Investigation of breakup fusion processes in ^{14}N + ^{169}Tm system via Forward Recoil Range Distribution method

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Introduction

In recent years, the study of heavy ion incomplete fusion (ICF) in addition to complete fusion (CF) reactions is a resurgent subject of interest in nuclear physics [1-2]. In the ICF reactions the fusion incompleteness comes via projectile break-up and/or partial fusion with the target nuclei. The excited composite system formed via complete and/or partial fusion, generally de-excites by the emission of particles followed by γ-rays. Britt and Quinton were the first to observe the break-up fusion reactions during the experimental studies of heavy ions (^{12}C, ^{14}N, ^{16}O) induced reactions with the targets ^{197}Au and ^{209}Bi at laboratory energies (E_{lab}) ≈ 7-10 MeV/nucleon [3]. Later, Inamura *et al.* [4] performed a series of experiments using particle-γ-coincidence technique wherein they observed the spin distribution of the residues populated through the ICF process behave differently from the residues populated through the CF process. To investigate the CF and ICF dynamics a variety of measurements are available viz. excitation functions (EFs), forward recoil range distributions (FRRDs), spin distributions (SDs) etc.

In view of above, an experiment opting FRRDs technique was carried out to investigate the dynamics of ICF process for a non-alpha cluster projectile (^{14}N). The measurement and analysis of forward recoil ranges is one of the most direct and undeniable method to distinguish such events. As the matter of fact, it is based on the linear momentum transfer from projectile to target nuclei. In the CF reactions, the linear momentum completely transfers to the target nucleus, while in the case of ICF reactions partial linear momentum transfer takes place. The partial momentum transfer may be possible due to the break-up of projectiles or peripheral collisions with the target nucleus.

Experimental Details

The experiment was carried out at Inter University Accelerator Centre, New Delhi, India using $^{14}N^{+6}$-beam at a single projectile energy ≈ 83 MeV, with current intensity between 25 to 30 nA. Self-supporting natural ^{169}Tm (abundance 100%) target foils of thickness 0.5 mg/cm^2 was prepared by rolling technique, target foil was arranged backed with 17 thin Al-catcher foils of thickness range from 20 to 50 μg/cm^2, which were prepared by implying thermal evaporation vacuum deposition technique in target lab. The thickness of Al-catcher foils were chosen properly such that recoiling residues populated via CF and/or ICF process may get trapped in their respective thickness and the contribution of the CF and ICF can be distinguished clearly. The target-catcher foil assembly was mounted on the target ladder for irradiation, which was performed in General Purpose Scattering Chamber, using the in-vacuum transfer technique. The irradiation time was fixed for several hours in order to get sufficient statistics. The candle based data acquisition system [5] is used to record the activities induced in each Al-catcher foil via a pre-calibrated high purity Germanium detector. For the calibration of the gamma spectrum, a standard ^{152}Eu, gamma source was used. The evaporation residues (ERs) are identified by looking at the corresponding characteristic γ-rays in the spectrum, which were cross checked by the decay curve analysis.

.Results and Discussion

In the present experiment, several ERs were identified out of which only two ERs are discussed here. The data analysis of the other evaporating residues is still in process and will be presented during the conference.

The measured FRRDs for the ERs ^{179}Os (4n) and ^{176}W (α3n) were shown in Fig.1 and Fig.2, respectively. The measured yields of ERs are fitted by Gaussian single and multi-peak using ORIGIN software. The measured FRRD of the ER ^{179}Os (4n) shows single peak at a corresponding cumulative aluminum thickness of

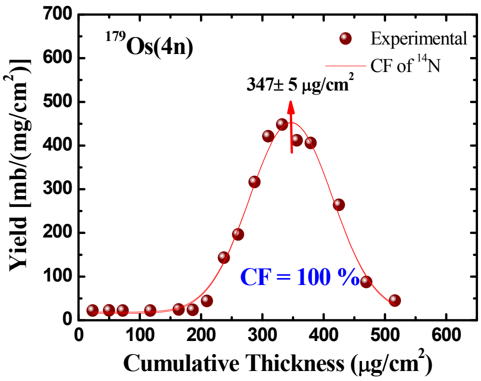

Fig. 1: Measured FRRD of ER ^{179}Os populated in ^{14}N + ^{169}Tm system at $E_{Lab} \approx$ 83 MeV.

≈ 347 μg/cm^2 (shown in Fig. 1), which satisfactorily matches with the theoretical value within the experimental uncertainties. Hence, it may be conclude that the ER ^{179}Os with exit channel 4n is populated via CF mode. Further in Fig.2, one can notice, the ER ^{176}W (α3n) have two distinct peaks, one of them at shorter cumulative thickness ≈ 171 μg/cm^2 while other at relatively larger cumulative thickness ≈ 337 μg/cm^2. It is worth to note that the observed peak positions agree well with theoretical ranges calculated using SRIM08. The observed multi-peak appearance during the measurement may be because of the partial liner momentum transfer from projectile to target nuclei. The studied reaction ^{176}W (α3n) indicates the contribution not only from CF of ^{14}N but also have contribution from ICF of ^{14}N (fusion of fragment ^{10}B) with target nucleus.

Further, the relative contributions of ERs ^{179}Os (4n) and ^{176}W (α3n) of CF are found to be ≈ 100% and ≈12% respectively, while for ICF of ^{176}W (α3n) have been found to be ≈ 88%, which suggest the break-up of ^{14}N projectile in α + ^{10}B at the ≈ 83 MeV projectile energy.

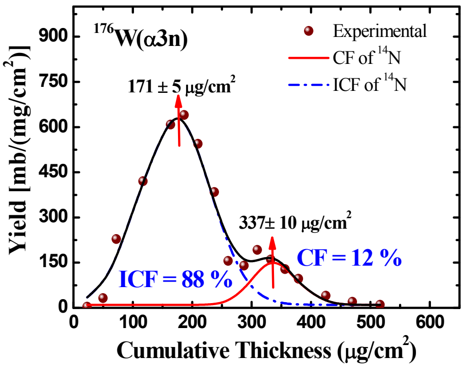

Fig. 2: Measured FRRD of ER ^{176}W populated in ^{14}N + ^{169}Tm system at $E_{Lab} \approx$ 83 MeV.

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