Linear momentum transfer in complete and incomplete fusion of ^{16}O with ^{175}Lu: Forward recoil range distribution measurements

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Introduction

In recent years, the study of light-heavy ion ($Z \leq 10$) induced reactions at energies above the Coulomb barrier and below 10 MeV/ nucleon, has been the subject of interest for better understanding of reaction dynamics. Excitation energy and angular momentum play important roles in fusion reactions. At projectile energy just above the Coulomb barrier, complete fusion (CF) and incomplete fusion (ICF) processes has been considered to be the dominant reaction modes. In complete fusion (CF) process, the entire projectile fuses with the target nucleus and formation of an equilibrated composite system comes into existence which may decay by emitting the particles and / or γ-rays. However, in case of incomplete fusion process (ICF), the break-up of the projectile takes place into two fragments, when it comes near to the Coulomb field of the nucleus. A part of projectile fuses with the target nucleus is supposed to form a less massive and charged excited incompletely fused compound system which shows the fractional momentum transfer from projectile to target while unfused part moves in forward cone with approximately projectile velocity [1-2]**.** The features of the study on ICF at lower projectile energy with break-up of projectiles like ^{12}C, ^{14}N, and ^{16}O into α-clusters, were first investigated by Britt and Quinton [3]. The additional but concrete informations regarding ICF has been provided by Inamura *et al*. [4], which gave the further support to understand the ICF reaction mechanism. Linear momentum transfer in these reactions plays a great role in the study of recoil range distributions (RRDs). In case of CF process, entire linear momentum is transferred from projectile to the target nuclei. As a result, the residues produced through CF process follow a larger range in the stopping medium. On the other hand, for ICF process, there is a fractional transfer of momentum, which has the proportionality with the mass of fused fragment. Thus, ICF products follow a shorter range as that of CF products [5]. Measurement of recoil range may also be used to distinguish different ICF processes where the same residue may be produced by fusion of different fragments in the projectile breakup with the target followed by different groups of particle emission. In the present work, forward recoil range distributions of some evaporation residues recoiled in thin Al-catcher foils, have been measured and the results are interpreted in terms on CF and ICF reactions.

Experimental Details and Analysis

Forward recoil range distributions (RRDs) of the residues produced in the reaction ^{16}O + ^{175}Lu have been measured at 96 MeV, using 15UD Pelletron Accelerator of the Inter University Accelerator Centre (IUAC), New Delhi. Thin target of lutetium (^{175}Lu) of thickness ≈ 659 $\mu g/cm^2$ was prepared by vacuum evaporation technique and deposited onto a thin Al-foil of thickness ≈ 43 $\mu g/cm^2$. A stack of 14 thin Al-catcher foils having a thickness lying between 36-70 $\mu g/cm^2$ were used as stopping medium. The energy loss suffered by 5.49 MeV α- particle obtained from ^{241}Am source, was used to determine the target and Al-catcher foils thickness. The irradiation with $^{16}O^{7+}$ beam of current ≈ 20 nA is carried out in the General Purpose Scattering Chamber (GPSC), which has an in-vacuum transfer facility. The target along with Al-catchers is irradiated for about 14 hrs at

96 MeV of $^{16}O^{7+}$ beam. γ-rays of the evaporated residues trapped in different catcher foils were recorded using a pre-calibrated, 100 cm^3 HPGe detector coupled to a CAMAC based Freedom Software.

Results and Discussion

In the present experiment, the RRDs for various recoiled residues ^{187}Pt, ^{186}Pt, ^{187}Ir, ^{186}Ir, ^{184}Ir, ^{181}Re and ^{178}Ta populated via (p3n), (p4n), (α), (αn), (α3n), (2α2n) and (3αn) emission channels have been measured at ≈ 96 MeV. In order to obtain the differential RRDs, the thickness independent measured cross-sections have been plotted against the cumulative catcher thickness and experimental recoil ranges of residues are fitted by Gaussian peaks using the software ORIGIN. As a representative the RRDs of two residues are shown in Figs.1and 2. As shown in Fig.1, for residue ^{187}Pt produced in (p3n) emission channel has only one Gaussian peak corresponding to the recoil range ≈ 443 μg/cm^2, which agrees with the recoil range calculated for the compound system using the classical approach and the stopping power and range software SRIM. This shows that the evaporation residue ^{187}Pt is produced in the reaction ^{175}Lu (O, p3n) via CF of ^{16}O with target ^{175}Lu and the equilibrated compound system ^{191}Au decays to form ^{187}Pt by emitting a single proton and three neutrons. The measured RRD for the evaporation residue ^{186}Ir shows two peaks in its distribution pattern (Fig. 2), corresponding to the cumulative thickness around ≈ 451 μg/cm^2 and ≈ 325 μg/cm^2. The higher range peak corresponds to thickness ≈ 451 μg/cm^2 shows the entire momentum transfer from projectile to target and produced via CF of ^{16}O with^{175}Lu. As it is understood that when the projectile comes near to the nuclear field it breaks-up into two fragments. In the present example, the projectile ^{16}O breaks-up into ^{12}C and ^{4}He(α) near the nuclear field of ^{175}Lu. One of the component ^{12}C fuses with the target ^{175}Lu and remnant ^{4}He(α)-particle moves in forward direction with projectile velocity. Due to the fusion of the fragment ^{12}C with target nucleus an incompletely fused (ICF) composite system ^{187}Ir is formed which may decay into ^{186}Ir by emitting a neutron, owing to the fractional momentum transfer. Thus, a peak at shorter range ≈ 325 μg/cm^2 corresponds to the production of the residue ^{186}Ir via ICF.

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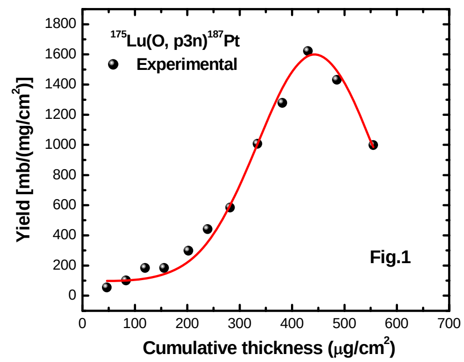

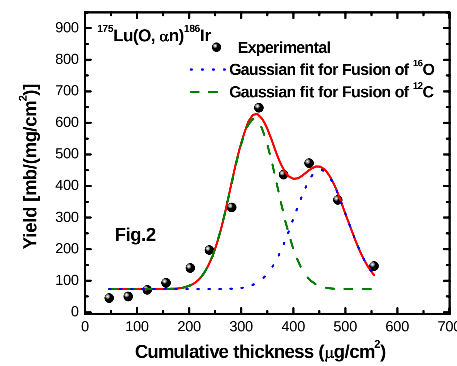

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