Disintegration of Sn^{113}†

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A re-investigation of the decay of 119-day Sn^{113} was carried out with scintillation spectrometers, as well as with lithium-drifted silicon and germanium detectors. In addition to x rays, two γ rays of 0.2555 ± 0.0005 and 0.3910 ± 0.0005 MeV were found of relative intensity $(2.9\pm0.3)\times10^{-2}$. The K-conversion coefficient of the 0.2555-MeV transition was measured to be 0.040 ± 0.006 and that of the 0.3910-MeV transition, 0.49 ± 0.04 $[K/(L+M)=4.2\pm0.4]$. The electron-capture ratio $P_{EC}(L+M+\cdots)/P_{EC}(K)$ to the 0.6465-MeV level of In^{113} was determined to be 0.33 ± 0.14. The bremsstrahlung endpoint energy to the same level was (0.080 ± 0.005 MeV). From these values, the decay energy transitions to that level were deduced to be 0.050–0.110 MeV and (0.110 ± 0.005) MeV, respectively. A decay scheme is constructed.

I. INTRODUCTION

The different parameters characterizing the decay of Sn^{113} have been measured by many authors, leaving at the present time a few inconsistencies in some of the reported values. The main discrepancy results from the values of the decay energies derived from the $P_{EC}(L+M+\cdots)/P_{EC}(K)$ capture ratios. This is one reason why an additional method for determining the decay energy, such as the measurement of the bremsstrahlung spectrum, has been used in the present work. In addition, a systematic series of measurements of different parameters has been undertaken, using conventional scintillation spectrometers as well as lithium-drifted silicon- and germanium-semiconductor counters. As a result of these measurements, a disintegration scheme for Sn^{113} is proposed.

II. MEASUREMENTS

The radioactive source of Sn^{113} was produced by ORTEC; it contained in addition an activity of Sn^{119m} (250 day).

A. "Singles" γ-Ray and Electron-Conversion Spectra

The electromagnetic radiation was detected with a lithium-drifted germanium counter of 3-mm depletion region; the corresponding spectrum is depicted in Fig. 1.

Table I. Energies and relative intensities of the γ rays following electron capture in Sn^{133}.

$E(\gamma_2)$ (MeV)	$E(\gamma_1)$ (MeV)	$N(\gamma_2)/N(\gamma_1)$ $\times(10^{-2})$	Reference
0.255	0.393	2.8 ± 0.1	1
0.257 ± 0.002	0.393	3.0 ± 0.3	2
0.255	0.393	2.7 ± 0.2	3
0.2555 ± 0.0005	0.3910 ± 0.0005	2.9 ± 0.3	Present authors

The average energies of both γ rays as well as their relative intensities are shown in Table I, where the latest values obtained by other authors[1–3] are also quoted.

The electron-conversion spectrum was recorded with a lithium-drifted silicon detector of 3-mm depletion depth and is shown in Fig. 2.

B. Conversion Coefficients, $K/L+M$ Ratios, and Branching Ratios

The K-conversion coefficient for the 0.3910-MeV transition was determined by measuring the areas of the electron and γ-ray peaks in the corresponding "singles" spectra. Since the conversion electrons belonging to the 0.2555-MeV transition cannot be detected, the K-electron intensity ratio corresponding to the cascade 0.2555–0.3910 MeV, as reported by other authors,[2–5] must be used. The corresponding results are presented in

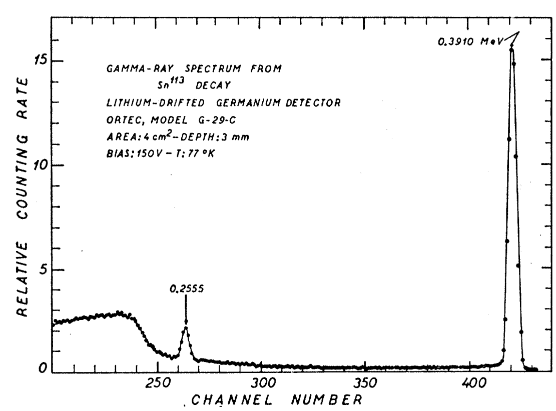

Fig. 1. Gamma rays of Sn^{113} detected with a lithium-drifted germanium detector (ORTEC, model G-29-C).

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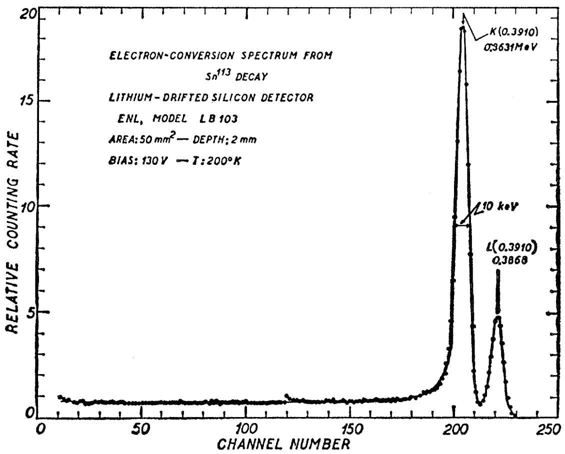

FIG. 2. Electron-conversion spectrum from a Sn^{113} source as taken with a lithium-drifted silicon counter (ENL, model LB-103).

Table II. The branching b_2 to the 0.6465-MeV level was determined to be $(1.9\pm0.2)\times10^{-2}$, assuming no feeding to the ground state.

C. $P_{EC}(L+M+\cdots)/P_{EC}(K)$ Orbital-Electron Capture Ratio to the 0.6465-MeV Level

The $P_{EC}(L+M+\cdots)/P_{EC}(K)$ orbital-electron capture ratio to the 0.6465-MeV level was derived by comparing the intensity of the 0.2555-MeV γ ray in cascade with the $K\alpha$ and $K\beta$ x-ray transitions with the intensity of the same peak in the "singles" spectrum. The corresponding coincidence spectrum is displayed in Fig. 3.

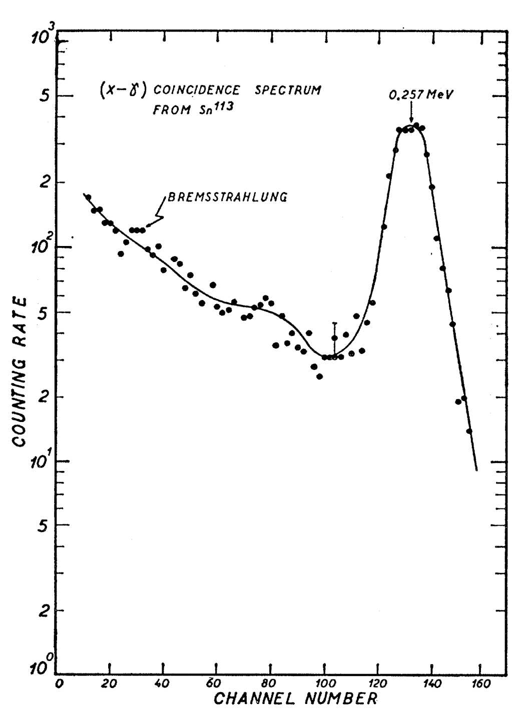

FIG. 3. Electromagnetic-radiation spectrum from the decay of Sn^{113} recorded by a NaI(Tl) crystal operated in coincidence with pulses corresponding to 24-keV x rays detected in a NaI(Tl) crystal covered with a beryllium window.

TABLE II. Internal-conversion coefficients and $K/(L+M+\cdots)$ ratios for both transitions in In^{113}.

0.2555-MeV α_K	transition $K/(L+M\cdots)$	0.3910-MeV α_K	transition $K/(L+M\cdots)$	Reference
0.044 ± 0.008		$0.43\ \pm0.06$		2
0.039 ± 0.003	8 ± 3		$4.3\ \pm0.1$	3
		0.431 ± 0.007	4.30 ± 0.04	4
		0.44		5
0.040 ± 0.006		$0.49\ \pm0.04$	$4.2\ \pm0.4$	Present authors

The ratio of the intensity of the 0.2555-MeV peak in both spectra allows one to get the numerical value of the K-electron–capture probability decay $P_{EC}(K)$ to the 0.6465-MeV level, determined to be $P_{EC}(K)=0.75\pm0.10$. Accordingly the $P_{EC}(L+M+\cdots)/P_{EC}(K)$ ratio becomes 0.33 ± 0.14.

The contribution of the L_{II} subshell can be neglected and that of the L_{III} one is null in allowed and first forbidden transitions.[6] On the other hand, the ratio $P_{EC}(M+N+\cdots)/P_{EC}(L)$ is found to be 0.193.[7] Nevertheless, the assumption can be made that all of the $P_{EC}(L+M+\cdots)/P_{EC}(K)$ ratio arises from the $P_{EC}(L)/P_{EC}(K)$ ratio, because of the large errors involved in the determination of the first ratio. In turn, this last ratio equals the value of the $P_{EC}(L_I)/P_{EC}(K)$ ratio. The values of the decay energies of Sn^{113} to the levels of In^{113} derived from the experimental $P_{EC}(L+M+\cdots)/P_{EC}(K)$ ratios obtained by different authors are quoted in Table III.[1,8–14]

D. Inner Bremsstrahlung from the Radiative Electron Capture from Sn^{113}

The transition energy from the ground state of Sn^{113} to the 0.6465-MeV level of In^{113} was determined by measuring the end-point energy of the bremsstrahlung spec-

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TABLE III. Values of partial disintegration energies from Sn^{113} to the excited levels of In^{113} as experimentally obtained by different authors.

$P_{EC}(L+M+\cdots)/P_{EC}(K)$		Bremsstrahlung end-point energy (MeV)		Partial decay energy (MeV)		
to the 0.3910-MeV level	to the 0.6465-MeV level	corresponding to the 0.3910-MeV level	corresponding to the 0.6465-MeV level	to the 0.3910-MeV level	to the 0.6465-MeV level	Reference
0.18±0.09				0.070−1.0		8
0.17±0.12						9
		0.072±0.010		0.100±0.010		10
	$2.23_{-0.88}^{+1.12}$				$0.036_{+0.004}^{-0.001}$	11
	<0.19				>0.150	1
		0.900±0.300		0.930±0.300		12
0.44±0.04				0.049±0.003		13
0.16±0.02				$0.280_{-0.100}^{+0.350}$		14
	0.33±0.14				0.050−0.110	Present authors
			0.080±0.005		0.110±0.005	Present authors

trum corresponding to the orbital-electron capture to this level. This was achieved by recording the bremsstrahlung spectrum in coincidence with the 0.2555-MeV γ ray. This spectrum is shown in Fig. 4(a) and the corresponding Kurie-type plot in Fig. 4(b). The decay energy as obtained by this method is (0.110±0.005) MeV.

The measurement of the γ continuum spectrum was also performed by other authors both in "singles"[12] and in coincidence with K x rays.[10] The corresponding results are quoted in Table III.

III. DISCUSSION

The spin of the ground state of In^{113} was measured to be $\frac{9}{2}+$,[15] and that of the first excited state $\frac{1}{2}-$.[16] These values are supported by the shell-model assignments.[17] The second excited level could be assumed to be $2p_{3/2}$. This configuration agrees with the values experimentally obtained for the K-conversion coefficient and $K/(L+M)$ ratio corresponding to the 0.2555-MeV transition. The proposed sequence is also predicted by Kisslinger and Sorensen.[18]

For the ground state of Sn^{113}, the assignment $3s_{1/2}$ is assumed, since it agrees with shell-model predictions as well as with those of Kisslinger and Sorensen,[18] Arvieu,[19] and the surface delta interaction model.[20]

The orbital electron-capture transition from the ground state of Sn^{113} to the second excited state of In^{113} is of the first-forbidden type. Choosing the measured bremsstrahlung end-point energy (plus the binding energy) as the transition energy between these states, a $\log ft$ of 7.1 is obtained. Similarly, a $\log ft$ of 6.5 for the transition to the isomeric state is deduced.

As results of the above discussion, a Q value of 0.760±0.005 MeV is derived and the disintegration scheme shown in Fig. 5 is proposed. In Table IV the Q values obtained from different mass tables are quoted.[21–24]

The imprecision of the values of the $P_{EC}(L+M+\cdots)/P_{EC}(K)$ capture ratios does not allow one to apply the exchange-overlap corrections theoretically derived by

TABLE IV. Q values of the pair $Sn^{113}-In^{113}$ obtained from different mass tables.

Q values (MeV)	Reference
1.100, 0.690	Hillman[a]
1.023	22
1.140	23
1.413	24
0.760	Present authors

[a] Reference 21. The first value corresponds to the calculated excess mass; the second one, to the observed mass.

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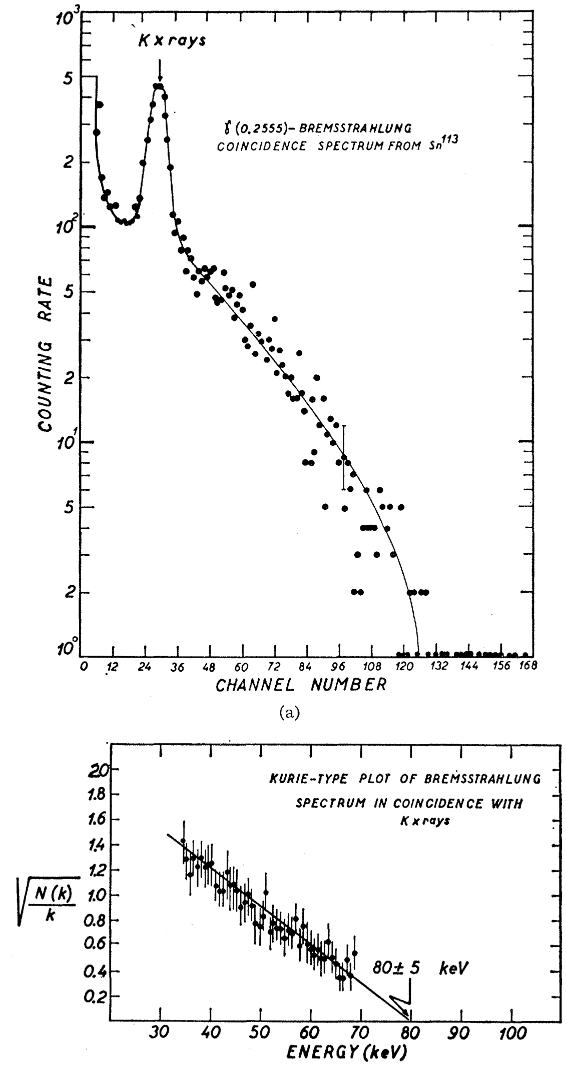

(a)

FIG. 4. (a) Bremsstrahlung spectrum from the decay of Sn^{113} recorded by a NaI(Tl) crystal covered with a beryllium window operated in coincidence with pulses corresponding to the 0.2555-MeV γ-rays detected in a NaI(Tl) crystal. (b) Corresponding Kurie-type plot.

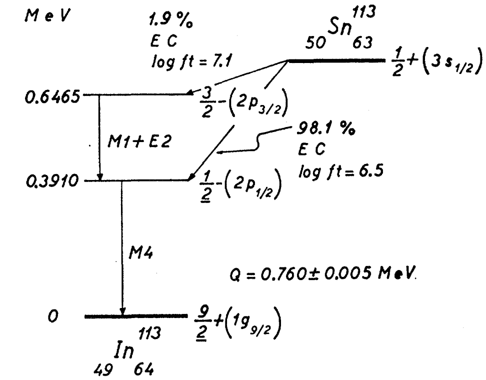

FIG. 5. Proposed disintegration scheme for Sn^{113}.

Bahcall[25,26] and by Robinson.[27] This is verified by the results of Fink and Ledingham.[28]

As far as the bremsstrahlung is concerned, the corresponding spectrum exhibits a shape similar to those of Sb^{119} and Cs^{131} obtained by Olsen *et al.*[29] and Wu *et al.*,[30] respectively. Despite the decay-energy differences and the order of forbiddenness of the transitions, it seems natural to assume that the bremsstrahlung spectrum from Sn^{113} could be composed of contributions from *S*- and mainly from *P*-state electrons.[31,32] Actually both the low energy available for the transitions and the relatively high atomic number give support to the above-mentioned hypothesis.[33] Since the Glauber and Martin theory [33] only applies to allowed transitions, no quantitative predictions can be derived from the present data.

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