Low energy heavy ion reactions: Incomplete fusion Vs Complete fusion

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Introduction

In recent years sincere efforts have been taken to understand the incomplete fusion (ICF) reaction dynamics at near the barrier energies [1]. Just above the barrier energy, if the incident projectile is able to transfer the total incident momentum to the target nucleus then it is called complete fusion (CF). However, in some cases the projectile may break-up near the periphery of the target nucleus prior to fusion, especially with weekly bound projectiles, leading to incomplete transfer of momentum from projectile to target. Such types of reactions are called ICF. The presence of ICF at low energies has triggered the resurgent interest to understand & find out the general systematics for low energy Heavy-ion reactions. The first experimental existence of ICF was observed by Britt and Quinton [2]. Later, several dynamical models like, Break-Up Fusion model, Sum-rule model, Promptly Emitted Particles model etc., have been proposed to explain ICF dynamics. Morgenstern *et.al.*[3] in his studies, correlated the ICF fraction with entrance-channel mass asymmetry. To explore consistent general systematic for low energy ICF reactions, measurements of excitation functions (EFs) for ^{18}O+^{93}Nb system at energies ≈ 3–6 MeV/nucleon have been undertaken and data obtained is compared with available nearby system.

Experimental Details

The experiment was planned and performed using 15 UD pelletron accelerator, at IUAC, New Delhi (INDIA) using General Purpose Scattering Chamber (GPSC) facility. Brief experimental details and descriptions are same as given in our earlier publication [1]. The well-established stacked foil activation technique followed by offline gamma ray spectroscopy was used. The target and Al catcher foils were prepared by the rolling technique and their thickness was ≈ 1.4 –1.5 mg/cm^2. To minimize the error in thickness measurement, thicknesses of both target foils as well as aluminum catcher foils were determined using microbalance as well as α-transmission method. Two pre-calibrated HPGe detectors one from IUAC, New Delhi and other borrowed from IIT Ropar were used for counting the activities produced in the target-catcher assemblies individually coupled to a CAMAC based data acquisition system CANDLE. In order to catch sort-lived residues, two detectors were used simultaneously. The energy and efficiency calibration of the HPGe detectors was done using standard ^{152}Eu γ -ray source of known strength.

Result and Discussion

Total sixteen residues were observed to be populated through CF and ICF for ^{18}O+^{93}Nb system. The ERs are identified on the basis of their characteristic γ-rays and confirmed by their half-life measurements. The theoretical analysis of the present system was carried out by using the statistical model code PACE-4, which follows the Monte Carlo simulation procedure for de-excitation of a compound nucleus (CN). This code is based on the Hauser-Feshbach formalism of CN decay [4]. Fig. 1(a-b) show the experimental and theoretical predictions of PACE–4 for the EFs of ^{107}In (4n) and ^{103}Ag(α4n)

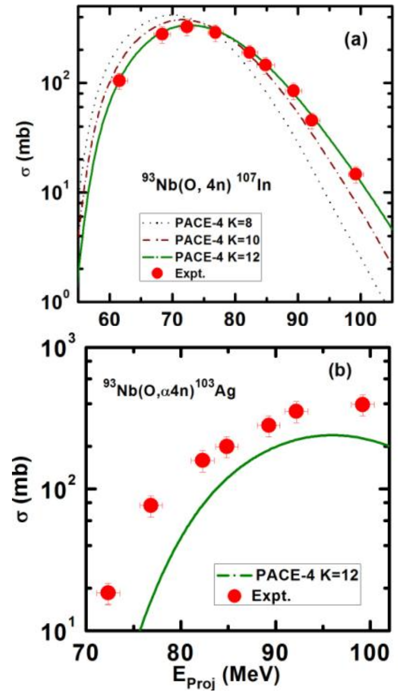

Fig.1: Experimentally measured EFs of evaporation residues ^{107}In(4*n*), and ^{103}Ag(α4*n*) along with PACE-4 predictions.

residues respectively. It is observed that the theoretical and experimental excitation function of *xn* and *pxn* channels are found to be in good agreement, suggesting the population of residues through these channels is due to CF reactions only. For α-emitting channels, a significant enhancement has been observed in experimentally measured cross sections over the theoretically predicted cross section values. Since the code PACE-4 does not take into account the ICF contributions, the enhancement of measured cross section values over theoretical ones may be attributed to incomplete fusion. An attempt has also been made to understand the effect of projectile on ICF reactions. For this the fraction of ICF to total fusion (F_{ICF}), have been deduced for ^{18}O+^{93}Nb and ^{16}O+^{93}Nb [5] systems and plotted in Fig. 2. From Fig.2, it is clear that F_{ICF} for different projectiles with same target reveals a strong projectile dependence on low-energy ICF reactions. It can also be observed that for ^{18}O the F_{ICF} is larger than ^{16}O. One of the possible reasons for this may be the difference in their α- Q values. The more-negative α- Q value for ^{16}O translates into the smaller breakup probability into constituent α-clusters, resulting in a smaller ICF-fraction than for ^{18}O induced reactions. In general, it may be concluded that the ICF fraction strongly depends on entrance channel parameter and a single entrance channel parameter is not sufficient to explicate the ICF reaction dynamics completely. Moreover a general systematic which can take into account all possible entrance channel parameters is still lacking and for that more and more conclusive measurements are required.

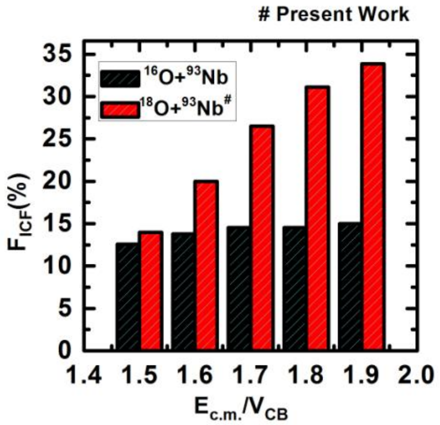

Fig.2: The comparison of F_{ICF} for ^{18,16}O projectiles on same target

Acknowledgements

The authors are thankful to the Director IUAC, New Delhi and Principal, Bareilly College, Bareilly for necessary facilities to carry out this work. One of the author A. A. is thankful to **SERB -DST** for financial support through research project **EMR/2016/006983**. The authors are also grateful to IIT Ropar for P type HPGe Detector used during the experiment

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