Projectile structure effect in low energy incomplete fusion reaction dynamics

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Introduction

Efforts are being made to comprehend the dynamics of incomplete fusion (ICF) reactions below 10 MeV/nucleon energies. Even though many theoretical and experimental studies have been carried out in this field, but there are many questions yet to be answered. The current interest in ICF reaction dynamics has its roots in the quest to understand how ICF depends on (a) incident projectile energy (b) projectile-target mass-asymmetry (c) projectile structure (α-cluster and non α-cluster) (d) Coulomb repulsion ($Z_P Z_T$) and to search some new entrance channel parameters on which ICF process may depend. At low impact parameter or smaller angular momentum values, incident projectile completely fuses with the target nucleus. On the other hand, at higher impact parameter or larger angular momentum values, the incident projectile breaks-up into its fragments in the locale of target nuclear field, one of the fragments fuses with the target nucleus and the remnant moves in the forward direction as an onlooker. Subsequently, the probability for other processes like (a) non capture break-up (b) sequential complete fusion (CF) of break-up fragments may also occur. The incompletely fused composite system formed in case of ICF has less charge, excitation energy and mass compared to compound nucleus formed via CF process. So far, various theoretical models have been proposed to explain the ICF reaction dynamics, but none of them is able to reproduce the experimentally measured ICF data satisfactorily below 10 MeV/nucleon energies [1,2]. The present work may be significant in the development of theoretical model in low energy ICF reaction dynamics, which is still a problem of keen interest. Hence, in order to investigate the ICF dependence on various entrance channel parameters, the excitation functions (EFs) of evaporation residues (ERs) produced in $^{12}C + {}^{165}Ho$ system have been measured at energies ≈ 4-7 MeV/nucleon.

Experimental Details

The experiment was carried out at Inter-University Accelerator Centre (IUAC) New Delhi. The thin uniform ^{165}Ho target foils of thickness ≈ 1.0 - 1.5 mg/cm^2 backed by Al-catcher foils were fabricated by employing the rolling technique. The thickness of both target and catcher foils was measured by using the micro-balance as well as by α-transmission method. Two stacks each comprised of four target-catcher foils assembly were irradiated separately by ^{12}C ion beam at ≈ 88 MeV and ≈ 71 MeV in the General Purpose Scattering Chamber (GPSC). Keeping the half-lives of radio nuclides into consideration, both the stacks were irradiated for about 7 hours. After the irradiation, the target-catcher assembly was dismantled using the in-vacuum transfer facility (ITF), which reduces the time lapse between stop of irradiation and start of counting. The activities induced in the irradiated samples were recorded by using the pre-calibrated HPGe detector coupled to a CAMAC based data acquisition system CANDLE.

Results and Discussion

In this work, the EFs of various ERs populated via their respective xn, pxn, αxn and 2αxn emission channels have been measured. The experimentally measured EFs have been compared with the statistical model code PACE4, which takes only CF cross-sections into account. The measured cross-sections of ERs populated via xn and pxn channels were found to agree well with PACE4 predictions at free parameter K = 10, indicating the population of xn and pxn channels via only CF. Hence, the free parameter K = 10 has been retained for the further analysis of αxn and 2αxn emission channels.

As a representative case, the EF of residue ^{172}Lu is shown in Fig. 1(a). This figure clearly shows the significant enhancement in the measured cross-sections over the PACE4 predictions at free parameter K = 10. It implies that the ICF process also contributes along with CF in the population of residue ^{172}Lu. Similarly, other αxn and 2αxn emission channel residues are also observed to be populated via ICF along with CF. Moreover, for better comprehension of ICF with mass-asymmetry systematic, the ICF fraction (F_{ICF}) has also been deducted for the present system and plotted in Fig. 1(b) against the mass-asymmetry (μ_m) parameter along with the deduced F_{ICF} for the systems available in the literature at constant relative velocity (i.e.,v_{rel} = 0.067c). As can be seen from this figure, the ICF fraction increases with increase in the mass-asymmetry but separately for each projectile induced reactions with different targets. Moreover, the higher F_{ICF} is observed for projectile ^{12}C induced reactions as that of ^{13}C projectile induced reactions with the same targets. Present findings also infer that projectile structure affects the ICF reaction dynamics and mass-asymmetry systematic is someway a projectile structure dependent. Further experimental observations of ICF dependence on projectile Q_α value, Coulomb repulsion (Z_PZ_T) and other entrance channel parameters will be presented during the conference.

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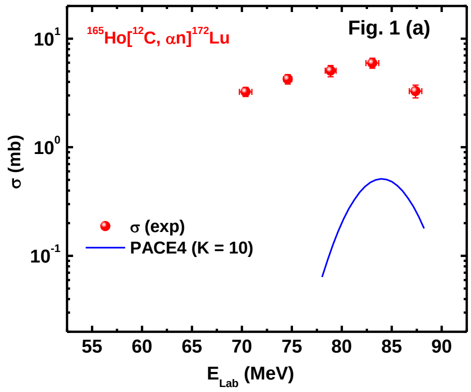

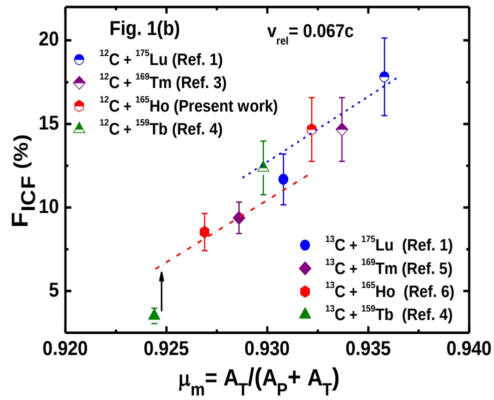

Fig. 1: (a) EF measurement of ^{172}Lu populated via emission of αn channel in the interaction of ^{12}C + ^{165}Ho and **(b)** ICF fraction as a function of various mass-asymmetry systems.

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