Probing of incomplete fusion dynamics by measurement of spin distribution in the ^{19}F + ^{154}Sm system

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

[1]*Centre for Applied Physics, Central University of Jharkhand, Brambe, 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

The study of incomplete fusion dynamics using heavy ions with different targets has been a growing interest at energies near and above the Coulomb barrier. It has been observed that at the projectile energies slightly above the Coulomb barrier, both the complete fusion (CF) and incomplete fusion (ICF) are considered as dominant reaction mechanisms. In case of CF, the projectile completely fuses with the target nucleus and the highly excited nuclear system decays by evaporating low energy nucleons and alpha particles at equilibrium stage. In the ICF, only a part of the projectile fuses with target nucleus, while remaining part moves as a spectator in the forward direction with unchanged velocity as that of the projectile with incomplete linear momentum transfer. The break-up of the projectiles ^{12}C, ^{14}N and ^{16}O into α-particle clusters in an interaction with the surface of target nuclei was first observed by Britt and Quinton [1] at energies above 10MeV/nucleon. However, major advances of this process referred to as ICF were made after the charged particle-γ coincidence measurements by Inamura et al. [2]. Several experimental studies have been carried out using alpha cluster structure projectile with different targets, but very small studies are available with non alpha cluster structure projectile. However, ICF dynamics studies by using non alpha cluster structure projectiles are very scarce. In the present work, spin distribution of the evaporation residues produced via complete and incomplete in the system ^{19}F + ^{154}Sm at projectile energy 100 MeV has been done. To the best of our knowledge spin distributions of the ERs produced through CF and ICF in the ^{19}F + ^{154}Sm system@100 MeV has been reported for the first time.

Experimental Details

The experiment was performed at the Inter-University Accelerator Centre (IUAC), New Delhi, India, using the 15UD Pelletron Accelerator. The gamma detector array (GDA) coupled with charged particle detector array (CPDA) has been used for the particle-gamma coincidence experiment. The γ-detector array (GDA) consists of 12 Compton-suppressed HPGe detectors at angles of 45^o, 99^o, and 153^o with respect to the beam direction, with four detectors arranged at each of these angles along with a charged particle-detector array (CPDA) consisting of 14 Phoswich detectors housed in a small scattering chamber. All 14 detectors of the CPDA are divided into three angular zones; (i) Forward angle(F) 10^o–60^o, (ii) Backward angles (B) 120^o–170^o and (iii) Sideways"(S), 60°-120^o. In the present experiment, two groups of α particles are expected to be detected by forward-angle CPDs: (i) the fusion-evaporation (CF) α particles of average energy $E_{\alpha\text{-CF}} \approx 18$ MeV and (ii) the ICF fast α particles of energy $E_{\alpha\text{-ICF}} \approx 25$ MeV. In front of the each four forward cone CPDs, aluminum absorbers of appropriate thickness were used to stop 'evaporation' α-particles (Eα-CF ≈18 MeV). Hence, only probability was 'fast' α-particles' with energy greater than 7 MeV have been detected in the forward cone. Projecting four coincidence gating conditions like particle-forward (PF), particle backward (PB), α-forward (F), and α-backward (B) on all the detected γ-ray spectra and identification of specific CF and ICF reaction products were done using forward and backward α-gated spectra.

Results and Discussions

The measured spin distributions for the evaporation residues ^{169}Lu(4n), ^{168}Lu(5n) and ^{164}Tm(α5n) produced via CF and ICF are shown in Fig.1(a)-(b). The ERs ^{169}Lu and ^{168}Lu produced through CF reaction channel by

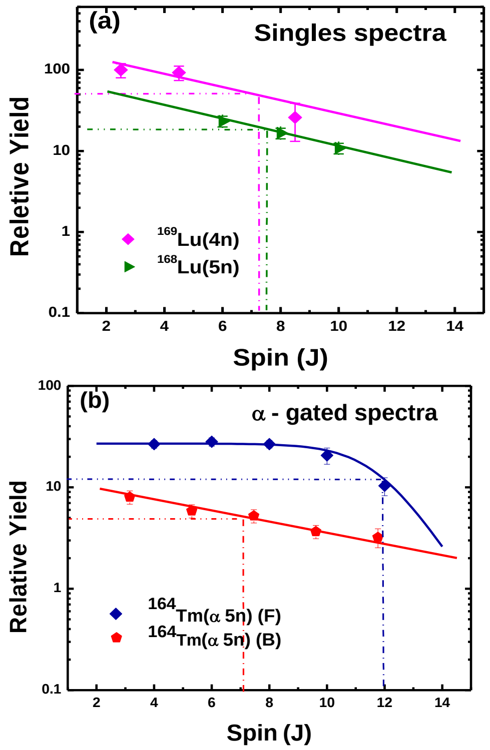

Fig-1. (a) Measured spin distributions of evaporation residues populated via CF and **(b)** CF and ICF channels.

emission of 4n and 5n have been identified from the singles spectra. It can be observed from Fig.1(a) that the spin distribution show a sharp exponential fall in the relative yield of γ-transitions with high spin states and give an indication of strong side feeding to the lowest member of yrast line transitions. The evaporation residue ^{164}Tm identified from forward α-gated spectra (associated with ICF), the yield appears to be almost constant up to J=10ħ for α-emitting channels and successively decreases exponentially with high spin states, indicating thereby the absence of side feeding to the member of yrast line transitions. The curve passing through the measured data points of the ERs ^{164}Tm (identified from α-forward spectra) populated via ICF is the best fits using an analytical function given in Ref. [3]. The same ERs may also be identified from backward α-gated spectra (associated with CF) and plotted in Fig. 1(b), is found to be distinctly different from the ERs ^{164}Tm identified from ICF forward α-gated spectra. Measured relative yields of the residues produced via CF are fitted with least-squares fit straight lines. The spin at half yield J_0 for these ERs produced through CF reaction channel is found to be ≈7ħ, while the spin at half yield J_0 for the ERs produced through ICF reaction channels in "fast" α-emission in the forward cone was found to be J_0≈12ħ.

Acknowledgments

The authors are thankful to Director and operational staff of Inter University Accelerator Centre (IUAC), New Delhi, India for providing the necessary experimental facilities to carry out the present work. D. Singh acknowledges encouragement from the Vice-chancellor of Central University of Jharkhand (CUJ), Ranchi. D. Singh is thankful to the Head, Center for Applied Physics, CUJ, Ranchi for providing the required facilities. D. Singh is also thankful to the Department of Science and Technology (DST) and Inter University Accelerator Centre (IUAC), New Delhi, India for providing financial support through SERC-Fast Track Scheme for Young Scientist (SR/FTP/PS-005/2011) and IUAC, New Delhi research project (Ref. IUAC/XIII.3A/UFR/54321) respectively.

References

[1] H. C. Britt *et al.*, Phys. Rev.124, 877 (1964).
[2] T. Inamura *et al*, Phys. Lett. 68 B, 51 (1977).
[3] D. Singh *al.*, Phys. Rev. C 81,027602 (2010).