The Branching Ratio of Potassium 40†

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The branching ratio of potassium 40 has been measured by determining the argon and potassium content of potassium feldspars of accurately known ages. The results obtained for five samples differing in age by more than a factor of five are all consistent within the limits of error with a branching ratio of 0.060 ± 0.006 when a total decay constant of 0.54×10^{-9} year^{-1} is assumed. The authors feel that the results obtained indicate that loss of argon from these samples during geological time is unlikely.

THE total radioactive decay constant λ of potassium 40 is the sum of two partial decay constants λ_β and λ_K, the former describing the rate of decay by β emission to calcium, and the latter describing the rate of decay by K-electron capture to argon. The ratio λ_K/λ_β is called the branching ratio. The average of the best available measurements[1] of λ_β is $(0.506\pm0.027)10^{-9}$ year^{-1}, but λ_K is less precisely known and values for the branching ratio have been reported from "less than 0.07" to 1.9 by x-ray measurements,[2] from 0.04 to 0.15 by gamma-ray measurements,[3] and from 0.02 to 0.10 by measurements of the argon content of old potassium minerals.[4]

In order to fix the value of λ_K more closely the authors have measured the radiogenic argon content of five potassium minerals of which the ages have also been determined. The samples were heated with metallic sodium to 850°C in a high-vacuum system in order to release the argon, which was then purified by means of a calcium furnace and measured in a McLeod gauge. Mass spectrometric analyses were made to determine the proportion of radiogenic argon. All argon samples contained less than 10 percent atmospheric argon and some less than 1 percent. Tests with atmospheric argon showed that the method of purification did not alter the A^{40}/A^{36} ratio. The results obtained are given in Table I.

Microcline samples No. 1 to No. 4 were obtained from the same or neighboring pegmatites as uraninite specimens I to IV, respectively, which have been dated in this laboratory by the lead isotope-ratio method with the results shown in Table II. The ages obtained from uraninite samples I and II have been averaged and used to date both microcline samples No. 1 and No. 2.

Microcline specimen No. 5 was obtained from a pegmatite in the Spruce Pine district, as was the uraninite for which a chemical analysis has been published by Føyn.[5] That uraninite contained 74.20 percent uranium, 2.70 percent thorium and 3.64 percent lead, indicating an age of 340 million years. Although no isotopic analysis was made, results published recently indicate that pegmatitic uraninites usually contain

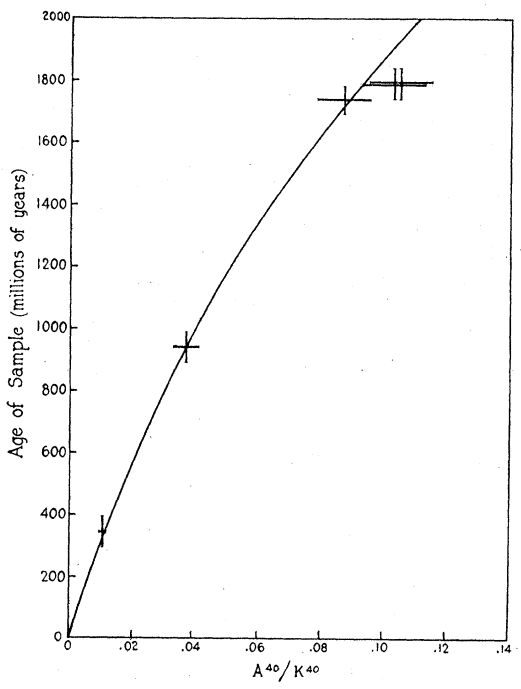

FIG. 1. Comparison of measured values with theoretical curve calculated for a branching ratio of 0.06 and a decay constant of 0.54×10^{9} years^{-1}.

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[3] For example: J. J. Floyd and L. B. Borst, reference 1; G. A. Sawyer and M. L. Wiedenbeck, Phys. Rev. **76**, 1535 (1949); W. R. Faust, reference 1; Smaller, May, and Freedman, Phys. Rev. **79**, 940 (1950); F. W. Spiers, reference 1; and earlier results.

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[5] E. Føyn, Report of the Committee on the Measurement of Geologic Time, National Research Council, Washington, D. C., p. 23, September, 1939.

TABLE I. Radiogenic A^{40}/K^{40} for microcline specimens of known age.

No.	Sample	Origin[a]	Number of runs averaged	% by weight radiogenic argon $\times 10^5$	K_2O%	A^{40}/K^{40} [b]
1	Pink microcline	Charlebois Lake, Saskatchewan; three miles from Row Group uraninite occurrence.	2	12.0	11.5	0.105 ±0.010
2	Pink microcline	Charlebois Lake, Saskatchewan; from pegmatite on island about a half mile from Row Group uraninite occurrence.	2	13.1	12.8	0.103 ±0.010
3	Pink microcline	Lee Lake, Lac La Ronge, Saskatchewan.	3	10.3(3)	12.0	0.087 ±0.009
4	Pink microcline	Bessner Mine, Lot 5, Con. B., Henvey Township, Ontario.	4	4.15	11.3	0.037 ±0.004
5	White perthite	Meadow Mine pegmatite, Spruce Pine District, Avery County, North Carolina, U.S.A.	2	1.34	12.8	0.0106±0.0010

[a] Sample No. 5 was collected by Dr. J. L. Kulp of Columbia University. Samples No. 1, No. 2, and No. 3 were collected by Dr. J. B. Mawdsley and Mr. G. L. Cumming of the University of Saskatchewan. Sample No. 4 was collected by the authors.
[b] The ratio for each sample has been assigned a possible error of ±10 percent, which includes possible errors in potassium analyses as well as in argon measurements. Argon measurements on any specimen were repeatable with much better precision.

TABLE II. Ages of uraninites calculated from radiogenic Pb^{207}/Pb^{206}.

No.	Mineral and locality[a]	Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}	Ratio radiogenic Pb^{207}/Pb^{206}%	Age (million years)
I	Uraninite, Charlebois Lake, Saskatchewan. Nuzone (channel) showing.	0.044±0.004	85.66	9.83	4.47	10.78±0.06	1780±50
II	Uraninite, Sickle Lake, Saskatchewan; four miles south of Charlebois Lake.	0.071±0.005	84.36	10.18	5.37	10.93±0.04	1800±50
III	Uraninite, Lee Lake, Lac La Ronge, Saskatchewan.	0.036±0.004	87.06	9.83	3.34	10.50±0.06	1740±50
IV	Uraninite, Bessner Mine, Lot 5, Con. B, Henvey Township, Ontario.	0.021±0.007	91.86	6.71	1.44	7.09±0.10	940±50

[a] Sample I was collected by Dr. S. C. Robinson of the Geological Survey of Canada, and is published with the kind permission of the Survey. Samples II and III were collected by Dr. J. B. Mawdsley, University of Saskatchewan. Sample IV was collected by the authors.

less than 1 percent–2 percent common lead.[6] A possible error of 50 million years has been assigned to this age.

Figure 1 shows the ages of the samples plotted against the ratio of radiogenic A^{40} to K^{40}. On the same graph a theoretical curve is shown, calculated for a decay constant of 0.54×10^{-9} year^{-1} and a branching ratio λ_K/λ_β of 0.060. It can be seen that the calculated curve lies within the assigned limits of error of the experimental values. The results of this experiment show that the branching ratio of K^{40} is 0.060±0.006 if the samples have been dated correctly and have not lost a significant amount of argon. That there has been little or no loss of argon during geological time is strongly suggested by the consistency of the results obtained for samples differing in age by as much as a factor of five. Preliminary measurements, not yet reported, on muscovite and feldspar from the same pegmatite agreed within the limits of experimental error, also suggesting that loss of argon is unlikely.

A more detailed report of this investigation, together with data from additional samples will be published shortly.

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[6] A. O. Nier, Phys. Rev. **55**, 150 (1939).