Mass-asymmetry effect on incomplete fusion process at energies ≈ 4 - 7 MeV/nucleon

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Introduction

It is now well established that incomplete fusion (ICF) reactions start competing with the complete fusion (CF) reactions at projectile energies just above the Coulomb barrier. Incomplete fusion (ICF) or massive transfer reactions have been studied extensively at lower projectile energies below 10 MeV/nucleon in recent years. However, the study of ICF is still an active area of investigations due to complex nature of incomplete mass transfer mechanism and its ambiguous dependence on various entrance channel parameters i.e. imparted angular momentum to the system, projectile energy, projectile structure, α-separation energy and mass-asymmetry of the target-projectile system. In CF process, the projectile may completely fuse with the target nucleus with involvement of all nucleonic degrees of freedom and formed compound nucleus (CN) may decay via emission of light particles and/or characteristic γ-rays. In CF processes, the entire projectile fuses with the target nucleus. On the other hand, in case of ICF, the break-up of projectile may takes place into two parts, near to the target nuclear field. One of the parts fuses with the target while remnant moves as spectator in the forward direction with approximately beam velocity [1-4]. Several models have been proposed to explain the ICF reactions. Unfortunately, all these models are available to fit the experimental data above 10 MeV/nucleon energies and no theoretical model is yet available to explain ICF process data satisfactorily at energies below 10 MeV/nucleon. In case of heavier target nuclei, the evaporation of α-particle from the composite system has relatively lesser probability due to the high Coulomb barrier. However, ICF process is observed to be the dominating reaction mode as that of CF process.

In order to reach on some definite conclusions regarding various parameters especially mass-asymmetry effect on ICF nuclear reaction dynamics, we have measured the excitation functions of evaporation residues produced in $^{12}C + ^{175}Lu$ system at energies 4 -7 MeV/nucleon.

Experimental Procedure

The present experiment was performed by using the facilities of 15UD Pelletron at Inter University Accelerator Centre (IUAC), New Delhi. Keeping in view the half-lives of the interest, two stacks of self supporting targets of ^{175}Lu having thickness ranges ≈ 1.0-1.5 mg/cm^2, backed by Al-catcher foils having thickness ≈ 1.4-2.0 mg/cm^2 were irradiated by ^{12}C-ion beam for about 6 to 8 hours in the General Purpose Scattering Chamber (GPSC) at energies ≈ 88 and ≈ 70 MeV. Target as well as Al-catcher foils were prepared using the rolling machine technique. In-vacuum target transfer facility (ITTF) was used to minimize the delay time between the stop of irradiation and the starting of counting. 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 CAMAC based FREEDOM software at IUAC, New Delhi. .

Results and Discussion

In the present work, several evaporation residues produced via xn, pxn, αxn and 2αxn channels have been measured for ^{12}C + ^{175}Lu system. We have made use of Cavinato *et al.* [5] formulation to calculate the independent cross-section of the identified residues. The measured EFs are compared with theoretical predictions of statistical model code PACE-2. Enhancement in the measured cross-sections from theoretical predictions are attributed to ICF reaction process, in the break-up of ^{12}C projectile into ^{4}He and ^{8}Be. An attempt has been made to estimate the ICF fraction and its dependence on projectile energy as well as mass-asymmetry of projectile-target systems.

Morgenstern *et al.*, [8], suggested that the onset of ICF process is governed by relative velocity (V_{rel}). The expression for V_{rel} takes into account the difference in Coulomb barrier between each two interacting partners. The ICF fraction has been deduced by using the relation; $[F_{ICF} = \sum\sigma_{ICF}/(\sum\sigma_{CF} + \sum\sigma_{ICF})]$. The ICF fraction has been deducted for the present ^{12}C + ^{175}Lu system and plotted along with the previously measured systems using the same projectile ^{12}C, as a function of mass-asymmetry $[m = A_T / (A_T + A_P)]$, at same relative velocity (V_{rel}) = 0.060c, and shown in Fig. 1(a). It may be observed from this figure that ICF fraction depends on projectile-target mass-asymmetry and is relatively higher for mass-asymmetric system than those of mass-symmetric system, which supports the finding of Morgenstern *et al.* [8].

In order to understand the effect of V_{rel} on ICF fraction for different targets, F_{ICF} has been plotted against the V_{rel} for ^{12}C + ^{175}Lu and ^{12}C + ^{159}Tb systems as shown in Fig. 1(b). It may also be pointed out form this graph that the ICF fraction increases with V_{rel} as well as with mass asymmetry parameter 'm'.

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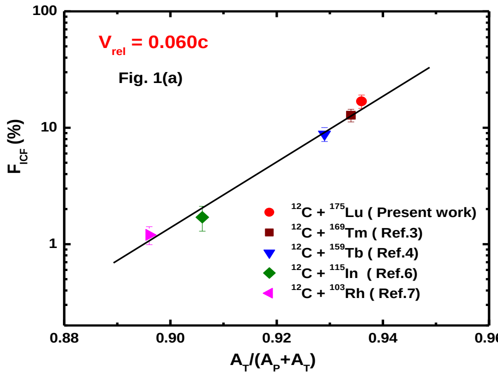

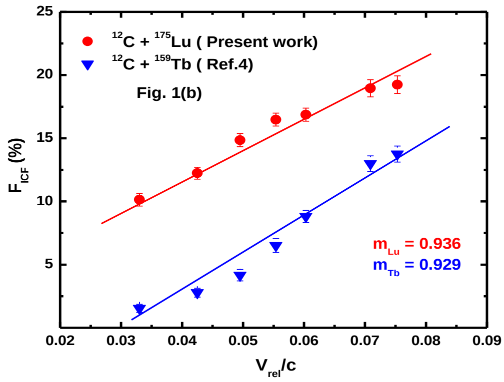

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