Effect of entrance channel in fission fragment anisotropies for the reactions forming compound nuclei ^{210}Rn and $^{188,190}Pt$

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Introduction

Investigation of angular distribution of fission products is one of the most commonly used method to differentiate fusion-fission and quasifission processes at near barrier energies. In heavy ion collision reactions, the fusion dynamics is strongly influenced by entrance channel properties of the colliding nuclei such as charge product ($Z_P Z_T$), mass asymmetry (α), deformation of the nuclei (β), collision energy, etc. The direction of the mass flow in the dinuclear system plays a dominant role in the reaction dynamics. It is reported in the literature that for a system with entrance channel mass asymmetry (α) greater than the Businaro-Gallone mass asymmetry (α_{BG}), the mass flow takes place from the projectile to the target leading to the formation of a compound nucleus (CN), which may decay via fission or particle evaporation in any later time. On the other hand, for $\alpha < \alpha_{BG}$, mass flow occurs in the opposite direction and a dinuclear system is formed which will decay before equilibrating in all degrees of freedom, leading to quasifission.

Fission fragment angular distributions of the systems ^{11}B+^{204}Pb and ^{18}O+^{197}Au (leading to same CN ^{215}Fr), having mass asymmetries that fall on either side of the α_{BG} value show no evidence of quasifission [1], which ruled out the presence of entrance channel effect around coulomb barrier energies. For ^{16}O+^{194}Pt , ^{24}Mg+^{186}W [2] and ^{30}Si+^{180}Hf [3] reactions, forming the same CN ^{210}Rn, the variance of mass distribution of the fission fragments found to be larger in later two reactions for which $\alpha < \alpha_{BG}$ implying presence of quasifission. In the recent study, Kavita *et al.* measured fission fragment mass distribution for CN $^{188,190}Pt$, where they found larger variance in mass distribution for the system with entrance channel mass asymmetry being lesser than α_{BG} value [4]. In this work we have calculated the fission fragment anisotropies as a function of reduced coulomb barrier E_{CM}/V_b for the compound nuclei ^{210}Rn and $^{188,190}Pt$ forming through different entrance channels with the help of standard saddle point statistical model (SSPM) to study the entrance channel effects.

SSPM formalism for angular distribution

According to the standard transition state model (TSM) or standard saddle point statistical model (SSPM), fission fragment angular distributions are characterized by anugular anisotropy (A). The angular anisotropy is defined as the ratio of yield at 0^0 or 180^0 to that at 90^0 and it is given by

$$A = 1 + \frac{< l^2 >}{4K_0^2}$$

where

$$K_0^2 = T \times \frac{I_{eff}}{h^2}$$

and

$$T = \sqrt{\frac{E^*}{a}} = \sqrt{\frac{E_{CM} + Q - B_f - E_{rot} - E_{pre}^{sad}}{a}}$$

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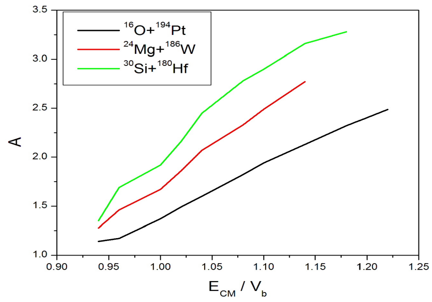

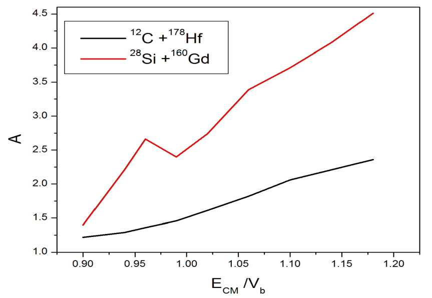

FIG. 1: Calculated fission fragment anisotropies as a function of reduced coulomb barrier E_{CM}/V_b.

here B_f, E_{rot} and I_{eff} values are calculated from rotating finite range model of Sierk [5] and a is the level density parameter taken as $A_{CN}/10$, where A_{CN} is the mass of the CN.

Result and Discussions

For the systems $^{16}O+^{194}Pt$, $^{24}Mg+^{186}W$ and $^{30}Si+^{180}Hf$ we have calculated the anisotropy values at energy range of $0.94 \leq \frac{E_{CM}}{V_B} \leq 1.22$ as shown in Fig.1 (upper graph). Similarly for $^{28}Si+^{160}Gd$ and $^{12}C+^{178}Hf$ reactions forming CN $^{188,190}Pt$ anisotropy values are calculated at energy range of $0.90 \leq \frac{E_{CM}}{V_B} \leq 1.18$ as shown in Fig.1 (lower graph). The values of anisotropy reflect the effect of entrance channel mass asymmetry. The systems with $\alpha < \alpha_{BG}$ give higher angular anisotropy as compared to the systems with $\alpha > \alpha_{BG}$ at same E_{CM}/V_B.

The onset of quasifission observed in the $^{24}Mg+^{186}W$ and $^{30}Si+^{180}Hf$ reactions based on fission fragment mass variance [2,3]

TABLE I: Relevant parameters of the reactions under study. χ is the fissility, β_2 is quadrupole deformation and V_b is barrier energy in center of mass frame.

Reaction	V_b (MeV)	χ	α	α_{BG}	β_2
$^{16}O+^{194}Pt$	75	0.735	0.847	0.856	0.130
$^{24}Mg+^{186}W$	103	0.735	0.771	0.856	0.393
$^{30}Si+^{180}Hf$	115	0.735	0.714	0.856	0.267
$^{28}Si+^{160}Gd$	105.6	0.670	0.702	0.818	0.351
$^{12}C+^{178}Hf$	53	0.667	0.874	0.816	0.279

favoured the present work calculation where large anisotropy values are found. For reaction $^{28}Si+^{160}Gd$ ($\alpha < \alpha_{BG}$), higher value of anisotropy is obtained than $^{12}C+^{178}Hf$ ($\alpha > \alpha_{BG}$). The dynamical models proposed eariler predicted the presence of quasifission for heavy system with coulomb factor $Z_PZ_T >$ 1600 but in recent studies QF were also observed in the light systems with $Z_PZ_T \approx 800$. During collision of projectile and target nuclei, the mass flow takes place from the target to the projectile for the systems with $\alpha < \alpha_{BG}$ leading to a dinuclear system which may reseparate before K-equilibrium giving anomalously large anisotropies. In this work calculated anisotropy at near barrier energies strongly depend on mass asymmetry which confirms the presence of entrance channel effect in the fission of CN ^{210}Rn and $^{188,190}Pt$.

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