Investigation of break-up fusion process below 8 MeV/nucleon energies

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Introduction

In recent years, considerable experimental efforts have been made to understand the break-up fusion or incomplete fusion process at energies just above the Coulomb barrier and well beyond it [1-4]. Different fusion processes may take place in the collisions of Heavy Ions (HIs) at these energies. One of the possible reaction modes is direct complete fusion (DCF), where the entire projectile amalgamates with the target nucleus. In addition to this, there may be possibility of projectile break-up into its fragments near the target nuclear field. When all the fragments fuse with the target one after each other, the sequential complete fusion (SCF) may take place. On the other hand, the fusion of only one fragment with the target, leads to incomplete fusion (ICF) process. Experimentally, the DCF process cannot be distinguished from SCF process. Hence, the complete fusion (CF) cross-section can only be measured experimentally, which is the algebraic sum of SCF and DCF. However, several studies have been carried out to unfold the role of various entrance channel parameters on ICF but any definite conclusion could not be established explicitly. Also, the non availability of any theoretical model below 8 MeV/nucleon energies makes the study of ICF study still a resurgent field of interest.

Recently, the effect of projectile structure on ICF has been observed which is interpreted more effectively in terms of projectile α-Q-value [5-8]. It is also observed that the Coulomb factor affects the ICF process only upto some extent [7, 8]. The role of target deformation (β_2) on ICF has also been studied recently by our group [2, 7]. The ICF study based on the parameters like Coulomb factor (Z_PZ_T), target deformation and projectile α-Q-value is limited only for few projectile-target combinations, which needs to be further investigated to reach on some definite conclusions. Hence, in order to have the better insight into these parameters effect on ICF especially the Coulomb factor (Z_PZ_T) and projectile α-Q-value, the present work was carried out. In this work, we have measured the excitation functions (EFs) of various evaporation residues produced in ^{16}O + ^{175}Lu system below 8 MeV/nucleon energies.

Experimental Details

The present experiment was carried out using the 15UD Pelletron accelerator facilities at Inter University Accelerator Centre (IUAC), New Delhi. Stacked foil activation technique was adopted for the EFs measurement of residues produced in ^{16}O + ^{175}Lu system. Two stacks of ^{175}Lu target (purity ≈ 97.41 %) having thickness ranges ≈ 1.0-1.5 mg/cm^2 were followed by Al-foils of thicknesses ≈ 1.5-2.0 mg/cm^2. The Al-foils were not only used to trap the recoiling residues but also as energy degraders. Rolling technique was used for the fabrication of target and Al-foils. Both stacks having four targets each were irradiated using ^{16}O ion-beam at ≈ 100 and 96 MeV energies, respectively in the General Purpose Scattering Chamber (GPSC). A Pre-calibrated 100 cc HPGe γ-ray detector of high resolution coupled to the CAMAC based FREEDOM software was used for the recording of induced γ-ray activities in each target-catcher foil assembly.

Results and Discussion

The measured excitation functions (EFs) of identified residues are compared with statistical model code PACE-4 predictions and interpreted as to be formed via CF and/or ICF. The code PACE-4 does not take into account the ICF contribution. The effect of Coulomb factor on ICF is demonstrated in Fig. 1(a). Here, the deduced ICF fraction (F_{ICF}) for the present ^{16}O + ^{175}Lu system has been plotted as a function of ($Z_P Z_T$) along with the F_{ICF} values obtained for earlier studied systems at same relative velocity ($v_{rel} \approx 0.053c$). As shown in this figure, the F_{ICF} values lie on the same line for the reactions induced by α-cluster structured projectile (^{12}C and ^{16}O) and are found relatively larger than that for the reactions induced by non α-cluster structured projectile (^{13}C). However, a simple linear growth in F_{ICF} with the increase in Coulomb factor ($Z_P Z_T$) was reported earlier. It may be pointed out that the Coulomb factor affects the ICF probability only up to some extent. In Fig. 1(a), the projectile structure effect on ICF is also reflected.

In order to understand the projectile structure effect more clearly the deduced F_{ICF} for the present system ^{16}O + ^{175}Lu and previously studied ^{12,13}C + ^{175}Lu systems [7] have been plotted as a function of projectile α-Q-value at same $v_{rel} \approx 0.053c$. As shown in Fig. 1(b), the higher F_{ICF} value is observed for less negative α-Q-value projectile ^{16}O (≈ –7.16 MeV) induced reactions than that for less negative α-Q-value projectiles ^{12}C (≈ –7.37 MeV) and ^{13}C (≈ –10.64 MeV) induced reactions. Moreover, less energy is required for the projectile ^{16}O to break-up it into its α-clusters than that for ^{12}C and ^{13}C. Conclusively, the Coulomb factor systematic of ICF is found somehow a projectile structure dependent and projectile α-Q-value seems to be an important parameter in the study of ICF dynamics.

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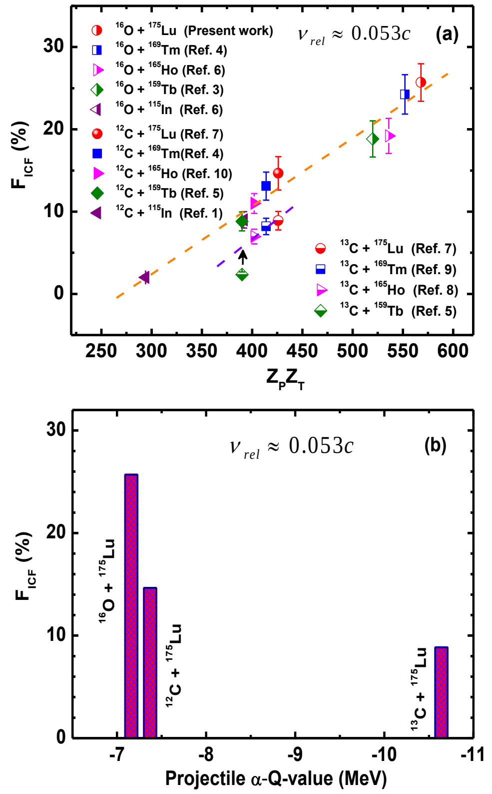

Fig. 1: **(a)** the deduced F_{ICF} as a function of parameter $Z_P Z_T$ and **(b)** projectile α-Q-value.

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