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THE LEVELS OF ^{103}Rh POPULATED IN THE DECAY OF ^{103}Ru

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Abstract: The gamma-ray spectrum associated with the beta decay of ^{103}Ru has been studied with curved-crystal and Ge(Li) spectrometers. The energy measurements obtained from the curved-crystal spectrometer data are of greater precision than previously reported measurements. Two gamma rays known to belong to the decay of ^{103}Ru but not seen directly by previous investigators in gamma-ray singles spectra were observed, and intensities are given. Coincidence spectra were taken using a Ge(Li)-Ge(Li) combination. The data confirm the essential features of previously proposed ^{103}Rh level schemes.

E | RADIOACTIVITY ^{103}Ru [from ^{102}Ru(n, γ)]; measured E_γ, I_γ, $\gamma\gamma$-coin. ^{103}Rh deduced levels. Enriched target, curved-crystal and Ge(Li) spectrometers.

1. Introduction

Although the beta decay of ^{103}Ru has been frequently investigated [1-8]), there has yet to be a study of the gamma-ray spectrum utilizing spectrometers capable of fully resolving all gamma rays known to belong to this decay. The present investigation was undertaken to fill this gap and to provide precision energy measurements and improved intensity measurements of the gamma rays associated with the decay of ^{103}Ru.

2. Experimental arrangements

The curved-crystal spectrometer energy measurements reported in this paper were taken on the University of Michigan 2 m curved-crystal spectrometers. One spectrometer utilized the Ge(0$\bar{2}$2) planes as diffraction planes, while the other utilized the Q(310) planes. These spectrometers and the experimental techniques associated with their use have been described previously [9-11]). Both crystals were calibrated using the 411.795±0.007 keV gamma ray [12]) occurring in the decay of ^{198}Au. We have adopted a smaller uncertainty for this gamma-ray energy than the one given in ref. [12]). This reflects the smaller uncertainty assigned to the value for the rest mass energy of the electron in the latest least-squares adjustment of the fundamental constants [13]). The source used with the curved-crystal spectrometers was a mixture of Ru metal (obtained from Oak Ridge National Laboratory, enriched to 99.53 % in ^{102}Ru) and

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epoxy resin. This source was irradiated in The University of Michigan Ford Nuclear Reactor (thermal neutron flux $\approx 3\times10^{13}$ neutrons/sec $\cdot$ cm^2) for a period of approximately 12 weeks; its activity at the end of this period was about 0.6 Ci. Energy resolutions of the two spectrometers were about equal: ΔE(FWHM) = (2.5×10^{-5}) (E^2/n) keV, where n is the order of reflection and E the gamma-ray energy in keV.

The detector used for energy and intensity measurements was an Ortec 32 cm^3 coaxial Ge(Li) detector coupled to a Canberra 1408C preamplifier and a Tennelec TC200 amplifier. Data were accumulated in a Scipp 1600-channel analyser. The nonlinearities in the system were accounted for using the method of Donnelly *et al.* [14]. A relative efficiency calibration [14] for the system was obtained for the range 90-1400 keV by utilizing sources for which the relative emission of pairs of gamma rays are precisely known; namely ^{180m}Hf, ^{108m}Ag, ^{22}Na, ^{60}Co, ^{160}Tb and ^{46}Sc. For gamma-ray intensities in the energy range below 90 keV a modified pair-point method [15] was used. In this method, a comparison is made of the relative peak areas of the gamma rays de-exciting a single level and the X-rays which follow internal conversion. By using three sources (^{137}Cs, ^{139}Ce and ^{160}Tb), the relative efficiency calibration was extended to 30 keV. The source material used for the Ge(Li) spectrometer was taken from the same enriched sample used in the fabrication of the curved-crystal spectrometer source. A few grains of this finely powdered ruthenium metal were encapsulated in a quartz vial and irradiated in The University of Michigan Ford Nuclear Reactor for about 12 weeks. The source was allowed to cool for about 16 weeks before spectra were taken. A Ge(Li) spectrometer source was prepared by placing some of the radioactive material into a cavity in a lucite disk. The activity of this source was about 3 μCi.

The source used for the measurement of gamma-ray energies and intensities on the Ge(Li) spectrometer was also used for the gamma-gamma coincidence study. The total spectrum channel of the coincidence system consisted of the coaxial Ge(Li) detector, preamplifier and amplifier described above; the gate channel consisted of a 40 cm^3 trapezoidal Ge(Li) detector coupled to a Nuclear Diodes 101 preamplifier, a Tennelec TC200 amplifier and TC250 biased amplifier and stretcher. The resolution of both detectors was about 2.5 keV at 662 keV. The coincidence electronics was of the fast-slow type. Leading-edge time was used for both channels. A resolving time 2τ of about 110 ns was used for all runs. Two coincidence spectra were taken for each run, one with the gate set on the photopeak of interest and the other with the gate set on the energy region immediately adjacent to it. The two spectra were routed to 800-channel subgroups of the Scipp 1600-channel analyser.

3. Results

The results of the energy and intensity measurements are presented in table 1. The values of E_γ (40 keV), E_γ (53 keV), E_γ (295 keV), E_γ (497 keV) and E_γ (610 keV) are curved-crystal spectrometer measurements; the uncertainties shown are a combination of the uncertainties associated with the data and the uncertainties associated with the curved-crystal spectrometer calibration. The values of E_γ (444 keV) and E_γ (557 keV) are the weighted averages of values obtained from the curved-crystal spectrometer and the Ge(Li) spectrometer (calibrations of the Ge(Li) spectra were performed

TABLE 1

Energies and intensities of gamma-ray transitions occurring in the decay $^{103}\text{Ru} \xrightarrow{\beta} {}^{103}\text{Rh}$

Energy (keV)	Relative gamma-ray intensity
39.755 ± 0.012	0.037 ± 0.009
53.275 ± 0.010	0.34 ± 0.06
294.72 ± 0.12	0.30 ± 0.03
443.77 ± 0.12	0.34 ± 0.03
497.080 ± 0.013	100
557.11 ± 0.13	0.88 ± 0.07
610.406 ± 0.067	6.24 ± 0.31

using our curved-crystal spectrometer measurements of the 497 and 610 keV gamma rays); the uncertainties are a combination of the uncertainties associated with the data and the uncertainties associated with calibration. Typical Ge(Li) spectra are shown in figs. 1 and 2. These spectra clearly show the peaks due to the 40 keV and 444 keV gamma rays which have been known [1-3]) to occur in the decay of ^{103}Ru. This is the first report of their observation as separate peaks in gamma-ray singles spectra.

Several gamma rays not observed in the present work have been reported by previous investigators as belonging to the decay of ^{103}Ru. We estimate the following upper limits for some of them (relative to the intensity of the 497 keV gamma ray, I_γ (497 keV) ≡ 100) : I_γ(65 keV) < 0.01, I_γ (323 keV) < 0.08 and I_γ (362 keV) < 0.05.

A partial summary of the results of the gamma-gamma coincidence study is shown in table 2. Allowance has been made for contributions due to chances and Compton scattered photons in the gated region.

A level scheme which is consistent with the result of the present investigation is shown in fig. 3. This level scheme is in essential agreement with the work of previous investigators [1-8]). The ground state spin and parity as well as the spins and parities of the 40 keV and 295 keV levels appear to be fairly well established. The available data regarding the spin and parity of the 537 keV level are not at all conclusive. Manthuruthil *et al.* [1]) have recently suggested $\frac{7}{2}^+$ and $\frac{7}{2}^-$ as possible spin and parity assignments for the 93 and 650 keV levels, respectively.

Several possible interlevel transitions can be placed in the level scheme of fig. 3. Curved-crystal spectrometer searches were made for two of these possible transitions (113 and 202 keV), but neither of them was observed. We estimate an intensity upper limit for each of these possible gamma rays of 0.03 (relative to the intensity of the 497 keV gamma ray, I_γ (497 keV) ≡ 100).

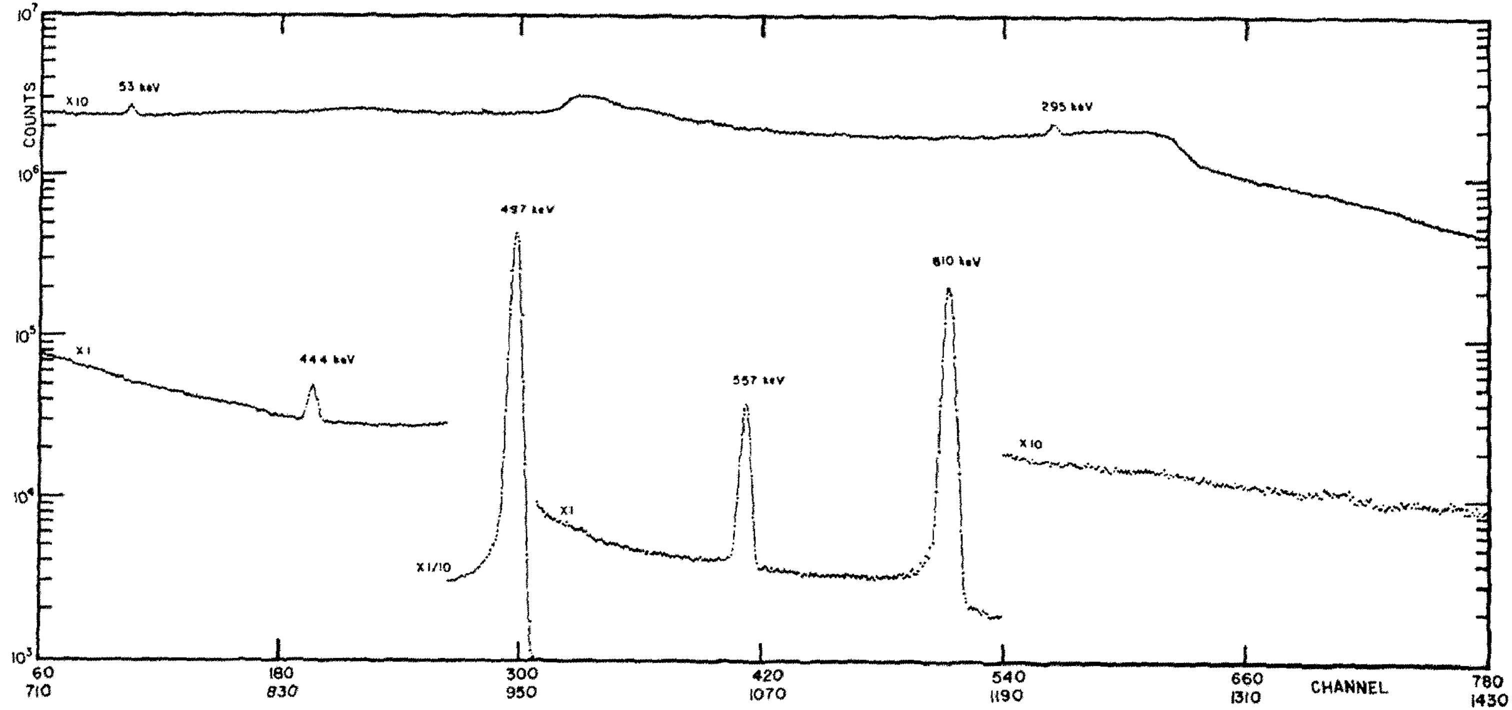

Fig. 1. The gamma-ray spectrum of ^{103}Ru observed with a 32 cm^2 Ge(Li) detector; source material in a quartz vial.

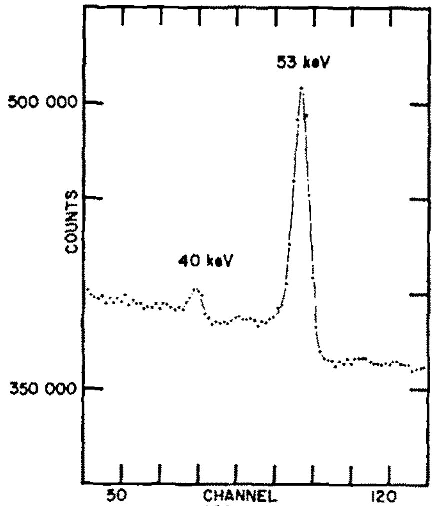

Fig. 2. The two low-energy gamma rays of ^{103}Ru observed with a 32 cm^3 Ge(Li) detector; source material on a lucite disk. Note that the vertical scale is linear.

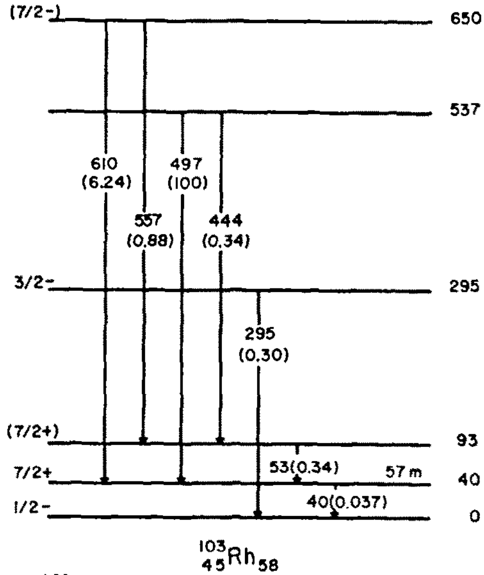

Fig. 3. The level scheme of ^{103}Rh populated in the beta decay of ^{103}Ru. Gamma-ray energies are given in keV; relative gamma-ray intensities are enclosed by parentheses.

TABLE 2

Gamma-gamma prompt coincidence results

Gate (keV)	Prompt coincident gamma rays (keV)
295	none
444	53
497	none
557	53
610	none

4. Conversion coefficients

It has been pointed out [1]) that the 53 keV transition occurring in the decay of ^{103}Ru is probably pure M1. If we assume that this is the case, then we can compute K-shell internal conversion coefficients by utilizing the gamma-ray intensities of the present work, the electron intensities of ref. [1]) and the theoretical value of the K-shell internal conversion coefficient for the 53 keV transition. We find by interpolation of the values given by Hager and Seltzer [16]) that α_K (53.275 keV, $Z = 45$; M1) = 1.82. With this value as a normalization constant, we calculate the following conversion coefficients:

$$\alpha_K\,(295\text{ keV}) = 0.016\ \pm 0.005,$$
$$\alpha_K\,(444\text{ keV}) = 0.012\ \pm 0.003,$$
$$\alpha_K\,(497\text{ keV}) = 0.0058 \pm 0.0015,$$
$$\alpha_K\,(557\text{ keV}) = 0.0068 \pm 0.0018,$$
$$\alpha_K\,(610\text{ keV}) = 0.0037 \pm 0.0009.$$

These values are in good agreement with those deduced by Manthuruthil *et al.* [1]).

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