Impact of optical model potential parameters and deformity of target nuclei on fractional incomplete fusion

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The complexity of incomplete fusion in heavy ion (HI) induced nuclear reactions has been explored with great interest during the last few decades [1]. Complete fusion (CF) and incomplete fusion (ICF) are some of the major contributory modes of HI induced nuclear reactions at energies ≤ 7 MeV/nucleon. They play an important role in the understanding of the dynamics of nuclear reactions. Along with various features, an enhancement in the fusion cross-sections for α-emitting channels is an important characteristic of ICF.

Various models have been used in the literature to explain the mechanism of HI induced nuclear reactions, the optical model being one of them. The parameters of this model, called optical model potential (OMP) parameters, are a function of projectile energy, mass number, and the atomic number of interacting particles. The OMP parameters, as defined by Perey et al [2], are phenomenologically determined from elastic scattering fittings. In the optical model, the depth and shape of nuclear potential alter with any variation in the corresponding OMP parameters, and this change influences the scattering as well as the reaction probability of the interacting particles. This change in the reaction probability due to the change in the OMP parameters further affects the corresponding reaction cross-sections of various evaporation residues (ERs) of the reaction systems.

In order to estimate the contribution of ICF in a reaction system, one of the methods is the analysis of the enhancement in the experimental cross-sections, as compared to the respective theoretical cross-sections for α-emitting channels predicted by statistical model based computer codes. Hence the change in the theoretical cross-sections due to the variation in the choice of the OMP parameters may also influence the estimation of the strength of ICF in a reaction system [1]. The fusion probability of projectile and target nuclei is also influenced by the angle of projectile-target interaction which may influence the ICF dynamics [3]. Within the nucleus, the deviation of the electric charge distribution from spherical symmetry can be described by the ground state deformation parameter β_2 which depends upon the intrinsic electric quadrupole moment Q_0 of the target nuclei. Thus the deformity of target nuclei may also influence the fusion probability of nuclei which in turn may affect the ICF dynamics.

In order to decipher the impact of OMP parameters and the deformation of target nuclei on the strength of ICF, the values of fractional ICF (F_{ICF}) for the chosen systems $^{12}C + ^{93}Nb$, $^{12}C + ^{115}In$, $^{12}C + ^{128}Te$, $^{12}C + ^{165}Ho$, $^{16}O + ^{181}Ta$, $^{16}O + ^{74}Ge$ [4-9] have been extracted in the present work, by analyzing the enhancement in the fusion cross sections for α-emitting channel from the available experimental data of excitation functions (EFs), already existing in the literature. The theoretical cross-sections for various ERs of the chosen reaction systems have been predicted by the optical model based computer code PACE4 [10] using different sets of OMP parameters. As the choice of OMP parameters is not global and unique; several sets of OMP parameters have been quoted in the existing literature for different ranges of target mass number and incident energies. The choice of OMP parameters for different reaction systems is based on comparison of respective theoretically predicted, and available experimental data of EFs for CF components. Here, we would like to point out that this choice for reaction systems having target mass number $A < 100$ is different from that for $A > 100$ [2].

The experimental data available in the literature for reaction systems $^{12}C + {}^{93}Nb$ and $^{16}O + {}^{74}Ge$, having $A < 100$, has been compared with the theoretical cross-sections predicted by PACE4 using default set of OMP parameters, which are in-built in the code PACE4. Whereas, the theoretical reaction cross-sections for the reaction systems $^{12}C + {}^{115}In$, $^{12}C + {}^{128}Te$, $^{12}C + {}^{165}Ho$, and $^{16}O + {}^{181}Ta$, having $A > 100$, have been predicted by the PACE4 using OMP parameters other than default set [1, 2]. Further, in order to calculate the ICF fraction for each system, the enhancement in the experimental cross-sections for α- emitting channels has been deduced by comparison with respective theoretically predicted cross-sections. The formulation to calculate the F_{ICF} (%) has been given elsewhere [11]. The deduced F_{ICF} for various reaction systems have been plotted as a function of deformation parameter β_2 at constant relative velocity (V_{rel} = 0.055c), and compared with F_{ICF} deduced using default set of OMP parameters for $A > 100$. The details will be presented at the time of conference.

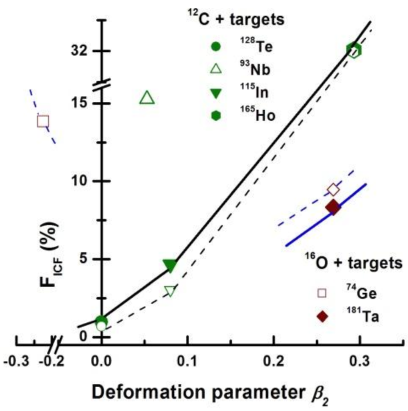

FIG. 1. Fractional ICF (F_{ICF}) as a function of target deformation parameter (β_2) for various systems at constant relative velocity (V_{rel} = 0.055 c). Lines are only to guide the eye. Open symbols represent calculations using default set of OMP parameters while solid symbols represent calculations using OMP parameters other than default [2].

It is worth noting that four reaction systems $^{12}C + {}^{93}Nb$, $^{12}C + {}^{115}In$, $^{12}C + {}^{128}Te$, $^{12}C + {}^{165}Ho$ have same projectile Carbon-12, so that, α-Q value of projectile in these reaction systems is same. Similarly, reaction systems $^{16}O + {}^{181}Ta$, and $^{16}O + {}^{74}Ge$, are having same projectile Oxygen-16 with same α-Q value. Further, It can be seen in Fig-1 that the percentage of ICF increases with the increasing value of $| \beta_2 |$ of different targets at particular α-Q value. The result indicates that, if the spherical symmetry of electric charge distribution in target nuclei is disturbed, and the deformity of target nuclei increases, the probability of incomplete fusion increases.

Conclusion

Reaction probability in the HI induced nuclear reaction is influenced by the variation in the OMP parameters and also by the deformity of the target nuclei. In the present work, an attempt has been done to explore the dependency of the strength of ICF on the deformation of the target nuclei. The fractional ICF (F_{ICF}) for systems increases as the deformation parameter $| \beta_2 |$ increases. Consequently, it can be inferred that deformed targets may have a greater tendency for incomplete fusion.

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