Disintegration Scheme of Rb^{83}†

M. L. PERLMAN AND JOAN P. WELKER
Chemistry Department, Brookhaven National Laboratory, Upton, New York

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The decay of Rb^{83} has been determined to proceed by electron capture to an excited state of Kr^{83} which is 0.566 Mev above the ground state. This excited state is depopulated exclusively by emission of a 0.525-Mev gamma ray ($M1$) to the 0.041-Mev state, Kr^{83m}. Little or no electron capture direct to the 0.041-Mev level or to lower levels occurs. The spin-parity designation of the 0.566-Mev state is $p_{3/2}$, and that of the Rb^{83} ground state is $f_{5/2}$.

DURING the course of an investigation concerned with certain features of the decay[1] of Rb^{84}, sufficient information was obtained about the radiations of Rb^{83} to ascertain the disintegration scheme of this nuclide. According to published work[2,3] Rb^{83} has a half-life of 83 days; x-rays, conversion electrons corresponding to gamma rays of energies $\sim$0.15 and $\sim$0.45 Mev, and a gamma ray of energy $\sim$0.8 Mev are reported to be emitted. The energy measurements are described as being crude.[3] At least a fraction of the decay proceeds to 114-min Kr^{83m}, as shown[3] by the growth of activity in rubidium fractions freshly separated from Sr^{83}. The level scheme of Kr^{83m} has been thoroughly investigated; the multipole orders of the electromagnetic radiations are established, and the spins and parities of the levels are known.[4] This information is summarized in Fig. 1.

EXPERIMENTAL METHODS AND RESULTS

The method of source preparation has been described in the paper which precedes this one.[1] Tests showed that the sources used in the following experiments did not emanate Kr^{83m}. As has been stated, decay measurements made with proportional counters and suitable absorbers confirmed the earlier observations that Rb^{83} disintegrates with the emission of K x-rays and of gamma rays, and that very little if any particle emission occurs. From the information shown in Fig. 1 of the preceding paper and with a knowledge of the particle to x-ray intensity ratio from Rb^{84}, it may be estimated that less than one percent of $Rb^{83} \rightarrow Kr^{83}$ events are associated with the emission of particles with energy exceeding 40 kev.

It has been noted also that a gamma ray of energy very nearly the same as that of annihilation radiation[1] is associated with the decay of Rb^{83}. The evaluation of the energy of this radiation was made from data obtained in a set of coincidence measurements in which Na^{22} and $Rb^{83,84}$ were compared. It was observed in the case of Na^{22} that the 0.511-Mev photopeak in coincidence with 0.511-Mev quanta was centered at the same position as the simultaneously recorded 0.511-Mev "singles" photopeak; in the case of the $Rb^{83,84}$, however, the "singles" peak, composed of annihilation radiation and the Rb^{83} gamma ray, was consistently a little higher in energy than the coincident photopeak. From the relative displacement of the two peaks and from a knowledge of the fraction of Rb^{83} gamma radiation present in the $Rb^{83,84}$ "singles" photopeak at the time of the measurement,[1] the energy of the Rb^{83} gamma ray was determined to be 0.525 ± 0.007 Mev. This radiation was found to be in coincidence with K x-rays and not in coincidence with annihilation radiation.[5] Several gray-wedge photographs of the gamma-ray spectra of $Rb^{83,84}$ were observed both with and without the requirement of coincidences with K x-rays and with 0.511 (0.525)-Mev gamma rays. There was no evidence for the emission, in the decay of Rb^{83}, of any gamma ray other than that of energy 0.525 Mev.

A determination was made of the fraction of Rb^{83} K-electron capture events which is associated with the emission of the 0.525-Mev gamma ray. The K x-ray, 0.525-Mev coincidence rate was compared with the K x-ray count rate. Two NaI(Tl) detectors and pulse-height selectors were employed. The result of this comparison measurement is independent of all x-ray efficiency factors. Apportionment of the x-ray rate between the 83-day Rb^{83} and the 33-day Rb^{84} was made by the methods described in the foregoing paper. Further, the Rb^{83} x-ray rate was corrected to take into account the fact that a part of the intensity, 0.22, is produced by internal conversion of gamma rays[6] from Kr^{83m}; the evaluation of this correction is described in the next section. For the coincidence-rate measurement, the area under the 0.525-Mev coincidence photopeak was scanned; small backgrounds associated with the radiations of Rb^{84} were evaluated and subtracted. The absolute efficiency of the detector and pulse-height selector for the 0.525-Mev quanta was measured by determination of the area of the 0.511-Mev annihilation

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[1] J. P. Welker and M. L. Perlman, preceding paper [Phys. Rev. **100**, 74 (1955)].
[2] D. G. Karraker and D. H. Templeton, Phys. Rev. **80**, 646 (1950).
[3] S. V. Castner and D. H. Templeton, Phys. Rev. **88**, 1126 (1952).
[4] M. Goldhaber and R. D. Hill, Revs. Modern Phys. **24**, 179 (1952).
[5] Reference 1, Table I.
[6] I. Bergström, Phys. Rev. **81**, 638 (1951).

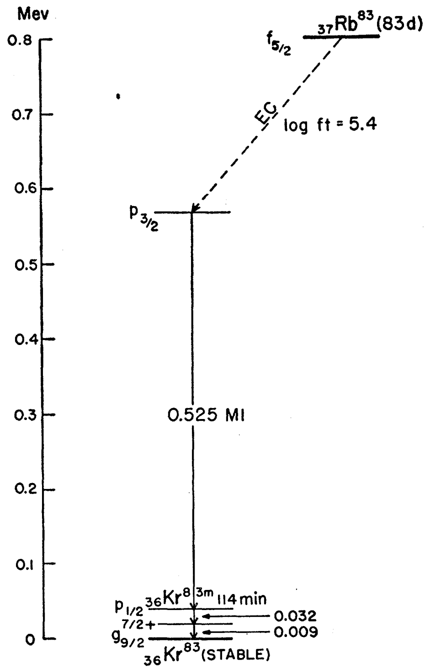

FIG. 1. The decay scheme of Rb^{83}.

photopeak from a calibrated Na^{22} source. The comparison experiment gave the result that 0.99 ± 0.10 of the electron-capture processes are followed by emission of the 0.525-Mev quanta.

DISCUSSION

The decay scheme shown in Fig. 1 was arrived at by combination of the experimental results given in this paper with information about the internal conversion[6] of the 32-kev transition in Kr^{83m} and about the growth of Kr^{83m} in freshly separated Rb^{83} fractions.[3] According to the compilation of Way and Wood[7] the disintegration energy of Rb^{83} is expected to be approximately 0.8 Mev; under this condition the ratio of L capture to K capture may be taken as 0.10.[8] The number of K vacancies per disintegration of Rb^{83} is expressed by the relation,

$$K_{\text{vac}}=0.91+0.26f. \tag{1}$$

The 0.91 vacancies are produced in the act of capture, f is the fraction of Rb^{83} disintegrations which populates the 0.041-Mev Kr^{83m} state, and 0.26 is the fraction of the 0.032-Mev Kr^{83m} transitions which produces a K vacancy.[6] The term $0.26f$ is evaluated as a function of K_{vac} from the growth curves of Castner and Templeton:

$$0.26f=(0.22\pm0.01)K_{\text{vac}}. \tag{2}$$

The solution of Eqs. (1) and (2) gives $K_{\text{vac}}=1.17$ and $f=1.00$. Three assumptions about the growth curves are implicit in Eq. (2): (a) the growth sources did not emanate Kr^{83}, (b) the count-rate measurements[9] were begun before appreciable growth had occurred, and (c) the count-rate data taken with a Geiger-Müller counter represent only the x-radiations. It should be noted that inaccuracy in any of these assumptions would tend to make f exceed 1.00, which would be an absurd result. Since each capture process in Rb^{83} populates the 0.041-Mev level and since 0.99 ± 0.10 of the capture events are in coincidence with 0.525-Mev quanta, capture followed by emission of 0.525-Mev gamma rays must populate the Kr^{83m} state. Moreover, little or no capture proceeds directly to the 0.041-Mev or to lower Kr^{83} levels. The allowed log ft value,[10] 5.4 ± 0.4, for the capture transition to the 0.566-Mev level is based on the decay energy estimated from the curves of Way and Wood.

The spin-parity assignments for the ground and first two excited states of Kr^{83} are well known.[4,6] Only two reasonable single particle assignments[11] remain for the 0.566-Mev Kr^{83} level, $p_{3/2}$ and $f_{5/2}$. If the level were characterized $f_{5/2}$, it should be depopulated more rapidly by $E1$ transitions to the 9-kev level than by $E2$ transitions to the 41-kev level, in contradiction of the experimental facts. The characterization $p_{3/2}$, on the other hand, is in agreement with the observation that all transitions from the 0.566-Mev level populate the 0.041-Mev level.

For the odd proton of Rb^{83} reasonable single particle characterizations are $f_{5/2}$, $p_{3/2}$, and, less probably, $p_{1/2}$ or $g_{9/2}$. Of these four $g_{9/2}$ is excluded because very little or no capture to the ground state of Kr^{83} occurs. Since the capture transition to the 0.041-Mev krypton state would be much more probable than that to the 0.566-Mev level if the assignment were $p_{3/2}$ or $p_{1/2}$, these two possibilities are excluded. Thus, $f_{5/2}$ would appear to be the designation for the ground state of Rb^{83}. The capture transition to the 0.566-Mev level of Kr^{83} is then allowed and the capture transitions to the other states of Kr^{83} are forbidden, which is in agreement with the experimental evidence. It may be noted that the ground-state assignments of the neighboring odd-even nuclides, Rb^{81} and Rb^{85}, are $p_{3/2}$ and $f_{5/2}$ respectively.[11,12]

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[8] M. E. Rose and J. L. Jackson, Phys. Rev. **76**, 1540 (1949).

[9] Reference 3, Fig. 1.

[10] S. A. Moszkowski, Phys. Rev. **82**, 35 (1951).

[11] P. F. A. Klinkenberg, Revs. Modern Phys. **24**, 63 (1952).

[12] Hobson, Hubbs, Nierenberg, and Silsbee, Phys. Rev. **96**, 1450 (1954).