Estimation of cross-section and its covariance analysis for the alpha-induced reaction on ^{nat}Ni

Namrata Singh[1],* Mahesh Choudhary[1], A. Gandhi[1], Aman Sharma[1], Mahima Upadhyay[1], Punit Dubey[1], Nitin Dubey[1], Utkarsh Mishra[1], J. Datta[2], S. Dasgupta[2], and A. Kumar[1]†
[1]*Department of Physics, Banaras Hindu University, Varanasi - 221005, INDIA and*
[2]*Analytical Chemistry Division, BARC,*
Variable Energy Cyclotron Center, Kolkata - 700064, INDIA

Introduction

Nuclear data are important for the application of nuclear reactors and protection of accelerator facilities [1-6]. At present time, radioisotopes are used extensively in medical diagnosis and therapy. The radioisotope ^{65}Zn ($t_{1/2} = 244.26d$, $E_\gamma = 1115.5$ keV (50.6%)) is used extensively in medical, biomedical, and agricultural research. It is also used in industry and metrology.

Nickel is an important material used in accelerator and nuclear technology [7]. It is one of the most frequently used structural material and its activation reaction cross-sections data are important when used in nuclear and space equipments. Excitation functions were measured for $^{nat}Ni(\alpha, x)$ reactions from 19-40 MeV. The excitation functions were compared with the experimental data from EXFOR and also with the theoretical data using TALYS-1.9.

Covariance analysis is a mathematical technique, used to correlate different measured quantities and describe specific experimental uncertainties. According to the principle of covariance, the formulation of physical laws can be done using measurements of physically correlated quantities. The main objective of this measurement was to extend the activation cross section data for $^{nat}Ni(\alpha, x)$ reactions associated with covariance analysis.

Experimental Details

The experiment was performed using the K-130 cyclotron at Variable Energy Cyclotron Center (VECC), Kolkata, India. We have used the stacked foil activation technique followed by the offline gamma ray spectroscopy using HPGe detector.^{nat}Ni foils (99.9% purity) having the isotopic composition (^{58}Ni, ^{60}Ni, ^{61}Ni, ^{62}Ni and ^{64}Ni) were used as a target material. Similarly, ^{nat}Al (99.9% purity) and ^{nat}Cu (99.9% purity) were used in the stacks as the energy degrader and as a monitor, respectively. The thickness of Ni, Al and Cu foils were 10 mg/cm^2, 6.76 mg/cm^2 and 8.92 mg/cm^2 respectively. The stacked targets were made with 6 and 5 sets of Cu-Ni-Al foils (10 X 10 mm^2). The ^{nat}Cu foils were placed in front of the stack as a monitor to confirm the intensity and energy of the incident beam, while ^{nat}Al foils have been used to capture the product nuclides extracted from nickel foils. The Ni-Al foils were measured simultaneously to capture the recoil products and to calculate the nuclear reaction cross-sections of the products. Both stacked targets were irradiated for 4 hours by a 40 MeV and 28 MeV alpha beam with the average intensity of 150 nA.

Result and Discussion

In the present work, efficiency calibration [8-9] of the HPGe detector for different gamma ray energies has been calculated using a standard ^{152}Eu point source.

The geometry dependent efficiency (ϵ_p) of the point source for source-detector at a distance of 12.5 cm was estimated using the following equation:

$$\epsilon_p = \frac{CK_c}{A_o I_\gamma \Delta t e^{-\lambda t}} \qquad (1)$$

In the above equation, A$_0$ is the known activity of ^{152}Eu (A$_0$ = 39080 Bq as on 17 May 1982) point source, C is the number of counts

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*Electronic address: `namratasingh.jwala@gmail.com`

†Electronic address: `ajaytyagi@bhu.ac.in`

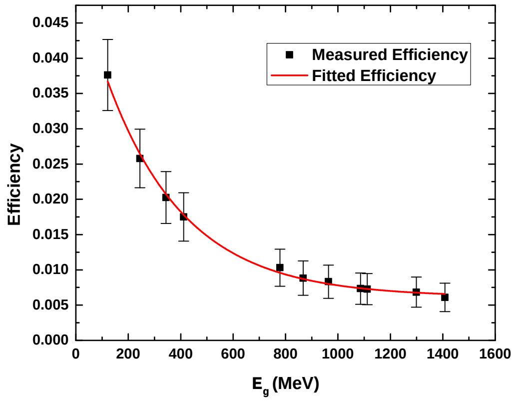

FIG. 1: Efficiency calibration curve of the HPGe detector calibrated at a distance of 12.5 cm from the source.

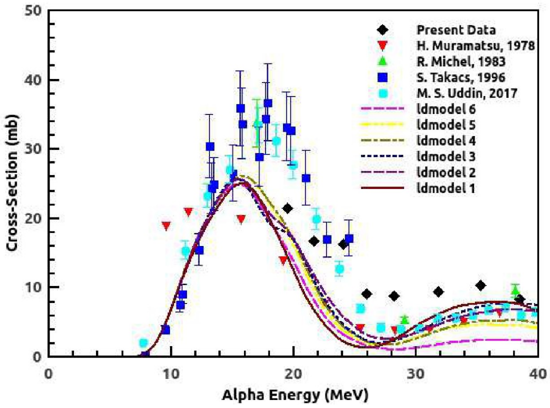

FIG. 2: Excitation function of $^{nat}Ni(\alpha,x)^{65}Zn$ reaction with literature data and the calculated values from TALYS-1.9.

taken in 10000 seconds for a γ-ray having absolute intensity (I_γ) and t is the lapse time between the date of manufacturing to the start of counting. The measured efficiency and the fitted efficiency curve are plotted in Fig. 1.

Production of ^{65}Zn radionuclide

The result of the present measurement and other experimental values reported in the literature of the reaction $^{nat}Ni(\alpha,x)^{65}Zn$ along with the theoretical calculations is shown in the Fig. 2. The measurement of the reaction cross-section of the $E_\gamma = 1115.57$ keV of ^{65}Zn ($t_{1/2} = 244.26d$) with intensity $I_\gamma = 50.06$ % was done after the cooling of 7 days. The nuclear reaction cross sections were calculated using the following activation formula:

$$\sigma = \frac{C_\gamma \lambda}{\epsilon_p I_\gamma D_t \Phi N_t e^{-\lambda t_c}(1-e^{-\lambda t_{irr}})(1-e^{-\lambda t_{count}})} \quad (2)$$

In the above formula, C_γ are the counts of the peak area of a particular $\gamma - ray$ with its abundance I_γ, ϵ_p is the detector efficiency with the dead time D_t, λ is the decay constant (sec^{-1}), N_t is the surface density of the target (cm^{-2}), ϕ is the number of the bombarding particles per unit time (sec^{-1}), t_c is the cooling time (sec^{-1}), t_{irr} is the irradiation time (sec^{-1}) and t_{count} is the counting time (sec^{-1}).

The details of the data analysis of the reaction cross sections and uncertainty quantification will be presented during the conference.

Acknowledgments

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