Probing of breakup fusion of ^{18}O projectile with ^{154}Sm target through forward recoil range distributions

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Introduction

The involvement of the incomplete fusion process (ICF) in heavy-ion (HI) induced fusion reactions has captivated significant attention in recent years [1]. During this process, the projectile nuclei break into fragments near the target. Heavier fragments merge with the target nuclei, creating an intermediate composite system (ICS), while the lighter fragments continue moving as spectators. It is now well established that the ICF process competes with the complete fusion (CF) process at the above barrier energies. Different investigators adopt various experimental methodologies in the literature to study the CF and ICF processes [2-4]. However, one can effectively analyze these processes using the forward recoil range distribution approach. This approach measures the degree of momentum transfer in these reactions by observing the linear recoil range of the evaporation residues (ERs) in an absorbing material. In CF reactions, a compound nucleus (CN) is formed through the complete transfer of linear momentum from the projectile to the target nucleus. In contrast, ICF involves the formation of an ICS via partial linear momentum transfer. Therefore, when ERs populated through the CF process show a greater forward recoil range in the absorbing medium while a smaller forward recoil range has been observed for the ERs populated via the ICF process.

With this motivation, a comprehensive study has been done to investigate the involvement of the ICF process in the present ^{18}O+^{154}Sm system through forward recoil range distributions (FRRDs) at a beam energy of 100 MeV.

Experimental methodology

Measurements were performed using the 15UD Pelletron accelerator facility at the Inter-University Accelerator Centre (IUAC), New Delhi, India. The FRRDs of the ERs populated in the ^{18}O projectile ^{154}Sm target have been measured using offline γ-ray spectroscopy. An enriched ^{154}Sm target with a thickness of ≈ 0.35 mg/cm^2 was prepared by vacuum evaporation technique in the target fabrication laboratory at IUAC, New Delhi, India [5]. A single stack consisting of a thin ^{154}Sm target followed by 21 thin aluminium catcher foils (20 - 60 μg/cm^2) was bombarded with the ^{18}O^{7+} beam energy 100 MeV in GPSC (General Purpose Scattering-Chamber) at IUAC, New Delhi. More details about the data recording and identification procedure employed for populated ERs have been discussed in the ref [6].

Analysis and result

In the present work, the FRRDs of various ERs populated through CF and ICF processes in the ^{18}O+^{154}Sm system have been measured. To get the normalized yields of measured ERs, the measured cross section of the ERs in each foil was divided by the thickness of the respective foil (in mg/cm^2). The resulting yields [mb/(mg/cm^2)] were plotted against the cumulative catcher thickness to obtain the range distribution of identified ERs. Further, the theoretical recoil ranges of the populated ERs were also calculated

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using the classical approach and the SRIM code [7]. As a representative case, the measured FRRDs for ^{167}Yb and ^{167}Ho populated via 5n and αp channels have been shown in Fig.1(a) and (b) respectively. As can be seen from Fig.1(a) the measured mean recoil range distributions for ^{167}Yb ER show a single Gaussian peak at a cumulative depth ≈ 637 ± 76 μg/cm^2 in aluminium catcher foil. Further, the measured mean range of this ER is found to agree with the theoretically calculated mean range for CN. Therefore, the present observations indicate that this ER is populated via the entire linear momentum transfer from the ^{18}O projectile to the ^{154}Sm target due to

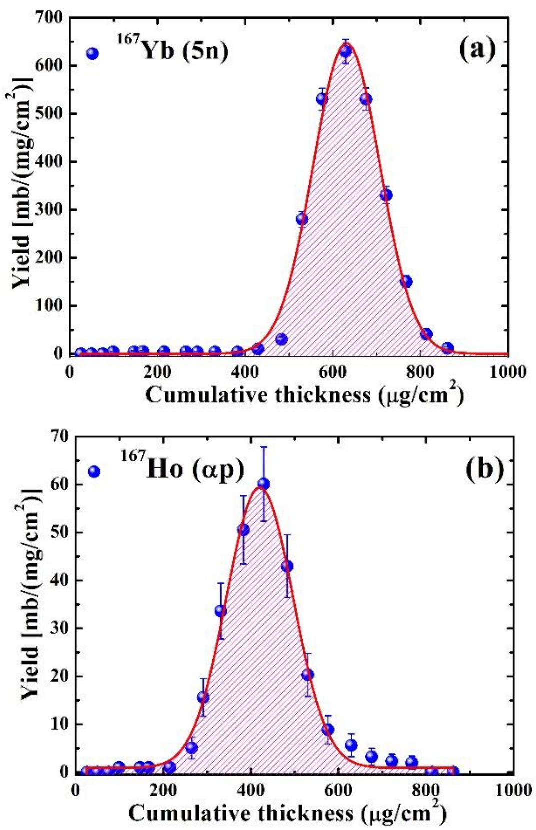

Fig.1. Experimentally measured FRRDs for a) ^{167}Yb (5n) and b) ^{167}Ho (αp) ERs at 99.74 MeV.

the CF process only.

Similarly, in Fig.1(b) the measured mean recoil range distributions for ^{167}Ho ER also show a single Gaussian peak at a cumulative depth ≈ 423 ± 60 μg/cm^2 in aluminium catcher foil. It is important to note that the population of this ER in the present system is not predicted by the PACE-4 code [8]. Therefore, the identification of this ER through the α emission channel strongly indicates the involvement of the ICF process in the present system. Besides that, the measured mean range of this ER is found to agree with the theoretically calculated mean range for ICS.

In conclusion, the present observations indicate that the FRRDs measurement of the populated ERs is an important tool for separating out contributions of CF and ICF processes. Residues formed via the CF process exhibit the complete transfer of momentum from the projectile to the target nucleus, as evidenced by the larger depth of mean recoil range in the aluminium foil. In contrast, residues populated through ICF processes, demonstrate partial momentum transfer due to the breakup of the ^{18}O projectile into ^{14}C + α and are characterized by a lower depth of mean recoil range in the aluminium foil. These signatures provide crucial insights into the ICF dynamics at energy above the Coulomb barrier.

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