Systematic study of the effect of shell closure and N/Z on odd-even compound nuclei using pre-scission neuton multiplicity as a probe.

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1. Introduction

Previous reasearch findings have shown that the entrance channel mass-asymmetry(α) shell effect, nuclear dissipation strength(β), N/Z ratio and collective enhancement in level density have been shown as important parameter in the nuclear fusion-fission dynamics.Numereous researchers have conducted theoretical and experimental studies to ascertain the influence of these parameters on fusion-fission dynamics[1-5].The pre-scission neutron multiplicity($\nu_{\rm pre}$) is one of the useful tools for studying fusion-fission dynamics.The number of neutron emitted per fission during the evolution of compound nucleus(CN) from its initial shape to scission point is defined as $\nu_{\rm pre}$ .Further, a prior examination found that the neutron multiplicity increases when the system's N/Z ratio increases[3].Experimental research also indicates that neutron multiplicity decreases in shell-closed nuclei relative to non-shell closed nuclei at lower excitation energy[2].Previous studies also indicated that nuclear dissipation increases with an increase in the Coulomb factor ($Z_P \cdot Z_T$) and decreases with increase in the entrance channel mass asymmetry. It was also observed that a higher number of neutrons are emitted at high excitation energy, thereby enhancing the system's stability against fission [5].The observation of these experimental results motivates us to do more systematics study in this field. Particularly, we have studied different isotopes of Actinium (^{213}Ac, ^{215}Ac, ^{217}Ac), Francium (^{213}Fr, ^{215}Fr, ^{217}Fr),Radium (^{212}Ra, ^{214}Ra, ^{216}Ra), and Radon(^{210}Rn, ^{212}Rn, ^{214}Rn, ^{216}Rn), investigate the features of fusion-fission dynamics in shell closed nuclei($N_c = 126$).Experimental data of Francium,Radium and Radon have been taken from given Ref.[2,3,4].Using systematics, we will compute the pre-scission neutron multiplicity in the present work and compare it with available experimental data.

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2. Systematics

The systematics used in our calculations to get the pre-scission neutron multiplicity is based on the Ref.[6]. We have incorported the shell correction energy(δW) into the excitation energy using the NRV-JINR web application.

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

Where E^* is the excitation energy,$\tilde{E}^*$ is the liquid-drop excitation energy and (δW) is the shell correction which is a function of Z and A.

We have calculated pre-scission neutron multiplicity by using this given expression:

$$\begin{aligned}\nu_{\rm pre}(A, \tilde{E}^*) = &- 10.64 + 0.0979A - 0.0154\tilde{E}^* \\ &- 0.000234A^2 + 0.000305A\tilde{E}^*\end{aligned} \tag{2}$$

By using this expression, we calculated $\nu_{\rm pre}$ for ^{212}Rn, ^{213}Fr, ^{214}Ra and ^{215}Ac systems and add error of $\Delta\nu_{\rm pre} = \pm 6\%$.

3. Theoretical Studies

In our present study, we have calculated the $\nu_{\rm pre}$ for four different compound systems by using the systematics formula given by Ref.[6]. All these systems are shell closed nuclei and shell effect apears at excitation energy($E^* \leq 50$ MeV) of each system in pre-scission neutron

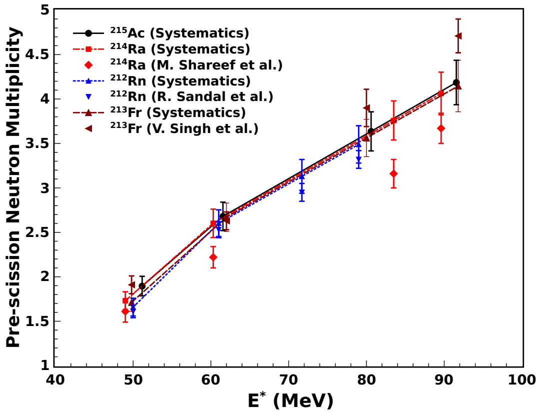

FIG. 1: Variation of $\nu_{\rm pre}$ with E^* for different shell closed odd and even compound nuclei.

multiplicity. Shell effect may wash out with increasing E^* .

From Fig.1 we can observe that the experimental ($\nu_{\rm pre}$) of odd compound nuclei is higher than that of even compound nuclei at higher excitation energies whereas the systematics data matches very well with experimental results at lower energies.As we know from the past studies that shell effect disappears with increasing E^* (beyond 50MeV), we have considered this in our calculations and only added shell corrections at lower values of E^* i.e. $E^* \leq 50\,\mathrm{MeV}$.

From Fig.2 we observed that $\nu_{\rm pre}$ of odd compound nuclei is higher than even compound nuclei at 1.45 N/Z value of all systems and after this value $\nu_{\rm pre}$ increases suddenly with higher N/Z ratio.In our study, we compared systematics calculation of Actinium with experimental result of [2,3,4].

4. Conclusion

Our present study suggests that shell closure and N/Z parameter are playing crucial role in fusion-fission dynamics at lower excitations energies. Furthermore, we have seen these impacts are higher for odd compound nuclei in comparison to even compound nuclei.Neutron multiplicity drastically decreases for the shell closed nuclei and increases as the N/Z ratio increases. To understand how these

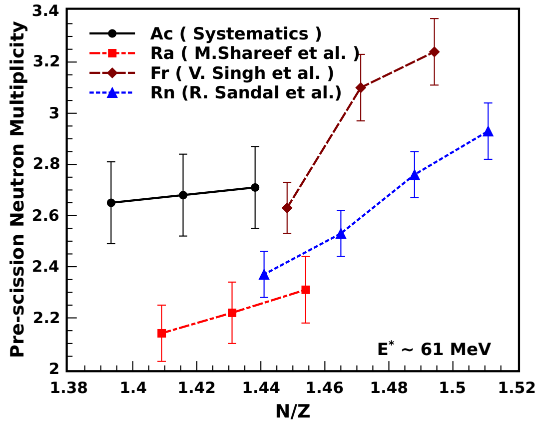

FIG. 2: Variation of $\nu_{\rm pre}$ with N/Z ratio around 50MeV excitation energy for each compound nuclei.

parameters work together, more systematics calculations are in progress.

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