Decay of ^{254}Fm* nucleus formed in ^{11}B+^{243}Am reaction

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Introduction

The study of fusion-fission dynamics is of great interest for the overall understanding of nuclear reactions and nuclear structure physics. Various aspects influence the fusion-fission phenomena, say, for example, the nuclear structure of the target and the projectile i.e the deformations of the projectile and the target nuclei. According to the entrance channel dependent (ECD) K state model, target deformation plays an important role in determining the non-compound nucleus (nCN) contribution. When the projectile collides with the tip of the deformed target then if the composite system lies within the saddle point then compound nucleus formation occurs otherwise it is elongated enough that it may escape into the exit channel without being captured and result in nCN fission contribution. Another parameter that affects the fusion process is the mass assymmetry α $[= (A_T - A_P)/(A_T + A_P)]$ of the entrance channel. If $\alpha > \alpha_{BG}$ (the Businaro Gallone mass asymmetry) then according to the pre-equilibrium model, the nCN contribution is not expected. Therefore, neither the mass asymmetry nor the deformations seem individually enough to account for the competing nCN decay.

In the present work, we have studied the decay of ^{254}Fm* nucleus formed in ^{11}B+^{243}Am reaction where both the target and compound nucleus are deformed and $\alpha > \alpha_{BG}$ for this reaction. Our calculations are made by using the dynamical cluster-decay model (DCM) [1] in reference to the experiment [2], considering the fragmentation of ^{254}Fm* to consist of either spherical or (β_2-β_4) deformed nuclei.

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The Model

Based on the fragmentation theory, the DCM [1] is worked out in terms of collective coordinates of mass asymmetry $\eta = \frac{A_1-A_2}{A_1+A_2}$, charge asymmetry $\eta_Z = \frac{Z_1-Z_2}{Z_1+Z_2}$ and relative separation R, which allows to define the compound nucleus decay cross section in terms of the partial waves as

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

with μ as the reduced mass and, l_{max}, the maximum angular momentum, fixed for the light particle cross section $\sigma_{LP} \rightarrow 0$. P_0, the preformation probability, is the solution of stationary schrödinger equation in η coordinate and P is the WKB penetrability of preformed fragments in R-motion. The multipole deformations $\beta_{\lambda i}$ (λ=2,3,4; i=1,2) and orientations θ_i of two nuclei or fragments are included via radius vectors R_i. It is important to note here that preformation probability P_0 imparts the important nuclear structure information which is otherwise missing in the alternative statistical models. The only parameter of the model is the temperature dependent neck length parameter ΔR(T), defining the first turning point $R_a = R_1(\alpha_1, T) + R_2(\alpha_2, T) + \Delta R(T)$ for the penetration of preformed fragments. DCM is also applied to nCN, quasi-fission process where P_0=1 since the incoming channel remains unaffected.

Calculations

We have studied the role of deformations in the decay of ^{254}Fm* nucleus formed in ^{11}B+^{243}Am reaction, taking higher multipole deformations upto hexadecapole (β_{2i}-β_{4i}) and "compact" orientations (θ_i^c) (i=1,2) for hot fu-

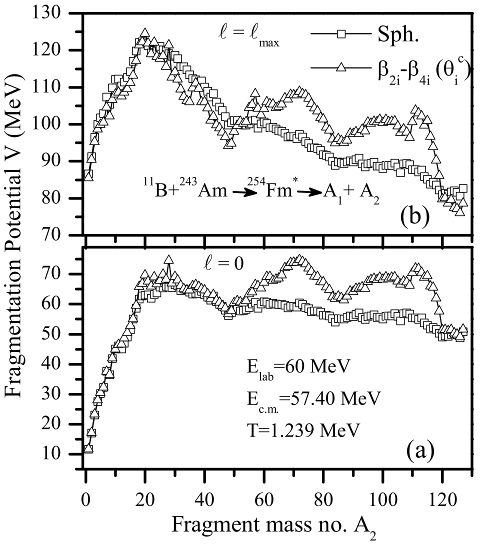

FIG. 1: Fragmentation potential as a function of light mass fragment A_2 for the decay of ^{254}Fm* formed in ^{11}B+^{243}Am reaction channel for spherical as well as deformed considerations at (a) ℓ=0 and (b) $\ell = \ell_{max}$.

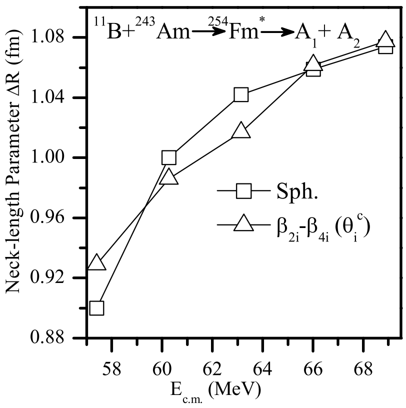

FIG. 2: The fitted neck-length parameter (△R) for fission decay of ^{254}Fm* formed in ^{11}B+^{243}Am reaction, for spherical as well as deformed considerations, as function of $E_{c.m.}$.

sion. Fig. 1 shows the fragmentation potential as a function of fragment mass A_2 for the decay of ^{254}Fm*. It can be seen from Fig. 1 that the potential energy surface is almost smooth for the spherical choice of fragments, which, however, show large structure with the inclusion of deformation effects. The important result is that the decay of ^{254}Fm* follows the symmetric fission path, independent of deformation effects. Furthermore, Figs. 1(a) and (b) show that the light-particles evaporation residue (ER) are more dominant at ℓ=0, whereas fission becomes the dominant mode of decay at $\ell=\ell_{max}$ value. Interestingly, the fission cross-sections calculated using spherical and β_{2i}-β_{4i} considerations are both in agreement with the experimental data, with the quasi-fission component calculated within DCM of the order of $\sim$ 3% of the total fission cross section in each case. The calculations are done by fitting the neck-length parameter △R which compensates for the larger interaction barrier or surface thickness at the saddle point. Such inclusion of △R could be useful to deal with loosely bound reactions involving halo-nuclei projectiles and radioactive ion beams.

Fig. 2 shows the variation of △R as a function of $E_{c.m.}$ for spherical as well as deformed choices of fragmentations. One can see that the △R values for spherical and (β_{2i}-β_{4i}) deformations are comparable with each other. This result emphasises the fact that reaction time for ^{11}B induced reaction do not alter much after the inclusion of deformation effects upto hexadecapole.

Summarizing, we have studied the role of deformations (upto hexadecapole) in the fragmentation path of ^{254}Fm*. The potential energy surface is smooth for the spherical case whereas a prominent structure appears in the deformed case. The decay of ^{254}Fm* follows symmetric mass distribution, independent of deformations, and the reaction time scale does not alter with deformation effects. The estimated quasi-fission component is small, approximately $\sim$3% in this reaction.

References

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