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Levels of ^{83}Kr populated in the decay of ^{83}Rb and ^{83}Br *

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The levels of ^{83}Kr were studied from the decay of both ^{83}Rb and ^{83}Br. Thirteen γ rays were observed in the decay of ^{83}Rb and eight in the decay of ^{83}Br. The ground-state $M2$ transition from the 562-keV level was observed to have a branching ratio of 1.4×10^{-4}. The conversion coefficients were measured for the 9.39 keV and for the 32.2-keV transition. Decay schemes are presented and the possible spins, parities, and structure for the levels of ^{83}Kr are discussed.

[RADIOACTIVITY ^{83}Rb, ^{83}Br measured E_γ, I_γ, I_{ce}, $\gamma\gamma$, deduced ICC. ^{83}Kr deduced levels, J, π, Λ. Mass, chemically separated sources.]

INTRODUCTION

The nucleus ^{83}Kr has three neutron holes in the closed neutron shell ($N = 50$) and an even number of protons. Below the shell closure at $N = 50$, neutrons fill the $2p_{1/2}$ and $1g_{9/2}$ single particle orbitals, and ^{83}Kr has a $\frac{9}{2}^+$ ground state and a low-lying $\frac{1}{2}^-$ state at 41 keV. In addition to these levels, a $\frac{7}{2}^+$ level occurs at 9.36 keV. Such low-lying $\frac{7}{2}^+$ levels occur in many odd mass nuclei with an odd proton number ranging from 43 to 47 (Refs. 1–4) and can be understood in terms of dressed three quasiparticle configurations.[4] Additional levels were found in ^{83}Kr at 562, 571, 690, and 800 keV.[2] To obtain a better understanding of these low-lying levels in ^{83}Kr, we remeasured the decay of both ^{83}Rb and ^{83}Br. The levels of ^{83}Kr were studied recently from the decay of ^{83}Br by Philippe *et al.*,[5] while the decay of ^{83}Rb was studied by Dostrovsky, Katcoff, and Stoenner,[6] Ikegami and Morinobu,[2] and Brown.[7] We have made preliminary reports of this work.[8,9]

EXPERIMENTAL

The ^{83}Rb activity was produced by the Rb(p, xn) reaction at the Gustaf Werner Institute in Uppsala, Sweden, followed by chemical separation; and by isolation of the daughter ^{83}Rb from ^{83}Sr that was produced by the ^{84}Sr(γ, n) reaction at the Lawrence Livermore Laboratory (LLL) linear accelerator. Enriched ^{84}Sr was used in the latter case. Details of the chemical separations are given elsewhere.[8,10] Also, mass separated sources were obtained to measure the conversion electrons and low-energy γ rays.[11]

Sources of ^{83}Br were prepared by irradiating natural Se in the Mark II Triga reactor at the Reactor Laboratory in Otaniemi, Finland. The bromine was chemically separated from the selenium target. A similar procedure was followed for the LLL sources that used enriched ^{82}Se as target material.

At Otaniemi, Finland, a 3-cm^3 and a 10-cm^3 Ge(Li) detector as well as a low-energy Ge(Li) and a Si(Li) detector were used for γ counting. A Si surface-barrier detector was used for low-energy conversion electron measurements. To observe γ-γ coincidences, Ge(Li)-NaI(Tl) measurements were performed. The singles as well as coincidence spectra were recorded with a TMC 4096 channel pulse height analyzer.[12,13] At LLL several Ge(Li) systems as well as a Compton suppression spectrometer[14] were used.

RESULTS

In Fig. 1 we show the low-energy ^{83}Rb spectrum, and in Fig. 2 we show the Compton suppression spectrum of ^{83}Rb decay. In Table I the energies and the relative intensities observed in the decay of ^{83}Rb are listed. The values presented represent the adopted values using both sets of data. In Fig. 3 we show a low-energy electron spectrum of a

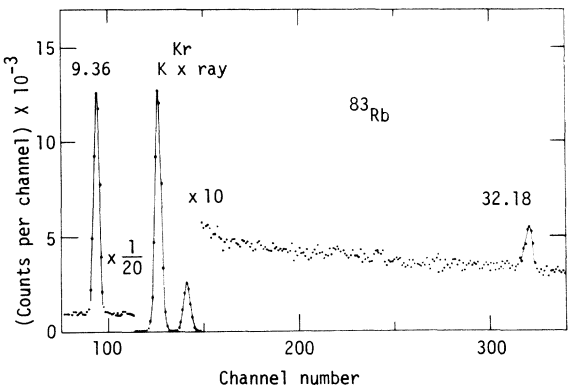

FIG. 1. A low-energy photon spectrum of a mass-separated ^{83}Rb source observed with the Si (Li) low-energy spectrometer.

mass-separated ^{83}Rb source taken with a surface-barrier Si detector. A value of 0.30 ± 0.05 for the conversion coefficient ratio α_K/α_{L+M} for the 32.2-keV transition was obtained from the conversion electron measurements. We obtain a value of 16 ± 5 for the conversion coefficient of the 9.3-keV transition in agreement with Kolk, Pleiter, and Heeringa.[15] The results of our coincidence data are given on the decay scheme (see Fig. 4.). We give our adopted values for the decay of ^{83}Br in Table II.

DECAY SCHEME

The decay scheme deduced from this and other studies[2,6,15–17] is shown in Fig. 4. The ground

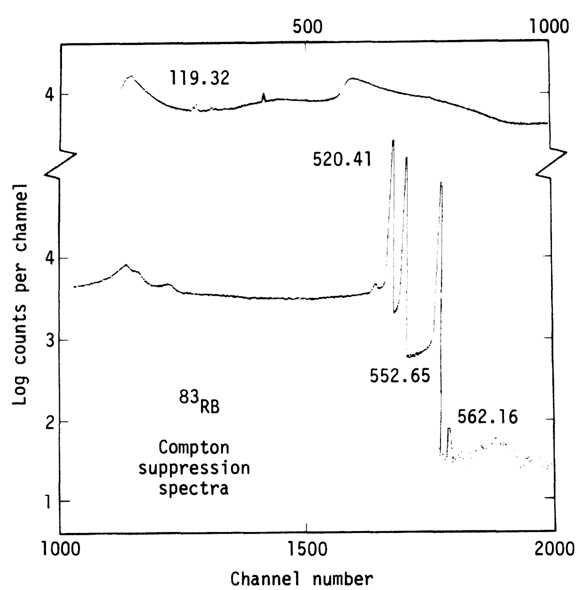

FIG. 2. Compton suppression spectra of ^{83}Rb (the 562-keV γ ray represents the $\frac{5}{2}^- \to \frac{9}{2}^+ M2$ transition).

TABLE I. γ-ray energies and intensities for the decay of ^{83}Rb.

$E_\gamma(\Delta E_\gamma)$ (keV)	$I_\gamma(\Delta I_\gamma)$ [a]	Assignment (from/to)
9.39(9)	131(30)	9/g.s.
K x-ray	1300(280)	···
32.18(5)	0.8(1)	42/9
119.32(9)	0.32(5)	691/571
128.55(12)	0.030(5)	691/562
237.19(–)	<0.011	799/562
520.41(3)	1000(50)	562/42
529.64(1)	656(30)	571/42
552.65(2)	357(15)	562/9
562.16(7)	0.19(2)	562/g.s.
648.96(5)	1.9(1)	691/42
681.17(7)	0.7(1)	691/9
790.14(5)	14.7(4)	799/9
799.36(5)	5.3(2)	799/g.s.

[a] To obtain absolute decay rates a 2% error must be added in quadrature. Conversion factor used is $0.465 \times I_\gamma$.

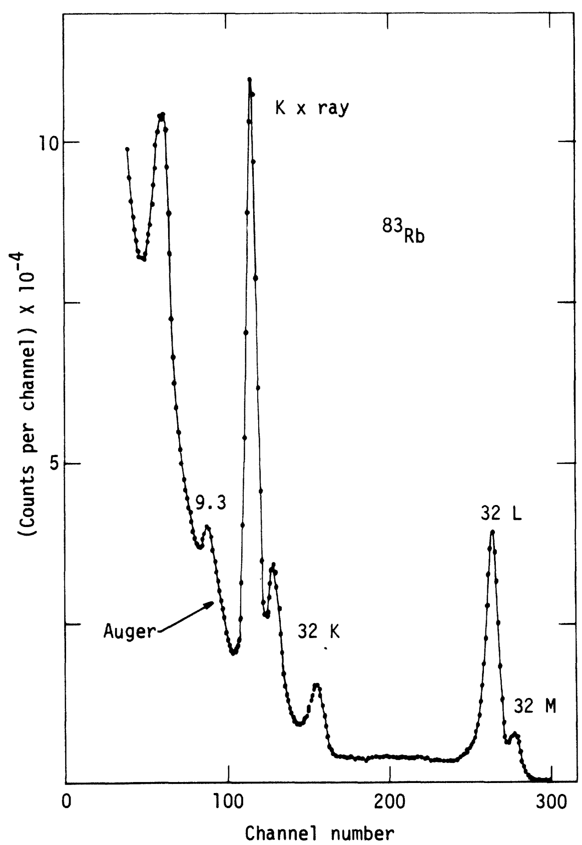

FIG. 3. A low-energy electron spectrum of a mass-separated ^{83}Rb source.

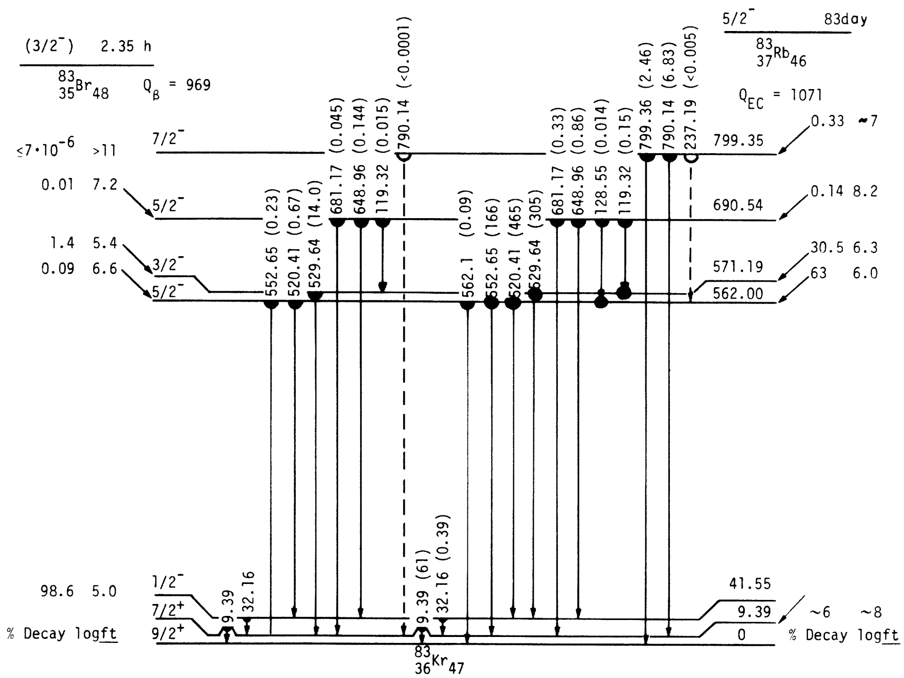

FIG. 4. The decay scheme of ^{83}Rb and ^{83}Br. A full circle at the bottom of the arrow signifies placement of the γ ray by the $\gamma\gamma$ coincidence experiment. A full circle at the top of the circle signifies a $\gamma\gamma$ coincidence gate was taken at this energy. A half circle represents placement by the Reitz principle. [*Nota bene:* the absolute intensities in γ rays per 1000 decays of the ^{83}Rb given in Fig. 4 were obtained by using the feeding of $(6.4\pm3)\%$ to the 9-keV level, while those of ^{83}Br were obtained by using a value of 98.6% to the 41-keV level (Ref. 17). In both cases, any unique first forbidden to the g.s. and 9-keV levels for Rb and Br decay respectively were taken as negligible.]

state of the ^{83}Rb is known to be $\frac{5}{2}^-$ and that of ^{83}Br is suggested to be $\frac{3}{2}^-$ from other works.[17] Also, the J^π values of $\frac{9}{2}^-$, $\frac{7}{2}^+$, and $\frac{1}{2}^-$ for the ground state and 9- and 42-keV levels, were determined previously.[17] For the 562-keV level we suggest a J^π value of $\frac{5}{2}^-$. For this level, J^π can be limited to $\frac{5}{2}^-$ or $\frac{3}{2}^+$ on the basis of previously known γ-ray branching and log*ft* values.[18] Our observation of a 562.16-keV γ ray would represent an $M2$ ground-state transition if the J^π assignment of this level were $\frac{5}{2}^-$. The 571-keV level is suggested to be $\frac{3}{2}^-$ on the basis of the allowed nature of the β decay to this level and the lack of any transitions to the ground state or 9-keV level. The energy of an $M2$ transition to the latter level would be 561.80. We found no second component of the 562.16 ± 0.07-keV γ ray. We suggest $\frac{5}{2}^-$ for the 691-keV level on the basis of its γ-ray branching ratios and the log*ft* values. We favor an assignment of $\frac{7}{2}^-$ for the 799-keV level over $\frac{7}{2}^+$. However, the latter cannot be ruled out on the basis of the log*ft* limit of 11 for the decay of ^{83}Br to this level, since the unique first-forbidden β decay to a $\frac{7}{2}^+$ level would be expected to be hindered over the base value of 8.5 for such a transition.[19]

DISCUSSION

The positive-parity levels observed in the odd neutron nuclei with $N\leq 47$ were characterized by Marumori *et al.*[20-26] They are successful in pre-

TABLE II. γ-ray energies and intensities for the decay of ^{83}Br.

$E_\gamma(\Delta E_\gamma)$	$I_\gamma(\Delta I_\gamma)$ [a]	Assignment (from/to)
9.39(1)		9/g.s.
32.16(3)	0.5(1)	42/9
119.32(2)	1.1(1)	690/571
128.55(8)	0.05(1)	690/562
520.41(5)	48.0(15)	562/41
529.64(1)	1000(14)	571/41
552.65(3)	16.7(9)	562/9
562.16(−)	···	562/g.s.
648.96(5)	10.3(8)	690/41
681.17(7)	3.22(25)	690/9
790.1(−)	0.01	799/9

[a] Error includes statistical and peak-shape error only. For absolute intensities, a 2% error in the knowledge of the absolute efficiency of the Ge(Li) detectors must be added in quadrature.

dicting the energy and branching ratios of the "anomalous coupling states" (ACS) using their dressed n-quasiparticle formalism. For nuclei such as ^{83}Kr they can calculate the 9-keV splitting of the $\frac{9}{2}^+$ and $\frac{7}{2}^+$ ground and first excited state. In addition, they predict a value of 12.8 $e^2\,cm^4\times10^{-50}$ for the $B(E2)\downarrow$ value of the $\frac{7}{2}^+\to\frac{9}{2}^+$ transition, which is in fair agreement with the measured value[15,21] of 6± 3 $e^2\,cm^2\times10^{-50}$. Also, they calculate a value of −0.22 for the g value compared with −0.268 ±0.001 as measured by Campbell, Perlow, and Grace.[27] The calculations of Kuriyama *et al.*[20–26] predict a J^π level of $\frac{5}{2}^+$ to occur at low energies. For the 47-neutron nuclei this level is suggested to occur at approximately 800 keV. If this level occurs below approximately 900 keV in ^{83}Kr, we would expect to observe it in the decay of ^{83}Rb, which has a measured decay energy of 1071± 32 keV.[17] We cannot identify any level with J^π of $\frac{5}{2}^+$ below 900 keV in this study. This is in contradiction with the ^{85}Y decay studies of Arlt *et al.*[3] who suggest a $\frac{5}{2}^+$ level at 786 keV in the $N=47$ nucleus ^{85}Sr. A more detailed study of the decay of the ^{85}Y isomers would be useful in resolving this discrepancy and in aiding in the understanding of the $N=47$ structure.

The two levels at 562 and 691 keV with J^π values of $\frac{5}{2}^-$ presumably have a mixed configuration of $|f_{5/2}00\rangle$ plus $|p_{1/2}12\rangle$.[28] The lower logft values for the population of the 562-keV level suggests a more single particle nature for this level. The observation of an $M2$ ground-state transition allows us to estimate the $E2$ speed of the transition from the 562-keV level to the $p_{1/2}$ level at 42 keV. We assume a hindrance of 50 over the Moskowski single particle estimate for the $M2$ transition, which is in line with the known systematics of $M2$ transitions.[4,29] This gives an effective enhancement of 20 for the $E2$ transition to the $\frac{1}{2}^-$ level and suggests the $E2$ transition occurs through the deexcitation: $|\frac{1}{2}12\rangle\to|\frac{1}{2}00\rangle$. The $M1$ transition from the 691-keV level to the $\frac{3}{2}^-$ level at 571 is relatively unhindered over the single particle estimate when the 648 is taken to have a speed of 30 single particle units similar to the even-even core.

For the negative parity states, the low-lying structure of ^{83}Kr can be understood from a simple vibration coupling model. However, the description of the positive parity levels require the application of the dressed n-quasiparticle model of Marumori and co-workers. The remaining discrepancy is the lack of a $\frac{5}{2}^+$ level in ^{83}Kr below 900 keV and the proposed existence of one in ^{85}Sr at 786 keV.

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