Investigation of dynamics of fusion reactions through cross-section and spin distribution measurements

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Introduction

The CN populated at high excitation energy and angular momentum in fusion reactions can undergo decay through fission or emission of different light particles (α-particles, neutrons and protons). The statistical model has been extensively used to explain the evaporation spectra of these light particles and to extract important information about the properties of the CN. However, many of the evaporation studies show anomalous results from the statistical model predictions, for the mass symmetric systems [1,2]. The charged particle spectra were found to be softer and the neutron spectra were harder than the theoretical spectra. These deviations for the charged particles spectra were explained using the spin dependent level density or using the HICOL model predicted *l* values whereas the neutron spectra were explained through the use of lowered value of level density parameter *'a'*. However most of these measurements were inclusive measurements and the simultaneous analysis of other variables such as spin distribution, cross-section measurements etc. have not been taken into account. With this motivation we have performed the ER-gated spin distribution and the cross-section measurements for two systems ^{16}O + ^{64}Zn (mass asymmetric) and ^{32}S + ^{48}Ti (mass symmetric) populating the same CN (^{80}Sr) for which the evaporation spectra studies have [1, 2] reported the existence of deviations for the symmetric system. Present measurements have been performed using 15 UD Pelletron accelerator and Heavy Ion Reaction Analyzer (HIRA) facility at Inter University Accelerator Centre (IUAC), New Delhi. The details of these measurements and analysis procedure have been described elsewhere [3].

Analysis and results

The evaporation residues (ERs) populated during the reaction were separated from beam background using the HIRA spectrometer. A two-dimensional spectrum was generated using the time of flight and the energy loss of ERs. It provided a clean separation of the ERs from the beam-like contaminations. For obtaining the absolute cross-sections, the transmission efficiency of different ERs through HIRA was estimated by γ-ray co-incidence method and using the TERS code. The cross-section values at lower energy points for ^{16}O+^{64}Zn system have been taken from ref. [4]. Fig.1 shows that the experimental cross-section values are in agreement with theoretical calculations performed using CCDEF and TDHF codes [5] for both the reactions within 16% of uncertainty. The experimental cross-sections were given in PACE code to explain the deviations reported in α-particle spectrum for symmetric system. However the deviations still could not be explained. The fusion time scales were also obtained using the TDHF calculations, at highest energies and were found to approach the decay times showing that the fusion time scales are elongated for both the systems. The enhancement in the fusion time scales gives the indication of the presence pre-equilibrium emission of the light particles that may affect the shape of spin distribution of the CN.

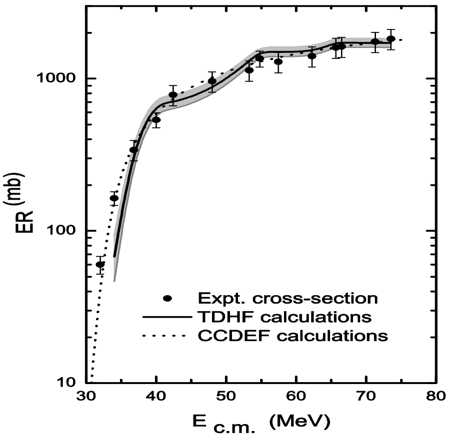

Figure 1: Comparison of experimental cross-sections for ^{16}O + ^{64}Zn with theoretical calculations.

To investigate the role of spin distribution on fusion dynamics, we have also performed the ER-gated spin distribution measurements for both the systems. Van der Werf's prescription [6] was used for unfolding the γ-multiplicity distributions from γ-fold distributions. γ-multiplicity distributions were converted to CN spin distribution by assuming that average spin carried away by each non-statistical γ-ray is 1.6 and taking into account the corrections from the spin carried away by the light particles. Using the experimental cross-sections, the CN spin distributions were obtained. These were compared with CCDEF calculations. It was observed that for the symmetric system, the contribution of the higher partial waves towards fusion goes on decreasing with the increase in incident energy. The experimental spin distributions, for ^{32}S + ^{48}Ti at E_{lab} = 125 MeV, were give as an input to the PACE code and it was observed that the generated α-particle spectrum was found to be in reasonable excellent agreement with experimental spectrum as shown in Fig. 2.

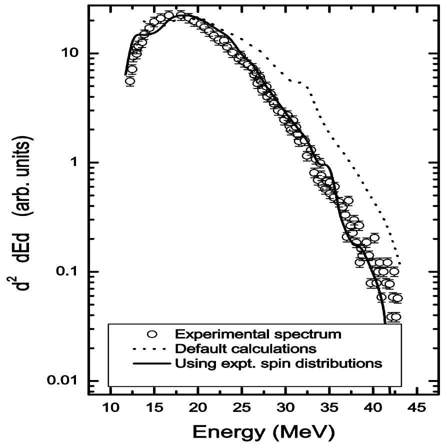

Figure 2: Explanation of the deviations in α-particle spectrum.

Conclusions

The cross-section measurements do not give any indication of the existence of dynamical effects for the symmetric system. However, the comparison of experimental spin distributions with the CCDEF calculations indicate the effect of entrance channel mass asymmetry on fusion dynamics and experimental spin distributions reasonably explained the deviations in the α-particle spectrum for the system ^{32}S + ^{48}Ti.

In this talk, I give a general introduction about the anomalous behaviour of the light particle spectra obtained from heavy-ion fusion reaction and later I highlight the importance of cross section and spin-distribution measurement for the interpretation of the particle spectra.

References

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