Measurement of Neutron Multiplicity to investigate the role of entrance channel and E/A in Nuclear Dissipation

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Introduction

Nuclear dissipation is evident in the heavy-ion reaction dynamics which hinder the fusion-fission process [1-4]. The measured neutron multiplicity shows a considerable increase when compared with the predictions of the statistical model is a signature of nuclear dissipation. It has also been observed that the entrance channel influences the nuclear dissipation and hence effects the neutron multiplicity and evaporation residues, if entrance channel mass asymmetry **α** = **(At-Ap)/(At+Ap)** is smaller than the critical Businaro-Gallone mass asymmetry **α(BG)** for the compound nucleus [2]. It would be interesting to measure the neutron multiplicity and observe the dissipation for the system having same entrance channel mass asymmetry populating different compound nuclei, and also to observe the neutron multiplicity for various systems having different entrance channel mass asymmetry, less than **α(BG)**, populating same nucleus and to see the variation of neutron multiplicity with various **α** less than **α(BG)**. It would also be interesting to see the nature of dissipation with same lab energy but different E/A values. Proton shell closure effect also needed to be explored.

Studies show that pre-scission neutron multiplicity is deviating largely from the predictions of statistical model [1-3]

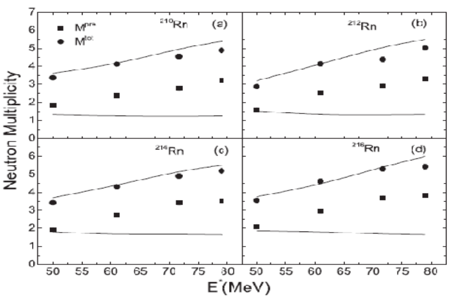

Fig.1: Comparison of experimental and theoretical neutron multiplicities for $^{16,18}O+^{194,198}Pt$.

The symmetric channel has larger multiplicity as compare to asymmetric entrance channel populating same compound nucleus (CN). This shows that entrance channel with smaller mass asymmetry having larger dissipation [2].

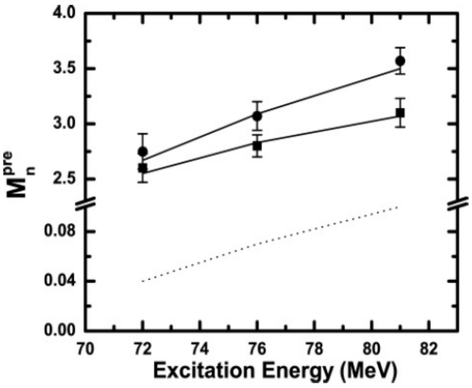

Fig.2: Comparison of the pre-scission multiplicity for symmetric and asymmetric channels for $^{19}F+^{178}Hf$ & $^{16}O+^{181}Ta$.

Studies also show that the shell closure in the CN affects the dissipation [3]. CN with shell closure (N=126) have weaker dissipation as compare to the one which is not having shell closure. It has been observed that dissipation does not depend on N/Z value [1].

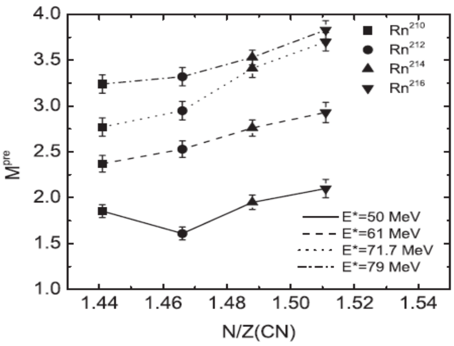

Fig.3: Comparison of the pre-scission multiplicity for CN having different N/Z values at different energies.

It has also been observed that there exists some threshold (energy) above which dissipation comes into the picture and it increases with increasing energy [4].
All these factors show that the nature of the dissipation needs to be explored so that it can be quantified and by including its effect a dissipative dynamical model can be developed which can reproduce the experimental results. In this way on can reduce the gap between the theoretical predictions and the existing realities (experiments).

Theoretical Analysis

In the present work we have calculated the pre-scission neutron multiplicities (ν_{pre}) for (^{204}Pb, ^{202}Pb, ^{198}Pb, ^{192}Pb) systems using statistical model code JOANNE2. This code also incorporates the pre-saddle delay (τ_{pre}) and saddle to scission transition time (τ_{ssc}) which constitutes total fission time scale [5]. Enhancement in the fission time scale is of course one of the signatures of nuclear dissipation. τ_{pre} and τ_{ssc} values in the code can be used as free parameter to reproduce experimental values of particle multiplicities. We have used the values of these parameters as reported in [5].
A comparison of calculated ν_{pre} for ^{202,198,192}Pb system populating at same excitation energy is shown in Fig.4. The ν_{pre} values for higher mass system are higher at particular excitation energy while for a given system it is increases with excitation energy.

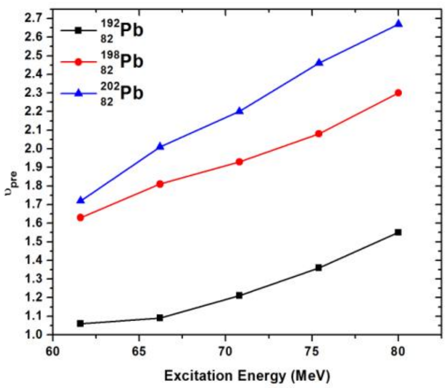

Fig.4: Comparison of calculated values of ν_{pre} for ^{202,198,192}Pb system as a function of excitation energy.

The ν_{pre} is also plotted as a function of E/A at Ex=70.8 MeV for different systems and is shown in Fig.5. ν_{pre} changes randomly with E/A values, no specific trend is found.

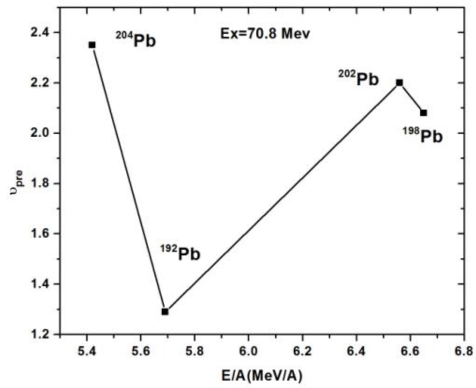

Fig.5: Calculated ν_{pre} for ^{204,202,198,192}Pb systems at Ex=70.8 MeV as a function of E/A.

Conclusion

The ν_{pre} values are calculated using τ_{pre}=9x10^{-21}s and τ_{ssc}=22x10^{-22}s [5]. The ν_{pre} is higher for higher mass no even if the entrance channel mass asymmetry (α) is smaller. This shows that the compound nucleus mass is more sensitive parameter than 'α' which affects the ν_{pre}. For a particular excitation energy ν_{pre} is not showing any specific behavior with E/A values.
The calculated ν_{pre} may reproduce the experimental pre-scission neutron multiplicity by incorporating fission delay in the statistical model (JOANNE2) and if not then either we have to choose different values of τ_{pre} and τ_{ssc} for our system or some other factors are effecting the dissipation and hence ν_{pre}. Proton shell closure may be one of the possible factors in this case.

References

[1] Rohit Sandal et al. PRC 87, 014604(2013).
[2] Hardev Singh et al.PRC 78, 024609 (2008).
[3] Varinderjit. Singh et al.PRC 86,014609 (2012).
[4] M Thoennessen et al, PRL, 25, 59,(1987).
[5] J.P. Lestone et al, PRL, 2245-2248,70(1993)