Incomplete fusion studies for $^{12}C+^{175}Lu$ system at 15UD Pelletron energies

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One of the nuclear reaction processes known as 'incomplete fusion (ICF)' may be considered to take place when the projectile breaks up into fragments near the vicinity of target nuclear field. One of the fragments fuses with the target nucleus forming an excited composite system which may eventually de-excite by particle and γ emission, while the other one moves into the forward direction without any interaction and acts as spectator. In 1984, Trautmann et al. [1], observed that ICF is associated with peripheral collisions, while some studies [2, 3] suggest the involvement of lower angular momenta than the critical angular momentum (ℓ_c) for complete fusion (CF) to occur in these reactions [4]. Nonetheless, the above mechanism is not clearly understood, and is still an active area of investigation. The pioneering work on the measurement and analysis of excitation functions in $^{12}C+^{197}Au$ reactions was carried by Bimbot et al., [3], where an enhancement in the total cross-section comes via transfer processes (i.e. α, ^{8}Be and ^{12}C on ^{197}Au) as a function of energy. The same method has been adopted in the studies of CF and ICF at energies $\approx$ 4-7 MeV/A, where a drastic enhancement over the theoretical predictions for the alpha emitting channels has been acknowledged by several authors [4, 5]. This enhancement in measured cross-sections with respect to the corresponding theoretical predictions may be attributed to the ICF processes. The dependence of ICF processes on various entrance channel parameters viz., projectile type/energy, imparted input angular momentum (ℓ) to the system, α-break-up energy (Q_α), mass-asymmetry of the interaction partners, etc., has been studied but an unambiguous picture is yet to emerge.

In the present work, an attempt has been made to explore the break up reaction dynamics for an even-even nuclei (^{12}C). An experiment using $^{12}C^{5+}+^{175}Lu$ system at energies $\approx$ 4-7 MeV/A was carried out at the Inter University Accelerator Centre, New Delhi, India using 15-UD Pelletron Accelerator. Further experimental details are similar to our earlier experiments [4, 5] based on off-line gamma-ray spectroscopy.

Several evaporation residues have been identified by their characteristic γ-lines, which were further confirmed by decay curve analysis. Afterwards, the production cross sections of the residues have been determined using the standard formulations [6]. The production cross-sections for $^{187-x}Ir$ (x=4-5), ^{182}Os, $^{181,179}Re$ and ^{176}Ta residues were measured and tested within the framework of statistical complete fusion model code PACE4 [7] at constant level density parameter A/10 MeV^{-1}. On comparison, isotopes of Ir and Os reveals that their production route is via complete fusion mode, whereas, substantially higher production cross-section for Re and Ta isotopes has been observed. This enhanced cross-section may be attributed due to the incomplete fusion. The sum of cross-section for

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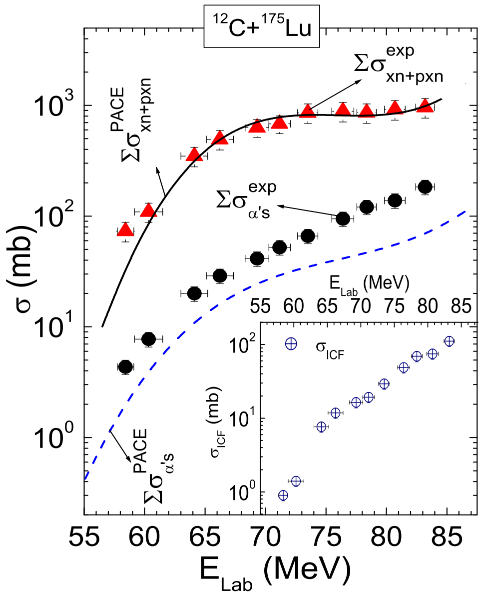

FIG. 1: Comparison of experimentally measured total xn and pxn channels (up traingles), total α's with PACE4 code at K=10. In the inset σ_{ICF}ICF is plotted as a function of projectile energy. (For more details, see text)

xn and pxn channels (up triangles) are plotted at the studied energies in Fig.1 alongwith PACE4 calculations (Black line). In the same figure, the sum of cross-section for α-emitting channels (filled circles) are also arranged and compared with PACE4 calculations (dashed line). As can be seen, experimentally measured cross-sections (i.e. sum of σ_{xn} and σ_{pxn}) have been found to be reproduced well with PACE4 calculations. However, the substantial difference can be seen for α-emitting channels i.e. $\sigma^{exp}_{\alpha's} > \sigma^{th}_{\alpha's}$. Further, the enhanced cross-section has been deduced by subtracting $\sigma^{exp}_{\alpha's}$ from $\sigma^{th}_{\alpha's}$ and is plotted in the inset of Fig.1 with respect to projectile energy. As has already been remarked that an enhancement in the cross-section may be attributed to the ICF, which is found to be projectile energy dependent.

For a better understanding of ICF process, the strength function of incomplete fusion (%F_{ICF}) has been deduced and is plotted as a function of reduced projectile energy (E_{Lab}/V_b, where V_b is Coulomb barrier) in Fig.2. The reduced projectile energy (E_{Lab}/V_b) has been used to incorporate the effect of Coulomb barrier. A detailed explanation of this figure alongwith the role of projectile structure, α separation energy and/or mass asymmetry on ICF strength function will be presented.

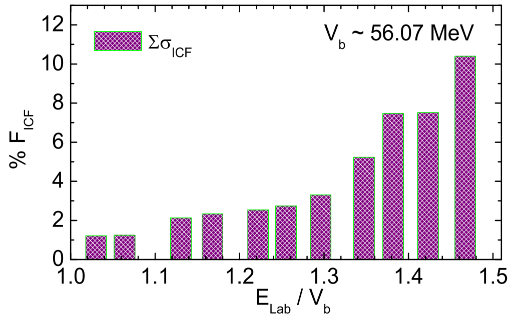

FIG. 2: Percentage incomplete fusion fraction (%F_{ICF}) as a function of reduced projectile energy (E_{Lab}/V_b) for $^{12}C+^{175}Lu$

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References

[1] W. Trautmann et al., Phys. Rev. Lett. **53**, 1630 (1984).

[2] H. Tricoire et al., Z. Phys. A **306**, 127 (1982).

[3] Bimbot et al., Phys. Rev., C **58**, 1999.

[4] Vijay R. Sharma et al., Phys. Rev. C. **89**, 024608 (2014)

[5] Abhishek Yadav et al., Phys. Rev. C. **86** , 014603 (2012)

[6] Vijay R. Sharma et al., Phys. Rev. C. **84**, 014612 (2011)

[7] A. Gavron, Phys. Rev. C **21**, 230 (1980).