Forward recoil range distribution (FRRD) measurements in $^{16}O + ^{156}Gd$ system at ~72, 82 and 93 MeV energies

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1. INTRODUCTION

Incomplete fusion (ICF) reaction dynamics has been a subject of increasing interest in the last two decades. It has been observed that above the Coulomb barrier ICF process is the dominant one. In the ICF reaction mechanism, a part of the projectile fuses with target nucleus and remaining part of the projectile (projectile like fragments) moves in the forward direction as a spectator, which lead to transfer of partial linear momentum from the projectile to the target nucleus. On the other hand, in complete fusion reaction, entire projectile is captured by the target nucleus, where complete momentum transfer takes place from projectile to target nucleus. The ICF reaction mechanism was first observed by Britt and Quinton [1]. Later on, quantitative studies on ICF reactions were done by Inamura et al [2]. In view of literatures, some important features of ICF-reaction dynamics are as follows: (i) forward projected range is shorter in the stopping medium as a result of fractional momentum transfer from projectile to target; (ii) the recoil energy of the reaction products formed via ICF has been observed to be less than those populated via CF, (iii) projectile like fragments (PLFs) are mainly concentrated in the forward cone and peaks in energy spectrum at projectile velocity, (iv) spin distribution of the residues populated via ICF is distinctly different that of the CF process, (v) ICF probability is greater in the mass-asymmetric systems than in the mass-symmetric systems.

To understand the features of ICF dynamics, varieties of dynamical models like : sum-rule model [3], break-up fusion model [4], promptly emitted particle (PEP) model [5] etc. are available to explain some of the above said features of ICF. In general, above existing models qualitatively explain the experimental data at energies ≥ 10 MeV/nucleon. Moreover, in early nineties, several report indicated that ICF-reaction even takes place at low bombarding energies [6-8] around 5-7 MeV/ nucleon. The main objective of the present work is the measurement of forward recoil range distributions (RRDs) to understand the degree of linear momentum transfer from projectile ^{16}O to target ^{156}Gd, at different projectile energies, E ~ 72, 82 and 93 MeV.

The ^{16}O-ion beam of different energies have been delivered from 15UD-Pelletron, at Inter-University Accelerator Centre (IUAC), New Delhi, India, to measure the forward recoil range distributions (FRRDs) of evaporation residues populated in $^{16}O + ^{156}Gd$ system. The targets were prepared by vacuum evaporation technique. The thicknesses of ^{156}Gd samples and thin Al-catchers have been measured with the help of α-transmission method. Thicknesses of ^{156}Gd samples comes out to be 0.589 mg/cm^2 (irradiated at E~ 72 MeV), 0.63 mg/cm^2 (irradiated at E ~ 82 MeV) and 0.767 mg/ cm^2

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(irradiated at E~93 MeV), which were deposited on Al-foils of thickness ~1.2 mg/cm^2. For the present measurement, stacks of thin Al-catcher foils have been used, whose thicknesses lie between ~20-90 μg/cm^2. The stacks of Al-catcher foils followed by ^{156}Gd-samples were irradiated at ~ 72, 82 and 93 MeV energy for ~12 to 15 hrs.

The forward recoil range distributions of several radio-nuclides like ^{168}Hf (4n), ^{167}Lu (p4n), ^{167}Yb (αn), ^{162}Yb (α6n), ^{165}Tm (αp2n), etc., have been measured at E ~72, 82 and 93 MeV by using recoil catcher technique. As a representative case, forward recoil range distributions (FRRDs) of evaporation residue

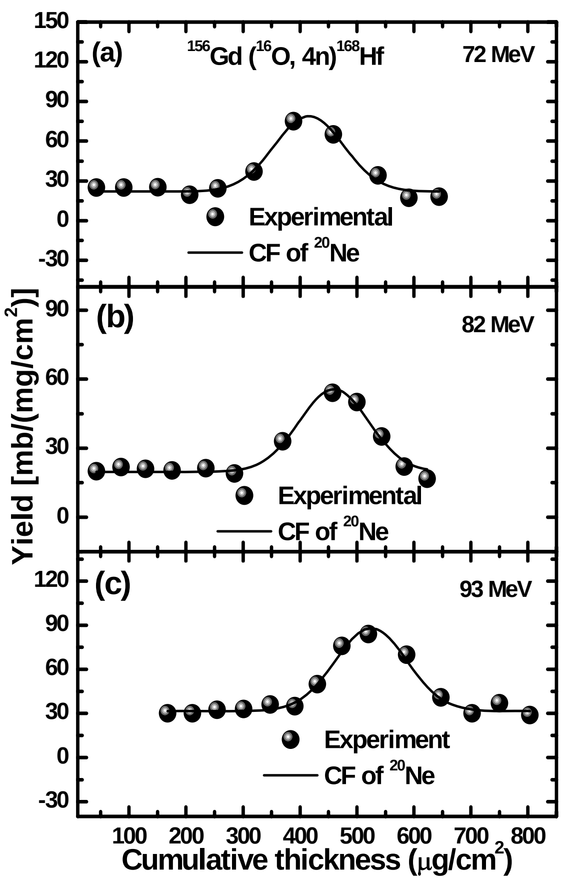

Fig.1: The experimentally measured forward recoil range distributions (FRRDs) of evaporation residue ^{168}Hf, produced via CF, for ^{16}O + ^{156}Gd system at three different energies, E ~72, 82 and 93 MeV.

^{168}Hf populated via 4n channels from equilibrated compound system ^{172}Hf* are shown in Fig.1. It can be observed from Fig.1 that measured forward recoil range distributions (RRDs) of residue ^{168}Hf shows only single peak at three different projectile energies, and there are only single linear momentum transfer (LMT) component involved at respective energy in the production of ^{168}Hf. It is observed from the range distribution curves that the peak appearing at full momentum transfer is associated with complete fusion of the projectile. More over, peak position shifts towards higher cumulative catcher thickness, as the projectile energy increases. It is simply because linear momentum transfer (LMT) increases with energy. The experimentally measured most probable ranges $R_p(exp)$ and theoretically estimated forward mean ranges $R_p(theo)$ using code SRIM, agree well which reveals that the residue ^{168}Hf is produced via CF of projectile with target nucleus.

The FRRDs of evaporation residues (ERs) ^{167}Yb and ^{165}Tm show two peaks, one peak at larger cumulative catcher thickness referred to CF of ^{16}O and other peak at shorter cumulative catcher thickness due to ICF of ^{16}O (fusion of fragment ^{12}C), which involves two different LMT components and hence these ERs produced via CF and/or ICF. While, the reaction products ^{162}Yb and ^{163}Tm have only singles peak, which corresponds to the ICF of ^{16}O (fusion of fragment ^{12}C) which involves partial LMT component and it mainly goes through ICF. Further, FRRDs of other residues have been measured and will be presented. It may further be pointed out that observation of FRRDs of various reaction products obtained in the present work may be considered as the confirmation of ICF process at the respective energies.

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