Alpha Q-value effect on incomplete fusion dynamics below 8 MeV/nucleon energies

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Introduction

Incomplete fusion (ICF) or massive transfer reactions have been studied extensively at lower projectile energies in recent years [1-4]. The complex nature of ICF dynamics is still a dilemma and the role of entrance channel parameters effect like: projectile energy, projectile structure, mass-asymmetry and alpha Q-value on ICF could not be established explicitly below 8 MeV/nucleon energies. Most of the studies on ICF were centered to α-cluster structured projectiles like ^{12}C, ^{16}O and ^{20}Ne etc. with heavier target nuclei (A ≥ 150) but reactions involving non α-cluster structured projectiles like ^{11}B, ^{13}C, ^{14}N and ^{18}O have also shown the significant ICF contribution to the total cross-section. Britt and Quinton [5] first observed the ICF features in the break-up of projectiles into α-clusters at lower projectile energies. Inamura *et al*. [6] provided the most unambiguous informations regarding ICF dynamics. Non availability of any theoretical model to fit the experimental ICF data below 8 MeV/ nucleon energies adds complexity in the study of ICF dynamics. Thereby, more refined experimental studies are required in the better understanding of ICF in this region.

Morgenstern *et al.* [7] observed that projectile-target mass-asymmetry governs the ICF probability (F_{ICF}), which was further supported by Refs. [1-2]. In recent studies, the projectile structure effect on ICF by using α- and non α-cluster structured projectiles is also observed along with the mass asymmetry of interacting partners, which is interpreted in terms of alpha Q-value of the projectiles [4,8]. The detailed information regarding the alpha Q-value effects on ICF probability is still limited for a very few studies and needs to be further investigated to reach on any definite inference in this regard. Hence, to provide more strength to the aspect of alpha *Q*-value effect on the onset of ICF the present work was carried out. The present work is based on excitation functions (EFs) measurement of residues produced in ^{13}C induced reactions with ^{175}Lu target below 8 MeV/nucleon energies. This work may be useful to develop a theoretical model for ICF studies which is still a relevant problem in this energy region.

Experimental Details

The experiment was performed using the 15UD Pelletron Accelerator facilities at Inter University Accelerator Centre (IUAC), New Delhi. Stacked foil activation technique has been adopted for the EFs measurement of residues evaporated in the interaction of ^{13}C ion-beam with ^{175}Lu target. Two ^{175}Lu target stacks of thickness ranges ≈ 1.0-1.5 mg/cm^2 were followed by Al-degrader foils having thickness ranges ≈ 1.4-2.0 mg/cm^2. Targets as well as Al-catcher foils were prepared using the rolling technique and the energy loss suffered by 5.49 MeV α-particle obtained from ^{241}Am source used for the thicknesses measurement of target and Al-catcher foils. Both stacks were irradiated using ^{13}C ion-beam at 88 and 72 MeV energies respectively, in the General Purpose Scattering Chamber (GPSC) for about 7-10 hrs. The induced γ-ray activities in each target-catcher assembly were recorded by using the Pre-calibrated 100 cc HPGe γ-ray detector of high resolution coupled to the CAMAC based FREEDOM software.

Results and Discussion

In the present work, several residues produced via xn, pxn, αxn and 2αxn channels have been measured for ^{13}C + ^{175}Lu system. The statistical model code PACE-4 predictions are used for the comparison of measured EFs, which does not take into account the ICF contribution. In Fig. 1(a), the mass-asymmetry effect on the onset of ICF is demonstrated, where the deduced ICF probability function (F_{ICF}) for present system ^{13}C + ^{175}Lu has been plotted along with F_{ICF} obtained for previously studied systems as a function of mass-asymmetry [$\mu_m = A_T/(A_P + A_T)$] at same relative velocity (v_{rel} = 0.061c). This figure clearly shows the systematic linear dependence of ICF probability with mass-asymmetry separately for each projectile with different targets. It is observed that the ^{12}C induced reactions have more ICF probability than ^{13}C induced reactions with same target nuclei. Hence, the present findings indicate towards the projectile structure dependent mass-asymmetry systematic, which is interpreted in terms of alpha Q-value of projectiles. In Fig. 1(b), the F_{ICF} for the present system ^{13}C + ^{175}Lu and previously studied ^{12}C + ^{175}Lu [9] and $^{12,13}C$ + ^{159}Tb [4] systems have been plotted as a function of alpha *Q*-value at same v_{rel} = 0.061c. It may be observed from this figure that ICF probability is higher for less negative alpha Q-value (case of ^{12}C induced reactions) as that of larger negative alpha Q-value (case of ^{13}C induced reactions) of projectiles i.e. projectile structure in terms of alpha Q-value also plays an important role to affect the ICF dynamics. Moreover, we may conclude that Morgenstern's mass-asymmetry systematic is probably the projectile structure dependent mass-asymmetry.

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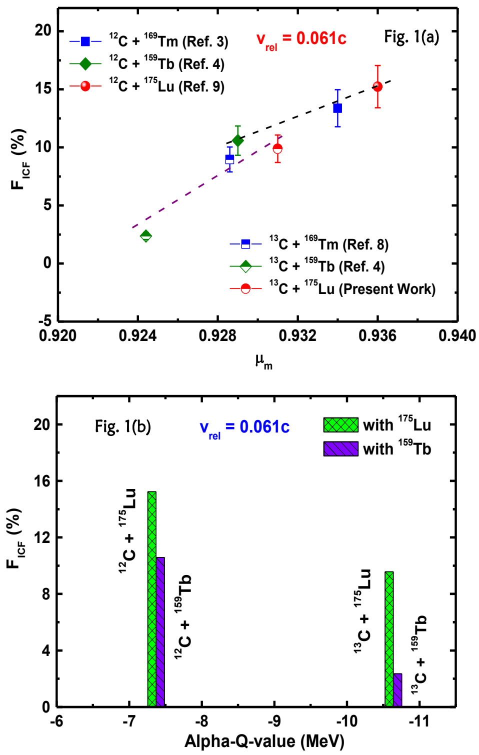

Fig. 1: (a) the ICF probability function (F_{ICF}) against the mass-asymmetry (μ_m) and **(b)** a comparison of F_{ICF} on the basis of projectile alpha Q-value at same value of v_{rel} = 0.061c.

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