Radiations from Rb^{86} and Rb^{86m}†

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An upper limit of 1×10^{-3} is determined for the ratio of K electron capture to negative beta emission in the decay of 19.5-day Rb^{86}. The one-minute Rb^{86} isomer is shown to decay by isomeric transition, probably $E4$ or perhaps $E3$, with the emission of 560-kev gamma rays.

THE 19.5-day Rb^{86} is known to decay to stable Sr^{86}, emitting 1.76-Mev negative beta particles to the ground state and betas of about 0.67-Mev energy in coincidence with 1.08-Mev gamma rays. The intensity ratio of the beta groups is about 4:1, the ground-state transition being the more probable.[1] An upper limit of 1.6×10^{-5} has been established for the ratio of positron to negative beta decay.[2] From the measured masses[3] of Kr^{86} and Sr^{86} and the energy of the Rb^{86} beta-decay process, the energy release in the electron-capture decay of Rb^{86} should be 630 ± 460 kev. This communication reports a search for electron-capture decay of the 19.5-day activity; experiments were done also to investigate the radiations of the one-minute Rb^{86} isomer, recently reported to decay by emission of 780-kev gamma rays and of x-rays.[4]

Rb^{86} 19.5 Day

The 19.5-day Rb^{86} was produced by a three-day irradiation of rubidium carbonate in the Brookhaven nuclear reactor. After sodium and potassium impurity activities had decayed for about one week, the rubidium carbonate was dissolved; and cesium activity was removed[5] by two precipitations of added carrier cesium as $Cs_3Bi_2I_9$. Finally, about ten milligrams of potassium as salt and then $(NH_4)_2SiF_6$ solution were added; the precipitate, a mixture of K_2SiF_6 and Rb_2SiF_6, was filtered onto a small paper disk and washed.

For the measurements on the 19.5-day activity two such samples were prepared. The counting rate of one of these was suitable for measurement of its absolute beta-disintegration rate in a G-M counter of known geometry, with appropriate corrections for absorptions, coincidence loss, and backscattering; the activity of this sample was found to decay with the expected half-life. The second sample, about 50 times more active, was used in the search for krypton x-rays, which would accompany K capture in rubidium. Both samples were counted in a fixed geometry with a proportional counter in order to determine their activity ratio and thus the beta-disintegration rate of the stronger source.

A search for x-rays was made with a four-inch diameter proportional counter filled with 2 atmospheres of argon and 0.1 atmosphere of methane. A beryllium absorber, 794 mg/cm², was used to prevent beta-particles from entering the counter; a selenium critical absorber, 14 mg/cm², which transmits 72 percent of krypton K radiation but only 9 percent of rubidium K radiation, was used between the beryllium and the counter window to remove rubidium fluorescence. The pulse-height spectrum from the counter, as observed with a single-channel analyzer, is shown in Fig. 1, curve A. For comparison curve B shows the selenium fluorescence spectrum observed from one of the absorbers when it was irradiated with the silver K x-rays from a Cd^{109} source. The two curves appear to be the same except for a sloping bremsstrahlung background, which has been subtracted from A to give curve C. There is no evidence for krypton K x-rays, which should have been observable if present at as little as one-fourth the selenium intensity. An upper limit for the K electron capture disintegration rate was calculated by a method previously described;[6] and from

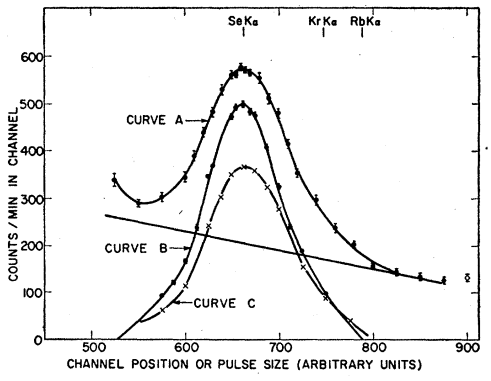

FIG. 1. Proportional counter pulse-height distribution for 19.5-day Rb^{86} (Be and Se absorbers) and for Se fluorescence.

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[1] *Nuclear Data*, National Bureau of Standards, Circular No. 499 (U. S. Government Printing Office, Washington, D. C., 1951).

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[5] H. B. Evans, *Radio Chemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), Paper No. 284, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. IV.

[6] Friedlander, Perlman, Alburger, and Sunyar, Phys. Rev. **80**, 30 (1950).

this rate and the beta-disintegration rate an upper limit 1×10^{-3} was established for the ratio of the electron capture probability to the beta-decay probability.

Rb^{86} 1.02 Minute

Thin samples of Rb_2SiF_6 bound with small amounts of plastic were irradiated for one minute in the reactor to produce the one-minute activity described by Flammersfeld.[4] Tests made with similarly prepared samples of K_2SiF_6 eliminated the possibility that the activity is not associated with neutron capture in rubidium. The energy of the gamma radiation associated with the one-minute activity was found to be 0.56 ± 0.03 Mev as determined with a scintillation spectrometer by comparison with the gamma rays of Cs^{137} (0.661 Mev) and Au^{198} (0.411 Mev). The count-rate decay observed with a single-channel analyzer set to register at the 560-kev photoelectric peak is shown in Fig. 2. The gamma ray decays with the half-life

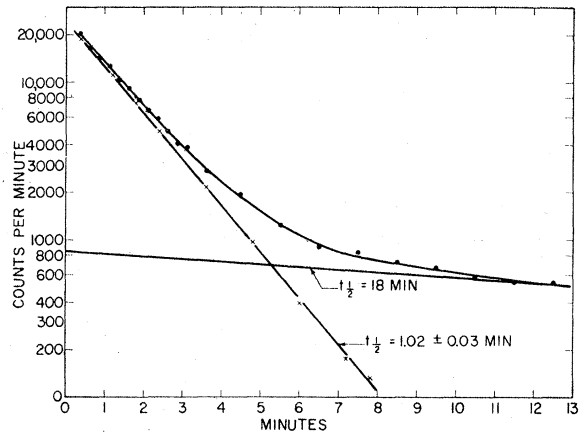

FIG. 2. Decay of the 560-kev gamma-ray of Rb^{86m}.

1.02 ± 0.03 minutes; a small amount of longer-lived activity probably represents degraded radiations of 18-minute Rb^{88}.

In order to confirm the assignment of the one-minute activity to Rb^{86}, comparison measurements were made with two irradiated rubidium chloride samples of the same weight, one of normal isotopic constitution and the other[7] depleted in Rb^{85}. The Rb^{85} content ratio was approximately 7. The observed ratio of the one-minute activities in the two samples was 6.4. If the one-minute activity were Rb^{88}, the ratio observed should have been approximately 0.3.

[7] Supplied by the Y-12 plant, Carbide & Carbon Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

With a gray-wedge pulse analyzer[8] and the proportional counter described above, which has 62 percent efficiency for Kr K x-rays, the short-lived Kr or Rb x-rays reported by Flammersfeld could not be observed in the one-minute-irradiated thin Rb_2SiF_6 samples. The apparatus was sufficiently sensitive to detect the fluorescence radiations from the brass counter and from the rubidium sample, neither of which decayed perceptibly ($<\sim20$ percent) in a few minutes. Identification of the higher energy x-rays as those of rubidium was made by the use of a selenium absorber, which caused the rubidium peak to be replaced by the lower-energy selenium fluorescence peak; a peak representing krypton K radiations emitted in electron capture would have been unchanged in position; and the brass fluorescence peak was unchanged. If the 560-kev gamma radiation is converted to the extent of several percent, the intensity of rubidium K x-rays to be expected could be masked by the nondecaying rubidium fluorescence.

The conclusion that the 1.02-minute activity decays by isomeric transition to the ground state of Rb^{86} rather than by electron capture to Kr^{86} is supported by the fact that an energy in the neighborhood of 1.5 Mev is to be expected[9] for the first excited state of the singly magic nucleus Kr^{86}. From its lifetime and energy, the Rb^{86} isomeric transition appears to be $E4$ or perhaps $E3$;[10] $M4$ would seem to be excluded.[11] For a 560-kev $E4$ transition the half-life should be of the order of 600 seconds; for $E3$ roughly 0.02 second. Rb^{86} in the ground state has spin 2 and negative parity.[12] For the first excited state of Rb^{86}, shell theory permits no unique spin-parity prediction;[13] both 6− and 5+ would be possible, corresponding to $E4$ and $E3$ transitions, respectively. The K conversion coefficients calculated[14] for these transitions are 1.7×10^{-2} ($E4$) and 6.5×10^{-3} ($E3$). The magnitude of these coefficients is consistent with the fact that no one-minute decay was observed in the intensity of the rubidium K x-radiation.

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[11] See reference 10, Fig. 5.
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