Competing mechanisms in the decay of α and non-α composite systems at different excitation energies

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Introduction

The investigation of fission process helps to explore the nuclear dynamics and structure of nuclei, created at higher excitation energy and spin. The heavy ion reactions have been primarily focused to study fission in heavy mass region, where symmetric fission is predominant. In case of lighter nuclei, Coulomb and centrifugal forces do not considerably surpass the attractive nuclear force, therefore fusion of colliding nuclei becomes probable channel and fission occurs subsequently . Several studies showed that asymmetric fission is favored in light nuclear systems, due to the dependence of macroscopic potential energy surface on shape asymmetry and nuclear deformation [1]. Another feature of light-nuclei fission is the significance of spin in determining the occurrence of fission. The fission competes with light particles emission only at higher ℓ-values, whereas such a possibility decreases at low spin values due to rapid increase in fission barrier for more symmetric outgoing channels.

In order to obtain information about the underlying reaction mechanism in lighter nuclei, angular and mass distributions are measured experimentally, which are sensitive probes of equilibrium achieved in the reaction. The compound nucleus (CN) fission has the $1/Sin\theta_{c.m.}$ dependent angular distribution, whereas the enhanced back angles yields show the near entrance channel presence of deep inelastic orbiting (DIO) [2] process. These observations show that yields are resulting either from CN fusion-fission (FF) or DIO process (having memory of entrance channel). In the present work, the presence of such competing mechanisms in the emission of different complex/ intermediate mass fragments at different temperatures have been discussed for different light mass composite systems $^{20,21,22}Ne^*$, $^{28}Si^*$, formed in $^{10,11}B$+$^{10,11}B$, ^{16}O+^{12}C reactions, respectively, within the dynamical cluster-decay model (DCM) formalism [3, 4].

Methodology

The decay of hot and rotating compound nucleus is studied within the DCM [3, 4], worked out in terms of collective coordinates of mass asymmetry η = (A$_T$-A$_P$)/(A$_T$+A$_P$) and relative separation R with effects of temperature, deformation and orientation duly incorporated in it. In terms of these collective coordinates, using the ℓ- partial waves, the decay cross-section is defined as

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

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

Calculations and discussions

Fig. 1 shows the excitation function for different Z-fragments in the decay of α-conjugate composite systems $^{20}Ne^*$ (Fig. 1(a,b,c)) and $^{28}Si^*$ (Fig. 1 (d,e,f)), in reference to available experimental data [5]. By adjusting the neck length parameter (only parameter of DCM) within proximity range $\sim 2fm$ (given in Table I of [3]), the FF cross-sections σ_{FF} have

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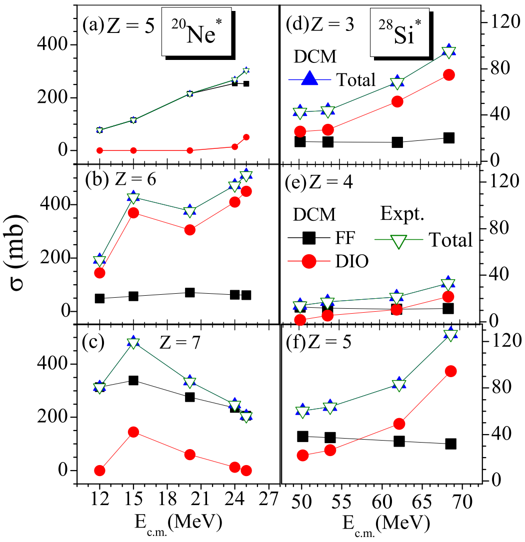

FIG. 1: Excitation function for different Z fragments in the decay of α-conjugate composite systems (a,b,c)$^{20}Ne^*$ and (d,e,f)$^{28}Si^*$.

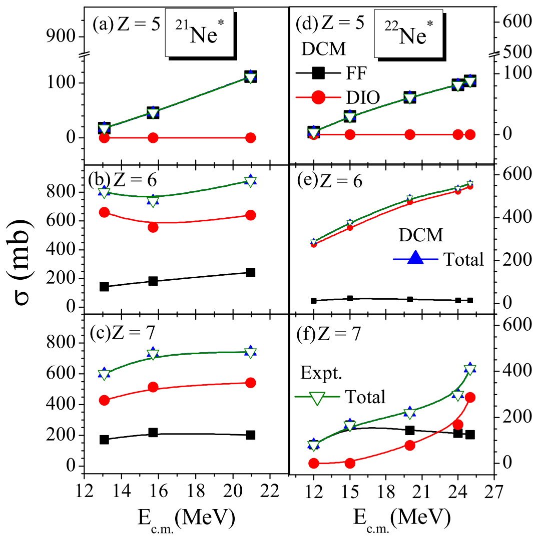

FIG. 2: Same as for Fig. 1, but for non-α systems (a,b,c)$^{21}Ne^*$ and (d,e,f)$^{22}Ne^*$.

been calculated. On the other hand, the DIO cross-section σ_{DIO} estimated empirically.

The experimental data for $^{20}Ne^*$ shows that yield is more for Z=6,7 (or complimentary Z=4,3) fragments than for Z=5, i.e. asymmetric fragmentation is more plausible. The results for $^{20}Ne^*$ in case of Z=5 shows that DIO comes into picture only at highest energy, which may be attributed to that within DCM, P_0 for Z=5 fragment is large (see Fig.6(a) of [3]). For Z = 7, FF is more than DIO, again due to higher P_0, whereas for Z=6 fragments, σ_{DIO} is relatively high compared to σ_{FF}, for which the value of P_0 is less than that of both Z=5 and 6. In case of $^{28}Si^*$, the DIO is more than FF for all Z=3,4,5 and the contribution of σ_{DIO} increases with $E_{c.m.}$, may be due to comparatively small P_0 for these fragments (see Fig.6(b) of [3]). Here, the $\%age$ contribution of DIO is highest near to entrance channel, i.e. Z=5, in agreement with experiments.

Fig. 2 is similar to Fig. 1, except that it is for non-α-conjugate composite systems $^{21}Ne^*$ (Fig. 2(a,b,c)) and $^{22}Ne^*$ (Fig. 2(d,e,f)). For both $^{21}Ne^*$ and $^{22}Ne^*$, Z=5 fragment emissions comes from FF process only (Fig. 2(a,d)), whereas for Z=6,7 fragments, the DIO contribution is significant, which rises with temperature. Similar results come into picture from Fig.7(a,b) of Ref.[3], discussed above for the α composite systems. Furthermore, it will be interesting to explore the higher DIO content in C-yields of the nuclear systems studied here.

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