Investigation of incomplete fusion dynamics in $^{16}O + ^{175}Lu$ system from the measurement of recoil range distributions

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Introduction

The study of light-heavy-ion (Z ≤ 10) induced reactions at energies above Coulomb barrier (CB) provides an ample opportunity to explore the information about the nuclear reaction dynamics. It has been observed from earlier studies that incomplete fusion (ICF) process starts competing with complete fusion (CF) at projectile energies just above the Coulomb barrier [1, 2]. The ICF reactions were first pointed out by Britt and Quinton [3] who observed the ICF features at lower projectile energy with break-up of projectiles like ^{12}C, ^{14}N, and ^{16}O into α-clusters. The most unambiguous evidence for ICF was provided by Inamura *et al.* [4]. The terminology of impact parameter may be used to illustrate the CF and ICF processes in HI interactions. At zero and/or very small value of impact parameter, 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 leading to the CF process. On the other hand, at relatively larger impact parameter window as that of above process, CF gradually gives way to ICF in which the projectile may break-up into its fragments as it comes near to the nuclear field of target nucleus. One of the fragments fuses with target and the remnant moves as spectator in the forward direction with approximately beam velocity.

Both the processes may also be characterized by the angular momentum l carried by the projectile. For CF to occur the entrance channel angular momentum should be $\le l_{crit}$ and the γ-multiplicity measurements by Inamura *et al.* [4] showed that ICF involves l values more than l_{crit}. Recoil range distribution (RRD) measurements are particularly attractive for the study of fusion incompleteness due to fractional linear momentum transfer from projectile to target nucleus. Thus, owing to the fractional linear momentum transfer the ICF product follows a shorter range in the stopping medium as that of CF product. The objective of the present work is to investigate the ICF reaction dynamics in $^{16}O + ^{175}Lu$ system at ≈ 96 MeV energy.

Experimental Procedure

Experiment for the measurement of forward recoil range distributions (RRDs) was carried out using 15UD Pelletron accelerator of the Inter University Accelerator Centre (IUAC), New Delhi. For the measurement of RRDs, thin target of lutetium (^{175}Lu) was deposited by vacuum evaporation technique onto a thin Al-backing facing the beam followed by a stream of thin Al-catcher foils having the thickness lying between 30-70 μg/cm^2. The Al-catcher foils were used as stopping medium so that the evaporation residues produced via CF and/or ICF may be trapped at various catcher thicknesses. The target and Al-catcher foils thickness estimation was done by measuring the energy loss suffered via 5.49 MeV α- particle obtained from ^{241}Am source in the target and catcher foils. The target-catcher assembly was irradiated for about 14 hrs using ≈ 96 MeV $^{16}O^{7+}$ beam in the General Purpose Scattering Chamber (GPSC), which has an in-vacuum transfer facility. A pre-calibrated, 100 cc HPGe detector coupled to a CAMAC based FREEDOM software was used for recording the γ-ray activities induced in different catcher foils.

Results and Discussion

The thickness independent measured cross-sections have been plotted against the cumulative catcher thickness to obtain the differential RRDs and experimental recoil ranges of residues are fitted by Gaussian peaks using the ORIGIN software. In order to study the ICF reaction dynamics, the RRDs of some evaporation residues produced in α, 2α and 3α-emission channels in the projectile break-up have been measured for ^{16}O + ^{175}Lu system at ≈ 96 MeV. As a representative case the RRD of two residues ^{182}Re(2αn) and ^{181}Re(2α2n) are shown in Figs. 1(a) and 1(b). As can be seen from Fig. 1(a), the forward RRD of evaporation residue ^{182}Re shows two peaks in its distribution pattern, corresponding to the recoil range (R_p) ≈ 358 and ≈ 179 μg/cm^2, which agree with the theoretical mean ranges [5] calculated for incompletely fused composite system ^{187}Ir* (formed due to fusion of ^{12}C and may decay into ^{182}Re via emission of 1α-particle and 1 neutron) and incompletely fused composite system ^{183}Re* (formed due to fusion of ^{8}Be and may decay into ^{181}Re via emission of 2α-particles and 1 neutron), respectively. The RRD pattern of evaporation residue ^{181}Re also shows two peaks as facilitated in Fig. 1(b), indicating the presence of more than one linear momentum transfer component associated with the cumulative catcher thickness of ≈ 329 μg/cm^2 (due to fusion of ^{12}C) and ≈ 203 μg/cm^2 (due to fusion of ^{8}Be), respectively. It may be pointed out that there is no peak corresponds to CF component for both the residues, thereby CF process may not be contributed for the population of ^{182}Re and ^{181}Re. Thus, the presence of more than one linear momentum transfer component infers that the residues ^{182}Re and ^{181}Re are populated in the reaction ^{175}Lu(O, 2αn) and ^{175}Lu(O, 2α2n) via ICF only. The relative contribution for the population of residue ^{182}Re, coming from the fusion of fragments ^{12}C and ^{8}Be is found to be ≈ 43% and ≈ 57%, while ^{12}C fusion and ^{8}Be fusion contributes ≈ 89% and ≈ 11%, respectively in the population of residue ^{181}Re. Hence, the major contribution for production of residue ^{181}Re comes out from ^{12}C fusion. It may be concluded from the present study that the ICF process is also found to play an important role in the production of various reaction products.

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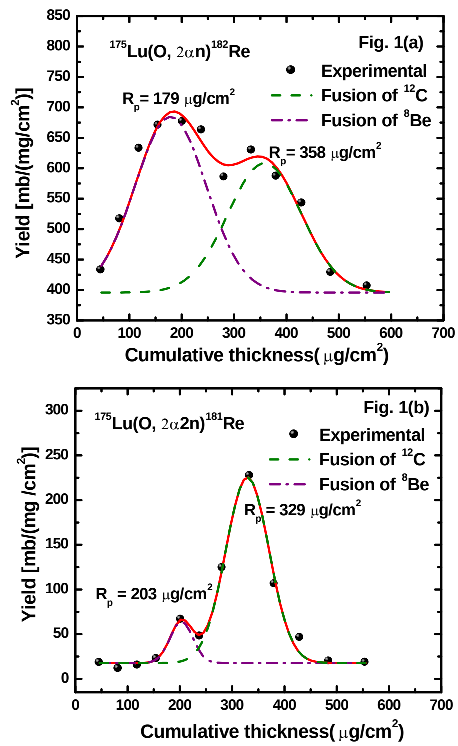

References

[1] D. J. Parker *et al.*, Phys. Rev. C **30** (1984) 143.

[2] B. Bindu Kumar, *et al.*, Phys. Rev. C **57** (1998) 743.

[3] H.C. Britt and A.R. Quinton, Phys. Rev. **124** (1961) 877.

[4] T. Inamura *et al.*, Phys. Lett. B **68** (1977) 51

[5] J. F. Ziegler, SRIM08, The Stopping Power and Range of Ions in Matter, 2008.