Side-feeding intensity measurement for $^{16}O + ^{160}Gd$ system at 90 MeV energy

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Introduction

The substantial yield of the projectile like fragments (PLFs) which leads to the incomplete fusion reaction (ICF) have been found at energy well above the Coulomb barrier. The PLFs associated with ICF process was first investigated by Britt and Quinton [1]. Similar studies were carried out by Glain et al [2]. The large scale effort has been motivated to study complete and incomplete fusion in ^{16}O induced reaction on ^{160}Gd at beam energy ≈ 5.6 MeV/ nucleon. The CF and ICF can be disentangled on the basis of mean input angular momentum. The mean input angular momentum lying in the range $0 < \ell \le \ell_{crit}$, complete fusion (CF) is the dominant mode of the reaction in which entire projectile amalgam with target nucleus involving all the nucleonic degree of freedom and formed the excited composite nucleus and later de-excite by nuclear particle and/or gamma rays emission. On the other hand, mean input angular momentum lying in the range $\ell_{crit} < \ell \le \ell_{\max}$, nuclear field is no longer hold all the nucleonic degree of freedom of the projectile as a consequence projectile break-up into projectile like fragments (PLFs) in the field of the target nucleus, one part of the projectile fuses with target nucleus called participant and rest part moving in the forward direction as a spectator with almost same velocity as that of incident ion beam. This incompletely fused composite system having less charge and mass in comparison to completely fuse composite nucleus.

It is now generally recognized that study of heavy ion induced reactions (like fusion, direct reaction, transfer reaction and deep inelastic collision) is of great interest at beam energies above the Coulomb barrier. Predominant among them are complete (CF) and incomplete fusion (ICF) reaction mechanism provided that projectile energy is just above the Coulomb barrier [3]. The particle–γ coincidence experiment has been performed to study the ICF reaction for ^{16}O + ^{160}Gd at 90 MeV beam energy. The feeding intensity of the CF and/or ICF reaction channels have been deduced from experimentally measured spin distribution [4].

Experimental Details and Data Analysis

In order to study the CF and ICF reaction dynamics, particle-γ coincidence experiment have been performed at Inter University Accelerator Centre (IUAC), New Delhi. In order to perform the experiment, GDA+CPDA facility have been used at IUAC. The CPDA are phoswitch detectors which are surrounded by n type Compton suppressed High Purity Germanium (HPGe) detectors. The enriched rare-earth target ^{160}Gd (98.2%) was available in the form of metallic rod in the target laboratory of IUAC, New Delhi. The targets of ^{160}Gd were made by rolling machine and measured the thickness of the samples by α-transmission method, which comes out to be 1.3 mg/cm^2. The target of ^{160}Gd was irradiated by ^{16}O – ion beam at 90 MeV energy. These CPDA were divided into three annular rings (i) four CPDA in the Forward cone (10^0-60^0) (ii) four CPDA in the Backward cone (120^0-170^0) and (iii) four CPDA in Sideways (60^0-120^0). The data have been recorded in “Singles” and “Coincidence” mode.

The coincidences were demanded between particles (Z=1, 2) and prompt γ-rays of the evaporation residues. In order to identify CF and ICF reaction products, prompt γ-rays spectra have been recorded in coincidence with α, 2α in forward and backward direction. The analysis of the data has been carried out by software INGASORT, CANDLE and FREEDOM by looking into various gated spectra. Moreover, xn-channels have been identified from the singles spectra. The neutron channels like ^{172}Hf (4n) and ^{170}Hf (6n) (predominantly populated via CF) have been identified from the singles spectra. The αxn/2αxn channels produced via CF have been identified from α-backward spectra. Moreover, αxn/2αxn channels produced via ICF have been identified from α-Forward spectra.

Results and Discussion

In the present work, feeding intensity patterns for the identified reaction channels have been displayed in Figs. 1-2. As shown in Fig. 2, feeding intensity for $^{167,\,168}$Yb (α-channels) and ^{164}Er (2α-channels) increases up to J ≈ 8.5ħ and J ≈ 10.5ħ respectively, then decreases towards lower spin states. But in Fig. 1, feeding intensity for the evaporation residues like $^{170,\,172}$Hf (these xn-channels have been identified from singles spectra), ^{168}Yb and ^{165}Er (these α-channels have been identified from α-Backward spectra) showing sharp exponential rise towards lower spin states. On the basis of presently measurement, side-feeding intensity ICF channels ($^{167,\,168}$Yb and ^{164}Er) are strongly fed to higher spin states. It means that residual nucleus de-excites and feeding intensity decreases with available excitation energy and angular momentum, which indicates the absence of side-feeding to the lowest member of yrast line transition and this type of feeding intensity arises from l-window localized around critical angular momentum for CF. In case of CF channels ($^{170,\,172}$Hf, ^{168}Yb and ^{165}Er), feeding intensity exponential rise towards the lower spin states, which indicates band is fed over the broad spin range. From Fig. 1, it is observed that the feeding intensity is less in xn channels in comparison to αxn channels and this may be understood because of the fact that neutron emission carry less angular momentum from composite nucleus while α-particle carries significant amount of angular momentum and excitation energy, which may not provide broad feeding range towards the band head.

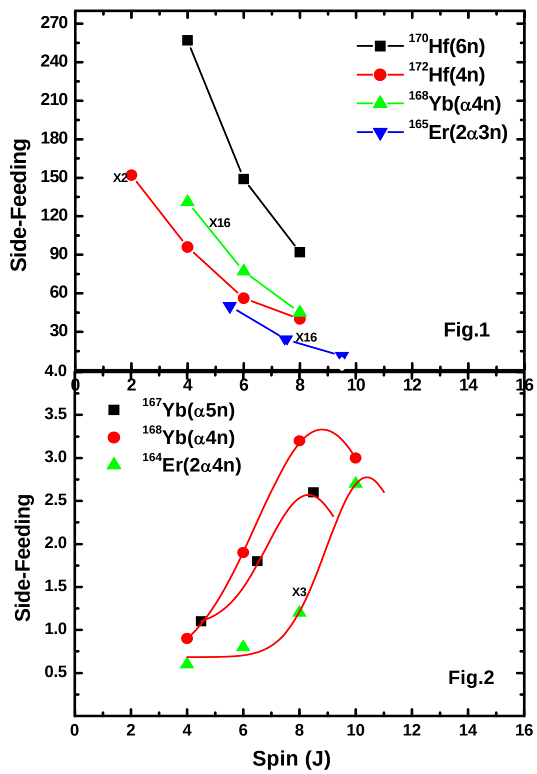

Fig.1

Fig.2

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