Effect of pairing coefficient in $^{12,13}C +^{12} C$ reactions within collective clusterization mechanism

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Introduction

The clustering effects on the reaction dynamics of compound systems $^{24,25}Mg^*$ formed via respective entrance channels $^{12}C+^{12}C$ and $^{13}C +^{12} C$ are studied within the collective clusterization approach using dynamical cluster decay model (DCM)[1–5]. 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 [3]. The role of the α-cluster structure of the complementary fragments (^{18}F and ^{16,18}O) was investigated, which enhanced the yields of the respective IMF as compared to fragments with absence of α-cluster.
To support the ^{14}C clustering in the resonant excited states of ^{18,20}O and ^{22}Ne nuclei M. Bansal *et al.* modified the temperature dependent pairing energy coefficient $\delta(T)$ in the liquid drop energy [4]. In this work, we will use the modified $\delta(T)$ obtained from these calculations. QMFT suggests a slower fall of pairing energy term with temperature than that used by Davidson *et al.* [6] in their T-dependent liquid drop model. Davidson gave the values of $\delta(T)$ upto $T = 2MeV$. In the present study of $^{24,25}Mg^*$ CN formed in $^{12,13}C +^{12} C$ reactions are at T = 4.689 MeV and T = 4.592 MeV, hence we will use this modified pairing energy coefficient $\delta(T) = 1.491$ MeV and $\delta(T) = 1.808$ MeV, respectively. The fragmentation profiles with the inclusion of modified $\delta(T)$ have been compared with the previous work [5] at critical ℓ value and for both the spherical and deformed configurations.

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Methodology

The dynamical cluster decay model DCM [1–5] of Gupta and collaborators is based on the collective coordinates of mass asymmetry $\eta_A = \frac{A_1-A_2}{A_1+A_2}$ and relative separation R, with deformations β_2 and orientations θ_i 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.

Calculations and Discussions

Fig. 1(a-d) presents the potential energy surface or fragmentation potential V (MeV) of the favored fragments, for the decay of nuclei $^{24}Mg^*$ and $^{25}Mg^*$ using spherical and deformed configurations with and without the inclusion of pairing energy coefficient δ. The modified δ presented by filled Red Circle in comparison to previous DCM based calculations (without the inclusion of δ) presented

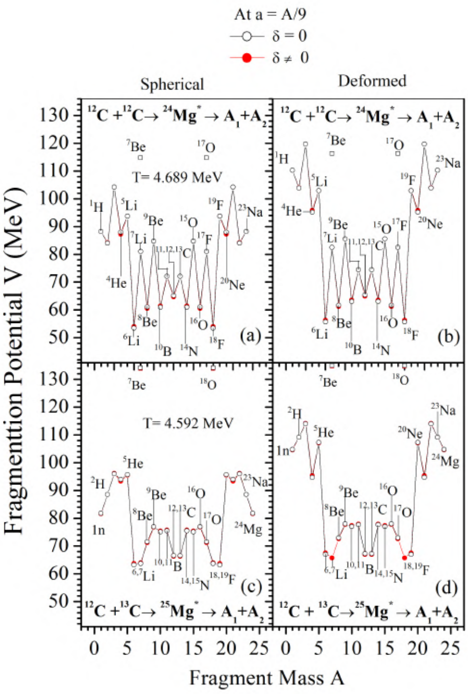

FIG. 1: The Preformation probability as a function of fragment mass A for (a and b) $^{24}Mg^*$ (c and d)$^{25}Mg^*$ with, respectively, Spherical and Deformed configuration at $E^*\sim$ 53.9 MeV at critical ℓ value with and without inclusion of pairing energy term.

by hollow circle in Fig. 1.

It is clear that by adding one neutron in $^{24}Mg^*$ light particles (LPs) becomes more minimized and by inclusion of deformations, again become less favored. Among the IMFs, ^{5}Li is one of the favored fragment in the decay of $^{24}Mg^*$, but by going to neutron rich $^{25}Mg^*$ CN IMF ^{5}He starts favoring with complementary fragment (C.F) ^{20}Ne which is N = Z α-conjugate nucleus. The IMF ^{6}Li is more minimized in case of $^{24}Mg^*$ in comparison to ^{6}Li in the case of $^{25}Mg^*$, while for ^{7}Li case it is more minimized in $^{25}Mg^*$ than in case of $^{24}Mg^*$. This may be due to the absence and presence of α-cluster in of C.F ^{17,18,19}F. The IMFs ^{6,7}Li in $^{25}Mg^*$ CN decay leads to ^{19,18}F as C.F (^{13}C + ^{12}Li $\rightarrow$ $^{25}Mg^*$ $\rightarrow$ ^{6,7}Li + ^{19,18}F), while for $^{24}Mg^*$ decay leads to ^{18,17}F as C.F (^{12}C + ^{12}Li $\rightarrow$ $^{24}Mg^*$ $\rightarrow$ ^{6,7}Li + ^{18,17}F). Among the isotopes of Be, ^{7}Be is more favored for $^{24}Mg^*$ than for $^{25}Mg^*$ decay, but less favored than ^{7}Li in both the CN. The IMF ^{8}Be in case of $^{25}Mg^*$ is less favored than ^{8}Be in $^{24}Mg^*$. The exit channels of $^{24}Mg^*$ i.e., ^{8}Be and ^{16}O both are well known α-cluster nucleus. Hence, they are more pronounced. Similarly, ^{16}O is corresponding C.F. of one of the outgoing fragment ^{9}Be in case of $^{25}Mg^*$ has relatively lesser fragmentation potential in contrast to ^{9}Be and ^{15}O in case of $^{24}Mg^*$ which may be again due to presence of α-cluster nucleus in ^{16}O. The IMF ^{10}B is more minimized in $^{24}Mg^*$ than in case of $^{25}Mg^*$ because the C.F ^{14}N in $^{24}Mg^*$ is α-cluster nucleus than the C.F ^{15}N in $^{25}Mg^*$. The IMF ^{11}C with C.F. ^{13}C is more favored in $^{24}Mg^*$ but on increasing neutron number by one the IMF ^{11}B starts favoring with α-clustered C.F ^{14}N which is neutron rich 2npα-conjugate nucleus. The ^{12}C in the decay of $^{25}Mg^*$ CN is more favored with C.F ^{13}C than ^{12}C in the decay of neutron deficient $^{24}Mg^*$ with C.F ^{12}C, because on going to $^{25}Mg^*$ there is decrease in temperature, which also increase the minimization in fragmentation potential by adding pairing energy term.

These observations are present for the cases of spherical and deformed configurations and with both values of δ (i.e. with and without inclusion of δ). With the inclusion of paring energy coefficient there is enhancement in the minimization of particular fragments for both the $^{24}Mg^*$ and $^{25}Mg^*$ CN. Other related details are reported in [5], along with level density parameter effects in the reaction dynamics.

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