Decay of exotic nucleus ^{191}Ir* formed in α-induced reaction

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Introduction

The Dynamical Cluster-decay Model (DCM) [1] has served as an important tool to govern the reaction dynamics of the various compound nuclei (CN) lying over a wide range of mass. The novelty of the clusterization approach lies in the fact that it treats the emission of light particles (LPs), intermediate mass fragments (IMFs) and heavy mass fragments (HMFs)/fission fragments (ff) on parallel footing. With a motive to expand the domain of DCM, it has been applied to investigate the decay of CN formed in α-induced reactions and to extract relevant information regarding the impact of excitation produced by light mass projectile on the fragmentation structure. In view of this, the present work deals with the decay of CN ^{191}Ir* formed in the α + ^{187}Re reaction over an incident beam energy E_α=10-14 MeV in reference to experimental data on neutron-evaporation[2]. The DCM based cross-sections, calculated by varying the neck-length parameter of the model ΔR find nice agreement with the experimental results. The values of neck-length parameter ΔR vary from 0.820 fm to 0.975 fm over the considered energy range. It is note-worthy that the reaction α + ^{187}Re involves the amalgamation of spherical projectile (α) with deformed target (^{187}Re; β_2=0.212), thereby resulting in a deformed compound system (^{191}Ir*; β_2=0.155). Hence, a specific analysis is done to investigate the role of deformations in the dynamics of the compound nucleus ^{191}Ir*, and the investigations are made in terms of fragmentation structure, preformation profile (P_0) and decay barrier height (V_B) at highest beam energy $E_{c.m.}\sim$14.0 MeV. The experimentally available cross-sections are also fitted after inclusion of deformations, but for higher values of neck-length parameter ΔR. For the extreme energy $E_{c.m.}\sim$14.0 MeV, the experimental data is fitted at ΔR=0.975 fm for spherical fragmentation approach while it requires a higher value of ΔR=1.162 fm for deformed approach.

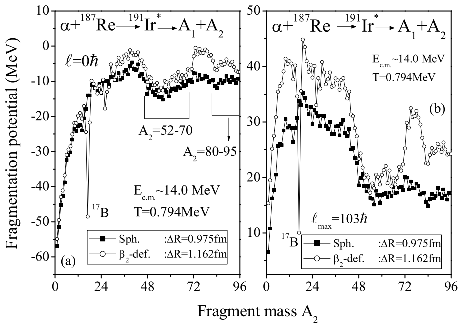

FIG. 1: Variation of fragmentation potential as a function of fragment mass (A_2), for the decay of compound system ^{191}Ir* plotted at $E_{c.m.}\sim$14.0 MeV for both spherical as well as deformed choice of fragmentation at (a)ℓ=0$\hbar$ and (b)ℓ=ℓ_{max}.

The Dynamical Cluster-decay Model (DCM)

The DCM [1], based on quantum mechanical fragmentation theory (QMFT), is worked out in terms of collective coordinates of mass (and charge) asymmetries $\eta_A = (A_1 - A_2)/(A_1+A_2)$ (and $\eta_Z = (Z_1-Z_2)/(Z_1+Z_2)$) and relative separation R. With inclusion of deformation and orientation, the compound nucleus decay cross-sections for hot (T$\neq$0)and rotating ($\ell\neq$0) nucleus is given as:

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (1)$$

The preformation probability (P_0) refers to the stationary state solution of the

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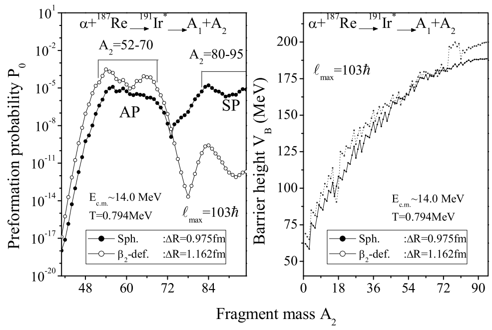

FIG. 2: (a) Preformation probability P_0 and (b) decay barrier height V_B plotted as a function of fragment mass at $E_{c.m.}$~14.0 MeV for both spherical as well as deformed choice of fragmentation.

Schrodinger equation in η-coordinates while the tunnelling probability P refers to R-motion, calculated via WKB approximation. Also, ℓ_{max} is the maximum angular momentum fixed for the vanishing of n-emission cross-sections i.e.$\sigma_n \rightarrow 0$.

Calculations and discussions

The present work deals with the investigation of decay of compound system ^{191}Ir* formed in α-induced reactions by opting spherical as well as β_2-deformed choice of fragmentation. Fig.1 represents the variation of fragmentation potential as a function of fragment mass A_2 plotted at $E_{c.m.}$~14.0 MeV for both spherical as well as deformed choice of fragmentation at (a)ℓ=0$\hbar$ and (b)$\ell=\ell_{max}$. It has been observed that the compound nucleus prefers to decay via light particle emission (n-evaporation) at lower values of angular momentum (ℓ=0$\hbar$) and this result seems to be consistent for both choices of fragmentation. A minima in symmetric fission region and asymmetric HMF region is observed for spherical fragmentation. On the other hand, minima is observed only in asymmetric HMF region for deformed choice of fragmentation. But they do not form the competing decay channel as they possess much higher magnitude of fragmentation potential as compared to light particles. As we shift towards higher ℓ-values, a decrease in magnitude of the fragmentation potential for HMF and fission fragments is observed there by making them probable candidates towards the decay channel. Hence at higher ℓ-values, HMF and fission fragments constitute the competing decay mode for the decay of ^{191}Ir*. Moreover, the structure of the plot for spherical fragmentation is different from that of deformed fragmentation attributed to minimas in different mass regions. This is further clarified in Fig. 2(a) where preformation probability P_0 is plotted as a function of fragment mass at $E_{c.m.}$~14.0 MeV for both spherical as well as deformed choice of fragmentation at ℓ_{max}=103$\hbar$. For the use of spherical fragmentation, the CN opts near symmetric decay consisting of fission fragments with A_2=80-95 with significant contribution from asymmetric heavier fragments with A_2=52-70. While with inclusion of deformations, the fragmentation structure becomes purely asymmetric having major contribution from A_2=52-70 fragments. Further, the effect of deformations is also investigated on the decay barrier height V_B as shown in Fig.2(b). It has been observed that the decay barrier height follows almost similar behavior as a function of fragment mass for both choices of fragmentation, with significant enhancement in the barrier height for the use of β_2-deformed fragmentation. Hence, it is concluded that deformations play a significant role in the decay of compound system ^{191}Ir* formed in α-induced channel. With inclusion of deformations, the decay pattern changes from near symmetric (with contribution from HMF) to purely asymmetric fragmentation.

Acknowledgement

The financial support from DST, New Delhi is gratefully acknowledged.

References

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