Excitation function of (p,n) reaction on ^{67}Zn

A. Patel[1], M. Hemalatha[1],* and S. Kailas[1,2]
[1] *UM-DAE Centre for Excellence in Basic Sciences, Mumbai - 400098, INDIA and*
[2] *Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

Introduction

Proton-induced reactions on medium-mass nuclei are of fundamental interest and useful for several applications. Recently, the radioisotopes ^{66,67,68}Ga have attracted much attention and are being widely used in the field of nuclear medicine. In the present work, we calculate the production cross section of ^{67}Ga via (p,n) reaction on ^{67}Zn using the statistical model. A detailed statistical model analysis has been carried out to describe the proton induced reactions over a range of energies and understand the major nuclear reaction mechanisms such as direct, pre-equilibrium and compound nuclear reactions. In carrying out the statistical model analysis, we have investigated the sensitivity of the data to the inputs like the proton and neutron optical model potential parameters, and level density parameters of nuclei involved. As a result of this study, we recommend the best parameters to be used in the statistical model analysis of the proton-induced reaction on ^{67}Zn for producing ^{67}Ga. For this purpose, the calculations were carried out using the latest TALYS-1.6 nuclear reaction code [1].

Statistical Model Analysis

The cross-section calculations for proton energies ranging from threshold energy (E_{th}=1.8 MeV) to 25 MeV were performed for (p,n) reaction on ^{67}Zn using the statistical model codes TALYS-1.6 [1] and EMPIRE-3.2 [2]. Here, the pre-equilibrium particle emission has been described using the exciton model while the Hauser-Feshbach theory takes into account the equilibrium particle emission [1]. The experimental information on nuclear masses, deformation, and low-lying spectra are considered, where available, and in cases where data are not available, local and global input models are incorporated to describe the nuclear structure properties, level densities, optical potentials and other inputs. The proton and the neutron optical model potentials considered here are from the global parameterization [3]. The cross section data for various reactions are taken from the EXFOR database [4]. In the compound and pre-equilibrium models, the level densities of the nuclei involved play a crucial role. The nuclear level densities can be calculated using phenomenological or microscopic prescriptions. We have calculated the level densities within the Back-shifted Fermi gas Model (BFM) using TALYS-1.6 code and Enhanced Generalized Superfluid Model (EGSM) using EMPIRE-3.2 [2] code. Both discrete and continuum levels for different nuclei are considered in the present work. These calculations are referred to as TALYS-default and EMPIRE-default, respectively.

There are several input parameters that can be adjusted to obtain better agreement with the data. The adjustable parameters in the level density formula [1] are the asymptotic level density parameter (a), shell damping parameter (γ), shell correction parameter (δW) and constant for pairing energy (K). The input parameters such as the depth of the potential, radius parameter and diffusseness parameter can be varied for the real and imaginary parts of the central and spin-orbit potentials. We have adjusted the above parameters and the results for the reaction ^{67}Zn(p,n)^{67}Ga are presented below.

Results

In the present work, we have calculated the cross section of reaction ^{67}Zn(p,n)^{67}Ga

*Electronic address: hema@cbs.ac.in

by varying a, γ, δW and K to obtain the best parameters that give better agreement to the corresponding data. We find that the values a = 14, γ = 0.03, δW = -5 and K = 30 are required to get better agreement with data. This calculation is referred to as TALYS-present. It is to be noted that the default values for a, γ, δW and K (TALYS-default) are 8.06, 0.10, 1.0 and 12, respectively. Using the above values fixed, we have checked the sensitivity of data to the real and imaginary parts of the central and spin-orbit potentials. Only the variation of the imaginary part of the central optical model potential was essential to get good agreement with data.

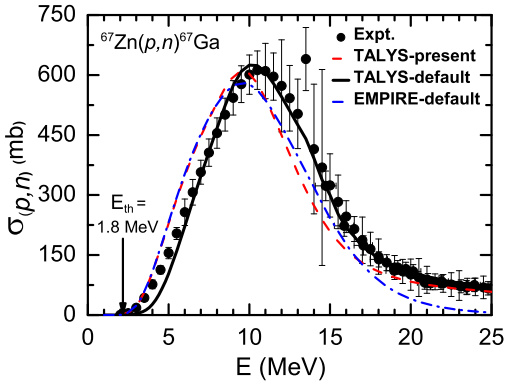

FIG. 1: Calculated excitation function for ^{67}Zn(p,n)^{67}Ga reaction obtained with best input parameters (TALYS-present). The cross sections calculated using TALYS-default and EMPIRE-default are also shown for comparison. The corresponding experimental values [5] are also plotted.

The calculated cross sections of the (p,n) reaction from threshold energy to 25 MeV for ^{67}Zn, using best parameters (TALYS-present) is shown in Fig. 1. The corresponding experimental values of (p,n) cross section [5] are also shown in the same figure. It is to be noted that only the data set recommended by IAEA nuclear data section [4] is considered here. The cross section calculations, TALYS-default and EMPIRE-default are plotted in Fig. 1 for comparison. It can be seen from the figure, that both the default calculations using TALYS and EMPIRE codes are similar to one another up to 18 MeV and both show a significant shift towards lower energies when compared with the data. Moreover, the EMPIRE-default cross sections are lower for higher energies (> 18 MeV). Clearly, the best parameters obtained from the present analysis using the code TALYS-1.6 show good agreement with the data at all energies. The calculated excitation function peaks at 11 MeV and is in good agreement with data.

In summary, we have investigated the excitation function of ^{67}Zn(p,n)^{67}Ga reaction with proton energies ranging from threshold to 25 MeV using the code TALYS-1.6 considering Back-shifted Fermi gas and two-component exciton models. We find that the level density parameter, shell damping parameter, constant for pairing energy and imaginary part of the central optical model potential are required to be adjusted to obtain good agreement with (p,n) cross-section data considered.

Acknowledgments

A.P. would like to acknowledge the financial support through the INSPIRE fellowship from Department of Science and Technology, Government of India. S.K. acknowledges the support from the Raja Ramanna fellowship of the Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India.

References

[1] A.J. Koning, and D. Rochman, Nucl. Data Sheets **113**, 2841 (2012) and references therein.
[2] M. Herman *et al.*, Nucl. Data Sheets **108**, 2655 (2007).
[3] A.J. Koning, and J.P. Delaroche, Nucl. Phys. **A 713**, 231 (2003).
[4] IAEA Nuclear data section, EXFOR data base, www-nds.iaea.org.
[5] F. Szelecsenyi *et al.*, Appl. Radiat. Isot. **49**, 1005 (1998).