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Comments

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Internal-conversion coefficient determination of odd parity for the 108.8-keV first-excited state of ^{91}Rb

F. K. Wohn, W. L. Talbert, Jr., R. S. Weinbeck, M. D. Glascock, and J. K. Halbig*
Ames Laboratory-USAEC and Department of Physics, Iowa State University, Ames, Iowa 50010
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Internal-conversion coefficients of the 108.8-keV transition in the decay of ^{91}Kr and the 93.6-keV transition in the decay of ^{91}Rb were measured by the electron-to-γ-ray ratio method using a high-resolution magnetic spectrometer and by the x-ray-to-γ-ray ratio method using a low-energy photon spectrometer. The 93.6-keV transition was found to be pure $E2$. The 108.8-keV transition from the first-excited state of ^{91}Rb was found to be pure $M1$, which determines the parity of this state as odd, as expected from spherical shell-model considerations, and contradicts a recently reported assignment of even parity for this state.

[RADIOACTIVITY ^{91}Kr, ^{91}Rb [from ^{235}U(n,f)]; measured E and I for low-energy ce's, x rays, γ's; $\pi\sqrt{2}$ magnetic spectrometer, Ge(Li); deduced ICC, transition multipolarities; mass-separated $A=91$ activity.]

I. INTRODUCTION

Since the nuclei ^{91}Rb and ^{91}Sr are only a few nucleons away from the semimagic nucleus ^{88}Sr, the configurations predicted by the spherical shell model should dominate the structure of the low-energy levels of these nuclei. In the odd-Z nucleus ^{91}Rb, the low-energy levels are thus expected to have odd parity due to the $2p_{3/2}$, $1f_{5/2}$, and $2p_{1/2}$ proton orbitals near $Z=38$. In the odd-N nucleus ^{91}Sr, the low-energy levels are expected to have even parity due to the $2d_{5/2}$, $3s_{1/2}$, and $2d_{3/2}$ neutron orbitals above $N=50$. For either nucleus, the transition from the first-excited state should involve no change of parity and should be characterized by $M1$ and/or $E2$ multipolarity.

In the study of the decays of ^{91}Kr and ^{91}Rb by Achterburg *et al.*,[1] the 93.6-keV transition from the first-excited state of ^{91}Sr was found to have $E2$ multipolarity, in agreement with earlier studies[2,3] and the expectations of the spherical shell model. However, Achterberg *et al.* reported a multipolarity of $E1$ for the 108.8-keV transition from the first-excited state of ^{91}Rb; this result implies even parity for the 108.8-keV level since the ground state of ^{91}Rb is expected to have odd parity. Achterburg *et al.* found it necessary to postulate a low-energy excited-state deformation, with $\epsilon \approx 0.1-0.15$, in order to provide a plausible explanation of even parity for the 108.8-keV level. Prior to the present study, there was no additional experimental evidence to either support their hypothesis or disagree with it. Our conflicting experimental results of $M1$ multipolarity for the 108.8-keV transition indicates that the hypothesis of a low-energy excited-state deformation in ^{91}Rb is unnecessary.

II. EXPERIMENTAL PROCEDURE AND RESULTS

The internal-conversion coefficient (ICC) measurements were made with mass-separated sources provided by the TRISTAN mass separator on line to the Ames Laboratory research reactor.[4,5] Two independent techniques, the normalized-electron-peak-to-γ (NPG) technique and the x-ray-peak-to-γ (XPG) technique, were used in the ICC determinations.

The NPG measurements were made with a 60-cm^3 Ge(Li) detector and the TRISTAN $\pi\sqrt{2}$ magnetic spectrometer. The spectrometer design and the techniques involved in on-line NPG measurements with the spectrometer have been de-

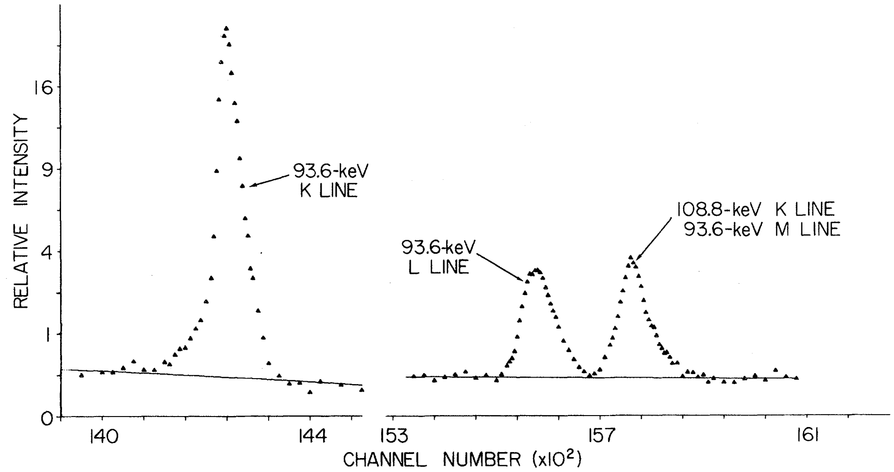

FIG. 1. Internal-conversion electron spectrum for an equilibrium ^{91}Kr-^{91}Rb source.

scribed elsewhere.[6-8] For the measurements reported here, equilibrium sources of ^{91}Kr-^{91}Rb were used in the spectrometer, which was used with two different modes of operation. One mode, with a resolution of 0.2% and a transmission of 0.4%, was used in order to resolve the 93.6-keV L-conversion peak from the 108.8-keV K-conversion peak. Figure 1 shows an example of the resulting electron spectrum with nearly complete separation obtained using this mode of operation to obtain the K/L ratio for the 93.6-keV transition and the equilibrium ratio of the K-shell ICC of the 93.6- and 108.8-keV transitions. The other mode of operation, with a resolution of 0.5% and a transmission of 1.0%, was used to determine the K-shell ICC of the 93.6-keV transition. The 555.6-keV isomeric transition of ^{91}Y, which has a well-established $M4$ multipolarity,[9,10] was used as the

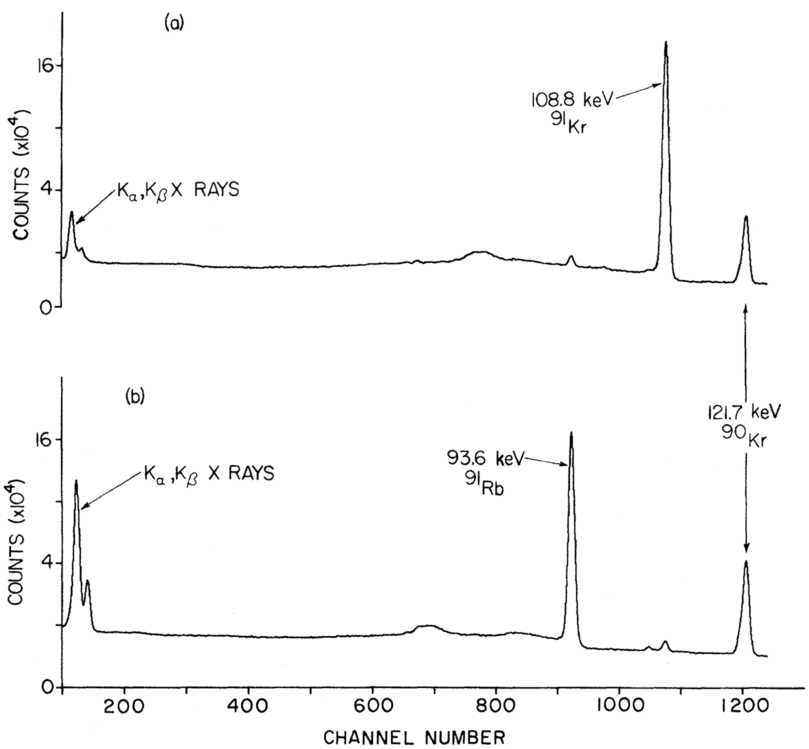

FIG. 2. X-ray and γ-ray spectra for mass 91 with (a) ^{91}Kr activity enhanced and (b) ^{91}Rb activity enhanced.

TABLE I. Internal-conversion coefficients.

	Experimental values						
Transition [a]	Achterburg *et al.*	Present study NPG	Present study XPG	Mean	Theoretical [b] $E1$	Theoretical [b] $M1$	Theoretical [b] $E2$
93.6 K	1.05 ± 0.10	1.19 ± 0.06	1.01 ± 0.07	1.10 ± 0.09	0.109	0.172	1.09
93.6 K/L	...	5.95 ± 0.24	...	...	9.01	8.78	5.99
108.8 K	0.067 ± 0.012	...	0.108 ± 0.011	0.109 [c] ± 0.007	0.066	0.101	0.607
93 K/108 K	15.7 ± 3.2	10.1 ± 0.5	9.4 ± 1.2	10.0 [d] ± 0.3	...	...	...

[a] Transitions labeled by energy in keV and atomic shell.
[b] R. S. Hager and E. C. Seltzer, Nucl. Data 4, 41 (1968).
[c] Mean value obtained from XPG result and the result found by dividing the 93.6 K mean value by the 93 K/108 K mean value.
[d] Mean value obtained by averaging the above NPG and XPG values together with the value of 10.1 ± 0.5 found by Halbig (Ref. 6).

normalization transition in the ICC calculation. Further details of the spectrometer measurements and the ICC calculations are given in Ref. 8.

The XPG measurements were made with a 1-cm^3 low-energy photon spectrometer having a resolution of 0.9 keV at 122 keV. These measurements were done with the mass 91 ion beam from the mass separator deposited on a moving tape collector in order to provide isobaric enhancement of the activity of interest. Figure 2 shows a ^{91}Kr enhanced spectrum in part (a) and a ^{91}Rb enhanced spectrum in part (b). Compared to equilibrium mass 91 activity, the ratio of the enhanced activity to the nonenhanced activity was greater by a factor of 50 for the ^{91}Kr enhanced data and by a factor of 100 for the ^{91}Rb enhanced data. The intense 121.7-keV doublet from the decay of ^{90}Kr is evident in both spectra of Fig. 2 since hydride molecular ions of ^{90}Kr are also deposited at mass 91. The determination of K-shell ICC values for the enhanced isotope in each of the enhanced spectra of Fig. 2 thus required correction of the observed x-ray intensity for the contribution from x rays due to the ^{90}Kr hydride contaminant and the nonenhanced mass 91 activity. Analysis of preliminary γ-ray data on masses 90 and 91 taken at the TRISTAN facility indicated that only the three low-energy γ rays seen in Fig. 2 contribute substantially to the x-ray intensity.[11] For the ^{91}Kr and ^{91}Rb decays, only about 0.5% of the K-shell x rays in the respective decays are due to other γ rays. For the ^{90}Kr decay, about 92% of the K-shell x rays are due to the 121.7-keV doublet. A K-shell ICC of 0.159 for the 121.7-keV doublet was used in correcting the XPG data for the ^{90}Kr contaminant[11]; corrections for the nonenhanced mass 91 activity required only a few iterations of the deduced ICC values for the 93.6- and 108.8-keV transitions.

The ICC values of the present study are given in Table I together with the values reported by Acterburg *et al.*[1] and theoretical ICC values. The NPG value for the 93.6-keV K-shell ICC was obtained with the $M4$ 555.6-keV isomeric transition in ^{91}Y as the normalization transition; consequently, the experimental uncertainty contains contributions due to the uncertainty in the Ge(Li) relative photopeak efficiency as well as the uncertainties in the determination of the areas of the electron and γ-ray peaks involved in the measurement. The uncertainties in the XPG values are dominated by the photopeak efficiency uncertainty but also include the contributions arising from the x-ray intensity corrections described above.

The uncertainties in the NPG determinations of the 93.6 K/L electron peak ratio and the 93 K/108 K ICC ratio are independent of the photopeak efficiency uncertainty since only the uncertainties in the areas of the peaks involved contribute to the uncertainties in these ratios. Several runs were made to determine these ratios, and the values given in Table I are weighted averages with rms uncertainties. The rms uncertainties provide a better indication of the reproducibility of these ratios than do the smaller statistical uncertainties in the average values. As is evident from Fig. 1, the 108.8 K electron peak is not resolved from the weaker 93.6 M electron peak; the latter was taken to be pure $E2$ in calculating the 93 K/108 K ratio. The small correction for the 93.6 M contribution had little effect on the accuracy of the determination of the 93 K/108 K ratio, as can be seen from the exact agreement between the present determination of 10.1 ± 0.5 and the previous determination by Halbig[6] of 10.1 ± 0.5. In Table I the uncertainties in the mean values of the NPG and XPG results are given by the larger of the rms and statistical uncertainties.

III. DISCUSSION

The results given in Table I of the present study indicate that the 93.6-keV transition from the first-excited state of ^{91}Sr is of pure $E2$ multipolarity and the 108.8-keV transition from the first-excited state of ^{91}Rb is of nearly pure $M1$ multipolarity. Neither transition involves a change of parity from the corresponding ground state, in agreement with the predictions of the spherical shell model, which is expected to be valid for such nuclei with only a few nucleons outside of closed shells or subshells. The hypothesis of Achterburg *et al.*[1] that ^{91}Rb has a low-energy excited-state deformation is shown by our results to have no basis in fact.

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*Present address: Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87544.

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