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Excitation function and covariance analysis of ^{nat}Cu(α,x)^{67}Ga nuclear reaction

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Introduction

The data on neutron and charge particle induced reaction on different target is impoartent for the study of investigation of nuclear physics phenomena such as nuclear reaction dynamics, astrophysical process of nucleosynthesis and element formation [1, 2]. The applications of radionuclides in nuclear medicine are increasing significantly, and ^{67}Ga is one of such radioisotopes used in nuclear medicine for various types of human tumors and inflammatory lesions. The ^{67}Ga radioisotope has a half-life of 3.26 days and emits γ-ray of 300.22 keV.

In the present study, we have measured the excitation function for the nuclear reaction ^{nat}Cu(α,x)^{67}Ga in the energy range 15-37 MeV. The excitation functions are compared with the available experimental data from EXFOR data library and the theoretical prediction from TALYS nuclear reaction code. The TALYS nuclear reaction code is based on Hauser-Fesbach statistical model and has separate options for level density as well as optical model parameters [3–5]. A detailed uncertainty propagation and covariance analysis of the measured reaction cross-section data have also been performed in this study.

Experimental Details

The experiment was performed at the K-130 cyclotron at VECC, Kolkata, India. We have used the stacked foil activation technique followed by the offline gamma-ray spectroscopy using HPGe detector. Thin metallic foils of ^{nat}Cu, ^{nat}Al and ^{nat}Ti were used. The thickness of Cu, Al and Ti foils were 6.27 mg/cm^2 , 13.5 mg/cm^2 and 1.80 mg/cm^2 respectively. Two different stacks were irradiated to cover the energy range from threshold energy up to 37 MeV. The efficiency of the HPGe detector has been calculated for different gamma-rays energy using the standard ^{152}Eu point source.

RESULT AND DISCUSSION

The nuclear reaction cross sections were calculated using the following standard activation formula;

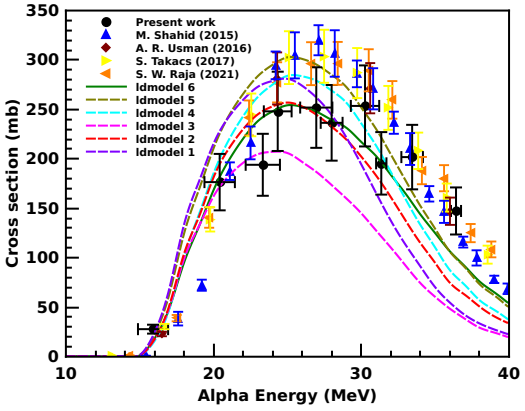

FIG. 1: The measured cross sections of reaction ^{nat}Cu(α,x)^{67}Ga along with available experimental data from EXFOR and theoretical results from TALYS.

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TABLE I: Cross sections for ^{nat}Cu(α,x)^{67}Ga reaction from this study with uncertainties and covariance matrix.

E_α (MeV)	Cross-section (mb) ($\sigma \pm \triangle\sigma$)	Covariance matrix									
15.90 ± 1.02	27.86 ± 4.50	20.2									
20.41 ± 1.03	176.53 ± 28.53	120.5	814.3								
23.33 ± 1.16	194.06 ± 31.33	132.3	838.4	981.6							
24.34 ± 0.94	248.10 ± 40.08	169.2	1072.8	1177.7	1607.1						
26.95 ± 1.09	251.93 ± 40.73	171.9	1089.9	1199.6	1531.1	1659.4					
27.99 ± 0.74	326.49 ± 38.25	161.4	1096.4	1203.7	1540.3	1564.9	1468.8				
30.25 ± 0.96	253.58 ± 40.97	173.0	1096.4	1203.7	1540.3	1564.9	1468.8	1678.7			
31.35 ± 0.35	195.52 ± 31.59	133.3	844.8	927.5	1186.9	1205.8	1131.8	1213.0	997.9		
33.44 ± 0.73	201.84 ± 32.61	137.6	872.4	957.8	1225.6	1245.2	1168.7	1252.6	965.2	1063.6	
36.41 ± 0.34	147.37 ± 23.79	100.4	636.6	698.9	894.3	908.6	852.8	914.1	704.3	727.3	566.2

$$\sigma = \frac{C_\gamma \lambda}{\varepsilon(E_\gamma) I_\gamma \phi N_t e^{-\lambda t_c}(1 - e^{-\lambda t_{irr}})(1 - e^{-\lambda t_m})} \quad (1)$$

In the above formula [6], the peak area counts is C_γ of a particular γ-ray with it's abundance (I_γ), $\varepsilon(E_\gamma)$ is the detector efficiency, λ is the decay constant (s^{-1}), N_t ((cm^{-2})) is the particle density in the target material, ϕ is the incident particle flux per unit time(s^{-1}).

The covariance matrix [7–11] of cross-sections I_σ can be written as;

$$I_\sigma = H_x C_x H_x^T \quad (2)$$

Where I_σ is the covariance matrix of the measured reaction cross-sections, C_x is the covariance matrix of different attributes used in the activation formula (equation 1), H_x is the sensitivity matrix.

The measured cross-section as a function of the incident alpha energy for the nuclear reaction ^{nat}Cu(α,x)^{67}Ga with the available experimental data from the EXFOR and the TALYS calculation are shown in Fig.1. The γ-ray of energy 300.22 keV and intensity of 16.64 % was used to measure the cross section for ^{nat}Cu(α,x)^{67}Ga reaction. The present experimental data for this reaction are found to be in good agreement with the available experimental data from EXFOR. Also, we can see from Fig.1 that the present experimental data of this nuclear reaction are found in good agreement with the theoretical results by using ldmodel-4.

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