Incomplete fusion studies using recoil range distribution measurement for ^{16}O + ^{156}Gd system at 86 MeV

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Introduction

In the past two decades, there has been renewed interest in study of nuclear reaction mechanism especially; complete fusion (CF) and incomplete fusion (ICF) dynamics of heavy ions at energies below 10 MeV/A [1-4]. The complete fusion (CF) is a single step process in which projectile amalgams into target nucleus, involving all the nucleonic degrees of freedom leads to composite system and then de-excites by particles and/or γ-rays emission, while ICF-process viewed as a two-step process. In the first step, projectile breaks up into two fragments and in the second step one fragment moves in the forward direction while fusion of the remaining part of the projectile takes place with target nucleus to form the composite system, which further decays with the evaporation of the particles and/or γ-rays. The ICF reaction dynamics were first observed by Britt and Quinton [5]. Some important features of ICF-reaction mechanism is as follows; (a) Forward projected range of the residues produced in ICF process show relatively shorter range in the stopping medium as a result of fractional momentum transfer from projectile to target, while in CF process, where as entire linear momentum of projectile is transferred to the target nucleus, the recoiling residues traverse relatively larger distance in the stopping medium. (b) Spin distribution of CF process is distinctly different from ICF process; (c) ICF probability is more in mass-asymmetric projectile-target system than mass-symmetric system. In the present study we have made an attempt to measure the forward recoil range distributions (RRDs) of the residues produced in an interaction of ^{16}O with ^{156}Gd at 86 MeV to get a more clear picture of linear momentum transferred from projectile to target. The measurement of RRD can also be used to distinguish different ICF processes where the same residue may be formed by fusion of different fragments in the projectile break-up with target followed by the emission of different groups of particle. To the best of our knowledge RRDs for this system has been measured for the first time.

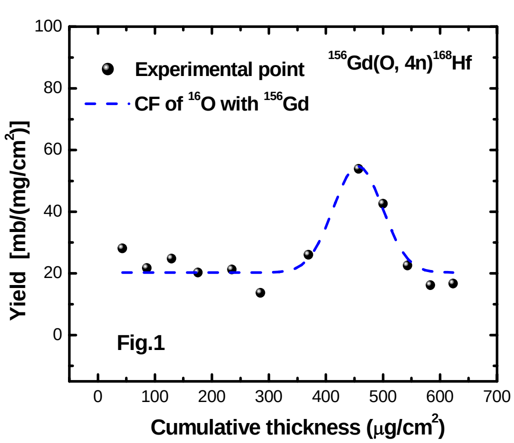
Experimental Details and Data Analysis

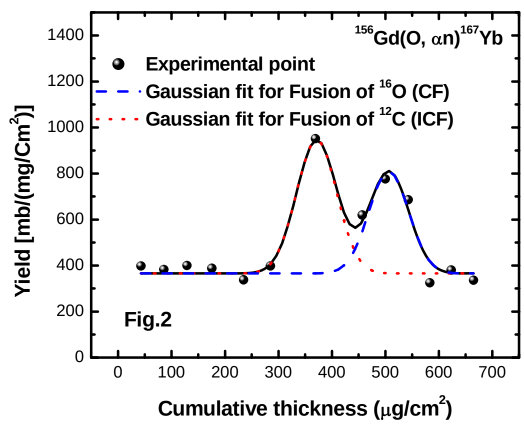
The experiment has been performed to study the RRDs of evaporation residues at Inter University Accelerator Centre (IUAC), New Delhi, India using 15UD Pelletron facility. Target of ^{156}Gd of thickness about $\approx$ 1.0 mg/cm^2 have been prepared by vacuum evaporation technique onto the backing of thin Al-foil of thickness $\approx$ 53 μg/cm^2. Thickness of ^{156}Gd target has been measured with the help of α-transmission method and electronic balance. The arrangement was made in such a way that target material is followed by the stack of sixteen thin Al-catcher foils of thickness lying in the range $\approx$ 40-80 μg/cm^2. The stack of 16 Al catcher foils followed by ^{156}Gd-sample was irradiated at 86 MeV ^{16}O-ion beam for about $\approx$ 13 hrs with average beam current of $\approx$ 60 nA keeping in view the half-lives of interest of radio-nuclides. The residual γ-activities induced in individual catcher foils were recorded using a pre-calibrated

100cm^3 HPGe detector coupled to a CAMAC based FREEDOM software. The RRDs for each residue has been obtained by plotting the yield with cumulative thickness. The normalized yields for various residues have been obtained by dividing the measured cross-section by the thickness of individual catcher foil.

Results and Discussions

The recoil range distributions of several ERs such as ^{168}Hf (4n), ^{167}Lu (p4n), ^{167}Yb (αn), ^{162}Yb (α6n), ^{165}Tm (αp2n), ^{163}Tm (αp4n), ^{161}Tm (αp6n) and ^{157}Dy (3α3n) have been measured. The measured differential forward RRDs of evaporation residues ^{168}Hf and ^{167}Yb are displayed in Figs. 1 and 2. The RRD of evaporation residue ^{168}Hf shows only one peak at cumulative thickness ≈ 462 μg/cm^2 in aluminium which corresponds to the calculated mean recoil range of the composite system. Hence, the residue ^{168}Hf is populated via CF of the projectile ^{16}O with ^{156}Gd target nucleus in the emission of 4 neutrons from the compound system ^{172}Hf. Again, as shown in Fig.2, the RRD of the residue ^{167}Yb has two peaks at cumulative thickness ≈ 494 μg/cm^2 and 362 μg/cm^2 in aluminium. The observed mean recoil range at cumulative thickness ≈ 494 μg/cm^2 is obtained due to CF of the projectile ^{16}O with target ^{156}Gd leading to emission of 1α-particle and 1 neutron from the composite nucleus ^{172}Hf. In addition to it, another peak observed at cumulative thickness ≈ 362 μg/cm^2 corresponds to ICF of the projectile ^{16}O i.e fusion of fragment ^{12}C (if the projectile breaks-up into ^{12}C and α-particle) with target nucleus ^{156}Gd leading to the emission of 1 neutron from the composite nucleus ^{168}Yb. In the measured RRD of ^{167}Yb, the resolved peaks correspond to different degrees of linear momentum transferred from projectile ^{16}O to ^{156}Gd at 86 MeV. Measured RRDs of these residues strongly reveal that significant contribution from partial momentum transfer of the projectile associated with ICF is present.





Authors are thankful to Dr. Amit Roy, Director IUAC, for providing the experimental facility at IUAC, New Delhi. One of the authors (MAA) thanks to Dr. A.K. Sinha, Director, UGC-DAE-CSR, Kolkata for providing the financial support.

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