Measurement of fast neutron induced (n,p) reactions on Sn isotopes

Rebecca Pachuau[1],* H. Krishnamoorthy[1], A. Mazumdar[1], V. Nanal[1], S.V. Suryanarayana[2], B.K. Nayak[2], Laxman Danu[2], Yogesh Sawant[2], Saroj Bishnoi[3], Tarun Patel[3], and Imran Pasha[4]

[1]*Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[3]*Neutron and X-ray Physics Division, Bhabha Atomic Research Center, Mumbai 400085, India and*
[4]*Department of Physics, Bangalore University, Bengaluru,Karnataka 560056, India*

Introduction

Cross sections of neutron induced (n,p) reactions are widely used in nuclear reactors and basic research. They are also used to test the accuracy of different statistical model codes. But the evaluators often face difficulty due to insufficient information on the uncertainty in the measured cross sections. [1]. Therefore, in the present work, the cross sections of the neutron induced (n,p) reactions on Sn isotopes have been measured with detail uncertainty propagation and covariance analysis.

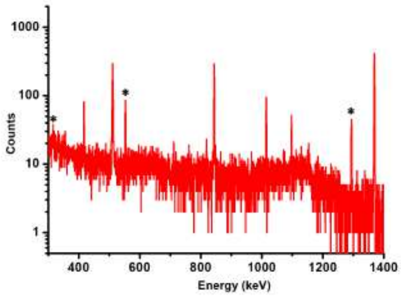

FIG. 1: (Color online) Spectrum of irradiated Sn sample ($T_{1/2} = 618$ secs).

Experimental Details and Data Analysis

The experiment was carried out using the neutron generator at BARC, Mumbai. In the present experiment, the D+ ion beam was accelerated to 180 keV and tritium target was bombarded producing 15.10±0.01 MeV neutrons at 0° via the ^{3}H(d,n)^{4}He reaction. The typical average deuteron beam current during irradiation was 60 μA. A natural Sn target of thickness 131.8±0.1mg/cm^2 and purity 99.9999 % was used. Au foil of purity 99.99 % was used as standard monitor. After irradiation of the sample and sufficient cooling, the activity of the sample was measured using a precalibrated HPGe detector. The data acquisition was carried out using CAMAC-based Linux Advanced Multiparameter System software. The HPGe detector was calibrated using ^{152}Eu of known activity. The cross section was calculated using the equation

TABLE I: Decay data adopted in present work.

Nuclide	Half life	E_γ (keV)	I_γ (%)
^{116}In^m	54.29±0.17 m	1293.56	84.8
^{117}In	43.2±0.3 m	552.9	100
^{117}In^m	116.2±0.3 m	315.302	19.1
^{196}Au	6.1669±0.0006 d	355.73	87

$$\sigma_{Sn} = \sigma_{Au} \frac{A_{Sn}\lambda_{Sn}}{A_{Au}\lambda_{Au}} \frac{a_{Au}n_{Au}I_{Au}\varepsilon_{Au}f_{Au}}{a_{Sn}n_{Sn}I_{Sn}\varepsilon_{Sn}f_{Sn}} \quad (1)$$

where A_x is number of gamma ray counts, λ_x is decay constant of product nucleus, a_x is isotopic abundance of tin isotopes, n_x is number of atoms, I_x is gamma intensity, ε_x is efficiency of the HPGe detector at a given energy and f

*Electronic address: `pcrl.bec@gmail.com`

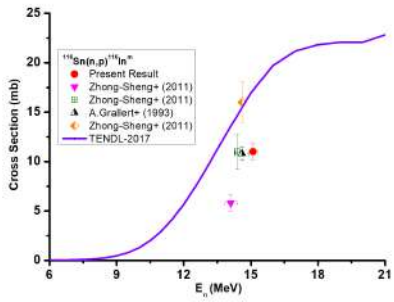

FIG. 2: (Color online) Excitation function of the ^{116}Sn(n,p)^{116}In^{m} reaction.

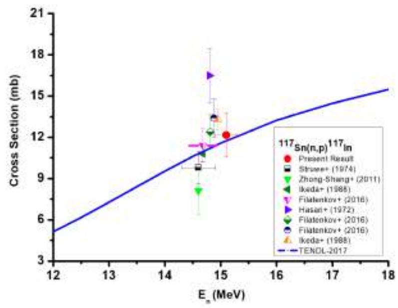

FIG. 3: (Color online) Excitation function of the ^{117}Sn(n,p)^{117}In reaction.

is the timing factor given by

$$f = [1 - exp(-\lambda t_i)]exp(-\lambda t_c)[1 - exp(-\lambda t_m)] \quad (2)$$

with t_i is irradiation time, t_c is cooling time and t_m is counting time.

Results and Discussions

The measured cross sections at 15.1±0.01 MeV neutron energy along with their uncertainties and correlation between each reactionss are presented in the Table II. Our results are compared with reported values available in the EXFOR database [2] and with the evaluated nuclear data file TENDL-2017 [3]. The results are shown in Figure 2 to 4.

TABLE II: The cross sections measured in the present work along with their uncertainties and correlation coefficients.

Reaction	Cross section (mb)	Correlation coefficient
^{116}Sn(n,p)^{116}In^{m}	11.01±1.14	1.00
^{117}Sn(n,p)^{117}In	12.16±1.78	0.04 1.00
^{117}Sn(n,p)^{117}In^{m}	5.32±1.79	0.02 0.01 1.00

Conclusion

Figure 3 shows that our result is in good agreement with both the measured and theoretical values. Although our result for the metastable states agrees with most of the reported values as shown in Figure 2 and 4,

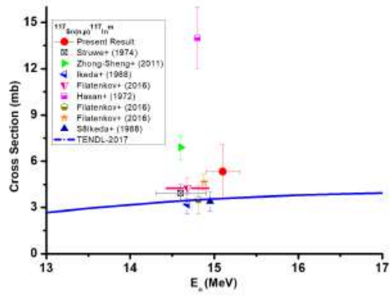

FIG. 4: (Color online) Excitation function of the ^{117}Sn(n,p)^{117}In^{m} reaction.

they are not in good agreement with theoretical value. Hence, TENDL-2017 library might be improved for this state. The present work shows that besides the total uncertainties, the fractional uncertainties and their correlation properties are required in order to obtain the covariance information between the measured cross sections.

References

[1] N. Otuka, B. Lalremruata, M. U. Khandaker, A. R. Usman, and L. R. M. Punte, Radiat. Phys. Chem. **149**, 151 (2018).

[2] EXFOR, Experimetal Nuclear Reaction Data https://www-nds.iaea.org/exfor/exfor.htm

[3] A.J. Koning and D. Rochman, Nuclear Data Sheets **113** , 2841 (2012).