Testing Ghosal like experiment for heavy ion induced reactions: An exclusive study of incomplete fusion

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Introduction

Comprehensive studies of heavy ion induced reactions have been vigorous area of investigation by nuclear physicists. In recent years, significant endeavors have been made to understand the dynamics of the complete fusion (CF) and incomplete fusion (ICF) process at energy close to the barrier. [1]. In the case of CF, all of the incident momentum is transferred to the target, while in case of ICF, just a fraction of the projectile fuses with the target and only a fraction of the incident momentum is transferred. The ICF reactions are quite specific due to partial linear and angular momentum transfer to the composite system in the first stage of interactions. The first experimental confirmation 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. Our group has shown great interest to study the dependence of ICF dynamics on various entrance channel parameters [3 - 4]. These studies show that the onset of ICF dynamics does not depend on a single entrance channel parameter, while it depends on various entrance channel parameters.

It may be quite interesting to see how the ICF fraction varies when the two different projectile target systems lead to the same compound nucleus and also test the Ghosal experiment with HI induced reactions for compound nucleus theory of Neil Bohr.

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The attempts have been made to have exclusive study on strength of incomplete fusion, dependence of it on various parameters along with testing of Ghosal like experiment for heavy ions for ^{18}O + ^{159}Tb [5] and ^{12}C + ^{165}Ho [6] systems that leads to the production of same compound Nucleus.

Results and discussions

In the interaction of ^{18}O + ^{159}Tb [5] and ^{12}C + ^{165}Ho [6] systems EF of evaporation residues (ERs) formed through CF and ICF process has been measured at energy around 4-7 MeV/A. The test for Ghosal like experiment has been undertaken for both CF and ICF channels. The sum of experimentally measured cross sections for all xn/pxn channels have been observed to be in good agreement with those obtained through nuclear model code PACE4. It designates that these channels are formed only CF over the considered range of energy. The enhancement in the experimentally measured cross sections for the alpha emitting channels is found over the theoretical predictions obtained using PACE4 code for both the systems. Since PACE4 code does not incorporate ICF in its decay mode, the increases in the experimentally measured production cross-sections for these channels may be assigned to ICF. An attempt is made to separate out the ICF contribution from the measured data of the ^{18}O + ^{159}Tb [5] and ^{12}C + ^{165}Ho [6] systems. The ICF fraction [F_{ICF}(%)] for both the system has been calculated as suggested in Ref. [3]. The value of F_{ICF}, which is a measure

of relative strength of incomplete fusion to the total fusion is calculated by using the formula, defined as (%) $F_{ICF} = (\Sigma\sigma_{ICF}/\sigma_{TF}) \times 100$ and is plotted as a function of normalized projectile energy (E_{lab}/V_{lab} ; where V_{lab} is fusion barrier) and is shown in Fig. 1. The ICF fraction raises for both systems as the incident projectile energy increases, however the F_{ICF} (%) is smaller for $^{12}C+^{165}Ho$ than for the $^{18}O+^{159}Tb$. Moreover, this figure also shows a disagreement with the mass-asymmetry systematic, given by Morgenstern *et al* [7].

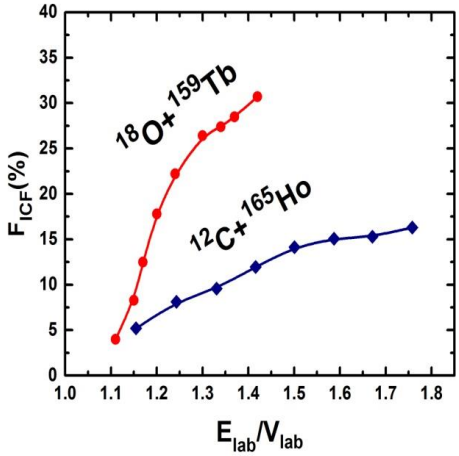

Fig.1: Comparison of deduced F_{ICF} for $^{18}O+^{159}Tb$ and $^{12}C+^{165}Ho$ systems against the normalized energy

According to the Morgenstern *et al* that the mass asymmetry between the interacting partners influences the ICF probability at the constant relative velocity. The relative velocity (Vrel) between the interacting partners is defined as $V_{rel} = [2(E_{c.m.} - V_{CB})/\mu]^{1/2}$ where $E_{c.m.}$ is the projectile energy in the center-of-mass frame, μ is the reduced mass of the system, and V_{CB} is the Coulomb barrier between two interacting partners. The mass asymmetry of the interacting partners is given as $\mu_A = A_T/(A_T + A_P)$, where A_T is the mass of the target and A_P is the mass of the projectile. According to Morgenstern mass-asymmetry systematics, the ICF fraction for $^{12}C+^{165}Ho$ (μ_A=0.9322) being most mass asymmetric, must be greater than that for $^{18}O + ^{159}Tb$ (μ_A =0.8983) system. This disagreement can be explained in terms of Coulomb effect (Z_PZ_T, where Z_P and Z_T are the atomic numbers of projectile and target, respectively).

The Z_PZ_T values for $^{12}C+^{165}Ho$ and $^{18}O+^{159}Tb$ systems are 402 and 520, respectively, which implies that in the case of a low Z_PZ_T value system, the incident projectile will face less Coulomb repulsion than a higher Z_PZ_T value system. Hence, ICF fraction is smaller in the former than later. Furthermore, in order to gain a better understanding, more studies covering lower to higher-mass regions are required.

Conclusion

The Ghosal experiment like test has been done for HI induced reactions and it is observed to be consistent with the findings of him with light ions. In the present study the incomplete fusion fraction has also been deduced for the $^{18}O+^{159}Tb$ and $^{12}C+^{165}Ho$ systems. It has been found that the F_{ICF} (%) is lesser for more mass asymmetric system $^{12}C+^{165}Ho$ than for the less mass asymmetric system $^{18}O+^{159}Tb$. This inconsistency may be understood on the basis of the Coulomb effect.

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