Decay of ^{213,217}Fr* formed in ^{19}F+^{194,198}Pt reactions using the dynamical cluster-decay model

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Introduction

Fission excitation functions, i.e., fission cross-section σ_{fiss} as a fuction of center-of-mass energy $E_{c.m.}$ or compound nucleus (CN) excitation energy E_{CN}, together with fission fragment angular distribtions are measured for the ^{19}F+^{194,198}Pt reactions forming the CN ^{213,217}Fr* [1]. As expected, σ_{fiss} for the more fissile CN ^{213}Fr* is significantly larger over the entire measured energy range as compred to that for the less fissile ^{217}Fr*. A significant contribution from the evaporation residue cross-section σ_{ER} is also measured at some of the energies (three of six), giving the total fusion cross-section at these energies. The anisotropy data for ^{217}Fr* (with N=130) are in good accord with the statistical saddle-point model (SSPM) over the entire energy range, except at the highest one energy. On the other hand, the anisotropy data for ^{213}Fr* (with N=126) show noticeable deviations from SSPM calculations at a few energies. The authors of this work [1] associate this deviation with the magic neutron number of the CN, whereas in a recent work [2] some of us considered the possibility of a noncompound, quasifission (qf) component in the fission cross-section.

In this paper, we look for both the possibilities of the role of CN N=126 and the qf component, on the basis of the dynamical cluster-decay model (DCM) of Gupta and collaborators [2, 3]. We have carried out our calculations for the deformed fragments, using quadrupole, octupole and hexadecapole (β_2, β_3 and β_4) deformations, having "optimal" orientations of hot configuration [4]. Note that the DCM is applied for the first time to an odd-mass fissioning nuclear system with a significant σ_{ER} contribution.

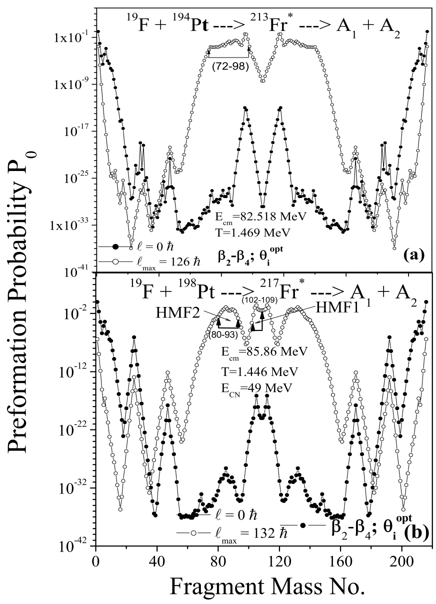

FIG. 1: Preformation probability as a function of the fragment mass number, for the decay of ^{213}Fr* (upper panel) and ^{217}Fr* (lower panel).

The Model

In DCM, we use the collective co-ordinates of mass asymmetry $\eta = (A_1 - A_2)/(A_1 + A_2)$ and relative separation R, which allow to define the CN decay cross-section, in terms of

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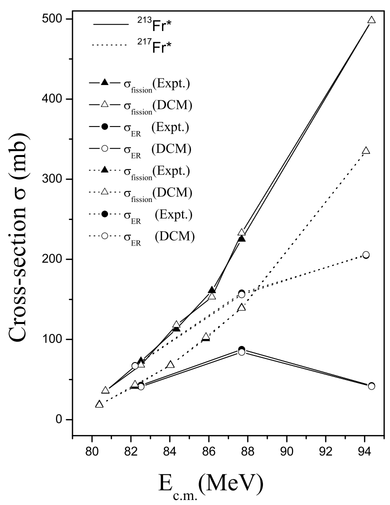

FIG. 2: Comparison between the experimental [1] and calculated σ_{fiss} and σ_{ER} using the DCM for ^{213,217}Fr*.

the partial waves, as

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

with μ as the reduced mass and l_{max}, the maximum angular momentum, which could be taken as a free parameter or else fixed for the vanishing of the fusion barrier of the incoming channel, or for the light particle cross-section $\sigma_{ER}(\ell) \rightarrow 0$. P_0, the pre-formation 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 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 process.

Calculations and Results

Fig. 1 shows the behavior of preformation probability P_0 as a function of the fragment mass for the decay of CN ^{213}Fr* and ^{217}Fr* at about the same E_{CN} ∼49 MeV, and at the two extreme ℓ_{min} and ℓ_{max} values. The interesting result is a double-humped, asymmetric fission distribution for ^{213}Fr* (N=126) and a tripple-humped symmetric-asymmetric distribution for ^{217}Fr* (N=130). This difference arises due their neutron number being different, resulting in different minima corresponding to either Z=40 or N=50, or both, in their fragmentation potentials. In terms of the contribution to fission cross-section, apparently, the symmetric fission (SF) component is small (or zero) for ^{213}Fr* and non-zero for ^{217}Fr*. This difference in the structure of fragmentation potential or, equivalently, the preformation probability could be associated with the shell closure of neutrons in ^{213}Fr*.

Fig. 2 presents the comparison between our DCM calculated σ_{fiss} and σ_{ER} for both the ^{213}Fr* and ^{217}Fr* systems with the experimental data [1]. The near exact comparison between the calculations and data for both the cross-sections leaves no scope for the qf component in either of the two σ_{fiss} data.

Summary and Conclusions

The calculated double-humped, asymmetric fission distribution for ^{213}Fr* and a tripple-humped symmetric-asymmetric distribution for ^{217}Fr* point out to the possible role of magic N=126 in ^{213}Fr*, resulting in an almost zero contribution to the σ_{fiss} due to the symmetric fission. The near exact comparisions between the σ_{fiss} (as well as σ_{ER}) for both the CN give rise to *no* possibility of quasifission component in the fission cross-sections of either of the two systems.

References

[1] K. Mahata, S. Kailas, A. Shrivastava, A. Chatterjee, P. Singh, S. Santra and B. S. Tomar, Phy. Rev. C **65** (2002) 034613.

[2] B. B. singh, M. K. Sharma and R. K. Gupta, Phy. Rev. C **77** (2008) 054613.

[3] R. K. Gupta, *et al.*, Phy. Rev. C **71** (2005) 014601; J. Phys. G: Nucl. Part. Phys. **32** (2006) 345; Int. J. Mod. Phys. E **15** (2006) 699; Phy. Rev. C **79** (2009) 034602; Int. J. Mod. Phys. E **18** (2009) 1453.

[4] R. K. Gupta, *et al.*, J. Phys. G: Nucl. Part. Phys. **31** (2005) 631.