Entrance channel dependence on Pre scission neutron multiplicities

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Introduction

The systematic study of the dependence of pre scission neutron multiplicity on different entrance channel parameters in heavy ion induced fusion fission reactions is a topic of greater importance. The effect of the entrance channel parameters, such as mass asymmetry, fissility, charge product ($Z_P Z_T$), and N/Z ratio on pre scission neutron multiplicity (n_{pre}) has not yet been understood clearly. The n_{pre} is found to be smaller for a symmetric entrance channel than an asymmetric entrance channel populating the same compound nuclei (CN) [1]. The formation of the compound nucleus with varying spin distributions is attributed to the smaller n_{pre} in the symmetric entrance channel. However, a contradictory observation is also found. The n_{pre} is larger for symmetric systems than the asymmetric systems [2, 3] forming the same CN. The higher n_{pre} of the symmetric system is explained by the longer time required for the process of formation of CN. Further, the n_{pre} is found to increase with increasing in N/Z of CN for certain reactions [4].

In the present work, we have considered the recently measured prescission neutron multiplicities of compound nuclear reactions [5–7], induced by the same projectile on different target nuclei, to explore the dependence of entrance channel parameters on n_{pre}.

Present study

The measured n_{pre} for the ^{30}Si induced reactions is taken from the literature. The entrance channel parameters such as charge product ($Z_P Z_T$), N/Z ratio of CN, mass asymmetry(α), Businaro-Gallone critical mass asymmetry (α_{BG}) of these reactions are considered for the analysis. These parameters for the system under study are tabulated in the table I.

TABLE I: The entrance channel parameters for the reactions considered for the analysis.

Reaction	CN	$Z_P Z_T$	N/Z	α	α_{BG}	Ref.
$^{30}Si + ^{178}Hf$	^{208}Rn	1008	1.419	0.712	0.859	[5]
$^{30}Si + ^{182}W$	^{212}Ra	1036	1.409	0.717	0.868	[6]
$^{30}Si + ^{184}W$	^{214}Ra	1036	1.432	0.72	0.866	[6]
$^{30}Si + ^{186}W$	^{216}Ra	1036	1.455	0.722	0.865	[6]
$^{30}Si + ^{197}Au$	^{227}Np	1106	1.441	0.736	0.885	[7]

Result and Discussion

The variation of n_{pre} with excitation energies (E^*) for the reactions under consideration is plotted in the figure 1. Out of these measurements, we have considered the n_{pre} for particular excitation energy and dependence on the entrance are studied. The n_{pre} is plotted against the N/Z ratio of compound nucleus, $Z_P Z_T$, and mass asymmetry is shown in figure 2. Further, we have calculated the

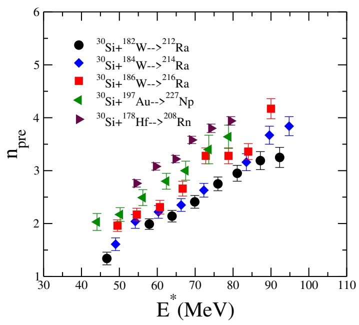

FIG. 1: The variation of n_{pre} with E^*.

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spin distribution of each reaction using CCFULL to find the average angular momentum populated in each reaction and the values are listed in the table II.

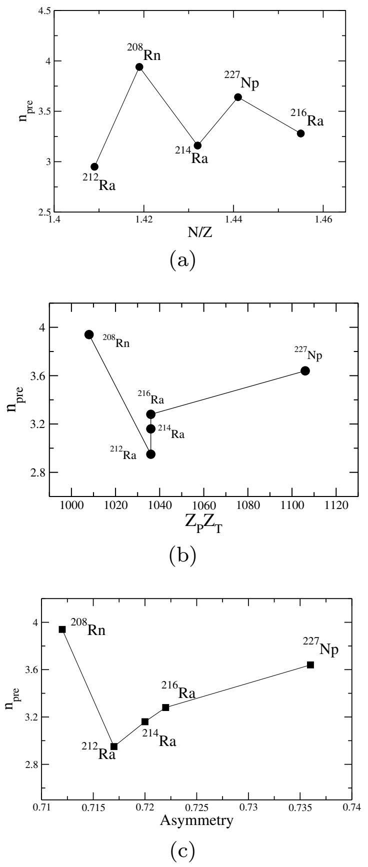

FIG. 2: Variation of n_{pre} with (a)N/Z ratio,(b) $Z_P Z_T$, and (c) α(the lines are guides for the eye).

TABLE II: The selected excitation energies of reactions, Qvalue, and average angular momentum calculated by CCFULL.

Reaction	CN	E^*	Q value	$< l >$	n_{pre}
$^{30}Si +^{178} Hf$	^{208}Rn	79.4	-67.215	45.9	3.94
$^{30}Si +^{182} W$	^{212}Ra	81.1	-72.482	47.8	2.95
$^{30}Si +^{184} W$	^{214}Ra	83.5	-70.234	46.7	3.16
$^{30}Si +^{186} W$	^{216}Ra	78.8	-70.235	47.1	3.28
$^{30}Si +^{197} Au$	^{227}Np	78.8	-88.136	54.5	3.64

For the reaction $^{30}Si +^{178} Hf- >^{208} Rn$, which has a lower N/Z ratio than the ^{214}Ra, ^{227}Np, and ^{216}Ra reactions, the n_{pre} is noticeably higher. Furthermore, in comparison to the reactions of ^{212}Ra, ^{214}Ra, and ^{216}Ra, the ^{227}Np reactions, which has a higher $Z_P Z_T$, shows a higher n_{pre}. Conversely, for ^{208}Rn reactions which have a lower $Z_P Z_T$ compared to ^{212}Ra, ^{214}Ra, and ^{216}Ra reactions, n_{pre} is also higher. Moreover, for ^{212}Ra, ^{214}Ra, ^{216}Ra, and ^{227}Np reactions, n_{pre} increases with mass asymmetry. However, the ^{208}Rn reaction, which is more symmetric, has a higher n_{pre} compared to other reactions. This may be due to the factors of the CN and fission fragments to attain stabilization, during which the probability of pre scission neutron emission is expected to increase. As can be seen from table II, the ^{208}Rn reaction tends to populate at the lowest spin state. Also, ^{208}Rn reaction having the highest Q value out of these reactions, the projectile requires less energy to populate the compound nuclei at same excitation energies than other reactions considered here and may lead to a complete equilibration process, thereby emitting more neutrons. Evidently, further studies on n_{pre} are required to explore the dependence of entrance channel parameters.

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References

[1] Varinderjit Singh et al. PRC 86, 014609, 2012

[2] Hardev Singh et al., PRC 78, 024609 (2008).

[3] Hardev Singh et al., PRC 76, 044610 (2007).

[4] Rohit Sandal et al. PRC 87, 014604 (2013)

[5] Neeraj Kumar et al. Physics Letters B 814, 136062 (2021)

[6] M. Shareef et al. PRC 107, 054619 (2023)

[7] M. Shareef et al. PRC 99, 024618 (2019)