Eu^{149} Decay*

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The electron capture decay of Eu^{149} to Sm^{149} has been studied using scintillation and proportional counters. A decay scheme is given which is consistent with the measured coincidence data. The half-life of the Eu^{149} decay was measured to be 106±2 days.

INTRODUCTION

The decay of Eu^{149} to Sm^{149} has been studied with magnetic spectrographs.[1,2] A half-life of about 120 days has been assigned[1,3] to the electron capture decay. The disintegration energy has been estimated[4] from beta-decay systematics to be about 800 kev.

In the present work, scintillation counters and gas proportional counters have been used to investigate the Eu^{149} decay. Half-life measurements on the prominent gamma-rays and Sm x-ray coincidences have been used to establish the isotope, which is present in composite sources with various other activities. The energies of gamma-rays found in singles and coincidence experiments are in agreement with more accurate results using magnetic spectrographs.[1,2] Results of the coincidence data indicate a decay scheme in general agreement with that proposed by Harmatz, Handley, and Mihelich[2] on the basis of their conversion electron data. However, coincidences between the 277 and 255-kev gamma-rays and a gamma-ray of about 280-kev indicates the presence of a transition not seen in singles spectra.

EXPERIMENTAL PROCEDURE

Equipment

A fast-slow coincidence spectrometer with a resolving time of one microsecond to ten nsec was used. Figure 1 shows a block diagram of the equipment. The fast circuit is essentially of the Bell and Petch[5] type. The scintillation detectors were of the integral line type. By the use of a number of broad-band amplifiers the 10-stage photomultipliers could be operated at conservative voltages. Typical resolution for the three-inch and the two-inch NaI crystals was 8% for Cs^{137}. A 400-

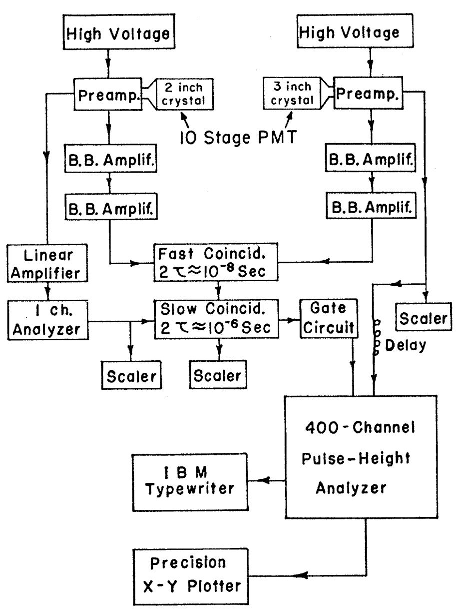

Fig. 1. Coincidence spectrometer.

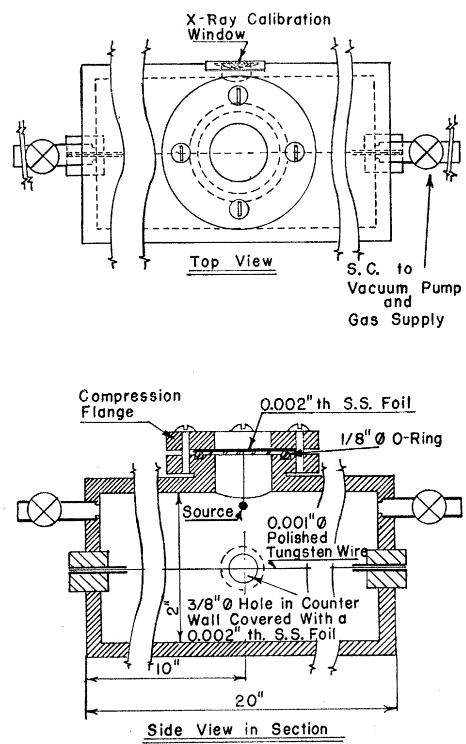

Fig. 2. High-pressure proportional counter.

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[1] N. M. Antoneva *et al.*, Izvest. Akad. Nauk. SSSR Ser. Fiz. **23**, 204 (1959) Feb.
[2] B. Harmatz, T. H. Handley, and J. W. Mihelich (to be published).
[3] R. C. Mack, J. J. Neuer, and M. L. Pool, Phys. Rev. **91**, 497A (1953).
[4] K. Way *et al.*, *Nuclear Data Sheets* (National Academy of Sciences-National Research Council, Washington, D. C.).
[5] S. Flügge, *Handbuch der Physik* (Springer-Verlag, Berlin, 1955), Vol. 45, p. 236.

channel analyzer was used for pulse-height analysis, ungated for singles spectra and gated for coincidences.

Figure 2 shows the proportional counter used to study the low-energy portion of the Eu^{149} gamma-ray spectrum. The counter was designed to operate at pressures up to 100-psi gage pressure and had an L/D of about 10 to 1 to reduce wall and end effects. A flanged opening was provided to permit insertion of sources directly into the sensitive volume of the counter. A commercially available mixture of argon and methane, 90%–10%, was used for the filling. At low energies the proportional counter had a resolution, 13% for 39-kev x-rays, and a peak to valley ratio which were considerably better than any of the available NaI detectors. The photons from a highly converted 22.5-kev transition in Eu^{149} were clearly resolved in the gas counter but could not be seen with a scintillation counter.

A four-inch long by three-quarter inch diameter lead collimator was employed for gamma-ray singles spectrum measurement. Precision positioning of the source was utilized for the half-life measurements.

Coincidence experiments were performed at 90° and 180° geometry. By using graded anticompton shields, coincidences resulting from compton scattering were greatly reduced.

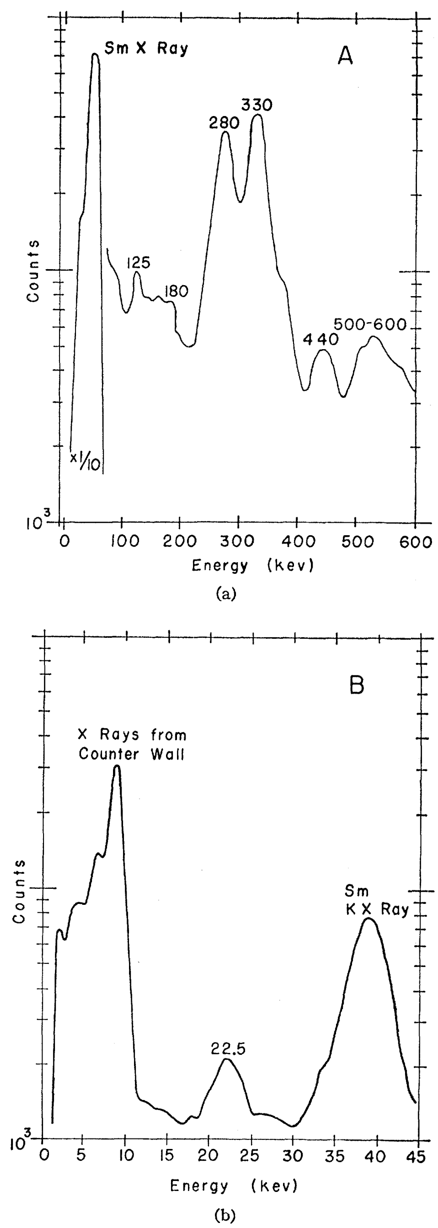


FIG. 3. Singles spectra of Eu^{149}. Curve A shows spectrum using a 3×3 in. NaI crystal. Curve B shows spectrum obtained with high-pressure proportional counter.

Sources

Sm^{150} and Sm^{149} targets composed of about 50 mg of the isotope were bombarded in the proton beam of the 86-in. ORNL cyclotron. The $Sm^{150}(p,2n)Eu^{149}$ reaction was carried out with an 80% enrichment of Sm^{150} at a proton energy of 20.8 Mev and a $Sm^{149}(p,n)Eu^{149}$ bombardment was made on 88% enriched Sm^{149} with protons of about 12 Mev. In both cases an integrated beam current of 170 μamp hours yielded sources with activities in the order of $\frac{1}{10}$ mC after allowing the short half-lived activities to die away for a few weeks. The main contaminant in these sources was Eu^{148} with a 55-day half-life. Other contaminants which caused difficulty were Eu^{147}, Sm^{151}, Eu^{152}, and Eu^{154}, which could be expected in the above irradiation due to proton-, neutron-, and gamma-ray-induced reactions.

The active source material was placed in thin plastic tubes or was cast into epoxy which was machined to fit a precision source holder for half-life determinations.

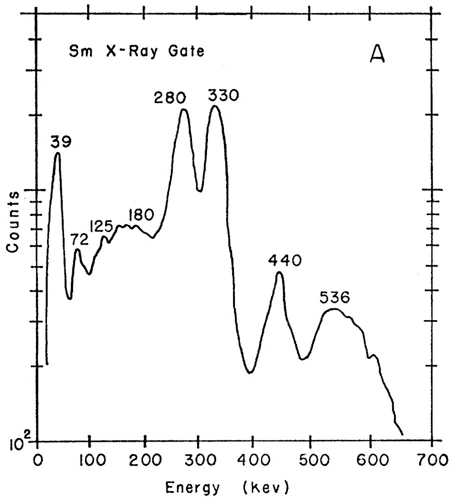
EXPERIMENTAL RESULTS

Figure 3, curve A, shows a singles spectrum of a Eu^{149} sample obtained with a three by three inch NaI crystal. Gamma-ray lines are seen at 125, 180, 280, 330, and 440

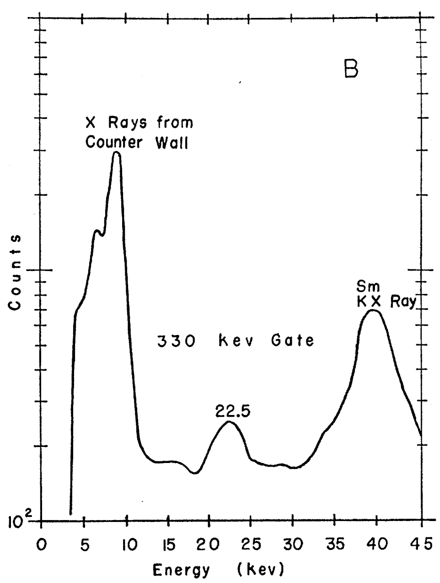
TABLE I. Relative numbers of gamma-rays (N_γ) and conversion electrons (N_{ce}) in the activity of Eu^{149} for gamma-ray energies (E_γ) expressed in kev.

Harmatz et al.[a]			Antoneva et al.[b]		Present work	
E_γ	N_γ	N_{ce}	E_γ	N_{ce}	E_γ	N_γ
22.5		3410			22.8±0.25	
72.95		>10			72 ±2.3	[c]
178.4	<30	2.3			178 ±2.5	[c]
207.9		0.3			208.5±3.5	[c]
254.7		25.7	256±1	20±2	255 ±2	~0.5
277.2	1145	113	279±1	100	276.3±4.5	51
327.7	1135	79.7	330±1	80±8	327 ±4.9	56
350.2	<90	4.1				
506.1		2.5				
528.7		1.6			500–570	
536.0		0.2				
558.3		0.24				

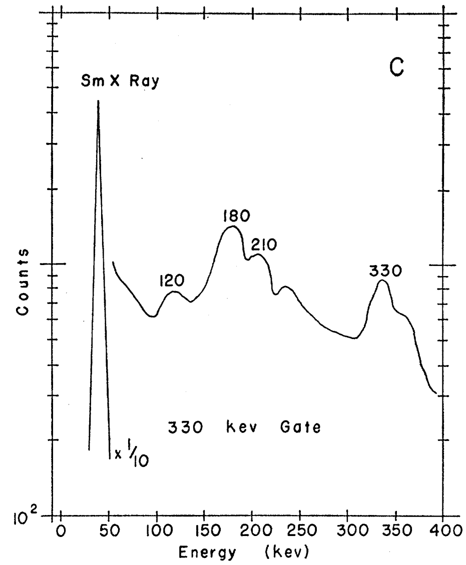
[a] See reference 2.
[b] See reference 1.
[c] Observed in coincidence spectrum only.



(a)



(b)



(c)

FIG. 4. Typical coincidence spectra. Part A, a spectrum of a NaI crystal gated by Sm x-ray counts. Part B, a proportional counter spectrum gated with 330-kev gamma-rays in a NaI crystal. Part C, a 3-in. NaI crystal spectrum gated by 330-kev gamma-rays in another NaI crystal.

kev; and multiple gamma rays in the interval from about 500 to 600 kev. All of these, except the 125- and 440-kev gammas, are in Eu^{149}. The four[2] gamma rays of Eu^{149} at 506, 529, 536, and 558 kev were not resolved in the NaI spectrometer. In addition, a strong transition in Eu^{148} at 550 kev helped to mask the separate peaks.

TABLE II. Gamma-gamma coincidences attributed to Eu^{149}. Designations are gamma-ray energies in kev.

	Position of 1-channel analyzer gate									
	K x-ray	22.5	73	178	208	255	277	328	350	500–
K x-ray	yes	yes	?			yes	yes	yes		yes
22.5	yes					yes	no	yes		yes
73							yes	[illegible]		
178	yes	yes					[illegible]	yes		
208		yes					[illegible]	yes		
255	yes	yes					yes			
277	yes	no	?				yes	no		
328	yes	yes		yes	?		no			
350										
500–570	yes	?								

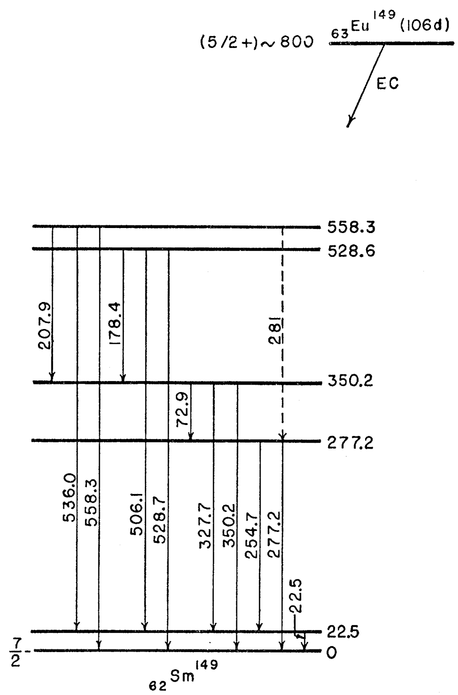


FIG. 5. Proposed decay scheme for Eu^{149}. (Energies in kev.)

The 125- and 440-kev gamma rays are probably due to the impurity activity of Eu^{152}. Gamma-gamma coincidence data have verified the existence of additional peaks at 73, 210, and 255 kev. The proportional counter spectrum of Eu^{149} is shown in Fig. 3, curve B. In addition to the Sm x ray and lower energy x rays from the counter walls, a 22.5-kev gamma ray is found in the Eu^{149} spectrum.

Half-life measurements on the 280- and 330-kev peaks were carried out for a period of about three half-lives and gave a result of 106 ± 2 days for the Eu^{149} decay.

All of the reported radiations emitted from Eu^{149} are listed in Table I. Column 7 lists our measurements of the relative intensity of the observed gamma rays with corrections for crystal efficiency. Columns 3 and 5 list the relative numbers of conversion electrons in references 1 and 2, and column 2 the photon intensities as reported in reference 2.

Gamma-gamma coincidence measurements were made by gating on every gamma ray listed in Table I. Two NaI crystals were used for most of the measurements, except those involving the 22.5-kev transition. For this low-energy gamma ray the high-pressure proportional counter was used in coincidence with a NaI crystal. Resolving times of one microsecond to ten nanoseconds were employed. The proportional counter was used exclusively with the slow coincidence circuit. Typical coincidence spectra are shown in Fig. 4. Curve A shows the gamma-rays in coincidence with the Sm x-ray. Curve B shows the proportional counter spectrum when gated by 330-kev gamma-rays, and curve C the higher energy gamma-ray spectrum in a NaI crystal gated by 330-kev gamma-rays. Curve C, in addition to coincidence peaks at the position of the Sm x-ray, 180 and 210 kev, shows peaks at 120, 230, and 330 kev. The 180- and 210-kev peaks, as well as the x-ray peaks, were shown to be in coincidence with the 330-kev gate by a comparison of the area under the peak in the coincidence spectrum with the singles count rate as the one-channel analyzer gate was moved through the 330-kev peak. The area under the coincidence peaks at 120, 230, and 330 kev did not vary in direct proportion to the count rate in the one-channel analyzer and were therefore caused by coincidences with the Compton tails of higher energy gamma-rays.

Table II gives a tabulation of the coincidence information obtained for Eu^{149}. Clear coincidences are indicated with a "yes," doubtful ones with a "?," and a "no" if the coincidence was searched for but could not be found.

Figure 5 shows an energy level scheme for Eu^{149} which is consistent with the experimental results of this investigation. A similar level scheme has been proposed by Harmatz, Handley, and Mihelich[2] on the basis of their conversion electron data. The 281-kev gamma-ray originating at the 558.3-kev level and terminating at the 277.2-kev level is based upon coincidence results only. A separate 281-kev gamma-ray has not been reported in the conversion electron (references 1, 2) but could have been masked by the relatively intense conversion electron peak at 277.2 kev.

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