Impact of breakup like processes on fusion and elastic scattering of weakly bound projectiles from medium mass target

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1. Introduction

The breakup of weakly bound projectile into its constituent clusters in the field of the target nucleus can affects the outcome of the collision between the reactant nuclei in several ways [1, 2]. Besides increasing the direct reaction cross section, it modifies the elastic angular distribution, quasi-elastic excitation function and the cross section of complete fusion (CF) reaction. Unlike the strongly bound projectiles, new reaction processes like the sequential complete fusion (SCF) of all the fragments after breakup of the projectile, a process experimentally indistinguishable from CF process and the incomplete fusion (ICF) of one of the breakup fragments of the projectile become more important [3].

In case of fusion of weakly bound stable projectiles like ^{6}Li (S_{α} = 1.47 MeV), ^{7}Li (S_{α} = 2.47 MeV) and ^{9}Be (S_n =1.67 MeV), two primary observations are: The suppression of CF cross section with respect to one dimensional barrier penetration model (1DBPM) prediction at the above barrier energies and the enhancement of fusion cross section at the below barrier energies. It is observed in the collision of these projectiles with heavy mass, high Z targets that the suppression of CF cross section at above barrier energies is caused by the removal of flux from the entrance channel by the breakup reaction. The evolution of this 'suppression effect' with lowering of mass and charge of target is an important aspect to understand. However, it is necessary to distinguish the ICF process from CF process experimentally to estimate the amount of suppression. It is increasingly difficult to separate CF from ICF with decreasing target mass as the measurement provides only the total fusion (TF=CF+ICF) cross section.

Exploring the enhancement of fusion cross section of weakly bound systems at below barrier region is important to probe the evolution of breakup or breakup-like processes with decreasing incident energy. It is necessary to delineate the influence of breakup or transfer followed by breakup in this energy region to understand the origin of enhancement.

The thesis presents new measurements of fusion and back angle quasi-elastic excitation functions for the weakly bound projectiles ^{6,7}Li with medium mass target ^{64}Ni. The primary motivation is to understand the effect of direct reaction channels, like breakup or transfer, on fusion and elastic scattering of these projectiles with medium mass target in terms of the 'suppression' at above and 'enhancement' at below the Coulomb barrier energies. The coupling of the entrance channel with other direct reactions channels splits the nominal Coulomb barrier into multiple barriers. Hence, the barrier distribution functions have also been extracted from both fusion and quasi-elastic excitation functions to probe the importance of these direct reaction channels and their evolution with decreasing energy.

2. Experimental details

Two different experiments have been performed at the Pelletron-Linac facility in Mumbai, India. The fusion and back angle quasi-elastic excitation functions have been measured for the systems ^{6,7}Li + ^{64}Ni at near barrier energies. The online characteristic γ-ray detection method has been used as main ex-

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perimental technique along with offline x-ray method for finding direct ground state transitions.

3. Analysis and Results

The TF cross sections have been defined as the sum of all residue cross sections. The CF excitation functions for the systems are subsequently extracted from the most dominating pure CF neutron evaporation channels by taking help of statistical model predictions. The extracted CF cross sections exhibit an average suppression of ∼13% [4] for more weakly bound projectile ^{6}Li compared to ∼6% for ^{7}Li at above barrier energies. This observation shows that the suppression is directly related with the breakup threshold of the projectiles.

Comparing the observations of CF suppression of these two projectiles with different targets at above barrier energies, it can be concluded that the suppression, in general, decreases with the decrease of target-projectile charge product. But no suppression is observed for TF cross sections in this energy region for both the systems.

At energies below the barrier, both the TF and the CF cross sections are enhanced for both the systems. The observed enhancement of the CF can be explained by coupling to the other degrees of the freedom, but the enhancement in TF cross sections is significantly higher than the theoretical predictions for both the cases. The large enhancement of TF has been identified to originate from the admixture of cluster transfer processes.

The back angle quasi-elastic excitation function for the system ^{6}Li + ^{64}Ni could be explained by the coupling scheme that includes the coupling of inelastic excitations of the target and the projectile as well as the 1n- and 1p-stripping of the projectiles with the entrance channel [5].

The barrier distributions have been extracted from fusion and quasi-elastic excitation functions for the both systems. It is observed that for the system ^{6}Li + ^{64}Ni, the barrier distribution from quasi-elastic excitation function peaked at an energy lower by ∼500 keV compared to fusion barrier distribution. On the other hand they peaked at almost the same energy for ^{7}Li + ^{64}Ni system. It is conjectured that for more weakly bound system ^{6}Li + ^{64}Ni, the reactions other than fusion dominates the absorption of flux at lower energies. The quasi-elastic barrier distribution actually provides the reaction threshold distribution, which peaks at a lower incident energy. But this is not the case ^{7}Li + ^{64}Ni system. Coupled reaction channel calculation also corroborated the observation of the shift.

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