Fusion-fission of compound nucleus $^{28}Al^*$ formed in $^{18,17}O+^{10,11}B$ reactions using dynamical cluster decay model

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Introduction

Several experiments have been made in recent years to understand the dynamics of compound nucleus (CN) formed in low-energy (E_{lab} < 10 MeV/nucleon) light and very light heavy-ion ($A_{projectile}+A_{target}$ ~ 30-60) reactions. For these light compound nuclei, the viability of fusion-fission (FF) process and the related reaction dynamics has been established [1], contrary to the expectations based on the predictions of the rotating liquid drop model (RLDM) [2] which advocates strong inhibition of FF as compared to the deep inelastic scattering process in these systems. In the FF mechanism, a completely equilibrated CN is formed, which decays into various exit channels, the decay probability for which is governed by the available phase space and barrier penetration probabilities for the respective decay channels. In an experimental study, a very light mass CN $^{28}Al^*$, produced in $^{18,17}O+^{10,11}B$ and $^{19}F+^{9}Be$ reactions at various center-of-mass energies $E_{c.m.}$, is observed to have fully energy damped binary decay process [3], supported by the statistical model calculations based on the transition-state model (TSM).

In the present contribution, the very light CN $^{28}Al^*$ is studied by using the dynamical cluster-decay model (DCM) of Gupta and collaborators [4], which has been applied successfully to the decay of light, medium, heavy and super-heavy mass compound nuclei. First, we have studied this CN formed in $^{18}O+^{10}B$ reaction at $E_{c.m.}$=17.42 MeV [5], with the individual fitting of the neck-length parameter ΔR (the only parameter of the DCM) for the fragments Z=3-6 (for which experimental data is available). We have then extended this work for the simultaneous fitting of the data for all the fragments and at different $E_{c.m}$ along with the decay of $^{28}Al^*$ formed in another reaction $^{17}O+^{11}B$ at different $E_{c.m}$. Interestingly, we find that the choice of the individual or the simultaneous fitting of the ΔR for different fragments does not affect the result too much.

Methodology

Based on the fragmentation potential at fixed relative separation R and temperature T, and the scattering potential at fixed $\eta = (A_1-A_2)/(A_1+A_2)$ and T, we calculate the CN decay cross-section by using the DCM, worked out in terms of the decoupled collective coordinates of mass (and charge) asymmetry η [$\eta_Z = (Z_1-Z_2)/(Z_1+Z_2)$] and R. In terms of these coordinates, using l partial waves, the CN decay cross-section is defined as

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

where the preformation probability P_0, referring to η motion, is the solution of stationary Schrödinger equation in η coordinate at a fixed R, and P, the WKB penetrability, refers to R motion. Both the quantities, i.e., P_0 and P carry the effects of T and angular momentum l of colliding nuclei at a given $E_{c.m.}$. Here, $\mu = [A_1A_2/(A_1+A_2)]m$, is the reduced mass, with m as the nucleon mass.

Calculations and Discussions

Figures 1(a) and 1(b) depict the fragmentation potentials of $^{28}Al^*$ into various fragments (light particles LPs: n, p and α-particle, and the intermediate mass fragments IMFs) at T = 3.970 MeV and T=3.928 MeV (or $E_{c.m.}$= 17.422 MeV and $E_{c.m.}$= 19.959 MeV) at two extreme l-values, respectively, for two reactions $^{18}O+^{10}B$ and ^{17}O

$+^{11}B$. In comparison, we see that the structure of the potential energy surfaces (PES) do not change significantly for both the reactions and also in going from $l = 0\ \hbar$ to $24\ \hbar$ (the l_{max}-value) for each reaction. Also, the fragmentation behavior of $^{28}Al^*$ is independent of simultaneous

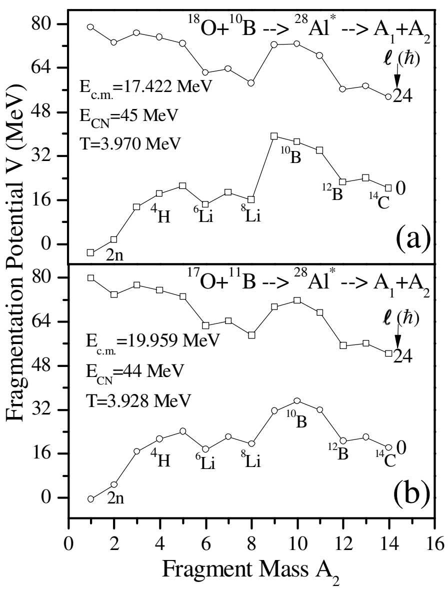

Fig. 1 Fragmentation potentials calculated for the decay of $^{28}Al^*$ formed in $^{18,17}O+^{10,11}B$ reactions at T= 3.970 MeV and T= 3.928 MeV, respectively, for the simultaneous fitting of the fragments.

or individual [5] choice of neck-length parameter. Table 1 shows that the results for the individual and the simultaneous mode of fitting ΔR are equally good for the different fragments in the decay of $^{28}Al^*$ formed in $^{18}O+^{10}B$ reaction at E_{CN} = 45 MeV. It is important to note that the

Table 1: The neck-length parameter ΔR (fm) for the individual as well the simultaneous fitting and the corresponding σ_{FF} (mb) for the different fragments in the decay of $^{28}Al^*$ formed in $^{18}O+^{10}B$ reaction at E_{CN}= 45 MeV.

Fragment Charge Z	Neck-Length Parameter ΔR (fm)		Fusion-fission cross section σ_{FF} (mb)		
	Individual	Simultaneous	Individual	Simultaneous	Expt.
3	0.832	0.740	18.30	18.10	18.30
4	1.420	1.600	5.90	5.661	5.95
5	1.124	1.136	13.60	13.56	13.60
6	1.134	1.148	35.90	35.76	35.70

values of ΔR for both the choices are showing a similar behaviour. In figures 2 (a) and (b) we have plotted the fusion-fission cross section of fragment Z=6 in the decay of $^{28}Al^*$ formed in $^{18,17}O+^{10,11}B$ reactions as a function of CN excitation energy E_{CN}. The results compare very

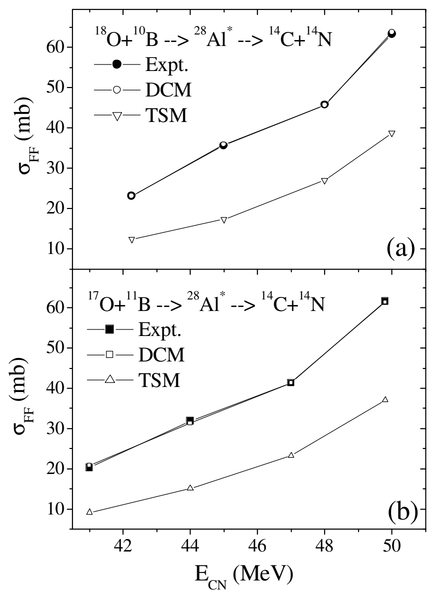

Fig. 2 Calculated σ_{FF} for Z=6 fragment for the decay of $^{28}Al^*$ formed in $^{18,17}O+^{10,11}B$ reactions as a function of E_{CN}, respectively, compared with the TSM calculations and experimental data.

well with the experimental data as well as with the TSM calculations for both the reactions. The calculations are done using the simultaneous mode of fitting. Further study is under progress.

References

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