Cross-section measurements for (n, 2n) reactions on stannum isotopes in the neutron energy range of 13.5 to 14.6 MeV*

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Abstract Cross-sections for (n, 2n) reactions have been measured on stannum isotopes at the neutron energies of 13.5 to 14.6 MeV using the activation technique. Data are reported for the following reactions: ^{112}Sn(n, 2n)^{111}Sn, ^{118}Sn(n, 2n)^{117}Sn and ^{124}Sn(n, 2n)^{123m}Sn. The neutron fluences were determined using the monitor reaction ^{93}Nb(n, 2n)^{92m}Nb or ^{27}Al(n, α)^{24}Na. The results of present work were compared with data published previously.

Key words stannum, cross section, activation technique, (n, 2n) reaction, 14 MeV neutron

PACS 24.50.+g, 25.40 -h

1 Introduction

Experimental data of neutron-induced reactions in the energy range around 13.5 to 14.6 MeV are needed to verify the accuracy of nuclear models used in the calculation of cross sections. Furthermore, the data are of considerable importance for practical applications, such as for integral calculations on the first wall, blanket and shield of a conceptual fusion power reactor. A lot of experimental data on neutron induced cross sections for fusion reactor technology applications have been reported and great efforts have been devoted to compilations and evaluations. The cross sections of stannum isotopes around 14 MeV have been obtained by several groups, but most of them were obtained before 1988. Furthermore, there was disagreement in those data. So we considered it was important to measure them again. In the present work three (n, 2n) reaction cross sections on stannum isotopes have been studied at neutron energies of 13.5 to 14.6 MeV. Pure stannum metal was used as the target material. The reaction yields were obtained by absolute measurements of the gamma activities of the product nuclei using a coaxial high-purity germanium detector. The neutron energies in these measurements were determined by cross section ratios for the ^{90}Zr(n, 2n)$^{89m+g}$Zr and ^{93}Nb(n, 2n)^{92m}Nb reactions[1].

2 Experiment

The irradiation of samples was carried out at ZF-300-II Intense Neutron Generator at Lanzhou University with the yield of about (3×10^{10}—4×10^{10}) n/s. Neutrons were produced by the T(d, n)^{4}He reaction with an effective deuteron beam energy of 135 keV and a beam current of 500 μA. The thickness of the tritium-titanium (T-Ti) target was 1.35 mg/cm^2. The neutron flux was monitored by a uranium fission chamber so that corrections could be made for small variations in the yield. The groups of samples were placed at 0°, 45°, 90° or 135° angles relative to the beam direction. The samples in each group were sandwiched between two Al or two Nb foils. Cross sections for ^{93}Nb(n, 2n)^{92m}Nb or ^{27}Al(n, α)^{24}Na reaction[2] were selected as monitors to measure the reaction cross section on several stannum isotopes.

Received 25 February 2007
* Supported by Natural Science Foundation of Gansu Province (3ZS042-B25-026)
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The gamma ray activities of ^{92m}Nb, ^{24}Na, ^{111}Sn, ^{117}Sn and ^{123m}Sn were determined by a CH8403 coaxial high-purity germanium detector (sensitive volume 110 cm^3) (made in the People's Republic of China) with a relative efficiency of 20% and an energy resolution of 3 keV at 1332 keV. The efficiency of the detector was calibrated using the standard gamma source, Standard Reference Material 4275 from the National Institute of Standards and Technology, Washington, D.C., USA. An absolute efficiency calibration curve was obtained at 20 cm from the surface of the germanium crystal. At this distance the coincidence losses can be considered to be negligible. In our case, however, we needed to calibrate the efficiency at 2 cm, the actual counting position used because of the weak activity of the sample. Therefore, we selected a set of single γ-line sources and placed them at two positions (20 and 2 cm) successively to measure their efficiency ratios to be able to evaluate the efficiency ratio curve as a function of energy. The absolute efficiency calibration curve at 2 cm was obtained from the calibration curve at 20 cm and the efficiency ratio curve. The error in the absolute efficiency curve at 2 cm was estimated to be ~1.5%, while the error of the activity of the standard source is ~1.0%.

The decay characteristics of the product radioisotopes and the natural abundances of the target isotopes under investigation are summarized in Table 1[3].

Table 1. Reactions and associated decay data of activation products.

reaction	abundance of target isotope(%)	half-life of product	E_γ/keV	I_γ(%)
^{112}Sn(n, 2n)^{111}Sn	0.97	35.3 m	761.97	1.48
^{118}Sn(n, 2n)^{117}Sn	24.22	13.6 d	158.56	86.4
^{124}Sn(n, 2n)^{123m}Sn	5.79	40.06 m	160.3	99.98
^{93}Nb(n, 2n)^{92m}Nb	100	10.15 d	934.4	99.07
^{27}Al(n, α)^{24}Na	100	14.959 h	1368.6	100

3 Results and discussion

The cross sections were calculated by the equation used in Ref. [4]. The cross sections measured in the present work were summarized in Table 2 and plotted in Figs. 1—3 together with the values in the literatures[5—11] for comparison. The corrections were made for gamma-ray self-absorption in the sample, for fluctuation of the neutron flux during the irradiation and for sample geometry. The major errors in the present work come from the errors of counting statistics, detector efficiency, monitor reaction cross sections, weight of samples, self-absorption of gamma ray, coincidence summing effect of cascade gamma rays, sample geometry and the effect of the scattering neutrons.

For the ^{112}Sn(n, 2n)^{111}Sn reaction, it can be seen from Fig. 1 that the cross sections increase with increasing neutron energy around 14 MeV and our results are in agreement, within the experimental error, with those of Refs. [5—9]. For the ^{118}Sn(n, 2n)^{117}Sn reaction, it can be seen from Fig. 2 that the cross sections increase slowly with increasing the neutron energy around 14 MeV and our results are in agreement, within the experimental error, with those of Refs. [6, 8, 9] except for Ref. [10]. Our results for the ^{124}Sn(n, 2n)^{123m}Sn reaction cross section are in agreement with the previously published results except for Ref. [11].

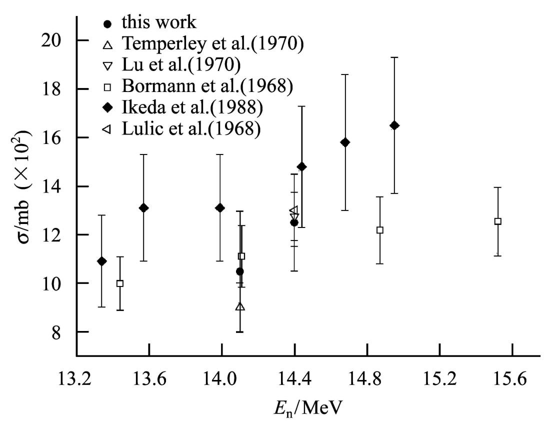

Fig. 1. The cross sections for the ^{112}Sn(n, 2n) ^{111}Sn reaction.

Table 2. Summary of cross section measurements.

reaction	cross sections/mb			
	(13.5±0.3)MeV	(14.1±0.2)MeV	(14.4±0.3)MeV	(14.6±0.3)MeV
^{112}Sn(n, 2n)^{111}Sn		1047±250	1249±200	
^{118}Sn(n, 2n)^{117}Sn	726±98	780±88	813±101	853±110
^{124}Sn(n, 2n)^{123m}Sn	610±30	629±29	567±28	

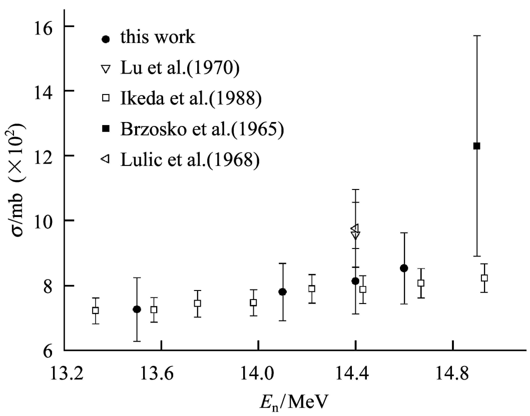

Fig. 2. The cross sections for the ^{118}Sn(n, 2n)^{117}Sn reaction.

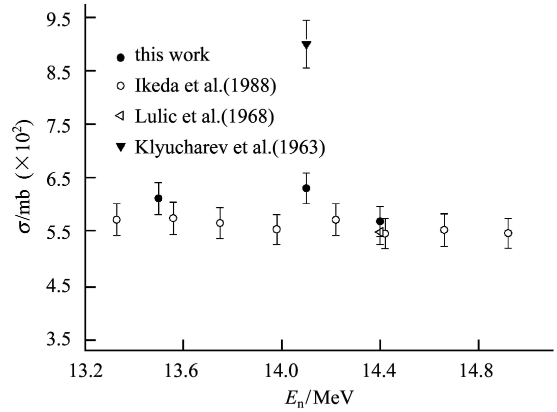

Fig. 3. The cross sections for the ^{124}Sn(n, 2n)^{123m}Sn reactions.

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