Competition between Complete and Incomplete Fusion Reaction Mechanism below 8 MeV/nucleon energies

Asif Ali[1*], Harish Kumar[1], M. Afzal Ansari[1**], D. Singh[2], Rahbar Ali[3], Suhail A. Tali[1], Siddharth Parashari[1], Kamal Kumar[1], N. P. M. Sathik[4], R. Dubey[5], Indu Bala[5], Rakesh Kumar[5], R. P. Singh[5] and S. Muralithar[5]

[1]*Department of Physics, Aligarh Muslim University, Aligarh – 202002, INDIA*
[2]*Centre for Applied Physics, Central University of Jharkhand Ranchi-835205, INDIA*
[3]*Department of Physics, G. F. (P. G.)College, Shahjhanpur-242001, INDIA*
[4]*Department of Physics, Jamal Mohammad College, Tiruchirappalli-620020, INDIA*
[5]*Inter University Accelerator Centre,, New Delhi – 110067, INDIA*
**amu.asifali@gmail.com*
***drmafzalansari@yahoomail.com*

Introduction

Fewer studies are available to study the effect of entrance channel parameters on the onset of incomplete fusion (ICF) reaction dynamics induced by light-heavy-ion ($Z \leq 10$) with heavier targets ($A \geq 150$) below 8 MeV/nucleon energies. It is now well established that ICF process starts competing with complete fusion (CF) at projectile energies just above the Coulomb barrier and its influence increases with increasing the projectile energy [1-3]. Entire projectile amalgamation takes place in CF process with involvement of all nucleonic degrees of freedom, while projectile may breaks-up into two fragments near the target nuclear field in case of ICF. Only one of the fragments fuses with the target to form the less massive incompletely fused composite system and the remnant moves as spectator in the forward direction with projectile velocity. Being related to the projectile energy, the impact parameter may also be used as a tool to understand the terminology of CF and ICF reactions. ICF processes are found to occur at relatively larger impact parameter window as that of CF process, where CF gradually gives way to ICF and the projectile break-up may takes place on continuous increase of impact parameter. Inamura *et al.* [4] facilitated that ICF involves ℓ values more than ℓ_{crit} i.e. ICF products are found to be carried the angular momentum $\geq \ell_{crit}$ as for CF products. The available theoretical models are not applicable to reproduce the experimentally measured ICF data below 10 MeV/ nucleon energies, thereby more and more experimental data are required to reach on some explicit inference regarding the effects of various parameters like projectile structure, energy, mass asymmetry of interacting partners and alpha Q-value of projectiles. In order to strengthen the study of ICF dominance on CF, we have measured and analyzed the excitation functions of evaporation residues produced in $^{18}O + {}^{175}Lu$ reactions at energies ranging from 4-6 MeV/nucleon, which in turn may be helpful for developing the theoretical model below 8 MeV/nucleon energies.

Experimental Procedure

15UD Pelletron Accelerator facilities of the Inter University Accelerator Centre (IUAC), New Delhi have been used to perform the excitation function (EF) measurements. ^{18}O ion-beam delivered from the Pelletron Accelerator was used for the irradiation of ^{175}Lu targets of thickness ranges 1.0-1.5 mg/cm^2. Al-catcher foils of thickness ranging from 1.5-2.0 mg/cm^2 were placed after each target so that the recoiled residues may get trap in the respective catcher foil thickness. The ^{175}Lu targets and Al-catcher foils were prepared by rolling machine. To have the energy range from 70-100 MeV, three stacks of target-catcher assembly were irradiated by ^{18}O ion-beam for about 7-10 hours in the General Purpose Scattering Chamber (GPSC). The activities induced in each target-catcher assembly were recorded using pre-calibrated and high resolution HPGe γ-ray spectrometer coupled to CAMAC based CANDLE software.

Results and Discussion

Experimentally measured excitation functions produced via different emission channels have been compared with theoretical predictions based on statistical model code PACE-4 [5] and interpreted in terms of CF and/or ICF. EFs for several residues ^{188}Au, ^{189}Pt, ^{188}Pt, ^{187}Ir, ^{185}Ir and ^{184}Ir etc. have been measured for the system ^{18}O + ^{175}Lu using the recoil catcher activation technique at energies ranging from 4-6 MeV/nucleon. Theoretical model code PACE-4 gives only the CF cross-section and does not take into account the ICF processes. This code is based on the Hauser-Feshbach theory of compound nucleus (CN) decay and uses statistical approach of CN de-excitation. The independent reaction cross-sections of each residue have been calculated by subtracting the contribution coming from higher charge precursor isobars [6]. Excitation functions of two residues ^{188}Au (5n) and ^{185}Ir (α4n) are shown in Fig. 1 and Fig. 2 respectively. Different level density parameter (K) values have been tested by varying the free parameter K (K = 8–12) to reproduce the experimentally measured EFs of xn-pxn channels using statistical model code PACE4, and to identify the right level density parameter value for the analysis of α-emitting channels. As shown in Fig. 1, it can be easily inferred that the experimentally measured cross sections well matched with the theoretically estimated predictions based on PACE-4 code for K = 10. Hence, the evaporation residue ^{188}Au populated via 5n emission channel is populated through complete fusion of ^{18}O incident projectile with ^{175}Lu target nucleus. Excitation function of residue ^{185}Ir (α4n) shows an enhancement in the experimental cross-sections from theoretical predictions and is displayed in Fig. 2, where the solid line corresponds to the theoretically estimated cross section of PACE-4 at K=10. This enhancement may be attributed to contribution from ICF process along with the CF process in the population of ^{185}Ir i.e. it is formed due the fusion of one of the fragments in the break-up of projectile ^{18}O into ^{14}C + ^{4}He (α).

The authors are thankful to the Director, IUAC, New Delhi, for providing the necessary facilities. One of the authors HK is also thankful to UGC-DAE-CSR, Kolkata for awarding Project Fellowship under its Project.

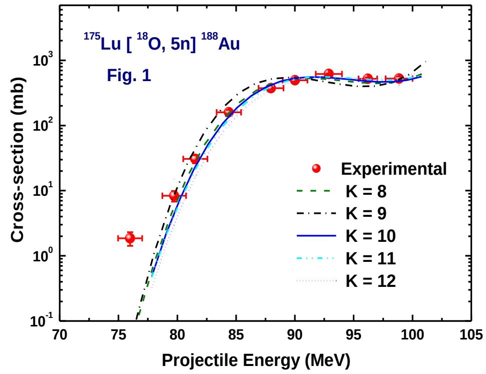

Fig. 1: Excitation function of evaporation residue ^{188}Au (5n) produced for ^{18}O + ^{175}Lu system.

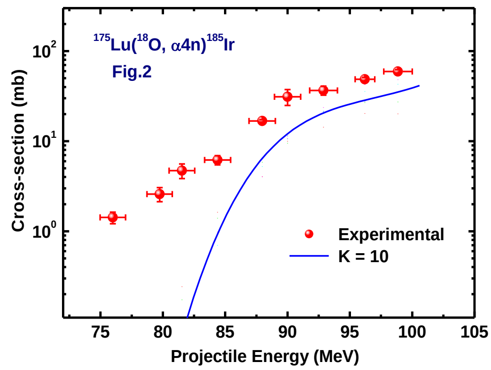

Fig. 2: Excitation function of evaporation residue ^{185}Ir (α4n) produced for ^{18}O + ^{175}Lu system.

References

[1] K Surendra Babu *et al.*, J. of Phys G: Nucl. and Part. Phys. **29** (2003) 1011.
[2] D. Singh *et al.*, Nucl. Phys. A **879** (2012) 107.
[3] R. Ali *et al.*, J. Phys. G: Nucl. Part. Phys. **37** (2010) 11510.
[4] T. Inamura *et al.*, Phys. Lett. B **68** (1977) 51
[5] A. Gavron Phys. Rev. C **21** (1980) 230.
[6] M. Cavinato *et al.*, Phys. Rev. C **52** (1995) 2577.