Measurement of ^{71}Ga(n,γ)^{72}Ga cross section at thermal energy using dual monitors

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Introduction

Neutron capture thermal cross section is one of the important low energy neutron data. As per the literature survey, most of the thermal cross sections of ^{71}Ga measured using the reactor neutron spectra are between 4.1 and 4.9 b. Many evaluated data libraries adopt in their latest version these experimental results [1]. However the latest version of the JENDL library (JENDL-4.0) [2] supports the thermal neutron cross section determined with the monoenergetic cold neutrons with a Christian filter (0.56±0.01 meV), which is 3.67±0.10 b [3]. In the present study the neutron capture thermal cross section of the ^{71}Ga(n,γ)^{72}Ga reaction is measured using neutron activation technique in a neutron field from an Am-Be source. The off-diagonal means were determined from the two measurements with dual monitor foils (^{197}Au and ^{55}Mn) based on a detailed covariance analysis.

Experimental

The neutron source facility at Manipal Centre for Natural Sciences contains an Am-Be source that emits 4×10^7 neutrons per second in 4π direction and is kept inside a concrete bunker[4].Analytical grade Ga_2O_3 powder with purity of 99.995% was used as the sample material. The powder samples were prepared in small packets. Mn (Mn(83 wt%)-Cu) foil and Au foil with purity 99.9% were used as the monitors. All samples were having a diameter of ≈ 12 mm. The samples were irradiated in the neutron beam with and without Cd cover. The half-lives of the product nuclei are 2.57 h (^{56}Mn), 14.10 h (^{72}Ga) and 2.6 d (^{198}Au). This Cd-cut off method is used to eliminate the contribution from epithermal neutrons (> 0.5 eV).The induced activity in each foil after irradiation was counted using a well shielded and pre-calibrated 30% efficiency HPGe (Bruker Baltic) detector having an energy resolution of 0.25% at 1.33 MeV.
The areas under each of the gamma peaks (C) of interest are used to estimate the reaction rates as shown below.

$$R = \frac{CTMf}{N_A\theta\epsilon I_\gamma m} \quad (1)$$

with

$$T = \frac{\lambda}{(1-e^{-\lambda t_i})e^{-\lambda t_d}(1-e^{-\lambda t_c})}, \quad (2)$$

where M is the molar mass, f is the gamma attenuation factor, N_A is the Avogadro constant, θ is the isotopic abundance, ϵ is the detector efficiency, I_γ is the gamma intensity, m is the sample mass, λ is the decay constant of the capture product, t_i is the irradiation duration, t_d is the cooling time, and t_c is the counting time.

The neutron capture thermal cross sections of the sample $\sigma_{0,S}$ was determined from the reaction rates of the bare (R) and Cd covered (R_{Cd}) by

$$\sigma_{0,S} = \frac{[R - R_{Cd}/F_{Cd}]_S}{[R - R_{Cd}/F_{Cd}]_M}\frac{[G_{th},g]_M}{[G_{th},g]_S}\sigma_{0,M}, \quad (3)$$

where $\sigma_{0,M}$ is the thermal cross section of the monitor reaction, and G_{th} is the thermal self-

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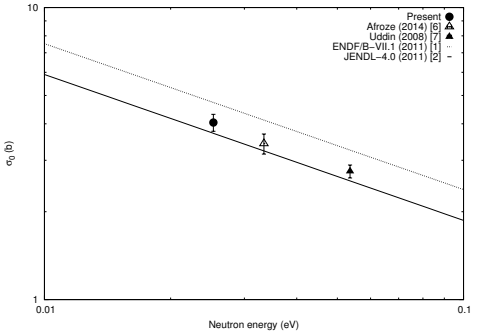

FIG. 1: Energy dependence of the ^{71}Ga(n,γ)^{72}Ga thermal cross sections in the thermal neutron energy region.

shielding factor.The subscripts S and M represent sample and monitor respectively. The off-diagonal weighted mean [5] of these two estimates are reported as final values. In the present work, the cross sections are estimated with two reference monitors. Hence, the detailed uncertainty and covariance analysis is essential to avoid underestimation of the uncertainty in their mean value.

Results and Discussions

The newly determined ^{71}Ga thermal neutron capture cross sections with the monitors ^{197}Au and ^{55}Mn are consistent each other. Their off-diagonal weighted mean is calculated and included in the Fig.1. We have made a careful treatment of various sources of uncertainties. The uncertainty is improved less in off-diagonal weighted mean because the same ^{72}Ga activity counting result is used in two estimations. The uncertainty in the present thermal capture cross section is higher than many of the earlier measurements mainly due to inclusion of various sources of the uncertainties in our uncertainty propagation.

The present result is lower than various experimental values as well as the various evaluations, but closer within the uncertainty to the JENDL-4.0 [2] which adopts Koester et al.'s cross section. The cross section estimated in the present study is compared with two experimental works reporting the ^{71}Ga(n,γ)^{72}Ga cross sections by using monoenergetic neutrons between the thermal neutron energy and 0.1 eV [6, 7] in Fig.1.This figure shows that their cross sections are consistent with our new cross section as well as JENDL-4.0 considering the $1/v$ dependence.

Conclusions

We measured the ^{71}Ga(n,γ)^{72}Ga thermal cross section using neutron activation by neutrons from an Am-Be source moderated by a concrete bunker. The results obtained with the Au and Mn monitor foils are consistent. The off-diagonal weighted mean is estimated by taking account the covariance between the preliminary results from two monitor foils and thus avoiding the underestimation of uncertainty in their mean value. The newly obtained thermal cross section compares better with those determined with mono-energetic neutron sources as well as the JENDL-4.0 library.

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