively wide cone are concentrated into a narrow band on the photographic plate, thus making it possible to detect the presence of groups of β rays of feeble intensity and to deduce their velocities with accuracy. The source of γ radiation S was a fine-bore glass tube containing about 50 millicuries of radium emanation. The glass walls were sufficiently thick to absorb all the α rays and the low velocity primary β rays. This source was surrounded by a cylinder of the absorbing substance which in different experiments varied between 0.1 and 1 millimetre in thickness.

From the work of Baeyer and Danysz it is known that the velocities of the groups of β rays are reduced by their passage through a thin sheet of matter, and that the β radiation at the same time ceases to be homogeneous. After passing through a small thickness of matter, the sharp bands initially observed on the photographic plate become broader and more diffuse, and with increasing thickness become undetectable against the general background of continuous radiation. Even the swiftest groups from radium C are undetectable after passing through the glass tube and an additional thickness of 0.14 mm. of lead or gold. All the low velocity β rays escaping under these conditions are those liberated by the passage of the γ rays through the absorbing screen. The magnetic spectrum of these excited β rays was examined in exactly the same manner as that of the primary β rays.

A number of fairly broad bands were clearly visible on the photographic plates, above the general fog due to the penetrating γ radiation. The outside edges of the bands, corresponding to the swiftest rays of the groups, were sharply defined, but the bands gradually decreased in intensity on the low velocity side. The appearance of the bands is easily explained on general considerations. If the passage through matter of γ rays of definite frequency gives rise to a β particle of definite speed, then the β rays excited at the outer surface of the absorbing screen should escape with no loss of velocity, but those generated some distance below decrease in velocity before they are able to escape. Consequently we should expect that the bands would show a well-marked outer edge corresponding to the swiftest rays, and a gradual fading of intensity on the inner side due to the effect of particles with lower velocities. In this respect the spectrum of the β rays excited by γ rays differs from

that of the primary rays, where each group consists of rays of the same speed, but is very similar to the spectrum observed when the primary β rays have passed through an absorbing screen.

With a lead-absorbing screen, the most prominent groups of excited β rays were observed in that part of the spectrum which corresponded to the strong groups of primary rays from radium B, viz. those having velocities between 0.6 and 0.8 of the velocity of light. The photographs were practically identical in appearance, whether the tube was covered with 0.1 or 1 mm. of lead, showing that a thickness of 0.1 mm. was sufficient to cut out entirely the effect of the primary β rays. When the tube was covered with thin lead, evidence was obtained of groups, of very feeble intensity, corresponding approximately in position with the strong groups of primary rays from radium B marked E and F in the list of lines given by Rutherford and Robinson. These are rays having velocities approximately 0.4 of that of light.

The values of the velocities of the excited β rays were determined by direct comparison of the positions of the groups with those of the stronger lines due to the primary rays from radium B. For this purpose, an α -ray tube containing about 10 millicuries of radium emanation was put in the place of the first tube, and the primary β -ray spectrum obtained with the same magnetic fields. Small corrections were necessary for the reduction in velocity of the primary β rays in passing through the walls of the α -ray tube, and also for the increase in dimensions of the radiating source when surrounded by a metal cylinder. With thicknesses of lead of about 1 mm., the latter correction is difficult to make with certainty, for account has to be taken of the fact that the excited β rays are mainly projected in the direction of the exciting γ rays, and are thus most concentrated in the direction normal to the absorbing cylinder.

The experiments with lead as the absorbing screen are of special interest, for it has been shown by Rutherford and Andrade in a previous paper that the spectrum of the soft γ rays from radium B corresponds to that of the "L" characteristic radiation of lead. It would thus appear very probable that radium B and lead have the same nucleus charge and the same external distribution of electrons although their atomic weights are different. If the primary β rays from radium B result from the conversion of γ rays into β rays in their escape from the radioactive atom, it is to be anticipated that the spectrum of the β rays excited in lead should be identical with that given by the primary

β rays. It was obvious on inspection of the plates that the stronger groups of excited β rays corresponded very nearly in position with the primary β -ray spectrum of radium B. The values of $H\rho$ for the stronger groups of β rays excited in lead are given in the following table ; for the purpose of comparison, we have added a list of some of the primary β rays of radium B, taken from the paper of Rutherford and Robinson. It will be seen that within the limits of experimental error, the velocities of the rays are the same in each case.

Table of β rays excited in Lead.

$H\rho$ of excited β ray.	Intensity.	$H\rho$ of primary β ray.	Intensity.
3610	f.		
3250	f.		
2990	s.		
2735	m.f.		
2225	m.	2235	s.
2130	f.	2140	f.
2000	f.	1990	m.s.
1935	v.s.	1925	v.s.
1825	m.f.	1815	m.
1750	m.f.	1752	m.s.
1670	v.s.	1660	v.s.
1560	f.		
1400	s.	1392	v.s.
1240	m.		
1150	m.f.		
1080	m.		
1010	m.s.		
950	s.	950-914 (group)	m.
870	v.s.		
800	s.	798	m.s.

[v.s.=very strong; s.=strong; m.s.=moderately strong; m.= moderate intensity; m.f.=medium faint; f.=faint.

Dependence of intensity and velocity of the excited β rays upon the material.

It is of great interest to determine whether the velocity of the excited β rays depends on the material through which the γ rays pass. For this purpose, comparative measurements were made with screens of aluminium, silver, gold, and lead surrounding the emanation tube. With the screen of aluminium 0.6 mm. thick, it was impossible to detect any groups of β rays against the general fog of the plates: with silver the lines were faint and difficult to measure, but the lines from lead and gold were well marked

and of about equal intensity. It appears certain that the groups of β rays observed with the two latter substances are due to the conversion into β rays of some of the more penetrating γ rays from radium B. It is well known that the greater part of the γ radiation from this substance is rapidly absorbed in heavy elements like lead and gold, and no doubt the greater intensity of the groups of β rays from these substances is a result of the rapid absorption of the γ rays and their conversion into β rays, since the absorption of γ rays of this type increases with atomic weight more rapidly than the absorption of β rays. In consequence, the β rays are more intense from heavy than from light elements.

The lines obtained with a silver screen were compared with those obtained with a lead screen for the same field, and no certain difference in the velocity of the three strong groups of rays could be detected.

On the other hand, the velocities of a number of the β rays excited in gold were distinctly higher than the corresponding velocities of the β rays excited in lead, the difference being of the order of two per cent. In view of the method of comparison it seems scarcely likely that the difference is due to experimental error.

Experiments on this subject will be continued by Robinson and Rawlinson. It is intended to continue the investigation into the region of the groups of swift β rays of radium C and to examine the velocities of the β rays excited in a number of different metals. Preliminary photographs have shown that the β rays excited by the very penetrating γ rays from radium C are difficult to observe, as would be anticipated from the considerations already advanced.

University of Manchester,
June 29, 1914.

XXXV. *The Ionization of Platinum by Cathode Rays.*

By NORMAN CAMPBELL, *Sc.D.**

1. **T**HE researches of many investigators[†] have shown that if slow cathode rays fall on a metal plate electrons leave the plate, the numbers and speed of which depend on the speed of the incident rays. As the speed of the rays is increased from zero, the number of electrons leaving the plate increases to a maximum at about 5 volts

* Communicated by the Author.

† For a summary of the literature see *Phil. Mag.* June 1913, p. 803.