Fusion-fission and deep inelastic orbiting in the target-like yields from ^{32}S* formed in ^{20}Ne+^{12}C reaction at different excitation energies

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Introduction

In our recent work [1], the target like yields σ_C in the decay of compound systems ^{32}S* and ^{31}P* formed in ^{20}Ne+^{12}C and ^{19}F+^{12}C reactions, respectively, was studied, at an excitation energy E^*_{CN}=60 MeV, for the contribution of fusion-fission (ff) decay cross-sections σ_{ff} from the compound nucleus(CN) process and deep inelastic orbiting (DIO) cross-sections σ_{orb} from non compound nucleus (nCN) process. The calculations were performed using collective clusterization of fragments within the dynamical cluster decay model (DCM) of Gupta and Collaborators [1, 2]. In case of ^{31}P* system, we find the only contribution of CN process in σ_C, whereas the same in case of ^{32}S* system have competition between σ_{ff} and σ_{orb} [1]. It is relevant to mention here that the experimental data for the above systems is available [3], and explained on the basis of the number of open channels (NOC) model [4] in which (Table I of [3]) the authors have marked that NOC for the reaction ^{20}Ne+^{12}C are very small in comparison to another reaction ^{19}F+^{12}C (forming ^{31}P*) resulting into a measured σ_C of ^{32}S* more than double in the decay of ^{31}P*, at E^*_{CN}=60 MeV for both the compound systems.

The decay of CN depend on its excitation energy alongwith shape and orientations of the emerging fragments. The shape and orientation of the nuclei influence the interaction potential i.e. the barrier height and barrier position. Keeping this in mind, the comparative analysis of σ_C of ^{32}S* for the considerations of spherical and oriented nuclei was carried out at an excitation energy E^*_{CN}=60 MeV [1], which came up with similar result with the only difference in the values of neck length parameter (ΔR), more for the later case. The calculated cross-sections σ_C showed good agreement with experimental data for both the considerations. Here, we have extended this study to investigate the competition between ff and DIO processes in the reaction dynamics of hot and rotating compound system ^{32}S* formed in the reaction ^{20}Ne+^{12}C, at different excitation energies, using the concept of collective clusterization within the DCM. A strong motivation behind this work is that, though NOC model marked large $\sigma_C^{Expt.}$ in the decay of ^{32}S* or small NOC for ^{20}Ne+^{12}C reaction indicating equivalently possibility of nCN contribution in it, but it does not work out the amount of contributions of σ_{ff} and σ_{orb} separately in the total σ_C and the dynamics behind it, at different centre of mass energies, $E_{c.m.}$. We intend to address this question in the present work.

Dynamical cluster decay model

The decay of hot and rotating compound nucleus is studied within framework of dynamical cluster decay model (DCM), which is worked out in terms of collective coordinates of mass asymmetry $\eta = (A_T - A_P)/(A_T + A_P)$ and relative separation (R) with effects of temperature, deformation and orientation duely incorporated in it. In terms of these collective coordinates, using the ℓ- partial waves, the decay cross-section is defined as

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

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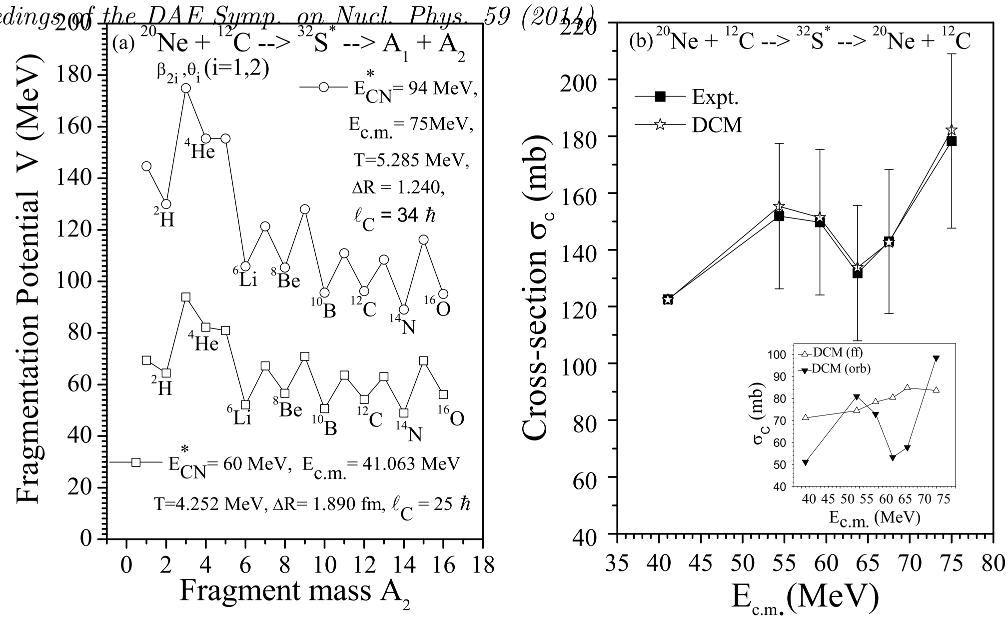

FIG. 1: (a) Fragmentation potential V (MeV) as function of fragment mass A_2 for the decay of ^{32}S* at two extreme energies with corresponding $\ell_c(\hbar)$ values. (b) The comparison of the DCM calculated total σ_C ($= \sigma_{ff} + \sigma_{orb}$) with the experimental data at different $E_{c.m.}$ for the decay of ^{32}S*. Inset of (b) shows the competition between σ_{ff} and σ_{orb} at different $E_{c.m.}$.

where preformation probability P_0 refers to η motion and is given by solution of stationary Schrodinger eq. in η, penetrability P refers to R motion and is calculated using WKB approximation, μ is the reduced mass and ℓ_c, the critical angular momentum.

Calculations and disscusions

The calculations for target like yield σ_C in the decay of ^{32}S* at different excitation energies, using quadrupole deformations and compact orientations are presented in this section. Fig. 1(a) shows a comparison of fragmentation potential V (MeV) as function of fragment mass A_2 for the decay of ^{32}S* at two extreme energies $E^*_{CN} = 60$ MeV and $E^*_{CN} = 94$ MeV with $\ell_c = 25\ \hbar$ and $\ell_c = 34\ \hbar$, respectively. Here we see that C-yield with A = 12 is minimized with strong competition from other fragments like ^6Li, ^8Be, ^{10}B, ^{14}N and ^{16}O, specifically at $E^*_{CN} = 60$ MeV. Whereas at higher $E^*_{CN} = 94$ MeV C-yield comparitively have stronger competition from ^{10}B, ^{14}N and ^{16}O. It may be noted here that, A = 11,13 are also minimized for Z = 6 at all the energies alongwith A = 12. So we add contributions of $^{11,12,13}C$ for σ_{ff} in the σ_C from ^{32}S*. The contribution of σ_{orb} is calculated by considering the P_0= 1 for the incoming channel i.e. incoming nuclei are considered not to lose their identity. Fig. 1(b) shows that σ_C^{DCM} is in good agreement with the experimental data $\sigma_C^{Expt.}$. We also find that σ_{ff} increases with $E_{c.m.}$ (inset Fig. 1(b)) and becomes constant at higher energies. Moreover, study also reveals that σ_{ff} component is higher in magnitude at all energies except at $E_{c.m.} = 54.38 MeV$ and $E_{c.m.} = 75 MeV$, where the σ_{orb} component shows prominence.

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