Statistical model calculations of pre-scission neutron multiplicity and nuclear dissipation for different isotopes of Pb

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Introduction

It is now well known that the pre-scission neutron multiplicity is one of the most fruitful probes to study the dynamics of heavy ion induced fusion-fission processes [1,2]. The quantification of pre-scission neutron yield is used to differentiate the fusion-fission and quasi-fission reactions and the quantity of dissipation if any, involved in these reactions [3]. In literature, many experimental and theoretical works have been done in the area of neutron multiplicity measurements. Several studies have shown that, the different parameters like entrance channel mass asymmetry, Coulomb barrier, fissility and N/Z of the compound nucleus concerned plays a very important role in the dynamics of fusion–fission processes [1-3].

In the recent work, Rohit Sandal et al. [2], studied the effect of N/Z in pre-scission neutron multiplicity for different isotopes of Rn. They found that pre-scission neutron multiplicity increases with increase in the N/Z of the compound nucleus. They also calculated the dissipation involved in studied reactions and found that the dissipation does not follow any specific trend. In the present work, we have calculated the pre-scission neutron multiplicity and strength of nuclear dissipation at nearly matching excitation energy for different isotopes of Pb, populated via, $^{19}F+^{181}Ta \rightarrow ^{200}Pb$ (N/Z=2.439), $^{28}Si+^{170}Er \rightarrow ^{198}Pb$ (N/Z=2.414) and $^{28}Si+^{164}Er \rightarrow ^{192}Pb$ (N/Z=2.341) reactions, using the code VECSTAT. The pre-scission neutron multiplicities for these systems are measured by J. O. Newton et al. [4]. In this work we choose the experimental data for nearly matching excitation energy point, i.e, ^{200}Pb (E*=70.46 MeV), ^{198}Pb (E*=71.08 MeV) and ^{192}Pb (E*=78.35 MeV).

Statistical Model Calculations

In the present model, we carry out the statistical model calculations for above said reactions at the nearly matching excitation energy. The pre-scission neutron multiplicity is calculated using the Bohr-Wheelar fission width as 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,
= level density at the initial state,
ρ_s = level density at saddle point,
V_B= the spin dependent fission barrier [5].

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

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

Where, ω_g and are the frequencies of the harmonic oscillator potential
β is the dissipation strength [6].

Results and Discussion

Statistical model calculations are performed for all the three systems using Bohr-Wheelar fission width as well as Kramers fission width and the results so obtained are plotted as a function of N/Z of the CN in figure 1. It is evident from the figure that the experimental neutron multiplicity as well as the theoretical multiplicity increases with increase in the N/Z of the compound nucleus. For similar kind of work, present results are consistent with

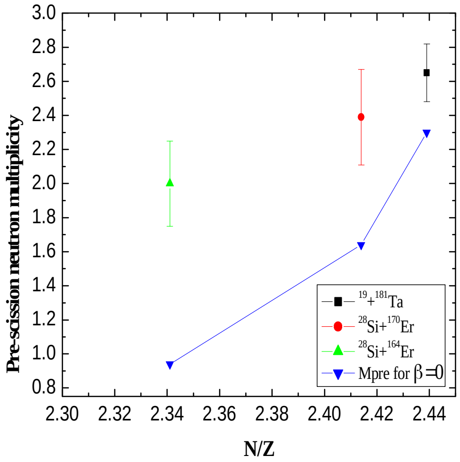

FIG. 1 The experimental pre-scission neutron multiplicity along with the model calculations using Bohr-Wheelar fission width (β = 0) for the systems $^{19}F+^{181}Ta \rightarrow ^{200}Pb$, $^{28}Si+^{170}Er \rightarrow ^{198}Pb$ and $^{28}Si+^{164}Er \rightarrow ^{192}Pb$ as a function of N/Z of the CN.

the findings of Rohit sandal et al [2]. From this figure we also observed that the model calculated values of pre-scission neutron multiplicity for all three reactions are highly under estimated when compared with experimental values.

By reproducing the experimental data, we have calculated the dissipation strength involved in all three reactions and same is plotted in the Fig. 2.

From the Fig. 2, it is evident that the dissipation strength decreases with increase in the N/Z of the compound nucleus, a trend which is complementary to the one observed for the experimental data. This complementary behavior observed in present calculations does not conform to some of the observations reported for similar studies in existing works [2]. The drastic difference between the calculated (without the inclusion of dissipation) and measured values of neutron multiplicity for highly neutron deficient ^{192}Pb compound system (figure 1) could either be due to some sort of experimental overestimation or same could also be possible due to highly underestimated pre-scission multiplicity for such a neutron deficient compound system. Because of this huge difference between the two values, as shown in figure 2, a large amount of dissipation is required to reproduce the experimental data.

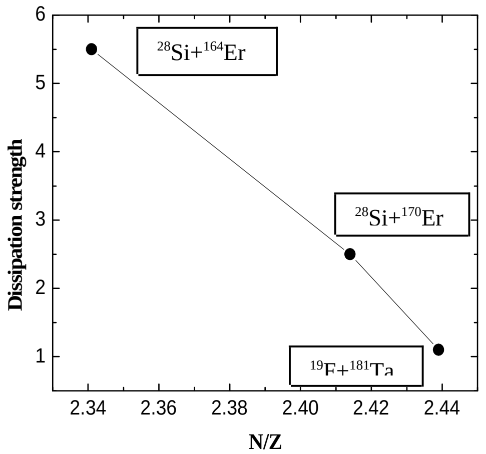

FIG. 2 Dissipation strength as a function of N/Z at nearly matching excitation energies for three reactions.

Therefore, for a better systematic behavior of nuclear dissipation, more data on average neutron yield before fission from would be very helpful.

References

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