Investigation of incomplete fusion dynamics by measurement of recoil range distributions in ^{16}O + ^{124}Sn system

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Introduction

The study of heavy ion (HI) induced reactions above the Coulomb barrier has been a resurgent subject of interest in nuclear physics. At projectile energies slightly above the Coulomb barrier, both the complete fusion (CF) and incomplete fusion (ICF) are the dominant reaction mechanism. In case of CF reaction the projectile completely fuses with the target nucleus and the highly excited nuclear system decays by evaporating low energy nucleons. In the ICF reaction, which is characterized by the fractional fusion of the projectile with the target, the projectile is assumed to break-up into fragments (e.g. ^{16}O-ion may break-up into $^{12}C + {}^{4}He$ and /or $^{8}Be + {}^{8}Be$) and one of the fragments fuses with the target nucleus, while remnant moves in the forward direction [1,2]. The excited composite system formed as a result of the fusion of the fragment of the projectile with the target may also undergo de-excitation by emission of particles and / or γ -rays. The possibilities of ICF reactions were first pointed out through experiment by Britt and Quinton [3], observed the break-up of the incident projectiles like ^{12}C, ^{14}N and ^{16}O into alpha clusters in an interaction with the target nucleus at bombarding energy 10.5 MeV/A. However, major advances in the study of ICF reactions took place after the work of Inamura *et al.* [4]. More experimental data on recoil range distributions (RRDs) of the evaporation residues (ERs) are demanded to have better insight into heavy ion (HI) reaction mechanisms at energies above the Coulomb barrier. Special interest lies in the understanding of degrees of linear momentum transfer in the interaction of a HI projectile with the medium mass target. It is possible to separate out the relative contributions of various ICF channels from the measurement of RRDs of ERs at a given projectile energy. The observed RRDs of the produced evaporation residues depend on the linear momentum transferred in the reaction. In the present work, the RRDs of ERs produced at projectile energy ≈6.2 MeV/A using ^{16}O-ion beam in interaction with ^{124}Sn target have been measured. An attempt has been made to separate out the relative contributions of complete fusion and incomplete fusion components from the analysis of measured RRDs data.

Experimental Details

The present experiment has been carried out at Inter University Accelerator Centre (IUAC), New Delhi. Enriched targets of ^{124}Sn with purity better than (97.4%) were prepared by vacuum evaporation technique at Target Laboratory of IUAC, New Delhi, India. The thickness of target and aluminium catcher foils were determined using α-particle transmission method. The stack of 20 Al catcher foils followed by ^{124}Sn-sample was irradiated at projectile energy ≈6.2 MeV/A using ^{16}O-ion beam in a General Purpose Scattering Chamber (GPSC). The target in the stack along with catcher foils were arranged in such a way that target material faced the beam, so that the recoil residues may be trapped in the aluminium catchers. Stack was irradiated for about ≈ 14 hrs, keeping in view the half-lives of interest of evaporation residue. After the irradiation, a stack of aluminium catchers along with target foil was taken out from the irradiation chamber and each catcher foil was counted separately for γ-ray activities of evaporation residues using a calibrated 100c.c. high purity germanium (HPGe)

detector coupled with a PC based data acquisition system employing with software CANDLE. The calibration of the HPGe detector was done using ^{152}Eu-source of known strength. The RRDs for each residue has been obtained by plotting the yield with cumulative thickness. The normalized yields for various evaporation residues have been obtained by dividing the measured cross-section by the thickness of individual catcher foil.

Results and Discussions

The recoil range distributions of several ERs ^{135}Ce(5n), ^{133}Ce(7n), ^{133}Ba (α3n) and ^{132}Cs (αp3n), have been measured. The measured differential RRDs of evaporation residues ^{135}Ce and ^{133}Ba are displayed in Figs. 1(a)-(b). As can be seen in the Fig. 1(a), the RRD of evaporation residue ^{135}Ce shows only one peak at cumulative thickness ≈ 942 ± 15μg/cm^2 in aluminium, which corresponds to the expected value of theoretical mean recoil range of the composite system. Hence, the residue ^{135}Ce is populated via CF of the projectile ^{16}O with ^{124}Sn target nucleus in the emission of 5 neutrons from the compound system ^{140}Ce. Again, as shown in Fig.1(b), the RRD of the residue ^{133}Ba has two peaks at cumulative thickness ≈ 947 ± 20 μg/cm^2 and ≈ 586 ± 16 μg/cm^2 in aluminium. The observed mean recoil range at cumulative thickness ≈ 947μg/cm^2 is obtained due to CF of the projectile ^{16}O with target ^{124}Sn leading to emission of 1α-particle and 3 neutrons from the compound nucleus ^{140}Ce, while another peak observed at cumulative thickness ≈ 586 μg/cm^2 corresponds to ICF of the projectile ^{16}O i.e fusion of fragment ^{12}C (if the projectile breaks-up into ^{12}C and α-particle) with target nucleus ^{124}Sn leading to the emission of 3 neutrons from the composite nucleus ^{136}Ba. In the measured RRD of ^{133}Ba, the resolved peaks correspond to different degrees of linear momentum transferred from projectile ^{16}O to the target ^{124}Sn at present projectile energy ≈ 6.2 MeV/A. Measured RRDs of these residues strongly reveal that significant contribution from partial momentum transfer of the projectile associated with ICF is present. The relative contributions of evaporation residue ^{133}Ba of CF (fusion of ^{16}O with ^{124}Sn) are found to be ≈ 11%, while for ICF (due to the fusion of fragments ^{12}C with ^{124}Sn) have been found to be ≈89% .

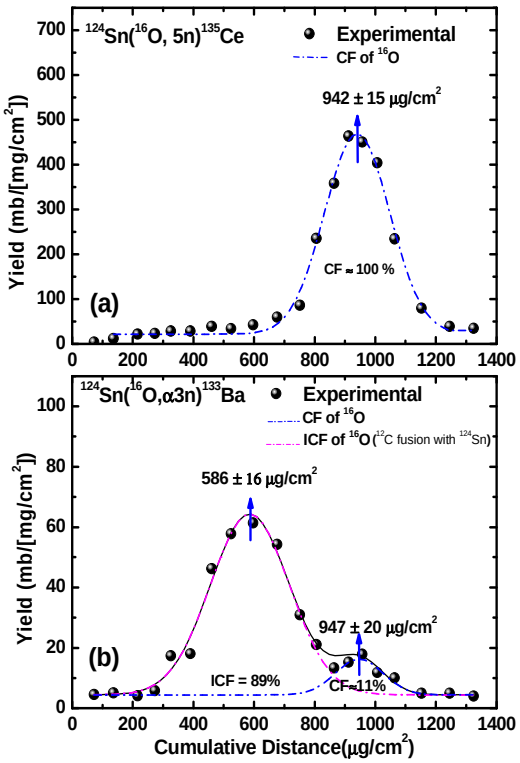

Fig.1. (Color Online) Measured recoil range distributions of the evaporation residues (a) ^{135}Ce(5n) and (b) ^{133}Ba (α3n) produced in ^{16}O + ^{124}Sn system at projectile energy ≈ 6.2 MeV/A.

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