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isomeric state in Y⁸⁶

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ABSTRACT

A 48 \pm 1 minute isomeric level in Y⁸⁶ has been produced by irradiations of rubidium (natural and enriched in Rb⁸⁵) with alpha particles and of strontium (natural and enriched in Sr⁸⁶) with deuterons. Two transitions with energies 10.15 \pm 0.1 keV and 208.0 \pm 0.3 keV are observed in the decay of Y^{86m}. From the L sub-shell ratios, the multipolarity of the 10 keV transition is determined to be E3. The K-conversion coefficient of the 208 keV transition is $\epsilon_{\rm K}$ = 0.04 \pm 0.01.

I. INTRODUCTION

In the course of an investigation of neutron-deficient yttrium isotopes, we have detected isomeric states in Y^{86} and in Y^{90} . Concurrently with the present work, other investigators have studied these isomers. 1,2,3,4 Since several groups have already reported their results on Y^{90m} , we will note here only that our results are in agreement with the reported data, and that we have measured the energy of the isomeric transition in Y^{90m} to be 202.4 \pm 0.3 keV, by use of a permanent-magnet 180° spectrograph.

II. EXPERIMENTAL PROCEDURES

 y^{86m} was produced by irradiation of RbCl (natural or enriched in Rb⁸⁵) with helium ions and $Sr(NO_3)_2$ (natural or enriched in Sr^{86}) with deuterons, in the Crocker 60-inch cyclotron.

In most of the experiments, the preparation of pure, carrier-free yttrium sources consisted of the following: the target was dissolved in concentrated $\mathrm{NH_{L}OH}$ and passed through a filter paper, to which the yttrium activity but not the strontium, adsorbed. After thorough washing of the filter paper by dilute $\mathrm{NH_{L}OH}$, the yttrium was removed with 8 N HCl.

The photons of Y^{86m} were studied with a 7.62 x 7.62 cm NaI(T1) scintillation crystal coupled to a 100-channel Penco analyzer, and the conversion electrons were examined with a 100-gauss 180° spectrograph and with a 25-cm double-focusing spectrometer.

III. RESULTS

Following the purification of yttrium from a target of natural RbCl which had been irradiated with 47-Mev helium ions, a 210-kev gamma ray was observed in the scintillation spectrum, with a decay period of 48 ± 1 minutes. At the same time, gamma rays known to occur in the decay of the Y^{86} ground state 5,6 were observed to grow into the spectrum and then to decay with the characteristic 14.6-hour half-life of Y^{86} . Similar results were obtained from targets enriched in Rb 85 and also from bombardments of enriched Sr 86 irradiated with 15-Mev deuterons. Irradiation of enriched Sr 86 targets with 5-Mev deuterons failed to produce the activity. From this information, the 48-minute activity can be assigned definitely as Y^{86} .

Figure 1 shows a typical decay curve of the 210-kev peak in the scintillation spectrum, and Fig. 2 shows a growth curve of the 1-Mev photon group of Y^{86} (ground state).

Additional information about the "210-kev" transition, obtained from measurements in a 100-gauss 180° spectrograph, is summarized in Table I.

Table I. Internal Conversion Data of Y 86m Binding Energy Transition Energy Intensity Ratios Electron Energy Shell (kev) (kev) (Y) L_{III}/L_{II}=1.5±0.5 10.15 2.17 7.98 \mathbf{L}_{TT} 10.16 8.06 2.10 LIII $K/I_T/M_T = 100/8.3/1.7$ 208.0 190.9 . 17.1 208.0% 205.6 \mathbf{L}_{T} 2.39 M_{T} 0.41 207.9 207.5

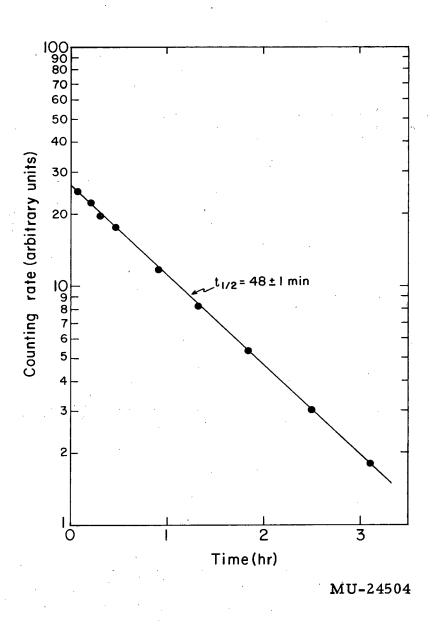


Fig. 1. Decay of the 210-kev photopeak of \mathbf{Y}^{86m} .

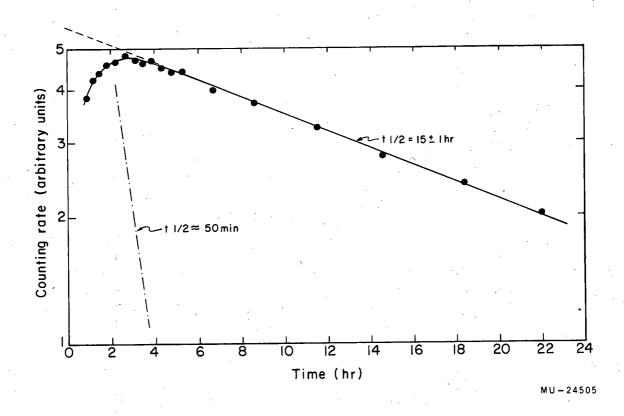


Fig. 2. Growth and decay of the 1.08-Mev photon group of 14.6-hour Y^{86} from a sample containing Y^{86} and Y^{86m} .

A more precise value of the energy, 208.0 ± 0.3 kev, was determined, and it was also verified from the energy differences between the K, L, and M lines that this transition is indeed converted in yttrium, not strontium.

The absolute K-conversion coefficient of the 208.0 kev transition was measured in a 25-cm double-focusing spectrometer, by use of the internal-external conversion method due to Hultberg and Stockendal. The experimental value $\epsilon_{\rm K}$ = 0.04 ± 0.01 corresponds to a mixed M1-E2 transition (.40% E2). 8,9

Although the 208.0 kev transition was the only one that could be assigned to $\rm Y^{86m}$ on the basis of the photon or initial electron spectra, it was obvious that the observed 48-minute half-life is much too long to be compatible with an E2 or M1-E2 transition. Therefore a search was made for a lowenergy transition, with use of a 50-gauss pre-accelerator spectrograph, 10 employing in this case an accelerating voltage of 9.82 kv. Two electron lines, which decayed with a half-life of about 50 minutes, were observed with an energy separation of 0.08 \pm 0.01 kev (see Table I). This spacing is in good agreement with the characteristic $\rm L_{II}^{-L}_{III}$ energy difference of yttrium, 0.075 kev, 11 and indicates an isomeric transition of energy 10.15 \pm 0.1 kev.

If the assumption is made that the 10.15 kev transition is responsible for the 48-minute half-life, it follows that the transition must be of multipole order E3 or M3. 12 These two alternatives are readily distinguishable by an examination of the L-subshell conversion pattern. A straight-line extrapolation to 10 kev on log-log paper of Rose's theoretical L-shell conversion coefficients indicates for M3 radiation the subshell pattern, $\rm L_{I}/\rm L_{III}/\rm L_{III}=24/2.6/100$ and for E3 radiation the ratios $\rm L_{I}/\rm L_{III}/\rm L_{III}=0.9/49/100$. The experimental observation of only $\rm L_{II}$ and $\rm L_{III}$ conversion, with the ratio $\rm L_{III}/\rm L_{III}=1.5\pm0.5$, is compatible only with an E3 assignment.

A transition of 98.5 ± 0.2 kev was also noted which, on the basis of its K-L electron energy separation, appears to be converted in strontium rather than yttrium. The electron lines decay with a half-life of roughly 50 minutes. Although these data might appear to be indicative of a direct electron-capture branch of Y^{86m}, we could not observe a 98-kev photon in the scintillation spectrum, and also no other transitions characteristic of the Sr⁸⁶ levels appeared in the spectrum until the daughter (14.6-hour Y⁸⁶) began to grow into the sample. K X-ray-gamma coincidence experiments also failed to indicate any radiations in coincidence with K X-rays. The present evidence on this transition is inconclusive.

IV. DISCUSSION

The 48-minute isomeric state of Y^{86} decays by a 10.15 kev E3 transition followed by a 208.0 kev E2 transition. It is interesting to speculate briefly on the possible nature of the levels in Y^{86} from which these transitions arise.

 y^{86} , with 39 protons and 47 neutrons, has a ground-state configuration $(p_{1/2})_P^{-1}(g_{9/2})_N^{-3}$ and hence, according to Nordheim's "strong" rule, spin and parity 4-. This assignment is consistent also with the recent results of Yamazaki, Ikegami, and Sakai on the decay of 14.6-hour y^{86} .

The excited states of this odd-odd nucleus are expected to arise as combinations of the neutron states found in $_{38}^{85}$ and proton states in $_{39}^{85}$ or $_{39}^{87}$ $_{48}^{87}$. These are shown in Table II.

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Toble Ti	T Transat	tod confid	gurations	Λf	$^{\sim}$
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Proton state (Y ⁸⁷)	Ne	eutron state (Sr ⁸⁵)	Resultant spins	Resultant parity
P _{1/2}		^g 9/2	4,5	_
^p 1/2		7/2+	3,4	-
^p 1/2		^p 1/2	0,1	+
^g 9/2		^g 9/2	0,1,29	+
^g 9/2		7/2+	1,2,38	+ · · · · · · · · · · · · · · · · · · ·
^g 9/2		^p 1/2	4.,5	

Preliminary results of a study of the decay of $_{40}^{27}$ Zr $_{46}^{86}$ being carried on at this laboratory indicate that the 48-minute isomeric state of Y 86 is not populated in Zr 86 decay. This fact suggests that the spin of the isomer is higher than the ground state spin 4-. Of those states shown in Table II, a most likely choice for Y 86m is the 8+ state arising from $(g_{9/2})_P$ $(7/2+)_N$. Thus, the levels of the isomer might be as shown in Fig. 3.

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$$(9_{9/2})_{P} (9_{9/2})_{N}^{3} 8+ \frac{y^{86m} (48 min)}{E 3} 218.2$$
 $(P_{1/2})_{P} (9_{9/2})_{N}^{3} 5- \frac{y^{86m} (48 min)}{M1-E 2} 208.0$
 $(P_{1/2})_{P} (9_{9/2})_{N}^{3} 4- \frac{y^{86} (14.6 hr)}{39^{86} (14.6 hr)}$

Fig. 3. Suggested level scheme of Y^{86} m.

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