find the upper limit. From the discrepancy between the observed ranges and the true ranges for radium E and uranium X_2, we can estimate that the correct range for the potassium beta-rays is 0.55 g/cm². This value, by the use of Feather's[5] range energy equation $R=0.543\times E-.160$, gives 1.3×10^6 volts as the upper limit of the K^{40} beta-ray spectrum.

No claims of exactness can be made for this value, but it is clear from the curves that K^{40} emits beta-particles of higher energy than does radium E, where the upper limit is known[9-11] to be 1.15×10^6 volts. Another estimate may be made from the absorption coefficients since the absorption curves are exponential over a large part of their length. The absorption coefficients of radium E and uranium X_2, and data from other bodies where the upper limits and absorption coefficients are known give a rough μ/ρ *vs.* upper limit curve. From this curve the $\mu/\rho=12.8$ for potassium yields an upper limit of 1.4×10^6 volts. The last estimate is valid only if the shape of the potassium spectrum is sensibly the same as that of the other bodies. That the K^{40} spectrum is not highly complex is indicated by the low intensity of the gamma-rays emitted. It is felt that the value derived from the corrected range is more reliable and that the best value is 1.3×10^6 volts with an estimated error of 0.15×10^6 volts.

The former lower values of about 700 kilovolts for the upper limit of K^{40}, derived largely from absorption data, are due in part to the fact that corrections were not made for the low activity of the source. Libby and Lee[12] have investigated the K^{40} spectrum with a concentric arrangement of source and counter, and an axial magnetic field, and give a value of 725 kilovolts, but state that no effort was made to obtain an accurate value. This type of measurement with a more elaborate system of counters, has been repeated recently by Dzelepow, Kopjave, and Vorobjov,[13] who find a value of 1.35×10^6 volts.

These measurements were done some years ago at Queen's University, Kingston, Canada, and I wish to thank Dr. J. A. Gray, F.R.S., for the use of the equipment, and radioactive sources used in the experiment.

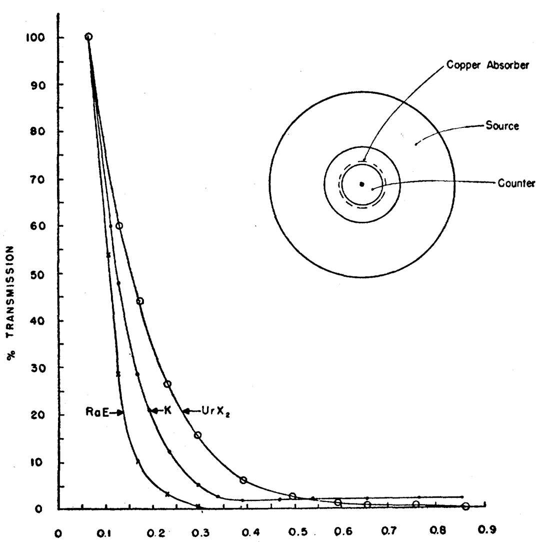

FIG. 1.

[1] E. Konopinski, Rev. Mod. Phys. **15**, 209 (1943).
[2] W. J. Henderson, Phys. Rev. **55**, 238 (1939).
[3] L. H. Gray and G. T. P. Tarrant, Proc. Roy. Soc. **A143**, 695 (1934).
[4] O. Klemperer, Proc. Roy. Soc. **A148**, 638 (1935).
[5] N. Feather, Proc. Camb. Phil. Soc. **34**, 599 (1938).
[6] Rutherford, Chadwick, and Ellis, *Radiations from Radioactive Substances*, p. 406.
[7] N. Feather, Proc. Camb. Phil. Soc. **34**, 115 (1938).
[8] B. W. Sargent, Proc. Roy. Soc. **A139**, 659 (1933).
[9] J. A. Gray and A. G. Ward, Can. J. Research **15**, 42 (1937).
[10] A. Flammersfeld, Physik. Zeits. **38**, 973 (1937).
[11] E. M. Lyman, Phys. Rev. **51**, 1 (1937).
[12] W. Libby and D. Lee, Phys. Rev. **55**, 245 (1939).
[13] B. Dzelepow, M. Kopjava, and E. Vorobjov, Phys. Rev. **69**, 538 (1946).

Coincidence Experiments on Ga^{72}

ALLAN C. G. MITCHELL, ED. T. JURNEY, AND MARGARET RAMSEY
Indiana University, Bloomington, Indiana

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A PRELIMINARY investigation has been made, with coincidence methods, of the radiations from the 14.0-hour radioactive Ga^{72}. A sample of gallium was activated by exposure to slow neutrons from the cyclotron. The short period activity (20 min.) of Ga^{70} was allowed to die out and the longer period activity investigated. The radiation consists of both gamma- and beta-rays.

The most energetic gamma-ray was found by measuring the energy of Compton recoil electrons ejected from an aluminum radiator. The recoil electrons were made to pass through two thin-walled counters connected in a coincidence circuit. Thin sheets of aluminum were placed between the counters until the number of coincidences dropped to a small, constant background. The range of the recoil electrons was found to be 1.22 g/cm² (including counter wall thickness). From the curve of Curran, Dee, and Petrzilka[1] for the energy of the gamma-ray in terms of the range of the Compton electrons ejected from aluminum, the energy of the most energetic gamma-ray is found to be 2.4± Mev. An absorption curve of the gamma-rays in lead shows, in addition to the hard component, a soft component whose absorption coefficient corresponds to that of a gamma-ray of about 0.82 Mev energy.

The beta-ray endpoint was determined by absorption in aluminum and was found to be 2.3 Mev.

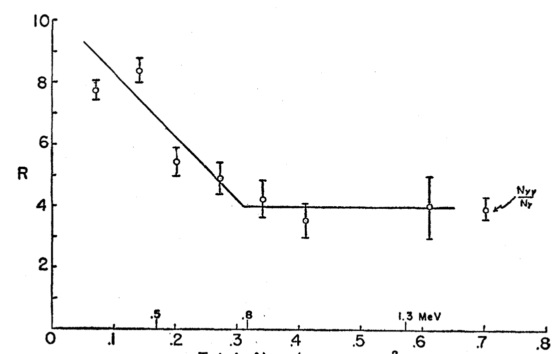

FIG. 1.

Experiments were performed on gamma-gamma- and beta-gamma-coincidences.[2] The source was placed between two counters in coincidence. Enough aluminum was placed on each side of the source to stop all beta-rays. Gamma-gamma-coincidences were measured and the number of coincidences per recorded gamma-ray was found to be 0.39×10^{-3}. Aluminum was now removed from one side of the source and the number of beta-gamma-coincidences measured as a function of the energy of the beta-rays. The results are shown in Fig. 1, in which the number of beta-gamma-coincidences per recorded beta-ray is plotted as a function of the thickness of absorber in g/cm^2. It will be seen at once that the beta-ray spectra of Ga^{72} is complex.

Since beta-gamma-coincidences were observable practically out to the beta-ray endpoint, it follows that the beta-transition does not lead to the ground state of the product Ge^{72}. In addition, there is a softer group of beta-rays having an endpoint at approximately 0.77 Mev.

From the evidence available—beta-rays of 2.3 and 0.77 Mev; gamma-rays of 0.8 and 2.4 Mev—no reasonable energy level scheme can be proposed unless one assumes that the low energy gamma-radiation consists of two quanta. Miller and Curtiss[3] have found three gamma-rays 0.64, 0.84, and 2.25 Mev. Assuming these three gamma-rays and using the results of the coincidence experiments, the following level scheme is possible. The 2.4-Mev beta-ray leads to an excited state of Ge^{72} which is 1.46 Mev above the ground state. The 0.64- and 0.82-Mev gamma-rays are emitted in cascade, from this level. The 0.77-Mev beta-ray goes to a level 3.3 Mev above the ground level, from which the 2.4-Mev gamma-ray leads to the 0.84-Mev level and thence to the ground state.

This work was carried on under contract with the Office of Naval Research.

[1] Curran, Dee, and Petrzilka, Proc. Roy. Soc. 169, 269 (1938).
[2] For a detailed description of this experimental technique, see Langer, Mitchell, and McDaniel, Phys. Rev. 56, 422 (1939).
[3] Miller and Curtiss, PPR 9B, 7 ·45 ·6 (1946).

Non-Primary Cosmic-Ray Electrons above the Earth's Atmosphere

G. J. PERLOW AND J. D. SHIPMAN, JR.
U. S. Naval Research Laboratory, Washington, D. C.
February 7, 1947

IN a V-2 rocket fired to a height of 70 miles on January 10 at White Sands, New Mexico, data were obtained on the penetration of cosmic rays through 2 and 4 cm of lead. In addition showers below each lead slab could be measured. The apparatus is diagrammed schematically in Fig. 1. Its axis was at 45° to that of the rocket and during flight it precessed about the latter. The rocket axis was a few degrees off vertical. The telescope pointed through a steel "window" 2.8 mm thick. Protection against the warhead showers, found in this and each previous flight,[1] was obtained by anti-coincidence counters (marked with crosses in the figure). The arrangement of the equipment in the warhead was such that a considerable amount of lead shielded most of the solid angle from below. The significance of this will be seen presently.

While a full account of the experiment awaits more detailed analysis, it seems desirable to report one interesting result at this time—namely, the presence above the earth's atmosphere (<1 mm Hg) of relatively large numbers of particles absorbed in the lead. About 25 percent of the total ionizing component was stopped in the first 2 cm and 10 percent in the second. Of the latter group about 1 in 8 produced showers tripping at least 3 counters under the first slab. The number of particles stopping in 4 cm or less was about the same as the number which penetrated without multiplication. The remainder of the radiation penetrated 4 cm and produced showers either under 2 or 4 cm, or under both. The soft particles (range $\leq$4 cm) had an intensity in free space roughly 15 percent of the total intensity observed in the flight at the Pfotzer maximum.

It seems most reasonable to ascribe this soft radiation to electrons. On the basis of the cascade theory these will have energies $<5\times10^8$ ev for the most part. An extrapolation by Mr. Siry of this laboratory of the Lemaitre-Vallarta curves to 40°N geomagnetic latitude gives as the minimum energy for an extra-terrestrial electron $\sim$4–5×10^9 ev at 45° zenith angle. Thus the soft electrons appear to come as re-entrant particles generated in some atmospheric layer below.

The existence of such a component was suggested to the group at this laboratory by Professor J. A. Wheeler in a private communication some time ago. It was pointed out that the almost isotropic angular distribution of the decay electrons from low energy mesons would result in some vertical intensity upwards and that these would describe helical oribits about the magnetic field lines. It is possible that the soft particles observed are to be ascribed to this hypothesis.

If the downcoming soft particles observed arise from some atmospheric layer below, then an appreciable upward intensity must exist and it would appear that the results of certain types of balloon experiments reported in the

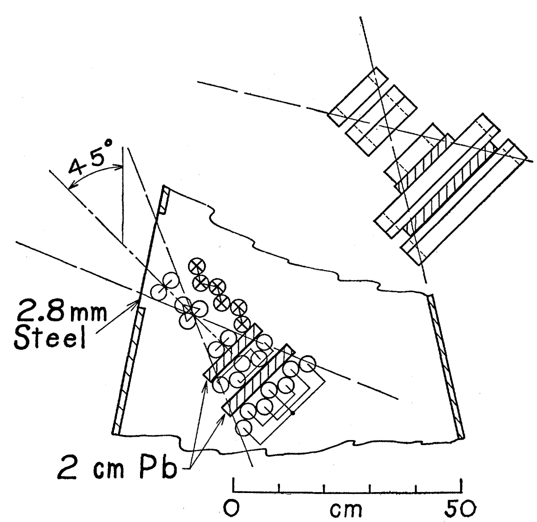

FIG. 1. Counter telescope in V-2 warhead.