Isotopic effects on the potential energy surface of very light mass compound nuclei

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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. One of which is the investigation of decay analysis of the very light mass composite systems $^{20,21,22}Ne^*$, $^{28}Si^*$, $^{39}K^*$, $^{40}Ca^*$ formed in low-energy heavy ion reactions at different excitation energies [1], where the role of the clustering effects with considerations of quadrupole deformations and compact orientations of nuclei, have been studied within the collective clusterization approach of the dynamical cluster-decay model (DCM) [1, 2] based on quantum-mechanical fragmentation theory.

In the present investigation of the decay mechanism of very light mass compound nuclei, we have considered the different isotopes of light mass Ne compound nuclei (CN) with spherical consideration only. We intend to analyze the effects of the gradually increasing neutron number on the fragmentation potentials of $^{20,21,22}Ne^*$ CN, within DCM. A comparative analysis of light particles and fusion fission fragments in the decay of $^{20,21,22}Ne^*$ will be carried out for the reactions ^{10}B +$^{10,11}B$ and ^{11}B +^{11}B. We find that the potential energy surface (PES) of the Ne compound nuclei, under study, changes significantly with an addition of neutron. The temperature (T) addition further affects the PES, quite significantly. There is competition between Coulomb and nuclear proximity potentials, to give final values to the binary fragments in the total PES, which eventually decides their chance for the subsequent decay path. This competition is further supplemented by the contribution of angular momentum potential in the favor of nuclear proximity potential, at higher T values of the compound nuclei. Further discussions and results are described briefly in the last section.

Methodology:

The DCM is worked out in terms of collective coordinates of relative separation R, with multiple deformations $\beta_{\lambda i}$ and orientations θ_i of two fragments (λ = 2, 3, 4....; i = 1, 2) and mass (and charge) asymmetries $\eta_A = (A_1 - A_2)/(A_1 + A_2)$ [and $\eta_Z = (Z_1 - Z_2)/(Z_1 + Z_2)$] where A_1 and A_2 are the masses (and Z_1 and Z_2 are charges) of incoming nuclei. In terms of these coordinates, the compound nucleus (CN) decay cross-section for ℓ-partial waves, is defined as

$$\sigma = \frac{\pi}{k^2}\sum_{l=0}^{l_{max}}(2l+1)P_0\,P; \quad k = \sqrt{\frac{2\mu E_{C.M}}{\hbar^2}} \qquad (1)$$

where, P_0 is preformation probability obtained by solving the stationary Schrodinger equation (using the fragmentation potential), refers to η-motion and P, the barrier penetrability, calculated as the WKB tunneling probability, refers to R- motion both dependent on T and ℓ. The fragmentation potential is the sum of binding energies (B_i), Coulomb (V_c), proximity(V_p), centrifugal potential (V_ℓ), all being temperature (T) dependent, represented by

$$V(\eta,R) = -\sum_{i=1}^{2} B_i(A_i,Z_i) + V_c(R,Z_i) + V_p(R,A_i) + V_\ell(R,A_i) \qquad (2)$$

Calculations and Discussions:

To explore the isotopic effect on the potential energy surface of very light mass Ne compound nuclei (CN) with spherical consideration are studied. Figure 1, gives the comparative presentation of the total fragmentation potential (MeV) as a function of fragment mass (A) for $^{20,21,22}Ne^*$ at T = 0 MeV, 1.59 MeV and 4.50 MeV. As going horizontally, it is observed that when we increase the neutron number from $^{20}Ne^*$ to $^{22}Ne^*$, the fragmentation

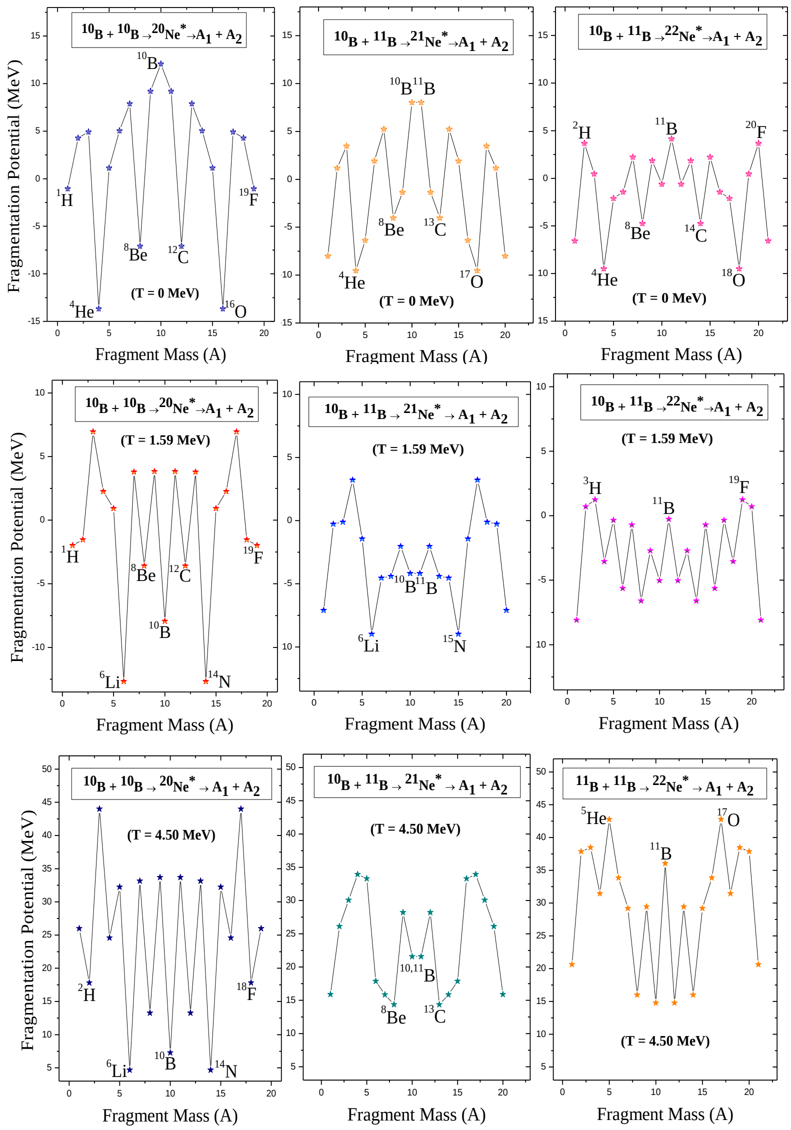

Fig. 1: Variation of the total fragmentation potential (MeV) with fragment mass (A) of $^{20,21,22}Ne^*$ at T=0 MeV, 1.59 MeV, 4.50 MeV, respectively.

Profile changes considerably. Moreover, vertically down, we see for the given CN the T addition also significantly affects the fragmentation profile. The symmetric fragments have maximum contribution in the decay of $^{20}Ne^*$, least for $^{22}Ne^*$ and in between for the $^{21}Ne^*$ CN. On increasing the neutron number there is the change in the magnitude of structures as well as the complementary fragments of most stable clusters become neutron rich. From these plots it is also evident that the alpha structure plays very dominant role. Work is in progress.

References

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