Study of incomplete fusion dynamics in $^{16}O+^{45}Sc$ interactions

Avinash Agarwal[1,*], Sunil Dutt[1], Munish Kumar[1], I. A. Rizvi[2], R. Kumar[3] and A. K. Chaubey[4]

[1]*Department of Physics, Bareilly College, Bareilly - 2430055, INDIA*
[2] *Department of Physics, Aligarh Muslim University, Aligarh - 202002, INDIA*
[3]*Nuclear Physics Group, Inter University Accelerator Centre, New Delhi - 110067, INDIA*
[4]*Department of Physics, Addis Ababa University P. O. Box 1176, Addis Ababa ETHIOPIA*
** email: avibcb@gmail.com*

The study of reaction dynamics in heavy ion induced reactions ($Z \leq 10$) near and above the Coulomb barrier energies has been the field of specific interest in recent years [1-3]. The reaction cross section is shared predominantly among the following competing processes: (i) complete fusion (CF), involving full momentum transfer; (ii) incomplete fusion (ICF), in which some part of the projectile moves as a spectator while the remainder fuses with the target, leading to transfer of a fraction of the incident momentum (also called massive transfer reactions); and (iii) direct reactions, involving transfer of a single nucleon or cluster in a grazing collision, with very little momentum transfer. At higher incident energies (>10 MeV/A) pre-equilibrium emission processes also become important. Britt and Quinton [4] first observed such kind of reactions in the bombardment of different targets by ^{12}C, ^{14}N, ^{16}O projectiles at energies > 10 MeV/A. Further, particle-γ coincidence studies by Inamura et al. [5] contributed to the understanding of the mechanism of these reactions. Morgenstern et al. [6] showed that incomplete fusion reactions significantly contribute to total reaction cross section for mass asymmetric systems as compared to mass symmetric systems at the same relative velocity. Several models have been proposed to explain the features of these processes.

Following our previous work of the measurement of excitation functions (EFs) for $^{16}O+^{45}Sc$ system [7], in this paper, we have studied the dependence of ICF fraction (F_{ICF}%) on projectile energy in the energy range ≈ 50-105 MeV. An attempt has also been made to probe the dynamics of F_{ICF}% with entrance channel mass-asymmetry for different projectile-target combinations.

The detailed information of experimental procedure, target preparation, data analysis etc. is given in our earlier publication [7].

The theoretical analysis of the data was carried out using the statistical model code PACE4 [8]. Since, at these energies, the reactions leading to lighter compound nucleus (CN) (A_{CN}<100), the formation of evaporation residues (ERs) is the main decay mode. However, there is competition between complete fusion (CF) and incomplete fusion (ICF) reactions and the picture is still not clear. The fraction of ICF in α- emitting channels can be

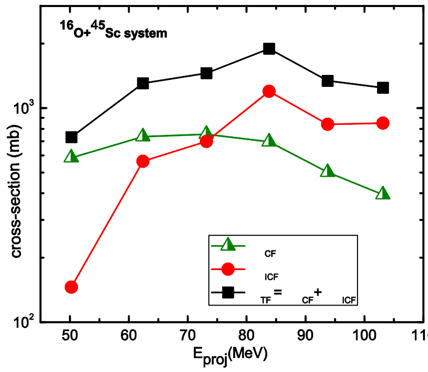

Fig. 1 Total fusion cross-sections σ_{TF} along with $\Sigma\sigma_{CF}$ and $\Sigma\sigma_{ICF}$ is plotted as a function of projectile energy for the system $^{16}O+^{45}Sc$. Solid lines are drawn to guide the eyes.

accounted by analyzing EFs of evaporation residues in the framework of statistical model predictions. As we know that the code PACE4 does not take ICF in to account, therefore, the enhancement in the measured cross-sections over PACE4 predictions is attributed to ICF along-with CF dynamics. The ICF contribution (σ_{ICF}) for individual channels was estimated by subtracting the PACE4 values from the experimentally measured cross-sections. The total CF cross-section ($\Sigma\sigma_{CF}$) was calculated by adding the experimentally observed values for all non α-emitting channels and PACE4 values for observed α-emitting channels. In order to incorporate with the missing CF channels, the value of $\Sigma\sigma_{CF}$ has been corrected using PACE4 predictions. However, no correction could made to incorporate the missing ICF channels, therefore, the total ICF cross-section ($\Sigma\sigma_{ICF}$) was obtained by adding the incomplete fusion cross-sections of all the measured evaporation residues populated through α-emitting channels. The total fusion cross-section σ_{TF} was obtained simply adding $\Sigma\sigma_{CF}$ and $\Sigma\sigma_{ICF}$ and is plotted along with ($\Sigma\sigma_{CF}$) and ($\Sigma\sigma_{ICF}$) as a function of incident projectile energy as shown in Fig. 1.

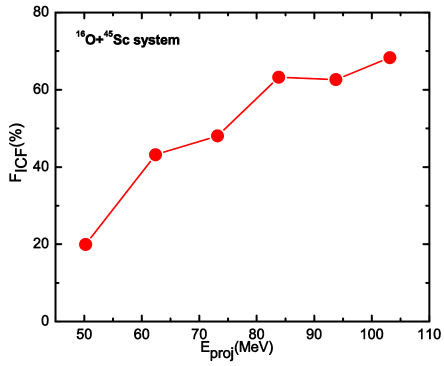

Fig. 2 The probability of incomplete fusion (F_{ICF}%) as a function of projectile energy. Solid line is drawn to guide the eyes.

For better approach into the inception and influence of ICF, the percentage fraction of incomplete fusion (F_{ICF}%) has been calculated by the formula, $F_{ICF}\% = (\Sigma\sigma_{ICF}/\ \sigma_{TF})\times 100$. The value of F_{ICF} is plotted as a function of projectile energy as shown in Fig. 2. The value of F_{ICF} for the present system is found to be ≈ 20% at $1.52V_b$ (i.e. ≈ 52% above the barrier), and increases smoothly up to ≈ 68% at the highest energy (i.e. $3.11V_b$).The observed increasing trend of F_{ICF} with energy indicates that the break up probability of incident projectile increases under the influences of input angular momentum. The incident projectile ^{16}O (4α-cluster structure)) may break up into several combinations of α-clusters (i.e. $^{4}He(\alpha)+^{12}C(3\alpha)$, $^{8}Be(2\alpha)+^{8}Be(2\alpha)$, four α-fragments) and depending upon the favorable input angular momentum, one or a group of fragments may fuse with the target and the other moves as a spectator to form an incompletely fused composite system.

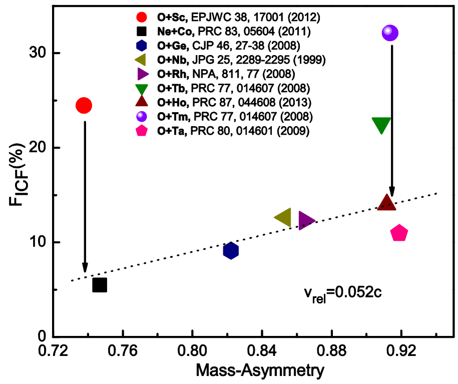

Fig. 3 Variation of % incomplete fusion fraction (F_{ICF}%) as a function of mass-asymmetry for different systems at a constant relative velocity 0.052c. Lines are drawn to guide the eyes.

An attempt has also been made to investigate the effect of mass-asymmetry [$M_a = A_T/(A_T+A_P)$] of interacting partners on the ICF reaction dynamics. The value of $\%F_{ICF}$ for the present system is plotted in Fig. 3 along-with several other systems at a constant relative velocity (i.e. v_{rel}= 0.052c) to normalize the effects of Coulomb barrier. As can be seen from the figure, the data points suggest more $\%F_{ICF}$ for more mass-asymmetric systems and are in accordance with Morgenstern et al. [6]. However, there is large discrepancy for $^{16}O+^{45}Sc$ and $^{16}O+^{169}Tm$ systems that has to be investigated/discussed. One of the possible reason may be the target/projectile structure and/or α-Q-value effects.

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