Fragments emission from light mass composite nuclei within collective clusterization mechanism

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Introduction

Based on the quantum mechanical fragmentation theory (QMFT) the dynamical cluster decay model (DCM) has been developed by Gupta and Collaborators to study the decay of hot and rotating compound systems [1, 2]. Number of compound nuclei (CN) in different mass regions have been studied quite extensively while taking into consideration nuclear structure effects in the same. It is quite relevant to mention here that in the binary decay of CN nuclear structure effects comes into picture, within DCM, via preformation probability P_0 of the complimentary fragments before penetrating the potential barrier between them with certain probability P. It is interesting to note here that the statistical models treat various decay modes of the CN on different footing contrary to the DCM.

In last one decade the application of DCM has been extended to very light mass to super heavy compound systems quite successfully. In very light mass region the decay of number of composite systems ^{20,21,22}Ne*, $^{26-29}$Al*, ^{28}Si*, ^{31}P*, ^{32}S*, ^{39}K* and ^{40}Ca*, formed in low energy heavy ion reactions, have been investigated for different reaction mechanisms particularly fusion-fission (FF) and deep inelastic orbiting (DIO) from equilibrated and non-equilibrated compound nucleus processes, respectively [2]. It is important to note here that different fragments emission from CN like light particles, LP, intermediate mass fragments, IMF and symmetric fragments, SF within collective clusterization process show peculiar behavior despite equal treatment within DCM. In some cases we have observed competition between FF and DIO contributions (^{20,21,22}Ne*, ^{28}Si*, ^{32}S*, ^{39}K* and ^{40}Ca*), and also evaluated the same, while in other cases ($^{26-29}$Al* and ^{31}P*) FF have the only contribution in the decay of IMF. It makes an interesting case to study few more composite nuclei in this mass region to develop a systematics. Moreover, in a recent study based on QMFT the nuclear cluster structure has shown to play significant role in the binary decay process of these compound systems [2]. We intend to extend this study for other composite nuclei in this mass region.

In recent years, fragments emission from composite nuclei ^{24,25}Mg* formed in the reactions ^{12,13}C+^{12}C at $E_{lab}\sim$ 6 MeV/nucleon have been studied experimentally [3]. The study has investigated the fragments ($3\leq Z\leq 5$) emission from the completely equilibrated and long lived composite nuclei with the observation that more neutron rich fragments are emitted from ^{13}C+^{12}C in comparison to ^{12}C+^{12}C reaction. Here within DCM, we are interested in a dynamical description of the mechanism based on collective clusterization approach.

Methodology

The collective clusterization mechanism of DCM is different from another statistical models as it treats the LP or evaporation residues, IMF and SF on equal footing [1, 2]. The missing nuclear structure information of compound nucleus in statistical model enters in DCM via preformation probability P_0 of the fragments and is calculated by solving Schrödinger equation in η co-ordinate. Within DCM, the decay of hot and rotating compound nucleus into different fragment emissions are worked out in terms of collective coordinates of mass asymmetry $\eta = (A_T-A_P)/(A_T+A_P)$ and relative separation R. In terms of these collective coordinates, using the ℓ- partial waves, the decay cross-section is de-

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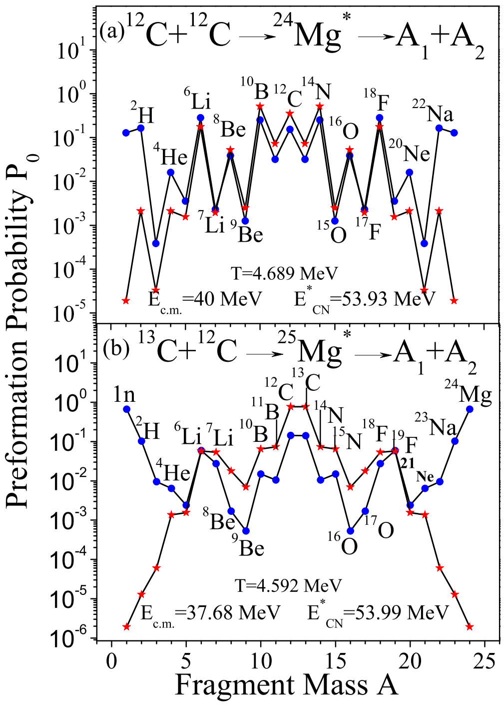

FIG. 1: The P_0 of fragments emission from a) ^{24}Mg* and b) ^{25}Mg* composite nuclei.

fined as

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

Where, $\mu = [A_1A_2/(A_1+A_2)]m$, is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum, fixed for vanishing the fusion barrier of incoming channel η_i or LP cross-section $\sigma_{LP}\to 0$. The penetrability P is calculated as the WKB tunneling probability.

Calculations and discussions

Fig. 1 presents the preformation profile of different fragments in the decay of a) ^{24}Mg* and b) ^{25}Mg* composite nuclei, formed in the reactions ^{12}C+^{12}C and ^{13}C+^{12}C, respectively, at $E_{lab}\sim 80$ MeV, with the spherical consideration of nuclei. The profile is presented for two different values of angular momentum $\ell = 0\hbar$ (solid blue circle) and $\ell_{max} = 16\hbar$ (solid red star). We see that with increase in ℓ-values IMF emission get dominated over the LP emission for both the cases. In the decay of ^{24}Mg* compound system IMF ^{6}Li, ^{8}Be, ^{10}B are highly preformed in comparison to the neighbouring ones. However, in line with the experimental observation, we see here that the neutron rich IMF ^{7}Li, ^{9}Be, ^{11}B are in strong competition, specifically, at large ℓ-values in ^{13}C+^{12}C reaction for the decay of ^{25}Mg* [3]. Quite evidently, an enhancement in the observed experimental yield of ^{9}Be is due to the probable binary splitting channel ^{9}Be+^{16}O in the decay of ^{25}Mg*, in comparison to ^{24}Mg* having binary decay channel ^{9}Be+^{15}O.

The preliminary results are highly motivating to have comparative study of penetrability of these IMF emissions and further calculations of IMF cross sections σ_{IMF} within the formalism of DCM. Moreover, it is pointed in the experimental study that the IMF are emitted from both FF and orbiting processes, though, their relative contribution in the σ_{IMF} have not been evaluated. The work, on these lines, is in progress within collective clusterization approach of DCM.

Acknowledgement

The support by the Department of Science and Technology (DST), New Delhi, in the form of a Young Scientists award under the SERC Fast Track Scheme, vide letter No. SR/FTP/PS-013/2011 is acknowledged.

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