Effect of target neutron skin thickness on incomplete fusion probability

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The complexity involved in heavy-ion induced reactions is mainly due to the structure effects and convoluted potential. On the basis of structure, nuclear reactions may be categorised into direct and compound nuclear reactions. One of the competing mode of reactions at low incident energies is incomplete fusion (ICF) [1], which is found to be surface dominated. In ICF reactions, only a part of projectile fuses with the target nuclei and the remnant behaves like a spectator [2, 3]. Understanding of ICF reactions is important to draw a clearer picture of heavy-ion interactions, and to probe some static and dynamic properties of nuclei as they behave like an interface between the elastic scattering and compound nucleus reactions. In existing studies, the strength of ICF has been co-related with mass-asymmetry of interacting partners, incident energy, negative alpha-Q-value, input l-values, etc., but the effect of all the entrance channel parameters have not yet fully explored in low energy domain [3–5].

It may be pointed out that the neutron skin thickness is a residual property of nuclei which appears mainly in heavy nuclei due to unequal number of neutrons and protons[6]. In heavy nuclei, the number of neutrons are found to be more as compared to the number of protons which lead to the formation of neutron skin on its surface [7]. Since ICF reactions, at low incident energies, are mainly surface dominated, it would be interesting to study the effect of neutron skin thickness on the onset & strength of ICF. In order to study the effect of neutron skin thickness, experimental data for different targets bombarded by ^{12}C and ^{16}O have been analysed. It may be pointed out that the target nuclei corresponding to ^{12}C and ^{16}O projectiles have different mass and charge which lead to dissimilar Coulomb barrier of respective systems. In order to see the variation of ICF fraction in terms of neutron skin thickness, the Coulomb effect has been reduced by comparing data obtained at constant relative velocity v_{rel}, *i.e.*, $v_{rel} = \sqrt{2(E_{cm} - V_b)/\mu}$, where, E = incident energy of projectile, V_b= Bass barrier of the system and $\mu = \frac{mM}{m+M}$ reduced mass of the system, m and M are mass of projectile and target, respectively.

The fraction of ICF has been calculated at a value of v_{rel}=0.053c by using following formula,

$$F_{ICF} = \frac{\sum \sigma_{ICF}}{\sum \sigma_{ICF} + \sum \sigma_{CF}} \qquad (1)$$

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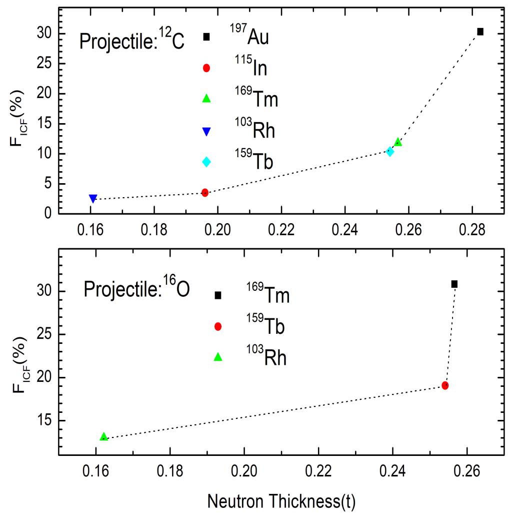

FIG. 1: The variation of F_{ICF} in terms of neutron skin thickness for ^{12}C+^{197}Au[2], ^{12}C+^{159}Tb[3], ^{12}C+^{115}In[10], ^{12}C+^{103}Rh[4], ^{16}O+^{169}Tm[9], ^{16}O+^{159}Tb[5] and ^{16}O+^{103}Rh[8]systems.

The complete and incomplete fusion cross-sections have been taken from the literature.

The target neutron skin thickness(t_n) has been calculated by subtracting the charge radius from its matter radius, *i.e.*, $t_n = R_N - R_Z$, while the R_N and R_Z are calculated in following manner,

$$R_Z = r_0 \left[\frac{2Z}{(1-3\epsilon)(1-\delta)} \right]^{\frac{1}{3}} \tag{2}$$

$$R_N = r_0 \left[\frac{2N}{(1-3\epsilon)(1+\delta)} \right]^{\frac{1}{3}} \tag{3}$$

The value of t_n may be estimated as,

$$t_n = \frac{2}{3} r_0 A^{\frac{1}{3}} (I - \delta) \tag{4}$$

where, I= (N−Z)/A, and δ represents the density dependent factor calculated using the liquid drop model[6].

The percentage fraction of ICF obtained for different projectile-target combinations are plotted in Fig.1 as a function of t_n. As shown in this figure, the value of incomplete fusion fraction increases with t_n, indicating the ICF dependence on neutron skin thickness. This may be due to the fact that the neutron skin thickness slightly reduces the Coulomb potential and increases the attractive nuclear potential of target which influences the probability of CF and gives a way to ICF to happen. It may be pointed out that the F_{ICF} increases with t_n individually for ^{12}C and ^{16}O for different targets. This suggests projectile structure effect on ICF.

In summary, the effect of target neutron thickness has been studied in present work which shows that the incomplete fusion probability increases in accordance with neutron skin thickness. The detailed results & analysis of the present work will be presented during the symposium.

One of the authors PPS thanks to CSIR for a research grant ref. no. 03(1353)/16/EMR-II.

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