Radioactive Isomers of Sn^{117} and Sn^{119}

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The 14-day Sn^{117m} activity has been found to consist of two transitions: 159 kev of multipole order 5, and 162 kev of multipole order 2.

An activity ~250-day half-life has been assigned to Sn^{119m} and a transition of 69 kev, multipole order 5, has been observed.

I. INTRODUCTION

BECAUSE of the large number of stable tin isotopes, and their low neutron capture cross sections, the activities from radioactive tin isotopes cannot be determined readily. Reference to the table of Seaborg and Perlman[1] shows only two tin activities of class A assignment, namely, 100-day $(K, e^-, \gamma)Sn^{113}$ and 28-hour $(\beta^-)Sn^{121}$. In a survey using separated isotopes, Lee and Pool[2] identified the following activities: 28-hour (β^-)-Sn^{121}, 40 min. $(\beta^-, \gamma)Sn^{123}$, 130-day $(\beta^-)Sn^{123}$, 10 min. $(\beta^-)Sn^{125}$, and 10 day $(\beta^-)Sn^{125}$. Duffield and Langer[3] who also used separated isotopes have investigated further the 40-min. $(\beta^-, \gamma)Sn^{123}$ and 10-min. $(\beta^-, \gamma)Sn^{125}$ activities. The present paper is concerned with the activities of Sn^{117m} and Sn^{119m} produced from Sn^{116} and Sn^{118} by neutron capture.

II. EXPERIMENTAL DATA

Four tin samples, enriched in Sn^{116}, Sn^{118}, Sn^{120}, and Sn^{122} were bombarded in the Oak Ridge pile for a period of one month. The compositions of the sources before bombardment are given in Table I. Following bombardment the activities were investigated principally by photographic and counter spectrometers.

Sn^{117m}

An isomeric activity of $14\pm\frac{1}{4}$ day has been assigned[4] to Sn^{117m}. This activity was previously[1] attributed to Sn^{119m}. Aluminum absorption showed the presence of a nearly monochromatic group of electrons of approximately 130 kev. An exposure in a spectrograph showed electron conversion lines corresponding to two γ-ray transitions of 159 ± 1 and 162 ± 1 kev. Table II shows the energies and relative intensities of these lines. Intensities of the lines were determined photometrically and over a period of one month it was found that all lines had the same decay rates to within about 10 percent.

The higher relative intensities of the 159 kev transition lines, together with their lower N_K/N_L ratio, indicate that this transition is of higher multipole order than the 162-kev transition, and is most likely associated with the 14-day decay of the Sn^{117m} isomer. An analysis of the experimental and theoretical values is given in Table III. The experimental N_K/N_L value for the 159 kev transition lies between the available theoretical values for 2^4 magnetic and 2^5 electric transitions.

Assuming that the 159-kev transition is followed only by the 162-kev transition, and also that the 159-kev transition is practically 100 percent internally converted, we can obtain immediately the K-conversion coefficient of the 162-kev transition. The experimental value of N_K/N_γ indicates that this transition is 2^1 magnetic.

Experiments by R. Stump, of this laboratory, have shown the existence of $e^- - \gamma$(~160 kev) and $X - \gamma$-(~160 kev) coincidences which confirm the double transition process assumed above. An upper limit of

TABLE I. Composition of tin sources.[a]

Stable isotope	"116" sample	"118" sample	"120" sample	"122" sample
112	<0.1%	0.2%	1.1%	<0.2%
114	<0.1	<0.1	0.2	<0.2
115	<0.1	<0.1	<0.1	<0.2
116	74.5	1.1	0.4	6.3
117	8.0	2.0	1.1	5.0
118	3.0	91.8	0.8	10.5
119	7.4	2.2	1.3	6.2
120	2.9	2.2	95.4	19.2
122	3.7	0.3	0.2	45.8
124	0.4	0.3	0.3	7.1

[a] The enriched isotopes used in this investigation were supplied by the Isotopes Division, Carbide and Carbon Chemical Corp., Y-12 Plant, Oak Ridge, Tennessee, and obtained on allocation from the U.S. Atomic Energy Commission.

TABLE II. Conversion electron lines of Sn^{117m}.

Energy (kev)	Relative Intensity	Assignment
130 ± 1	60	159—K
133 ± 1	10	162—K
155 ± 1	27	159—L
158 ± 1	4	162—L 159—M

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[1] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).

[2] J. C. Lee and M. L. Pool, Phys. Rev. **76**, 606 (1949).

[3] R. B. Duffield and L. M. Langer, Phys. Rev. **76**, 1272 (1949); **77**, 743 (1950).

[4] E. C. Mallary and M. L. Pool, Phys. Rev. **77**, 743 (1950); **77**, 75 (1950); J. W. Mihelich and R. D. Hill, Phys. Rev. **77**, 743 (1950).

TABLE III. Comparison of experimental and theoretical results.

Isomer	γ-energy (kev)	Lifetime Experiment (sec.)	Lifetime Theoretical[a] (sec.)	N_K/N_L Experiment	N_K/N_L Theoretical		N_K/N_γ Experiment	N_K/N_γ Theoretical	
Sn^{117m}	159±1	1.3×10^6	1×10^4 ($l=4$)	2.2±0.4	4.1	2^4 mag.[b]		25.8	2^4 mag.[d]
			8×10^6 ($l=5$)		0.7	2^5 elec.[c]		23.3	2^5 elec.[d]
	162±1		4×10^{-9} ($l=2$)		11.8	2^1 mag.[b]	0.10±0.03	0.13	2^1 mag.[d]
					6.5	2^2 elec.[c]		0.04	2^1 elec.[d]
								0.23	2^2 elec.[d]
Sn^{119m}	69±2	2.2×10^7	9.0×10^8 2^4 mag.	1.5±0.5	1.5	2^4 mag.[b]		2600	2^4 mag.[e]
			5.7×10^7 2^5 elec.		0.015	2^5 elec.[c]		1200	2^5 elec.[e]

[a] Theoretical lifetimes derived from the formula: $\tau_\gamma = 3(l!)^2/\rho^{2l}\cdot(137/W)^{2l+1}\cdot(h/mc^2)$, for $\begin{cases}2^l \text{ elec.}\\ 2^{l-1} \text{ mag.}\end{cases}$, and the above tabulated values are equal to: $\tau_\gamma/(1+N_e/N_\gamma)$.
[b] Obtained from N. Tralli and I. S. Lowen, Phys. Rev. **76**, 1541 (1949). Curves apply to $Z=35$.
[c] Calculated from M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).
[d] Obtained from M. E. Rose and others, "Tables of K-Shell Conversion Coefficients," Phys. Rev. **76**, 1883 (1949).
[e] Calculated from S. D. Drell, Phys. Rev. **75**, 132 (1949) and M. H. Hebb and E. Nelson, reference c.

10^{-6} sec. was tentatively set for the lifetime of the intermediate state.

The proposed decay scheme for Sn^{117m} is shown in Fig. 1.

Sn^{119m}

A new activity of approximately 250-day half-life has been ascribed to Sn^{119m}. This activity has now been followed for more than 9 months and its decay curve thus far is shown in Fig. 2. The activity appears to be produced only weakly by neutron bombardment in the pile. The decomposition of the decay curve is complicated by the presence of other possible long-lived contaminants, such as: 104-day Sn^{113}, 130-day Sn^{123} and $2\frac{1}{2}$-year Sb^{125}. However, by comparison of this decay curve with similar ones from samples "116," "120," and "122" tin, it is apparent that there is in the "118" sample a unique long-lived component ascribable to Sn^{119m}.

A long exposure in a spectrograph showed the presence of three very faint conversion lines which had energies corresponding to the K, L, and M conversions of a 69±2-kev transition. A search was then made in a counter spectrometer and the existence of these lines was confirmed, as is shown in Fig. 3.

Owing to the low energy and low intensity of the conversion lines, an accurate value of N_K/N_L for this

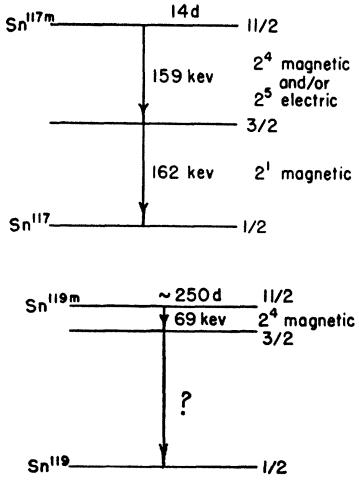

FIG. 1. Decay schemes for Sn^{117m} and Sn^{119m}.

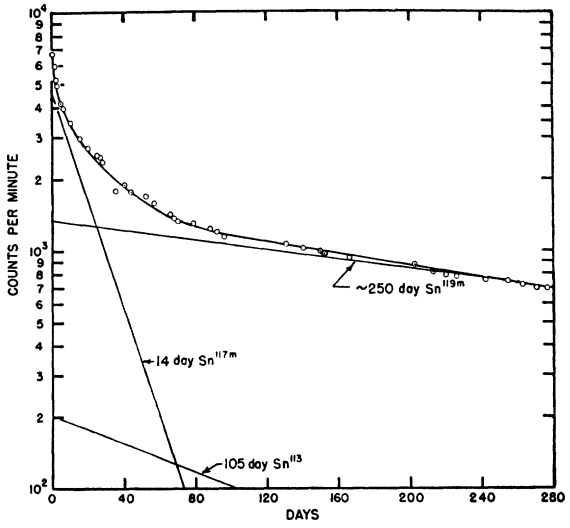

FIG. 2. Decay curves of Sn^{119m}.

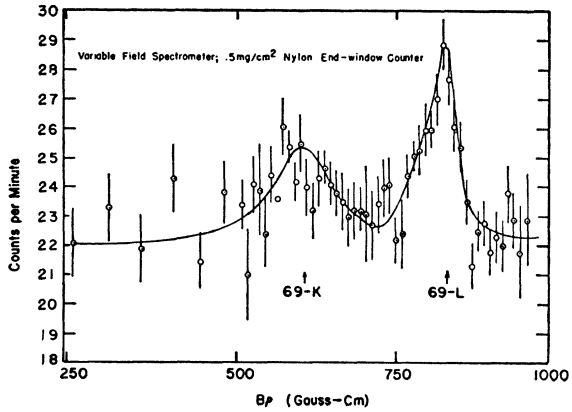

FIG. 3. Electron conversion lines from Sn^{119m}.

transition was difficult to obtain. After correcting for the ρ-values of the lines[5] and for absorption in the 0.5 mg/cm^2 Nylon window of the counter,[6] a value of $N_K/N_L=1.5\pm0.5$ was obtained. Comparison of this value with theoretical values is made in Table III. It would appear that the lifetime of the Sn^{119m} isomer is consistent only with a multipole order of 5 and the N_K/N_L ratio indicates predominantly magnetic 2^4-pole radiation.

The spin of the ground state of Sn^{119} has been measured[7] and observed to be $\frac{1}{2}$. If, as is indicated from current nuclear shell-structure theory, the angular momentum of the upper excited state of Sn^{119m} is 11/2, and if it is correct that the 69-kev transition is magnetic 2^4-pole, then the ground state of Sn^{119} can only be reached via a second transition, as in the case of Sn^{117m} decay. It is unlikely that the second transition would have been observed in our experiments because of its probable low internal conversion and the weakness of the source. The proposed decay scheme for Sn^{119m} is shown in Fig. 1.

[5] J. L. Lawson and A. W. Tyler, Rev. Sci. Inst. **11**, 17 (1940).
[6] D. Saxon, privately distributed absorption curves.
[7] W. G. Proctor, Phys. Rev. **76**, 684 (1949); H. Schüler and H. Westmeyer, Naturwiss. **21**, 660 (1933).

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Radioactive Isotopes of Gadolinium*

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A 236-day neutron induced activity in gadolinium purified by ion exchange methods is assigned to Gd^{153}. The activity decays by K-electron capture emitting a 106-kev γ-ray giving rise to K- and L-electron groups. A 7.2±0.2 day and approximately 24-hour activity present in the neutron bombarded gadolinium were separated on an ion exchange column. The 7.2-day activity assigned to Tb^{161} decays by emission of 0.50-Mev β-particles. The 24-hour activity is tentatively assigned to Gd^{159}.

Half-life measurements on gadolinium produced by deuteron bombardment of europium extend over 600 days. The activity decaying with a half-life of 155 days initially is slowly lengthening into a longer half-life. A 265-kev γ-ray is detected in addition to the 106-kev γ-ray previously found in Gd^{153}. The 265-kev γ-ray is assigned to Gd^{151} which decays with a half-life of 150 days. This half-life is based on ratios of the 106-kev γ-ray to the 265-kev γ-ray observed over a 600-day period.

THE gadolinium activities produced by deuteron bombardment of europium and neutron bombardment of gadolinium are discussed in this paper.

The gadolinium oxide was loaned for this investigation by the rare earth group under Dr. F. H. Spedding. Spectrographic analysis indicated the presence of samarium (0.28 percent) and possibly terbium, but the amount of this contaminant could not be estimated. Samples of the gadolinium oxide were irradiated at two different times at the Argonne Laboratory. The first bombardment of 400 hours did not give a sufficiently intense sample of the long-lived gadolinium, so a second bombardment lasting 854 hours was obtained.

In order to eliminate possible europium and samarium activities produced by (n, p) and (n, α) reactions, the active sample was extracted several times with sodium amalgam. The small amount of activity extracted into the amalgam had the same energy characteristics as did the non-extracted portions. It appeared safe to say that no europium or samarium activities were present in the long-lived gadolinium.

Cation exchange experiments with Nalcite high capacity resin separated the rare earth contaminants that could not be separated by reduction methods. The irradiated gadolinium was adsorbed on a resin bed 1 cm I.D. and 20 cm long. The mesh size of the resin varied in different experiments. Generally the resin was put in the ammonium cycle and the activity eluted with 0.1 percent ammonium citrate solution. The separation of activities effected in such an experiment is indicated in Fig. 1. The counts/min./ml in the fractions of eluate were determined with a dipping counter tube and scaling circuit. The contaminants were identified by half-life and energy measurements with the Yb^{169} activity identification aided by electron coincidence measurements.

Half-life measurements on the neutron bombarded gadolinum now extend over 550 days. Measurements through 225 mg/cm^2 of aluminum give 236±3 days as the half-life value (see Fig. 2). No positrons could be detected by magnetic deflection experiments. The x-ray present was identified as the Eu K x-ray by critical

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