Observation of pre-equilibrium particle emission in $^{16}O + ^{124}Sn$ system by measurement of yield ratio

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Introduction

The study of pre-equilibrium (PE) particle emission process induced by heavy ion (HI) and light ion (LI) has been the subject of interest at projectile energies above the Coulomb barrier [1,2] in nuclear physics. Fast light particles are observed in light and heavy ion induced reactions, indicated the existence of PE light particle emission process. In PE particle emission process, fast light energetic nuclear particles, like proton and neutron are emitted during the thermalization of composite system.. The PE emission may be considered as a bridge between two extreme reaction mechanisms. Presence of PE emissions at HI projectile energies slightly higher from Coulomb barrier has also been noticed [3]. There are some important features of PE particle emission process; (i) forward peaked angular distribution of energetic light nuclear particles, (ii) slowly descending tail portion of excitation functions (EFs) at higher energy region, (iii) the presence of relatively larger number of energetic light nuclear particles in the exit reaction channels as compared to that emitted in equilibrium decay etc.

There are several theoretical approaches to explain the PE-decay of highly excited composite system viz. geometry dependent hybrid (GDH) model, PE particle emission EXCITON model, inter-nuclear cascade (INC) model, and quasifree scattering (QFS) model. The existing models have been used to fit the various experimental data, no theoretical model is available to explain the dependence of reactions on driving input angular momenta, entrance channel mass asymmetry and energy regime etc.

In-beam particle-gamma coincidence experiment has been performed with a view to study the PE particle emission in the $^{16}O + ^{124}Sn$ system at 100 MeV beam energy during the complete fusion (CF) process. Earlier most of the PE particle emission studies have been carried out by excitation function measurement using activation technique, with LI induced reactions. However, there are few studies on PE particle emission on HI induced reactions with medium mass spherical target nuclei using particle gamma coincidence technique. In order to understand the PE particle emission reaction mechanism, an attempt has been made to deduced yield ratio (Y^F/Y^B) from the experimentally measured relative intensity of the prompt γ -rays transitions of evaporation residues ^{135}La and ^{133}La using particle gamma coincidence technique. In this paper, PE particle emission for two evaporation residues ^{135}La (p4n) and ^{133}La (p6n) have been observed by measurement yield ratio (Y^F/Y^B).

Experiment and Analysis

The particle gamma coincidence experiment has been performed at Inter-University Accelerator Centre (IUAC), New Delhi, using Gamma Detector Array (GDA) along with Charged Particle Detector Array (CPDA) set-up. The GDA consist of 12 Compton suppressed, High Purity Germanium (HPGe) detectors at angles 45^0, 99^0, 153^0. The

CPDA is a group of 14 phoswich detectors. In the CPDA scattering chamber, 7 CPD were placed on the top and 7 in the bottom of the chamber. The 14 phoswich detectors of CPDA divided in three angular segments. There are 4 detectors at 'forward angles (F)' (10^0-60^0), 4 detectors at 'backward angles (B)' (120^0-170^0) and 6 detectors 'sideways (S)'. Self-supporting enriched target ^{124}Sn (enrichment ≈97.2%) of thickness 2.0 mg/cm^2 (prepared by rolling technique) was mounted at 45^0 with respect to the beam direction inside the CPDA chamber. The target ^{124}Sn 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. Gamma-ray spectra in coincidence with particle (p, α) and α-particle in forward cone, backward cone and side ways have been recorded. Further experimental details are given in Ref [4]. 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

Analysis of the data has been performed in the following two steps. In the first step of analysis we have separated PE contribution from ICF process; the α-gated γ-spectra have been subtracted from the particle-gated γ-spectra. So, in this step a pure proton gated γ-spectra have been obtained. By projecting three different gating conditions (a) proton-backward (b) proton-forward (c) proton-90^0 on γ-ray energy spectra three types of proton gated spectra have been obtained. In the second step of analysis the evaporation residues have been identified their characteristic prompt γ-lines and confirmed by decay gamma lines in decay spectra. Area under the photo peak of characteristic prompt γ-ray transitions were used to determine the relative production yield of the different evaporation residues. The yield ratio defined as the ratio of yield in forward to backward direction i.e. Y^F/Y^B, have been measured for ^{135}La and ^{133}La produced through p4n and p6n channels of the ^{16}O + ^{124}Sn system and displayed in Fig. 1. As can be seen from this figure that the yield ratio (forward to backward yield) Y^F/Y^B is much higher than unity. It may be due to the significant PE contribution in these reaction channels. Thus the enhancement in Y^F/Y^B over unity may be attributed due to the PE emission along with the equilibrium (EQ) evaporation process of compound nucleus.

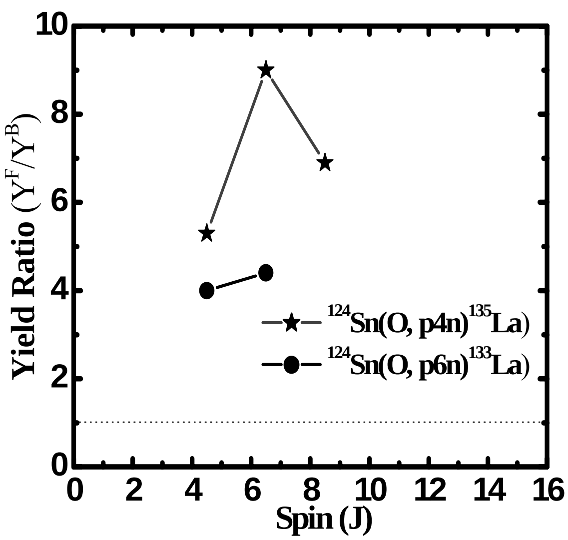

Fig.1 Measured Yield Ratio (Y^F/Y^B) of gamma transitions for evaporation residues ^{135}La and ^{133}La.

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