Breakup fusion of ^{18}O Projectile with ^{154}Sm at energy ≈ 3-7 MeV/nucleon

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Introduction

In recent years, the entanglement of incomplete fusion (ICF) in heavy ion (HI) induced nuclear reactions at projectile energy above the Coulomb barrier has been explored with great interest [1]. Multiple reaction channels may open during the interaction of a heavy ion with the target. Generally, in the vicinity of the barrier, complete fusion (CF) becomes the only contributor to the cross-section of total fusion (TF). However, at higher energies, the ICF process becomes a major contributor to the total fusion cross-section. Therefore, ICF plays a significant role in understanding nuclear reaction dynamics. Enhancement in the fusion cross-sections for α-emitting channels is an important characteristic of ICF. The first experimental evidence of ICF contribution reported [2] in the break-up of incident projectiles. Recent investigations [1,3,4] suggest that various entrance channel parameters have a great impact on ICF dynamics.

Experimental Procedure

The present experiment was carried out by our group at the Inter-University Accelerator Centre (IUAC), New Delhi, India. Enriched Targets of ^{154}Sm (98.69%), with a thickness ≈ 400-600 μg/cm^2 were irradiated by beam of $^{18}O^{7+}$, in the energy range E_{Lab} = 70-104 MeV. The offline stacked foil activation technique has been employed to measure the Excitation Functions (EFs). A single stack consisting of seven samarium foils backed by thick aluminium foils (1.0-1.5 mg/cm^2) was bombarded with the ^{18}O ion beam in GPSC (General Purpose Scattering-Chamber) at IUAC, New Delhi. The γ-ray activities produced in various targets and successive catcher foils were then identified by counting them using HPGe detectors. The detectors used in this experiment were pre-calibrated for energy and efficiency using standard ^{152}Eu γ–ray source. The residues arising from both complete and incomplete fusion were identified from the characteristic γ-rays and following the half-lives of the residues. The Faraday Cup installed behind the target-catcher foil assembly was used to measure the beam flux which is required for the calculation of fusion cross-section and to observe the stability of the current during irradiation.

Analysis and result

The Evaporation Residues (ERs) $^{167}Yb(5n)$, $^{166}Yb(6n)$, $^{167}Tm(p4n)$, $^{166}Tm(p5n)$, $^{165}Tm(p6n)$, $^{161}Er(\alpha 7n)$, $^{167}Ho(\alpha p)$, $^{162}Ho(\alpha p5n)$, and $^{157}Dy(2\alpha 7n)$ are populated through CF and ICF in the system ^{18}O + ^{154}Sm. Theoretical calculations of EFs for these residues were carried out with the statistical model code PACE-4 [5]. Three ERs i.e., $^{167}Tm(p4n)$, $^{166}Tm(p5n)$ and $^{165}Tm(p6n)$ involving the precursor contribution from $^{167}Yb(5n)$, $^{166}Yb(6n)$ and $^{165}Yb(7n)$ respectively have been observed.

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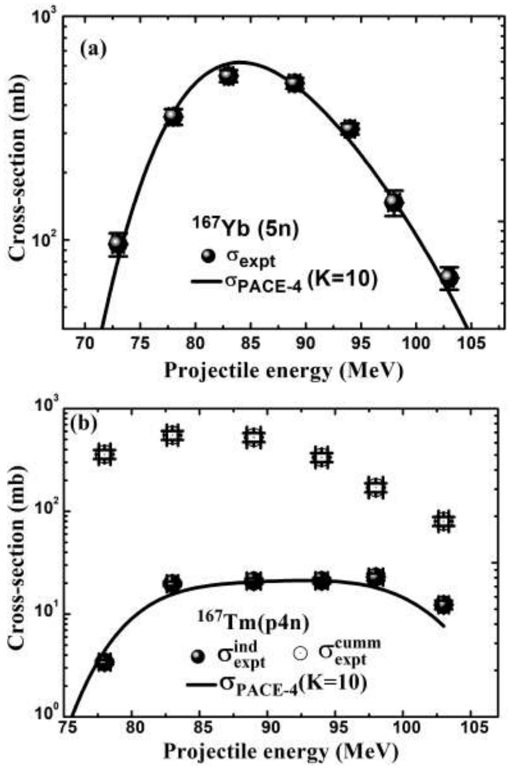

Fig. 1. Measured excitation functions of ERs (a) ^{167}Yb(5n) and (b) ^{167}Tm(p4n) along with theoretical predictions of PACE-4 (K=10) code of populate in ^{18}O+^{154}Sm system.

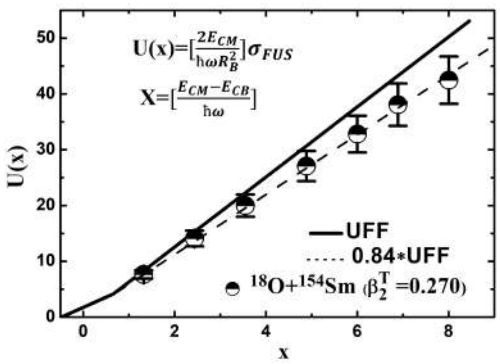

Fig. 2. The experimental fusion functions (EFFs) along with the universal fusion function (UFF) for the ^{18}O + ^{154}Sm system.

The independent cross-section of these residues has been extracted using standard formulation [6,7]. As a representative case, the measured cross sections for ^{167}Yb and ^{167}Tm along with their PACE-4 predictions are shown in Fig. 1(a) and (b). It can be seen from these figures that the measured cross-section of ERs ^{167}Yb(5n) and ^{167}Tm (p4n) agree well with PACE 4 (K=10) predictions. Therefore, these ERs have been produced only via CF. The negligible PACE-4 cross-section are found for ERs produced via α emission channels. As such these ERs ^{161}Er($\alpha 7n$),^{167}Ho(αp),^{162}Ho($\alpha p5n$),and^{157}Dy($2\alpha 7n$) produced through ICF of ^{18}O with ^{154}Sm.

The present analysis was also done with the reduction procedure of universal fusion function (UFF) suggested by Canto et al. [8]. This procedure eliminates the geometrical and static effects of the potential acting between the interacting partners. The measured CF cross section have been reduced using this prescription and plotted with UFF as shown in Fig 2. The input parameters used for UFF calculations for ^{18}O + ^{154}Sm were taken as Coulomb Barrier (E_{CB}) = 60.04 MeV, Barrier Radius (R_B) = 11.7 fm and Barrier Curvature (ħω) = 4.02 MeV. As can be seen clearly from this figure, the reduced CF cross section is suppressed by ≈ 16% than UFF. Therefore, any deviation in the Experimental Fusion Functions (EFFs) from the UFF is due to the breakup of the projectile. Further analysis is in progress.

Acknowledgments

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