Complete and incomplete fusion dynamics in ^{20}Ne + ^{165}Ho system

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Introduction

The study of Complete Fusion (CF) and Incomplete Fusion (ICF) dynamics in heavy ion (HI) induced reactions has been resurgent interest in past few decades at energies above the Coulomb barrier. Enough evidences are available in the literature [1-2] to believe that CF and ICF are the only dominant reaction modes at projectile energies below 8 MeV/nucleon. In the complete fusion process, the incident projectile totally fuses with the target nucleus and the highly excited nuclear system decays by evaporating low energy nucleons and alpha particles at equilibrium stage. In this process, entire linear momentum of the projectile transferred to the compound nucleus. In the incomplete fusion process, only a part of the projectile fuses with target nucleus, while remaining part of the projectile moves as a spectator in the forward direction with unchanged velocity as that of the incident projectile with incomplete linear momentum transfer.

Most of the ICF reaction studies available in the literatures [3-4] are confined to medium mass target nuclei, very few studies are available with heavier mass (A>150) target nuclei. In the case of low and medium mass target nuclei, the ICF cross-section is a small fraction of the total fusion cross-section of the evaporation residues (ERs). In the present work, an attempt has been made to address some of the important aspects of CF and ICF dynamics for the system ^{20}Ne + ^{165}Ho in the projectile energy range 4-8 MeV/nucleon by employing the recoil catcher technique followed by off-line γ-ray spectroscopy. The excitation functions (EFs) of the two ERs ^{171}Ta and ^{168}Hf have been measured. In the present measurement no precursor decay contributions has been measured.

Experimental Details

The present experiment for the measurement of EFs was carried out at Variable Energy Cyclotron Centre (VECC) Kolkata, India. Self-supporting natural ^{165}Ho targets of desired thickness with purity better than (99.9%) were prepared by rolling machine. The thickness of each target foils was determined using micro-balance as well as by α-particle transmission method. Two stacks of target-catcher assemblies were bombarded with the ^{20}Ne-ion beam in a vacuum chamber. The targets in the stack along with catcher foils were arranged in such a way that target material faced by the beam, so that the recoiled residues may be trapped in the aluminum catchers. Two stacks consisting of six rolled holmium foils each of ^{165}Ho backed by thick aluminum foils were bombarded with ^{20}Ne^{+7}-beam energy ≈ 165 and 132 MeV. Two independent irradiations were carried out to cover the beam energy ranging between ≈ 4-8 MeV/nucleon. The irradiations have been carried out for ≈ 8 hours duration for each stack. More information of the experimental details is given in [5].

Results and Discussions

The EFs of the two reaction channels ^{165}Ho (^{20}Ne, 2α6n) ^{171}Ta and ^{165}Ho (^{20}Ne, 2αp8n)^{168}Hf produced in the interaction of ^{20}Ne with ^{165}Ho have been measured between projectile energy range ≈ 4-8 MeV/nucleon. The experimentally measured excitation functions have been compared with PACE-4 predictions as shown in Figs. 1 (a)-(b). It can be seen from fig. 1(a) that experimentally measured EF for the evaporation residue ^{171}Ta produced through 2α6n emission channel is much enhanced over their PACE-4 predictions (K=8,10,12). Since ICF contribution is not considered in PACE-4 calculations, this enhancement may be attributed to the fact that the ^{165}Ho (^{20}Ne, 2α6n) ^{171}Ta channel may be populated not only by CF of ^{20}Ne but may also have a significant contribution from ICF of ^{20}Ne. In case of evaporation residue ^{168}Hf, the theoretical predictions of code PACE-4 gives negligible cross-sections, and hence are not shown in the Fig. 1(b), while the measured cross-sections are comparatively much larger. This large enhancement in the experimentally measured cross-sections than their theoretical predictions, the reaction channel ^{165}Ho (^{20}Ne, 2αp8n) ^{168}Hf may again be populated through the ICF process only. Fusion fraction (CF and ICF fraction) as a function of projectile energy for the ^{20}Ne + ^{165}Ho system is plotted as shown in Fig.2. It can be seen from this figure that the ICF fraction exponentially increases with projectile energy, while CF fraction decreases exponentially with the projectile energy. It means that the present data also suggests that the probability of ICF increases with the projectile energy, while the probability of CF decreases with the projectile energy.

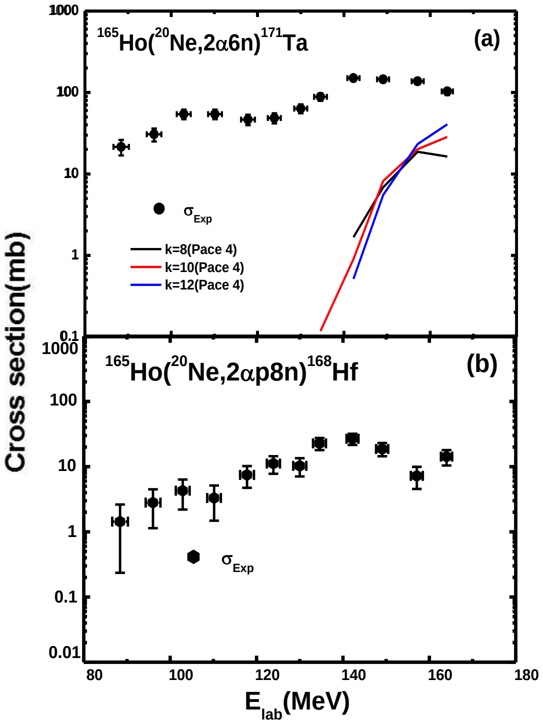

Fig.1. Excitation functions of the evaporation residues (a) ^{171}Ta and (b) ^{168}Hf produced in ^{20}Ne +^{165}Ho system.

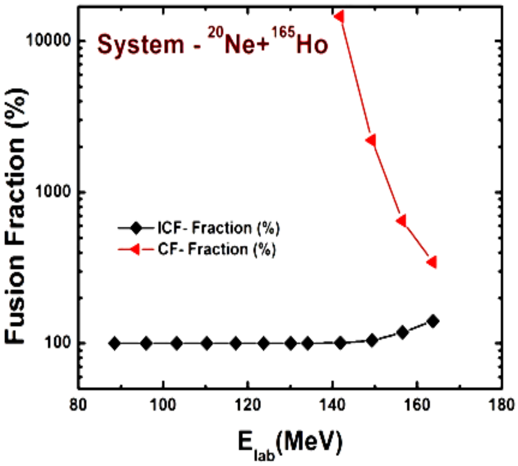

Fig. 2. Fusion fraction (CF and ICF fraction) as a function of projectile energy for the ^{20}Ne + ^{165}Ho system.

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Reference

[1]H.C. Britt et al., Phys. Rev.124, 877 (1961).
[2]T. Inamura et al., Phys .Lett. B 68, 51 (1997).
[3]D. Singh,et al.,Phys.Rev.C 83,054604 (2011).
[4]D. Singh,et al.,Phys.Rev.C81, 027602 (2010).
[5]D. Singh,et al.,Nucl. Phys A 879, 107 (2012).