Measurement of neutron induced reaction cross-section on ^{118}Sn at neutron energy of 14.96 ± 0.03 MeV

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Introduction

Tin (Sn) is utilised in the fusion reactor's core to instigate, control the shape and regulate the fusion plasma. Sn exhibits strong anti-corrosive properties, withstanding at high temperatures and can be exploited as a structural material in certain reactor components. Sn is one of the components of the Nb_3Sn (niobium-tin) compound exhibiting superconductivity at appropriate temperatures and is preferred for making the toroidal coils of superconducting magnets that help in containing and confining the fusion plasma within the reactor core [1]. Accurate data on the reaction cross-section is essential for reactor design, fuel cycle analysis, and nuclear waste management. Therefore, estimating the neutron induced reaction cross-section for various Sn isotopes is crucial as there is a discrepancy in the experimental and evaluated data.

The aim of this work is to measure the cross-section of ^{118}Sn(n,2n)^{117m}Sn reaction at a neutron energy of 14.96 ± 0.03 MeV. Furthermore, measured cross-section data is compared with the EXFOR data [2] and Evaluated libraries [3] as ENDF/B-VIII.0, JEFF 3.3, JENDL-5, along with precise propagation of error from various parameters.

Experimental Details

The experiment was performed using a Neutron and Ion Irradiation Facility at Institute of Plasma Research, Gandhinagar (India). The ^{3}H(d,n)^{4}He (D-T) fusion reaction was carried out to produce monoenergetic neutrons in which the deuterium beam energy of 200 keV with a beam current of 2.5 mA was incident on stationary Tritium – Tritide (TiT) target of thickness 2.19 mg.cm^{-2} [4]. Neutrons were incident on the stable isotope of Sn for 4 hours. The Au-Si surface barrier α detector was used at an angle of 135° to detect the flux of the α particles. The Sn pellet having an area of 2.25 cm^2 was placed in front of an aluminium foil which was used as monitor foil. The irradiation setup was enclosed within lead shielding to prevent any radioactive contamination. The stable natural sample was exposed to neutron energy. After the irradiation, the activated sample emitted γ-rays. The cooling time of the sample was decided in accordance with the intensity of the gamma-ray produced. The γ-rays were subsequently detected and counted using a high-purity germanium (HPGe) detector, that had been pre-calibrated with a radioactive ^{152}Eu sample. The detector was placed at a distance of 3 cm from the sample. The energy resolution of the HPGe detector was ≤2.1keV at 1.33 MeV γ ray energy. The neutron activation cross-section is calculated from the following eq (1):

$$\sigma_p = \sigma_q \frac{C_p \lambda_p W_q M_p A_q \varepsilon_q I_q f_q (C_{att} C_g)_p}{C_q \lambda_q W_p M_q A_p \varepsilon_p I_p f_p (C_{att} C_g)_q} \quad (1)$$

The subscripts p and q stand for sample and monitor reaction respectively.

where I is the γ-ray abundance, σ represents the cross section in barns, C denotes the detected photo-peak counts of the γ ray, λ signifies the decay constant in sec^{-1}, ε indicates the efficiency for the radionuclide's characteristic γ ray, W refers to the weight in grams, A denotes the isotopic abundance, and M is the atomic mass in amu. The time factor is denoted by f, C_{att} is the γ-ray self-

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attenuation correction factor, and C_g is the geometric correction factor.

The timing factor (f) in eq (1) is given by the eq (2):

$$f = (1 - \exp(-\lambda t_{irr}))\,(\exp(-\lambda t_{cl}))\,(1 - \exp(-\lambda t_{cn})) \quad (2)$$

Where t_{irr} is the irradiation time, t_{cl} is the cooling time, t_{cn} is the counting time of the sample given in Table 2.

Table 1: Spectroscopic Data of Reactions

Nuclear Reaction	^{118}Sn(n,2n)^{117m}Sn	^{27}Al(n,α)^{24}Na
E_{th} (MeV)	9.315	3.47
Half-life (hrs)	334.56	14.99
E_γ(keV)	158.56	1368.6
I_γ (%)	86.4	99.9

Table 2: Detail of Experiment

	^{118}Sn(n,2n)^{117m}Sn	^{27}Al(n,α)^{24}Na
Irradiation time (s)	14400	14400
Cooling time (s)	6728	16783
Counting time (s)	101.262	502.856

Results and Discussion

In the present work, the cross section of ^{118}Sn(n,2n)^{117m}Sn reaction is measured at neutron energy of 14.96 ± 0.03 MeV. The measured cross-section of the reaction is 1.118 barns with an uncertainty of 5.1% as shown in Fig. 1. Measured cross-section data is compared with the EXFOR data, evaluated data from ENDF/B-VIII.0, JEFF3.3, TENDL-2023 libraries within the reaction threshold to 20 MeV neutron energy. As demonstrated in Figure 1, several measurements are available between 13 to 16 MeV and the present work is partially in agreement with the EXFOR data. Measurement of reaction cross section by J.Brzosko et al.[5] (1965) was carried out by the NaI(Tl) scintillation detector. As indicated in Fig. 1, only a few experiments have been conducted within this energy range. Additionally, more experiments are required to obtain precise cross-section values in the neutron energy range from the threshold to 20 MeV.

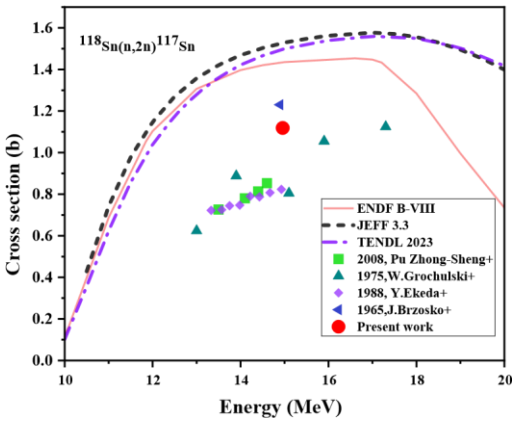

Fig.1 Experimental and Evaluated cross section for ^{118}Sn (n,2n)^{117}Sn nuclear reaction from 10 to 20 MeV neutron energies.

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