Fusion-evaporation and partial fusion-fission events for hot and rotating compound system $^{88}Mo^*$

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Introduction

In a very recent paper [1], the fusion-evaporation and the partial fusion-fission events has been measured for hot and rotating compound nucleus $^{88}Mo^*$ formed in the reaction $^{48}Ti +^{40} Ca$ at three beam energies =300, 450 & 600 MeV and a comparison has been presented with the prediction of statistical model, implemented through GEMINI++ code [2]. The hot and rotating compound nucleus formed decays either by evaporation or by symmetric or asymmetric fission and fission channel become more significant with increase in angular momentum of the compound system. Here, in this paper, we have used a non-statistical approach for the study of decay of this compound system using dynamical Cluster decay model (DCM) of Gupta and collaborators ([3, 4] and references there in). In this model the fusion-evaporated (FE) particles are designated as light particles, LPs (particles with $Z \leq 2$) and partial fusion-fission (FF) particles are designated as intermediate mass fragments, IMFs (particles with $2 < Z \leq 12$). The emission of both types of the particles in this model are treated on equal footings i.e, both LPs and IMFs are considered as dynamical mass motions of preformed fragments or clusters through the barrier.

Formalism

A non-statistical approach, the DCM, has been used for calculations of the FE and FF cross-sections. This model is worked out in terms of two coordinates (i) mass (charge) asymmetry $\eta = (A_1 - A_2)/(A_1 + A_2)$, ($\eta_Z = (A_{Z1} - A_{Z2}/(A_{Z1} + A_{Z2})$, and (ii) relative separation R, which characterizes, the nucleon exchange between the outgoing fragments and the incident channel kinetic energy (E_{cm}) transferred to internal excitation of outgoing channel. This energy transfer process is $E_{cm} + Q_{in} = |Q_{out}| + TKE(T) + TXE(T)$, here TXE and TKE are the total excitation and total kinetic energies respectively. The temperature (T) of compound nucleus is obtained using

$$E^*_{CN} = E_{cm} + Q_{in} = (A/9)T^2 - T, \qquad (1)$$

where A is mass number of compound system. The DCM, in terms of partial waves, defines the compound nucleus decay cross-section as,

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

where, P_0 is the preformation probability, referring to η motion and is given by the solution of stationary Schrodinger equation in η coordinate with temperature dependent collective fragmentation potentials at a fixed $R = R_a = R_t(\eta, T)+\overline{\Delta R}(T)$, $\overline{\Delta R}(T)$ is the only parameter of this model. The penetrability 'P', referring to R-motion and is WKB integral solved analytically with R_b as the second turning point, satisfying $V(R_a) = V(R_b) = Q_{eff}$, the effective Q-value for outgoing fragments , given as

$$P = \exp\left[-\frac{2}{\hbar}\int_{R_a}^{R_b} \sqrt{\{2\mu[V(R) - Q_{eff}]\}}dR\right] \quad (3)$$

The critical angular momentum, $\ell_c = R_a\sqrt{2\mu(E_{cm} - V(R_a, \eta_{in}, l = 0))}/\hbar$, with μ as the reduced mass and η_{in} as the entrance channel mass asymmetry.

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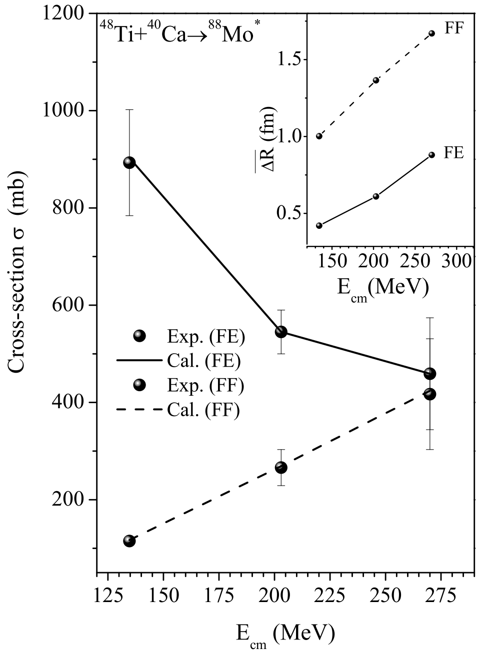

FIG. 1: The calculated FE and FF channel cross-sections for hot and rotating CN $^{88}Mo^*$, formed in the reaction ^{48}Ti+^{40}Ca at two $\overline{\Delta R}$-values for E_{cm} = 134.7, 203 & 270 MeV is compared with the experimental-data [1] and the inset shows the $\overline{\Delta R}$-values required at different center of mass energies for FE and FF channels.

Calculations and results

The fusion-evaporation (FE) and partial fusion-fission (FF) cross-sections have been calculated using DCM for the decay of hot and rotating compound nucleus $^{88}Mo^*$ at three center of mass energies E_{cm} =134.7, 203 & 270 MeV and at two different $\overline{\Delta R}$-values and these values are chosen to fit the observed data for FE and FF channels separately. The ℓ_c-values for FE (FF) channels are 84$\hbar$ (90$\hbar$), 107$\hbar$ (118$\hbar$) and 130$\hbar$ (142$\hbar$) at respective E_{cm}.

Fig.1, shows the comparison of two different channel cross-sections (i) for FE channel (solid line) and (ii) FF channel (dashed line) with experimental data [1] (scattered solid-spheres) for both channels as a function of E_{cm}. From the figure we find that with increase in the value of E_{cm} the FE channel cross-section decreases while the FF channel cross-section increases and become comparable to the FE channel cross-section at E_{cm} = 270 MeV. The FE cross-sections are not summed up to ℓ_c-values but up to that value of ℓ at which FE/FF channel cross-section reduces to almost zero value, here that value of ℓ is called ℓ_{max}. For FE channel, it is 46$\hbar$ for all value of E_{cm} but for FF channel the ℓ_{max}-values are not same for all E_{cm}-values, these are 72, 74 and 70 $\hbar$ for E_{cm} 134.7, 203 and 270 MeV, respectively. The inset of Fig.1 shows the average values of ΔR required to fit the observed data for FE channel (line with solid sphere) and FF channel (dashed line with solid sphere.) From the variation of $\overline{\Delta R}$-values with E_{cm} we find for both the channels the required value $\overline{\Delta R}$ increases with increase in E_{cm}, although the FE and FF channel cross-sections has different variation with E_{cm}. In conclusion of the study we want to say that to fit the observed data for FE and FF channels one has to opt for different $\overline{\Delta R}$-values, these $\overline{\Delta R}$-values increases with E_{cm} for both the channels and with increase in E_{cm} FE cross-section decreases while FF cross-section increases and become comparable near 270 MeV of E_{cm}.

References

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