Study of break-up fusion process in light heavy ion projectile induced reactions

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Introduction

Heavy Ion (HI) induced fusion reactions have been a subject of great interest from the last two decades. These reactions prove to be helpful: in understanding various nuclear astrophysical processes, in exploring the nuclear landscape and hence searching for the heaviest possible chemical element that may exist etc. Depending upon the nature of projectile-target combination and the energy of interacting nuclei, various nuclear reaction processes may occur. However, in the energy region of 4-8 MeV/nucleon using light heavy ion projectiles such as ^{12}C, ^{13}C, ^{16}O, ^{18}O etc., with heavier mass targets, the reaction processes that dominate are complete fusion (CF) and break-up fusion (BUF) [1-3]. As the name suggests, in case of CF, the incident projectile completely merges with the target nucleus, leading to the formation of compound nucleus (CN) in highly excited state. This excited CN then de-excites initially, by emitting light nuclear particles such as neutrons (n), protons (p) and alpha (α) particles, followed by emission of gamma (γ) rays. In case of BUF, which is also termed as incomplete fusion (ICF) or massive transfer reaction, the break-up of incident projectile occurs in the environs of the target nucleus. Further, depending upon the energy of projectile either lighter or heavier fragment of projectile may fuse with the target nucleus, leading to formation of composite system (CS) in excited state. This CS then also de-excites, initially by emitting light nuclear particles followed by γ-rays. In BUF, the un-fused fragment moves in the forward direction as spectator, without having any impact on the reaction, the way it proceeds [1, 2]. To explain the break-up fusion dynamics, various models such as BUF, sum rule, hot spot etc., have been proposed, but none of these models can reproduce the BUF or ICF cross section satisfactorily, below 8 Mev/nucleon [1-3]. To develop a proper theoretical model, the dependence of BUF on various entrance channel parameters, that govern this process have to be studied in a very systematic and careful manner. Various attempts have been made earlier, but to reach the goal there are miles to go. Further, various methods such as excitation function (EF), forward recoil range distribution (FRRD), angular distribution (AD) and spin distribution (SD) have been used to comprehend the BUF process. To have further better understanding of BUF reaction dynamics, we have carried out the EF measurements of various evaporation residues (ERs) populated in ^{12}C + ^{156}Gd system in the energy region of 4-8 MeV/nucleon.

Experimental Details

The experiment was carried out at Inter-University Accelerator Centre (IUAC), New Delhi by using the pelletron accelerator facilities. ^{156}Gd foils of thickness ranging from 0.8-1.5 mg/cm^2 and Al foils (acting as catcher as well as energy degrader) of thickness 1.5-2.0 mg/cm^2 were fabricated at target development laboratory IUAC, by using the rolling technique [4]. For better accuracy, the thickness of both ^{156}Gd foils as well as Al foils was measured first by microbalance and then by α-transmission method. The stacked foil activation technique was employed for the measurement of EFs. Each stack comprised of four ^{156}Gd foils backed by Al foils. The irradiation of these stacks was carried out in General Purpose Scattering Chamber (GPSC) separately for about eight hours. The stacks were dismounted after irradiation using in-vacuum transfer facility provided with GPSC. The activities built-up in the irradiated samples at different energy points were recorded with the help of pre-calibrated high purity Germanium (HPGe) detectors.

Results and Discussion

The EF measurement is an efficient method which provides the information regarding the insight of reaction mechanism involved. In the present work, the EF measurements of various ERs populated via CF and/or BUF process were identified. The cross section of measured ERs was compared with the theoretical predictions of statistical model code PACE4 [5]. It is important to mention that PACE4 code gives the CF cross sections only and any significant deviation from it is ascribed to BUF process. It has been observed that the measured cross sections of ERs populated via xn and pxn channels were in good agreement with the PACE4 predictions. As a representative case experimentally measured EF of ER ^{164}Yb populated via 4n channel is shown in Fig. 1 (a). It may be seen from this graph that the measured cross sections match well with the theoretical predictions, employing that this ER is populated via CF process. However, in case of the ERs populated via α and 2α emission channels a considerable enhancement is observed in the measured cross sections from that of theoretical predictions. This is evident from the Fig. 1 (b), which implies that the ER ^{165}Ho is populated via BUF in addition to CF reaction process.

The dependence of BUF on various entrance channel parameters such as mass asymmetry, Coulomb repulsion effect, target deformation, alpha separation energy of projectile has been studied and remarkable results have been observed, which will be presented during the conference.

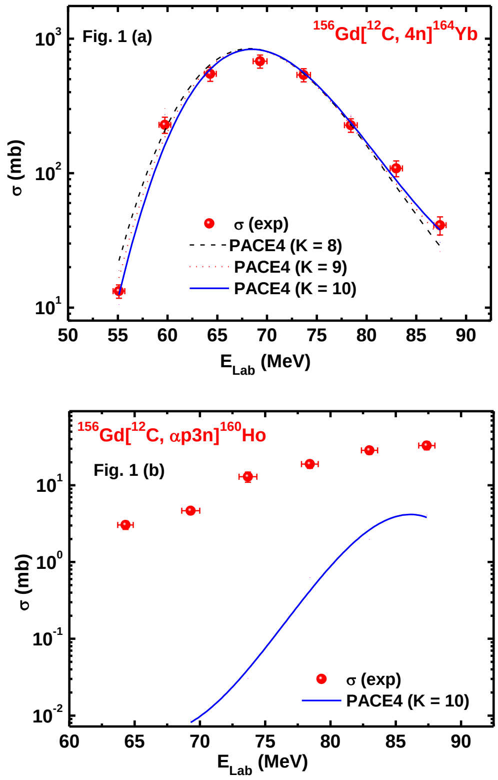

Fig. 1: Comparison of experimentally measured EFs of the ERs **(a)** ^{164}Yb (4n) and **(b)** ^{160}Ho (αp3n) populated in ^{12}C + ^{156}Gd system, with theoretical predictions of statistical model code PACE4.

Acknowledgements

The authors are grateful to the Director IUAC, New Delhi for providing the experimental facilities.

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