Angular momentum dependence of low energy incomplete fusion reaction

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Introduction

Incomplete fusion (ICF) studies with heavy ions has been a topic of resurgent interest. In ICF reaction, only a part of projectile fuses with the target nucleus, while the remaining part of projectile moves in the forward direction without any interaction with the target nucleus. However, in the complete fusion (CF) process, the projectile is completely merged with the target nucleus, forming a highly excited composite system which further decay by the emission of light nuclear particles followed by γ-rays. The first experimental evidence of ICF dynamics was given by Britt and Quinton [1]. In this experiment [1], they observed the break-up of the incident projectiles ^{12}C, ^{14}N and ^{16}O into alpha clusters in an interaction with the target nucleus at energies greater than 10.5 MeV/nucleon. However, advances in the study of ICF dynamics came into picture after the charged particle-γ coincidence measurements by Inamura et al [2] for ^{14}N + ^{159}Tb system at beam energy > 7 MeV/nucleons. Recently, particle-γ coincidence studies [3–5] have been carried by using HI projectile with ^{169}Tm and ^{159}Tb targets. The experimental results indicates that as on increasing the mass of the target the mean input angular momenta associated with it also increases. In the present work, a particle-γ coincidence experiment was performed for the ^{16}O+^{159}Tb system at two set of energies i.e. starting from 5% to 12% of Coulomb barrier. The motivation of the experiment is to disentangle the mean input angular momenta associated in the system for ICF/CF residues and to understand the role of mean input angular momenta on reaction mechanism at near barrier energies, so that a complete set of information for the system ^{16}O+^{159}Tb on ICF dynamics will be available.

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Experimental Details

The present experiment have been carried out by using Gamma Detector Array (GDA) coupled with Charged Particle Detector Array (CPDA) for the ^{16}O+^{159}Tb system at Inter University Accelerator (IUAC), New Delhi, India. A self-supporting target of ^{159}Tb (enrichment $\approx$ 99.9%) of thickness $\approx$ 1.7 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. Aluminum absorbers of appropriate thickness were used to stop evaporation scattering via ^{16}O projectile.

Measurements

In the present work, off-line data analysis has been performed by projecting different gating conditions with the help of nuclear physics data analysis software CANDLE. Spectra have been recorded in the list mode data. A precise gain matching and a pre-calibration has been done to add the projected spectra of all the HPGe detectors employing the ^{152}Eu gamma-source before and after the experiment at the target position. A typical example of the quality of calibration and gain matching taken by the HPGe-3 and HPGe-4 detectors are shown in Fig. 1, where different peaks of standard ^{152}Eu-source are assigned. It may, however, be pointed out that each γ-ray may have contribution due to background, therefore, its contribution has been corrected by subtracting separately taken background spectra. Also, to fix the CPDA gain matching ^{241}Am α-source has been used.

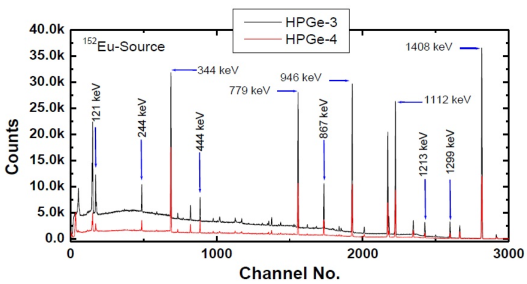

FIG. 1: (a) Typical γ-ray spectra of standard ^{152}Eu-source. Gain matching with HPGe3 and HPGe4 is also shown in this figure.

The multiplicity spectra of charged particles (Z=1, 2) and α-particles are define the coincidence between charged particles and prompt γ-rays. In Fig. 1(a), three peaks has been observed, which clearly indicates breakup of ^{16}O in α + ^{12}C, 2α + ^{8}Be and 3α + α along with neutrons or without neutrons during the reaction process, on the other hand Fig. 1(b) indicates four peaks which represents the maximum four groups of α particle will be emitted along with proton and/or neutrons.

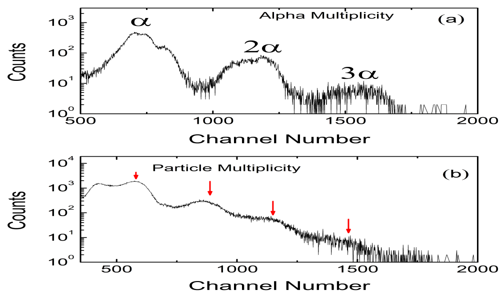

FIG. 2: (a) α-particle multiplicity spectra and (b) charge-particle multiplicity spectra of ^{16}O+^{159}Tb system.

With the aim to investigate reaction dependent decay patterns, relative production yield of α residues have been measured. The distribution of yield with γ-transition or associated spin, termed as spin-distribution, is expected to be entirely different in nature for complete and incomplete fusion. This may be used as a tool to probe reaction dynamics by looking into entry state spin population. The results will be presented.

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