Experimental nuclear level density of ^{69}Zn and its application in ^{68}Zn(n, γ) capture cross-section estimation

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Introduction

Nuclear level density (NLD) is an important ingredient in the statistical model description of compound nuclear (CN) reaction. In nuclear astrophysics, neutron capture reactions in s-process and r-process synthesis of nuclei heavier than iron, are often described using the statistical Hauser-Feshbach model [1,2], Along with NLD, the optical model potential(OMP) for particle transmission and γ-ray strength function for photon transmission are the input parameters of the model. However, these parameters are poorly constrained and suffer from systematic uncertainties introducing large discrepancy in the capture reaction rate [3].

In the present work, we studied the reaction ^{64}Ni(^{9}Be,αnγ)^{68}Zn and adopted a new experimental approach to extract the NLD of ^{69}Zn in the region above the n-threshold. Subsequently, the extracted NLD is used to estimate the n-capture cross section of ^{68}Zn(n,γ)^{69}Zn reaction. The technique is to populate ^{69}Zn in the continuum above the n-threshold through the compound nuclear reaction ^{64}Ni(^{9}Be,α)^{69}Zn. NLD is then extracted from evaporation α-particle spectrum gated with suitable γ-decay lines of ^{68}Zn produced in n-evaporation from ^{69}Zn* to segregate the pure CN contribution in α-spectrum. Extracted NLD parameter has been used in TALYS code [4,5] to obtain ^{68}Zn(n,γ)^{69}Zn capture reaction cross section.

Experimental details and analysis

The experiment was performed using ^{9}Be (30 MeV) beam (current~5 nA) from BARC-TIFR Pelletron Linac Facility, Mumbai. A self-supporting ^{64}Ni foil (~500 μg/cm^2 thick) was used as the target. Evaporation α-particles from CN reaction, were detected on both sides of the beam using CsI(Tl) detectors placed at angles covering a region from 22° to 67°. The de-exciting γ -rays of residual nucleus ^{68}Zn from ^{64}Ni(^{9}Be,αnγ)^{68}Zn were detected using the 14 Compton-suppressed Clover detectors placed at 40°, 90°, 140°, 115° and 157° with respect to the beam direction. Data recorded in list mode in a digital data acquisition system (DDAQ) based on Pixie-16 modules of XIA-LLC, which provides both energy and timing information. The data were sorted using Multi parameter time stamped based Coincidence Search programme (MARCOS) [6] to construct the α-γ matrix. From α-γ matrix we generated 1078, 332 and 152 keV γ-gated α spectrum which belong to ^{68}Zn residual nucleus. Except 1078 keV γ–line, 332 and 152 keV γ-s decay from unnatural parity (J^{π} = 6^- and 8^-) states in ^{68}Zn. The α spectra gated with these γ–lines are pure evaporation spectra as the 6^- and 8^- unnatural parity states can only be populated through CN reaction.

Results and Discussions

Alpha spectrum gated with 332 and 152 keV γ-rays are fitted with statistical model calculation with CASCADE [7] code. The fit is shown in

Fig.1. It is found that the contribution in the spectrum at E_n >12 MeV is mainly dominated by first step alpha evaporation from compound nucleus ^{73}Ge and hence it enables us to extract the level density. The Fermi gas model [8] NLD prescription used in CASCADE calculation.

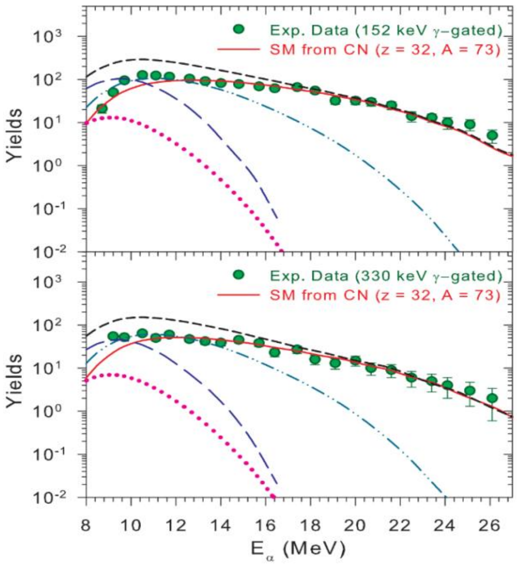

Fig. 1 Filled symbols are the experimental data (γ-gated alpha spectra). Lines represent the statistical model CASCADE calculations. Red continuous line represents first step α emission from CN ^{73}Ge. Cyan dashed-dot-dot line, blue large dashed line and dotted line represents the α emissions following 1n, 2n, p2n decay channels of ^{73}Ge, respectively. The black dashed line represents the α-spectrum from all channels.

The value of 'k' has been extracted from the best-fit statistical model calculations using a $\bar{\chi}^2$-minimization in the energy range of E_α ~ 12-24 MeV. The extracted values of inverse level density parameter ($k = A/\tilde{a}$) are 9.5 ± 0.6 MeV and 9.7± 0.6 MeV for 152 keV and 333 keV γ-gated α spectrum, respectively. The values are quite consistent with each other. Using this k value we estimated NLD parameter $a(S_n)$ following Ignatyuk prescription [9] at neutron separation energy S_n=6.48 MeV. Furthermore, the obtained $a(S_n)$ has been utilized in TALYS nuclear reaction code to calculate ^{68}Zn(n, γ)^{69}Zn capture cross-section. The preliminary result from the calculation is shown in Fig.2.

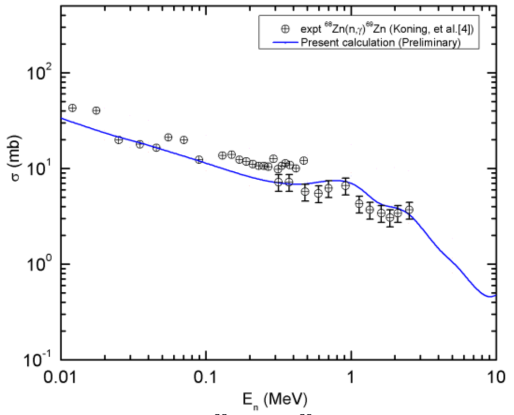

Fig.2 Cross-section of ^{68}Zn(n,γ)^{69}Zn capture reaction.

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