Competing reaction mechanisms in the decay of $^{20}Ne^*$ for Z=5,6,7 fragments at different excitation energies

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Introduction

The light mass composite nuclei formed in heavy ion reactions at low energy (E/A∼10 MeV) have been studied extensively, both experimentally and theoretically [1–4]. Composite nuclei (CN) $^{20,21,22}Ne^*$, ^{28}Al*, ^{31}P*, ^{32}S*, ^{47}V*, ^{48}Cr* and ^{56}Ni* in the lighter as well as light mass region have been studied successfully within collective clusterization approach of dynamical cluster decay model (DCM) of Gupta and collaborators [3, 4]. It has been observed that in case of ^{28}Al*, ^{31}P*, ^{47}V*, ^{48}Cr*, ^{56}Ni*, the fusion fission (ff) of equilibrated compound nucleus is the only decay mode while in case of light composite nuclei ^{32}S* formed in ^{20}Ne+ ^{12}C, the study of target like "carbon-yield" shows that the process of ff and deep inelastic orbiting (DIO) are in competition in the decay path. Similar observation has been made for very light CN $^{21,22}Ne^*$.

We analyzed the decay dynamics of very light mass CN $^{20,21,22}Ne^*$ formed in ^{10,11}B+ ^{10,11}B reactions at E_{lab}=48 MeV for the binary symmetric decay first with spherical and then with the consideration of quadrupole deformations and orientations of the interacting nuclei [4], since shape (deformations) and orientations of decaying nuclei are known to affect the barrier height and position [5]. Our study shows the presence of competition between ff and DIO processes specifically for CN $^{21,22}Ne^*$. In the present work we extend our study for the decay of $^{20}Ne^*$ and look for the decay mechanisms for other fragments Z=6,7 in comparison with the binary decay of Z=5 at different excitation energies with consideration of oriented nuclei for the outgoing fragments and their comparison with the available experimental data [1].

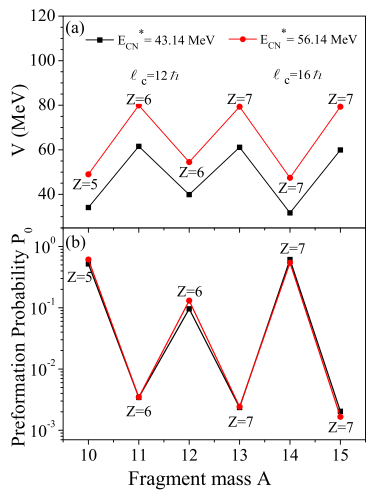

FIG. 1: (Color online) (a) Variation of fragmentation potential V(MeV) and (b) preformation probability P_0 with fragment mass A for the decay of ^{20}Ne* at respective ℓ_c values for E^*_{CN}=43.14, 56.14 MeV.

Methodology

The DCM [3, 4] is based on quantum mechanical fragmentation theory and is worked out in terms of collective coordinates of mass asymmetry $\eta = (A_T\text{-}A_P)/(A_T\text{+}A_P)$ and relative separation (R) with effects of deformations and orientations duely incorporated in it. In terms of these collective coordinates, using the ℓ- partial waves, the decay cross-section is defined as

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

where ℓ_c, the critical angular momentum, penetrability P refers to R motion (calculated using WKB approximation), preforma-

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TABLE I: The DCM calculated ff cross-sections σ_{ff} for the fragments Z=5,6,7 in the decay of ^{20}Ne* summed up to ℓ_c value and the value of σ_{DIO} has been estimated empirically.

E_{lab} (MeV)	$E_{c.m.}$ (MeV)	E^*_{CN} (MeV)	T (MeV)	l_c ($\hbar$)	Z	A	ΔR_{ff} (fm)	σ^{DCM}_{ff} (mb)	$\sigma^{Expt.}$ (mb)	σ^{emp}_{orb} (mb)
24	12	43.14	4.63	12	5	10	2.177	77.29	77.37	—
					6	11,12	2.2	26.77	192.90	166.13
					7	13,14,15	2.2	281.63	313.25	31.62
30	15	46.14	4.78	13	5	10	2.19	114.29	115.01	—
					6	11,12	2.2	35.45	427.10	391.65
					7	13,14,15	2.12	330.92	482.41	151.49
40	20	51.14	5.02	15	5	10	2.18	213.47	214.33	—
					6	11,12	2.18	62.35	376.40	314.05
					7	13,14,15	1.97	271.63	334.83	63.2
48	24	55.14	5.21	16	5	10	2.197	268.99	268.70	—
					6	11,12	2.095	60.59	472.06	411.47
					7	13,14,15	1.88	234.19	247.33	13.14
50	24	56.14	5.25	16	5	10	2.2	249.52	303.0	53.48
					6	11,12	2.1	57.36	510.75	453.39
					7	13,14,15	1.863	205.43	205.33	—

tion probability P_0 refers to η motion (given by sol. of stationary Schrödinger eq. in η).

Calculations and Discussions

The Fig. 1 shows the calculated (a) mass fragmentation potential and (b) the corresponding P_0 for Z=5,6,7 in the decay of ^{20}Ne* at the respective ℓ_c values for two extreme energies E^*_{CN}=43.14 MeV and 56.14 MeV. We observe that for given Z, the fragments with N=Z are more favored energetically in comparison to neighboring fragments and hence preform strongly, comparatively. Also, we note that with increase in energy, the structure of potential energy surface does not vary much and P_0 is only sightly affected with increase in the excitation energy.

Table I shows the calculated ff cross-sections for Z=5,6,7 fragments by the best fit of neck length parameter (ΔR), the only parameter of DCM and the contribution of DIO have been evaluated empirically. For Z=5 fragment, the ff is the only decay mode at different excitation energies except E_{lab}=50 MeV, at which DIO starts competing with ff and for Z=6,7 there is competition between ff and DIO. We note that for Z=6, the DIO dominates the ff in comparison to the case of Z=7. The calculated cross-sections are compared with the experimental data [1]. Further, it will be highly interesting to investigate the competition between ff and DIO processes in the decay of CN $^{21,22}Ne^*$ into the fragments having Z=5,6,7, at different excitation energies.

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