Beta Decay of Ru^{103}†

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In an earlier investigation, the intense inner beta spectrum of Ru^{103} was observed by Kondaiah to have an anomalous shape corresponding to a deficiency of electrons at low energy. This shape could not be explained by the generally accepted theory of beta decay. By use of a 4π beta-ray scintillation spectrometer, this beta group has been studied in coincidence with the 495-kev gamma ray. The Fermi plot of the data is now found to be linear down to 37 kev.

The beta spectrum in coincidence with the 610-kev gamma ray was also measured. By a comparison of the total decay energies of the inner beta groups and their cascading gamma rays, it is deduced that the 610- and 495-kev gamma rays decay to the same energy level of Rh^{103}.

The end-point energies of the two beta groups measured in coincidence with the 495- and 610-kev gamma rays are, respectively, 227 ± 4 and 119 ± 4 kev.

INTRODUCTION

THE intense inner beta group of Ru^{103} was reported by Kondaiah[1] to have an anomalous deficiency of electrons at low energy; the Fermi plot of this beta spectrum curved towards the energy axis at low energies. Such a shape is not readily explained by the generally accepted theory of beta decay.[2] It is the purpose of the present experiment to re-examine the shape of this beta spectrum. Use is made of the fact that this beta-ray group is in coincidence with a 495-kev gamma ray. By gating the spectrometer with this gamma ray, only the intense inner beta group is measured. The uncertainties introduced in the subtracting of spectra are thus avoided.

It is of interest also to examine the beta group which is in coincidence with the 610-kev gamma ray since previous investigations[3,4] do not agree on the energy level to which this gamma ray decays. By measuring the end-point energy of the beta group in coincidence with the 610-kev gamma ray, it is possible to determine the position of this gamma ray in the decay scheme.

INSTRUMENTATION

The beta spectra were studied with a 4π beta-ray scintillation spectrometer. The source was sandwiched between two cylindrical plastic phosphors each $1\frac{3}{16}$ inches in diameter$\times 1\frac{3}{16}$ inches thick. The phosphors were optically coupled with silicon fluid to 6292 Dumont photomultiplier tubes. The resolution for the Cs^{137} internal conversion electron line was between 13 and 14% for all experimental runs. For the measurement of beta rays in coincidence with gamma rays, the gamma rays were detected with a $1\frac{3}{4}$-inch diameter$\times$1-inch thick NaI crystal mounted on a 6292 Dumont photomultiplier tube. The NaI crystal was placed in contact with the two phosphors and at 90° to their line of axis. In such a position, the solid angle subtended by the NaI crystal was 21% of the total solid angle.

A block diagram of the electronic apparatus for beta-gamma coincidence measurements is shown in Fig. 1. The spectrometer, as used for measurement of single

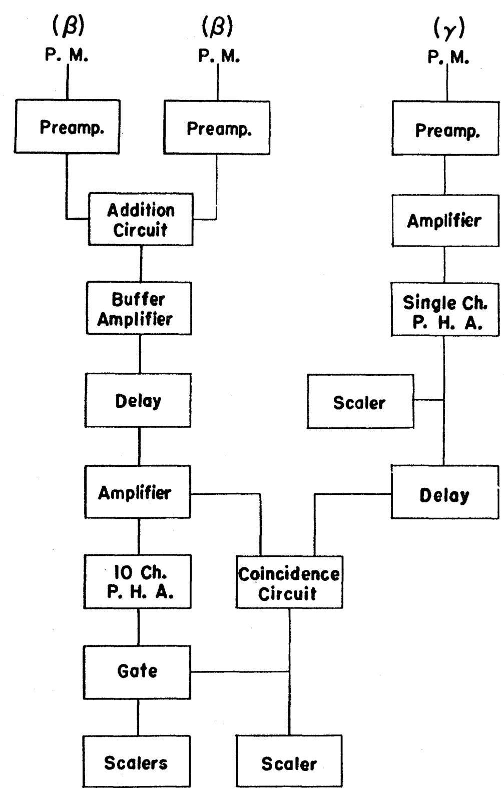

FIG. 1. Block diagram of the electronic circuits for the beta-gamma coincidence scintillation spectrometer.

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[1] E. Kondaiah, Phys. Rev. **79**, 891 (1950); *M. Siegbahn Commemoration Volume* (Almqvist and Wiksells Boktryckeri AB, Uppsala, 1951), p. 442.

[2] Another case of a beta spectrum with an apparent deficiency of electrons at low energy was reported for Th^{233} [Bunker, Langer, and Moffat, Phys. Rev. **80**, 468 (1950)]. Recently it has been re-examined by B. J. Dropesky and L. M. Langer [Phys. Rev. **108**, 90 (1957)], and is found to behave normally.

[3] De Raad, Middelkoop, Van Nooyen, and Endt, Physica **20**, 1278 (1954).

[4] B. Saraf, Phys. Rev. **97**, 715 (1955).

TABLE I. End-point energy and lowest energy for which each spectrum was found to be linear.

Isotope	Coincidence γ-ray (kev)	End-point energy (kev)	Lowest energy (kev)
Ce^{141}	145	440	170
Ce^{144}	134	177	39
Au^{199}	209	251	44

beta spectra, has been described by Johnson *et al.*[5] The single-channel pulse-height analyzer was adjusted to accept the gamma rays which were in coincidence with the beta group of interest. The values of the two time delays were chosen to give 100% coincidence efficiency throughout the beta-ray energy range which was investigated. The resolving time of the coincidence circuit was either 0.5 or 1.0 microsecond.

To check the relation between beta-ray energy and pulse height, five internal conversion electron lines between the energies of 61 and 976 kev were studied. A linear relation between pulse height and energy was found. However, a linear extrapolation to zero pulse height yielded an energy intercept of 15.5 kev. This is similar to the results of Johnson *et al.*[5] and Hopkins.[6]

The reliability of this spectrometer to measure a beta spectrum in coincidence with a gamma ray was checked by studying three known beta spectra. The method of mounting the source was the same as that used for Ru^{103} and is described in the next section. All three spectra are once forbidden, nonunique transitions and might be expected to exhibit linear Fermi plots. In Table I, the measured end-point energy and the lowest energy for which each spectrum was found to be linear are recorded. The Fermi plot of Ce^{141} deviated from a straight line below 170 kev because of an impurity of Ce^{144}. The end-point energies of the beta spectra agree within $\pm 2\%$ of the average of the end-point energies measured by other investigators.

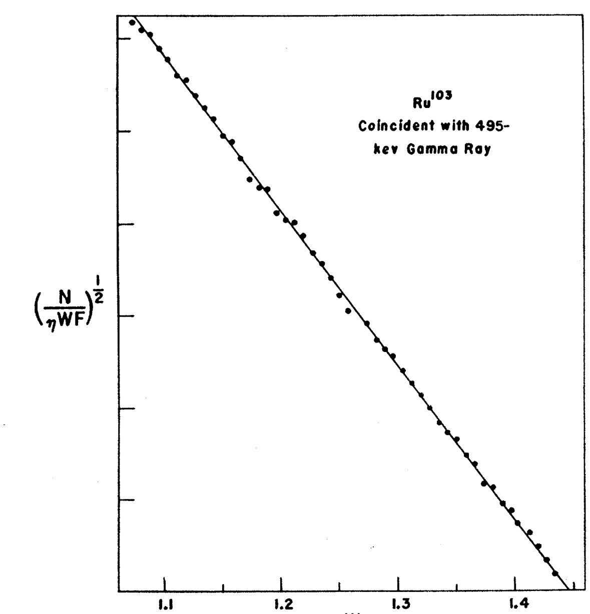

FIG. 2. Fermi plot of the inner beta spectrum, measured in coincidence with the 495-kev gamma ray.

PROCEDURE AND RESULTS

A molybdenum rod was bombarded with 22-Mev alpha particles in the Indiana University cyclotron. The bombardment produced both ruthenium and technetium activities. Ninety days after the bombardment, the surface layer was filed off and the ruthenium was separated from the technetium isotopes and target material by using the chemical procedure of Gile *et al.*[7] To check on the effectiveness of the chemical separation, the gamma-ray spectrum of the Ru^{103} was studied. The spectrum showed no lines arising from impurities. Peaks were observed only at 0.054±0.002, 0.496±0.010, and 0.61±0.02 Mev in good agreement with the energy measurements of Saraf.[4] After corrections for the efficiency of the NaI crystal and for the ratio of counts in the photopeak to the total counts, the relative intensities of the gamma rays were determined to be 0.005, 1, and 0.07, respectively.

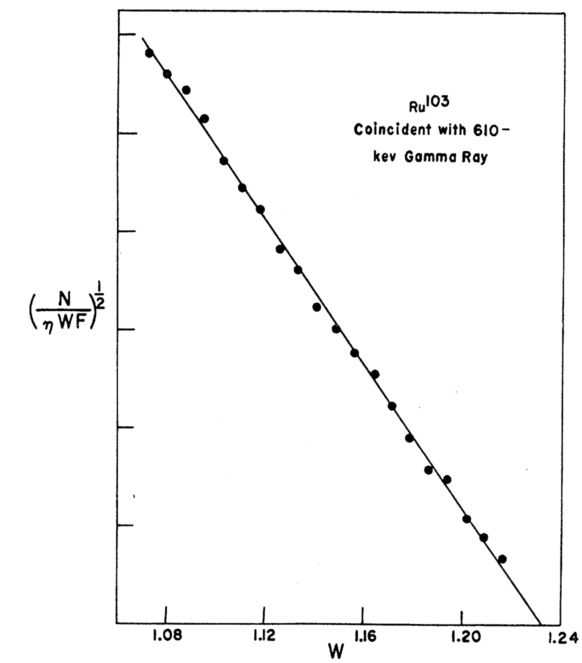

FIG. 3. Fermi plot of the inner beta spectrum, measured in coincidence with 610-kev gamma ray.

In order for all beta rays to be stopped in the plastic

[5] Johnson, Johnson, and Langer, Phys. Rev. **102**, 1142 (1956).
[6] J. I. Hopkins, Phys. Rev. **77**, 406 (1950).
[7] Gile, Garrison, and Hamilton, University of California Radiation Laboratory Report UCRL-1419, 1951 (unpublished).

phosphors as well as for all light to be collected, the two phosphors must be brought into contact. A film of $\sim 10\ \mu g/cm^2$ Zapon was put on the first phosphor to prevent contamination. The source material was deposited from a weak HCl solution and spread with the aid of insulin over an area of $\sim 1\ cm^2$. The intensities of the sources ranged from 28 to 42 millimicrocuries. A cover of Zapon of $\sim 7\ \mu g/cm^2$ was placed over the source to prevent contamination of the other phosphor.

With the single-channel pulse-height analyzer adjusted to accept the 495-kev gamma-ray peak, the coincidence beta spectrum was measured in the 10-channel pulse-height analyzer. The single-channel analyzer, besides accepting pulses produced by 495-kev gamma rays, also accepts pulses arising from Compton electrons which are produced by the 610-kev gamma rays. Beta rays in coincidence with the 610-kev gamma rays are then counted. These counts were estimated to contribute only $\sim 0.1\%$ of the total counts and, therefore, cause negligible distortion to the beta spectrum. The real/chance ratio was greater than 500 for 39 of the 50 experimental points. More than half of the points had a mean statistical error of less than 3%. The total background was 0.3% of the total counting rate. The Fermi plot (Fig. 2) is linear down to 37 kev and yields an end-point energy of 227 ± 4 kev (average value of two runs). Body and end-point corrections for finite resolution were applied.[8]

The beta spectrum in coincidence with gamma rays from the high-energy side of the 610-kev gamma-ray peak was investigated. Only the high-energy side of the gamma-ray peak was used in order to avoid any coincidence counts with the 495-kev gamma ray. The real/chance ratio was greater than 80 for all points, with a mean statistical error of less than 5% for 12 of the 20 experimental points. The Fermi plot for this beta group is shown in Fig. 3. The end-point energy is determined as 119 ± 4 kev.

A third gamma-ray transition, with an energy of 54 kev, was also observed by Saraf[4] and De Raad *et al.*[3] An effort was made to locate the position of this transition in the decay scheme by determining the beta spectrum in coincidence with it. However, no definite conclusion could be made because of interference, mainly from Compton electrons in the 55-kev region (produced by the 495- and 610-kev gamma rays) which produced counts in coincidence with beta particles and scattered gamma rays.

[8] J. P. Palmer and L. J. Laslett, U. S. Atomic Energy Commission Bulletin, ISC-174, 1950 (unpublished).

DISCUSSION

The linear Fermi plot of the intense beta spectrum disagrees with the anomalous shape reported by Kondaiah.[1] It is difficult to determine why, in this earlier investigation, a deficiency of electrons was observed at low energy. However, there are, now, known effects which can cause such a deficiency, e.g., electrostatic charging of the source or defocusing of the spectrometer because of distortion of the magnetic field.

The linear Fermi plot found in the present investigation is consistent with the $\log ft$ value of 5.6. It is also consistent with the parity and spin assignments of the parent and daughter levels suggested by De Raad *et al.*[3] and Saraf.[4]

From the end-point energy of the beta spectrum measured in coincidence with the 610-kev gamma ray, it is possible to determine the energy level to which this transition proceeds. Adding the end-point energy of the beta group and the energy of the coincidence (610 ± 5)-kev gamma ray,[4] a value of 729 ± 9 kev is obtained. From a similar addition of the end-point energy of the intense beta spectrum and the energy of the coincidence (495 ± 5)-kev gamma ray,[4] the total value is 722 ± 9 kev. It appears likely, therefore, that both the 495- and 610-kev gamma rays terminate at the same energy level in Rh^{103}. This is in agreement with the decay scheme proposed by Saraf[4] and in disagreement with that proposed by De Raad *et al.*[3]

ACKNOWLEDGMENTS

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