Incomplete fusion dynamics in $^{16}O+^{124}Sn$ collisions

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Introduction

The study of heavy ion induced incomplete fusion (ICF) reaction dynamics has been the subject of interest in nuclear physics for past few decades. The first observation of PLFs by Britt and Quinton [1] in the bombardment of ^{197}Au and ^{209}Bi using projectiles ^{12}C, ^{14}N and ^{16}O at ≈10.5 MeV/nucleon led to 'massive transfer' of projectile to the target nucleus. Later on, Galin et al. [2] carried out similar studies and observed PLFs in the forward cone and termed these reactions, leading to PLFs as 'incomplete fusion' (ICF). These reactions were termed as incomplete fusion (ICF) reaction, in which a part of projectile behaves as a spectator and moves in the forward cone while the remainder fuses with the target nucleus, leading to transfer of a fraction of the incident momentum to the target nucleus. In the complete fusion (CF) process of the projectile with the target, the highly excited compound system decays by evaporating low energy nucleons and α-particles at the equilibrium stage. However, advances in the understanding of ICF dynamics has taken place after the charged particle-γ coincidence measurements by Inamura *et al.* [3] for ^{14}N + ^{159}Tb system at beam energy about ≈7 MeV/nucleons. Some earlier studies [4, 5] on ICF by particle-gamma coincidence technique had mainly been focused on yield measurements in coincidence with emitted PLFs in forward cone. Observation of 'fast' alpha particles in forward cone in coincidence with prompt γ-rays of the populated evaporation residues provides an evidence of ICF.

The particle-gamma coincidence experiment has been performed with a view to study ICF reaction dynamics in the $^{16}O+^{124}Sn$ system at 100 MeV beam energy. Earlier most of the ICF reaction studies have been carried out by particle-gamma coincidence technique, with heavy targets (A >150). However, there are few studies at lower beam energies and with medium mass spherical target nuclei. In order to investigate the role of target and residual nucleus deformation on the spin population in incomplete fusion reaction, the present experiment has been undertaken. In order to understand the feeding pattern in different CF and/or ICF reaction channels, the direct feeding intensity of γ-rays have been deduced from the experimentally measured spin distributions of evaporation residues reported in ref [4].

Experimental Details and Analysis

To record the γ-rays for study the CF and ICF reaction dynamics, an attempt was made to perform in-beam particle gamma coincidence experiment at Inter-University Accelerator Centre (IUAC), New Delhi, using Gamma Detector Array (GDA) along with Charged Particle Detector Array (CPDA) set-up. The GDA is an assembly of 12 Compton suppressed, High Purity Germanium (HPGe) detectors at three different angles 45^0, 99^0, 153^0 with respect to the beam direction with the arrangement of 4 detectors at each of theses angle. The CPDA is a group of 14 phoswich detectors. In the CPDA scattering chamber, seven CPD were placed on the top and seven in the bottom of the chamber. The 14 phoswich detectors of CPDA divided in three angular zones. (i) 4 CPD in forward cone (10^0-60^0), (ii) 4 CPD in backward cone (120^0-170^0) and (iii) 6 CPD in sideways (60^0-120^0).

Self-supporting enriched target ^{124}Sn (enrichment ≈97.2%) of thickness 2.0 mg/cm^2 was mounted at 45^0 with respect to the beam direction inside the CPDA chamber. The target was bombarded with the 100 MeV $^{16}O^{+7}$ beam with the beam current ≈20nA. Coincidences were demanded between particles (Z=1,2) and the prompt γ-rays emitted from the evaporation residues during the interaction of ^{16}O with ^{124}Sn. In front of the each forward direction CPD an aluminum absorber of thickness 100 μm was used to stop 'evaporation' alpha particles in the forward direction. Extra absorber thickness was used for stopping the elastic scattered beam also. In the forward cone, only protons and α-particles were detected. The data analyses have been carried out off-line using software INGASORT. Identification of the CF and ICF channels in forward and backward cone were achieved by looking into various gated spectra.

Results and Discussion

In the present work, to study the feeding pattern of different CF and/or ICF channels, the direct feeding intensity pattern of γ-rays for reaction channels ^{124}Sn(O, α4n)^{132}Ba and ^{124}Sn(O, 2α2n)^{130}Xe have been measured and plotted as a function of observed spin (J) displayed in Figs. 1(a)-(b). In the Fig.1(a), the feeding intensity for forward α-gated reaction channels ^{123}Ba(α4n) and ^{130}Xe(2α2n) is found to be increasing upto J≈8h and J≈9h, respectively from the higher spin states, indicating that the high spin states are strongly fed in case of ICF channels. It means that the residual nucleus de-excites and than the feeding intensity decreases gradually with available excitation energy and/or angular momentum, which indicates the absence of feeding to the lowest members of the 'yrast' line. This type of feeding intensity pattern is expected to arise from l-window, localized near and/or above to the critical angular momentum for CF, that is associated with ICF. Fig. 1(b) shows that, the feeding intensity for backward α-gated reaction channels ^{123}Ba(α4n) and ^{130}Xe(2α2n), as expected for CF dynamics is showing sharp exponential rise towards low spin states, indicating presence of strong feeding.

On the basis of present results, it may be conclude that the experimentally measured spin distribution of ICF channels ^{123}Ba**(**α4n) and ^{130}Xe(2α2n) channels identified from forward α-gated spectra have been found distinctly different than that CF channels identified from backward α-gated spectra. The population of low spin states are observed to be less fed in ICF channels, while in case of CF, significant feeding has been observed over the broad spin range.

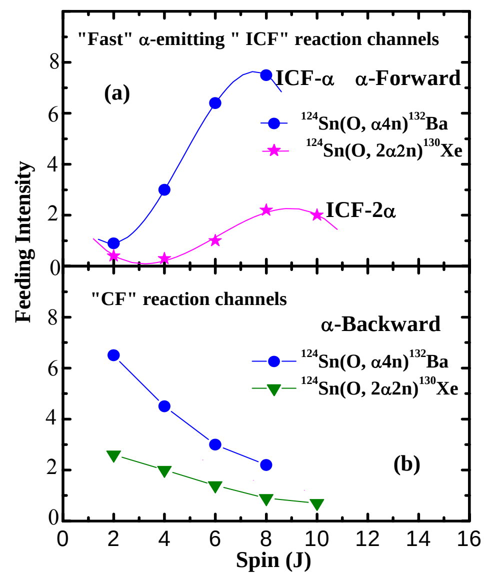

Fig. 1 Feeding intensities of gamma cascade transitions for evaporation residues ^{132}Ba and ^{130}Xe observed in ICF and CF channels.

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