Experimental and theoretical cross sections of ^{109}Ag(n,γ)^{110m}Ag reaction in the incident neutron energy 0.5- 1.6 MeV

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Introduction

^{109}Ag is used for the production of ^{109}Cd, ^{110m}Ag, ^{110}In radioisotopes which are used in X-ray fluorescence analysis, radiation sources and life sciences. It can also be used as flux monitors. ^{110m}Ag is produced by ^{109}Ag which undergoes β - decay into ^{110}Cd [1]. ^{110}Cd is used for the production of ^{110}In, ^{113m}In radioisotopes which have imperative role in health care, medical applications and pharmaceutical industries, also for production of helium-cadmium lasers. The EXchange FORmat (EXFOR) data repository shows that there is insufficiency of the data for ^{109}Ag(n,γ)^{110m}Ag at low energy of neutrons [2]. The main goal of this study is to measure cross section and covariance for this nuclear reaction.

In light of the discrepancy and inadequacy of nuclear data cross section; we are the first to calculate the cross section of ^{109}Ag(n,γ)^{110m}Ag reaction in the above mentioned neutron energies.

Experimental Details

The experiment was performed using the 6-MV Folded Tandem Ion Accelerator (FOTIA) facility, Bhabha Atomic Research Centre (BARC) Mumbai, India. The neutrons were produced by the reaction p + ^{7}Li → n + ^{7}Be. The proton beam of energies 2.5, 3, 3.6 MeV were bombarded a 56.18 μm thick Lithium target producing neutrons of average energies 0.53, 1.05, 1.66 MeV with an energy spread of 0.02 MeV. These neutrons impinged on silver targets of thickness 0.125, 0.125, 0.1 mm respectively.

Table 1 Decay data used in the experiment

Residue	Half-life (h)	E_γ (keV)	I_γ (%)
^{110}Ag^{m}	5995.92	657.76	95.61
^{115}In^{m}	4.486	336.241	45.9

The proton beam was continuous, thus to obtain the spectrum averaged neutron energies at the three proton energies, we used EPEN code [3]. To study neutron flux we have used Indium (thickness = 0.1mm) as monitor foil. Both the monitor foil and target were wrapped in aluminum foil of thickness 0.014mm individually and placed afore beam [4]. The current during irradiation was ~ 30 nA. The target was irradiated for 24 hours for all three energies. After completion of this process, they were cooled and transferred to the counting room.

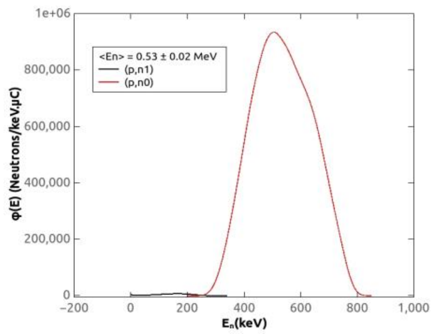

Fig. 1 Neutron flux energy spectrum corresponding to E_p= 2.5 MeV obtained from the EPEN code.

Data Analysis

We have used offline gamma ray spectroscopy technique for counting purpose [5]. The gamma-ray activity was measured using a pre-calibrated lead-shielded High-Purity Germanium (HPGe) detector [6]. The efficiency calibration was done using the ^{152}Eu point source ($T_{1/2}$=13.517 years of known activity A_0 = 6614.71 Bq as on 1 Oct. 1999). Details of decay data were obtained from the NNDC library. The efficiency of point source for source-detector distance 6 mm was calculated by following formula: -

$$\epsilon_p = \frac{CK_c}{A_o I_\gamma \Delta t e^{-\lambda t}} \quad [7]$$

To acquire reference monitor cross section we have used ^{115}In(n,n'γ)^{115m}In as monitor reaction. The cross section was estimated using the following equation: -

$$<\sigma_s> = <\sigma_m> \eta \frac{A_s \lambda_s a_m N_m I_m f_m}{A_m \lambda_m a_s N_s I_s f_s} \times \frac{N_{Corr(s)} C_{attn.(s)}}{N_{Corr(m)} C_{attn.(m)}} \quad [8]$$

where all the above symbols in above equation have their usual meaning.

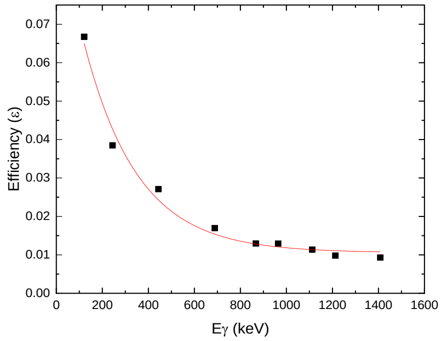

Fig. 2 Efficiency calibration curve

Computational details

We have used the statistical nuclear model code TALYS-1.96 for the theoretical calculations of the reaction. The present experimental data has been compared with the existing cross sections data available in the TALYS- generated Evaluated Nuclear Data Libraries (TENDL-2019), IRDFF-II, Japanese Evaluated Nuclear Data Library (JENDL/AD) and IRDF-2002G. Different level density models were used to rationalize the result [9].

Results and Discussions

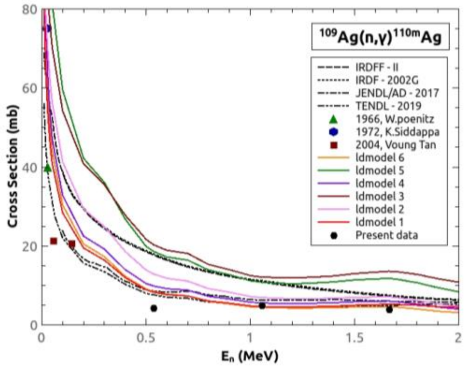

Fig. 3 Cross sections measured in present work and its comparative studies

The preliminary results of cross section are presented in Fig.3. The theoretical results predicted by TALYS by using ldmodel-6 is in good agreement with the present data.

More details about the cross section and uncertainty quantification will be presented during the conference.

Acknowledgements

We admiringly acknowledge the cooperation of the FOTIA facility staff. One of the authors (A. Kumar) would like to thank the Institutions of Eminence (IoE) BHU [Grant No. 6031].

References

[1] E. E. Peters *et al.*, Physical Review C **99**, 064321 (2019)

[2] J. R. Vanhoy *et al.*, Nuclear Physics A **939**, 121-140 (2015).

[3] Rebecca Pachuau *et al.*, Nuclear Science and Engineering **187**, 70 (2017)

[4] A. Gandhi *et al.*, Physical Review C **102**, 014603 (2020).

[5] Dimitar N. Grozdanov *et al.*, Physics of Atomic nuclei **81**, 588-594 (2018)

[6] S. Mukhopadhyay *et al.*, Physical Review C **99**, 014313 (2019)

[7] Rebecca Pachuau *et al.*, Nuclear Physics A **992**, 121613 (2019)

[8] A.Gandhi *et al.*, European Physical Journal A **57**, 1 (2021).

[9] A. Gandhi *et al.*, Indian Journal of Physics **93**, 1345 (2019).