Excitation function of the ^{71}Ga(n,γ)^{72}Ga reaction cross section in the incident neutron energy range 0.6-3.1 MeV

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Introduction

With respect to the production of radioisotopes, the neutron capture reaction cross sections are of great importance in nuclear reactors. Measurements of the radiative capture cross sections of fast neutrons have provided valuable information about a nuclear structure such as the dependence of level spacing on excitation energy and on nucleon number, and the effects of closed shells and of even or odd numbers of protons and neutrons on level spacing [1]. There have been several measurements of the ^{71}Ga(n,γ)^{72}Ga reaction cross section in the EXFOR library but there is no report on the uncertainty propagation and covariance analysis in the fast neutron energy region. In order to study the variation of the capture cross section with energy, it is most convenient to use an accelerated-particle source. Hence, the purpose of the present work is to study the excitation function of the ^{71}Ga(n,γ)^{72}Ga reaction cross section in the fast neutron energy region using the activation technique. Detailed uncertainty propagation and covariance analysis will be reported.

Experimental details

The experiment was performed using the FOTIA neutron facility at Bhabha Atomic Research Center (BARC), Mumbai. The neutron source was based on the charged particle accelerator source in which the proton beam was accelerated with energies 2.6, 4.0 and 5.0 MeV and current 90-100 nA and produces neutron using the ^{7}Li(p,n)^{7}Be reaction. Since the proton beam was continuous, the neutron energy spectrum code EPEN [2] was used to obtain the spectrum averaged neutron energies at the three proton energies. The neutron flux was calculated using the ^{115}In(n,inl)^{115}In^{m} reaction and it was found to be 10^{6} n/cm^{2}/s. Fig. 1 shows the neutron flux energy spectrum for the activated sample placed at 1 cm from a lithium target calculated by EPEN at proton energy 5 MeV.

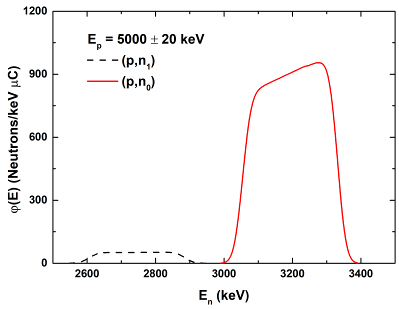

FIG. 1: Neutron flux energy spectra at proton energy 5 MeV.

A natural gallium lump (manufactured by Goodfellow Cambridge Limited) of purity 99.9999% was wrapped with a 0.025-mm thick super-pure aluminium foil. The indium metal foil was utilised as a relative sample for normalising the neutron flux by using the IRDFF-1.05 library's known cross section value for the ^{115}In(n,inl)^{115}In^{m} reaction.

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TABLE I: Nulear decay data properties of residue products used for the sample and monitor.

Residue	Half-life	E_γ (keV)	I_γ (%)
^{72}Ga	14.10 ± 0.02 h	834.13	95.45 ± 0.08
^{115}In^m	4.486 ± 0.004 h	336.24	45.9 ± 0.1

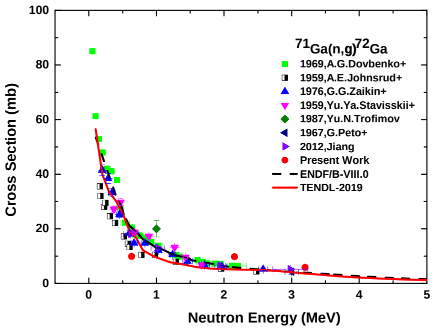

FIG. 2: Experiment result for ^{71}Ga(n,γ)^{72}Ga reaction.

After irradiation of the sample (6 hours) and sufficient cooling, the radioactive gallium and aluminium samples were transferred to the counting room. The gamma-ray activity was measured using a precalibrated lead-shielded 185-cc High-Purity Germanium (HPGe) detector having 30% relative efficiency and 1.8 keV energy resolutions at 1.33 MeV gamma energy. The data acquisition was carried out using CAMAC-based Linux Advanced Multiparameter System software (TCAMCON-95/CC 2000 crates controller and CM-48 ADCs), where the detector dead time was negligible. The efficiency calibration of the HPGe detector system was done using the photo-peak counts of 11 gamma lines of ^{152}Eu point source (T$_{1/2}$=13.517 years [3] of known activity (A$_0$=6659.21 Bq as on 1 Oct. 1999). Details of decay data adopted in the present work were obtained from the ENSDF library. The cross section was determined using the well-known standard Neutron Activation equation

$$\sigma_s = [\sigma_m][\eta]\frac{A_s I_m}{A_m I_s}\frac{\lambda_s f_m}{\lambda_m f_s}\frac{a_m N_m}{a_s N_s}\frac{N_{cor(s)}.C_{ab(s)}}{N_{cor(m)}.C_{ab(m)}} \quad (1)$$

and the timing factor $f_{s,m}$ parameters calculated by the following equation

$$f_{s,m} = [1-e^{-\lambda t_{irr}}]\times(e^{-\lambda t_{coo}})\times[1-e^{-\lambda t_{ms}}] \quad (2)$$

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

Results and Discussions

The preliminary results of the ^{71}Ga(n,γ)^{72}Ga reaction cross sections are presented in Fig. 2 in comparison with existing data and evaluated nuclear data. More details about the data analysis procedure of cross sections and uncertainty propagation will be presented during the conference.

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References

[1] A. E. Johnsrud *et al.*, Physical Review **116** 927 (1959).
[2] Rebecca Pachuau *et al.*, Nuclear Science and Engineering **187** 70 (2017).
[3] M. J. Martin Nucl. Data Sheets, **114** 1497 (2013).