TABLE I. Positive particles accompanying the beta-rays of P^{32}.

Filter	Thickness (g/cm²)	Number of pictures	Number of negatives N^-	Number of good positives N^+	N^+/N^- (percent)	Number of doubtful positives M^+	$(N^++M^+)/N^-$ (percent)
Glass	0.01	366	8224	1	0.01	3	0.05
Al	0.11	485	4983	6	0.12	2	0.16
Glass	0.09	389	8423	5	0.06	5	0.12

negative and positive tracks under 4 cm in length are rejected in order to eliminate, as far as possible, the reflected electrons from either the top or the bottom of the chamber. (b) Certain positive tracks which were either partially superposed by other tracks or became very faint in the neighborhood of the source are listed in the column of doubtful positives. The sum of the good and doubtful positives divided by the negatives gives the upper limit of the ratio of the positive to negative particles. (c) Among the good positives given in the table, there might still be tracks caused by reflected or scattered electrons which just hit the source. The chance of having a false positive due to this cause can be estimated from the total number of such reflected or scattered tracks and the ratio of the apparent diameter of the source to that of the chamber,[1] and is found to be about 0.03 percent of the number of negatives. Hence, the number of positive particles which we found with an almost bare source lies within our experimental error. With a filter of light substance, such as Al or glass, of thickness 0.1 g/cm², the ratio of the positive to negative particles is about 0.05 percent after taking due consideration of the reflected electrons. This gives evidence that positive particles are produced by beta-rays during their passage through matter. Though the ratio of the positive to negative particles we found is much smaller than those found by others with the same method, it is more in conformity with the values obtained by the beta-ray spectrometer. It is, therefore, very desirable to make measurements with different filtrations using a beta-ray spectrometer.

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On the Gamma-Rays of K^{40}

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IN the course of some work on the radioactivity of potassium, so far only partly published[1] owing to war conditions, we found a gamma-ray intensity several times larger than that published by Gray and Tarrant.[2] On account of the geophysical significance of this question[3] we feel that a preliminary account of our results may be of interest.[4]

The number of counts of a Geiger-Müller counter, first surrounded by pure K_2SO_4 salt disposed as a cylinder of 4.9-cm inner diameter and of 1.45-cm thickness, was compared with that given by a cylinder of cleveite of 5.75-cm inner diameter and of 0.21-cm thickness. According to previous determinations by the emanation method, the cleveite contained 0.345 g of uranium per gram, and no thorium. The counter was of aluminium 0.02 cm thick, and had a diameter of 2.2 cm. The length of both the counter and the K_2SO_4 cylinder was 5 cm, that of the cleveite cylinder only 0.8 cm. The counter was directly surrounded by a coaxial lead cylinder of 0.75-cm thickness, which stopped the beta-rays and also the softer gamma-rays of UX_2 and of radium $(B+C)$.

Special absorption measurements were carried out with 0.1 mg of radium. By the use of the correction factor deduced from these measurements, a corrected absorption coefficient of 0.58 cm^{-1} was obtained for the gamma-rays of potassium. This value agrees well with previous determinations.[5,6] We found no experimental evidence for softer components in the gamma-radiation of potassium. The intensities were reduced to values corresponding to zero absorber thickness, and corrected for absorption in the source itself, by the use of the absorption coefficients obtained with the same experimental arrangement. After applying minor corrections to account for differences in the geometrical conditions, we found that the gamma-rays of one gram of potassium produce the same number of counts as the hard gamma-ray components of $(1.06\pm0.12)\times10^{-10}$ g of radium. The known relation between absorption coefficient and energy yields for the gamma-rays of potassium an energy of 1.55 ± 0.05 Mev,[7] instead of 2 Mev, the value generally adopted following Gray and Tarrant.[2] By correcting for differences in the counter efficiency for the gamma-rays of potassium and of RaC, we obtain the final result that one gram of potassium emits the same number of quanta per second as $(1.23\pm0.15)\times10^{-10}$ g of radium, when only the hard components of RaC are considered. From data published by Ellis and Aston[8] and by Roberts,[9] we conclude that 80 ± 15 hard gamma-quanta are emitted per 100 disintegrating radium C atoms. For one gram of potassium we thus deduce 3.6 ± 0.8 emitted gamma-quanta per second. If we assume $(7\pm1)\times10^8$ years[10] as the most probable period for the beta-decay of K^{40}, we obtain 7 ± 1.5 gamma-quanta per 100 beta-rays of K^{40}. It is most likely that these rays are emitted by A^{40} atoms left in an excited state after the disintegration of K^{40} by the capture of a K-electron.[7,11] Figure 1 shows the disintegration scheme of K^{40}, with the intensities of the branching ratios for which 1.9 capture processes per beta-decay are assumed, following Bleuler and Gabriel.[10] The equivalence of the gamma-rays of one gram of potassium to those of 1.3×10^{-10} g of radium in equilibrium, found by Běhounek,[6] is in good agreement with our result. Gray and Tarrant[2] also state that their corresponding result of 1.6×10^{-11} g, from which they deduce 3 gamma-quanta per 100 beta-rays, agrees well with

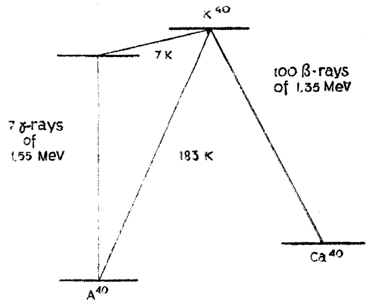

FIG. 1. Disintegration scheme for the decay of K^{40} with relative branching intensities.

the value of Běhounek. However, they cite this latter value erroneously as 1.3×10^{-11}. This fact renders it extremely likely that their own value also was taken too low by a factor ten.

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Significance of the Radioactivity of Potassium in Geophysics

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CONSIDERING recent data on the radioactivity of K^{40}, such as greater gamma-ray intensity,[1] higher beta-ray energy,[2] as well as a shorter half-value period[3] than previously admitted, some interesting consequences in geophysics are apparent to us. We should like to point out two of these consequences, the first concerning the ionization balance of the atmosphere, the second the radioactive heat production of K^{40} in rocks and, more generally, in the earth's crust. Recent measurements by V. F. Hess[4] with a thick-walled ionization chamber disclose a large discrepancy between the value of the ionization in air, produced by the gamma-rays of the different radioactive substances contained in Quincy granite, and that computed from the concentrations of these substances known by the measurements of Evans and Goodman.[5] Assuming, according to Gray and Tarrant,[6] that one gram of potassium is equivalent in its gamma-ray effect to 1.6×10^{-11} g of radium, Hess computes the value of 0.50 I (where I is a symbol for "ion pairs per cm³ per sec.") for the ionization of the air due to the potassium contained in Quincy granite. Uranium and thorium will produce in the same case 0.64 I and 0.92 I, respectively. The total of 2.06 I, computed for a point above an infinite layer of rock, compares with the measured value of 5.18 I obtained on a ground of crushed granite. With the use of our recent value[1] for the gamma-ray intensity of K^{40}, for potassium alone we obtain 2.6 I, which gives a total of 4.16 ± 1.25 I, in satisfactory agreement with the experimental result. Thus, in the case of granites, the gamma-rays of potassium play a more important part in the ionization of the air than those of the uranium and thorium families together.

For the radioactive-heat production of potassium, Evans and Goodman[5] compute the value of $(5\pm2)\times10^{-6}$ cal. per year per gram. If we admit $(7\pm1)\times10^{8}$ years for the period of the beta-decay of K^{40}, we find 52.5 beta-rays per second for one gram of potassium. Their average energy[2] being 0.49 ± 0.06 Mev we compute for the beta-rays alone a heat production of $3.15\times10^{7}\times52.5\times0.49\times0.382\times10^{-13}=(31\pm6)\times10^{-6}$ cal per year per gram of potassium (1 year$=3.15\times10^{7}$ sec.). For 3.6 ± 0.8 gamma-quanta[1] of 1.55 ± 0.05 Mev, the heat production amounts to $3.15\times10^{7}\times3.6\times1.55\times0.382\times10^{-13}=(7\pm2)\times10^{-6}$ cal. per year per gram of potassium. We thus arrive at a total heat output of $(38\pm7)\times10^{-6}$ cal. per year per gram of potassium. In the case of acidic igneous rocks, Evans and Goodman[5] compute, for average uranium, thorium, and potassium contents, the respective values of $(2.2\pm0.2)\times10^{-6}$, $(2.6\pm0.4)\times10^{-6}$, and $(0.14\pm0.06)\times10^{-6}$ cal per year per gram of rock. We obtain in the same case for potassium alone $(1.1\pm0.2)\times10^{-6}$ cal per year per gram of rock. This is about 20 percent of the total heat production in acidic igneous rocks. Much more important must have been the role played by potassium in the early history of the earth. Considering the total period of K^{40}, only $(2.4\pm0.5)\times10^{8}$ years[3] as a result of its dual decay, it is easy to see that 2.4×10^{9} years ago, for example, a time which corresponds to 10 periods of K^{40} and leads us back to the beginning of the earth's history, $2^{10}=1024$ times more K^{40} was present than today. The heat produced by K^{40} alone was about 200 times that generated at present by all the radioactive elements in the earth together. Of course, the heat output due to uranium and thorium then was also larger than now, but the difference did not exceed 50 percent of the present value. The tremendous source of energy, constituted by the active isotope of potassium, was diminishing continuously, but even 1.2×10^{9} years ago was still about 6 times larger than the present disintegration energy of all radioactive elements in the earth's crust.

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Excess-Defect Semiconductor Contacts

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TWO recent papers[1,2] have dealt with the theoretical aspects of silicon-germanium rectifiers. Impurity centers giving rise to both excess and defect conductivity are shown to exist with corresponding energy levels only