Cosmic Rays and Radioactive Potassium

It is probably well to put on record the results of an experiment completed last spring. As A. K. Brewer has pointed out,[1] the present abundance of radioactive K^{40} and its known life indicate that practically all the Ca and A now existing on the earth must have been produced by its disintegration. This conclusion seems unavoidable unless the supply of K^{40} has been replenished in some way. Several nuclear physicists stated to the writer their belief that K^{40} is formed from K^{39} by the absorption of a neutron, one source of which would be cosmic rays. For such an hypothesis the present intensity of cosmic rays seems inadequate, but two facts give it a certain plausibility, namely, that radioactivity seems to be confined to the outer crust of the earth and that, although there is no evidence of large differences in the radioactivity of potassium samples, it is true that most of those tested are from sources which have been near the surface of the earth during a large part of geologic time. It was suggested to the writer that we investigate this idea since the necessary equipment for testing small amounts of potassium was available here.

For this purpose Dr. H. J. Fraser of the geology department procured for us samples from an old geological formation in Canada in which a continuous mass of granite extends from the surface to great depths. The rock from which these samples was taken had not been subjected to the action of water and we can state with certainty that, during geologic time, it has never been closer to the surface than it now lies. A piece of granite from the greatest depth, 2500 feet, was given to Mr. D. K. Beavon, who under the direction of Dr. E. H. Swift of the Chemistry Department, prepared a 22-mg sample of KCl from it.

The counter on which the measurements were made was the one used for determining the radioactivity of the separated isotopes of rubidium.[2, 3] It is a cylindrical counter one cm in diameter and three cm long with an aluminum wall 0.00125 cm thick. The sample was fused as uniformly as possible on the inner surface of a half-cylinder of platinum foil of one cm radius and two cm length, which, for counting, was swung into position concentric with the counter so that all parts of the sample were equidistant from its center. The bare foil when in place gave the standard background count of one per minute, which 20 mg of ordinary KCl should increase to about two per minute. It was calculated that with such thin samples errors due to absorption with uneven distribution would be negligible. Redistribution of the samples confirmed this conclusion by leaving the count unchanged. Similar sized samples of chemically pure KCl and of KCl specially prepared from K_2SO_4 to avoid radioactive contamination, were mounted in the same way. Alternate fifteen-minute counts were made on the sample and a standard screen, until at least 400 counts on each were recorded. Such a set constitutes a "run." Repeated runs were made on all samples, sometimes with a moistening with HCl and redistribution between runs. The C.P. and the specially prepared specimens gave nearly identical counts, but the Canadian sample ran consistently lower. The two final samples were turned over to Mr. J. S. Billheimer for analysis. He found the comparison sample to be pure KCl but the Canadian sample contained about 20 percent of impurity, probably sodium. When correction was made for the impurity, the Canadian sample was found to be about ten percent less radioactive than the laboratory samples. Since the probable error of the experiment is about ten percent, we conclude that the amount of radioactive potassium produced by cosmic rays is unimportant and probably zero.

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[2] W. R. Smythe and A. Hemmendinger, Phys. Rev. **51**, 178 (1937).
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Photoconductivity of Metal Films

R. S. Bartlett[1, 2] in 1925, while working at this laboratory, showed that a photoconductive effect could be observed in thin films of copper, platinum, palladium and bismuth sputtered on glass. On exposure to ultraviolet light at liquid-air temperatures, decreases in resistance up to sixteen parts in one million were recorded. At room temperature, and with frequencies of incident light lower than the ultraviolet range, no effect was noticeable.

To establish whether this effect could be detected in conductors of bulk metal, a further experiment has recently been completed on fine ribbons of copper, platinum and palladium. The illumination was with x-rays in order to insure that appreciable absorption took place throughout the entire thickness of the conductor.

Ribbons approximately 0.01 mm in thickness, 1 mm wide and from 2 to 3 meters in length were rolled from fine wires of the materials mentioned, and wound upon frames so that the majority of the surface could be exposed to an x-ray beam (molybdenum target). At room temperature the resistance of the element was measured by a potentiometer method. No change in the resistance of amount greater than one part in one million could be detected at this temperature when the element was illuminated. At liquid-air temperature, fluctuations of the resistance of the element caused by temperature changes and various parasitic e.m.f.'s made the potentiometer method of detecting resistance changes unsuitable. A shutter was therefore interposed in the x-ray beam and rotated to interrupt the beam 1000 times a second. A steady direct current was passed through the element and the e.m.f. across its terminals fed to an amplifier-oscillograph circuit. No alternating component of frequency of 1000 cycles could be detected on the oscillograph with any of the three metals used. Although the accuracy of the alternating current method was estimated to be only one part in 250,000, because the elements were at most only a few ohms in resistance and the available e.m.f.'s across their terminals limited to a few volts, the method was still sensitive enough to have detected changes in resistance of the order of magnitude of those observed by Bartlett.

The conclusion therefore may be made that either (1) the photoconductive effect present in thin films of these metals sputtered on glass surfaces is a property of the bulk metal which can be caused by radiation of the ultraviolet range only, or (2) that the effect is not a property of bulk metal but is restricted to films alone and is related to their structure,—the effect may be an external photoelectric current passing between discontinuous patches of the film.

The latter alternative would seem to be supported experimentally by recent work by Lovell,[3] and Lovell and Appleyard[4] on the resistance of thin films of the alkali metals.

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[1] R. S. Bartlett, Phys. Rev. **26**, 247 (1925).
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On the Upper Limit of the β-Spectrum of ThC″ and ThB

In 1937 Lyman[1] published a paper in which, from the character of the β-spectrum near the upper limit, he points to the existence of a neutrino rest mass different from zero. Subsequently a number of investigators, such as Alichanian, Alichanow and Dzelepow[2] and also Alichanian and Nikitin,[3] undertook a thorough study of the upper limit of the β-spectra.

According to the last authors, the difference between the experimental value for the upper limits and that deduced from the theory of Konopinski and Uhlenbeck[4] determines the magnitude μ_0 of the mass of the neutrino, i.e.

$$W_0-(E_0/511+1)=\mu_0,$$

where W_0 is the extrapolated value of the limiting energy (in mc^2) while E_0 is the experimental value of this energy in kv.

If so, it has to be assumed that the β-decay of different elements is characterized by different values of μ_0 or else to associate each elementary process of β-decay with an odd number of neutrinos, as has been suggested by G. Breit.[5]

However, in our opinion both alternatives are equally unsatisfactory. The comparison of the shape of the experimental β-spectra with that given by Konopinski and Uhlenbeck (KU) has shown that the substitution of the value W_0 (obtained by extrapolating the KU plots) in the expression for the distribution of electrons according to their energies in the β-spectra does not lead to a closer agreement of the experimental β-spectrum with the calculated one. More satisfactory results can be obtained by taking W_0' between the limits

$$(1+E_0/511)<W_0'<W_0.$$

The computations with the experimental results obtained by Alichanian and Zavelsky[6] for ThC″ and ThB are shown in Figs. 1 and 2.

The solid curves refer to the experimental β-spectra for ThC″ and ThB. They are in fairly good agreement with

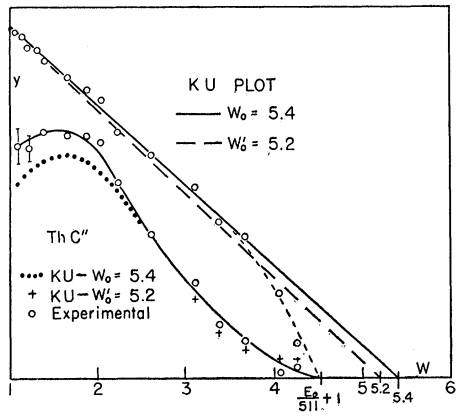

FIG. 1. Konopinski-Uhlenbeck plots and experimental results for ThC″.

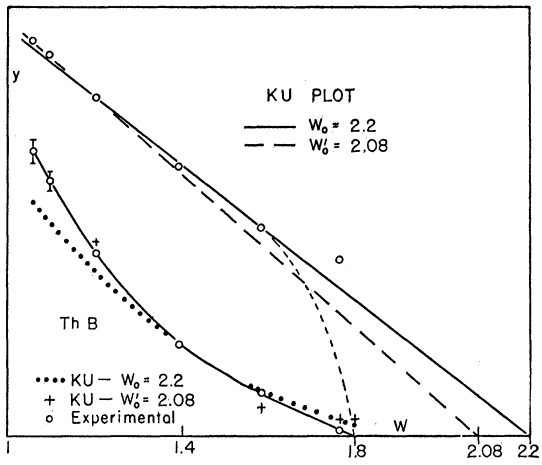

FIG. 2. Konopinski-Uhlenbeck plots and experimental results for ThB.

those obtained when substituting W_0' in the KU theoretical spectrum. The dotted lines show the results obtained by substituting W_0. The existence of the above disagreement has been already pointed out by the author[7] for ThB, RaE and ThC″.

The following conclusions may be drawn:

1. The equation given by Konopinski and Uhlenbeck must be considered as an empirical equation $[f(z,W)(W_0'-W)^4\sim N]$, requiring a suitable choice of the value W_0', distinct from that obtained by extrapolating the KU plots.

2. The assumption that the difference $W_0-(E_0/511+1)$ determines the rest mass of the neutrino, as expressed by certain authors, is not sufficiently justified.

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December 14, 1938.

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