Decay of Er^{172} and Tm^{172}†

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Er^{172} has been produced by double neutron capture in enriched Er^{170}. The beta decay of 50.4-hr Er^{172} and its daughter, 63.7-hr Tm^{172}, has been studied with a solenoidal beta spectrometer and beta and gamma scintillation spectrometers. The highest energy group of the Tm^{172} beta spectrum has an end-point energy of 1.83 Mev; this group represents the $Tm^{172} \rightarrow Yb^{172}$ ground-state beta transition. The beta decay of Tm^{172} is accompanied by gamma rays of the following energies: 0.079, 0.180, 0.422, 0.495, 0.915, 1.095, 1.29, 1.39, 1.41, 1.47, 1.51, and 1.59 Mev. A decay scheme for Tm^{172} is proposed with excited states in Yb^{172} at 0.079, 0.259, 1.174, 1.47, 1.55, 1.59, and 1.67 Mev. The beta decay of Er^{172} is accompanied by gamma rays of the following energies: 0.050 (Tm K x ray), 0.108, 0.126, 0.408, and 0.610 Mev, the last of which represents a transition to the Tm^{172} ground state. The beta spectrum measured in coincidence with the 0.610-Mev gamma ray has an end-point energy of ~0.26 Mev, which establishes a decay energy of 0.87 Mev for Er^{172}.

INTRODUCTION

FROM the products of high-energy proton fission of uranium, Folger, Stevenson, and Seaborg[1] isolated a 2- to 3-day thulium activity which they tentatively assigned to Tm^{172} on the basis of its decay properties.

Nethaway, Michel, and Nervick[2] observed a new erbium activity after exposure of normal erbium to an intense neutron flux for several days. By separating the thulium daughter activities with a mass separator, they were able to assign a 63.6 ± 0.3-hr half-life to Tm^{172}. By periodic chemical separation of the Tm^{172} activity from the erbium fraction, they deduced a half-life of 49.8 ± 1 hr for Er^{172}. They found associated with the beta decay of Tm^{172} the following gamma rays: 0.076, 0.18, 0.40, 1.09, 1.44, and 1.78 Mev. From aluminum absorption measurements, the Tm^{172} beta end-point energy was found to be 1.5 Mev.

Recently Helmer and Burson[3] have studied the decay of Tm^{172} with a 180° magnetic spectrometer and by scintillation spectrometry techniques. They reported the existence of 17 gamma-ray transitions and five beta components of the following end-point energies: 1.83, 1.65, ~0.74, ~0.46, and ~0.33 Mev. They proposed a level scheme for Yb^{172} having excited states at 0.079, 0.260, 1.17, ~1.45, ~1.53, ~1.59, ~1.63, and ~1.71 Mev.

Mihelich, Harmatz, and Handley,[4] by measurement of the conversion electron lines associated with the orbital electron capture decay of Lu^{172}, were able to establish that the 181.5- and 78.7-kev gamma transitions are the $4+ \rightarrow 2+$ and $2+ \rightarrow 0+$ transitions in the ground-state rotational band of Yb^{172}. Coulomb excitation of Yb^{172} further confirmed[5] the 2+ rotational level at 78.7 kev.

Wilson and Pool[6] have examined the decay of Lu^{172} by gamma scintillation spectrometry and have established levels above 260 kev in Yb^{172}.

The present study was undertaken to obtain more detailed information on the decay of Tm^{172} and its predecessor Er^{172}.

SOURCE PREPARATION

Er^{172} was produced by double neutron capture in Er^{170}. Samples containing about 30 mg of enriched Er^{170} (87.5%)[7] were irradiated in the Los Alamos Omega West reactor in a thermal neutron flux of about 7×10^{13} cm^{-2} sec^{-1} for periods of 50 to 60 hr.

About four days after the end of irradiation, the erbium was purified of thulium, ytterbium, scandium, and other contaminants by selective elution from a Dowex-50 resin column at 20°C with 0.5 M α-hydroxyisobutyric acid (α-HIB) at pH 3.10. Four days after the purification, when Tm^{172} had grown into near equilibrium with its Er^{172} parent, a thulium-erbium separation was again made.

Tm^{172} sources for beta-ray spectrometer measurements were prepared by destroying the α-HIB in the thulium solution with hot nitric and perchloric acids, evaporating to dryness, taking the activity up in a few drops of 0.1M HCl, and evaporating to dryness small droplets of this solution on a backing of 1.0-mg cm^{-2} aluminized Mylar. Although supposedly "carrier-free," the final source, 3 mm in diameter, contained enough residue to make it an estimated 1 mg cm^{-2} thick. For 4π counting, a small aliquot of this same stock solution was diluted ~100-fold and small droplets of this solution were evaporated to dryness on an ~20-μg cm^{-2} Zapon film. Small droplets of the freshly separated erbium and

† Work done under the auspices of the U. S. Atomic Energy Commission.

[1] R. L. Folger, P. C. Stevenson, and G. T. Seaborg, University of California Radiation Laboratory Report UCRL-1195, revised May, 1951 (unpublished).

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[5] E. L. Chupp, J. W. M. DuMond, F. J. Gordon, R. C. Jopson, and H. Mark, Phys. Rev. **112**, 518 (1958).

[6] R. G. Wilson and M. L. Pool, Phys. Rev. **118**, 1067 (1960).

[7] Enriched Er^{170} was made available by the Isotopes Division of the Oak Ridge National Laboratory.

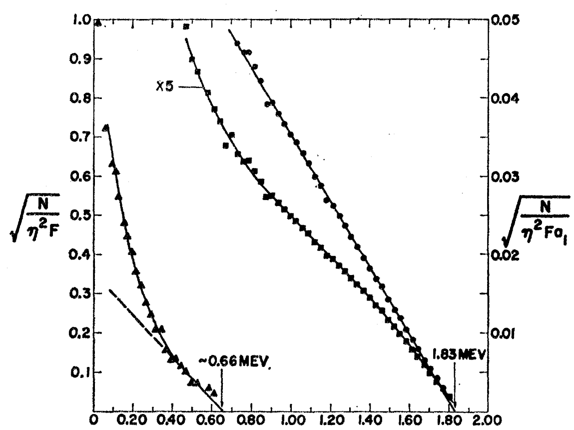

FIG. 1. Fermi-Kurie (F-K) plot of the Tm^{172} beta spectrum. ■ Uncorrected F-K plot (left-hand scale). ● F-K plot corrected by the $\Delta J=2$, yes, shape factor, $a_1=q^2L_0+9L_1$ (right-hand scale). ▲ Points resulting from subtraction of the corrected plot.

TABLE I. Tm^{172} gamma transition data.

Gamma-ray energy (Mev)	Relative photon intensity	Total transitions per 100 betas	Observed in coincidence with the following gamma rays
0.079±0.002	100	44±5	0.180, 0.422, 0.495, 0.915, 1.095, 1.29 1.39, 1.41, 1.51
0.180±0.003	39±5	4.9±1	0.079, 0.422, 0.495, 0.915, 1.29, 1.41
0.422±0.005	3±2	0.3±0.2	0.079, 0.180, 0.915, 1.095
0.495±0.005	5±2	0.4±0.1	0.079, 0.180, 0.915, 1.095
0.915±0.005	21±5	1.9±0.5	0.079, 0.180, 0.422, 0.495
1.095±0.005	78±5	7.1±1.0	0.079, 0.422, 0.495
1.29±0.02	~11	~1	0.079, 0.180
1.39±0.02	94±7	8.7±1.5	0.079
1.41±0.03	<3	<0.3	0.079, 0.180
1.47±0.02	54±5	5.0±0.5	...
1.51±0.02	73±7	6.7±1.5	0.079
1.59±0.02	53±5	4.9±1.1	...

thulium solutions were evaporated to dryness on glazed cardboard plates for the scintillation measurements.

INSTRUMENTATION

The beta-ray spectrum of Tm^{172} was measured with a uniform-field, ring-focusing solenoidal spectrometer patterned after the design of Schmidt.[8] The baffle system was set to give a nominal transmission of 1%; at this setting, a momentum resolution of ~1.2% would be expected for a 3-mm diam source. Decay corrections and Fermi-Kurie analyses of the spectrometer data were performed with an IBM-704 computer.

Beta-ray spectra of Er^{172} and Tm^{172}, in coincidence with gamma rays, were measured with a $\frac{9}{16}$-in. thick $\times 1\frac{5}{8}$-in. diam trans-stilbene scintillator unit.

Gamma spectra were obtained with a 3 in.×3 in. NaI(Tl) scintillator unit. Singles spectra were measured with the source at 10 cm distance in order to minimize summing. Pulse height analysis was accomplished with a fast 100-channel pulse height analyzer (average deadtime ~72 μsec). For gamma-gamma coincidence measurements, a second scintillator unit using a $1\frac{1}{2}$-in.$\times 1\frac{1}{2}$-in. NaI(Tl) crystal was placed at 90° to the axis of the large scintillator. A $\frac{1}{4}$-in. lead (Pb) adsorber was placed between the two crystals to minimize scattering effects. The source was usually mounted ~5 cm from the face of each crystal. The resolving time of the coincidence circuit was $2\tau=4\times10^{-7}$ sec for all coincidence measurements. The absolute beta-disintegration rate of a "carrier-free" Tm^{172} source was determined with a methane-flow 4π β-proportional counter.

THULIUM-172

Experimental Measurements

The decay of a sample of Tm^{172} was followed for about three weeks with a beta-proportional counter and the data were then submitted to least-squares analysis on an IBM-704 computer. The Tm^{172} half-life so obtained was 63.7±0.5 hr, in good agreement with the previously reported 63.6±0.3-hr period.[2]

The Tm^{172} beta spectrum as measured with the magnetic spectrometer and analyzed in the form of a Fermi-Kurie plot is shown in Fig. 1. The high-energy region clearly shows the "α" shape associated with "unique," first-forbidden transitions. Application of the $\Delta J=2$, yes, spectral shape correction factor $a_1=q^2L_0+9L_1$ gave a linear plot with an end-point energy of 1.83±0.03 Mev. The 1.83-Mev end-point energy of the Tm^{172} beta spectrum is in agreement with the measurement by Helmer and Burson.[3] The subsequent beta-gamma coincidence data provided evidence that this high-energy

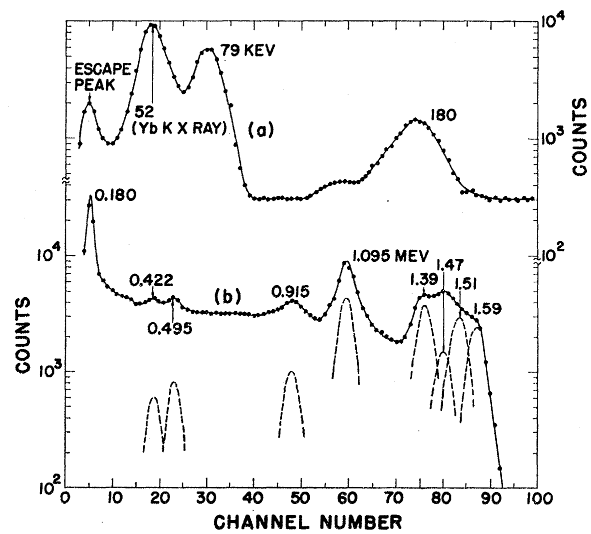

FIG. 2. Gamma-scintillation spectra of Tm^{172}, measured with 3 in.×3 in. NaI(Tl) crystal. (a) Low-energy region; (b) high-energy region.

[8] F. H. Schmidt, Rev. Sci. Instr. 23, 361 (1952).

component was a composite of three beta groups, of which the highest-energy "unique" group was strongest. Subtraction of this composite high-energy component from the gross spectrum gave a complex spectrum with an end point at ~0.66 Mev. Due to the complexity of the high-energy component, little, if any, significance could be attached to a breakdown of the beta spectrum below the ~0.66-Mev group.

The singles gamma-ray spectra of Tm^{172}, shown in Fig. 2, exhibited photopeaks at 0.052 (Yb K x ray), 0.079, 0.180, 0.422, 0.495, 0.915, 1.095, 1.39, 1.47, 1.51, and 1.59 Mev. There is also evidence of a low-intensity gamma ray at about 0.14 Mev. Gamma-ray energies, intensities, and coincidence data are presented in Table I. The number of 0.079-Mev gamma rays per Tm^{172} beta disintegration was determined by comparison with the similar 0.084-Mev gamma rays from a Tm^{170} source whose disintegration rate was also determined by $4\pi\ \beta$ counting. The Tm^{170} branching ratio to the 0.084-Mev level in Yb^{170} was taken to be 22%[9–11] and the conversion coefficients of Rose[12] were used to correct for the difference in conversion coefficients between the 0.079 and 0.084-Mev $E2$ gamma transitions.

The resolution of possible multiplets, and the positions of the corresponding gamma transitions in the Yb^{172} level scheme were investigated by a series of gamma-gamma coincidence measurements.

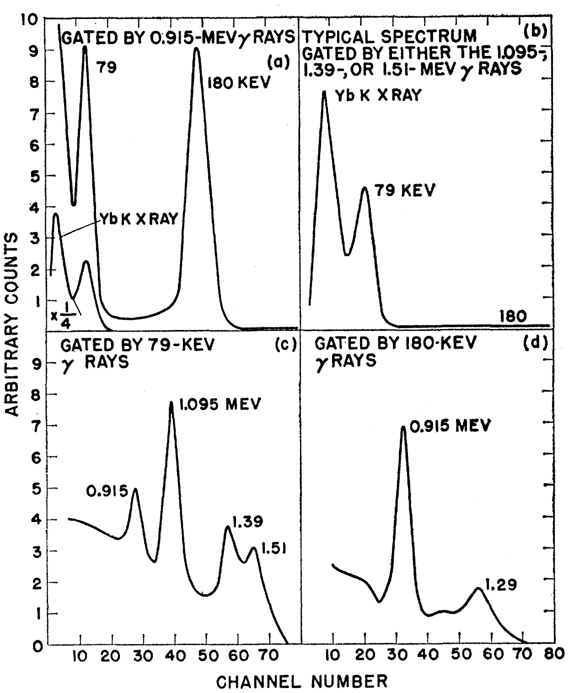

FIG. 3. Gamma-gamma coincidence spectra of Tm^{172}, measured with 3 in.×3 in. NaI(Tl) crystal and gated by photopeak pulses from a $1\frac{1}{2}$ in.×$1\frac{1}{2}$ in. crystal.

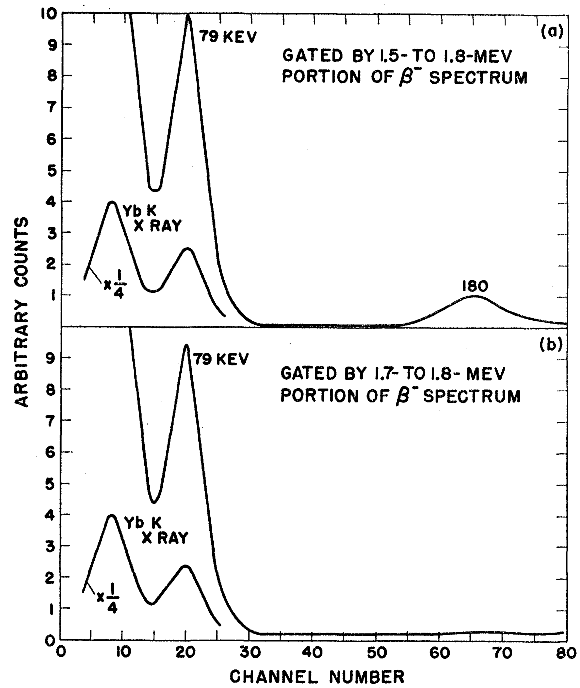

FIG. 4. Low-energy region of the Tm^{172} gamma-ray spectrum in coincidence with the high-energy regions of the beta spectrum, measured with scintillation crystals.

Gamma-Gamma Coincidences

The 79- and 180-kev photopeaks were used to provide gating pulses to establish the transitions populating the first two excited members of the ground-state rotational band. The results are plotted in Figs. 3(c) and 3(d). The spectrum gated by the 79-kev gamma rays [Fig. 3(c)] exhibits peaks at 0.915, 1.095, 1.39, and 1.51 Mev. Comparison of this spectrum with the singles spectrum in Fig. 2(b) discloses the disappearance of the 1.47-Mev peak and most of the 1.59-Mev peak.

The important features of the spectrum gated by 180-kev gamma rays [Fig. 3(d)] are the peaks at 0.915 and 1.29 Mev. The intense 1.095-Mev peak is strongly attenuated and the 1.39-, 1.51-, and 1.59-Mev peaks have completely disappeared, although a broadening of the high-energy side of the 1.29-Mev peak suggests the possible presence of a higher-energy transition.

An examination of the low-energy portion of the gamma spectrum gated by high-energy gamma rays produced the results shown in Figs. 3(a) and 3(b). The spectrum gated by the 0.915-Mev gamma ray [Fig. 3(a)] exhibits a decided increase in the 180-kev peak area over that of the 79-kev peak as observed in the singles spectrum [Fig. 2(a)].

A typical low-energy gamma spectrum gated by either

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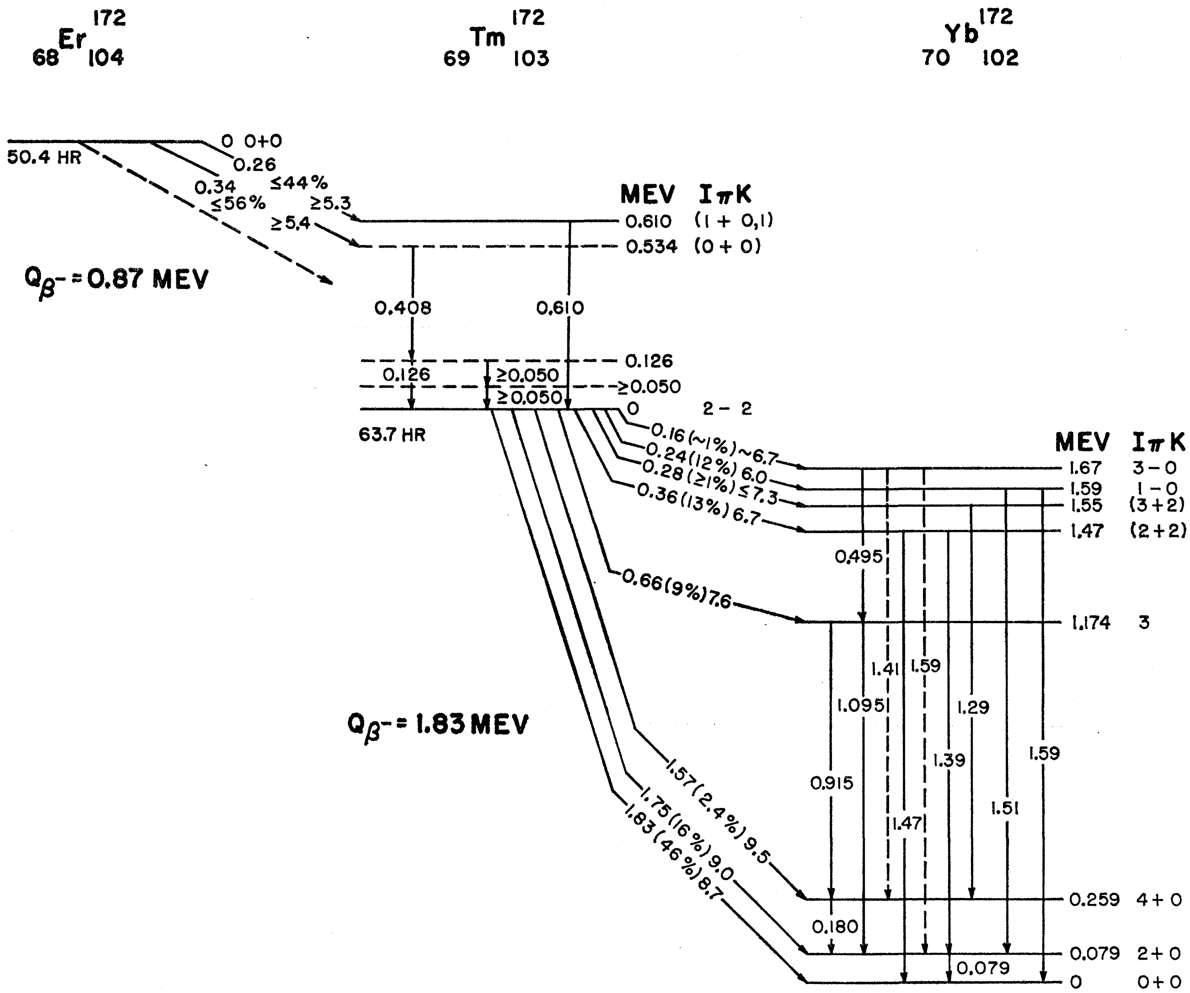

FIG. 5. Decay scheme proposed for Tm^{172} and Er^{172}. Energy levels and gamma transitions based on scanty information are shown dashed.

the 1.095, 1.39, or 1.51-Mev gamma rays is presented in Fig. 3(b). The absence of a 180-kev peak should be noted. Although not shown, the 422- and 495-kev gamma rays were found to be in coincidence with 1.095-Mev gamma rays but not with higher-energy gamma rays.

Beta-Gamma Coincidences

Additional information regarding the direct beta decay to the 2+ and 4+ ground-state rotational levels was obtained by beta-gamma coincidence studies. When the gamma-ray spectrometer is gated by that portion of the beta-spectrum between 1.5 and 1.8 Mev, both the 79- and 180-kev peaks are observed as shown in Fig. 4(a). When the gate pulses include only the beta spectrum region from 1.7 to 1.8 Mev, the 180-kev peak disappears, leaving only the 79-kev peak shown in Fig. 4(b). It is therefore concluded that both the 2+ and 4+ levels are directly populated by beta transitions. The fraction of all beta disintegrations leading directly to the Yb^{172} ground state was determined by comparison of the Tm^{172} disintegration rate (4π β counts) with gamma-ray intensity data. The complexity of the low energy beta spectrum was demonstrated by gating the beta spectrum with the high energy gamma rays. The beta spectrum in coincidence with the 1.095-Mev gamma ray was found to have an end-point energy of 0.66 ± 0.05 Mev, in agreement with the magnetic spectrometer measurements. The beta spectrum in coincidence with the 1.39-Mev region of the gamma spectrum was found to have an end-point energy of $\sim$0.3 Mev while the spectrum gated by the 1.51-, 1.59-Mev composite gamma-ray pulses ended at $\sim$0.2 Mev.

The beta transitions involved in the decay of Tm^{172} and computed on the basis of magnetic spectrometer data, 4π β-proportional counter measurements, beta-gamma coincidence data, and gamma-ray intensity measurements are presented in Table II.

TABLE II. Tm^{172} beta transition data.

End-point energy (Mev)	Intensity (%)	Log ft	Method of determination
1.83 ± 0.03	46 ± 10	8.7	a, b
1.75 ± 0.03	16 ± 5	9.0	b
1.57 ± 0.03	2.4 ± 1	9.5	b
0.66 ± 0.03	9 ± 3	7.6	a, b
0.36 ± 0.03	13 ± 4	6.7	b
0.28 ± 0.03	$\geqq1$	$\leqq7.3$	b
0.24 ± 0.03	12 ± 4	6.0	b
0.16 ± 0.03	~1	~6.7	b

[a] Fermi-Kurie analysis of magnetic spectrometer data.
[b] From beta-gamma coincidence evidence or from analysis of gamma-ray intensity data.

DISCUSSION OF THULIUM-172 RESULTS

A decay scheme for Tm^{172} consistent with the preceding measurements is presented in Fig. 5. The existence of the ground-state rotational levels in Yb^{172} at 0.079(2+) and 0.259(4+) Mev has been previously established by Coulomb excitation[5] and by studies of Lu^{172} electron-capture decay.[4]

Tm^{172} can be assigned a spin of 2 and odd parity on the basis of its beta decay to the first three members of the Yb^{172} ground-state rotational band. The "unique" shape ($\Delta J=2$, yes) observed for the 1.83-Mev ground-state beta transition confirms the 2− spin and parity assignment. This assignment is consistent with the log ft values of the beta groups feeding the 0+(8.7), 2+(9.0), and 4+(9.5) levels of the Yb^{172} ground-state rotational band. The large log ft (9.0) of the first-forbidden beta transition to the Yb^{172} 2+, 0($I\pi$,K) state is consistent with theory if one makes the reasonable assumption of a $K=2$ ground state for Tm^{172}, since the transition violates the K selection rule $\Delta I\geqq\Delta K$.

A 2−, 2 assignment for 63.7-hr Tm^{172} is also consistent with theoretical predictions based on the rules of Gallagher and Moszkowski[13] for coupling of the Nilsson[14] orbitals of the odd proton to the odd neutron in a deformed nucleus such as Tm^{172}. The 69th proton has been designated as being in the Nilsson orbital $\frac{1}{2}+[411]$ in the ground states of Tm^{169} [15–17] and Tm^{171}.[18,19] The $\frac{5}{2}-[512]$ designation has been proposed for the 103rd neutron in the ground states of Er^{171} [19] and Yb^{173}.[15,20,21]

The Yb^{172} level at 1.174 Mev, which has been previously established by the study of Lu^{172} decay[6,22] and Tm^{172} decay[3] can have a spin of 1, 2, or 3, based on the log ft (7.6) of the 0.66-Mev beta group populating it. Of the three choices, a spin of 3 is preferred, since the state de-excites by gamma transition to the 4+ and 2+ levels and not to the ground state. Whether the 1.174-Mev level is an intrinsic state or possibly the second member of a γ-vibrational band with $K=2$ is not known. Assuming the latter possibility, the 2+, 2 intrinsic state should be fed by the decay of Tm^{172} and would be expected to lie at 1.10 Mev, about 79 kev below the 1.174-Mev level. The experimental value for the ratio of the reduced transition probabilities for de-excitation of the 2+, 2 state to the 2+,0 and 0+, 0 levels in a similar nucleus, Er^{168}, was found[22] to be

$$B(E2;2+\rightarrow0+)/B(E2;2+\rightarrow2+)=1.4.$$

If such a 2+, 2 state in Yb^{172} at 1.10 Mev is fed by Tm^{172} decay, the gamma spectrum should show 1.02- and 1.10-Mev gamma rays resulting from de-excitation to the 2+, 0 and 0+, 0 levels, respectively. The degenerate 1.10-Mev gamma ray would be very difficult to distinguish from the 1.095-Mev gamma ray from the 1.174-Mev level; however, a 1.02-Mev gamma peak should be noticed in coincidence-gamma spectra gated by the 79-kev gamma ray. Inspection of Fig. 3(c) reveals the absence of a 1.02-Mev gamma ray, suggesting that a 2+, 2 level is either weakly fed or absent altogether.

Assuming pure quadrupole de-excitation of the 1.174-Mev level to the 2+, 0 and 4+, 0 levels by 1.095- and 0.915-Mev gamma transitions, the experimental ratio of the reduced transition probabilities is

$$B(E2;3\rightarrow2+)/B(E2;3\rightarrow4+)=1.53.$$

The value measured experimentally[22] for this ratio in the study of Lu^{172} decay was 1.2. The difference probably lies in the errors involved in the present measurement of gamma ray intensities.

The level at 1.47 Mev can be assigned a spin of 1 or 2 on the basis of the log ft (6.7) of the beta branch to it and the fact that it de-excites by gamma transitions to 0+, 0 and 2+, 0 levels. This level and the weakly populated level at 1.55 Mev which were also observed by Helmer and Burson[3] possibly form a γ-vibrational band of spins 2 and 3 ($K=2$). If indeed such a band exists in Yb^{170} at 1.23 Mev as postulated by Harmatz, Handley, and Mihelich,[23] this state could be expected at $\sim$1.47 Mev in the more highly deformed Yb^{172} nucleus. Assuming pure quadrupole de-excitation of the 1.47-Mev level to the ground-state band, the experimental ratio of the reduced transition probabilities is

$$B(E2;2+\rightarrow0+)/B(E2;2+\rightarrow2+)\leqq0.44.$$

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[23] B. Harmatz, T. H. Handley, and J. W. Mihelich, Phys. Rev. **119**, 1345 (1960).

TABLE III. Er^{172} gamma transition data.

E_γ (kev)	Photon intensity	Observed in coincidence with the following photons
Tm L x rays	($\geq$1)	50, 108, 408
50±3	~2	L x rays, 408
108±5	~0.06	L x rays, 408
126±5	~0.09	408
408±5	1.00	L x rays, 50, 108, 126
610±5	0.80±0.10	...

The ratio is considered to be an upper limit since part of the 1.47-Mev gamma-ray intensity may result from de-excitation of the 1.55-Mev level to the 2+, 0 state. This ratio for de-excitation of the 1.23-Mev state[23] in Yb^{170} is 0.49. Intense high-energy gamma rays from other levels render it impossible to make a similar comparison with the weakly populated 1.55-Mev level.

The previously established[3] level at 1.59 Mev is assigned a spin and parity of 1− on the basis of the log ft (6.0) of the beta group populating it and the fact that it de-excites by gamma transitions to the 0+, 0 and 2+, 0 levels of the ground-state band. This level could correspond to an octupole-vibrational state with $K=0$ or 1. If $K=0$, the theoretical value[24] for the ratio of the reduced transition probabilities of the gamma-ray transitions to the 0+ and 2+ states is calculated to be:

$$B(E1;\,1- \to 0+)/B(E1;\,1- \to 2+)=0.5.$$

For $K=1$, this ratio is 2. The present experimental measurements give a value of 0.44 for the ratio of the reduced transition probabilities. The level at 1.59 Mev is therefore assigned as 1−, 0.

A 1.67-Mev level is postulated on the basis of the 0.495-Mev gamma ray found in coincidence with the 0.915- and 1.095-Mev gamma rays which de-excite the 1.174-Mev level. Beta feeding, gamma de-excitation and energy spacing above the 1.59-Mev level are all consistent with a 3−, 0 assignment for the 1.67-Mev state. This assignment is also consistent with an earlier one made by Wilson and Pool.[6]

The weak 0.422- and possible 0.14-Mev gamma rays have been omitted from the decay scheme, since their position cannot be reliably established. Weak 1.41- and 1.59-Mev gamma transitions from the 1.67-Mev level based upon scanty information are shown dashed in Fig. 5.

ERBIUM-172

Experimental Measurements

The singles gamma-ray spectrum of Er^{172} shown in Fig. 6 contains prominent peaks at 50, 408, and 610 kev. The 50-kev peak is probably mostly, if not all, due to thulium K x rays.

[24] G. Alaga, K. Alder, A. Bohr, and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **29**, No. 9 (1955).

The decay of the 610-kev photopeak was followed for two weeks and gave an Er^{172} half-life of 50.4±1.0 hr, in good agreement with the previously reported[2] 49.8±1-hr period.

Although not resolved in singles gamma spectra, weak 108- and 126-kev gamma rays are apparent in the coincidence spectra. The presence of intense L x rays was observed with a thin-beryllium window scintillator unit. Gamma-ray data for Er^{172} are presented in Table III.

Coincidence measurements show that the 610-kev gamma ray is not in coincidence with other Er^{172} gamma or x rays. Coincidence gamma spectra gated by L x rays show peaks at 50, 108, and 408 kev [Figs. 7(a) and 7(b)]. Figure 7(c) shows that the 50-kev peak is in coincidence with itself. Figure 7(d) shows that the intense 50-kev and weaker 108- and 126-kev peaks are in coincidence with the 408-kev gamma ray.

Information concerning the Er^{172} beta groups populating levels in Tm^{172} was obtained by a series of beta-gamma coincidence measurements. The intense 0.33-Mev beta group from the Er^{169} present precluded any attempt at direct measurement of the beta spectrum or conversion electron lines associated with Er^{172} decay. Coincidence beta spectra gated by the 0.610-Mev gamma rays yielded a 0.26±0.05-Mev end-point energy, while beta spectra gated by the 0.408-Mev gamma rays gave ~0.34-Mev end-point energy. The existence of beta rays of higher energy than 0.34 Mev was not firmly established; however, such groups of moderate or low intensity cannot be ruled out by the present measurements.

DISCUSSION OF Er^{172} RESULTS

A partial decay scheme for Er^{172} is presented in Fig. 5 on the basis of the above measurements. Due to the absence of conversion electron data and to the complexity of the level structure of odd-odd nuclei, little can be stated with certainty; therefore the scheme is presented chiefly as a guide for future studies.

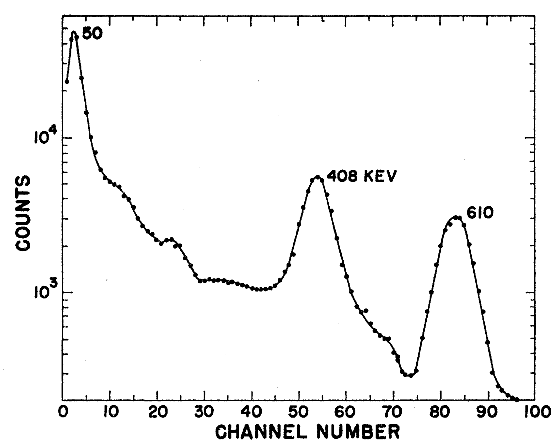

FIG. 6. Gamma-scintillation spectrum of Er^{172}, measured with 3 in.×3 in. NaI(Tl) crystal.

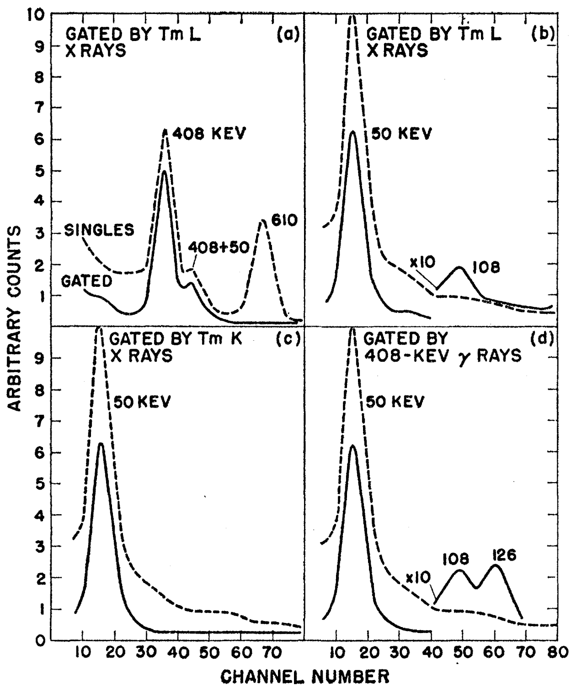

FIG. 7. Typical gamma-gamma coincidence spectra of Er^{172}. Singles spectra (dashed curves) are presented for comparison.

The 0.610-Mev gamma ray which was shown to represent a ground-state gamma transition from a Tm^{172} excited state at 0.610-Mev, plus the ~0.26-Mev beta group feeding this level, establish an Er^{172} decay energy of 0.87±0.05 Mev.

The 2−, 2 Tm^{172} ground-state assignment was discussed earlier. A Tm^{172} excited state is proposed at 0.534 Mev since the 0.408-Mev gamma ray is in coincidence with a 0.126-Mev gamma ray and a beta group of ~0.34-Mev end-point energy. Although not shown in the decay scheme, the 0.108-Mev gamma transition probably lies below the 0.126-Mev level. Since the relative intensity data in Table III indicate that the Tm K and L x rays are too intense to be accounted for entirely by the gamma cascade from the proposed 0.534-Mev level, direct beta feeding of one or more of the lower Tm^{172} levels is indicated; the existence of such beta branching is shown as a dashed line in the scheme.

The 0.610-Mev level and the proposed level at 0.534 Mev can be assigned a spin of 0 or 1 with even parity on the basis of the log ft values of the beta groups populating them. Even allowing for considerable beta feeding of the lower levels the log ft values of the beta branches to the 0.610- and 0.534-Mev states would still be <6. A 1+, $K=0$, 1 assignment is proposed for the 0.610-Mev level since it de-excites directly to the 2− ground state A 0+, 0 assignment is suggested for the 0.534-Mev level since it does not de-excite to the 2− ground state; instead, the 0.534-Mev level is considered to de-excite to the proposed 0.126-Mev level. A possible excited state shown dashed at ≧0.050 Mev is suggested on the basis of the gamma-gamma coincidence measurements. This level is designated at ≧0.050 Mev since it is not known if it de-excites by a 0.050-Mev gamma transition or by a highly converted gamma transition whose energy slightly exceeds that of the Tm K electron binding energy (59.4 kev).

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