Investigation of Incomplete Fusion Dynamics from the Measurement of Angular Distributions at E ≈ 88 MeV

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Introduction

The reaction mechanism other than compound nucleus formation via entire projectile amalgamation with the target nucleus has attracted considerable interest in heavy-ion (HI) induced reactions at projectile energies below 10 MeV/nucleon. These reactions are termed as incomplete fusion (ICF) or massive transfer reactions in which only one of the two fragments merges with the target nucleus and remainder moves in the forward direction with approximately the beam velocity. Earlier reported studies reveal that ICF has the significant contribution along with CF in the respective energy regime [1-5]. Since, the existing theoretical models are not applicable to reproduce the experimental ICF data satisfactorily in the energy region below 10 MeV/nucleon; thereby the study of ICF is still an active area of investigations and a topic of interest for exploring the nuclear structure and reaction dynamics. As, the Coulomb barrier is high in case of heavier target nuclei, the evaporation of α-particle from the composite system has the less probability and ICF fraction is observed to be dominating as that of CF fraction in α-particles emission products. There are fewer studies with heavier targets (A ≥ 150) at lower projectile energies below 10 MeV/nucleon. In most of the experiments, the properties like charge, mass, energy, angular distribution etc., of light particles and/or γ-rays emitted in such reactions are measured. Keeping in view the recent observations, the present work has been carried out to provide some definite conclusions regarding ICF reaction dynamics below 10 MeV/nucleon energies. We have measured the angular distributions of evaporated residues produced in ^{12}C + ^{175}Lu system at ≈ 88 MeV energy. Moreover, this work is aimed to provide the new experimental data on angular distributions, which is not available in the literature to the best of our knowledge. This is a complementary experiment to support and strengthen the findings of Excitation Functions and Recoil Range Distribution measurements.

Experimental Procedure

Experiment for the measurement of angular distributions of produced evaporation residues in ^{12}C + ^{175}Lu system was performed at Inter University Accelerator Centre (IUAC), New Delhi. Self supporting target of ^{175}Lu (thickness ≈ 1.5 mg/cm^2) was followed by a stack of five annular concentric Al-catcher foils of thickness ranging from 0.4-0.5 mm, which was placed at about 2.0 cm from the target to trap the recoiling residues in different annular Al-catcher foils at different angles lying between 0^o and 50^o. Recoil catcher technique followed by the OFF-Line gamma-ray spectroscopy was used for the measurement of produced evaporation residues. Target was bombarded with ^{12}C-ion beam of energy ≈ 88 MeV for about 5 hours in the General Purpose Scattering Chamber (GPSC). A pre-calibrated 100 cc HPGe γ-ray detector of high resolution coupled to CAMAC based FREEDOM software at IUAC, New Delhi was used for the recording of induced γ-ray activities in each target-catcher assembly. The evaporated residues are then identified from their characteristic gamma-rays by following the half-lives and their intensities provide the basic information about the specific evaporation residue.

Results and Discussion

The angular distributions of several residues produced via xn, pxn, αxn and 2αxn channels have been measured in ^{12}C induced reactions with ^{175}Lu target. The experimentally measured angular distributions are analyzed and compared in the frame of statistical model code PACE-4 [6], which gives only the CF contributions. Excitation energy and linear momentum play important roles in fusion of projectile with target. The residues populated via CF are likely to be trapped at forward angles and those populated via ICF at much higher angles in the concentric annular Al-catcher foils. As a representative case, the angular distributions of residues ^{183}Ir(4n) and ^{181}Re(α2n) are shown in Fig. 1(a)-(b). It is clear from the Fig. 1(a) that angular distribution of residue ^{183}Ir is peaked only in forward cone leading to the fact that this residue is formed via CF, which is in good agreement with the compound nucleus mechanism.

$$^{12}\text{C} + {}^{175}\text{Lu} \longrightarrow [{}^{187}\text{Ir}^*] \longrightarrow {}^{183}\text{Ir} + 4\text{n}$$

On the other hand, the angular distribution of residue ^{181}Re exhibit one maximum around 42^0 other than forward peak around 0^0 as shown in Fig. 1(b). It may be pointed out from this figure that 'ICF' reaction mechanism also contributes in the formation of ^{181}Re produced in α-emission channel i.e. one of the components ^{8}Be in the break-up of ^{12}C fuses with the target to form the composite system ^{187}Ir*, which further decays to form residue ^{181}Re by emitting two neutrons. Hence, ICF reaction dynamics also plays an important role in the population of evaporation residues along with CF. We already have measured the Excitation Functions for the same system in energy range 3-8 MeV/nucleon. The present findings are in agreement with previous work [7].

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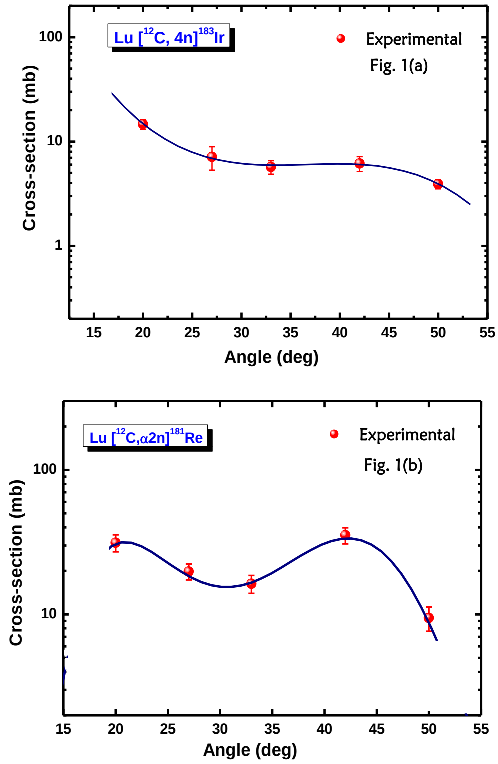

Fig. 1: (a) Angular distributions for the residues ^{183}Ir(4n) and (b) ^{181}Re(α2n) produced in ^{12}C + ^{175}Lu system.

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