Effect of shell closure and N/Z parameters on pre-scission neutron multiplicity

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1. Introduction

It is evident from the publish research work that the nuclear fusion-fission dynamics critically based on the entrance channel mass asymmetry (α), shell effect and N/Z . To find the impact of these parameters in case of fusion-fission dynamics many researchers have done experimental and theoretical studies [1–8]. In fission dynamics, pre-scission neutron multiplicity (ν_{pre}) is the best way to understand the dependence of these parameters.
It was also found in previous study, that with an increase in N/Z ratio of the system, the neutron multiplicity increases [9]. Experimental studies shows that neutron multiplicity decreases for the shell closed nucleus comparative to the non shell closed nucleus [10]. In our previous studies, we have observed that nuclear dissipation decreases with an increase in the entrance channel mass asymmetry and increases with an increase in the Coulomb factor (Z_pZ_t). It was also noticed that at high excitation energy larger number of neutrons are evaporated which shall stabilize the system against fission [11, 12]. Pre-scission neutron multiplicity also depends heavily on entrance channel mass asymmetry (α), as it was found that less asymmetric entrance channel ($\alpha < \alpha_{BG}$) takes larger formation time than higher asymmetry entrance channel ($\alpha > \alpha_{BG}$) as larger nuclear dissipation was found in less asymmetric reactions than higher asymmetric reactions [13, 14].

2. Systematics

In our calculation the systematics used by us to find the pre-scission neutron multiplicity ($\tilde{\nu}_{pre}$) is based on Ref. [15]. We have added the shell correction energy δW to excitation energy by using NRV JINR web application.

$$\tilde{E}^* = E^* + \delta W \tag{1}$$

Where $\tilde{E}^*$ is the liquid-drop excitation energy, E* is the excitation energy and δW is the shell correction which is a function of Z and A.
The $\tilde{\nu}_{pre}$ (A,$\tilde{E}^*$) dependence is described by the expression:

$$\tilde{\nu}_{pre}(A,\tilde{E}^*) = -10.64 + 0.0979A - 0.0154\tilde{E}^* \\ -0.000234A^2 + 0.000305A\tilde{E}^* \tag{2}$$

By using equation (2) we can find ν_{pre} and add error of $\Delta\ \tilde{\nu}_{pre}$ =± 6 % which we have taken from Ref.[13].

TABLE I: Calculated results of $\tilde{\nu}_{pre}$ and $\Delta\ \tilde{\nu}_{pre}$ at different excitation energy for compound nucleus Rn^{206}.

CN	E*	$\tilde{\nu}_{pre}$(A,$\tilde{E}^*$)	$\Delta\tilde{\nu}_{pre}$(A,$\tilde{E}^*$)
Rn^{206}	68.00	2.790	0.1674
	71.70	2.965	0.1780
	79.00	3.312	0.1987

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TABLE II: Calculated results of $\tilde{\nu}_{pre}$ and $\Delta\ \tilde{\nu}_{pre}$ at different excitation energy for compound nucleus Rn^{212}.

CN	E*	$\tilde{\nu}_{pre}(A,\tilde{E}^*)$	$\Delta\tilde{\nu}_{pre}\ (A,\tilde{E}^*)$
Rn^{212}	68.00	2.725	0.1635
	71.70	2.9076	0.1744
	79.00	3.2672	0.1960

TABLE III: Calculated results of $\tilde{\nu}_{pre}$ and $\Delta\ \tilde{\nu}_{pre}$ at different excitation energy for compound nucleus Rn^{216}.

CN	E*	$\tilde{\nu}_{pre}(A,\tilde{E}^*)$	$\Delta\tilde{\nu}_{pre}\ (A,\tilde{E}^*)$
Rn^{216}	68.00	3.0107	0.1806
	71.70	3.1976	0.1918
	79.00	3.5660	0.2139

3. Theoretical Studies

In the present work, we have calculated the $\tilde{\nu}_{pre}$ for three different compound systems $Rn^{206,212,216}$ by using the systematic given by Ref. [15]. In these three systems, the Rn^{212} compound system is a shell closed system (N=126). Here, we investigated the effect of N/Z after adding shell correction in all three systems and observed that with an increase in N/Z, $\tilde{\nu}_{pre}$ also increases, this happens when system is away from shell closure. In figure 1, we can clearly see that $\tilde{\nu}_{pre}$ for $Rn^{212} < Rn^{206}$ due to shell closure but as we go to higher N/Z value as $Rn^{216} > Rn^{206}$, we found an increase in $\tilde{\nu}_{pre}$ value. Calculations done by us are given in Table I, II and III.

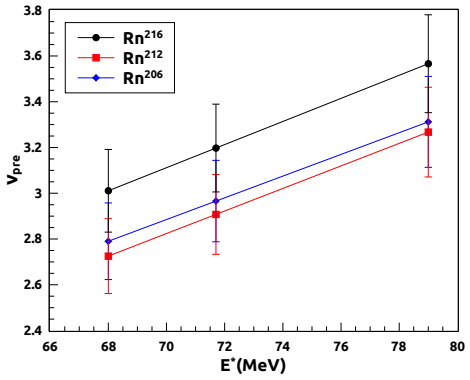

FIG. 1: A plot between pre-scission neutron multiplicty w.r.t Excitation energy for different N/Z of Rn.

4. Conclusion

From our present study, it is observed that both the shell closure and N/Z play a crucial role in fission dynamics. Neutron multiplicity decreases significantly in case of shell closed nuclei and increases with an increase in N/Z ratio. More experimental data are required to see the combined effects of these parameters. We are expecting to see these effects in our sanctioned beam time at IUAC.

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