Investigation of incomplete fusion by measurement of excitation functions in the ^{14}N + ^{27}Al system

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Introduction

Reveling of various mode of nuclear reaction has been a fascinating field of interest from the very beginning of the nuclear physics. In the Heavy Ion (HI) Induced nuclear reaction, there are two very distinct modes of nuclear reaction above the coulomb barrier within the frame of intermediate energy range [1], known as Complete Fusion (CF) and Incomplete fusion (ICF). In CF process, the projectile amalgam with the target nucleus along with all the degree of linear momentum from projectile to target leads fully equilibrated highly compound nucleus (CN) with high excitation energy and angular momentum. The CN decays by emitting low energy evaporation nucleons and alpha-particle at equilibrium stage. In ICF process, only a part of the projectile fuses with the target nucleus and remaining part moves as a spectator with unchanged velocity as that of the projectile in the forward direction; as a consequence, fractional or partial linear momentum transfer takes place.

Excitation function (EFs) measurements of evaporation residues is one of the inimitable tool for the investigation of CF and ICF dynamics in heavy ion induced reactions at intermediate energies range of 3-7 MeV/nucleon [2]. It is worthwhile to mention that most of the studies on ICF at lower beam energies have been carried out with projectiles like ^{12}C, ^{16}O and ^{20}Ne with heavy mass target nuclei [1-3]. However, such types of studies using ^{14}N-ion beam as a projectile with low mass targets below 7 MeV/nucleon are scarce. Keeping in view above aspect, an attempt has been made to get some discrete conclusive output towards the direction of ICF reaction mechanism. We have performed an experiment using ^{14}N beam with low mass target of ^{27}Al between the intermediate energy range ≈53-83 MeV using off-beam gamma ray spectroscopy activation methods.

Experimental Details: Target Preparation and Irradiation

Present experiment has been carried out using 15UD Pelletron accelerator facility and General Purpose Scattering Chamber (GPSC) at Inter University Accelerator Centre (IUAC), New Delhi, India. In this experiment target ^{27}Al was used. Targets of natural aluminum (^{27}Al) were prepared by rolling machine. The thickness of the each aluminum foil was determined by weighing individual foil using micro-balance as well as the α-particle transmission method. In vacuum transfer facility was used in the present experiment. A single stack of the targets was irradiated by the $^{14}N^{+6}$ ion beam. The activities induced in the irradiated targets was recorded using a high purity germanium (HPGe) detector coupled with a PC based data accusation system employing with CANDLE software. The calibration of the HPGe detector was carried out using ^{152}Eu-source ($T_{1/2}$ = 13.33 yrs) of known strength. The ERs were identified by their characteristic γ-rays as well as following their half-lives.

Experimental Results and Discussion

In the present work excitation functions of the two evaporation residues ^{34m}Cl (αp2n) and ^{28}mg (2α4pn have been measured for the ^{14}N+^{27}Al system at projectile energy range ≈≈53-83 MeV. The experimentally measured excitation functions have been compared with theoretically calculated excitation functions by PACE-4 code for the radio-nuclides ^{34m}Cl and ^{28}mg are shown in Fig. 1 and 2. The evaporation residue ^{34}Cl has both meta-stable and ground states. In the present work, only the meta-stable state of the residue ^{34}Cl has been observed. The production cross sections of the meta-stable residues ^{34m}Cl has been converted into the total cross section of the residue ^{34}Cl by using standard radioactive decay method and is shown in Fig. 1 along with PACE-4 calculations at different values of level density parameter K.

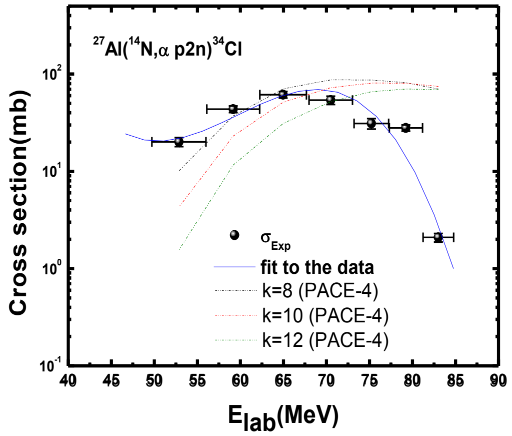

Fig. 1 Excitation function of the evaporation residue ^{34m}Cl (αp2n) produced in ^{14}N+^{27}Al system.

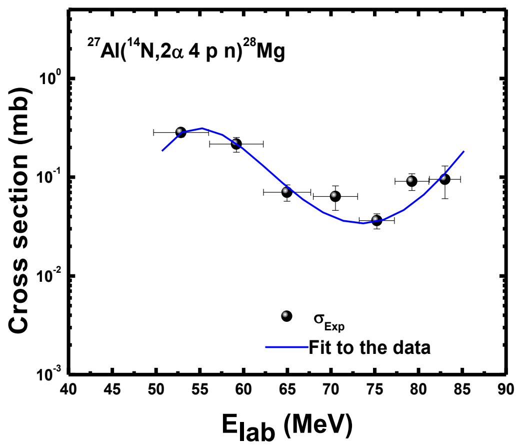

Fig. 2 Excitation function of the evaporation residue ^{28}Mg (2α4pn) produced in ^{14}N+^{27}Al system.

The measured values of cross sections in the lower projectile energy region of Fig. 1 are well reproduced by PACE-4 calculations (K=8), suggesting the contribution of the αp2n channel from complete fusion, while at higher bombarding energies both the trend and magnitude of measured cross sections are different as predicted by PACE-4. At higher bombarding energies the theoretical prediction are much higher than experimentally measured cross-sections, it indicate that the residue ^{34}Cl not only populated by complete fusion but also produced through processes other than complete fusion.

The theoretical calculations performed for the production of the evaporation residue ^{28}Mg (2α4pn) in the interaction of ^{14}N with ^{27}Al gives negligible cross-section values and hence they are not shown in the Fig. 2. Thus, the observed enhancement over their negligible theoretical predictions for this channel may be attributed to the fact that the residue ^{28}Mg is not likely to be populated by the CF process but it most likely contribute due to ICF process.

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