Fusion Incompleteness in ^{16}O induced reactions with ^{175}Lu between 70-100 MeV energy

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Introduction

In recent years, the study of heavy ion induced reactions has been become a topic of interest in nuclear physics, especially Complete Fusion(CF) and Incomplete Fusion(ICF) process below 10 MeV/nucleon [1, 2]. CF is the process in which the projectile completely fuses with the target, which leads to the formation of excited composite system. And then it de-excites by particle and/or γ-ray emission. Where as in case ICF mechanism, the projectile breaks into two fragments, of which one will fuse with the target to form an excited composite system, which may decay via emission of light-particles and/or γ-rays, while the other fragment moves forward as spectator with same velocity as that of the projectile carrying a large part of the angular momentum and kinetic energy of the projectile.

The first evidence of ICF process was observed by Britt and Quinton [3]. The later study done by Inamura *et al* [4] gave more strength to illustrate the ICF reaction dynamics. Several theoretical models have been proposed to explain the ICF dynamics, for example, Sum-rule model of Wilczynski *et al*., Break up fusion model by Udagawa and Tamura, etc. However none of them could reproduce the experimental data successfully at energies below 10 MeV/nucleon. Hence despite of the existence of so many models, a clear picture of the mechanism of ICF reactions is yet to emerge.

The present work has been carried out with the aim to extract more information about ICF contributions by the excitation function measurement of evaporation residues formed in ^{16}O + ^{175}Lu system at energies ranging from 70-100 MeV.

Experimental Details

The experiment was performed using 15UD Pelletron at Inter-University Accelerator Centre (IUAC), New Delhi, which provides ^{16}O-ion beam up to 100 MeV energy. General Purpose Scattering Chamber (GPSC) of diameter 1.5 meter having in-vacuum transfer facility is used to perform the experiment. With the help of rolling machine, self supporting target foils of thickness ranging from 1.0-1.5 mg/cm^2 were prepared. ^{241}Am-α source is used to determine the thickness of the target by α-transmission technique. Two stacks, each having four target foils, along Al-foils were used. Al catcher foils of thickness ranging from 1.5-2.0 mg/cm^2 were kept after each target foils. The Al foils not only serve as catcher foils to trap the evaporation residues produced in the reaction with in the catcher foil thickness but also as energy degraders which helped to irradiate the target foils with different energies in a single irradiation. The Stacks are irradiated at energies ≈ 100 MeV and ≈ 95 MeV. Pre-calibrated HPGe γ-ray detector of high resolution coupled to CAMAC based FREEDOM software is used to record the induced activities. The spectrometer is calibrated for both energy and efficiency using ^{152}Eu standard γ-source.

Results and Discussion

To study the fusion incompleteness, the excitation functions of several evaporation residues produced in α, 2α, 3α- emission channels for the system ^{16}O + ^{175}Lu have been measured using the recoil catcher activation technique at energies ranging from 70-100 MeV. As a representative case, the excitation functions of two residues ^{182}Re and ^{181}Re, populated via (2αn) and (2α2n), respectively are shown in Figs. 1 and 2.

The evaporation residue ^{182}Re is expected to be produced by two ways: either by emission of two alpha particles and one neutron from the compound nucleus ^{191}Au, formed by the complete fusion of ^{16}O with ^{175}Lu or by the incomplete fusion of ^{16}O, i.e. fusion of the fragment ^{8}Be of ^{16}O (after its breaking into ^{8}Be and ^{8}Be) with ^{175}Lu, followed by emission of one neutron. Similarly, for the evaporation residue, ^{181}Re, we expect that it may be produced either by emission of two alpha particles and two neutrons from the compound nucleus ^{191}Au, formed by complete fusion of ^{16}O with ^{175}Lu or by the incomplete fusion of ^{16}O, i.e. fusion of the fragment ^{8}Be of ^{16}O with ^{175}Lu, followed by the emission of two neutrons.

In both the cases, the residues may also be populated by the decay of the produced higher charge pre-cursor isobars. For residue ^{182}Re, the decay of ^{182}Ir and ^{182}Os, and for residue ^{181}Re, the decay of ^{181}Os has been taken into account. Hence, we obtained cumulative cross-section which includes contributions from the direct production as well as from the precursors decay. Following expression has been used for the cross-section measurements:

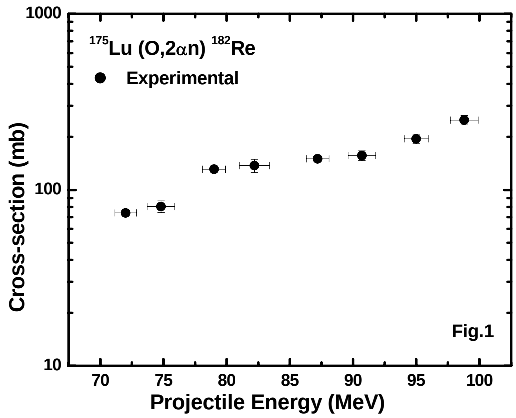
$$\sigma_r(E) = \frac{A\lambda \exp(\lambda t_2)}{N_0 \phi(\varepsilon_G).\theta.K[1-\exp(-\lambda t_1)][1-\exp(-\lambda t_3)]]}$$

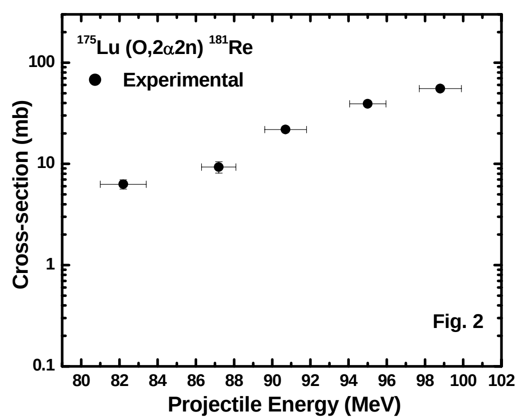
The independent cross-sections have been extracted from the measured cumulative cross-sections using Cavinato *et a*l. formulation [5].

$$\sigma_{ind}\left({}^{182}\mathrm{Re}\right) = \sigma_{cum}\left({}^{182}\mathrm{Re}\right) - 1.5\sigma_{ind}\left({}^{182}Os\right) - 1.53\sigma_{ind}\left({}^{182}Ir\right)$$

$$\sigma_{ind}\left({}^{181}\mathrm{Re}\right) = \sigma_{cum}\left({}^{181}\mathrm{Re}\right) - 1.09\sigma_{ind}\left({}^{181}Os\right)$$

For the residues ^{182}Re and ^{181}Re, it has been observed that no PACE values are available, i.e. there is no contribution from the complete fusion process, and thereby it may be pointed out that these residues are populated only by ICF process. Also from the figure it has been noticed that the ICF contribution increases with increase in projectile energy.





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