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ABSTRACT

A 48 ± 1 minute isomeric level in Y^{86} has been produced by irradiations of rubidium (natural and enriched in Rb^{85}) with alpha particles and of strontium (natural and enriched in Sr^{86}) with deuterons. Two transitions with energies 10.15 ± 0.1 kev and 208.0 ± 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 $\epsilon_K = 0.04 \pm 0.01$.

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 ± 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 Rb^{85}) 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 NH_4OH 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 NH_4OH, the yttrium was removed with 8 N HCl.

The photons of Y^{86m} were studied with a 7.62 x 7.62 cm NaI(Tl) 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}

Electron Energy (kev)	Shell	Binding Energy (Y)	Transition Energy (kev)	Intensity Ratios
7.98	L_{II}	2.17	10.15	L_{III}/L_{II}=1.5±0.5
8.06	L_{III}	2.10	10.16	
190.9	K	17.1	208.0	$K/L_I/M_I$=100/8.3/1.7
205.6	L_I	2.39	208.0	
207.5	M_I	0.41	207.9	

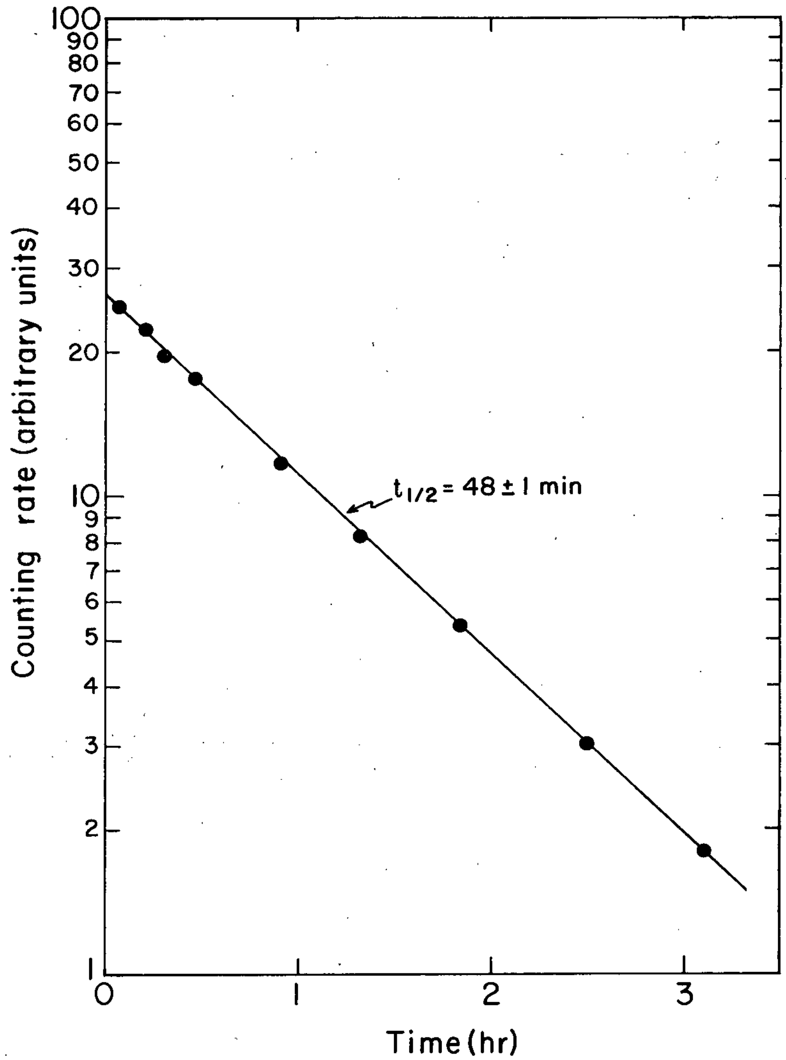

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Fig. 1. Decay of the 210-kev photopeak of Y^{86m}.

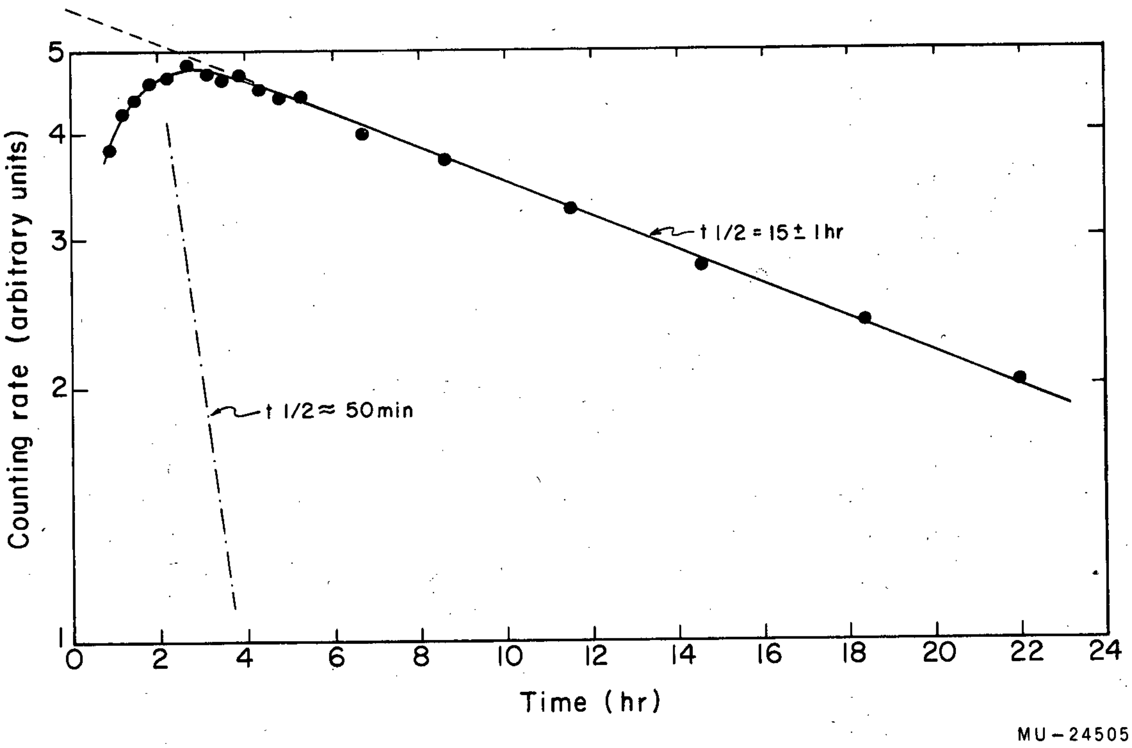

Fig. 2. Growth and decay of the 1.08-Mev photon group of 14.6-hour Y^{86} from a sample containing Y^{86} and Y^{86m}.

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.[7] The experimental value $\epsilon_K = 0.04 \pm 0.01$ 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 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 low-energy 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 ± 0.01 kev (see Table I). This spacing is in good agreement with the characteristic L_{II}-L_{III} energy difference of yttrium, 0.075 kev,[11] and indicates an isomeric transition of energy 10.15 ± 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[9] indicates for M3 radiation the subshell pattern, $L_I/L_{II}/L_{III} = 24/2.6/100$ and for E3 radiation the ratios $L_I/L_{II}/L_{III} = 0.9/49/100$. The experimental observation of only L_{II} and L_{III} conversion, with the ratio $L_{III}/L_{II} = 1.5 \pm 0.5$, 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 Sr^{86} levels appeared in the spectrum until the daughter (14.6-hour Y^{86}) 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[6] 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 ${}_{38}Sr^{85}_{47}$ and proton states in ${}_{39}Y^{85}_{46}$ or ${}_{39}Y^{87}_{48}$. These are shown in Table II.

Table II. Expected configurations of Y^{86}

Proton state (Y^{87})	Neutron 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	+
$g_{9/2}$	$g_{9/2}$	0,1,2....9	+
$g_{9/2}$	7/2+	1,2,3....8	+
$g_{9/2}$	$p_{1/2}$	4,5	

Preliminary results of a study of the decay of ${}_{40}Zr^{86}_{46}$ 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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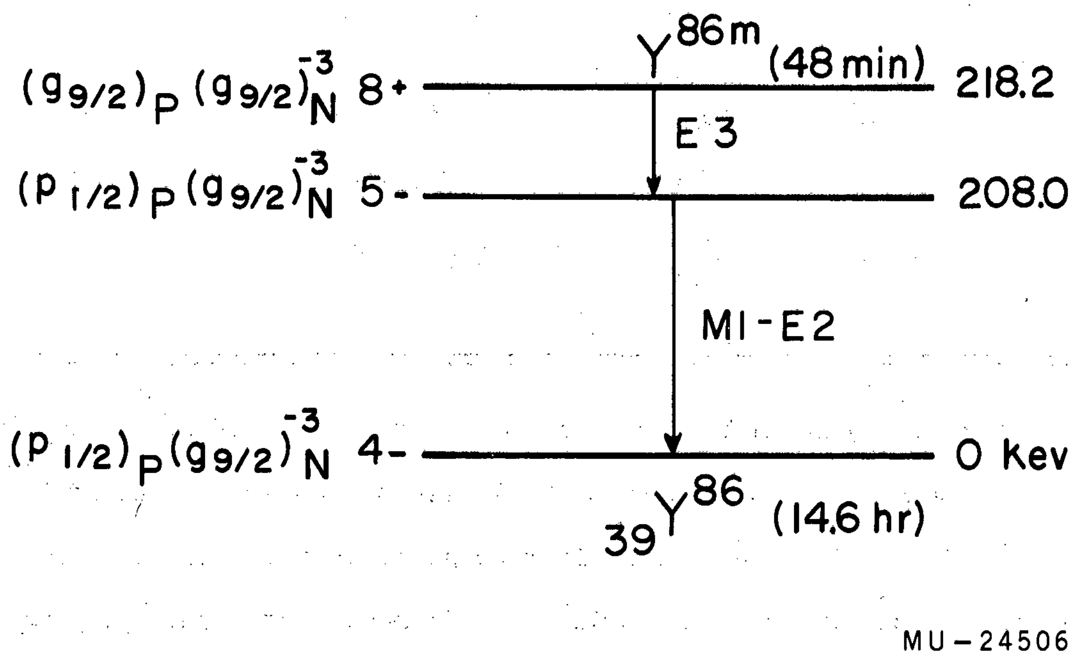

Fig. 3. Suggested level scheme of $Y^{86}m$.

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