Role of higher multipole deformations and compact orientations in the decay of ^{217}Fr* nucleus

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Introduction

The decay of compound nucleus (CN) depends on a variety of factors like the incident energy of projectile, excitation of CN and shape orientations of target nucleus, etc. A number of factors and properties influence the fusion-fission process which need be handled with proper care in order to make meaningful predictions. One such aspect, which plays a significant role in the fusion-fission dynamics, is the role of deformed shapes of target, projectile and the decaying fragments. Nuclear shapes, i.e., the deformations and orientations of nuclei, during fusion reactions, change the interaction barrier (its height as well as position) thereby affecting the dynamics of reaction process. It is therefore, important to account for the shapes of target-projectile combinations by considering proper deformations and orientations effects. Keeping this in mind, we have investigated the role of deformations and orientations in the decay of complex odd nuclear system ^{217}Fr* formed in ^{19}F+^{198}Pt reaction, using the well established Dynamical Cluster Decay Model (DCM) of Gupta and collaborators.

The DCM has so far been used to study the evaporation residue (ER), intermediate mass fragments (IMF) and fusion-fission (FF) processes in the decay of hot and rotating CN systems from different mass regions, i.e., light, medium and superheavy mass regions [1]. We have carried out the calculations for spherical and for deformed fragments using quadrupole (β_2) deformations having "optimum" orientations θ_i^{opt}, taken from Table 1 of [2] and the higher multipole deformations (β_2 - β_4) having compact orientations θ_i^c of hot configurations [3]. Note that, the optimum orientations for hot fusion reactions are decided by the signs alone of quadrupole and hexadecapole deformations and hence are insensitive to the magnitude of hexadecapole deformations. On the other hand, compact orientations depend strongly on both the signs and magnitudes of both the quadrupole and hexadecapole deformations.

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The Model

The DCM uses 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 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. l_{max} corresponds to that value of angular momentum at which evaporation residue cross-sections become negligible i.e. $\sigma_{ER}(\ell) \to 0$. P_0, the preformation probability, is the solution of stationary Schrödinger equation in mass asymmetry coordinate η. P in equation (1) refers to 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 discussion

It is established that the role of deformations and orientations of the colliding nuclei

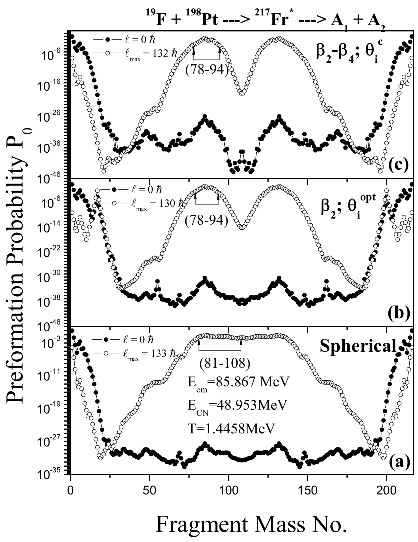

FIG. 1: Preformation probability P_0 as a function of fragment mass number A_2 for the decay of compound systems ^{217}Fr*, plotted for ℓ=0 and $\ell = \ell_{max}$, for spherical and deformed nuclei.

and decaying fragments is almost indispensable in the dynamics of nuclear reactions [2, 3]. Therefore, we have carried out a systematic study of the decay of ^{217}Fr* nuclear system formed in ^{19}F+^{198}Pt reaction over a wide range of incident energies, in order to investigate the specific role of nuclear deformations and orientations.

Fig. 1 shows the preformation probability P_0 as a function of fragment mass (A_2) for a fixed $E_{c.m.}$ (and the corresponding temperature) at two extreme ℓ values, ℓ=0 and $\ell = \ell_{max}$, for both the spherical as well as deformed considerations. The preformation probability P_0 of the fragments (before tunnelling through the barrier) accounts for the structure effects in the decay process of a nuclear system. It has been shown explicitly in this figure that the inclusion of deformations and orientations effects of the decaying fragments changes the relative preformation probability P_0 quite significantly, and hence, equivalently, the potential energy surface (PES). We find that the fission distribution pattern changes from near symmetric to asymmetric fragmentation with the inclusion of quadrupole (β_2) as well as higher multipole deformations (β_2-β_4). However, the mass distribution remains almost same (as discussed below) when one goes from quadrupole deformed (β_2) to hexadecapole (β_2-β_4) deformed system; the only difference lies at ℓ=0. At ℓ=0, one may see significant change in PES for β_2 and β_2-β_4 choices. Such variations could be of interest to investigate the ground state decays and nuclear structure effects. The specific role of angular momentum can also be accessed from the variation of preformation probability for ℓ=0 and ℓ_{max} cases. It may be noticed that the light particles are more prominent at lower ℓ values and the heavier fragments start competing with light particles with increase in ℓ and eventually at $\ell = \ell_{max}$ the heavy fragment formation probability supersedes that of lighter ones. The calculated fission cross-sections are found to match the experimental data [4] nearly exactly, leaving no room for the non-compound nucleus, qf component in fission cross-sections of ^{217}Fr*. An interesting feature of the present study is that the experimental data is fitted with all possible choices of deformations and orientations, i.e., spherical, β_2 alone or β_2-β_4 deformed fragments and hence it provides an ideal case to look for the explicit role of deformations in the decay pattern of ^{217}Fr* nucleus. Further calculations are underway.

Acknowledgements

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