Investigation of incomplete fusion dynamics by measurement of excitation functions in the ^{20}Ne + ^{59}Co system

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Introduction

The study of heavy ion induced reaction in medium energy region has been a growing interest in nuclear physics from past few decades. It has been observed that the projectile energies above the Coulomb barrier of both complete fusion (CF) and incomplete fusion (ICF) may be considered as dominant reaction mechanisms. In case of CF reaction, the projectile completely fuses with the target nucleus and the highly excited compound nucleus decays by evaporating low energy nucleons and alpha particles at equilibrium stage. In the ICF reaction process, only a part of the projectile fuses with the target nucleus, while remaining part moves in the forward direction with almost same velocity of incident ion beam. The excited composite system may undergo de-excitation by emission of particles and /or γ-rays. The first experimental evidence of ICF reactions were given by Britt and Quinton [1], who observed the break-up of the incident projectiles like ^{12}C, ^{14}N and ^{16}O. Inamura et al. [2] observed incompletely fused α-particles peaked at forward angles in their particle-γ coincidence measurement.

In the present work, an attempt has been made to address some important aspects of CF and ICF dynamics for the system ^{20}Ne + ^{59}Co in the projectile energy range ≈ 62–150 MeV by using recoil catcher activation technique with the following off-line γ-ray spectroscopy. Excitation Functions (EFs) for the following reactions: ^{59}Co(Ne, αp4n)^{70}Ga, ^{59}Co(Ne, 3αp3n) ^{63}Zn, ^{59}Co (Ne, 3αp4n) ^{62}Zn and ^{59}Co (Ne, 4α3n) ^{60}Cu have been measured. No precursor decay contribution has been observed for these measured evaporation residues. The measured values of total fusion cross-sections of the above evaporation residues have been compared with the theoretical total complete fusion cross-sections calculated by code PACE-2, which do not take into account ICF contribution.

Experimental Procedure

The experiment was carried out using Heavy Ion Accelerator Facilities at Variable Energy Cyclotron Centre (VECC) Kolkata, India. Targets for irradiations were made by depositing spec-pure ^{59}Co on aluminum backing of thickness ≈2 mg/cm^{2}by a vacuum evaporation technique. The thickness of the each deposited target material on Al-backings was determined by weighing individual Al- backing foils before and after deposition of target ^{59}Co material using micro-balance as well as the α-particle transmission method. Two stacks consisting of five targets of each of ^{59}Co backed by≈2 mg/cm^2 thick aluminum foils were bombarded with a ^{20}Ne^{+7} beam energy of ≈150 and 110 MeV. Irradiations of the target were carried out to encompass the beam energy range from 62–150 MeV.

Results and Discussions

The Excitation Functions (EFs) for the following four reactions: ^{59}Co (Ne, αp4n) ^{70}Ga,

^{59}Co (Ne, 3αp3n) ^{63}Zn, ^{59}Co (Ne, 3αp4n) ^{62}Zn and ^{59}Co (Ne, 4α3n) ^{60}Cu have been measured.

The measured values of total fusion cross-sections $(\sum \sigma^{TF})$ of the evaporation residues (ERs) ^{70}Ga, ^{63}Zn, ^{62}Zn and ^{60}Cu compared with the theoretical total complete fusion cross-sections $(\sum \sigma^{TCF})$ of the above ERs calculated by code PACE-2 corresponding the level density parameter constant K=10 is as shown in Fig. 1. As can be seen from this figure, the measured total fusion cross-sections of these four ERs are found to be much higher than that of total complete fusion cross-sections of PACE-2 predictions. The enhancement may be attributed to the fact that these residues may be populated not only by CF of projectile ^{20}Ne with target ^{59}Co but may have significant contributions from ICF process. Subsequent emission of neutrons and protons during de-excitation of the composite system lead to the production of these residues populated through ICF process.

The fusion fractions of CF and ICF for the system ^{20}Ne + ^{59}Co were calculated by using present measured data and the previous data [3] as shown in Fig. 2, which shows that, initially fusion fraction of CF decreases rapidly, while for ICF increases exponentially between the projectile energies ≈ 62 to 115 MeV. After that both of them remains almost constant up to the projectile energy ≈150 MeV.

From these observations, we can conclude that CF probability decreases very faster in low projectile energy region ≈ 62 to 115 MeV, while ICF probability increases exponentially and then remains constant up to 150 MeV.

Finally it is clear from this figure that the CF fraction is more than that of ICF throughout the projectile energies ≈ 62-150 MeV. It means that the ICF probability is smaller than that of CF in the lighter mass-asymmetric system ^{20}Ne + ^{59}Co.

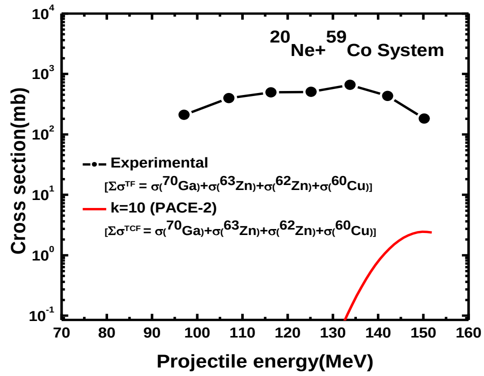

Fig. 1: The measured total fusion cross-sections of the ERs ^{70}Ga, ^{63}Zn, ^{62}Zn and ^{60}Cu and theoretical total complete fusion cross-sections (PACE-2).

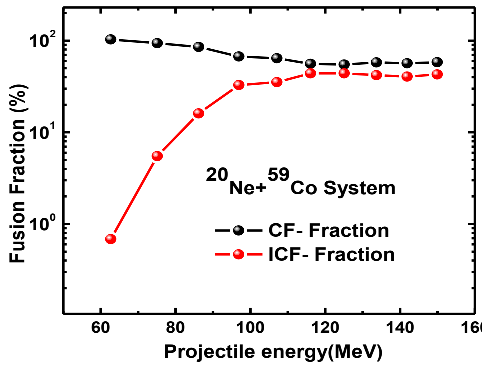

Fig.2. Fusion fraction of CF and ICF for the system ^{20}Ne + ^{59}Co.

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