Neck length parameter and incident energy correlation for the decay of hot and rotating compound nucleus ^{186}Pt*

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Introduction

Hot and rotating compound nuclei formed in low-energy heavy-ion collisions generally populate the exit channels with the emission of light particles, intermediate mass fragments, and fission fragments. The formation of an exit channel is a function of the fragmentation potential energy via neck length. The effect of neck formation/shape elongation during the dynamical mass motion for the formation of an exit channel can be assimilated by a free parameter $\overline{\Delta R}$ in the dynamical cluster-decay model. The $\overline{\Delta R}$ is a measure of the relative separation between the surfaces of two decaying/colliding fragments in terms of their radii R_1, R_2, see details in ref. [1]. The neck length parameter $\overline{\Delta R}$ refers to the actually used potential barrier height in barrier penetration calculation and is an indicator of the time for the occurrence of an event (evaporation, fission and intermediate mass fragments) at a given excitation energy of a compound nucleus [2]. It is therefore possible to vary $\overline{\Delta R}$ within the nuclear proximity range of 2 fm to fit the experimental data. The potential energy or fragmentation potential is a combination of self-binding energies, shell-correction, nuclear proximity, Coulomb, and centrifugal terms.

In this work, $\overline{\Delta R}$-values at various incidence energies have been adjusted to reproduce the measured evaporation residue for reactions: ^{32}S + ^{154}Sm [3] and ^{48}Ti+^{138}Ba [4].

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Methodology

Dynamical cluster-decay model [1] is based on the quantum mechanical fragmentation theory worked out in terms of collective coordinates of mass (or charge) asymmetry η=(A_1-A_2)/(A_1+A_2) (or η_Z=Z_1-Z_2)/(Z_1+Z_2)), relative separation R, and neck length parameter $\overline{\Delta R}$. The complex fragment emission cross section in terms of the partial waves is:

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; \quad k=\sqrt{\frac{2\mu E_{cm}}{\hbar^2}} \quad (1)$$

where P_0, the fragment preformation probability, is obtained from the solution of stationary Schrödinger equation in η-motion using fragmentation potential calculated at fixed internuclear separation R=R_a=C_1(T)+C_2(T)+$\overline{\Delta R}$, the Süssmann central radii C_i are expressed in terms of radii R_i; i=1, 2. The probability of penetration P, refer to R-motion, is obtained by using the WKB integral, for detail see [1]. The maximum value of angular momentum ℓ_{max}=$\ell_{\sigma_{LPs}\to 0}$, the angular momentum at which $\sigma_{LPs} \to 0$, LPs are fragments with Z$\leq$2. The temperature T of the compound nucleus is related to its excitation energy as

$$E^*_{CN} = (A/9)\,T^2 - T \quad (2)$$

where A(=A_1+A_2) is the mass of the compound nucleus.

Calculation and results

Fig. 1 shows the ℓ-windows, the ℓ-range over which evaporation probability is relatively large, e.g., for E_{cm}=127.9 MeV ℓ-window is 61-120 $\hbar$. The maximum value of

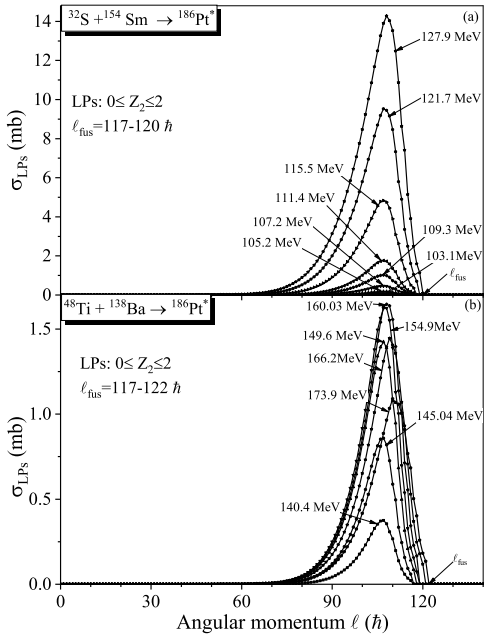

FIG. 1: Cross-section summed up for LPs as a function of angular momentum for (a) ^{32}S+^{154}Sm →^{186}Pt* and (b) ^{48}Ti+^{138}Ba →^{186}Pt* for E$_{cm}$ 101-127.9 and 140.4-173.9 MeV, respectively.

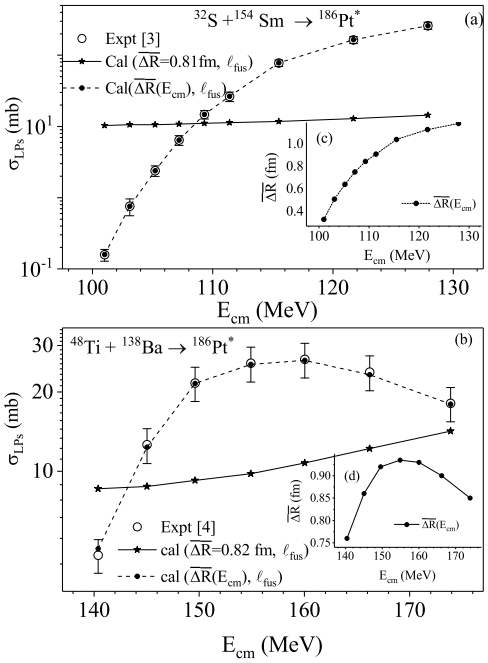

FIG. 2: Comparison of the σ_{LPs} calculated with the measured evaporation residue for (a) ^{32}S+^{154}Sm→ ^{186}Pt* [3] and (b) ^{48}Ti+^{138}Ba→ ^{186}Pt* [4]. Inset Figs. (c) and (d) for $\overline{\Delta R}$ as a function of E_{cm}.

angular momentum in an ℓ-window is called ℓ_{fus}. For $\ell > \ell_{fus}$ the evaporation cross-section σ_{LPs} is negligible and saturates (no increase in σ_{LPs} with ℓ). Therefore, σ_{LPs} should be summed up over the angular momentum range of 0-ℓ_{fus}. The variation of ℓ_{fus} with E$_{cm}$ is small and hence the width of ℓ-windows for evaporation can be considered nearly independent of incident energy.

Fig. 2 shows the comparison of the calculated cross-section for LPs (σ_{LPs}), summed over the angular momentum range 0-ℓ_{fus} and keeping internuclear surface separation $\overline{\Delta R}$ (i) constant and (ii) E$_{cm}$ dependent, with the measured evaporation residue. The constant $\overline{\Delta R}$ is not able to reproduce the observed evaporation residue and hence its variation is needed. When $\overline{\Delta R}$ is allowed to vary with E$_{cm}$ to reproduce the measured evaporation residue, the required $\overline{\Delta R}$ has variation similar to σ_{LPs}(E$_{cm}$). This means, the evaporation time of a compound nucleus varies with incident energy.

Conclusion

The need to vary the neck length parameter with the incident energy corresponds to the variation in evaporation time.

References

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