Effect of level density parameter on the decay of $^{25,24}Mg^*$ within collective clusterization mechanism

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Introduction

The decay for number of compound nuclei formed in low energy heavy ion reactions have been successfully studied using dynamical cluster decay model (DCM) [1–4]. In a previous study the decay of $^{25,24}Mg^*$ compound nuclei (CN) for the experimentally observed intermediate mass fragments (IMFs) $^{6,7}Li$ and $^{7,8,9}Be$ have been explored [4] within DCM. The role of the α-cluster structure of the complementary fragments was investigated, which results in the enhanced preformation probability (P_0) with respect to other fragments. These enhanced P_0 values accordingly affect the yields of the respective IMF.

In the present study, we have extended this work to study the effect of level density parameter(LDP) on the clustering aspects of compound systems $^{25,24}Mg^*$ formed via respective entrance channels $^{13}C + ^{12}C$ and $^{12}C + ^{12}C$ at $E^*\sim$ 53.9 MeV, within the collective clusterization approach of Quantum Mechanical Fragmentation Theory (QMFT). In the earlier work, LDP was taken a = A/9. However, in present study we have taken it a = A/8, which is said to be more appropriate in light mass region.

In DCM, the incident channel center-of-mass energy ($E_{c.m.}$) transferred into excitation energy E^*_{CN} of compound nuclei [5], which further depends on temperature (T) and the level density parameter (LDP). For $^{25,24}Mg^*$ CN under study, the excitation energy E^*_{CN} is kept same, therefore the variation in the value of LDP results in excitation of compound nucleus to different temperature. The preformation profiles with the inclusion of new LDP have been compared with the previous work at critical ℓ value and for both the spherical and deformed configurations. The investigations show that by including modified level density parameter preformation profile is modified with small changes. There is decrease in P_0 but the enhancement in Penetrability (P) accordingly affects the yields of the respective fragments.

Methodology

The dynamics of $^{25,24}Mg^*$ formed via $^{13,12}C + ^{12}C$ reactions is studied by using the DCM [1–4] of Gupta and collaborators. It is worked out in terms of collective coordinates of relative separation R, with deformations β_2 and orientations θ_i of two fragments (i = 1, 2) and mass asymmetry $\eta_A = (A_1\text{-}A_2)/(A_1+A_2)$ where A_1 and A_2 are the masses of outgoing nuclei. In terms of these coordinates, the compound nucleus (CN) decay cross-section for ℓ-partial waves, is defined as

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

where ℓ_c, the critical angular momentum, P is penetrability and is calculated using WKB approximation, P_0 is preformation probability and is given by solution of stationary Schrodinger equation

$$\{-\frac{\hbar^2}{2\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}+V_R(\eta,T)\}\psi^\nu(\eta) = E^\nu\psi^\nu(\eta) \quad (2)$$

The temperature T of the nucleus (in MeV) is related to the excitation energy E^*_{CN} of the compound nucleus, through a semi-empirical statistical relation as:

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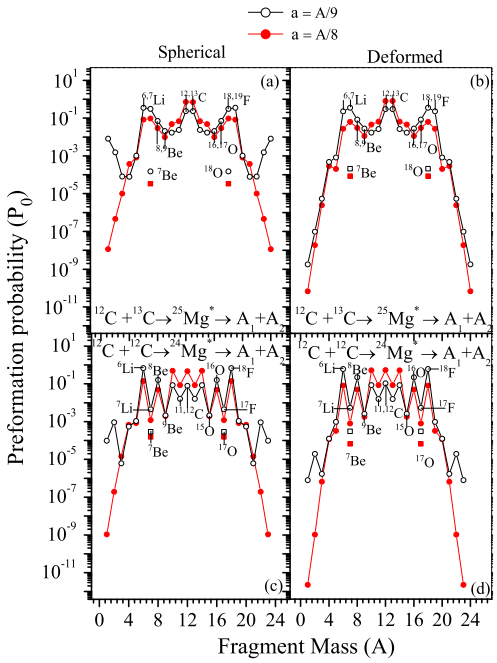

FIG. 1: The Preformation probability as a function of fragment mass A for (a and b) $^{25}Mg^*$ (c and d)$^{24}Mg^*$ with, respectively, Spherical and Deformed configuration at $E^*\sim$ 53.9 MeV at critical ℓ value with old and modified level density parameter.

$$E^*_{CN} = E_{c.m.} + Q_{in} = aT^2 - T \qquad (3)$$

where a is level density parameter(LDP), depending on the mass of the compound nucleus [5].

Calculations and Discussions

Fig. 1(a-d) presents preformation profile as a function of fragment mass A of the decaying nuclei $^{25}Mg^*$ and $^{24}Mg^*$ using spherical and deformed configurations with old and modified level density parameter (LDP). For the modified LDP value the T for both $^{25}Mg^*$ and $^{24}Mg^*$ CN reduced to T= 4.32 MeV and 4.41 MeV, respectively, from T = 4.592 MeV and 4.689 MeV. The modified LDP presented by filled Red Circle in comparison to previous DCM based [4] calculations presented by hollow Black Circle in Fig. 1.

From Fig. 1(a, c) it is clear that IMF ^{6}Li is more preformed in case of $^{24}Mg^*$ in comparison to ^{6}Li in the case of $^{25}Mg^*$ and becomes minutely less probable with modified LDP i.e. a = A/8. Because with modified value of LDP there is decrease in T of compound nucleus, as various parameters involved in DCM are temperature dependent, hence, preformation profile will significantly affected. The IMF ^{7}Li in case of $^{24}Mg^*$ has relatively less preformation probability (P_0) in comparison to ^{7}Li in case of $^{25}Mg^*$ it is more probable for $^{25}Mg^*$ due to presence and absence of clustering in the complementary fragment (C.F) ^{18}F. Among the isotopes of Be, ^{7}Be is more probable for $^{24}Mg^*$ than for $^{25}Mg^*$ decay but P_0 is less than ^{7}Li in both the CN. The IMF ^{8}Be in case of $^{24}Mg^*$ is more probable than ^{8}Be in $^{25}Mg^*$. Because in the exit channels ^{8}Be and ^{16}O both are well known α-cluster nucleus. Hence, they are more probable and becomes minutely less probable by changing LDP A/9 to A/8. The IMF ^{9}Be in case of $^{25}Mg^*$in compare to $^{24}Mg^*$ is more probable again due to presence of α-cluster nucleus in C.F. ^{16}O and P_0 is almost comparabe by changing LDP A/9 to A/8.These observations are also observed for the deformed configurations as shown in Fig. 1(b, d). From the Preformation profile of $^{25}Mg^*$ and $^{24}Mg^*$ it can be concluded that clustering effects of the IMFs and their C.F. affected minutely by changing LDP a = A/9 to a = A/8. Other related details are reported in [6], along with pairing energy effects in the reaction dynamics.

References

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