The charged particle decay of hot and rotating compound nucleus $^{118,122}Ba^*$ using dynamical cluster decay model

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Introduction

In heavy ion reactions, the compound nucleus (CN) formed possesses large angular momentum and high excitation energy. When it decays, it emits multiple light particles (LPs: n, p, α & γ-rays) along with a significant (5-10%) of intermediate mass fragments (IMFs: $2 < Z \leq 14$) for $A_{CN} \geq 40$. The measured angular distributions and energy spectra for IMFs are consistent with fission-like decays of the respective CN.

The emission of LPs is understood using statistical Hauser-Feshbach analysis and this analysis is extended to include IMFs emission in BUSCO code [1] or the extended Hauser-Feshbach scission-point model [2]. For IMFs, a more accepted process is the binary fission of the CN and is worked out in the statistical scission-point fission model [3] or the saddle-point transition-state model [4], with the *LPs still treated within the HF method*. The statistical models are lacking in structure information which in dynamical cluster-decay model (DCM) is included via the preformation probability of the fragments. The DCM treats both the LPs and IMFs on equal footings i.e. considered both as the dynamical mass motion of the preformed fragments or clusters through the barrier. In terms of the barrier, a cluster decay process is in fact a fission process with structure effects of the compound nucleus included, which follows the dynamical cluster decay process rather than the fission process of the statistical model. In this paper, we have calculated the decay cross-section for $^{118,122}Ba^*$ CN formed in the reactions $^{78,82}Kr +^{40} Ca$ using DCM at $\overline{\Delta R}$ 1.1 & 1.6 fm and center of mass energies $E_{cm} = 145.42$ & 147.87 MeV, respectively.

Formalism

The DCM is worked out in terms of coordinates of mass (charge) asymmetry $\eta = (A_1-A_2)/(A_1+A_2)$ $(\eta_Z = (A_{Z1}-A_{Z2}/(A_{Z1}+A_{Z2})$, and relative separation R, characterizing, the nucleon exchange between the outgoing fragments, and the incident channel kinetic energy (E_{cm}) transferred to internal excitation of outgoing channel ($E^*_{CN}, +Q_{out} = TKE(T) + TXE(T)$; TXE and TKE as the total excitation and kinetic energy). Since $R = R(T, \eta)$, so for decoupled R-,η-motions the CN decay cross-section (see [5] and references there in, in terms of partial waves, is

$$\sigma = \frac{\pi\hbar^2}{2\mu E_{cm}} \sum_{\ell=0}^{\ell_c} (2\ell+1) P_0 P \qquad (1)$$

P_0 is the preformation probability, referring to η motion, is the solution of stationary Schrodinger equation in η coordinate (with T-dependent collective fragmentation potentials) at a fixed $R = R_a = R_t(\eta, T) + \overline{\Delta R}(T)$, where $\overline{\Delta R}(T)$, the only parameter of model. The temperature (T) of CN is obtained using

$$(E^*_{CN}) = E_{cm} + Q_{in} = (A/9)T^2 - T, \qquad (2)$$

P the penetrability, referring to R-motion, is the WKB integral, given as

$$P = e^{\left[-\frac{2}{\hbar}\int_{R_a}^{R_b}\{2\mu[V(R)-Q_{eff}]\}^{1/2}dR\right]} \qquad (3)$$

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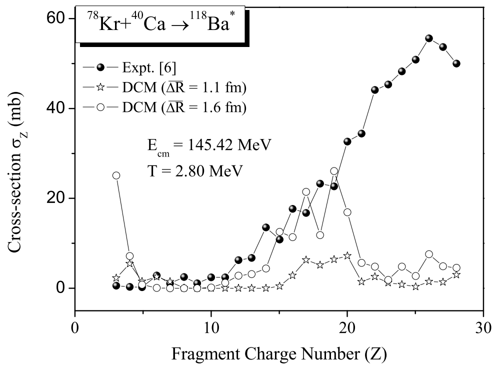

FIG. 1: The calculated charge distribution of decay cross-section using DCM for hot and rotating compound nucleus $^{118}Ba^*$ at $\overline{\Delta R}$ (=1.1 & 1.6 fm), at E_{cm} = 145.42 MeV is compared with the experimental data [6].

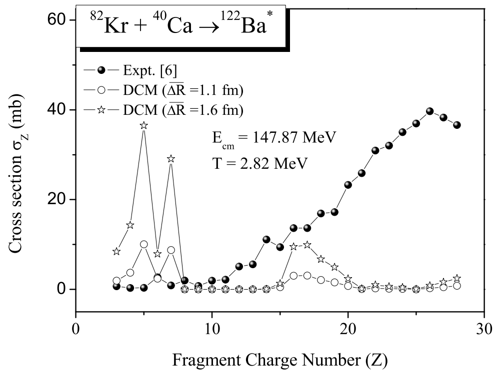

FIG. 2: Same a Fig. 1, but for compound $^{122}Ba^*$ at $E_{cm} = 147.87$ MeV

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solved analytically with R_b as the second turning point, satisfying $V(R_a) = V(R_b) = Q_{eff}$, where Q_{eff} is the effective Q value, for the decay of the hot CN at a temperature T and $\ell_c = R_a\sqrt{2\mu(E_{cm} - V(R_a, \eta_{in}, l = 0))}/\hbar$, is the critical angular momentum with μ as reduced mass and η_{in} is the entrance channel mass asymmetry.

Calculations and results

The charge distribution of the decay cross-section for hot and rotating CN $^{118,122}Ba^*$ formed in reactions $^{78,82}Kr +^{40} Ca$ at E_{cm} = 145.42 and 147.87 MeV, respectively, has been obtained using DCM.

Fig. 1, shows the calculated decay cross section for CN $^{118}Ba^*$ formed in the reaction $^{78}Kr +^{40} Ca$ over atomic number range 3 to 28 at $\overline{\Delta R}$ =1.1 & 1.6 fm, compared with the experimental data [6]. The solid line with empty $\star$ symbols, shows the calculated decay cross-section for $\overline{\Delta R}$ =1.1 fm and the solid line with empty circles symbols, represents the same but for $\overline{\Delta R}$ =1.6 fm. The experimental data [6] in both figures is shown by scattered solid spheres. Its is clear from the Fig. 1 that $\overline{\Delta R}$ =1.1 fm reproduces the data nicely for $3 \leq Z \leq 11$ only, while $\overline{\Delta R}$ =1.6 fm is able to reproduce the data nicely up to Z = 20, except z = 3. Fig. 2, shows the same but for the decay of $^{122}Ba^*$ compound system at E_{cm} = 147.87 MeV and the chosen $\overline{\Delta R}$. From the figure 2, it is found that $\overline{\Delta R}$ =1.1 fm reproduce the data over charge range $z = 3 - 12$ and $\overline{\Delta R}$ =1.6 fm reproduces almost over the charge range $Z = 8 - 18$. In other words single $\overline{\Delta R}$ is not sufficient to reproduce the data and hence has to be adjusted suitably to reproduce that observed data. These are the preliminary results and more investigation is required for different $\overline{\Delta R}$ over different fragment charge number.

References

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