Statistical model calculations of pre- scission neutron multiplicity and nuclear dissipation for ^{19}F- induced reactions

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Introduction

It is now well established that the pre-scission neutron multiplicity is one of the most efficient probes to study the dynamics of fusion-fission processes [1]. Such measurements are used to distinguish between the fusion-fission and quasi-fission reactions and the amount of dissipation if any, involved in those reactions can also be estimated [2]. In literature, several experimental studies have been done in the area of neutron emission. Several studies have shown that, the projectile-target combination (entrance channel mass asymmetry) plays a very important role in the dynamics of fusion–fission process [1-2].

In the recent work, Meenu Thakur et al. [3], did statistical model calculations for the systems ^{19}F+^{232}Th (α = 0.84) and ^{28}Si+^{232}Th (α = 0.78) at matching excitation energy in the range of 54.6-86.0 MeV. They found that the pre-scission neutron multiplicity decreases with increase in the projectile mass, i.e, going from ^{19}F to ^{28}Si with same target. Basically, in going from ^{19}F+^{232}Th (α = 0.84) to ^{28}Si+^{232}Th (α = 0.78), the entrance channel mass asymmetry decreases. The Authors proposed that the on-set of quasi-fission in ^{28}Si+^{232}Th reaction could be the probable cause for observed decease in pre-scission neutron multiplicity but due to the non-availability of the experimental data for the said system, quasi-fission signature could not be verified experimentally. They proposed to investigate these features in their future experiments. In the current work, we decided to explore the phenomenon of pre-scission neutron multiplicity as a function of entrance channel mass asymmetry at nearly same excitation energies for ^{19}F-induced reactions on various targets. The pre-scission neutron multiplicity for the reaction ^{19}F+^{194}Pt (α = 0.82) has been measured by V. Singh et al. [4], for the reactions ^{19}F+^{181}Ta (α = 0.81) and ^{19}F+^{159}Tb (α = 0.78) by J. O. Newton et al., [5].

Statistical Model Calculations

In the present model, we performed the statistical model calculations for above said reactions over the nearly matching excitation energy range. The pre-scission neutron multiplicities are calculated using the Bohr-Wheelar fission given by the following expression,

$$\Gamma_{BW} = \frac{1}{2\pi\rho_g(E_i)} \int_0^{E_i - V_B} \rho_s(E_i - V_B - \varepsilon)\, d\varepsilon \,,$$

Where, E_i = energy of the initial state, ρ_g = level density at the initial state, ρ_s = level density at saddle point, V_B= the spin dependent fission barrier [6].

In order to incorporate dissipation in fission channel, we used the Kramers fission width as,

$$\Gamma_K = \frac{\hbar\omega_g}{2\pi} e^{-\frac{V_B}{T}} \left\{ \sqrt{1 + (\frac{\beta}{2\omega_s})^2} + (\frac{\beta}{2\omega_g})^2 \right\},$$

Where, ω_g and ω_s are the frequencies of the harmonic oscillator potential and β is the dissipation strength [7].

Results and Discussion

Statistical model calculations are performed for all the three systems using Bohr-Wheelar fission width as well as Kramers fission width. The Pre-scission neutron multiplicity predicted with Bohr-Wheelar fission width is highly underestimated for all these reactions at all the energies as shown in the figure 1.

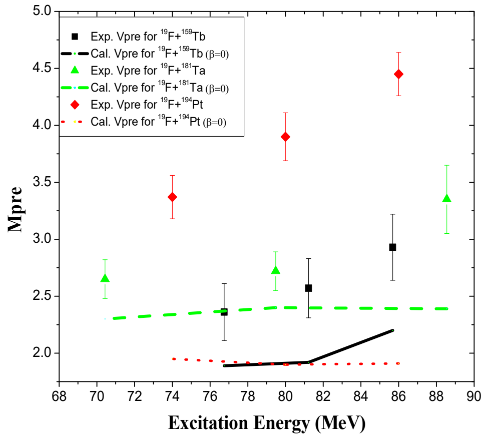

FIG. 1 The experimental pre-scission neutron multiplicity along with the model calculations using Bohr-Wheelar fission width (β = 0) for $^{19}F+^{194}Pt$, $^{19}F+^{181}Ta$ and $^{19}F+^{159}Tb$ reactions.

From this figure, it also has been observed that the experimental pre-scission neutron multiplicity decreases with decrease in entrance channel mass asymmetry for the chosen nearly same excitation energy range, but, pre-scission neutron multiplicity calculated using statistical model calculations, did not follow any such trends. So, for complete understanding of such phenomenon, one would require the experimental data at exactly matching excitation energies for a good number of reactions. By reproducing the experimental data, we have calculated the dissipation strength involved in all these reactions and same is plotted in the Fig. 2. From the Fig. 2, it is evident that the dissipation strength increases with increase in excitation energy for all the three reactions. The dissipation is found to be highest in the reactions $^{19}F+^{194}Pt$ and lowest in the reaction $^{19}F+^{181}Ta$. Even though the experimental data for the $^{19}F+^{159}Tb$ and $^{19}F+^{181}Ta$ reaction does not have any significant difference over the studied energy range, and despite of being higher for $^{19}F+^{181}Ta$ reaction.

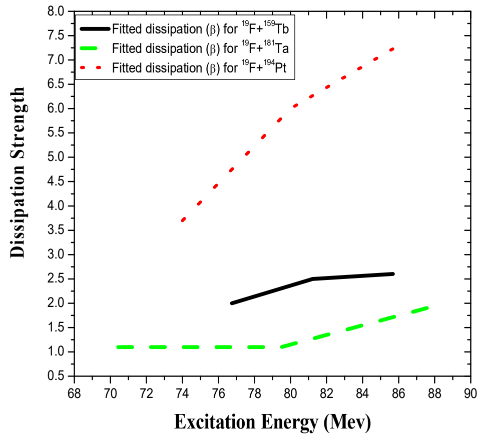

FIG. 2 Dissipation strength as a function of excitation energy for $^{19}F+^{194}Pt$, $^{19}F+^{181}Ta$ and $^{19}F+^{159}Tb$.

The calculated best fit β values shows the contrary trend. This unexpected trend will be explored further using more experimental data and with further detailing the model calculations.

Acknowledgements

One of the authors (Rakesh Kumar) wants to acknowledge UGC-RGNF, New Delhi, for financial support through fellowship for carrying out the present research work.

References

[1] Rohit sandal et al., Phys. Rev. C 87, 014604 (2013).
[2] H. Singh et al., Phys. Rev C 76, 044610 (2007).
[3] Meenu Thakur et al., EPJ Web of Confrences 86,00060 (2015).
[4] V. Singh et al., Phys. Rev. C 87, 064601 (2013).
[5] J. O. Newton et al., Nuclear Physics A 483 (1988) 126-152.
[6] N. Bohr, et al., Phys. Rev. C 56, 426 (1939).
[7] H. A. Kramers, Physics (Amsterdam) 7, 284 (1940).