Comprehension of break-up fusion process from linear momentum transfer measurements

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Introduction

The interest in the study of Heavy Ion (HI) induced fusion reactions has enhanced significantly in the past two decades. Investigation of such nuclear reactions has an utmost implication in astrophysics and some of them may also be a doorway for the production of super heavy elements. For tightly bound projectiles within an energy region of 4-8 MeV/nucleon, different fusion processes can take place. A projectile may completely fuse with the target nucleus, known as direct complete fusion (DCF). The projectile may break-up into fragments and all the fragments may fuse with the target sequentially, known as sequential complete fusion (SCF). However it is important to mention that experimentally we can measure only the complete fusion (CF), which is the sum of DCF and SCF. The third process is that when the projectile break-up occurs in the vicinity of target nuclear field, only one of the fragment fuses with the target nucleus, known as break-up or incomplete fusion (ICF). The unfused fragment in ICF moves as a spectator in the forward direction with nearly the beam velocity. More over in ICF, as some of the projectile energy is utilized in the break-up process and also due to partial mass transfer from projectile to the target nucleus, the recoil energy of the evaporation residues (ERs) will be less compared to those formed via CF process. Hence the measured yield distribution of the ERs as a function of recoil range may act as a probe to comprehend the fusion process involved. Furthermore, the study of CF and ICF reaction process near and above the Coulomb barrier (CB) is still an enigma due to its dependence on various entrance channel parameters and also below 8 MeV/nucleon energies there is no theoretical model available which could appropriately reproduce the experimentally measured ICF data, hence study of ICF is still an interesting area of research work [1-3]. Also there are a few studies available in the literature, which involve non α-cluster projectiles. Hence in order to get a proper understanding of ICF and its dependence on various entrance channel parameters the forward recoil range distribution (FRRD) measurements using ^{13}C (non α-cluster) projectile and ^{165}Ho as target has been carried out.

Experimental Details

The experiment was carried out using 15UD Pelletron accelerator facilities at Inter University Accelerator Center (IUAC), New Delhi. The ^{165}Ho target foils were fabricated by using the rolling technique, where as the thin aluminum catcher foils were prepared by using the vacuum evaporation technique at target development laboratory IUAC. Alpha transmission method was used for measuring the thickness of both ^{165}Ho target foils as well as thin aluminum catcher foils. The thickness of target foil was around 800 μg/cm^2, while as that of Al-catcher foils was in-between 20-50 μg/cm^2. As the distribution in recoil ranges of ERs populated via CF and ICF is not much significant, hence by using very thin Al-catcher foils it is possible to separate the CF and ICF residues. The ^{165}Ho

target foil, followed by the stack of thin Al-catcher foils was irradiated by ^{13}C beam in General Purpose Scattering Chamber (GPSC) for about 14 hours. After the irradiation, the activity induced in each catch catcher foil was recorded by using pre-caliberated HPGe detector coupled to CAMAC based CANDLE software.

Results and Discussion

In the present work, the FRRDs of several ERs populated in the interaction of ^{13}C + ^{165}Ho system have been measured at $E_{lab} \approx 87$ MeV. As a representative case, the FRRD measurement of ^{171}Lu populated via α3n channel is shown in Fig.1(a). It is clear from this figure that there are two Gaussian peaks, one at large cumulative thickness (415 ± 51μg/cm^2) and the other at smaller cumulative thickness (218 ± 66μg/cm^2). This infers that the ER ^{171}Lu is populated via CF as well as ICF process because in CF the total linear momentum transfer (LMT) from projectile to target nucleus takes place, while as in ICF partial LMT occurs. Similarly, other αxn and 2αxn emission channel residues are also observed to be populated via ICF along with CF. More over the relative contribution of CF and ICF for the ER ^{171}Lu is found to be 14% and 86% respectively.

In order to understand the ICF dependence on various entrance channel parameters, the ICF fraction (F_{ICF}) has also been deducted for the present system (^{13}C + ^{165}Ho) and is compared with that obtained for previously studied systems at same relative velocity (i.e.,V_{rel} = 0.074c). As an example, the ICF dependence on Coulomb effect (Z_PZ_T) is shown in Fig.1(b). It may be seen from this figure, that with an enhancement in the value of Z_PZ_T, the F_{ICF} increases for nuclear reactions induced by ^{12}C and ^{13}C (having the same Z_P) projectiles with the targets of same or different Z_T, but separately for each projectile. Reactions induced by ^{13}C show less F_{ICF} compared to that of ^{12}C. This may be explained on the basis of projectile structure effect. Further experimental observations of ICF dependence on other entrance channel parameters will be presented during the conference.

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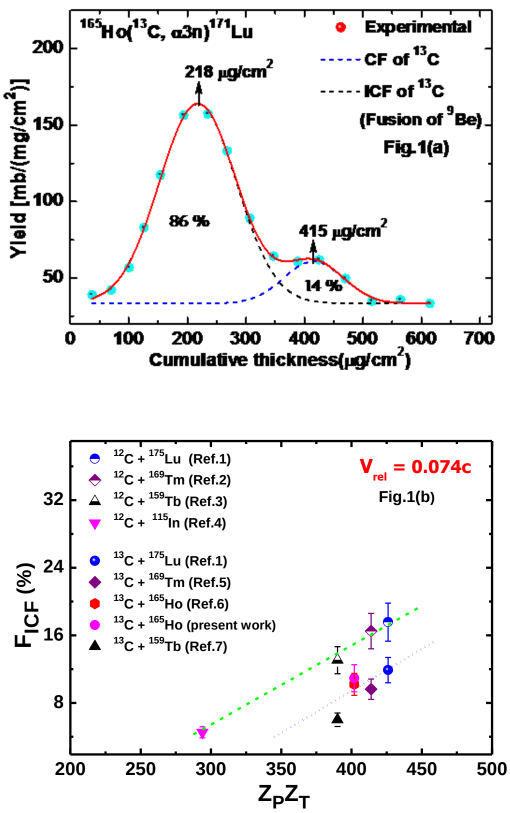

Fig. 1: (a) Experimentally measured FRRD of ER ^{171}Lu **(b)** comparison of F_{ICF} (%) for various systems as a function of Z_PZ_T at same relative velocity (V_{rel} = 0.074c).

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