Cross section measurement for (n,α) and (n,$2n$) reactions with covariance analysis

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Introduction

Nuclear reactions involving neutron either as projectile or ejectile are of particular interest for the application part as well as for understanding the nuclear reactions processes [1–10]. Neutron induced reactions cross section is the quantitative attribute of the nuclear processes that can reveal features of the excited atomic states as well as it also provides information about the different reaction mechanisms which are dependent on the incident neutron energy. Neutron activation is the most commonly used technique to quantify the cross section. The study of the fast neutron induced reaction cross sections in the energy range of roughly 14 MeV is critical for the advancement of fusion reactor technology in terms of activation, radiation damage, and mechanical stability of the construction materials. The elements potassium and copper were chosen for this investigation because both are essential structural materials and are commonly employed in reactor construction.

Experimental details and Data analysis

The neutron irradiation for this experiment was done at the Bhabha Atomic Research Center (BARC)'s PURNIMA neutron generator facility in Mumbai. The t(d,n)α fusion process was used to create the neutrons in which the d^+ ions with energy 140 $\pm$ 5 keV having current 60 μA were accelerated and

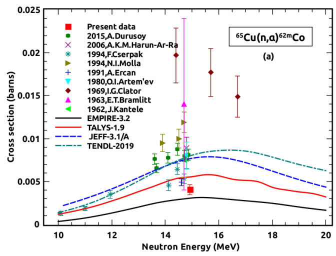

FIG. 1: Experiment result for ^{65}Cu(n,α)^{62m}Co reaction.

hit on a Ti-T (Titanium-Tritide) target, creating neutrons in the advancing direction with a flux value of 9.42$\times$10^7 n/cm^2/s on the sample. The energy of neutrons and associated uncertainty were calculated using the two-body kinematics.

TABLE I: Decay data with associated uncertainties used for the samples and reference reactions.

Residue	Half-life	E_γ (keV)	I_γ (%)
^{62m}Co	13.86 $\pm$ 0.09 min	1163.50	70.5 $\pm$ 1.4
^{38}Cl	37.230 $\pm$ 0.014 min	1642.68	32.9 $\pm$ 0.5
^{64}Cu	12.701 $\pm$ 0.002 hr	1345.77	0.475 $\pm$ 0.011
^{24}Na	14.997 $\pm$ 0.012 hr	1368.62	99.9936 $\pm$ 0.0015

We used a copper metal sheet having dimension 1.0$\times$1.0 cm^2 and thickness 0.0125 cm and same was wrapped in an aluminium foil for irradiation purpose. This aluminium foil was utilised as a relative sample for the normalising neutron flux by using the IRDFF-1.05 library's known cross section value for the ^{27}Al(n,α)^{24}Na reaction. A pure K_2SO_4 powder was taken for the potassium irradiation having a diameter of 1 cm and thickness of 0.2 cm.

After the completion of neutron irradiation

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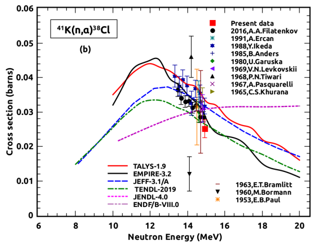

FIG. 2: Experiment result for ^{41}K(n,α)^{38}Cl reaction.

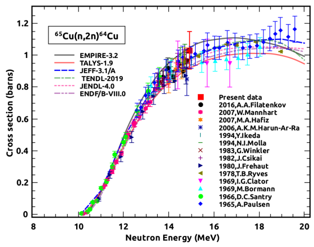

FIG. 3: Experiment result for ^{65}Cu(n,$2n$)^{64}Cu reaction.

and sufficient cooling, the induced activity of gamma rays counting were done with the lead-shielded HPGe detection system. The decay data properties used in the data analysis are provided in Table-I. The detailed information related to the calibration and efficiency calculation of the HPGe detector, including its uncertainty quantification, coincidence summing-effect are explained in our previous work [8]. The parameters and their correlation coefficients as given in Section II.(C) of Ref. [8] were used for the detector efficiency calculations in the current measured work. These correlation coefficents have been further used to propagate the total uncertainty and correlation matrix between the different reactions cross section measured in the present work [8–10].

The following neutron activation formula was used for the cross section quantification:

$$\sigma_s = \sigma_{Al}[\frac{A_s \varepsilon_{Al} I_{Al}}{A_{Al} \varepsilon_s I_s}][\frac{\lambda_s f_{Al}}{\lambda_{Al} f_s}][\frac{a_{Al} N_{Al}}{a_s N_s}][\frac{C_{self(s)}}{C_{self(Al)}}] \tag{1}$$

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

$$f_{s,Al} = (1 - e^{-\lambda t_{ir}}) \times (e^{-\lambda t_{co}}) \times (1 - e^{-\lambda t_{ms}}) \tag{2}$$

where all the symbols in these above equation have their usual meaning.

Results and Discussions

Table-II summarizes the obtained cross sections of ^{65}Cu(n,α), ^{41}K(n,α) and ^{65}Cu(n,$2n$) reactions measured at incident energy 14.92 ± 0.02 MeV with their uncertainties and correlation matrix. The plots were also constructed to compare the current results with literature data, estimated results from EMPIRE & TALYS codes, and evaluated nuclear data files as shown in Figs. 1−3. More details about the data analysis of cross sections and uncertainty quantification will be presented during the conference.

TABLE II: Experimentally measured cross sections (in barns) with their uncertainties and correlation matrix.

Reaction	Present data [σ_s]	Correlation matrix		
^{65}Cu(n,α)^{62m}Cu	0.00404 ± 0.00059	1.0000		
^{41}K(n,α)^{38}Cl	0.02509 ± 0.00260	0.1451	1.0000	
^{65}Cu(n,$2n$)^{64}Cu	1.03082 ± 0.11776	0.1237	0.2119	1.0000

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