Quasifission in reactions forming ^{210}Rn nucleus

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The field of heavy-ion fusion reactions has been the central topic of nuclear physics research for the last few decades due to the quest for super heavy elements (SHE) [1]. As we go to heavier systems, fusion-fission (FF) and quasi-fission (QF) [1, 2] are the two competing reaction processes at near and above the Coulomb barrier. It is difficult to separate the FF and QF processes as the observable characteristics have considerable overlap. Conclusive evidence of QF can be inferred from anomalous fission fragment angular anisotropies, broadened fission fragment mass distributions, mass-angle correlations and strong reduction in evaporation residue (ER) cross-section [3].

Here, we report the study of the fission fragment mass ratio distribution for the reaction ^{30}Si + ^{180}Hf populating the compound nucleus (CN) ^{210}Rn. The results are compared with two other reactions, ^{16}O+^{194}Pt and ^{24}Mg+^{186}W, populating the same CN [2]. We also report the di-nuclear system (DNS) model predictions [4] of QF cross sections normalized with respect to capture cross sections for the three reactions mentioned above.

Measurement was performed at the 15UD Pelletron accelerator facility of Inter University Accelerator Centre (IUAC), New Delhi, using the General Purpose Scattering Chamber (GPSC) [5]. The mass angle correlations and the mass ratio distributions of the fragments were obtained at energies above and below the Coulomb barrier. FIG. 1 shows the Mass Angle Distribution (MAD) plot for the reaction at E_{cm} = 126.7 MeV. No mass angle correlation has been observed in this reaction, in the entire energy range studied. The symmetric fragment mass ratio distribution may be coveniently represented using the Gaussian distribution with the standard deviation (σ_m) representing the width of the experimental mass ratio distributions. The mass ratio width is found to increase

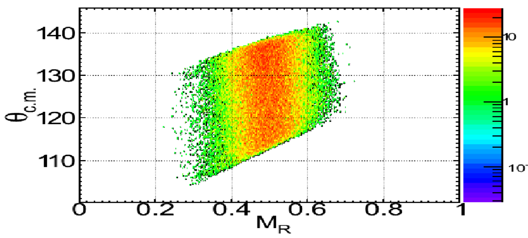

FIG. 1: The mass ratio vs center-of-mass angle density plot for the reaction ^{30}Si + ^{180}Hf at E_{cm}= 126.7 MeV.

linearly with the excitation energy. For an equilibrated CN, the variance of fragment mass ratio distribution (σ_m^2) varies linearly with the nuclear temperature (T) and mean square angular momentum $<l^2>$. That is,

$$\sigma_m^2 = \lambda T + \kappa <l^2> \qquad (1)$$

where, λ and κ are proportionality constants [2]. T is evaluated using saddle point model assumptions and $<l^2>$ using the coupled-channels code CCFULL [6] including the rotational couplings (β_2) of the target nucleus. The experimental mass ratio widths are significantly larger than the values calculated using eqn. (1) in the entire energy range for the two reactions, ^{24}Mg+^{186}W

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and ^{30}Si+^{180}Hf.

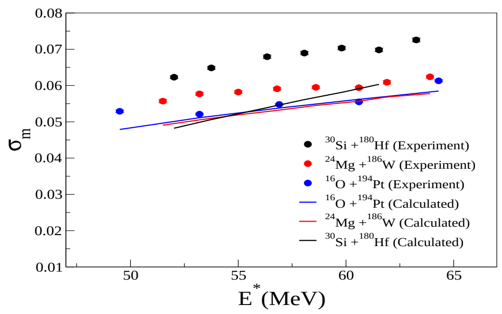

FIG. 2: Experimental mass ratio widths of ^{30}Si+^{180}Hf at different excitation energies compared with the calculations assuming CN formation. Results are compared with that of ^{16}O+^{194}Pt and ^{24}Mg+^{186}W [2], forming the same CN ^{210}Rn.

The different behavior of the mass ratio distributions of the three systems populating the same composite system ^{210}Rn indicates the possible onset of QF in ^{24}Mg+^{186}W and ^{30}Si+^{180}Hf reactions. However, the uncorrelated MAD plot suggests that these systems do not separate immediately after contact, and may be getting separated after one or few full rotations, but before complete mass equilibration, as suggested by Rietz *et al.*[7]. Hence these systems may be grouped in MAD III category in terms of reaction dynamics, where FF and QF exhibit a substantial overlap in its observables. The onset of QF may be attributed to the entrance channel parameters in these reactions.

We also performed DNS model [4] calculations for the three systems. The capture and QF cross sections for ^{30}Si+^{180}Hf reaction and the ratio of QF cross section to capture cross section for the three reactions are shown in FIG. 3(a) and FIG. 3(b) respectively. It may be noted that the model predicts almost negligible QF probability for ^{16}O + ^{194}Pt reaction, in agreement with the experimental measurements [2, 8]. However, 5-15% QF probability is predicted for the other two reactions. The increased mass ratio widths in these reactions may thus be attributed to the admixture of QF events.

In summary, the fission frgment mass ratio distributions and mass angle correlations have been obtained for ^{30}Si+^{180}Hf reaction. No mass angle correlation has been observed in the entire energy range of the present study. However, the system shows larger mass ratio widths when compared with other two reactions populating the same CN. DNS model calculations predict about 5-15% probability for the QF component to occur during the reaction. The present results thus indicate the entrance channel dependence of QF despite the relatively lower values of $Z_P Z_T$ in these reactions.

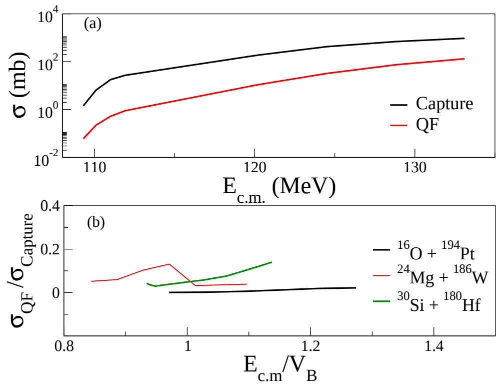

FIG. 3: DNS Model calculations: (a) The capture and QF cross sections for ^{30}Si+^{180}Hf and (b) the ratio of QF cross section to capture cross sections for the three reactions.

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