Proclaiming the validity of systematics for low energy incomplete fusion

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The phenomenon of incomplete fusion (ICF) in heavy ion (HI) interactions may be considered to take place when the projectile breaks up near the vicinity of target nuclear field, into fragments, one of which fuses with the target nucleus forming an excited composite system which may eventually de-excite by particle and γ emission, while the other part of fragment moves into the forward direction without any interaction and acts as spectator. It has been observed [1] that ICF is associated with peripheral collisions, while some studies [2, 3] suggest the involvement of lower angular momenta as well than the critical angular momentum (ℓ_c) for complete fusion (CF) to occur in these reactions. However, the mechanism of the ICF reactions is still not clearly understood, and is an active area of investigation. In 1973, Bimbot et al., [3] carried out the pioneering work on the measurement and analysis of excitation functions (EFs) in ^{12}C+^{197}Au reactions and showed the total cross-section for transfer processes (i.e. α, ^{8}Be and ^{12}C on ^{197}Au) as a function of energy. The same method has been adopted in the studies of CF and ICF at energies $\approx$ 4-7 MeV/A, where a drastic enhancement over the theoretical predictions has been acknowledged by several authors [4, 5] for the alpha emitting channels. This enhancement in measured cross-sections with respect to the corresponding theoretical predictions may be attributed to the ICF processes. Further, dependence of ICF processes on various entrance channel parameters viz., projectile type/energy, imparted input angular momentum (ℓ) to the system, α-break-up energy (Q_α), mass-asymmetry of the interaction partners, etc., has been studied with projectiles such as ^{12}C, ^{16}O and ^{20}Ne, which are considered to have α-cluster structure. But an unambiguous picture is yet to emerge. The cluster structure has been suggested as one of the factors leading to forward peaked alpha particles in ICF reactions. However, no systematic studies have been carried out to ascertain this aspect. In order to explore the underlined issues, the EFs of ^{13}C+^{169}Tm (present work) and ^{12}C+^{169}Tm [5] systems at energies $\approx$ 4-7 MeV/A have been compared to study convincingly the projectile structure effects on the ICF reaction dynamics.

The experiments were carried out at the IUAC, New Delhi, India using 15-UD Pelletron Accelerator. A detailed description of target preparation, irradiations of the targets, post irradiation analysis, identification of evaporation residues etc., is given elsewhere [6].

Several radioactive residues populated in ^{13}C+^{169}Tm interactions have been identified by their characteristic γ-lines, which were further confirmed by decay analysis. The production cross sections of the residues have been determined using the standard formulations. In the present work, the cross-sections for $^{182-x}$Re (x=3-6), ^{177}W, $^{178-x}$Ta (x=3-5) and $^{174-x}$Lu (x=2, 3) residues produced

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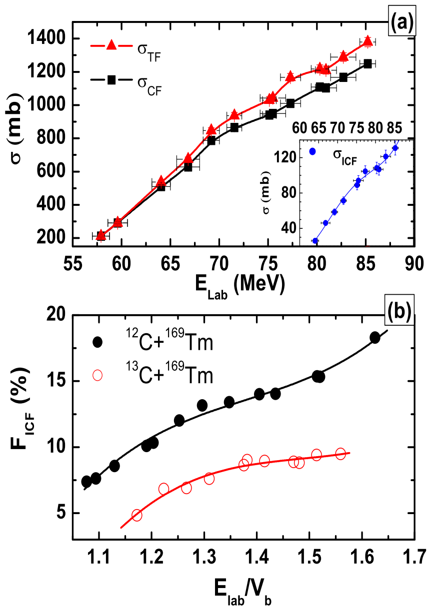

FIG. 1: (a) The total fusion cross-section plotted with complete and in-complete fusion cross section against the projectile energy. (b) The deduced % F_{ICF} for ^{12}C, ^{13}C+^{169}Tm systems as a function of normalized projectile energy.

through CF and/or ICF reaction processes have been measured in the energy range ≈ 55-86 MeV. The measured EFs have been analyzed within the framework of the statistical model code PACE4 [7]. Detailed definition and listing of the physically reasonable input parameters of this code are given in ref. [6]. The code PACE4 takes formation and decay of compound nucleus into account according to the Hauser-Feshbach theory. As such, any deviation in the experimental EFs from the calculations may be attributed due to the competing ICF processes. The experimentally measured EFs of all xn and pxn channels populated in ^{13}C+^{169}Tm interactions have been found to be reproduced by calculations done with reasonable set of parameters. On the other hand, the measured cross-sections of α-emitting channels are found to be substantially higher than the PACE4 calculations done employing the same set of input parameters, as used for CF channels. Figure 1 (a) shows the total fusion cross-section (σ_{TF}) with CF cross-sections (σ_{CF}) and ICF cross-sections (inset). Further, to study the dependence of ICF contribution on various entrance channel parameters, the percentage fraction of ICF cross section ($\%F_{ICF}$) for the presently studied ^{13}C+^{169}Tm system has been deduced and plotted in Fig. 1(b), as a function of beam energy normalized to Coulomb barrier and compared with ^{12}C+^{169}Tm. As can be seen from this figure, the percentage ICF is significantly higher for the ^{12}C projectile as compared for ^{13}C projectile. The strikingly different behavior of ICF contribution in two cases may be attributed to the differences in projectile structures of two incident nuclei. One of the reasons for drastically smaller ICF fraction for ^{13}C projectile may be due to its relatively large negative α-Q value as compared to ^{12}C. Further details regarding the dependence of ICF contribution on various entrance channel parameters including that on α-Q value of the projectiles will be discussed.

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