Fractional momentum transfer in incomplete fusion dynamics by measurement of recoil range distributions in ^{20}Ne + ^{165}Ho system

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Introduction

The study of heavy ion (HI) fusion reactions around Coulomb barrier has been the subject of growing interest in experimental nuclear physics for the past few decades. Under the domain of semi-classical theory of heavy ion interaction, it has been found that at energies below 10 MeV/A the projectile interacts strongly with the target and the phenomena like complete fusion (CF) and incomplete fusion (ICF) may predominantly take place [1]. In case of complete fusion (CF), projectile completely fuses with the target nucleus and forms the excited compound nucleus from which particle and/or gamma rays emission take place. However, in case of incomplete fusion (ICF), projectile is supposed to be break up into fragments and one of the fragments fuses with the target nucleus while rest part of the projectile moves in the beam direction as that of the projectile velocity. The excited composite system formed as a result of the fusion of the fragments of the incident ion may also undergo de-excitation by emission of particles and/or gamma rays. In the recent years, CF and ICF reactions have been studied from the analysis of recoil range distribution (RRDs) of evaporation residues. The measurement of the RRDs of the residues is based on the momentum transfer from projectile to the target. In CF process, momentum of the projectile is completely transferred to the target nucleus hence entire momentum carried by the compound nucleus and hence travels large distance in the stopping medium. But, in case of ICF reaction, partial momentum transfer of the projectile takes place into the target nucleus, hence incompletely fused composite system of the projectile traverse shorter distance in the stopping medium. It is worth to note that most of the studies in ICF at low beam energies have been carried out with projectile ^{12}C and ^{16}O [2, 3]. These projectiles easily break into α-clusters, while one of the fragments fuses with the target nucleus. Incomplete fusion (ICF) reaction dynamics has been studied extensively with low-Z projectiles ($Z \leq 10$) interact with medium and heavy mass target. The experimental ICF studies using projectile ^{20}Ne with heavy mass target are scarcely available. More experimental data on recoil range distributions insight into the HI reaction mechanism that are involved at energies above Coulomb barrier. For the measurement of RRDs of evaporation residue stacked foil activation technique followed by off-line gamma spectroscopy has been used.

Experimental Details

The present experiment has been performed at Variable Energy Cyclotron Centre (VECC), Kolkata, India. The holmium target of thickness 1.265 mg/cm^2 was prepared by rolling machine at Saha Institute of Nuclear Physics (SINP), Kolkata. The target was mounted for irradiation in the specially designed chamber along with 15 aluminium catcher foils. The target and catcher assembly was bombarded with ^{20}Ne-ion beam for about 9 hours. Gamma-ray activities induced in each catcher foils were recorded by 60 cc high purity germanium (HPGe) detector and PC based data acquisition system. The populated evaporation residues have been identified by their characteristic γ -lines and confirmed by decay curve analysis.

Results and discussion

In the present work, the recoil range distributions for the evaporation residues ^{172}Ta(2α5n), ^{171}Ta(2α6n), ^{170}Hf (2αp6n) and ^{168}Hf (2αp8n) produced in ^{20}Ne + ^{165}Ho system at E_{lab} ≈ 8.2 MeV/A have been measured. The measured recoil ranges of evaporation residues were fitted by Gaussian peaks using software ORIGIN. The measured recoil range distribution of the evaporation residues ^{172}Ta(2α5n) shows three component peaks, corresponding to cumulative aluminium thickness of ≈ 1017, ≈ 772 and ≈ 535 μg/cm^2 as shown in Fig. 1(a). In fact the evaporation residue ^{172}Ta is also expected to be produced via three different reaction channels. The peak at thickness ≈ 1017 μg/cm^2 is assigned to CF of the projectile, peak at thickness ≈772 μg/cm^2 is associated with ICF of the projectile (fusion of fragment ^{16}O of the projectile with the target ^{165}Ho) and peak at thickness ≈ 535 μg/cm^2 is assigned to ICF of the projectile (fusion of the fragment ^{12}C of the projectile with the target ^{165}Ho). It is worth to note that observed peak positions in forward RRD agree well with that using classical approach and the theoretical calculation of the ranges made using stopping power tables. The measured RRD of the evaporation residue ^{171}Ta shows three peaks is shown in Fig. 1(b). As can be seen from Fig.1(b), the peak at larger cumulative catcher thickness ≈ 996 μg/cm^2 corresponds to the recoil range of the compound nucleus ^{185}Ir produced via complete fusion of ^{20}Ne with ^{165}Ho, while the peak observed at smaller cumulative catcher thicknesses ≈759 μg/cm^2 and ≈ 536 μg/cm^2 may be produced due to the incomplete fusion of ^{20}Ne (fusion of fragment ^{16}O and ^{12}C with ^{165}Ho), because the partial linear momentum transferred is expected to be less than that for the CF of ^{20}Ne with the target ^{165}Ho. This indicates that the reaction ^{171}Ta(2α6n) may have contribution not only from CF of ^{20}Ne but also have contribution from ICF of ^{20}Ne (fusion of fragment ^{16}O and ^{12}C with ^{165}Ho). The relative contributions of evaporation residues ^{172}Ta and ^{171}Ta of CF (fusion of ^{20}Ne with ^{165}Ho) are found to be ≈ 44% and ≈61% respectively, while for ICF have been found to be ≈29%, ≈ 29%, (due to the fusion of fragments ^{16}O with ^{165}Ho) ≈27% and ≈ 10% (due to the fusion of fragments ^{12}C with ^{165}Ho) respectively.

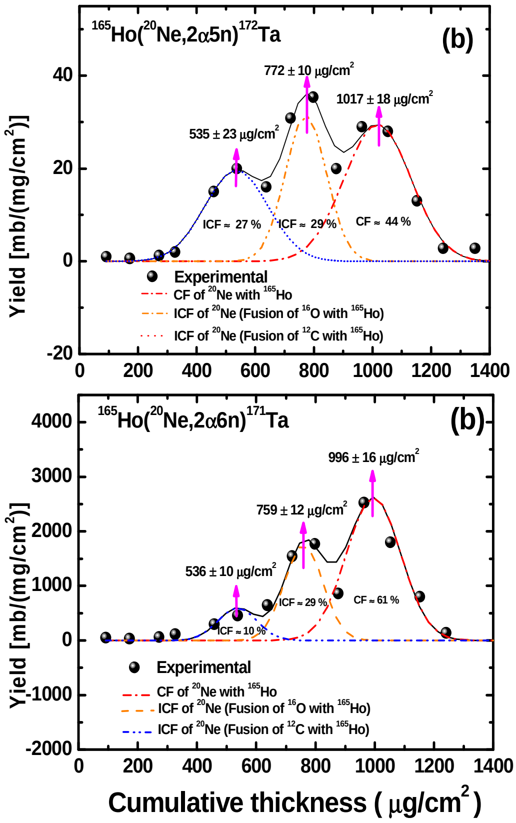

Fig. 1:(Color online) Measured recoil range distribution of evaporation residues(a) ^{172}Ta (b) ^{171}Ta populated in ^{20}Ne+^{165}Ho system at E_{Lab}≈8.2 MeV/A.

Acknowledgments

Authors are thankful to Director and operational staff of Cyclotron, VECC, Kolkata for providing the necessary experimental facilities during the course of this experiment. D. Singh is thankful to University Grant Commission (UGC), New Delhi, India for financial support through UGC-BSR research start-up grant (Project no. F.30-14/2014(BSR) dated 22/07/2014)

References

[1] P.E. Hodgson, Nuclear Heavy Ion reaction, Claredon Press, Oxford, 1978.

[2] S. Chakrabarty et al, Nucl. Phys. A 678 (2000) 366.

[3] M. K.Sharma et al, Phys. Rev. C 70 (2004) 044606.