Fusion-Fission and related aspects of ^{204}Po formed in heavy ion reactions

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Introduction

The decay of heavy nuclear system under the extreme conditions of temperature and angular momentum etc. has been a topic of great interest in recent years as it provides useful information regarding fusion-fission reaction dynamics. The fusion cross-section is the sum of measured cross-section due to evaporation residue, fission and other NCN processes, if applicable. In the pre-actinide region, it is of upmost importance to investigate the fusion hindrance and/or NCN fission along with its possible implications in nuclear dynamics and related phenomena. The observation of fusion hinderance is attributed to entrance channel mass asymmetry, α=A_t-A_p/A_t+A_p. If $\alpha < \alpha_{BG}$, then there may be some contribution from NCN. Basically α_{BG} separates the mass symmetric liquid drop fission barrier from the asymmetric one(s). Recently fission cross sections were measured [1] for ^{16}O + ^{188}Os reaction over a wide range of energy (E_{lab}=84MeV - 99MeV). This fission cross section data was used to extract statistical model parameters and consequently complete fusion and evaporation residue cross section for ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reactions were predicted [1] over a energy range (E_{lab}=84-155MeV). Interesting aspect of the study is that the measurements/calculations were done at comparable E_{cm}/V_C values in the range 1.05-1.24 for both the reactions producing ^{204}Po nuclear system. In the present work we have studied the decay of ^{204}Po nuclear system formed in ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reactions using the Dynamical Cluster decay Model (DCM) [2]. A brief report on this reaction, having β_2-deformed fragmentation alone, was presented in [3]. In the present work, we have carried out the calculations with spherical fragmentation as well as quadrupole (β_2) deformations having optimal orientations of hot configuration. DCM treats all the decay processes on equal footings as barrier penetration of pre-formed fragments or clusters. DCM also supports the only acceptable explanation for the hindrance phenomenon in ccc in terms of modified shape of potential inside the barrier at sub barrier energies. The basic aim of present study is to look for the fusion-fission, entrance channel effects and the role of deformations in the pre-actinide nuclear system ^{204}Po.

The Model

The DCM uses the collective coordinates of mass asymmetry $\eta = \frac{A_1-A_2}{A_1+A_2}$ 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_o, the preformation probability, is the solution of stationary schrodinger equation in mass asymmetry coordinate η and P is the WKB penetrability of preformed fragments in R-motion. It is important to note here that preformation probability P_o imparts the important nuclear structure information which is otherwise missing in the competing statistical models. In the frame work of DCM, the complete fusion cross-section is defined as $\sigma_{CF} = \sigma_{ER}+\sigma_{fission}+\sigma_{qf}$ where σ_{CF}, σ_{ER}, $\sigma_{fission}$, σ_{qf} refer to complete fusion, evaporation residue, fission and quasi fission respectively.

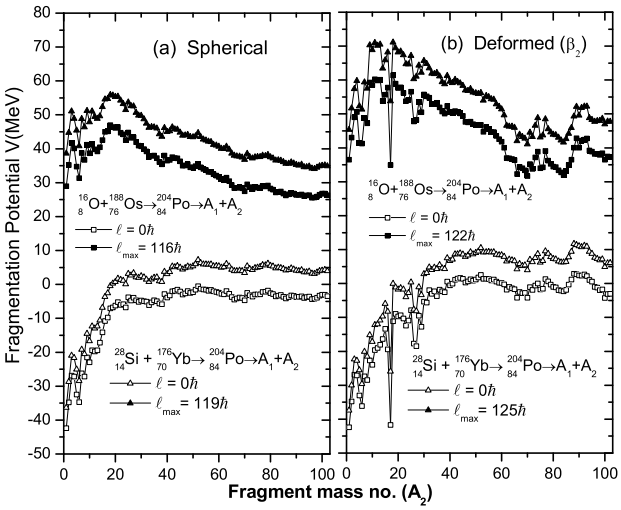

FIG. 1: Fragmentation potential as a function of light mass fragment for the decay of ^{204}Po formed in ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reaction channels at comparable Ecm/Vc value(=1.05) using spherical and deformed fragmentations.

Calculations and Discussions

The decay of ^{204}Po nucleus formed in ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb channels is studied over a wide range of centre of mass energies and having comparable E_{cm}/V_C value. Calculations are made for different $\triangle$R (neck length parameter), chosen to fit simultaneously the respective available data for ER and fission cross sections. With the spherical choice of fragmentation within DCM approach, we succeeded in fitting the fission cross sections, whereas the reported σ_{ER} could not be achieved, which prompted us to look out for the effective role of deformations in the decay of ^{204}Po. Fig.1(a&b) shows the fragmentation potentials for the decay of ^{204}Po formed in the channels ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb at two extreme ℓ values, using spherical nuclei as well as with β_2-deformed choice of fragmentation. It can be seen from Fig.1(a&b) that with the inclusion of deformation effects, potential energy surfaces change significantly at lower as well as at higher ℓ values. The reported ER could be fitted only with the inclusion of deformation effects. This implies that deformations play an important role in the decay of pre-actinide nuclear system ^{204}Po. With the deformed choice of fragmentation we could fit the available data at all incident energies except at the highest energy for the channel ^{28}Si + ^{176}Yb, which can be associated with some amount of NCN contribution (qf contribution of about 20% is predicted at highest energy). The qf contribution at highest energy is in line with the predictions of [1]. The almost comparable fragmentation path for ^{16}O and ^{28}Si induced reactions for spherical and deformed choice indicate the entrance channel independence for ^{204}Po nuclear system.

In summary, the available data for ^{204}Po formed in ^{16}O and ^{28}Si induced reactions is fitted nicely using DCM. The role of deformations play an important role in the decay of ^{204}Po and quasi fission seems to contribute (about 20%) at the highest energy for the channel ^{28}Si + ^{176}Yb. The concept of entrance channel is addressed on the basis of fragmentation path.

Acknowledgments

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