Role of Target Deformation (β_2) in incomplete fusion at energies ≈4-7 MeV/A

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Delving into heavy-ion interactions at energies 4-7 MeV.A [1-7] can provide a great deal of information on the systematic trend of the in-complete fusion (ICF) reactions. In such interactions at energies near and above the Coulomb barrier using alpha-clustered and non – alpha clustered projectiles [9-10], a substantial contribution of ICF has been observed. In order to unfold the ICF reaction, several studies have been made and a large fraction of enhancement of the fusion cross section with respect to the statistical model code PACE[11] has been reported.

In recent literature [12], dependence of ICF on entrance channel mass asymmetry $\mu(=A_T/A_T+A_P)$ of the interacting partners has been reported [12] at energies above 10 MeV.A. However, Singh *et. al.*[12] has proposed the projectile dependent mass asymmetry to explain the trend of the ICF. Further, Yadav *el. al.* divulge the impact of projectile structure on ICF and α–Q–value systematic[1]. The larger Q_α translates smaller breakup probability into its constituent i.e. α-particles. In this way, Shuaib et al plotted the F_{ICF} fraction as function Z_PZ_T for ^{12}C, ^{16}O, and ^{19}F projectiles with different targets (Z_PZ_T ≈ 270–640; 11 projectile-target combinations), where linear dependence has been observed. However, it is also reported that proposed Z_PZ_T systematics [12] is unable to explain the data for systems with same Z_PZ_T values. Hence, the systematic behavior of the enhancement of fusion cross section is still an open area of investigation, particularly in low energy region. In this scenario, the role of deformation of the entrance channel in fusion enhancement is not well understood; despite the several literatures on ICF are available [1-5]. Present work is focused to study the role of deformation of the entrance channel in incomplete fusion reactions at energies of interest.

To reveal the role of projectile as well as the targets on the onset of ICF, several experiments have been performed at Inter University Accelerator Centre (IUAC), New Delhi using the activation followed by offline gamma ray spectroscopy. The detailed descriptions of the experiments, methodology used and experimental setups have been discussed elsewhere [8]. However, a brief of experimental details are given here for ready reference. For the measurements of the excitation functions, irradiation of the samples has been carried out in the General Purpose Scattering Chamber (GPSC) having in-vacuum transfer facility. The excitation function (EF) of each individual residues populated via CF and/or ICF in ^{12}C,+X(In, Tb, Ta, Tm,& Lu) and ^{16}O+X(Nb, In, Rh, Tb, Ho and Tm) systems have been measured at energies near and above the Coulomb barrier. To cover the wide range of the projectile energies, stacked foil technique for the energy degradation has been used. A stack of 2-3 target 2 to 3 thickness ≈ 1 to 2 mg/ cm^2 followed by the aluminum catchers foils of appropriate thicknesses to stop the recoiling residues as well as served the energy degrader. The target-catcher assembly was irradiated in GPSC with ^{12}C & ^{16}O beams of energy range ≈ 4-7 MeV.A, the beam current was ≈30 nA. The evaporation residues populated during the irradiation were collected into the catcher foils and then counted using pre-calibrated HPGe detectors. The residues have been identified by their characteristic γ-rays and confirmed by their half-live. The cross-sections of residues have been calculated using by standard prescription. The overall estimated error in cross-sections is to be ≈15 %. The fraction of incomplete fusion (F_{ICF}) has been deduced using formulations given by Gomes *et al.*,[6]. The strength of incomplete fusion (σ_{ICF}) has been obtained via subtracting the experimentally measured complete fusion cross-section (σ_{CF}) from the measured total production cross section (σ_T) for each channel. However, the relative strength of ICF at each energy may be calculated as[5],

$$F_{ICF} = \frac{\sigma_{ICF}[=(\sigma_T - \sigma_{CF})]}{\sigma_T} \times 100$$

Fraction of incomplete fusion has been deduced for all projectile and target combinations energies [1,8,12,14]. The fraction of ICF verses reduced beam energy has been plotted[12]. Further to understand the effect of the target structure on the onset of ICF the fraction of ICF (F_{ICF}) at constant relative velocity (v_{rel} = 0.053c) for ^{12}C,+X=(In, Tb, Ta, Tm,& Lu) and ^{16}O+Y=(Nb, In, Rh, Tb, Ho & Tm) systems has been extracted and plotted as function of β_2[15] in Fig.1. It has been observed from the figure that higher the defamation higher the ICF and consequently lower the deformation mean spherical nuclides having less probability and deformed nuclei have higher probability. The trend of incomplete fusion increases exponentially with the deformation of the target nucleus. Further the role of deformation for different projectile-target combinations under investigation. And their results may present during the conference.

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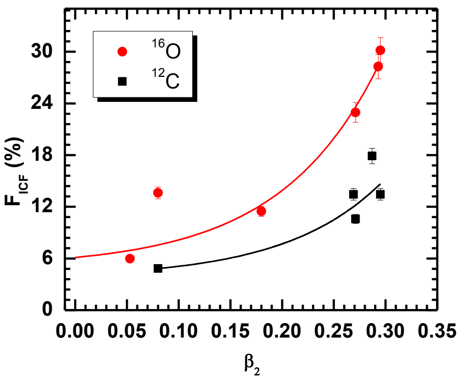

Fig. 1 F_{ICF} as function of target deformation (β_2) for 11 systems ^{12}C,+X=(In, Tb, Ta, Tm,& Lu) and ^{16}O+Y=(Nb, In, Rh,Tb, Ho and Tm). Lines are fit of the data.

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