Systematic study on low energy incomplete fusion dynamics and its correlation with various entrance channel effects

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Introduction

The study of incomplete fusion (ICF) reactions, where the projectile breaks up and one of its fragment fuses with the target are gaining a lot of attention in the field of nuclear physics research [1, 2]. Experimental studies on ICF shows a significant contribution of ICF along with complete fusion (CF) of the projectile with the target. Since its first evidence, as observed by Britt and Quinton [1], the study of ICF dynamics has fascinated researchers of both experimental and theoretical nuclear physics a lot. A remarkable work was done by Inamura *et al.* [2] using the charged particle-γ coincidence measurements. Apart from experimental evidences, several theoretical models were also proposed to explain the ICF dynamics such as, the break up fusion model, Smurule model, etc. All these models can explain the ICF dynamics, up to some extent, at higher energies above 10 MeV/nucleon. As such, none of them could satisfactorily reproduce the experimental data at energies below 10 MeV/nucleon. This is the reason why the study of ICF is still an active area of investigation.

Study [3, 4] have also been done to understand the dependence of ICF dynamics on various entrance channel parameters namely; entrance channel mass-asymmetry, α-Q-value, $Z_P Z_T$ etc. It has been shown by these studies that a single entrance channel parameter is not able to explain completely the measured yields of the incomplete fusion dynamics at low projectile energy. Recently, Singh et al. [3] have revealed that the ICF dynamics is also affected by the deformation of the target (β_2), from the measurements of excitation functions of evaporation residues (ERs). Further, efforts have also been done to understand the combined effects of entrance channel parameters by considering various combinations of them. However, the problem of dependence of ICF dynamics on entrance channel parameters is still a problem of great interest. In this respect, an attempt has been made to encounter this problem through measured excitation functions of evaporation residues (ERs) populated via xn/pxn emission channels in ^{14}N + ^{124}Sn system at low projectile energy ≈ 4-7 MeV/nucleon.

Experimental details

The experiment was performed using 15 UD Pelletron accelerator at Inter University Accelerator Centre (IUAC), New Delhi. The isotopically enriched ^{124}Sn targets of thickness ≈ 0.1- 0.6 mg/cm^2 were used in these measurements. Stacked foil activation technique followed by offline γ-ray spectrometry was employed. Aluminum catcher foils of thickness ≈ 1.0-1.5 mg/cm^2 were placed after the targets to trap the recoiling ERs. The thickness of targets and Al-backing foils were measured by weighing method using microbalance as well as by the α-particles transmission method. The irradiation of ^{124}Sn was carried out in General Purpose Scattering Chamber (GPSC) facility at IUAC, New Delhi. The activities produced in these foils were recorded at different time intervals using a pre-calibrated High Purity Germanium Detector (HPGe) detector. The software CANDLE was used for recording the data and offline analysis process. The identification of ERs produced was done by the identification of their characteristic γ-ray in the recorded spectrum and also by their decay curve analysis. The production crosssection (σ) for different ERs was measured using the standard formalism given in [5].

Results and discussion

The measured EFs were analyzed within the framework of statistical model code PACE-4. It was observed that the xn and pxn channels are satisfactorily reproduced by PACE-4 predictions. On the other hand, in case of α-emitting channels, the measured EFs are found to be significantly enhanced over the theoretical predictions. The ICF fraction (F_{ICF}), which is a measure of the relative contribution of ICF process over the CF process, was deduced from the measured data and compared with other systems available in literature. It is now well established that the ICF dynamics is affected by the entrance channel parameters namely; mass-asymmetry (μ_A) of the system, Coulomb factor (Z_PZ_T) and target deformation parameter (β_2). In the present work, the combined effect of these entrance channel parameters has been studied through two newly introduced combined parameters $(1-\beta_2)\cdot Z_PZ_T\cdot\mu_A$ and $(1-\beta_2)/(Z_PZ_T\cdot\mu_A)$, which are the combination of above mentioned parameters. The ICF fraction was plotted as a function of these parameters and shown in Figs. 1-2. As can be clearly seen from Fig. 1 that the ICF increases almost exponentially with the combined parameter $(1-\beta_2)\cdot Z_PZ_T\cdot\mu_A$, but independently for different projectiles. Also from Fig. 2, interesting pattern of F_{ICF} has been observed with another parameter $(1-\beta_2)/(Z_PZ_T\cdot\mu_A)$. It has been found that the ICF fraction decreases exponentially with this parameter, but the rate of decrease is different for different projectiles. These results show that the combined effects of mass-asymmetry (μ_A) of the system, Coulomb factor (Z_PZ_T) and target deformation parameter (β_2) should be considered. The present results clearly show that the structure of projectile always plays important role with all other entrance channel parameters.

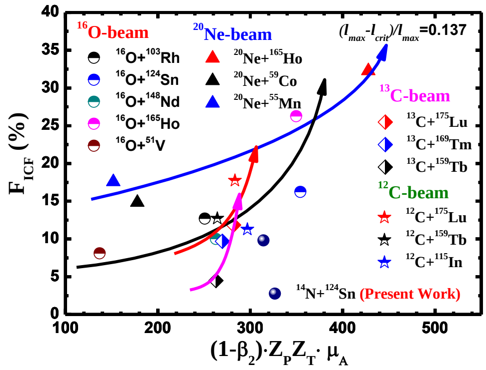

Fig. 1 The ICF fraction as a function of the combined parameter $(1-\beta_2)\cdot Z_PZ_T\cdot\mu_A$ for the ^{14}N + ^{124}Sn system along with others from literature.

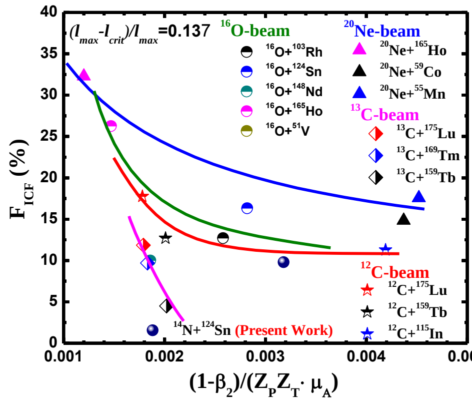

Fig. 2 The ICF fraction as a function of the combined parameter $(1-\beta_2)/(Z_PZ_T\cdot\mu_A)$ for the ^{14}N + ^{124}Sn system along with others from literature.

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