Mass distribution of Erbium (Er) isotopes formed in heavy ion induced reactions in low energy regime

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Introduction

Heavy-ion induced reactions offer an opportunity to investigate the nuclear dynamics and related properties at various extremities. Such reactions are fascinating as they lead to the formation of compound nucleus of heavy/superheavy mass, which subsequently disintegrates into the binary fragments depending upon a numbers of factors such as incident energy, angular momentum, deformations and orientations and N/Z value (neutron to proton ratio). In the exit channel one may find multiple channels such as evaporation residue (ER), intermediate mass fragments (IMF), heavy mass fragments (HMF), fission fragments etc. In view of this, it is intriguing to understand the decay dynamics of the compound nuclei belonging to Actinide, Pre-actinide and Lanthanide regions. In the present work, an attempt has been made to comprehend the dynamics of Lanthanide isotopes ^{152,154,156,158,160,162,164,166}Er* with neutron number ranging from N = 84-98. The aim of this study is to analyse the mass distribution of the above mentioned isotopes of Er*. We have used The Dynamical Cluster-decay Model (DCM) [1–4] based on Quantum Mechanical Fragmentation Theory (QMFT) that explains the disintegration of compound nuclei into binary fragments. In DCM, both the light particles (LPs) and complex, intermediate mass fragments (IMFs) up to symmetric division are treated as the dynamical collective mass motions of the preformed clusters or fragments.

Methodology

The Dynamical Cluster-decay Model (DCM) [1–4] rooted in the QMFT, is employed to calculate the decay cross-sections in terms of the partial wave analysis. The cross-section depending upon the incident/center of mass energy ($E_{c.m.}$) is given by

$$\sigma = \sum_{\ell=0}^{\ell_{max}} \sigma_\ell = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell+1) P_0 P;$$

$$\mathrm{k}=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} (1)$$

P$_0$ is the preformation probability and P is the barrier penetrability, where P$_0$ caters to mass asymmetry η-motion and P to the R-motion. It is worth mentioning here that the preformation probability P$_0$ imparts the important nuclear structure information which is otherwise missing in other statistical models and is given by the solution of the stationary Schrödinger equation and reads as

$$P_0 = \mid \psi^{\nu=0}(\eta(A_i)) \mid^2 \sqrt{B_{\eta\eta}} \frac{2}{A_{CN}}. \quad (2)$$

The only parameter of the model is the neck length parameter R(T), defining the first turning point of the penetration path across the barrier as

$$\mathrm{R}_a = R_1(\alpha_1, T) + R_2(\alpha_2, T) + \Delta R(T)$$

Observations and Results

Recently an experiment has been performed and evaporation residue (ER) cross-sections data [5] is made available for ^{158,166}Er* compound nuclei, belonging to the Lanthanide series, formed via ^{16}O+^{142,150}Nd reactions over a wide range of incident energies $E_{c.m.}$ (MeV)

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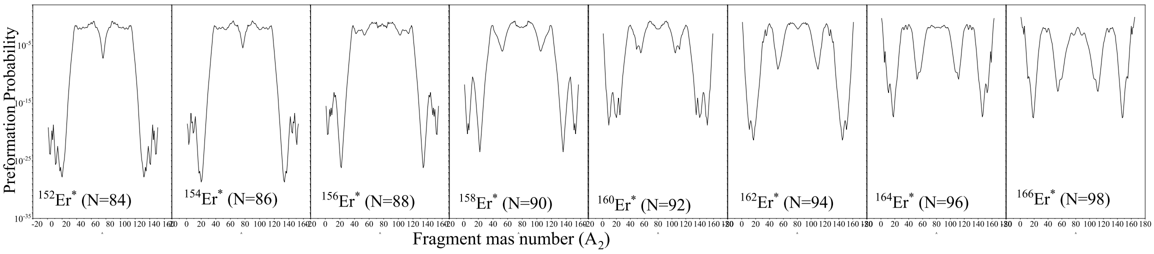

FIG. 1: Preformation probability P_0 as a function of fragment mass number A_2 for the isotopes ^{152,154,156,158,160,162,164,166}Er* at a common E_{CN}=67.55 MeV.

spread across the Coulomb barrier. For the above said isotopes of Er*, the experimental data of [5] has been addressed within the permissible limit of neck-length parameter (ΔR) of DCM in the work [6]. In the present work we intend to explore the isotopic analysis. We have considered ^{152,154,156,160,162,164}Er* isotopes of Er besides ^{158,166}Er* mentioned in [5] and analysed their mass distribution at a common E_{CN}=67.55 MeV. Fig. 1 depicts the preformation probability P_0 (calculated using eq.2) as a function of fragment mass number (A_2) for the decay of Er* isotopes. It can be seen from Fig.1 that the relative contribution of fragments belonging to different mass regions (i.e ER, IMF, HMF, fission fragments) changes significantly with increase in N/Z ratio. Following observations can be made from Fig.1: (i) the relative contribution of ER increases with increase in N. For N=84, the contribution of ER is negligible which starts competing with other decay channels as N becomes equal to 92 or higher. (ii) Similar results are observed for intermediate mas fragments (IMF) ($A_2 = 5$ to $A_2 = 20$) (iii) Heavy mass fragments (HMF) are the fragments which lie between IMFs and fission fragments. The HMF and the fission fragments show broad shoulder structure for lighter isotopes which changes to triple humped structure for heavier isotopes studied here. Similar results have been observed in the mass distribution of Bismuth (Bi) isotopes reported in [7]. In the present work, Isotopic analysis of Er* suggests that the mass distribution show different dominance of the decay modes of exit channel with increase in Neutron number (N). Similar analysis of other members belonging to lanthanide family is also being analysed for proper understanding of competing decay modes governed in the exit channel of lanthanide nuclei.

Acknowledgments

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