Incomplete fusion dynamics in ^{16}O + ^{154}Sm system by measurement of spin distribution

D. Singh[1*], Sneha B. Linda[1], Pankaj K. Giri[1], Harish Kumar[2], Rahbar Ali[3], R. Tripathi[4],N.P.M. Sathik[5], M. Afzal Ansari[2], R. Kumar[6], Indu Bala[6] , S. Muralithar[6] and R. P. Singh[6]

[1]Centre for Applied Physics, Central University of Jharkhand, Ranchi–835 205, INDIA
[2]Department of Physics, Aligarh Muslim University, Aligarh–202 002, INDIA
[3]Deptartment of Physics, G.F.(P.G.), College, Shahjahanpur-242 001, INDIA
[4]Radio-chemistry Division, Bhabha Atomic Research Centre, Trombay, Mumbai-400 085, INDIA
[5]Department of Physics, Jamal Mohammed College, Trichurapalli-620 020, INDIA
[6]Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi–110 067, INDIA
* email: dsinghiuac@gmail.com

Introduction

Incomplete fusion (ICF) of heavy ion (HI) with different targets has been a topic of growing interest at energies near and/or above the Coulomb barrier. In these reactions, complete fusion (CF) and incomplete fusion (ICF) process are the dominant mode. In ICF process, only a part of projectile fuses with the target nucleus, while remaining part of projectile moves in the forward cone. In the complete fusion (CF) process, the projectile is completely fused with the target nucleus, forming a highly excited composite system, which decays by evaporating low energy nuclear particles and alpha particles at equilibrium stage. Britt and Quinton [1] was given by first experimental evidence of ICF dynamics, who observed the break-up of the incident projectiles like ^{12}C, ^{14}N and ^{16}O into alpha clusters in an interaction with the surface of the target nucleus at bombarding energies ≈10.5 MeV/nucleon. However, major advances in the study of ICF dynamics has taken place after the charged particle-γ coincidence measurements by Inamura *et al.* [2] for ^{14}N + ^{159}Tb system at beam energy ≈7 MeV/nucleon. Semi classical theory of HI interaction categorizes the CF and ICF processes on the basis of driving angular momentum ℓ imparted in the system. In the CF process the driving input angular momentum lying in the range $0 \le \ell \le \ell_{crit}$, while for ICF process the driving input angular momentum lying in the range $\ell_{crit} \le \ell \le \ell_{\max}$ [3]. Recent experimental studies of CF and ICF by measurement of spin distribution of evaporation residues (ERs) [4] have been carried out by using HI projectile with spherical target. However, the experimental studies of CF and ICF dynamics by measurement of spin distribution of ERs using HI projectile with deformed target nuclei are still demanded.

Experimental Details

The present particle-γ coincidence experiment have been carried out by using Gamma Detector Array (GDA) coupled with Charged Particle Detector Array (CPDA) for the system ^{16}O + ^{154}Sm at projectile energy 100 MeV at Inter University Accelerator Centre (IUAC), New Delhi, India. A self-supporting target of ^{154}Sm (enrichment ≈98.69%) of thickness ≈3.1 mg/cm^2 were prepared by rolling machine. GDA consists of 12 Compton suppressed high purity germanium detectors at angles 45^0, 99^0, 153^0 with respect to the beam direction and there are 4 HPGe detectors at each of these angles. The CPDA is a group of 14 Phoswich detectors. In the CPDA scattering chamber, seven CPD were placed on top and seven on bottom of the chamber. All 14 detectors of CPDA are divided into three angular zone. There are 4 CPDA detectors at ‘forward angles (F)’ (10^0-60^0), 4 detectors at ‘backward angles (B)’ (120^0-170^0) and 6 detectors ‘sideways (S)’ i.e., between 60^0-120^0. In the present experiment two groups of α-particles are expected to be detected by forward angles (F) CPDs: (i) the fusion-evaporation (CF) α-particles of average energy Eα-CF≈17 MeV and (ii) the ICF ‘fast’ α-particles of energy Eα-ICF≈25 MeV. To detect only 'fast' α-particles' of energy 8 MeV in the forward cone, in front of the four forward cone CPDs, the aluminum absorbers of appropriate thickness were used to stop low energy 'evaporation' α-particles (Eα-CF≈17 MeV). In-beam prompt γ-ray spectra have been recorded in multi-parameter mode employing different gating conditions.

Results and Discussion

In the present work, Off-line data analysis has been performed by projecting four gating conditions α-forward, α-backward, P-forward, P-backward on recorded γ-spectra. The evaporation residues ^{161}Er(α5n) has been identified from the α-forward gated γ-spectra, which is populated through ICF. The evaporation residues ^{166}Yb(5n) and ^{165}Yb(4n) are identified from the singles spectra, which are populated though CF. The relative yield of the measured evaporation residues ^{166}Yb, ^{165}Yb and ^{161}Er has been calculated from the measured data and plotted against the spin of the corresponding evaporation residues as shown in Fig. 1.

The measured relative yields of the evaporation residues ^{166}Yb (5n) and ^{165}Yb(4n) produced through CF are fitted with least-squares fit, which are straight lines. It is observed from the Fig.1 that the spin distribution curves of these evaporation residues show a sharp exponential fall in the relative yield of γ-transitions with high spin states. It is an indication of strong side feeding to the lowest members of yrast band.

It is also observed that from Fig.1 that the yield of the evaporation residue ^{161}Er(α5n), appears to be almost constant up to spin value J=10ħ for α-emitting channel and then decreases exponentially with high spin states indicating that the absence of side feeding to the lowest members of yrast band. The spin at half yield J_0 for ERs produced through CF reaction channel is found to be ≈8ħ, while the spin at half yield J_0 for the ERs produced through ICF reaction channels in "fast" α-emission in the forward cone is found to be J_0≈11ħ. The present measurements also confirm that the measured spin distributions of the ERs produced through ICF are distinctly different from those produced though CF.

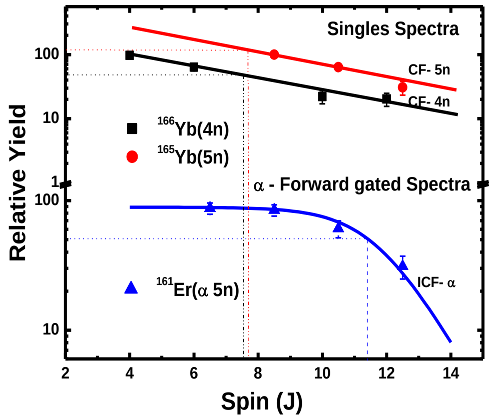

Fig.1. The measured spin distributions of evaporation residues ^{166}Yb(5n), ^{165}Yb(4n) and ^{161}Er(α5n) populated through CF and ICF in ^{16}O + ^{154}Sm system.

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