# Probing of Incomplete Fusion from the Measurement of Recoil Range Distributions

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## Introduction

The study of incomplete fusion (ICF) reaction dynamics has been the topic of keen interest due to the dependence of ICF on various entrance channel parameters like projectile structure, projectile energy, driving angular momentum, mass asymmetry of interacting partners and alpha Q-value of projectiles. In last few years, much interest has risen to study the competition between complete fusion (CF) and ICF at energies below 8 MeV/nucleon [1-3]. In case of ICF reaction mechanism, the incident projectile breaks-up into two fragments in the vicinity of target nuclear field. Only one part of the projectile which fuses with the target nucleus leading to the formation of incompletely fused composite system, while the remaining part moves as a spectator in forward direction with incident projectile velocity. It has also been reported that the projectile break-up probability or ICF influence on CF also increases with increasing the projectile energy [3]. Since, there is no theoretical model available which can reproduce the experimental ICF process cross-section satisfactorily below 8 MeV/nucleon energies, the investigation of ICF reaction mechanism is still an active research field. Britt and Quinton [4] firstly observed the ICF signatures in the break-up of projectiles like $^{12}$C, $^{14}$N, and $^{16}$O into α-clusters. Additional informations were provided by Inamura *et al.*, [5], which revitalized the ICF study. The transferred fractional mass i.e. transferred partial linear momentum leads the ICF product to be traversed in the stopping medium at lower thickness as compared to CF product. Being based on linear momentum transfer, forward recoil range distributions of evaporation residues provide a sensitive probe to study the ICF reaction dynamics and the effect of various fusion components on the onset of ICF. In order to have a clearer picture regarding the influence of various fusion components on ICF, forward recoil range distributions (FRRDs) measurement for $^{18}$O + $^{175}$Lu was carried out at ≈ 100 MeV energy.

## Experimental techniques

The present experiment was carried out at Inter University Accelerator Centre (IUAC), New Delhi. Vacuum evaporation technique was adopted in the preparation of $^{175}$Lu target, which was mounted onto the Al-backing foil facing the incident beam after Al-backing. $^{175}$Lu target of thickness ≈ 850μg/cm$^2$ was followed by a stack of thin Al-catcher foils. In the measurement of forward recoil range distributions (FRRDs) of populated residues, the stack of Al-catchers (having thicknesses ranging ≈ 30-70 μg/cm$^2$) was used as the stopping medium so that recoiling residues produced due to CF and/or ICF may get trap at their respective depths in Al-catcher foil thicknesses. The energy loss suffered by 5.49 MeV α- particle coming from $^{241}$Am source, was used to determine the thickness of target-catcher foils assembly. The stack was irradiated for about 15 hours with $^{18}O^{7+}$ ion beam in General Purpose Scattering Chamber (GPSC), which has an in vacuum transfer facility. The Faraday cup was placed behind the target-catcher assembly to collect the total charge for the calculation of beam flux. A High Purity Germanium Detector (HPGe) coupled to a CAMAC-based CANDLE software was used for the counting of induced γ-ray activities in each catcher foils. The HPGe detector was pre-calibrated both for energy and efficiency.

## Results and Discussion

In the present measurements, the FRRDs for various recoiled residues $^{188}$Au, $^{189-87}$Pt, $^{188-87}$Ir, $^{185}$Ir and $^{183}$Os etc. populated via their respective emission channels in the interaction of $^{18}$O with $^{175}$Lu target have been measured at ≈ 100 MeV energy. In order to obtain the differential FRRDs, the thickness independent measured cross-sections have been plotted against the cumulative catcher thickness. As a representative case, FRRD patterns for the residues $^{188}$Pt (p4n) and $^{185}$Ir (α4n) are shown in Fig. 1 & Fig. 2 respectively. The evaporation residue $^{188}$Pt(p4n) has single Gaussian peak corresponding to the recoil range ≈ 429 μg/cm$^2$, which is in good agreement with theoretical range calculated using SRIM code [6] as shown in Fig. 1. The agreement between measured p4n emission channel range and calculated compound nucleus range reveals that the residue $^{188}$Pt is produced via CF of $^{18}$O with $^{175}$Lu target, indicating the entire linear momentum transfer from projectile to the target, thereby the CF product traverses the larger distance in the stopping medium. The population of residue $^{188}$Pt may be represented as;

$$^{18}O + {}^{175}Lu \rightarrow [^{193}Au^*] \rightarrow {}^{188}Pt + p + 4n$$

As shown in Fig. 2, the FRRD of residue $^{185}$Ir (α4n) shows two Gaussian peaks. The peak corresponding to larger cumulative thickness ≈ 507 μg/cm$^2$, shows the presence of entire linear momentum transfer from projectile to the target nucleus. On the other hand, the peak at lower cumulative thickness ≈ 323μg/cm$^2$ indicates the transferring of partial linear momentum from projectile to the target nucleus. The measured recoil ranges ($R_p$) for both peaks well agree with the calculated recoil ranges using SRIM code. It may be observed from the FRRD pattern of residue $^{185}$Ir (α4n) that this residue is not only formed via CF of projectile $^{18}$O with $^{175}$Lu target but fusion component $^{14}$C (in the break-up of $^{18}$O into $^{14}$C + $^{4}$He) is also found to contribute in the population of residue $^{185}$Ir. Similarly, other residues have also been interpreted in terms of CF and/or ICF and will be presented.

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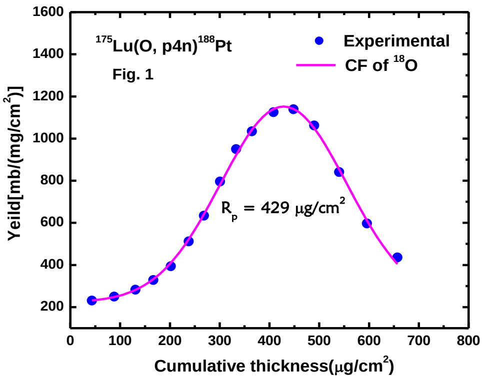


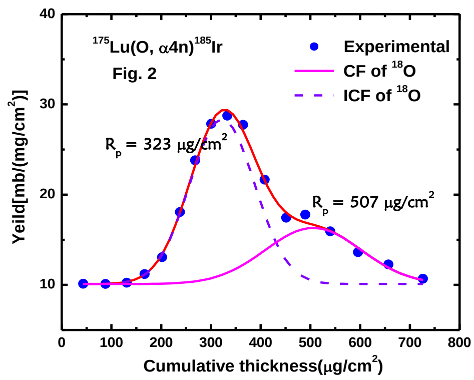


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