Comparative study of fragmentation profiles of the compound nuclei formed in different mass regions

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Introduction

The low energy heavy-ion reactions forming compound nuclear systems provide a unique platform to study the several nuclear properties. A number of reactions have been studied for a better understanding of nuclear behavior within collective clusterization approach of the quantum-mechanical fragmentation theory (QMFT). Among these are the investigations of decay of very light mass ^{25}Mg* [1], light ^{65}Ge* [2], medium ^{133}Xe* [2], and heavy ^{203}Pb* [3] mass compound nuclei formed in low-energy heavy ion reactions at different excitation energies, where the role of the clustering effects have been studied within the dynamical cluster-decay model (DCM) [1–3], based on QMFT.

The main objective of present work is to have comparative study of the total fragmentation potentials (along with that of the constituent potentials i.e. nuclear proximity, Coulomb and centrifugal potentials plus binding energies) of the selected compound nuclei, within the QMFT. The compound nuclei which are explored here are ^{25}Mg*, ^{65}Ge*, ^{133}Xe*, and ^{203}Pb*. It is pointed here that all the nuclei studied here are formed at a fixed temperature 2 MeV. All the reactions forming these compound nuclei are chosen with specific center of mass energies $E_{c.m.}$, accordingly. We have explored that as the mass number increases from ^{25}Mg* to ^{203}Pb*, the binding energy is gradually prioritized in the favor of symmetric fragment.The role of the Coulomb potential on the symmetric fragment, which increases as the mass number of the compound nucleus increases, is again overwhelmed by the combined effects of proximity potential and the centrifugal/angular momentum dependent potential (especially at higher ℓ-values). Further discussions and results are described in the last section.

Methodology

The DCM is based on the collective coordinates of mass asymmetry $\eta_A = \frac{A_1-A_2}{A_1+A_2}$ and relative separation R of two fragments (i = 1, 2). In terms of these coordinates, we define the compound nucleus decay cross-section for ℓ partial waves as

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

where ℓ_c is the critical angular momentum, P_0 is the preformation probability, and P is the penetrability.

The values of P_0 depends on the fragmentation profile of the given compound nucleus and given by

$$V_R(\eta,T) = B_i + V_c + V_p + V_l \quad (2)$$

i.e. it is sum of binding energies of two nuclei (B_i), Coulomb potential (V_c), proximity potential (V_p), centrifugal potential (V_ℓ) all being temperature (T) dependent. Present study is carried out with spherical consideration of the nuclei.

Calculations and Discussions

The fragmentation profiles of the compound nuclei, under study, formed in the given mass regions, are presented in Fig. 1(a-d), respectively for very light ^{25}Mg*, light ^{65}Ge*, medium ^{133}Xe*, and heavy ^{203}Pb* mass nuclei. It is observed that light particles, LPs (A≤4) are dominant along with few intermediate mass fragments, IMFs at lower angular

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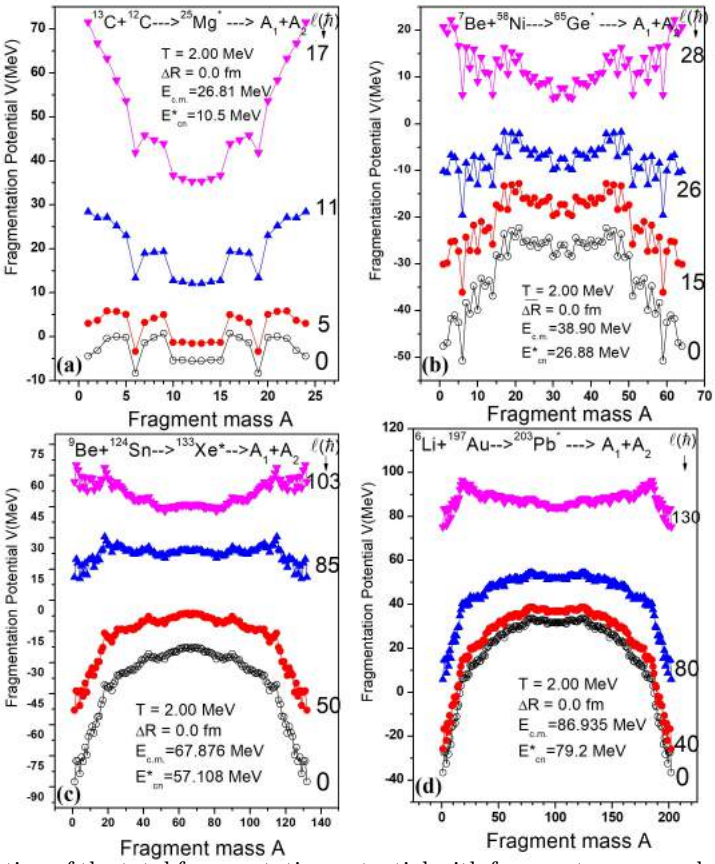

FIG. 1: The variation of the total fragmentation potential with fragment mass number(A) of compound nuclei (a) ^{25}Mg* (b) ^{65}Ge* (c)^{133}Xe* and (d) ^{203}Pb* at T= 2 MeV.

momentum (ℓ) values for all the compound nuclei. However, at higher ℓ-values IMFs strongly compete with symmetric fragments and near symmetric fragments, SFs. This fact is quite evident for very light mass CN ^{25}Mg* and light mass CN ^{65}Ge*. In both of these cases it is important to note that IMFs are quite dominant at lower as well as higher ℓ-values. However, for medium mass CN ^{133}Xe* we observe that SFs are quite dominant at higher angular momentum values. Whereas, for heavy mass CN ^{203}Pb* LPs dominate the potential energy surface (PES) at all the ℓ-values, with competition from SFs.

It is relevant to mention here that this scenario of competing fragments on the PES, within the QMFT, is the first step in the decay of compound nuclei. The total decay process is further affected by the second step of the penetration of the scattering potential barrier of the respective channel of the binary fragments. The role of Coulomb potential is against the symmetric fragments, which increases with the increase in mass number of the CN, is again overpowered by the combined effect of the proximity and angular momentum dependent (Centrifugal) potentials (particularly, at higher ℓ-values). This study has further scope to be extended for the effects of oriented nuclei and to the mass regions of exotic nuclei (having higher neutron to proton ratio or vice-versa), in the scenario of the world wide availability of the radioactive ion beams.

References

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