Dynamical hindrance effect in fusion for the decay of the compound nucleus ^{64}Zn

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Introduction

Light charged particle evaporation spectra from the compound nucleus, populated at moderate excitation energy (~ 100 MeV), allows us to test the application of statistical model for the decay of the compound nucleus. The basic parameters of nuclear properties such as yrast line, level density, emission barriers and angular momentum distribution parameters, are modified by the deformation of highly excited and rapidly rotating nuclei. This leads to dynamical hindrance to fusion. [1, 2]

We present here of analysis for decay of the compound nucleus ^{64}Zn. It was populated at same excitation energy E* ~ 70 MeV, through an asymmetric channel ^{16}O + ^{48}Ti (E_{lab} = 76 MeV) and symmetric channel ^{37}Cl + ^{27}Al (E_{lab} = 125 MeV). The inclusive alpha spectra and neutrons are compared with the predictions of conventional statistical model calculations (CASCADE). The limitations of this description for the case of symmetric reaction are also explained.

Experimental details

The experiment was performed with 15UD Pelletron at IUAC, New Delhi, India using the General Purpose Scattering Chamber (GPSC). A ^{48}Ti foil and an ^{27}Al foil each of about 1.0 mg/cm^2 thickness were used as targets. Light charged particle spectra were recorded using two ΔE-E telescopes. These spectra were taken at 30º, 36º, 42º, 48º and 54º for both the systems. While the neutrons were detected using the liquid scintillator cells of BC501 at laboratory angles θ = 30◦, 60◦, 90◦ and 120◦ with respect to the beam direction. The neutron detectors were placed at a distance of 1 m from the target.

Analysis and Discussions

The experimental analysis was carried out using CANDLE software, and the theoretical results were obtained using the statistical model code CASCADE. In the CASCADE code, the spin dependent energy is parameterized as

$$E_I = \frac{\hbar^2 I(I+1)}{2J_0(1+\delta_1 I^2+\delta_2 I^4)}$$

where δ_1 and δ_2 are deformation parameters, J_0 is rigid body moment of inertia and I is the spin.

The inclusive experimental spectra are well reproduced by CASCADE calculations. A typical comparison of alpha spectrum at 36° is shown in Fig. 1. For fitting the spectra, the spin dependent level density with E_I values generated with the increased values of δ_1 and δ_2 are introduced as it is observed that slope becomes softer as we increase δ_1 and δ_2.

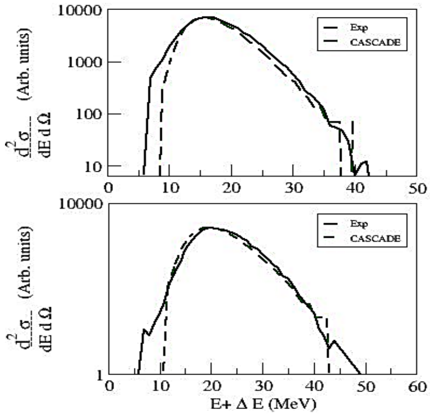

Fig. 1 Comparison of the inclusive experimental α-particle spectrum at 36° with CASCADE for **(a)** the asymmetric system $^{16}O+^{48}Ti$ (upper panel) with $\delta_1=0.41\times10^{-4}$ and $\delta_2=0.43\times10^{-7}$ and **(b)** the symmetric system $^{37}Cl+^{27}Al$ (lower panel) with $\delta_1=0.15\times10^{-3}$ and $\delta_2=0.14\times10^{-6}$ is found to fit.

The inclusive α-particle spectra from the symmetric $^{37}Cl+^{27}Al$ system fit perfectly with the theoretical calculations when we consider $l = l_{max} = 32\hbar$ (calculated using HICOL), as shown in in Fig. 1 (b). $\delta_1=0.15\times10^{-3}$ and $\delta_2=0.14\times10^{-6}$are used here along with HICOL l value. In case of symmetric systems, we need to increase δ_1 and δ_2 to get the fit while in the case of asymmetric system fit is easily obtained with default values only. All this suggests that symmetrical system severely hinders the fusion process. The fusion of lower partial waves is delayed progressively and the fusion of higher partial waves (> 32ħ) is completely inhibited.

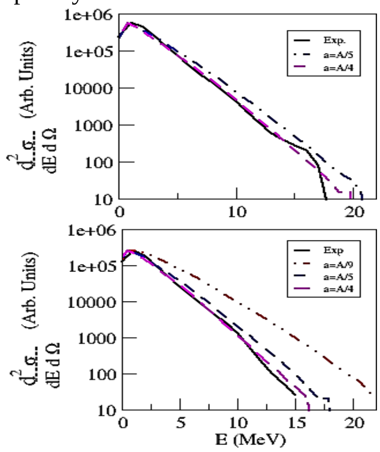

Fig. 2 Comparison of the neutron spectra at 120° for **(a)** the asymmetric system $^{16}O+^{48}Ti$ (upper panel) and **(b)** the symmetric system $^{37}Cl+^{27}Al$ (lower panel); with CASCADE calculations.

The neutron spectra are shown in Fig. 2, for asymmetric (upper panel) as well as symmetric (lower panel) case. In both the cases, it is seen that spectra are softer than the statistical model predictions. Unusually high value of level density parameter has to be used (a = $A/4$) to get the fit. This suggests a very low nuclear temperatures for neutron evaporation (as, $T=\sqrt{E/a}$).

References

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[2] Maninder Kaur *et al.*, Phys. Rev. C. **89** 034621 (2014).