The last four values of c given in the table represent respectively the best result by each of four quite different methods, and agree remarkably well. As a final weighted average of these results, I suggest $299,776 \pm 4$ km./sec.

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Oct. 18.

¹ NATURE, 133, 759, May 19, 1934.

² NATURE, 133, 948, June 23, 1934.

³ NATURE, 130, 602, Oct. 22, 1927. This table has been checked and republished by Mittelstaedt (*Phys. Z.*, 30, 165; 1929).

⁴ Annual Report of Director, Mount Wilson Observatory, 1930-31, p. 218; 1931-32, p. 170; 1932-33, p. 164. See also NATURE, 133, 169, Feb. 3, 1934.

⁵ The first three columns of this table differ from the data already published by de Bray³ and by Mittelstaedt³ only in the use of 10 in place of 20 km./sec., for the probable error of Mittelstaedt's own work (*Ann. Phys.*, 2, 285; 1929). He states explicitly on p. 310 of his paper that 20 km./sec. is his limit of error.

⁶ *J. Phys. Radium*, 5, 168; 1924. In this case, also, the published ± 30 km./sec. appears to be an estimated limit of error, rather than a probable error.

⁷ *Rev. Mod. Physics*, 1, 1; 1929.

⁸ Congrès International d'Electricité (Paris, 1932), 3, p. 202.

⁹ U.S. Bur. Standards, *Bull.*, 3, 433; 1907.

¹⁰ Nat. Research Council, *Bull.*, 93, 92; 1933.

¹¹ *Phil. Trans.*, 214, 27; 1914.

¹² *Ann. Phys.*, 63, 179; 1920.

¹³ NATURE, 130, 25, July 2, 1932.

¹⁴ NATURE, 130, 277, Aug. 20, 1932.

β -Rays of Radium D

THERE has been much uncertainty as to the energies of the nuclear β -rays of radium D. All the expansion chamber investigations^{1,2,3,4} showed, in addition to the known secondary β -rays, numerous rays of ranges around 6 mm. in oxygen at s.t.p. and therefore of energies of about 20 kilovolts. These were interpreted by Feather³ and one of us⁴ (H. O. W. R.) as due to the nuclear electrons.

FIG. 1.

On the other hand, (1) Kikuchi¹ had failed to find pairs of secondary + nuclear tracks starting from the same atom on a weakly activated silk fibre; and (2) Stahel⁵, using a counter, had failed to count more than 0.83 β -rays per disintegration through a collodion film of small stopping power, though there is evidence that the secondary electrons amount to at least 0.6 per disintegration^{4,6,7}.

We have obtained new evidence by photographing in the expansion chamber β -tracks coming from radium D tetramethyl. This is a vapour, and the minute quantity used is handled and introduced into the chamber by using lead-tetramethyl as a carrier. It is thus possible to observe the β -disintegration of individual radioactive atoms in the gas.

From measurements of about a hundred dis-

integrations, we find that the typical disintegration of radium D consists in a 47,200 volt γ -transition accompanied by the emission of a nuclear electron of small range, 0-3 mm. in air. The estimation of the high energy limit of the nuclear spectrum is complicated by the presence of occasional tertiary electrons due to the Auger effect with ranges similar to those of the fastest nuclear electrons. The limit is probably near 10 or 12 kilovolts.

The β -rays between 10 and 30 kilovolts found in previous experiments are absent, so that they must be identified as secondary electrons which had lost energy in the solid material on which the radio element has previously been mounted.

The appearance of a disintegration can be judged from Fig. 1, which is reproduced from a photograph showing three tracks coming from the same atom in air in a field of 650 gauss. They are interpreted as a nuclear ray of about 1 mm. range, a tertiary of 3 mm. and an L secondary of 2.35 cm.

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¹ Kikuchi, *Jap. J. Phys.*, 4, 143; 1927.

² Petrova, *Z. Phys.*, 55, 628; 1929.

³ Feather, *Proc. Camb. Phil. Soc.*, 25, 522; 1929.

⁴ Richardson, *Roy. Soc. Proc.*, A, 133, 367; 1931.

⁵ Stahel, *Z. Phys.*, 68, 1; 1931.

⁶ Gray, NATURE, 130, 738, Nov. 12, 1932.

⁷ v. Droste, *Z. Phys.*, 84, 17; 1933.

Effects of Cosmic Radiation in a Wilson Chamber at the Hafelekar Observatory (2,300 m.) near Innsbruck

A MAGNETIC field of 1,500 gauss was produced in a Philipp-Dörffler Wilson chamber of 12 cm. diameter and 3 cm. depth, and the effects of cosmic radiation at a height of 2,300 m. above sea-level were investigated. We obtained the following results:

On 1,200 exposures, 160 electron-tracks are visible. Those which are nearly vertical can be interpreted as 31 positive and 34 negative, if we assume that the particles have been moving downwards. The charge of the others cannot be determined, since nothing is known about the direction of their motion. On 25 exposures several simultaneous tracks are visible. A distinct shower with about seven tracks (they are not all equally distinct) was photographed. The radius of curvature could be determined for 98 tracks. The statistics show that a considerable number of soft rays is present. Half the tracks have a radius of curvature of less than 3 cm., corresponding to an energy of 500,000 e.v. 34 have a radius of more than 30 cm., corresponding to 10^7 e.v. Taking the statistics for positive and negative rays separately, we get about the same distribution. Using a strip of lead (0.6 cm. thick), laid horizontally across the chamber, only one particle penetrating it was detected. It did not show any noticeable curvature even after passing through the lead.

Beside the tracks of electrons, tracks of heavy particles were also found. We cannot assume that these rays were due to a contamination of polonium or radium (actually only polonium has to be seriously considered), as three of them had a range of 5 cm. or more (exceeding the range of polonium considerably). One ray of 4 cm. range had both ends in the chamber, which is not likely to occur with polonium. Moreover, 9 out of 15 tracks were vertical, while only 14 out of

94 were vertical in the case of a weak polonium activity *ceteris paribus*. Thus the cosmic radiation is to be regarded as the cause of these rays.

Two thicker but very short tracks (0.6 cm. range) were observed, horizontal, but with both ends in the chamber, very similar to N-atoms set in motion by neutrons. They too must be due to cosmic radiation.

As to the nature and process of origination (whether directly or indirectly due to cosmic radiation) nothing can be said so far.

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Rock Salt Absorption of Cosmic Rays

Cosmic ray absorption measurements have until recently been carried out with relatively few light elements and compounds. Rock salt mines being very often used in the determination of the residual ionisation, it seemed especially interesting to measure the absorption of cosmic rays by this mineral.

FIG. 1.

Powdered rock salt was used for this research. In one set of experiments, about 40 tons of this material was heaped above the apparatus, which was contained in a wooden box. Care was taken to create conditions analogous to those existing for experiments in water; hence great extension of the external surface was aimed at. In a second set of experiments a kind of salt hill or mound was available to the author. The results of the measurements are shown in Fig. 1, where the observations made within the mound are marked by circles. A Kolhörster apparatus made by Messrs. Günther and Tegetmeyer, of Braunschweig, was used.

On computing the results by means of the $e^{-\mu x}$ function, I find for the coefficient μ/ρ at the depth of 1-3 metres a value of $0.7 \times 10^{-4} \text{ cm.}^2 \text{ gm.}^{-1}$, which is many times lower than the corresponding value, namely, $3.6 \times 10^{-4} \text{ cm.}^2 \text{ gm.}^{-1}$, for water. Thus, rock salt seems to be the most transparent substance for cosmic rays yet examined. The detailed data concerning this work will be published in the *Acta Physica Polonica*.

I take this occasion to express my thanks to the management of the Solvay Industrial Establishments in Poland, which provided the best conditions for the realisation of this investigation at the rock salt mines of Wapno (Province of Poznań).

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Fermi's Element 93

We have recently pointed out¹ that element 93 should have, according to the Periodic Law, other properties than those displayed by Fermi's element 93², and we found, on repeating his experiments with protactinium, that his 13-minute product from uranium is chemically identical with element 91.

The Italian workers, in continuation of their interesting work on neutron bombardment, have just described³ a new reaction of their element with an atomic number above 92 (co-precipitation with rhenium sulphide), and also found that their product with a period of 90-100 minutes is isotopic with the 13-minute body.

We have studied the rhenium sulphide reaction with protactinium as an indicator, and found that element 91 is precipitated to the extent of 40-60 per cent together with rhenium sulphide from 15 per cent hydrochloric acid solution, exactly like Fermi's products. Our conclusion is therefore that, instead of Fermi's assumption of

the products with 13- and 90-100-minute periods are isotopes of ekatantalum, changing by β -emission into isotopes of uranium.

Fermi's proof of the non-identity of his products with element 91, based on experiments with brevium, is not conclusive, because we have to expect the freshly formed brevium atoms to be, at least to some extent, in a chemically different state (for example, tervalent ions) than the bulk of the much longer-lived atoms of 'element 93'.

Details of our experiments will be published elsewhere.

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¹ A. V. Grosse and M. S. Agruss, *Phys. Rev.*, **46**, 241; 1934.

² E. Fermi, *NATURE*, **133**, 898, May 17, 1934.

³ E. Fermi, E. Amaldi, O. d'Agostino, F. Rasetti and E. Segré, *Proc. Roy. Soc., A.*, **146**, 495; 1934.

Experiments on Supraconductors

In a previous letter¹ it was reported that the magnetic induction in tin spheres, which were cooled in an external magnetic field until they became supraconductive, did not vanish entirely, but that part of the magnetic flux remained in the body. This 'freezing in' of lines of force was observed, when supraconductivity was attained either by cooling the specimen in a constant magnetic field or by decreasing the external field at constant temperature. Since then, this result has been confirmed by magnetic experiments by Rjabinin and Shubnikow² and by calorimetric measurements by Keesom and Kok³.

Meanwhile, two of us (T. C. K. and K. M.) have