Decay of ^{204}Po nucleus formed in ^{16}O and ^{28}Si induced reactions

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Introduction

A large amount of work is being done in order to investigate non compound nucleus fission (NCN), quasi fission (QF), incomplete fusion (ICF), fusion hinderance (FH) and other related aspects in the pre-actinide mass region. In general large entrance channel coulomb repulsion ($Z_pZ_t \geq 1000$), lower entrance channel mass asymmetry ($\alpha < \alpha_{BG}$) and broadening in the fission fragment mass distribution are considered to be the reasons responsible for NCN, QF, ICF, FH etc. Therefore it becomes extremely interesting to study the decay path of nuclear systems in pre-actinide region in order to see impact of these nuclear phenomena. Recently fission fragment angular distributions were measured [1], in the ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reactions producing same compound nucleus ^{204}Po over a wide range of centre of mass energies (78MeV - 134MeV). Interesting aspect of the study is that the measurements were carried out at comparable E_{cm}/V_C values in the range 1.05-1.24 for both the reactions. In this experiment [1] the angular anisotropies deduced from measured fission angular distributions, find decent comparison with statistical and pre-equilibrium fission model calculations, descarting the possibility of NCN contribution in either of reaction channels.

In the present work we have studied the decay of ^{204}Po formed in ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reactions using the Dynamical cluster decay model (DCM). On the basis of Dynamical Cluster Decay model (DCM) of Gupta and collaborators [2], we have carried out the calculations with quadrupole (β_2) deformations, having optimal orientations of hot configuration. In DCM, all decay products are calculated as emissions of preformed clusters through the interaction barriers, treating the ER and fusion-fission decays on equal footings. The basic aim of present study is to investigate the fusion-fission and related aspects of a pre-actinide nuclear system ^{204}Po. It is relevant to mention here that DCM has been successfully applied to a large number of nuclei in light, intermediate, heavy and superheavy mass region over last one decade.

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The Model

The DCM uses the collective coordinates of mass asymmetry $\eta = \frac{A_1 - A_2}{A_1 + A_2}$ and relative separarion 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. The only parameter of DCM model is, the temperature dependent neck length parameter ΔR(T), defining the

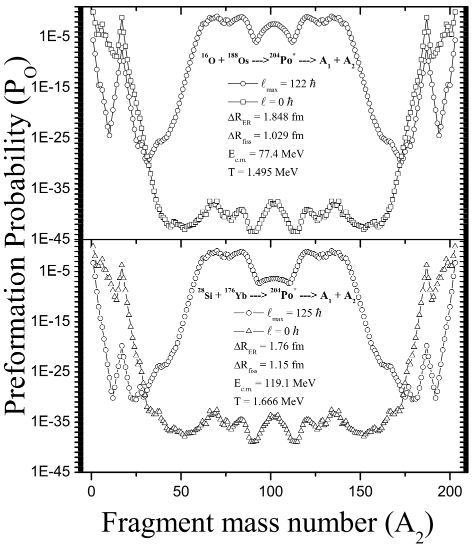

FIG. 1: Preformation Probability as a function of fragment mass number(A_2) for the decay of ^{204}Po.

first turning point R_a=$R_1(\alpha$,T)+ $R_2(\alpha$,T)+ ΔR(T) for the penetration of preformed fragments. In the frame work of DCM, the complete fusion cross-section is defined as σ_{CF} = σ_{ER}+$\sigma_{fission}$+σ_{QF} where σ_{CF}, σ_{ER}, $\sigma_{fission}$, σ_{QF} refer to complete fusion, evaporation residue, fission and quasi fission respectively.

Calculations and Discussions

Fig 1. shows the preformation probability for ^{16}O + ^{188}Os and ^{28}Si + ^{176}Yb reactions at comparable value of E_{cm}/V_C ($\simeq$ 1.05). It is important to note that there is significant difference between entrance channel coulomb repulsion (Z_pZ_t product) for these reactions. Therefore the broadening in the fission fragment mass distribution is expected specifically for ^{28}Si + ^{176}Yb reaction as Z_pZ_t for this reaction is close to 1000. However one may see from fig 1. that fission fragment mass distribution is identical in both the reactions and seem to behave similarly at two extreme l-values despite having significant mass asymmetry variation. One may note that at l=0, ER part is dominant where as the situation get reversed at higher l-value i.e at l=l_{max} where fission starts competing with ER process. One may clearly see a double humped fission distribution in both the cases and fragments A_2= 65-72, 75-76, 79-86 seem to contribute towards fission cross sections. We have calculated ER, fission cross sections and total fusion cross section for the channel ^{16}O + ^{188}Os at energies E_{cm}=77.4, 82.0, 86.6, 91.2 MeV and for the channel ^{28}Si + ^{176}Yb at energies E_{cm}=119.1, 125.1, 128.5, 133.7 MeV based on DCM model. We have fitted the available experimental data by taking appropriate values for the neck length parameter ΔR simultaneously for evaporation residue and fission contributions. DCM based ER, and complete fusion cross sections find nice comparison with the available CASCADE and CCFUS based results. The available experimental fission cross sections for ^{16}O + ^{188}Os reaction are also reproduced with in DCM approach. In case of fission, the neck length parameter ΔR is found to increase almost linearly with E_{cm} whereas the same is relatively constant (but higher in magnitude) in case of ER. The higher magnitude of ΔR for ER simply mean that ER occurs before the fission process is initiated . In summary, DCM based cross-sections find nice comparison with available experimental data. Although fission fragment mass distribution is found to be similar in both the reactions, there seems a possibility of small qf contribution in case of ^{28}Si + ^{176}Yb reaction at the highest energy.

Acknowledgments

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