Linear Momentum Transfer Effect on Incomplete Fusion Process at Energy ≈ 88 MeV

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Introduction

The incomplete fusion (ICF) features were first pointed out by Britt and Quinton [1] at lower projectile energies with break-up of projectiles like ^{12}C, ^{14}N, and ^{16}O into α-clusters. Inamura *et al.* strengthen the study of ICF and provided the additional but concrete information regarding ICF from the γ-multiplicity measurements [2]. This study also showed that ICF involves *ℓ values* more than ℓ_{crit} as for occurrence of complete fusion (CF). Due to complex nature of incomplete mass transfer mechanism, investigation of ICF reaction dynamics is still an active area of research, also these reactions are governed by the entrance channel dynamics or by the properties of the composite system is not clearly established. Existing studies reveal that linear momentum transfer (LMT) plays an important role in the study of heavy ion induced nuclear reactions below 8 MeV/nucleon energies [3, 4]. One may differentiate the CF and ICF processes on the basis of recoil range, which is associated with the various degrees of linear momentum transfer (LMT) from projectile to the target. The LMT has the proportionality with the fused fragment mass; thereby maximum LMT may give rise to maximum recoil velocity to the populated residues. For a different LMT, the residues may have different recoil ranges in the stopping medium. As entire mass is transferred from projectile to the target, thereby the complete fusion (CF) product traverses a larger range in the stopping medium. On the other hand, the ICF product is formed via fractional mass transfer from projectile to target nucleus. Thus, the ICF product follows a smaller range in the stopping medium as that of CF product. In order to disentangle the contribution of various fusion components, we have measured the forward recoil range distributions (FRRDs) of reaction products produced in the interaction of ^{12}C beam with ^{175}Lu target at ≈ 88 MeV energy. FRRDs measurement gives the direct signature of ICF i.e. various fusion components (fusion of ^{8}Be and ^{4}He in case of ^{12}C projectile), which are interpreted in terms on CF and ICF reactions.

Experimental Procedure

The experimental facilities of 15UD Pelletron at IUAC Inter University Accelerator Centre (IUAC), New Delhi was used for the measurement of Forward Recoil Range Distributions (FRRDs) of evaporation residues populated in ^{12}C + ^{175}Lu system. ^{175}Lu Target having thickness ≈ 950 μg/cm^2 was prepared by rolling machine and followed by a stream of thin Al-catcher foils having the thickness lying between 35-50 μg/cm^2. The target-catcher assembly was irradiated by using ^{12}C ion-beam for about 12 hrs in the General Purpose Scattering Chamber (GPSC) at ≈ 88 MeV energy. The thicknesses of the Al-catchers were chosen such that recoiling residues produced via CF and/or ICF may get trapped at various catcher foil thicknesses. The induced gamma-rays activities trapped in different catcher foils were recorded by using a pre-calibrated, 100 cc HPGe detector coupled to a CAMAC based software FREEDOM.

Results and Discussion

Forward Recoil range distributions (FRRDs) provide information about the extent of linear momentum transfer (LMT) for the formation of a particular reaction product. FRRDs of various evaporation residues produced via xn, pxn, αxn and 2αxn emission channels have been measured for ^{12}C + ^{175}Lu system at ≈ 88 MeV energy. The relative contributions of various partial fusion components have been investigated by plotting the thickness independent cross-sections against the cumulative thickness and experimental recoil ranges of residues are fitted by Gaussian peaks using the ORIGIN software. As shown in Fig. 1(a), the FRRD pattern of residue ^{183}Ir is found to have only one Gaussian peak at recoil range ≈ 306 μg/cm^2, which agrees well with the theoretical range calculated for the compound system using the stopping power and range software SRIM. It is clear that the reaction product ^{183}Ir produced via 4n channel is associated with the entire LMT from projectile to the target nucleus, which reveals that residue ^{183}Ir is formed via CF only. The measured FRRD pattern of evaporation residue ^{181}Re is resolved into two Gaussian peaks as facilitated in Fig. 1(b), indicating the presence of more than one LMT component associated with the larger cumulative thickness ≈ 346 μg/cm^2 (due to fusion of ^{12}C) and comparatively at smaller thickness ≈ 193 μg/cm^2 (due to fusion of ^{8}Be), respectively. Thus, the presence of more than one LMT component infers that ICF process also contributes in the population of residue ^{181}Re along with CF.

We have also separated out the relative contribution for the population of residue ^{181}Re. The relative contribution due to the fusion of fragment ^{12}C is found to be ≈ 9% and due to ^{8}Be is found to be ≈ 91%. Hence, the major contribution for production of residue ^{181}Re comes out from ^{8}Be fusion. This observation also facilitates the fact that when the projectile comes near to the target nuclear field, it breaks-up into two fragments.

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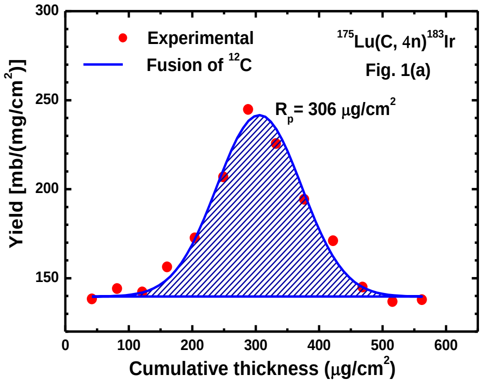

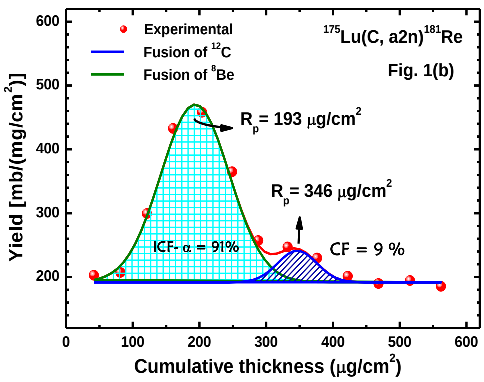

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