Fusion-fission of ^{215}Fr* nucleus using the Dynamical Cluster-decay Model

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Introduction

For the successful formation of heavy nuclei, deep understanding of fusion-fission process of the compound nucleus formed in low energy heavy ion reaction is essential. A number of factors and properties influence the fusion-fission process and hence need be handled with proper care in order to make meaningful predictions regarding the behavior of a nuclear system. Considering the importance of these factors (to be discussed in the following), we have done an extensive study on the fusion-fission excitation functions of ^{215}Fr* formed in ^{18}O+^{197}Au reaction.

It has been reported in Ref. [1] that, the systems having entrance channel mass asymmetry ($\alpha = (A_T - A_P)/(A_T + A_P)$) smaller than the Bussinaro-Gallone mass asymmetry (α_{BG}) show preference for pre-equilibrium or quasi-fission, compared to the ones with larger mass asymmetry. These observations are made in reference to the variance of measured anisotropies with respect to the stanard saddle-point statistical model (SSPM) anisotropy predictions. In other words, the difference in measured and SSPM based anisotropies indicate the possibility of quasi-fission in addition to normal fission process.

The decay of ^{215}Fr*, formed in ^{18}O+^{197}Au reaction over a wide range of energy, has been studied using the Dynamical Cluster-decay Model (DCM) of Gupta and collaborators [2]. The DCM provides an effective alternative to the statistical Hauser-Feshback analysis and the statistical fission models, and hence used successfully to understand the cross-sections for Evaporation Residues, Intermediate Mass Fragments, Fusion-Fission and Quasi Fission processes. We have carried out the calculations using quadrupole deformed (β_2) considerations alone, using the "optimum" orientations for hot (compact) configurations in the fragmentation process.

The Model

The DCM, based on the well-known quantum mechanical fragmentation theory, including the effects of deformations and orientations of the two incoming or outgoing nuclei, contains the effects of angular momentum ℓ and temperature T. Using partial waves, the compound nucleus decay cross-section is

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

with μ as the reduced mass and l_{max}, the maximum angular momentum, fixed for the vanishing of the fusion barrier of the incoming channel, or else for the light-particles cross-section $\sigma_{ER} \rightarrow 0$. P_0, the preformation probability, is the solution of stationary Schrödinger equation in mass asymmetry coordinate η and P is the WKB penetrability of the preformed fragments or clusters in R-motion. The only parameter of the model is the T-dependent neck-length parameter ΔR(T). The fission anisotropy is also calculated for the DCM based parameters, within the SSPM approach [3].

Calculations and discussion

In the present work, we have calculated the fission cross-sections for the decay of ^{215}Fr

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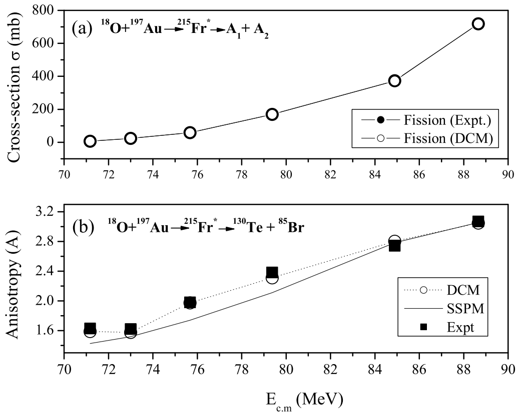

FIG. 1: (a) Fission cross-sections $\sigma_{fission}(E_{c.m.})$ calculated on DCM using I_S limit, compared with experimental data and (b) The DCM calculated anisotropies using I_{NS} limit, compared with SSPM calculations and experimental data on anisotropy, for decay of compound nucleus $^{215}Fr^*$.

(α_{BG}=0.855) compound system formed in $^{18}O+^{197}Au$ (α=0.833) channel in reference to recent experimental data [4]. Hence, this is a case of $\alpha < \alpha_{BG}$, and should prefer quasi-fission process [1]. However, our DCM calculated fission cross-sections ($\sigma_{fission}$) in Fig. 1(a) show an excellent agreement with the experimental data at all reported centre of mass energies, thereby providing no signature of quasi-fission or any other non-compound nucleus decay process in the decay of ^{215}Fr nucleus. It is important to note that these calculations are made for use of the sticking moment-of-inertia I_S, where the ℓ_{max} is fixed for $\sigma_{ER} \rightarrow 0$. In this connection, it is relevant to say that ℓ_{max} is controlled by the only parameter ΔR of the model, the neck length parameter, which in turn depends strongly on choice of moment-of-inertia for angular momentum effects in the potential. We find that the sticking limit I_S, used here for fitting the fission cross-sections, is more appropriate which has consequences for the limiting ℓ_{max}-value to be much larger than for the other choice of non-stickig moment-of-ineria I_{NS}.

In addition to fission cross-sections, Fig. 1(b) shows the fission-fragment anisotropies calculated for use of the constants, along with the predictions of standard SSPM, and available experimental data. Once again, the DCM based fission-fragment anisotropies are found to be consistent with the SSPM predictions, suggesting the absence of quasi-fission component in the decay of ^{215}Fr. Note that here the DCM calculated anisotropies are for use of moment-of-inertia in the non-sticking limit I_{NS} ($=\mu R^2$). Thus, the DCM-based anisotropies are compared with SSPM and experimental data at a relatively much smaller value of angular momentum ℓ_{max}-value.

Concluding, within the DCM, the non-sticking moment-of-inertia is found more appropriate for the anisotropy calculations whereas the sticking moment-of-inertia is more appropriate for obtaing the fission cross-sections which involves a larger limiting value ℓ_{max} and hence a smaller neck-length parameter ΔR required for the proximity potential ($\leq$2fm).

Acknowledgements

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