Effect of static and dynamic deformations in the decay of ^{241}Pu* nucleus

Gudveen Sawhney, Raj Kumar, and Manoj K. Sharma*
School of Physics and Materials Science,
Thapar University, Patiala - 147004, INDIA

Introduction

In recent times our understanding has grown regarding the formation and decay process of nuclear systems, and a lot many exotic experiments and advanced theoretical developments have enabled us to study the nuclear behavior in new perspective. It is a well established fact that the decay of compound nucleus (CN) depends on parameters like excitation energy, incident energy of projectile, shape and orientations of target nucleus etc. The shape of both the nuclei participating in a reaction, influence the interaction potential which in turn provides appropriate variation in barrier height and barrier position. This barrier modification is of great importance in order to investigate nuclear dynamics near and below Coulomb barrier.

In order to look out for such effects, the reaction dynamics of hot and rotating compound nucleus ^{241}Pu* [1] formed in the reaction ^{9}Be + ^{232}Th around the Coulomb barrier ($\approx$ 42.16 MeV), at energies ranging from 37 - 48 MeV, is investigated using the dynamical cluster-decay model (DCM) [2] which is extended to include the temperature dependant (dynamic) deformations of nuclei. It is important to note that so far only the static deformations [3] is used in the framework of DCM to understand the heavy ion reactions. The projectile, target and the compound nucleus formed are all strongly deformed so the role of deformation and orientation effects is expected to be important in the context of present study. We have carried out the calculations using higher multipole deformations (β_2-β_4) having "compact" orientations of hot configurations for decaying products [4].

*Electronic address: msharma@thapar.edu

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. The compound nucleus decay cross-section obtained using the partial wave analysis, depends on both the preformation probability P_0 and penetration probability P. P_0, 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 deformation parameter β_i is taken to be temperature dependent in DCM using the relation [5].

$$\beta_{\lambda i}(T) = exp(-T/T_0)\beta_{\lambda i}(0); i = 1, 2 \qquad (1)$$

where $\beta_{\lambda i}(0)$ is static deformation and T_0 is the temperature of the nucleus at which shell effects start to vanish (T_0=1.5 MeV) [5].

Calculations and discussion

The compound nucleus, ^{241}Pu*, formed in the reaction ^{9}Be + ^{232}Th is highly fissile and decays mainly via fission, therefore σ_{fiss} is the major contributer to the total decay cross-section. It is clear from Fig. 1 that with the inclusion of temperature dependence in higher multipole deformations (β_2-β_4) of the decaying fragments, the potential energy surface (PES) change significantly for A_2 > 50 and hence the relative preformation probability P_0 for all the fragments would change

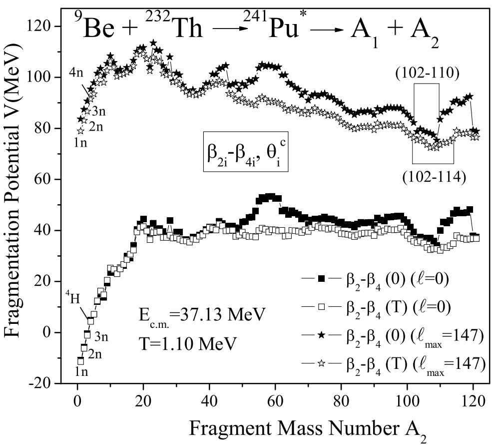

FIG. 1: Fragmentation potential for the decay of ^{241}Pu*, plotted at extreme ℓ-values, for both static and dynamic choices of deformation up to hexadecapole (β_2-β_4) deformed fragments.

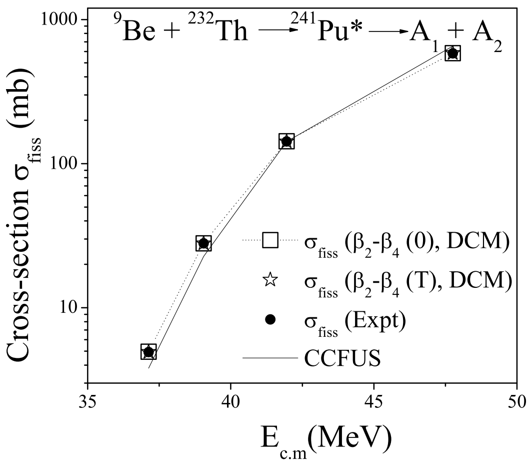

FIG. 2: The DCM calculated σ_{fiss} for the decay of CN ^{241}Pu*, compared with experimental data along with CCFUS predictions [1] for both static and dynamic choices of deformation up to hexadecapole (β_2-β_4) deformed fragments.

accordingly. However there is no noticeable change in the structure of $V(A_2)$ up to A_2 = 50, except in the characteristics of emitted LPs. The contributing LP(s) change in going from $\ell = 0$ to ℓ_{max} with the inclusion of higher multipole deformations up to β_4. However this result does not remain consistent with the increase in energy from below to above barrier.

Similarly, the barrier characteristics are also modified with the inclusion of temperature dependent deformations of outgoing fragments, thereby affecting the tunneling probability P through barrier. However the preformation probability is more sensitive and get strongly modified as compare to penetrability. We find that although the PES in the fissioning region are different, the distribution yield is asymmetric for both static as well as dynamic deformed considerations up to hexadecapole in the decay of ^{241}Pu*. One may see some contribution of symmetric fission fragments as well, particularly for static deformed case. This emergence of symmetric mass distribution along with observed asymmetric fragmentation provides the possibility of the fine- or sub-structure in the fusion-fission of compound nucleus ^{241}Pu*.

The interesting feature of this study is that the DCM calculated fission cross-section fit the data very nicely (see Fig. 2) at all the energies, within a single parameter description ΔR for the use of both static and dynamic choices of deformation up to hexadecapole. Thus the present study clearly points out the importance of static and dynamical deformations and related orientations in the heavy ion reaction dynamics.

Acknowledgements

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