Fragmentation analysis of compound nuclei formed in ^{16}O and ^{48}Ca induced reactions

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Introduction

The dynamics of nuclear reactions induced by heavy-ions lying in near barrier energy region have been a subject of great interest since decades and are specifically exploited to explore the nuclear properties for the nuclei having masses $A = 200 - 300$. In context to this, the present work aims towards carrying out the fragmentation analysis of the compound nuclei (CN) ^{219}Ac* and ^{251}Md* formed via ^{16}O [1] and ^{48}Ca[2] induced reactions respectively, using same target nucleus ^{203}Tl. The methodology employed here is the collective clusterization technique of Dynamical Cluster-decay Model (DCM)[3] and the analysis is carried out in terms of barrier characteristics [barrier height (V_B) and barrier position (R_B)] and preformation probability profiles of the chosen CN.

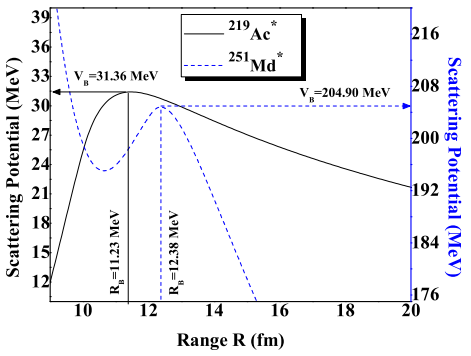

FIG. 1: Scattering potential for the $2n$-decay channel from ^{219}Ac* and ^{251}Md* respectively formed via ^{16}O and ^{48}Ca induced channel.

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Methodology

In DCM[3], the barrier profile is studied in terms of scattering potential which includes contribution from Coulomb potential (V_C), proximity potential (V_P) and centrifugal potential (V_ℓ), in to which the effect of deformations and temperature are duly incorporated and is given by:

$$V_R(\eta, T) = V_C(R, Z_i, \beta_{\lambda i}, \theta_i, T) + V_P(R, A_i, \beta_{\lambda i}, \theta_i, T) + V_\ell(R, A_i, \beta_{\lambda i}, \theta_i, T). \quad (1)$$

The preformation probability (P_0) is obtained by solving the stationary Schrödinger equation in η, at fixed R=R_a:

$$\left[-\frac{\hbar^2}{2\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta} + V(\eta, T)\right]\psi^\nu(\eta) = E^\nu_\eta\psi^\nu(\eta) \quad (2)$$

Calculations and discussions

In Fig. 1, the scattering potential for the decays ^{219}Ac* $\rightarrow^{217}$Ac+$2n$ (solid line) and ^{251}Md* $\rightarrow^{249}$Md+$2n$ (dotted line) is plotted in terms of relative separation R (fm) at respective center of mass energies $\mathrm{E}_{c.m.} = 76.10$ MeV and $\mathrm{E}_{c.m.} = 173.075$ MeV and best-fit values of neck-length parameter. The curve is plotted at lower values of angular momentum ($50\hbar$) because neutron evaporation is dominant at lower ℓ states only. Clearly, the barrier profiles are different for the two cases where

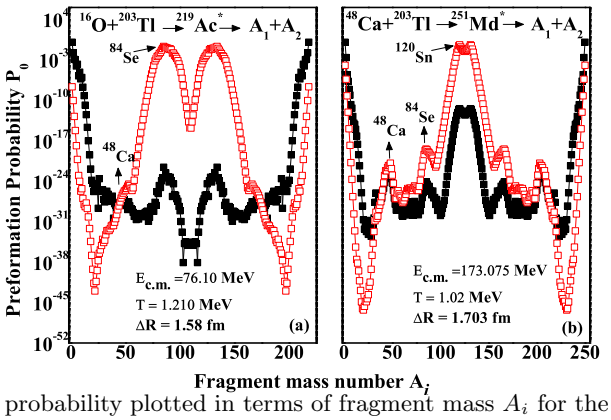

FIG. 2: Preformation probability plotted in terms of fragment mass A_i for the decay of (a)^{219}Ac* and (b)^{251}Md*. The respective values of $E_{c.m.}$ and other DCM based parameters are mentioned in the figure.

the barrier height (V_B) for the lighter CN ^{219}Ac* is 31.36 MeV whereas the same for heavier system is 204.90 MeV. On the other hand, the barrier position R_B is 11.23 fm and 12.38 fm, respectively, for lighter and heavier decaying CN. This difference in the barrier profile and barrier characteristics arises because of the different entrance channels- ^{16}O + ^{203}Ac and ^{48}Ca+^{203}Ac. However, notable variations might also be arising because of the difference in $E_{c.m.}$ (or T) that enters through the T-dependence of radius terms involved in defining the potential terms.

Additionally, the fragmentation behavior of the two chosen CN is compared and analyzed in terms of the preformation probability (P_0) values of all the probable exit channels from these CN in Fig. 2, where panel (a) is plotted for (a)^{219}Ac* and (b) is plotted for ^{251}Md* nucleus. The P_0 values are calculated for quadrupole deformed choice of fragments having orientations optimized for "hot" configurations and at extreme values of angular momentum (ℓ=0$\hbar$ and $\ell = \ell_{max}$). The ℓ_{max} value for ^{219}Ac* and ^{251}Md* is 102$\hbar$ and 109$\hbar$ respectively. The comparative analysis of the figure indicate that for both the decaying systems, the light particle emission (LP: A_2=1-4) or 2n-emission is dominant at lower ℓ-states. Dominant maximas are arising in heavy mass region (HMF: A_2=90±10 plus complementary region) for the ^{219}Ac* while for ^{251}Md* nucleus, the peaks originate in fission region (ff: A_2=125±20). However, the magnitude of these peaks is very less relative to that of LPs or 2n-emission at ℓ=0$\hbar$ states and do not contribute towards decay cross-sections. As the higher ℓ-states are incorporated, structural changes are observed for both the decaying systems due to the enhancement in P_0 values of the peaks lying in HMF and ff region. The comparative analysis of the structures of ^{219}Ac* and ^{251}Md* systems reveals that the two systems choose different decay paths, where, ^{219}Ac* undergoes asymmetric fragmentation while ^{251}Md* opts for symmetric fragmentation. The origin of the asymmetric peaks in HMF region for ^{219}Ac* may be attributed to the magic or near magic shell configuration for ^{84}Se and in case of ^{251}Md*, the symmetric fission peak may be arising due to magic shell closure at ^{120}Sn.

References

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