Effect of relative velocity on Incomplete Fusion Dynamics

Rahbar Ali[1*], D. Singh[2], M. Afzal Ansari[3], Harish Kumar[3], Rakesh Kumar[4], K. S. Golda[4], S. Muralithar[4], R. P. Singh[4], P. Sugathan[4], M. H. Rashid[5], R. Guin[5], S. K. Das[5] and R. K. Bhowmik[4]

[1]*Department of Physics, G. F. (P G.) College, Shahjahanpur-242001, India*

[2]*Centre for Applied Physics, Central University of Jharkhand, Ranchi -825202, India*

[3]*Department of Physics, Aligarh Muslim University, Aligarh-202002, India*

[4]*Inter University Accelerator Centre, New Delhi-110067, India*

[5]*,Variable Energy Cyclotron Centre, Kolkata-700064, India*

[*]*email: rahbarali@rediffmail.com*

In the last few decades, great efforts have been made in the study of fusion process in heavy ion (HI) induced reactions. It has been shown that at energies not too much above the Coulomb barrier, the fusion process plays an important role in reaction cross section [1, 2]. The widely used statistical model code PACE-2 [3], describes the fusion cross section. At higher projectile energy, fusion probability decreases and corresponding incomplete fusion (ICF) probability increases. The projectile break-up will take place and decreases the reaction cross section corresponding to the fusion. Large number of reports has been appeared to believe that CF and ICF are the dominating modes of reaction at energies near the vicinity of Coulomb barrier [4,5]. Fusion occurs when interacting nuclei have sufficient kinetic energy to overcome the Coulomb barrier and are subsequently trapped inside the potential pocket to form the composite nucleus, in which all the angular momentum of the system is retained. On the other hand, if only part of the projectile following break-up, fuses with the target nucleus, the process is called incomplete fusion (ICF). In ICF process, partial linear momentum and less nucleons of the projectile are involved with the target nucleus rather than CF process. Britt and Quinton [6] observed the first experimental evidence regarding ICF, by measuring the break-up of projectile like ^{12}C, ^{14}N and ^{16}O into α-clusters in a interaction with the target nucleus at beam energy ~10.5 MeV/nucleon. Projectile break-up in the interaction of the target nucleus leading to fast α-particle(s) has been observed by Galin *et al.,* [7]. ICF studies using loosely bound projectiles have also been done by Gomes *et al.,* [8].

In order to study the effect of relative velocity on incomplete fusion dynamics, experiments have been performed using ^{20}Ne and ^{16}O-ion beams delivered from VECC-machine (Kolkata) and 15UD Palletron (New Delhi). The details of the experimental set-up are given elsewhere [9,10]. Activation technique has been used for the present measurements.

A ratio of incomplete fusion (ICF) to the total fusion cross-section is said to define ICF fraction and is given by;

$$[\sum\sigma_{ICF} \big/ (\sum\sigma_{CF} + \sum\sigma_{ICF})]$$

The ICF fraction have been deduced and plotted as a function of projectile energy for all the three projectile-target systems ^{20}Ne + ^{55}Mn [9], ^{20}Ne + ^{159}Tb [10] and ^{16}O + ^{156}Gd [10] is shown in Fig.1 (a) and (b). It is observed from the figure 1 (a) and (b) that ICF fraction invariable increases with projectile energy. The ICF-fraction for the systems ^{20}Ne + ^{159}Tb, ^{16}O + ^{156}Gd and previously measured systems ^{16}O + ^{74}Ge [11,12], ^{20}Ne + ^{59}Co [12], ^{20}Ne + ^{165}Ho [13], as a function of mass-asymmetry $[(A_T - A_P)/(A_T + A_P)]$ between various projectile-target combination for different relative velocity V_{rel} = 0.044c and V_{rel} = 0.062c, have been calculated and plotted in Fig.1. Being different Coulomb barrier for above mentioned systems the following expression given by Morgenstern *et al*., [14] formulation has been used for the calculation of

relative velocity (V_{rel}) of the interacting nuclei approach each other and is given by;

$$V_{rel} = \sqrt{\frac{2(E_{CM} - V_B)}{\mu}}$$

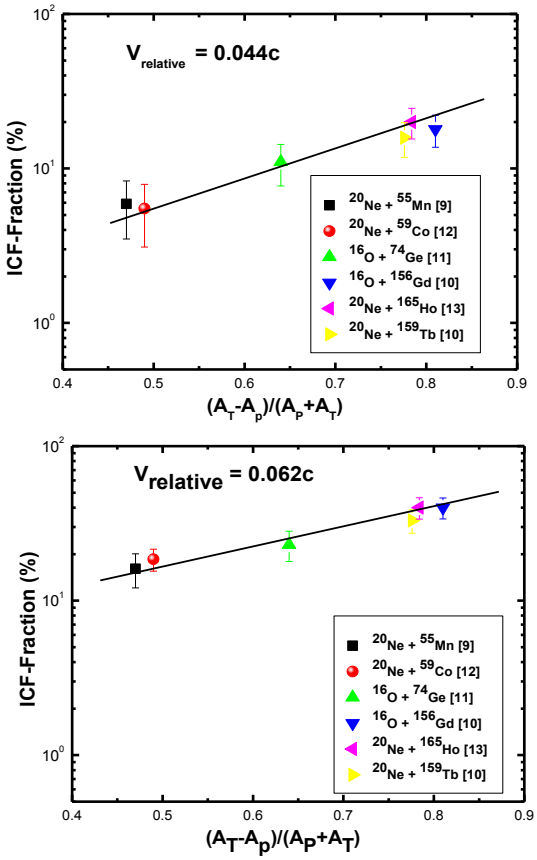

Fig. 1 (a) & (b): The ICF-fraction as a function of mass-asymmetry for different systems for different values of V_{rel} = 0.044c & 0.062c.

where the symbols have their usual meanings. It has been observed from the figure 1(a) & 1(b) that for different relative velocity, the ICF-fraction increases with mass-asymmetry of different projectile-target combinations. At higher relative velocity, magnitudes of ICF fraction are larger, which indicates that ICF probability is more at higher relative velocity of the interacting partners. The present measurement suggest that the relative velocity directly affects the ICF fractions for different projectile target systems and supports the findings of previous work by Morgenstern *et al.* [13]. However, a large number of data is needed to have a better understanding and definite conclusion about its dependence on nuclear structure effect and other parameters.

Authors wish to thank Director, IUAC-New Delhi and VECC-Kolkata for providing experimental facilities to carry out the experiments. Authors are also grateful to the members of the Pelletron and Cyclotron group for providing good quality beam of ^{16}O and ^{20}Ne; and their co-operation during the course of the experiment.

References:

[1] M. Dasgupta *et al;* PRC 70 *(*2004) 024606.
[2] D. J. Parker *et al; PRC* C 30 **(**1984) 143.
[3] A. Gavron; PRC 21 (1980) 230.
[4] B. S. Tomar *et al;* PRC 49 **(**1994) 941.
[5] B. S. Tomar *et al;* NPA 776 (2006) 83
[6] H.C. Britt and A.R. Quinton, PR 124 (1961) 877.
[7] J. Galin *et al;* PRC 9 (1974) 1126.
[8] Gomes *et al;* Phys. Lett. B 601 (2004) 20.
[9] Rahbar Ali *et al.*, JPG: N&P 37(2010) 11510.
[10] Rahbar Ali, Ph.D Thesis, AMU, Aligarh-2012.
[11] D. Singh *et al.*, CJP 46 (2008) 27.
[12] D. Singh *et al;* PRC 83 (2011) 054604.
[13] D. Singh *et al;* NPA 879 (2012) 107-131.
[14] H. Morgenstern et al; PRL 52 , (1984) 1104; ZPA, 313 (1983) 39.