^{122}In Isomers*

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Irradiation of enriched ^{122}Sn with 14.8-MeV neutrons was found to produce a new radioactivity with a half-life of 1.5 ± 0.3 sec which was assigned to an isomer of ^{122}In. The decay of the 7.5-sec ^{122}In isomer was also studied and a new half-life of 10.0 ± 0.5 sec determined.

I. INTRODUCTION

The only previously reported investigation of ^{122}In was the initial discovery by Kantle and Karras[1] who produced this nuclide through the ^{122}Sn-$(n, p)^{122}$In reaction at 14.8-MeV neutron energy. They observed a 7.5 ± 0.8-sec activity with a 4.5 ± 0.8-MeV β end-point energy.

In the present investigation, a new 1.5 ± 0.3-sec activity was observed when 92.25% enriched ^{122}Sn was bombarded with 14.8-MeV neutrons and was assigned as an isomer of ^{122}In. The decay of the previously reported 7.5-sec ^{122}In was studied and a new half-life of 10.0 sec was determined.

II. EXPERIMENTAL

A 200-mg sample of enriched ^{122}Sn oxide was obtained from the Stable Iosotpes Division, Oak Ridge National Laboratory. The isotopic composition of this sample is given in Table I. The sample was sealed in a polyethylene "Marlex" capsule, irradiated with 14.8-MeV neutrons, and transported to the detector system by a pneumatic transport system (transient time = 0.5 sec). The neutrons were generated by the University of Arkansas 400-kV Cockroft-Walton linear accelerator through the well known $T(d, n)^4$He reaction. The neutron flux varied from 1×10^9 to 5×10^9 neutrons/sec cm^2. Typically 30–100 bombardments of the enriched sample were required for each experiment in order to accumulate sufficient counts.

TABLE I. Isotopic composition of enriched ^{122}Sn.

Isotopes	Abundance (%)
^{112}Sn	<0.05
^{114}Sn	<0.05
^{115}Sn	<0.05
^{116}Sn	0.34
^{117}Sn	0.17
^{118}Sn	0.91
^{119}Sn	0.47
^{120}Sn	4.72
^{122}Sn	92.25
^{124}Sn	1.12

The detectors used for singles γ-ray spectra were a 7.6-cm × 7.6-cm NaI(Tl) detector and an 8-cm^3 Ge(Li) spectrometer in conjunction with a 4096-channel Nuclear Data 3300 analyzer. β-γ coincidences were measured using a 3.8-cm-diam by 2.1-cm-high cylindrical plastic detector and the NaI(Tl) detector in conjunction with a Canberra 800 series coincidence unit (1-μsec delay) and a 512-channel Nuclear Data 1100 analyzer. Gross γ-decay measurements were performed using the NaI(Tl) detector in conjunction with the multi-scaling mode of the 1100 model analyzer.

III. RESULTS AND DISCUSSION

Figures 1(a) and 1(b) show the singles Ge(Li) spectra of irradiated enriched ^{122}Sn. The spectra were obtained by accumulating counts from fifty 10-sec bombardments. The counting times for these successive spectra (a) and (b) taken immediately after bombardment were of 30 sec and 1 min, respectively. The 161- and 1174-keV γ rays can be assigned to the ^{124}Sn$(n, 2n)$ product, 40-min ^{123}Sn, and the ^{120}Sn(n, p) product, 44-sec ^{120}In, respectively. Contamination from 10-min ^{13}N (511-keV annihilation radiation) and 2.3-min ^{27}Al (1777-keV γ ray) were observed as the products from nitrogen and silicon impurities in the fast-transport capsule. The energies and relative intensities of those γ rays associated with ^{122}In are summarized

TABLE II. Radiation from ^{122}In isomers.

Isomer	Radiation	Energy (MeV)	Relative intensity	Remarks
10 sec	γ_1	0.104 ± 0.001	6.8 ± 1	
	γ_2	1.003 ± 0.001	56.1 ± 1	
	γ_3	1.142 ± 0.002	100	
	γ_4	1.194 ± 0.002	18.2 ± 2	
	β	5.3 ± 0.2		logft 5.1
1.5 sec	γ_3	1.142 ± 0.002		
	β	4.4 ± 0.2		logft 4.5

in Table II. Singles γ-ray spectra obtained with the NaI(Tl) detector did not reveal any higher-energy γ rays than 1.19 MeV which could be assigned to 10-sec ^{122}In.

The half-life of the 104 ± 30-, 1003 ± 30-, and 1142 ± 30-keV γ-ray regions were measured by biasing a NaI(Tl) detector on those regions and multi-scaling using the 512-channel Nuclear Data analyzer. The results of these measurements are shown in Fig. 2. The average half-life was determined to be 10.0 ± 0.5 sec. In each of the measurements a residual activity of 40 to 80 counts/channel was subtracted.

Singles β spectra of irradiated ^{122}Sn could not be obtained due to the 7.1-sec ^{16}N activity produced from oxygen in the sample.

The level structure of the even tin isotopes has been studied extensively by the Coulomb-excitation method,[2-5] and excited states of probable spin-parities of 2^+, 4^+ with energies of 1142 ± 1 and 2145 ± 1 keV have been reported for ^{122}Sn. In addition to these levels, an excited state of probable spin-parity 5^- was observed in this work at an energy of 2249 ± 1 keV.

A short-lived activity with a half-life of 1.5 ± 0.3 sec was found by biasing the NaI(Tl) detector on the 1142 ± 30-keV γ-ray region and multi-scaling using 0.8-, 0.4-, and 0.1-sec time interval per channel. The results of these measurements are shown in Figs. 3 and 4. This 1.5-sec activity was only observed when biasing on the 1142-keV γ-ray.

Yamada and Matumoto[6] have estimated the β-decay Q value of ^{122}In to be ≅6.8 MeV, whereas no other fast-neutron reaction product from ^{122}Sn is expected to have a $Q_{\beta^-} > 4.5$ MeV. The β-γ coincidence measurements on the 1142-keV region, obtained by 100 bombardments of the enriched sample, are shown in Figs. 5 and 6. Analysis of the coincident β spectrum taken for the first 20 sec after irradiation revealed a 5.3 ± 0.2-MeV β end-point energy, while the coincident β spectrum taken during the time interval from 20 to 40 sec after bombardment revealed a 4.4 ± 0.2-MeV β end point. The logft values for the 4.4-MeV (10 sec) and the 5.3-MeV (1.5 sec) β rays were calculated to be 5.1 and 4.5, respectively.

In Fig. 7 is shown the proposed decay scheme for ^{122}In which was derived from Table II. The

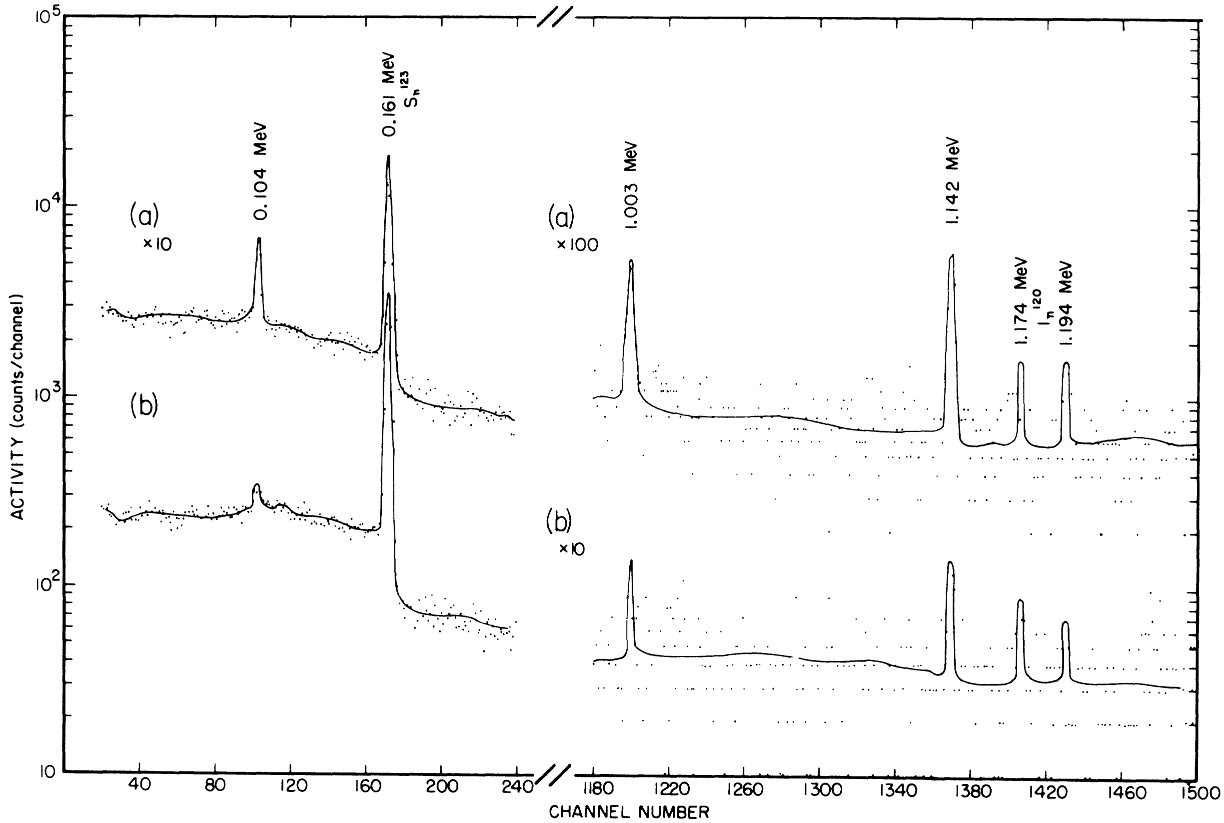

FIG. 1. Typical singles Ge(Li) γ-ray spectra from irradiated enriched ^{122}Sn. The spectra were obtained by accumulating counts from 50 bombardments of the ^{122}Sn: (a) a counting period of 30 sec from 5 sec after bombardment; (b) a counting period of 1 min from 35 sec after bombardment.

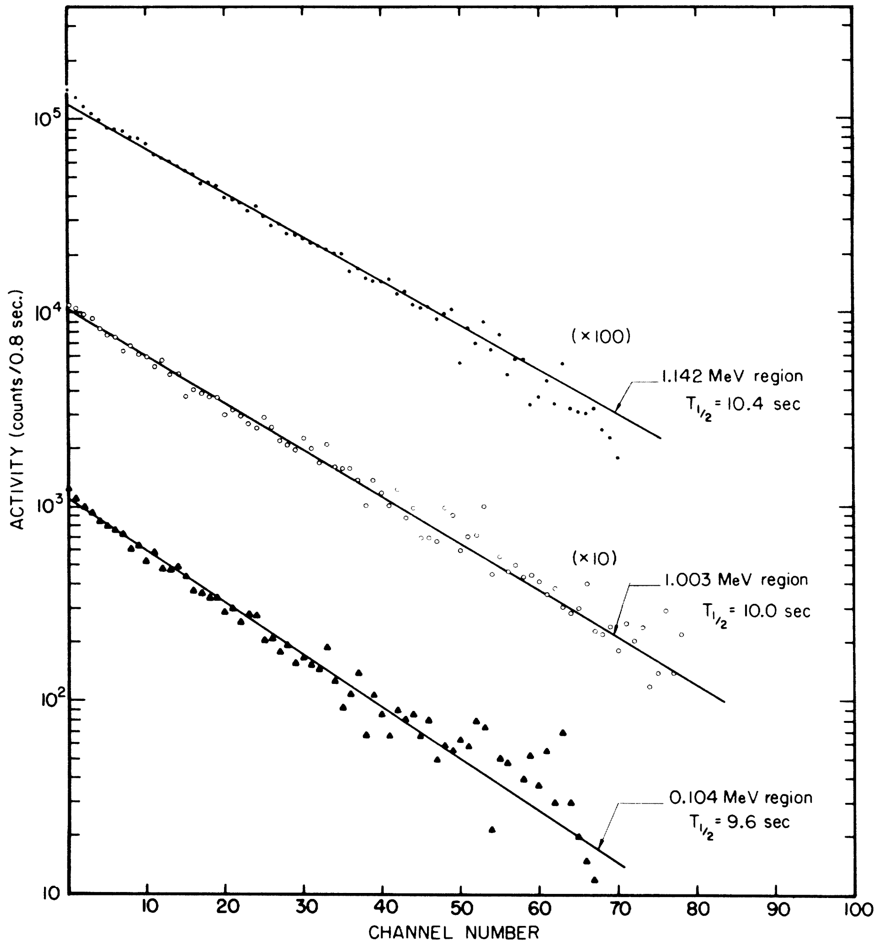

FIG. 2. The results of the measurements of the half-lives of the 104-, 1003-, and 1142-keV γ-ray regions.

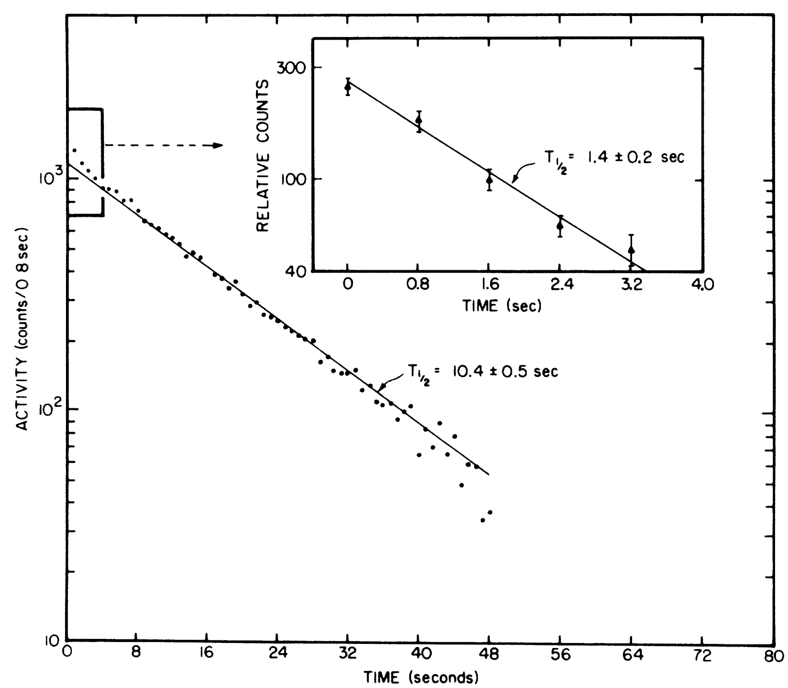

FIG. 3. Gross γ decay of the 1142-keV γ ray obtained by analysis of 50 consecutive 0.8-sec multiscale NaI(Tl) spectra of irradiated enriched ^{122}Sn.

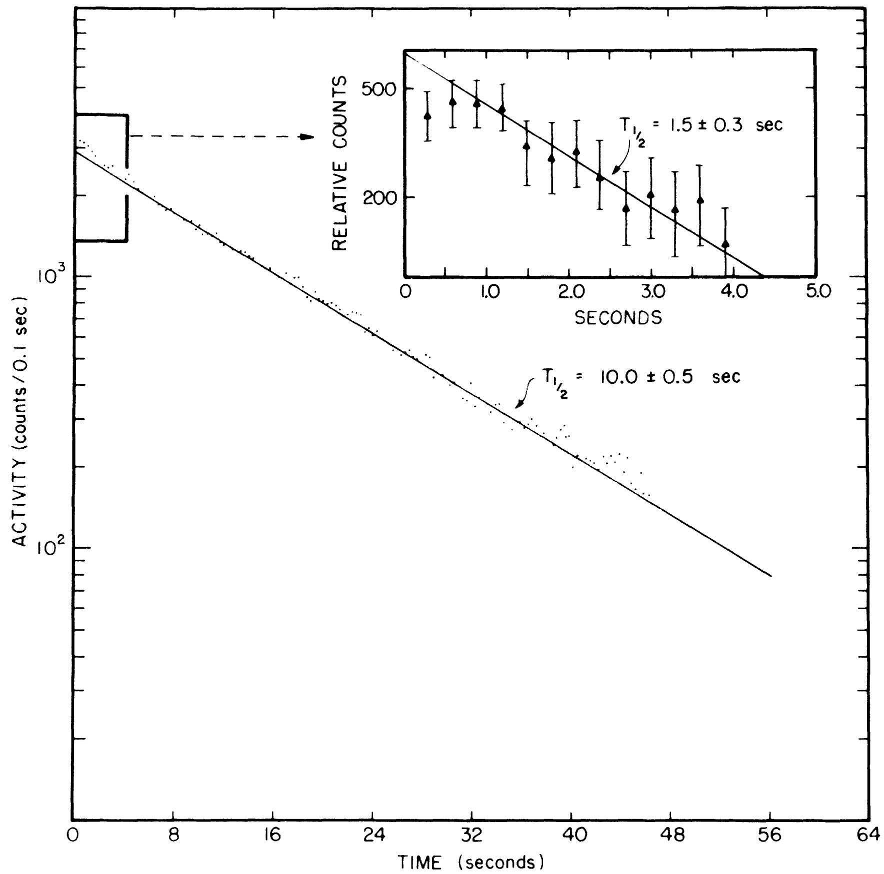

FIG. 4. Gross γ decay of the 1142-keV γ ray obtained by analysis of 100 consecutive 0.1-sec multiscale NaI(Tl) spectra of irradiated enriched ^{122}Sn.

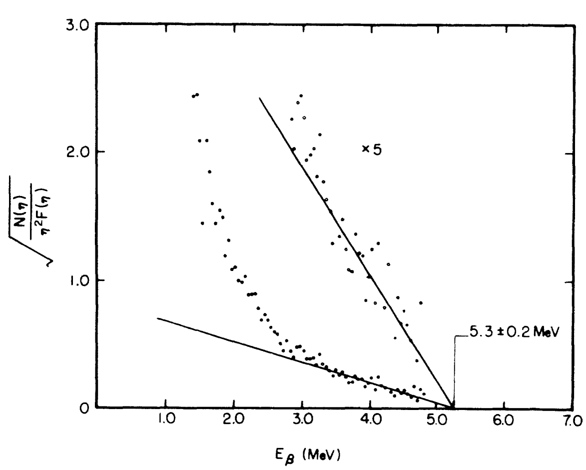

FIG. 5. Fermi-Kurie plot of β spectrum of 1.5-sec ^{122}In from irradiated enriched ^{122}Sn.

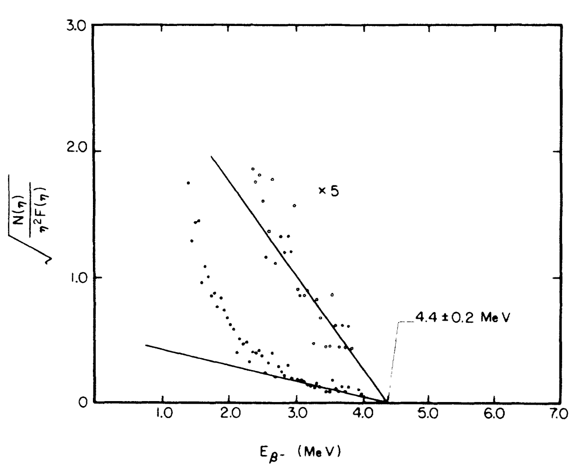

FIG. 6. Fermi-Kurie plot of β spectrum of 10-sec ^{122}In from irradiated enriched ^{122}Sn.

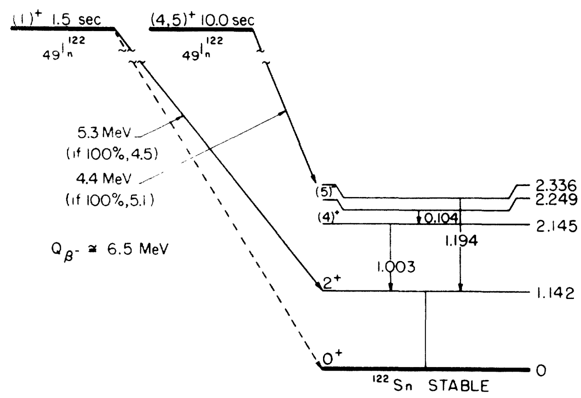

FIG. 7. Tentatively proposed decay scheme of the ^{122}In isomers.

proton-neutron configurations for a number of odd-odd In isomers have been proposed by Brennan and Bernstein.[7] Theoretically the shell model assigns the 49th proton of ^{122}In a $J^{\pi} = \frac{9}{2}^{-}$ and the 73rd neutron a $J^{\pi} = \frac{11}{2}^{-}$. Nordheim's[8] coupling rules for odd-odd nuclei predict a ground-state spin-parity of (1^{+}) for ^{122}In. The existence of an isomeric state in indium isotopes can be explained as due to the three low-lying configurations $(g_{9/2}^{-}, s_{1/2})$, $(g_{9/2}^{-}, d_{3/2})$, and $(p_{1/2}^{-}, h_{11/2})$. Since the β ray of 4.4 MeV was observed to feed the 4^{+} level at 2145 keV and had a corresponding $\log ft$ value of 5.1, this would imply a spin-parity of either 4^{+} or 5^{+} for the 10-sec ^{122}In isomer.

The new 1.5-sec activity observed in this investigation was assigned to an isomer of ^{122}In based on the following reasons: (a) The β-decay Q value of 6.5 ± 0.2 MeV obtained for the 1.5-sec activity is in good agreement with the estimated value of Yamada and Matumoto;[6] (b) no other fast-neutron product from Sn is expected to have greater than 5.3 MeV available for decay; and (c) a search of the *Table of Isotopes*[9] did not reveal any 1.5-sec activity with a β-decay Q value of 6.5 MeV which could be produced by fast-neutron bombardment on any possible contaminant.

The 7.5-sec half-life for ^{122}In reported by Kantle and Karras[1] from gross β-decay measurements could have been influenced by 7.1-sec ^{16}N produced from the oxygen in the sample.

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