Measurement of the $^{115}In(n,2n)^{114m}In$ reaction cross-section using the quasi-monoenergetic neutrons

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Introduction

Indium (In) is being used over the years for the measurement of the neutron flux for the calculation of nuclear reaction cross-section data as the (n, n') and (n, 2n) reaction cross-sections of the ^{113}In and ^{115}In isotopes have significant values from threshold to 25 MeV neutron energies. The In isotopes also serve the purpose for the activation studies and dosimetry applications [1]. It can be seen from the compilation of the EXchange FOrmat (EXFOR) [2] data library that, there is a numerous amount of cross-section data available for the $^{115}In(n,2n)^{1114}In$ reaction from threshold to 20 MeV neutron energies, that have large mutual discrepancies. Therefore, it is crucial to perform precise measurement of the cross-sections for different neutron-induced reactions for the In isotopes. The current work presents the measurement of the (n, 2n) reaction cross-section for the ^{115}In isotope at average neutron energy of 20.12 MeV using the quasi-monoenergetic neutrons produced from the $^7Li(p,n)$ reaction. The above mentioned reaction cross-section was also compared with literature data from taken EXFOR [2], ENDF-B/VIII.1 [3], JENDL-4.0 [4], and the theoretical model code TALYS-1.9 [5]. The different level density models (ld-model 1-6) included in the TALYS-1.9 model code were also tested for the better description of the present and the literature data.

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Experimental Details

The experiment was performed using the 14UD Pelletron facility at Bhabha Atomic Research Centre-Tata Institute of Fundamental Research (BARC-TIFR) Mumbai, India, using the activation and following the off-line γ-ray spectroscopy. The neutrons of the desired energy were generated using the $^7Li(p,n)$ (E_{th} = 1.88 MeV) reaction with a proton beam of 22 MeV. A Lithium (Li) foil of thickness $\approx 7\ mg/cm^2$ was used in between the two Tantalum (Ta) foils of thicknesses $\approx 3\ mg/cm^2$ in front of the Li and $\approx$ 0.1 mm at the back of the Li to stop the proton beam. The In (sample) foil of thickness $\approx$ 0.1 mm was used together with the Aluminum (monitor) foil of similar thickness for the irradiation. The Ta-Li-Ta stack with the sample and monitors wrapped in a thin aluminum foils were then irradiated for about 5-6 hours at the 6 meter port of the main beam line of the Pelletron. The area of both the monitor and the sample foils were taken as $1\times1\ cm^2$ in order to avoid the area corrections in flux. After the irradiation, the samples were allowed to cool for a sufficient time to accumulate the high dose of radiation. The sample as well as the monitor were then counted using a pre-calibrated 80 cc single crystal HPGe detector coupled with a PC based 4K multi-channel analyzer. The energy and efficiency calibration of the detector was done by using a standard ^{152}Eu source. The resolution of the detector system was measured as 1.88 keV during the counting.

The dead time the detector was kept $< 2\%$ by placing the samples at an appropriate distance from the detector head.

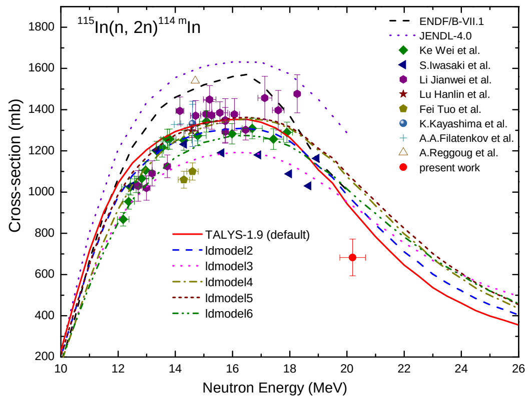

FIG. 1: Comparison of the present result with the literature data and the theoretical predictions using TALYS-1.9 [5] code.

Data Analysis

A detailed discussion has been given elsewhere [6] for the generation of the neutron spectra using the $^{7}Li(p,n)^{7}Be$ reaction. The $^{27}Al(n,\alpha)^{24}Na$ reaction was used to evaluate the neutron flux. The decay statistics of the 1368.68 keV γ-line of the ^{24}Na ($t_{1/2} = 14.997$ hours) were used for the calculation of the neutron flux using the weighted $^{27}Al(n,\alpha)$ reaction cross-sections from the ENDF-B/VII.1 [3] evaluated data library. Using the calculated neutron flux, the cross-section for the $^{115}In(n,2n)$ reaction has been calculated using the decay statistics (C_{obs}) of the 190.27 keV γ-line of the ^{114m}In ($t_{1/2} = 49.51$ days) in the following relation,

$$\sigma_R = \frac{C_{obs}(C_L/L_T)\lambda(e^{\lambda T_c})}{N_0\epsilon I_\gamma \phi K(1-e^{-\lambda T_i})(1-e^{-\lambda T_{LT}})} \quad (1)$$

where all the symbols have their usual meanings. A tailing correction [6] was applied to the measured reaction cross-section to discard the contributions from the lower energy neutrons. The uncertainty in the present measurement was calculated using the error propagation method [7] and was found to be 12.8%.

Result and Discussion

The cross-section for the $^{115}In(n,2n)^{114m}In$ reaction at average neutron energy of 20.12 ± 0.45 MeV was measured as 682.9 ± 88.4 (mb). A comparison of the present result with the literature data from the EXFOR [2], theoretical code using the TALYS-1.9 [5] and the evaluated data from the JENDL-4.0 [4] library are plotted in Fig. 1. It can be seen from the figure that the measured cross-section is in agreement with the trend of the literature data. However, the present result shows a value lower than the TALYS-1.9 prediction. The different ldmodels from the TALYS-1.9 were also found to be successful in order to reproduce the reaction cross-section data and were found to fit the literature data to an acceptable degree. On the other hand, the ENDF-B/VII.1 and the JENDL-4.0 evaluated data libraries were also found in agreement with the literature data up to 20 MeV neutron energies.

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