Correlation among neck length parameter and entrance channel mass asymmetry

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Introduction

Recently, it has been observed that within the dynamical cluster decay model (DCM), the value of empirically fitted ΔR^{emp} can be fixed uniquely for a particular set of reactions induced by the same projectile (loosely bound or stable) at the same incident energy E_{lab} (in MeV) [1]. Interestingly, for a given projectile at a fixed E_{lab} on different targets, we are able to calculate/ predict the total fusion cross section (σ_{fus}) for numerous reactions under study. This work has been provided an excellent platform to analyze those reactions which are yet to get experimental consideration due to limited availability of incident beam. The DCM has been applied to explore the nuclear reaction dynamics of the CN $^{60}Zn^*$, $^{60}Ni^*$ and $^{60}Fe^*$ formed in the reactions ^4He+^{56}Ni, ^4He+^{56}Fe and ^4He+^{56}Cr respectively, which have not been explored experimentally so for due to the non-availability of the stable targets [2]. It is to be noted here that entrance channel mass asymmetry ($\eta_{in} = 0.8$) is same for all the ^4He induced reactions. It further helps to reduce the degree of freedom for fixing the value of ΔR_{emp}.

In one of our recent work, particular choice of entrance channel mass asymmetry has been taken to fix the value of neck length (ΔR), for different compound nuclei (CN) formed through different reactions at fixed value of incident energy per nucleon (E/A). In that work, we had studied the decay of CN $^{75}Br^*$ and $^{79}Rb^*$ formed in the reactions ^{16}O+^{59}Co and ^{20}Ne+^{59}Co, respectively having $\eta_{in}\sim 0.5$ for each case at the same E/A$\sim$ 3.1 MeV [3]. We calculated the fusion cross section σ_{fus} for both the reactions at same value of ΔR and the results were nicely compared with the experimental data. It indicates that the size of the neck formed between two colliding nuclei leading to the formation of the compound nucleus depends on the η_{in}.

The motivation behind the present work is to establish the role of η_{in} on the ΔR-value. We have chosen the reactions ^{27}Al+^{73}Ge, ^{27}Al+^{74}Ge, ^{27}Al+^{76}Ge and ^{28}Si+^{94}Zr having η_{in} = 0.46, 0.46, 0.48 and 0.54, respectively, to study its effect on ΔR through $B_{\eta\eta}$. We have calculated the σ_{fus} of all the reactions by fixing the value of ΔR^{emp}-value.

Methodology

The DCM [1–4], worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for ℓ-partial waves, gives the compound nucleus decay cross-section as

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

P is penetrability of interaction barrier (of the preformed clusters with preformation probability P_0). The P_0 is obtained by solving the stationary Schrödinger equation in η/ $B_{\eta\eta}$, at a fixed $R_a = R_1(\alpha_1,T)+R_2(\alpha_2,T)+\Delta R(T)$, ΔR is the only free parameter of DCM. The $B_{\eta\eta}$ represents the smooth hydrodynamical masses, is defined as

$$B_{\eta\eta} = \frac{AmR^2}{4}\left[\frac{v_t(1+\gamma)}{v_c}\right], \tag{2}$$

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TABLE I: The DCM calculated σ_{fus} for different reactions at $E_{lab}/A \sim 3.1$ MeV and their comparison with the experimental data.

Reaction	η_{in}	$E_{c.m.}$ (MeV)	E^*_{CN} (MeV)	T (MeV)	ℓ_{max} ($\hbar$)	ΔR	$\sigma_{fus.}$ (mb) DCM	Expt.
^{27}Al+^{73}Ge$\rightarrow$^{100}Rh*	0.46	61.10	58.19	2.334	71	1.608	308.55	309.0±22
^{27}Al+^{74}Ge$\rightarrow$^{101}Rh*	0.46	61.32	58.12	2.321	71	1.608	291.00	292.3±34
^{27}Al+^{76}Ge$\rightarrow$^{103}Rh*	0.48	61.75	59.37	2.322	71	1.577	363.43	364.0±11
^{28}Si+^{94}Zr$\rightarrow$^{122}Xe*	0.54	66.60	43.19	1.822	72	1.180	2.140	2.160±0.31

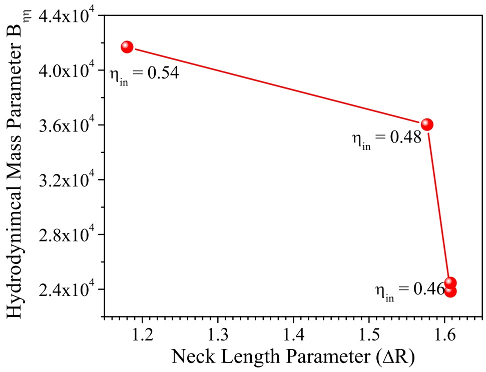

FIG. 1: The variation of $B_{\eta\eta}$ with ΔR for the decay of CN $^{100}Rh^*$, $^{101}Rh^*$, $^{103}Rh^*$ and $^{122}Xe^*$ formed in the reactions having η_{in} = 0.46, 0.46, 0.48 and 0.54, respectively.

with, v_c=πR_c^2R, v_t=v_1+v_2 is the total conserved volume and

$$\gamma = \frac{R_c}{2R}\left[(2 - \frac{R_c}{R_1} - \frac{R_c}{R_2}\right], \qquad (3)$$

$$R_c = 0.4 \times R_2 \qquad (4)$$

is the radius for the homogeneous mass flow among the decaying fragments.

Calculations and Discussions

Within DCM, it is shown explicitely that there is a relation between the ΔR and R_c [5]. The R_c gives $B_{\eta\eta}$, which has a significant effect on the σ_{fus} through P_0. Fig.1 shows the variation of $B_{\eta\eta}$ with ΔR at different values of η_{in}. Quite evidently, the value of $B_{\eta\eta}$ depends upon η_{in}. As η_{in} increases the value of $B_{\eta\eta}$ starts rising. But the converse is true for the variation of $B_{\eta\eta}$ with ΔR i.e. the value of $B_{\eta\eta}$ decreases with increase in the value of ΔR. It shows that the larger value of R_c through $B_{\eta\eta}$, requires a smaller value of ΔR or vice-versa. A larger value of R_c means, the radius of cylinder will be larger and flow of the nucleons requires a smaller neck i.e. smaller ΔR. If R_c is smaller, the mass flow requires relatively larger neck. It means that as $B_{\eta\eta}$ increases (which inturn depends on the value of η_{in}), the neck of the interacting nuclei i.e. ΔR feels restricted.

The calculated σ_{fus} for the reactions under study are given in the Table I. The DCM calculated σ_{fus} are very well compared with the available experimental data [6] at same incident energy per nucleon (E_{lab}/A) for all the reactions. These calculations have been made by fitting the value of ΔR^{emp}. It is important to note that, for the reactions having same η_{in}, the value of ΔR^{emp} also remains unchanged in order to address their respective σ_{fus}.

References

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