Incomplete fusion in ^{12}C +^{159}Tb interactions at energies ≈4-7 MeV/A

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Introduction

The study of in-complete fusion (ICF) processes in heavy-ion (HI)-induced reactions at projectile energies ≈ 4-7 MeV/A, where complete fusion (CF) is expected to be the sole contributor, has been a topic of resurgent interest. From recent studies [1-4] it can be inferred that the ICF starts competing with CF even at energies slightly above the Coulomb-barrier. The CF and ICF processes may be categorized on the basis of angular momentum (ℓ). The ℓ-values from ℓ=0 to ℓ_{crit} leads to the CF, however, for $\ell > \ell_{crit}$ the fusion of two interacting partners is strongly hindered leading to ICF reactions. In the case of ICF, to release excess input angular momenta, the projectile may break up into fragments, one of the fragments may merge with the target nucleus to form an incompletely fused composite system. The un-fused part of the projectile may flow at forward angles with the projectile velocity [1-4]. The main motivation of ICF studies is to explore the effect of various entrance channel parameters on reaction dynamics, such as the projectile energy, the mass asymmetry of interacting partners, the input angular momenta imparted to the system, etc. To explain the ICF reaction dynamics, several models and theories have been proposed but generally speaking, all of these explain the experimental data up to some extent at energies > 10 MeV/A or so. However, no satisfactory comparison has been observed at relatively low bombarding energies (i.e., ≈4-7 MeV/A). As such, in view of the unavailability of reliable theoretical models to explain the experimental data at low projectile energies, the study of ICF reaction dynamics is still an active area of investigation. In order to develop a theoretical framework to explain ICF reaction dynamics at low energies, it is required to have large amount of experimental data at these energies. As such, for better understanding of ICF reaction dynamics at low energies, in the present work, excitation functions (EFs) for several radio-nuclides produced, in the ^{12}C+^{159}Tb interactions, via CF and/or ICF have been measured in the projectile energy range ≈ 4-7 MeV/A.

Experimental Methodology

The experiments have been performed using $^{12}C^{5+/6+}$ beam delivered from the 15UD-Pelletron accelerator at the Inter University Accelerator Centre (IUAC), New Delhi, India. The targets of spectroscopically pure ^{159}Tb, of thickness ≈2 mg/cm^2, have been used. To trap the recoiling products produced via different reaction processes, Al-catchers of appropriate thicknesses were placed after each ^{159}Tb target. The thickness of each target and catcher foil was measured by α-transmission method. Irradiations were carried out in the General Purpose Scattering Chamber (GPSC), which has an in-vacuum transfer facility (ITF). In the present work, cross-section data at 15 different energies have been obtained by irradiating five stacks, each of three target-catcher foils, at energies ≈ 59, 70, 73, 85 and 88 MeV to cover a wide energy range. Keeping the half-lives of interest in mind, irradiations were carried out for ≈8-10 h for each stack. The beam current was ≈30 nA throughout the irradiations. The activities produced after irradiation were recorded using a pre-calibrated, HPGe detector of 100 c.c. active volume coupled to a PC through CAMAC based CANDLE software for data acquition. The reaction residues produced during the interaction of $^{12}C+^{159}Tb$ were identified by their characteristic γ-rays and confirmed by their decay curve analysis. The cross sections for the population of evaporation residues were determined from the observed γ-activity [5].

Results and Discussion

The EFs for 9 reaction residues populated via xn (x=3, 4, 6), pxn (x=3) and αxn (x=2, 4) 2αxn (x=2, 3, 4) channels, which may be formed through CF and/or ICF in the $^{12}C+^{159}Tb$ interactions, have been measured. As a representative case, the measured EFs for the residues populated via xn and pxn channels are shown in Fig.1. The EFs have also been calculated using code PACE4 [6], based on CN-model. In these calculations the level density parameter K=8 is taken. Information regarding the reaction mechanism involved may be obtained by comparing the experimentally measured EFs with the theoretical model based calculations.

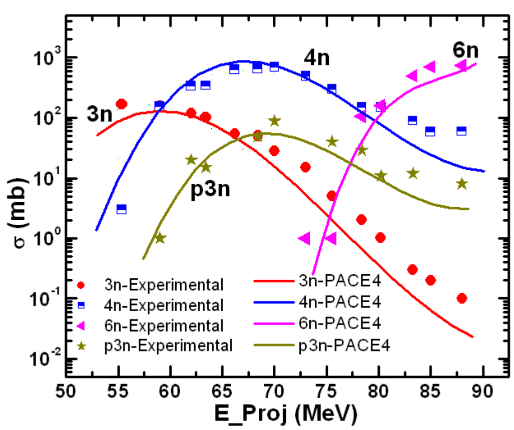

Fig.1: The experimentally measured EFs for xn (x=3, 4, 6) and p3n-channels. The lines drawn are the calculations with best choice of parameters, as discussed in text.

As is obvious from Fig.1, these channels are populated only by CF process and are satisfactorily reproduced by predictions of code PACE4 with physically reasonable set of parameters [2-4]. The measured EFs for all the α-emitting channels were also compared with the statistical model calculations employing the same set of parameters as used to reproduce the CF channels. It has been observed that in case of αxn and 2αxn channels the measured EFs are found to be enhanced over the theoretical predictions (as a representative case EF for α4n-channel is shown in Fig.2). This enhancement may be attributed to the contribution from ICF-reaction process in all α-emitting channels.

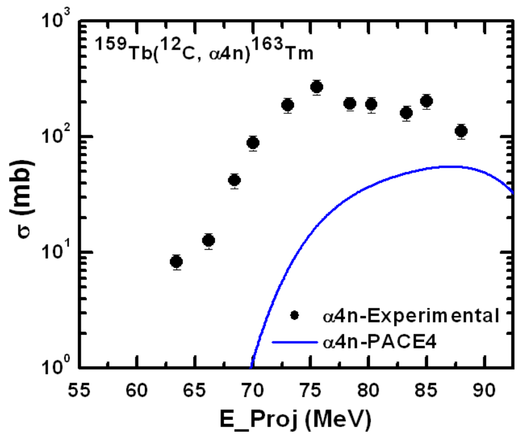

Fig.2: The experimentally measured and theoretically calculated EFs for α4n-channel.

The ICF fraction F_{ICF}, which is a measure of the relative importance of ICF process over the CF process, has also been deduced and is found to increase with energy. Further details of the work will be presented.

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