Evaporation Residues Cross-section Measurements and TDHF calculations for $^{16}O+^{64}Zn$ and $^{32}S+^{48}Ti$ Systems

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Introduction

Investigation of dynamical effects in heavy-ion induced fusion reactions is an area of intense research. Much progress has been made in this field both on the theoretical and experimental front. Experimentally, different studies [1] have established that the cross-section and spin distribution measurements act as sensitive probes for the investigation of fusion dynamics. In a recent experiment, it was found that the charged particles spectra from the compound nucleus (CN) ^{80}Sr populated through asymmetric system $^{16}O+^{64}Zn$ could be explained by standard statistical model calculations, whereas the spectra from the symmetric system $^{32}S+^{48}Ti$ could not be explained by these calculations [2]. It was observed that due to the dynamical effects the higher partial waves were not fusing for the symmetric system. Similar results were also observed for two relatively symmetric systems $^{28}Si+^{45}Sc$ and $^{32}S+^{45}Sc$ [3]. The presence of dynamical effects, if any, should be revealed in the cross-section measurements. In order to test this we have measured the fusion (Evaporation residue (ER)) cross-section for $^{16}O+^{64}Zn$ and $^{32}S+^{48}Ti$ systems. We report here the results on cross-section measurements and the comparison with the predictions of Time Dependent Hartree Fock (TDHF) calculations.

Experimental details

The experiment was carried out using Heavy Ion Reaction Analyzer (HIRA) [4] at IUAC, New Delhi. Pulsed beams of ^{16}O with repetition rate of 2 µs, in the energy range from 46 to 91.9 MeV and ^{32}S with repetition rate of 1 µs, in the energy range from 87 MeV to 125 MeV were provided by 15UD pelletron accelerator. The thickness of both of the targets (^{64}Zn and ^{48}Ti) was about 500 µg/cm^2. Two silicon surface barrier detectors (SSBD) were mounted at ±25^o with respect to beam direction at a distance of 10 cm from the center of the target. A 35 µg/cm^2 carbon foil was placed 10 cm downstream from the target to reset the charge state of the ERs. The ERs were separated from the other contamination by HIRA and were detected at the focal plane using a MWPC having an active area of 6 inch × 2 inch. The transmission efficiency of HIRA was measured by HPGe detector mounted at the target chamber.

Results

The transmission efficiency values of different ERs through HIRA were estimated by *γ*-ray method and using the TERS code [5]. The average ER transmission efficiency of all the ERs, η_{HIRA}, through the HIRA was obtained by taking the weighted average of the efficiency for different evaporation channels at each energy point using PACE code. Using the average value of transmission efficiency, the ER cross-sections were obtained using the expression

$$\sigma_{ER} = \frac{Y_{ER}}{Y_{norm}} \left(\frac{\partial\sigma}{\partial\Omega}\right)_{Ruth} \Omega_{mon} \frac{1}{\eta_{HIRA}},$$

where Y_{ER} is the ER yield at the focal plane of HIRA, Y_{norm} is the elastically scattered events detected by the monitor detector, $(d\sigma/d\Omega)_{Ruth}$ is the Rutherford scattering differential cross-section, Ω_{mon} is the solid angle subtended by the monitor detector. The comparison of reduced cross-sections for both the systems is shown in Fig. 1.

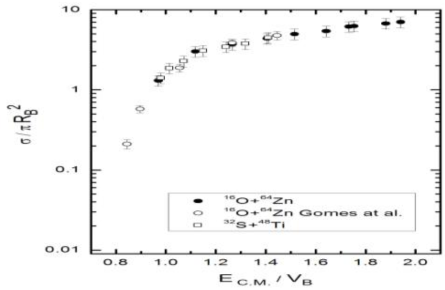

Fig. 1 Comparison of the reduced cross-sections for both the systems.

The cross-section values at lower energy points for $^{16}O+^{64}Zn$ system have been taken from the measurements by Gomes *et al.* [6]. Theoretical calculations were performed using the TDHF calculations taking in to account the target deformation [7]. A comparison of the experimental data with the theoretical model calculations (Fig.2) shows that the cross-section values are in agreement with theoretical values for both the reactions under study within 16% of uncertainty. Further, we have calculated the time evolution of the x-component of the intrinsic quadrupole moment at the highest energies for both the systems (as shown in Fig. 3 for the representative system $^{16}O+^{64}Zn$). The plot shows that rotation is not just a pure fixed sine wave, indicating the presence of dynamical effects due to shape change. The fusion time scales extracted, using the curve shown in Fig. 3, were found to be approaching the decay time for both the systems. The enhancement in the fusion time scales again gives the indication of the presence of dynamical effects for both the systems. During this time the pre-equilibrium emission of the light particles may take place, which in turn may affect the shape of spin distribution of the CN. More detailed TDHF calculations for these measurements are in progress. These observations are contrary to the observations reported in [2] in which the authors have predicted the presence of dynamical effects for the symmetric system.

Conclusions

We have observed shape changes due to the dynamical effects for both the systems. In order to establish it further a higher order friction term may be included in the TDHF calculations to compare the magnitude of the dissipation for both systems.

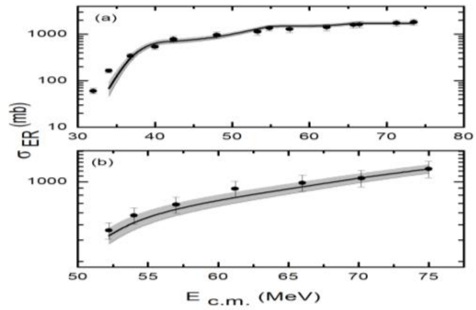

Fig. 2 The comparison of the experimental cross-sections (solid circles) with the TDHF calculations (black lines) for (a) $^{16}O+^{64}Zn$, (b) for $^{32}S+^{48}Ti$. The shaded area represents the uncertainty in cross-sections obtained from the TDHF calculations.

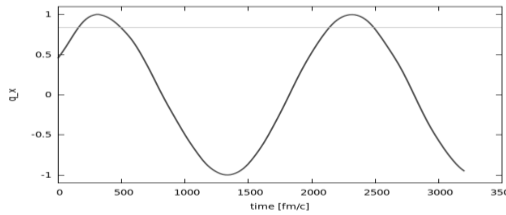

Fig. 3 Evolution of the projection of the principal quadrupole axis as a function of time for $^{16}O+^{64}Zn$.

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