Extricate of incomplete fusion reactions at 4-7 MeV/A System:^{19}F+^{159}Tb

Unnati[1*], S. K. Mandal[1], A. Yadav[2], D. P. Singh[3], S. Goswami[4], M. K. Sharma[5] and B. P. Singh[4]

[1]Department of Physics and Astrophysics University of Delhi, Delhi - 110007, INDIA
[2]Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA
[3]Department of Physics, University of Petroleum and Energy Studies, Dehradoon-248 007
[4] Department Physics, A. M. U. Aligarh-2020025
[5] Department of Physics, S. V. College Aligarh-201001
* email: unnatig@gmail.com

Probing of heavy ion interactions and extricating of incomplete fusion (ICF) reactions at low energy regime is a topic of current interest. The main points of such studies is to explore the effect of various entrance channel parameters, *viz.*, (i) the projectile energy, (ii) the mass asymmetry of interacting partners, and (iii) the input angular momenta imparted into the system. It is also pointed out that a separation of CF (Complete Fusion) from ICF is important for meaningful interpretation towards the splitting of nuclei. Further, considerable efforts are being employed to synthesize super heavy nuclei[1], the presence of various competing channels may add complexity to the synthesis of super heavy nuclei and obstruct the formation of such nuclei. Although, it is now possible to investigate reaction mechanism involved in formation of such nuclei but experimental studies are limited.

In general, the fusion of all nucleonic charge and mass of the projectile to the target nucleus is termed as complete fusion (CF)[1] and plays a role of sole contributor at energies 4-7 MeV/nucleon. However, at these energies, fusion of few charge and mass of the projectile to the target nucleus is termed as incomplete fusion (ICF). While, remaining part of the projectile moves in the beam direction with almost beam velocity. The ICF reactions occur in the range of angular momentum (ℓ) just above the angular momentum (ℓ_{crt}) for the complete fusion[1-6]. The separation of various competing mechanisms is very important to understanding the effect of ICF on CF. Fusion reactions with high intensity stable and/or radioactive beams which have a significant breakup probability are good references for testing the models, till now no theory is available to describe the complexity in such processes. To investigate the ICF using heavy ion beams and medium mass target at low energies and to see the effect of projectile energy and role of alpha Q-value on the onset of incomplete fusion, the excitation functions and recoil range distributions of heavy reaction products along with angular distributions of the recoiling residual nucleus have been measured for the different target-projectile combination using in-beam /off beam technique.

To investigate the effect of projectile on the onset of ICF, experiments have been performed at IUAC New Delhi using the activation technique. The irradiation of the samples has been carried out in the General Purpose Scattering Chamber having an in-vacuum. The detailed descriptions of methodology and experimental setups have been discussed elsewhere[1]. However, a brief account of experimental conditions is given here for the ready reference. The excitation function (EF) of individual reaction residues populated via CF and/or ICF in $^{12,13}C$,$^{18,16}O$+^{159}Tb systems have been measured using stacked foil activation technique . A stack of 3 target foils of natural ^{159}Tb of thickness ≈ 1 to 1.8 mg/ cm^{-2} backed via aluminum catchers of appropriate thicknesses to stop the recoiling residues was bombarded in GPSC with $^{12,13}C$ & $^{18,16}O$ beams of energy range ≈ 4-7 MeV/nucleon of beam current ≈20-30 nA. The evaporation residues populated during the irradiation were counted using off-line gamma ray spectroscopy with two pre-calibrated HPGe detectors. The residues have been identified by their characteristic γ-lines and confirmed via their decay curve analysis. The production cross-sections of residues have been calculated using standard formulation. The overall error in cross-sections is estimated to be ≈15 %. The fraction of F_{ICF} has been deduced using prescription given by Gomes *et al.*,[5].

The contribution of incomplete fusion (σ_{ICF}) has been obtained via subtracting the complete fusion cross-section (σ_{CF}) from the experimentally measured production cross section (σ_T) for each channel. However, the relative strength of ICF at each energy may be defined as[5],

$$F_{ICF} = \frac{\sigma_{ICF}}{\sigma_T} \times 100$$

Fraction of incomplete fusion has been deduced for all projectile energies[6]. From the analysis of measured EFs and forward recoil ranges (FRRDs)[1-6] of α-emitting channels at energies of interest, the enhancement of fusion cross sections has been observed. Nevertheless, both the measurements of FRRD and the EFs are fairly agreed with each other. The fraction of ICF verses reduced beam energy has been plotted in Fig. 1 which shows ~4.5% contribution of ICF at ~20% above the Coulomb barrier (CB) while ~8.2 % contribution of ICF at ~48% above the CB.

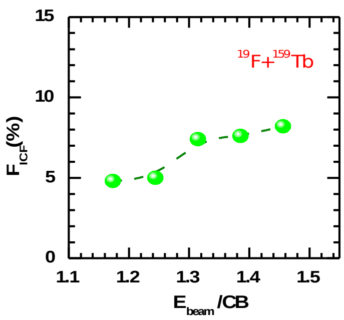

Fig. 1 F_{ICF} as function of reduced beam energy for $^{19}F+^{159}Tb$ system[6]

Further to understand the effect of the projectile structure on the onset of ICF the fraction of ICF (F_{ICF}) at constant relative velocity (v_{rel} = 0.053c) for ^{19}F + ^{159}Tb[6] system has been extracted and plotted as function of Q_α (MeV) in Fig.2. It has been observed from the figure that the F_{ICF} of $^{18,16}O$ and $^{12,13}C$ with ^{159}Tb can be understood by recently proposed α–Q–value systematic[1]. The more-negative α–Q–value for ^{13}C translates into the smaller breakup probability into its constituent α-particles, resulting in a smaller fraction of ICF than the F_{ICF} for ^{18}O induced reactions.

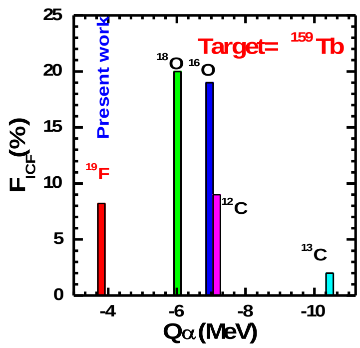

Fig.2 F_{ICF} as function of α-Q-values at constant relative velocity 0.053c

However, in case of ^{19}F beam such systematic has not been observed. To get a clear picture of α–Q–value systematic, more experimental date is required using ^{19}F beams with different targets. The theoretical calculations with computer code based on statistical model[7] are in progress, results with detailed discussion will be presented during symposium.

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