Observation of partial linear momentum transfer in incomplete fusion reactions: A study relevant to non α-cluster beam

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Recent studies on heavy ion collisions have established the presence of incomplete fusion (ICF) process as a significant competing channel to the complete fusion (CF) at energies ≈ 4-7 MeV/A [1-4]. Though, at such low energies, ICF is unlikely but recent experimental studies have indicated that a significant portion of the reaction proceeds through it. In CF process, at $\ell<\ell_{crit}$, the entire projectile merges with the target nucleus leading to the formation of an excited composite system that undergoes equilibration to become the compound nucleus (CN). However, in ICF process for the value at $\ell>\ell_{crit}$, the projectile may break up into fragments. One of the fragments fuses with the target nucleus forming an incompletely fused composite system, while remnant moves in the forward direction without any interaction. Several theoretical models [3-5] have been proposed to understand the reaction dynamics of ICF process, which are found to be reliable upto some extent at energies ≥ 10.5 MeV/nucleon, but unable to reproduce ICF data at lower energies. In addition to this, most of the ICF studies have been done using the α-cluster beams. However, the studies using the non α-cluster beams like ^{13}C, ^{14}N, ^{18}O, and ^{19}F are scarce. Therefore, the present work has been extended to investigate the relative contribution of CF and ICF processes using the non α-cluster beam ^{19}F. In the present work, the relative contribution of CF and ICF processes have been disentangled by measuring the forward recoil range distribution (FRRD) of reaction residues populated in ^{19}F + ^{169}Tm system at two distinct beam energies viz., 96 MeV and 106 MeV respectively. The present work has been reported for the first time and is in continuation of our recent investigation on ^{19}F + ^{169}Tm system, where the experimentally measured excitation functions (EFs) of reaction residues have been used to understand the break-up fusion processes [5]. In FRRD measurements, the recoil ranges of heavy residues populated via CF and ICF processes depend on the recoil velocity, which is associated with the degree of linear momentum transfer from projectile to the target nucleus. As such, in CF process, the CN is formed via complete linear momentum transfer (LMT) from projectile to the target nucleus. However, in ICF process, due to break-up of projectile, CN is formed via partial LMT from projectile to the target nucleus. The experiments for the RRD measurements were carried out at the Inter University Accelerator Centre (IUAC), New Delhi, India. The non α-cluster beam ^{19}F produced via 15UD pelletron accelerator is allowed to focussed on ^{169}Tm self-supporting target (thickness ≈ 160 $\mu g/cm^2$). The recoil catcher activation technique followed by offline γ-ray spectroscopy has been employed to study the RRD. Two stacks each consists of target followed by very thin Al-catcher foils (thickness

≈ 15-50 $\mu g/cm^2$) are bombarded at two different beam energies. The thin Al-catcher foils in the stack act as a stopping medium for trapping the recoiling residues populated via CF and ICF modes.

In the present work, nine radio-nuclides viz., ^{184}Pt(*4n*), ^{184}Pt(*5n*), ^{184}Ir(*p3n*), ^{185}Ir(*p4n*), ^{183}Os(αn), ^{181}Os($\alpha 3n$), ^{179}Os($\alpha 5n$), ^{177}W($2\alpha 3n$), and ^{175}Ta($2\alpha p4n$) have been identified from their characteristic gamma lines and further confirmed by their decay curve analysis. As a representative case, Fig.1 (a-b) represents the RRD of ^{183}Os(αn) residues expected to be populated via CF and/or ICF processes at two projectile energies 96 MeV and 106 MeV respectively. As can be observed from this figure, the RRD of ^{183}Os residues populated via αn channel show two Gaussian peaks one at higher cumulative depth and other at lower cumulative depth at both the energies. The peak at the higher cumulative depth indicates the contribution due to full LMT (complete fusion) from projectile to the target nucleus. However, the peak at lower cumulative depth corresponds to the fusion of ^{15}N (if ^{19}F breaks up into ^{15}N + α and ^{15}N fuses) with ^{169}Tm target nucleus. The measured RRDs of αxn channels indicate more than one LMT components, i.e., the same residues are formed via CF process and trapped at higher cumulative depth and also at lower cumulative depth, where these are populated via ICF processes. Further, the range integrated cross-section obtained for the CF channels (*xn/pxn*) from the RRD data are found to agree reasonably well with the theoretical calculations based on statistical model approach. Moreover, an attempt has also been made to study the energy dependence of ICF process from the measured RRDs of reaction products. The deduced F_{ICF} values from the measured RRDs are compared with the F_{ICF} values obtained from the EFs data [5]. It has been observed that, the deduced ICF contribution from the analysis of RRD data gives nearly the same values as obtained from the EFs data [5]. This strongly indicates the reliability and validity of the present measurement technique to disentangle the CF and ICF processes and ensured the self-consistent approach of the present work. Further details will be presented.

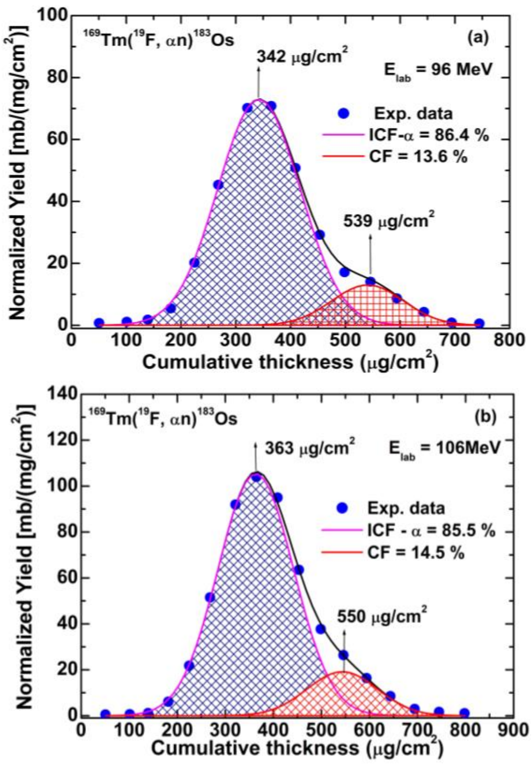

Fig.1 (a-b) Experimentally measured recoil range distribution of ^{183}Os residues populated through αn channel in ^{19}F+ ^{169}Tm system at two incident energies 96 and 106 MeV.

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