Low energy incomplete fusion study in the ^{16}O + ^{142}Nd system

Pankaj K. Giri[1], D. Singh[1,*], Sneha B. Linda[1], Amritraj Mahato[1], Harish Kumar[2], Suhail A. Tali[2], Siddharth Parashari[2,a], Asif Ali[2], M. Afzal Ansari[2], Rakesh Dubey[3,b], R. Kumar[3], S. Muralithar[3] and R. P. Singh[3]

[1]*Department of Physics, Central University of Jharkhand, Ranchi-835205, INDIA*
[2]*Department of Physics, Aligarh Muslim University, Aligarh-202 002, INDIA*
[3]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

Introduction

Low energy incomplete fusion (ICF) with stable projectile beams and heavy targets has been an active area of investigation in these past years to know the contribution of ICF over total fusion (TF) cross-section with respect to the complete fusion (CF) [1, 2]. For the investigation of the CF and ICF reactions mechanism, the measurements of excitation functions (EFs), recoil range distributions (RRDs), angular distributions (ADs) and spin distribution (SDs) of the evaporation residues (ERs) are the inimitable tools.

A part of the projectile fuses with the target nucleus and the other part keep moving in the forward direction as spectator, in ICF process. First time the ICF dynamics were observed by Britt and Quinton [3] in the break-up of the projectiles ^{12}C, ^{14}N and ^{16}O into α-clusters at energy ≈ 10 MeV/A. The mechanism of the ICF dynamics is still not well understood, partially with regards to the angular momentum involved in the process. The studies by Trautmann *et al.*[4] observed that ICF is associated with the peripheral collision, meanwhile some literature suggest that involvements of the lower angular momenta than ℓ_{crit} for CF[5].

In case of CF, projectile fuses entirely with the target nucleus by involving all nucleonic degrees of freedom and forms an excited compound nucleus which may further decay via emission of light mass particles.

* *Email: dsinghcuj@gmail.com*

Present address

[a] *Physics Department, The M. S. University of Baroda, Vadodara-390002,INDIA*

[b] *Department of Physics & Astronomy, University of the Western Cape, Bellville-7535, SOUTH AFRICA*

Many experimental studies were carried out to estimate the ICF contribution for different target projectile (α and non-α cluster structure) combination. But so far the experimental data with rare earth targets like ^{142}Nd is limited at intermediate energies and with ^{16}O projectile is first time reported here with best of our knowledge.

In this paper, we present our experimentally measured data of EFs of ERs produced in ^{16}O + ^{142}Nd system. The present work is undertaken in order to explain the low energy incomplete fusion for the stable projectile ^{16}O and to understand the target deformation effect for ICF. The present work may be helpful for theoretical model development.

Experimental Details

The present experiment of the EFs measurement of ERs produced in ^{16}O+^{142}Nd system has been carried out at Beam hall-I using 15UD Pelletron accelerator facility of Inter University Accelerator Centre (IUAC), New Delhi, India. The target foils of ^{142}Nd (Enrichment ≈ 98.26%) material were prepared by vacuum evaporation deposition technique. As the target material is oxidizing in nature, a thin coating of ^{27}Al is applied after the deposition of ^{142}Nd over thick ^{27}Al- backing foils.

For the irradiation of target with ^{16}O beam of energy 100MeV, one stack of target-Al foil assemblies were placed in the general purpose scattering chamber (GPSC), where the Al backing foils acts as energy degrader. After the beam irradiation about 10.4 hour, off-line gamma spectroscopy method is adapted to record the decaying gamma rays using a high purity germanium detector (HPGe) coupled to a PC based software CANDLE [6]. The standard ^{152}Eu γ-ray source was used for energy calibration of HPGe detector and the residues are identified primarily by their characteristics γ-rays then conformed by following the half-lives in the decay curve for each ER.

Results and Discussion

In this present experiment of EFs measurement, twelve evaporation residues have been identified in the ^{16}O+^{142}Nd system, out of those four ERs are shown in the Fig.1.

The interpretations of the results are done within the framework of the PACE-4[7]. The code PACE-4 is based on the Monte Carlo simulation procedure used for the de-excitation of compound nucleus formed via CF. The CF cross-sections of the system are calculated using Bass formula [8]. The level density parameter "a" (=A/K)MeV−1 is a very important parameter in this code. For the current analysis K=10 found best fit to the experimental data.

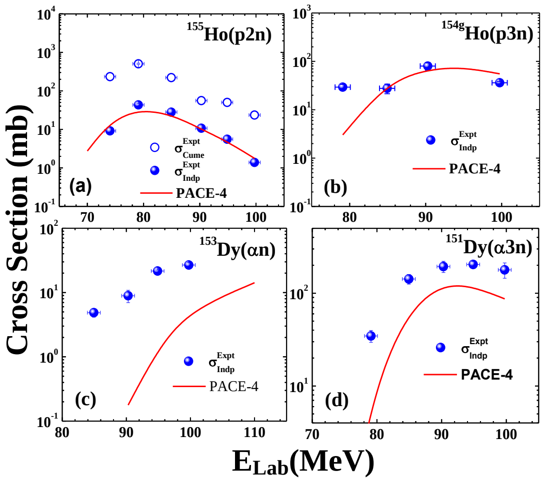

Fig.1. The exaltation functions of the evaporation residues (a) ^{155}Ho (b) ^{154}Ho(c) ^{15}3Dy (d) ^{151}Dy produced in the ^{16}O + ^{142}Nd system along with PACE-4 prediction. The symbol nomenclatures are defined within the figure.

As can be seen from the Fig.1 (a) and (b) the experimental data are fit reasonably will with the PACE-4 prediction. This indicates the production of ^{155,154}Ho ERs through pxn (x=2, 3) channels predominantly via CF dynamics from the compound nucleus. The Independent cross-section of ^{155}Ho(p2n) have been calculated using Cavinato *et al.*[9] formalism. From the Fig.1 (c) and (d) one can notice the enhancement of experimental data over the theoretical prediction for the ERs of *αxn* channels. This enhancement may be due to the incomplete fusion of the ^{16}O (α + ^{12}C) projectile with target.

Furthermore an attempt has been taken to calculate the incomplete fusion fraction (F_{ICF}) for the current system and compare it with other literature data w.r.t the deformation value of the target. From Fig.2 it may be predict that, the F_{ICF} increases with increasing $\beta_{2(T)}$ value. For more information in this regard need through investigation with different target projectile combination.

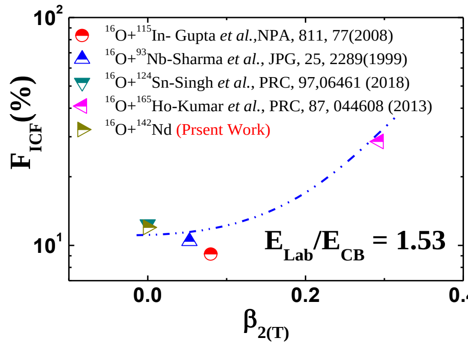

Fig.2. Incomplete fusion fraction (F_{ICF}) as a function of deformation parameter of target ($\beta_{2(T)}$).

Acknowledgments

Authors are thankful to the Director, convener of IUAC, New Delhi and also to the Pelletron and target laboratory personnel for providing the necessary experimental facilities during the experiment. PKG and DS are grateful to the IUAC, New Delhi for financial support (Ref: IUAC/XIII.3/UFR/54321).

References

[1] D. Singh *et al.*, Phys. Rev. C, 79, 054601 (2009).
[2] D. Singh *et al.*, Phys. Rev. C, 97, 064610 (2018)
[3] H. C. Britt *et al.*, Phys. Rev. 124, 877 (1994).
[4] W. Trautmann *et al.*, Phys. Rev. Lett. 53, 1630 (1984)
[5] H. Tricoire *et al.*, Z. Phys. A 306, 127 (1982)
[6] CANDLE, Data acquisition and analysis software, (IUAC), New Delhi, India.
[7] A. Gavron, Phys. Rev. C 21, 230 (1980).
[8] R. Bass, Phys. Rev. Lett. 39, 265 (1977).
[9] M. Cavinato *et al.*, Phys. Rev. C **52**, 2577 (1995).