Study of incomplete fusion probability induced by ^{20}Ne on different targets

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Introduction

In the past few years, several attempts have been made to understand the effect of the breakup of weakly bound nuclei. Following the projectile breakup, several processes may occur: one of the fragment may fuse with the target in a process named Incomplete Fusion (ICF) or all of the fragments may fly away from the target in a process called noncapture breakup, fusion of all the fragments with the target would lead to Sequential Complete Fusion (SCF). The sum of ICF+SCF+ the usual Complete Fusion (CF) is called Total Fusion (TF).

Recently, it has been observed by the comparison of fusion data with theoretical predictions (which do not take into account the dynamic breakup plus transfer channel effect) that for energies not too much above the barrier, CF involving the weakly bound projectiles ^{6,7}Li and ^{9}Be on heavy targets (^{208}Pb and ^{209}Bi)[1] are suppressed by around 30% where as TF for the same projectile on the target of any mass does not seem to be affected by the dynamic breakup + transfer effect. The suppression of CF is attributed to the presence of ICF. So far, there is no systematic behaviour of the CF suppression as a function of the charge or mass of the target. As the charge of the target decreases, one expects that the Coulomb breakup become weaker, and consequently ICF probability decreases.

For fusion induced by ^{20}Ne, there are at present four systems for which CF was separated from ICF with the target ^{51}V[2], ^{55}Mn[3], ^{59}Co[4] and ^{165}Ho[5].So, in this paper we have tried to analyze the behaviour of the ICF probability as a function of the target charge for the systems for which the data are available.

Theoretical prediction of ICF probability

Although there is no theory on the dependence of the target charge Z_{Target} of P_{ICF}($P_{ICF} = \sigma_{ICF}/\sigma_{TF}$), there is an empirical formula obtained by Hinde et al.[6], in a well-performed experiment, when the sub-barrier prompt breakup of ^{9}Be was measured using ^{208}Pb as the target. Their result suggested that the prompt breakup was largely due to a process close to the nuclear surface. So the breakup probability was taken to be proportional to the gradient of the nuclear potential V'_N, multiplied by an exponential factor $f(R_S)$, which is dependent on the surface to surface separation R_S and independent of the nuclear structure. The fit to their data gives $f(R_S)$ proportional to exp(-0.924R_S). The P_{ICF} for ^{208}Pb was then scaled to predict P_{ICF} of any target as

$$P_{ICF} = P_{ICF}(^{208}\mathrm{Pb})\frac{V'_N}{V'^{Pb}_N}\exp\{-0.924[R_s - R_s(^{208}\mathrm{Pb})]\}$$

when all quantities are evaluated at the fusion barrier radius R_B. The nuclear potential was evaluated using the empirical potential of Christensen and Winther [7],

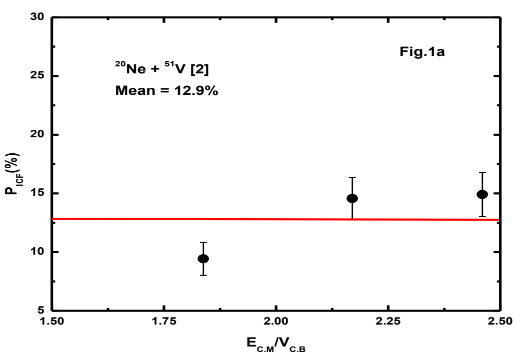
$$V'_N = -50\frac{R_P R_T}{R_P + R_T}\exp\left(-\frac{R_s}{0.63}\right),$$

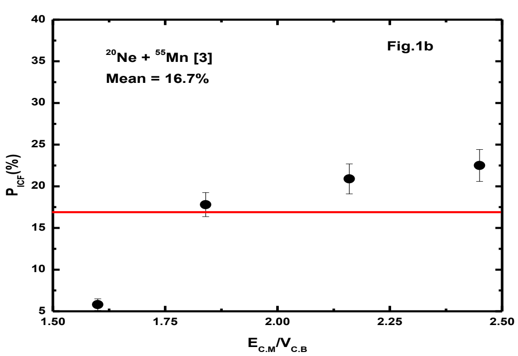
where $R_S = R_B - R(^9\mathrm{Be}) - R_T$, $R_i = 1.233A_i^{1/3} - 0.978A_i^{-1/3}$, R_P and R_T are projectile and target radii respectively.

Although this empirical prediction, based on geometrical assumption, is not a theory that has to be necessarily in agreement with data rather it is a good reference curve, and it has the expected behavior that P_{ICF} should decrease with the target charge, due to relatively smaller importance of the Coulomb breakup.

ICF probability as a function of target charge

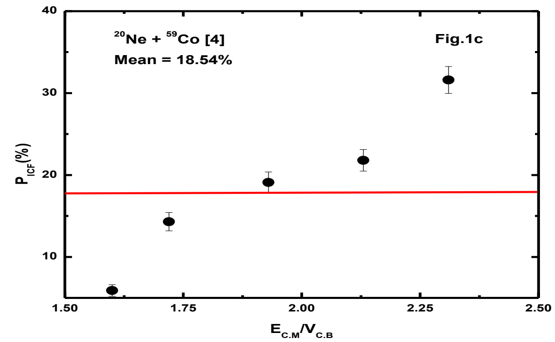
At present it is difficult to describe a systematic behavior for the P_{ICF} as a function of Z_{Target} since there are only four systems for which this quantity could be measured. Fig.1 (a-d) shows P_{ICF} for the four systems as a function of centre of mass energy in the vicinity of Coulomb barrier (V_{CB}). In Fig.2 we have shown the result of the average value for each system. The result shows a reasonable agreement between the data and the prediction. Although there are no available data for several systems, P_{ICF} for the four systems follows the trend of the empirical predication. As expected, P_{ICF} decreases when Z_{Target} decreases.

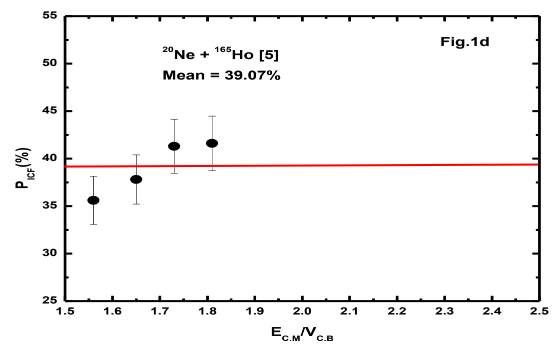


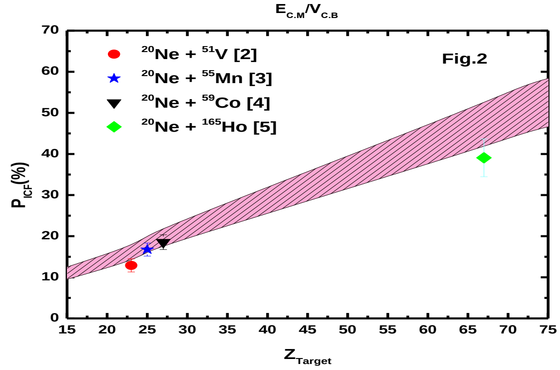


Conclusion

From the result shown in the figures we conclude that there is a trend of systematic behavior of P_{ICF} as a function of Z_{Target}. P_{ICF} decreases almost linearly when Z_{Target} decreases.







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