K^{40} Branching Ratio

A. McNair, R. N. Glover, and H. W. Wilson
Department of Natural Philosophy, The University, Glasgow, Scotland
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The ratio of gamma to beta transitions occurring in the decay of K^{40} has been accurately determined by two different counting methods, yielding the ratios 0.124±0.002 and 0.121±0.004, respectively.

It is generally accepted that the isotope K^{40} decays to A^{40} by electron capture followed by a gamma ray and to Ca^{40} by beta emission.[1,2] Two methods have been used to measure the branching ratio for the decay: (a) The ratio of gamma (or electron capture) to beta transitions, with suitable corrections, is determined by counting methods. (b) The ratio is inferred from the quantity of argon, or calcium, or both in a potassium-mineral of known age. Disagreement between the results obtained by the two methods[3] justified another careful study of the branching ratio by method (a).

Two different procedures were followed. The ratio of the number of gamma to beta transitions occurring in the decay of Co^{60} was compared with the corresponding ratio for the K^{40} decay, thus avoiding, to a first order, calculations of the efficiencies of the beta and gamma detectors. The ratio is given by the expression

$$R=2\frac{\gamma_K}{\gamma_{Co}}\cdot\frac{\beta_{Co}}{\beta_K},$$

where γ_K, γ_{Co} are the directly measured gamma counting rates and β_K, β_{Co} are the beta rates. Had the two beta spectra been identical and had the gamma transitions been of equal energy, a very precise value of R would have followed directly. As it was, various corrections, mentioned later, had to be made.

The gamma detector consisted of a cylindrical NaI crystal (2 in. long$\times\frac{3}{4}$ in. diam.) placed coaxially within a vessel of approximately 200 cc capacity into which could be poured the solutions under test. There was sufficient absorber to prevent the detection of the beta particles. The vessel and crystal were mounted on an E.M.I. type 6262 photomultiplier and the whole surrounded by a 4-in. lead screen. The solutions were water containing $Co^{60}Cl_2$ and KOH ($\sim$493 g K/liter) the latter giving $\sim$700 cpm above background ($\sim$80 cpm). Calibration was effected with the 46.7-kev gamma rays of RaD. A cylindrical proportional counter was used as a beta detector, and large source areas ($\sim$1000 cm^2) yielded reasonable counting rates even with thin sources of K^{40}.

The measurement had to be corrected for (i) coincident detection in the crystal of both Co^{60} gamma rays, (ii) absorption and scattering of K^{40} gammas by the potassium hydroxide solution, (iii) slight difference in the crystal detection efficiency for K^{40} and Co^{60} gamma rays, (iv) counts due to bremsstrahlung in the gamma-detector especially in the case of K^{40}. The fraction of electrons reflected at the source support in the proportional counter was found by a separate experiment to be the same for Co^{60} and K^{40} beta particles. These corrections will be discussed more fully elsewhere. The observed value of γ_K/β_K was 0.124±0.002, or

$$\gamma_K/(\beta_K+\gamma_K)=0.110\pm0.002.$$

The second method eliminated many of the correction factors involved in the first. The gamma-ray spectra of Na^{24} (1.38 Mev and 2.76 Mev) and of K^{40} (1.46 Mev) were measured by using a large (2 in. long$\times$2 in. diam.) NaI crystal mounted on a DuMont type 6292 multiplier associated with a kick-sorter. By measuring the areas under the peaks of the 1.46-Mev and the 1.38-Mev gamma rays and comparing the beta counting rates, an estimation of the ratio may be made. No correction for the scattering and absorption of gammas by the KOH solution is required if the Na^{24} is added to the potassium source. Also there is no correction for bremsstrahlung since the beta energies (1.36 Mev and 1.39 Mev for K^{40} and Na^{24}, respectively) are close to the gamma-ray energies. Allowance is made for (i) the effect of coincident detection of the 1.38-Mev and 2.76-Mev gammas of Na^{24} and (ii) the slight difference in gamma detection efficiency. The relative source intensities are determined by comparing the beta activities in the proportional counter. The ratio γ_K/β_K observed was 0.121±0.004.

These results are in agreement with the previous best physical measurements, but rather higher than the value (0.09) reported from recent geological determinations.

Fuller details of the methods will be given elsewhere together with the results of coincidence studies, absolute counting-rate and half-life determinations, and of experiments on the reflection of electrons.

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