Study of reaction mechanism in ^{16}O + ^{165}Ho system below 7 MeV/nucleon

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Introduction

A systematic study of the energy dependence of fusion cross-section is most essential to understand the reaction mechanism. At low energies complete fusion (CF) characterized by full momentum transfer is a dominant part of the total reaction cross-section. As the projectile energy increases (5-10 MeV/nucleon and above), it turns out that the fused system does not consist of all the nucleons involved. There are particles which can be emitted either very fast (much faster than those coming from an evaporation process) termed as incomplete fusion (ICF) particles or possibly very slow if they are emitted from the excited compound nucleus termed as complete fusion (CF) particles. The fast particles having forward peaks consist of nucleons as well as the clusters of nucleons, like an alpha particle.

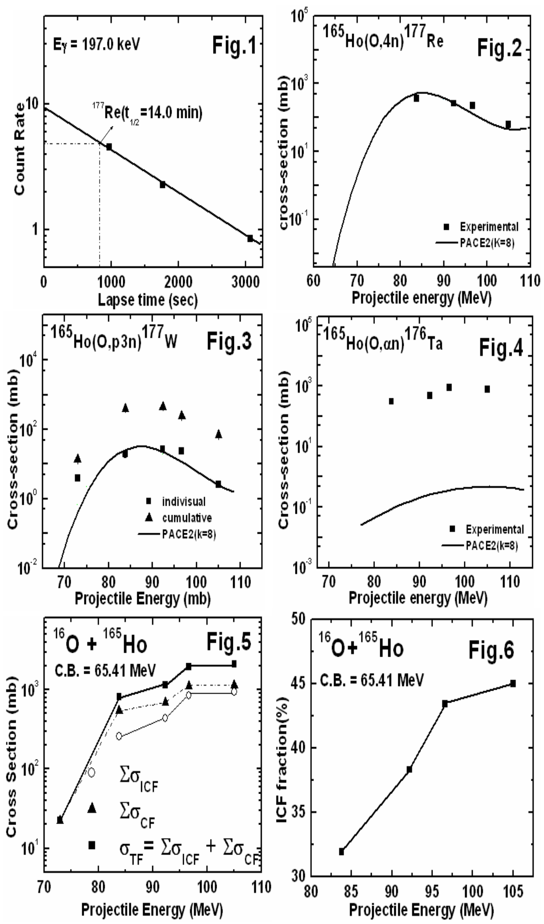
There has been a lot of interest in studying the reaction mechanism in the medium and high energy ranges, say, in the energy range up to 10 MeV/nucleon or so. With this view in mind, the present work is undertaken to study the reaction mechanism i.e. CF and ICF in the ^{16}O + ^{165}Ho system below 7 MeV/nucleon. Further, an attempt has also been made to estimate ICF fraction from the measured data.

Experimental details

The experiment was performed at the Inter University Accelerator Centre (IUAC), New Delhi, India. Self supporting ^{165}Ho samples of thickness ≈1.4 mg/cm^2 were prepared by rolling natural holmium. A stack of six samples interspersed with aluminum foils of thickness ≈ 2.15 mg/cm^2 was irradiated for ≈10 hours with a beam current of ≈30 nA at the beam energy 105 MeV in the General Purpose Scattering Chamber (GPSC). Post irradiation analysis was done using a high resolution, large active volume (100 cm^3) pre-calibrated HPGe detector coupled with a data acquisition system. Various standard sources of known strength were used to determine the efficiency of the detector. The evaporation residues (ERs) were identified using the characteristic γ-rays as well as by measuring their half-lives. A typical curve used to determine the half-life of the residue ^{177}Re is shown in Fig.1. Further, details of the experimental arrangement, formulation used and error analysis etc. are discussed in detail in Ref. [1]. The overall errors in the present work were estimated to be lying between 12-30% including the statistical errors.

Results and Discussion

The measured excitation functions (EFs) were compared with the calculated values using code PACE-2 [2], which is based on a statistical approach. Details of this code are enumerated in Ref. [3]. In this code, the level density parameter constant K may be varied to match the experimental data. In the present work, a value of K = 8 has been found suitable. The measured EFs for residues $^{178-175}Re$ (xn channels) are expected to be formed via complete fusion of ^{16}O with ^{165}Ho. As a representative case the measured EFs of ^{177}Re is shown in Fig.2. It may be ascertained from the figure that our measurements are consistent with PACE-2 calculations and, therefore, the agreement between the theoretical values and the experimental ones is firmly established. In case of pxn channels, the possibility of formation of residues $^{177,176}W$ may be via CF of ^{16}O with ^{165}Ho and/or via the β^+ decay of its higher charge isobar precursors. Thus the measured activities of ^{177,176}W may have contributions from both the independent production and from precursor decay modes. Again as a representative case, an attempt has been made to separate out the independent yield [4] of the residue ^{177}W produced via p3n channel. The cumulative (σ_C)



and independent yield (σ_i) for the residue ^{177}W are related by the equation.

$$\boldsymbol{\sigma_i(^{177}W) = \sigma_C(^{177}W) - 1.12\ \sigma_i(^{177}Re)}$$

As can be seen from Fig.3, the measured independent cross-section values agree well with PACE-2 calculations, which indicate that the evaporation residue ^{177}W is populated via CF process.

The theoretical EFs for residues $^{176\text{-}173}$Ta do not match with the experimentally measured values. PACE-2 calculations are lower compared to the experimentally measured EFs as shown in Fig.4. Since ICF is not considered in PACE-2 calculations, enhancement in the measured EFs values over PACE-2 predictions can be attributed to the fact that this channel may be populated not only by CF of ^{16}O with ^{165}Ho but also by ICF, where emission of alpha particle in the break up of projectile takes place.

For ^{16}O + ^{165}Ho system, the contribution coming from all ICF channels ($\Sigma\sigma_{ICF}$) and the sum of all CF ($\Sigma\sigma_{CF}$) obtained from PACE-2 calculations are plotted along with the total fusion cross-section (shown in Fig.5). It can be observed from the figure that CF component has measureable contribution even at ≈72 MeV, while ICF contribution seems to start from ≈ 83.8 MeV. To investigate relative contributions of CF and ICF, the percentage ICF fraction (F_{ICF}) for ^{16}O + ^{165}Ho system has been estimated from the experimentally measured cross-sections [4]. The ICF fraction has been deduced at different energies and is plotted as a function of projectile energy (as shown in Fig.6). It can be observed from the figure that at the threshold of ICF (i.e. 83.8 MeV), the relative percentage of ICF fraction is found to be 32% of the total fusion cross-section ($\Sigma\sigma_{TF}$), which increases with the projectile energy. At the highest studied energy (i.e. 105 MeV) ICF approaches to be 45%.

Conclusions

The xn and pxn channels are consistent with the theoretical predictions based on the model code PACE-2. It has been observed that, in general, residues are not populated via CF but ICF is also found to play an important role in the population of different reaction products. Further, ICF fraction from EFs data has been estimated and found to be dependent on the incident projectile energy.

References

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