Study of break-up fusion process from excitation function measurement in ^{16}O + ^{148}Nd system

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Introduction

Investigation of incomplete fusion (ICF) or projectile break-up reaction mechanism by using heavy ions (HIs) has been a subject of renewed interest in the energy region ≈ 3-7 MeV/A due to its complexity and dependence on various entrance channel parameters. In ICF process, only a part of the projectile fuses with the target nucleus and remnant moves in the forward direction as spectator [1, 2]. Consequently, the partial linear momentum transfer takes place from projectile to the target in ICF process. First time the ICF features were observed by Britt and Quinton [3] in the break-up of the projectiles ^{12}C, ^{14}N and ^{16}O into α-clusters at energy ≈10 MeV/A. On the other hand, in case of complete fusion (CF), projectile fuses entirely with the target nucleus by involving all nucleonic degrees of freedom and forms an excited compound nucleus which may further decay via emission of light mass particles like neutrons, protons, alpha along with their characteristic gamma rays.

In the study of CF and ICF reactions mechanism, the measurements of excitation functions (EFs), recoil range distributions (RRDs), angular distributions (ADs) and spin distribution (SDs) of the evaporation residues (ERs) are the inimitable tools. Most of the ICF studies were centered to the α- and non-α-cluster structured projectiles induced reactions with heavier targets having mass A >150. But so far the experimental data with rare earth targets like ^{148}Nd is limited at intermediate energies. Presently, an attempt has been made to study the CF and ICF reaction mechanism from the excitation functions (EFs) measurement of ERs produced in the interactions of projectile ^{16}O with ^{148}Nd target nucleus in the energy range ≈ 3-7 MeV/A. The present work may be helpful for better understanding of ICF and also in the development of theoretical model for the well reproduction of experimental ICF data which is still a relevant problem in this energy region.

Experimental Details

The present experiment for the EFs measurement of ERs produced in ^{16}O + ^{148}Nd system has been carried out using 15UD Pelletron accelerator facility at Inter University Accelerator Centre (IUAC), New Delhi, India. The target foils of ^{148}Nd (Enrichment ≈ 95.44%) material were prepared by vacuum evaporation technique and each sandwiched between two ^{27}Al foils. The Al foils serve as energy degrader as well as catcher. Two stacks of target-Al foil assemblies were irradiated using the ^{16}O-ion beam at energies ≈ 100 and ≈ 78 MeV respectively in the general purpose scattering chamber (GPSC). The γ-ray activities induced in each irradiated target-catcher assembly was recorded separately using a high purity germanium detector (HPGe) coupled to a PC based software CANDLE [4]. The standard ^{152}Eu γ-ray source was used for energy calibration of HPGe detector and the residues are identified by using theirs inherent characteristics γ-rays based on following the half-lives in the decay curve analysis.

Results and Discussion

Presently, the EFs of four ERs evaporation residues (ERs) ^{159}Er (5n), ^{158}Er (6n), ^{157}Dy (α3n) and ^{155}Dy (α5n) produced in the ^{16}O + ^{148}Nd system are measured at energies ≈ 3-7 MeV/A.

The experimentally measured cross-sections of ERs are compared with theoretical predictions of statistical model code PACE-4 [5]. The angular momentum projections are calculated at each stage of de-excitation, which enables to determine the angular distribution of emitted particles. The cross-sections are calculated using Bass formula [6]. This code calculates the value of level density parameter ‘a’ as using expression as a = A/K MeV^{-1}, where ‘A’ is the mass number of the residual nucleus and ‘K’ is a free parameter, called level density parameter constant.

As a representative case, the EFs of residues ^{159}Er and ^{157}Dy are shown in Figs. 1 (a) and 1(b) along with PACE-4 predictions. In the inset of these figures, the decay curves are also displayed.

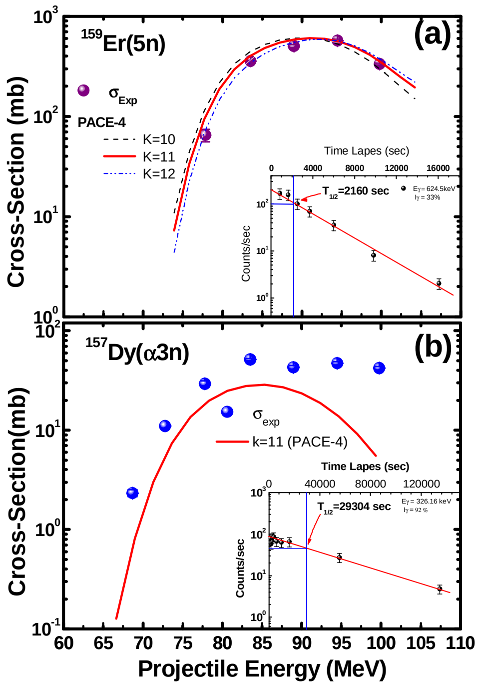

Fig. 1: The EFs of evaporation residues (a) ^{159}Er (5*n*) and (b) ^{157}Dy (α3*n)* produced in ^{16}O + ^{148}Nd system along with PACE-4 predictions.

The PACE-4 code is based on compound nucleus formation theory and takes into account only the CF contribution. As shown in Fig. 1(a), the experimentally measured cross-sections of residues ^{159}Er are compared with different free parameter values K = 10, 11 and 12. It is quite clear from this figure that measured cross-section values matched well with PACE-4 predictions calculated at level density parameter constant K = 11. Since, PACE-4 gives only the CF cross-section, thereby it may be pointed out that the residue ^{159}Er is populated via CF process. Similarly the residue ^{158}Er (6n) is also found to be produced via CF. On the other hand, the PACE-4 predictions substantially underestimate the measured cross-section values in case of residue ^{157}Dy as shown in Fig. 1(b). It is noteworthy that ICF contribution is not taken into consideration in PACE-4 code, hence the observed enhancement may be attributed to the ICF. In a more elaborative way, the residue ^{157}Dy may also be populated via ICF (due to fusion of ^{12}C formed in the break-up of projectile ^{16}O into ^{12}C + ^{4}He) along with CF. Furthermore, it may also be inferred from Fig. 1(b) that ICF contributes significantly along with CF upto energy ≈ 88 MeV after that it becomes dominant and increases gradually at higher projectile energies. The other measured EFs of ERs produced via CF and/or ICF in the present ^{16}O + ^{148}Nd system and the energy dependence of ICF will be presented during the symposium.

Acknowledgments

Authors are thankful to the Director, IUAC, New Delhi and also to the Pelletron and target laboratory personnel for providing the necessary experimental facilities during the experiment. Pankaj K. Giri is grateful to the IUAC, New Delhi for Project Fellowship in the UFUP research project (Ref: IUAC/XIII.3/UFR/54321) under Dr. D. Singh. One of the authors D. Singh acknowledges encouragement from the Vice-chancellor and Head, CAP, CUJ, Ranchi for providing the required facilities.

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