Measurement of neutron induced reaction cross-section on ^{115}In at the neutron energy of 14.96 ± 0.03 MeV

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Introduction

Neutron induced reaction cross sectional data is crucial for, nuclear engineering applications - particularly in fission and fusion reactors, and nuclear technologies such as Advanced Heavy Water Reactor [1]. Indium (In) is one of the materials that are being used in the control rod of the reactor. Moreover, the reaction cross section data also is necessary for developing 'Evaluated Data Libraries', and the validation of different theoretical models such as Talys-2.0 [2]. Neutron induced reaction of Indium (In) has been widely utilized in the measurement of neutron flux. ^{115}In(n,2n)^{114m}In reaction is employed in radiation dose assessment and activation studies due to significant cross sections of ^{115}In and ^{113}In from threshold up to 25 MeV neutron energy. Despite, the fact numerous sets of experimental data around 14 MeV has been reported, still there is a lot of discrepancy for more accurate measurements for cross section of In.

The prime objective of this study is to determine cross section of the ^{115}In(n,α)^{112}Ag and ^{115}In(n,2n)^{114m}In reactions at neutron energy 14.96±0.03 MeV, using offline gamma (γ) ray spectroscopy technique. Furthermore, Measured cross section data is compared with the previous literature data [3], evaluated files [4] such as JENDL-5, ENDF/B-VIII.0, JEFF-3.1/A, TENDL-2023 and also different ldmodels of Talys-2.0.

Experimental Details

The experiment was performed at Neutron and Ion Irradiation Facility at Institute for Plasma Research (IPR), Gandhinagar, India. Neutrons were generated via deuterium and tritium (DT) fusion reaction with deuteron beam of 200 keV and beam current of 2.5 mA where deuterium ions (D^+) were accelerated using DC electrostatic accelerator [5] on the stationary Titanium Tritide (TiT) target with yield of 8.35 × 10^9 n/s.

Natural Indium (In) sample foil (purity: 99.99%) of thickness 0.148 cm was irradiated for 4 hours under the neutron flux [6] of 1.68 × 10^8 n/(cm^2.sec). Aluminium (Al) (purity: 99.99%) foil of thickness 0.025 cm was used as flux monitor. The stack of Al-In foil was placed at 0° in front of the incident neutron beam. Activity produced in In and Al was measured at a distance of 3 cm with a calibrated High Purity Germanium (HPGe) detector with a relative efficiency ≥50% and resolution of ≤2.1 keV FWHM at 1.33MeV. ^{152}Eu was the standard source used to determine the efficiency and energy calibration of the HPGe detector. Detailed information of Irradiation time, cooling time and counting time of monitor reaction and irradiated sample are given in Table 1.

Table 1: Details of experiment

	^{115}In(n,α)	^{115}In(n,2n)	^{27}Al(n,α)
Irradiation time (s)	14400	14400	14400
Cooling time (s)	4695	63507	902.05
Counting time (s)	14400	6580	101.12

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The reaction cross section was determined using ratio method given in Eq. (1)

$$\sigma_r = \frac{\sigma_m A_r \lambda_r N_m \varepsilon_m I_m f_m C_r}{A_m \lambda_m N_r \varepsilon_r I_r f_r C_m} \qquad (1)$$

where r subscript stands for sample reaction and m subscript stands for monitor reaction. A is the detected counts of the gamma ray, λ is decay constant, N is the number of nuclei, ε is the efficiency for the characteristic gamma ray of the radionuclide, I is gamma ray abundance, f is time factor, c is the correction factors for self-absorption of gamma ray, neutron flux variation and counting geometry.

Results and Discussion

In present study, the cross section for $^{115}In(n,\alpha)^{112}Ag$ and $^{115}In(n,2n)^{114m}In$ reactions is estimated relative to the $^{27}Al(n,\alpha)^{24}Na$ monitor reaction at neutron energy 14.96 ± 0.03 MeV using neutron activation technique and off-line gamma ray spectroscopy given in Table 2. The cross section is also compared with data from EXFOR [3], evaluated data libraries [4] and also with the data predicted using different ldmodels of Talys-2.0 [2] presented in Fig. 1 and 2.

Table2: Details of measured cross section of $^{115}In(n,\alpha)^{112}Ag$ and $^{115}In(n,2n)^{114m}In$ reactions.

Cross section (b) at neutron energy 14.96 ± 0.03 MeV	
Reaction	Measured
$^{115}In(n,\alpha)^{112}Ag$	0.0026±0.0001
$^{115}In(n,2n)^{114m}In$	1.1946±0.0762

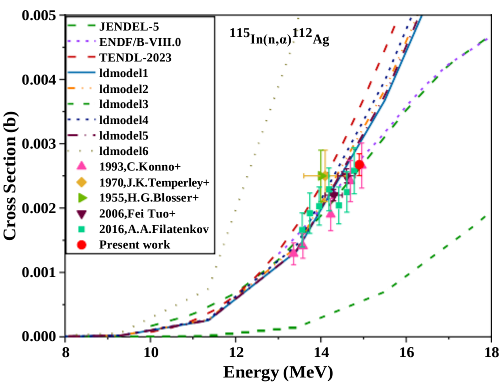

Fig 1: Plot for $^{115}In(n,\alpha)^{112}Ag$ reaction cross section along with EXFOR data, ENDF data and theoretical code.

The measured cross section values for both the reactions have the uncertainty in the range from 4 to 6%. As shown in Fig. 1, there is a scarcity in cross section data for $^{115}In(n,\alpha)^{112}Ag$ reaction in between 13 to 15 MeV energies. The measured cross section is in good agreement with the reported data by C. Konno et al. (1993) which has uncertainty of ~13.2 %. The measured cross section is also in good agreement with JENDL-5 and ENDF/B-VIII.0 data. Similarly, for $^{115}In(n,2n)^{114m}In$ reaction, the measured cross section is in good agreement with the reported data from H. O. Menlove et al. (1967) [3] which has uncertainty of ~10.8 %. The measured cross section is also in good agreement with the data predicted using ldmodel 3 of TALYS 2.0 code.

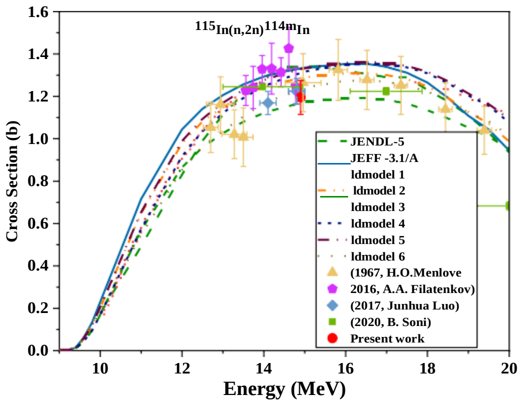

Fig 2: Plot for $^{115}In(n,2n)^{114m}In$ reaction cross section along with EXFOR data, ENDF data and theoretical code.

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References:

[1] C.D. Bowman et al. Annu. Rev. Nucl. Part. Sci. 48:505-56 (1998).
[2] A.J. Koning et al. Eur. Phy. J.A, 59:146 (2023).
[3] https://www-nds.iaea.org/exfor/
[4] https://www-nds.iaea.org/exfor/endf.htm
[5] M. Abhangi et al. Fusion Engineering and Design 204 (2024).
[6] R.K. Singh et al. Phy. Rev. C 107 (2023).