Statistical model calculations for super-heavy compound nuclei $^{260}Sg_{106}$ and $^{266}Ds_{110}$

Shruti[1]*, B.R. Behera[1], Santanu Pal[2]
[1]*Department of Physics, Panjab University, Chandigarh-160014, INDIA*
[2]*CS-6/1, Golf Green, Kolkata 700095, India (Formerly with VECC, Kolkata)*

Introduction

Fission dynamics has been extensively investigated in heavy compound nuclei by means of fusion-fission reactions. Such studies can provide information on the dynamics of nucleus-nucleus collisions, which will help in the optimal selection of target-projectile combinations and bombarding energies to maximize the formation probability of super-heavy nuclei as evaporation residue [1-3]. These studies are rather challenging as the survival probability of SHE is strongly inhibited due to the interplay of equilibrated and dynamical non equilibrated fission processes. Quasi-fission happens to be the most important mechanism that prevents the formation of SHE in the fusion of two massive nuclei. It has been observed that measurements of fission fragment angular distribution, mass distribution and mass-energy distribution (TKE) helps in distinguishing FF and QF processes but these probes are not sufficient to distinguish the above two components. Pre-scission neutrons are extensively used to understand fission dynamics.
The main advantage of using this probe is the absence of the coulomb barrier and also it serves as a clock to measure the time scale of the reaction being shorter for QF (10^{-20} sec) as compared to FF time scale which is generally in the range of 10^{-20} sec to 10^{-16} sec.
In the present work we are reporting theoretical pre-scission neutron multiplicity values (M_{pre}) for ^{260}Sg and ^{266}Ds super-heavy CN populated by the reactions of ^{52}Cr + ^{208}Pb and ^{58}Ni + ^{208}Pb at different values of lab energies. Recently M. Thakur et al. calculated neutron multiplicitiy for near super-heavy CN ^{256}Rf which is 0.25 including a saddle-to-scission contribution of 0.21 [4]. Y. Aritomo et al. analyzed the experimental data of M_{pre} for one of the above mentioned system of ^{58}Ni + ^{208}Pb but at much higher excitation energy of compound nucleus E*= 185.9 MeV where the experiment was performed by DeMoN neutron array at Louvain-LA-Neuve cyclotron facility [3].

Electronic address: shrutinarang.sn@gmail.com

Statistical Model Calculations

The statistical model has been widely used to understand the decay of the CN. Statistical model usually deals with the average properties of nuclei having an excitation energy and angular momentum. This model assumes that all the possible decay channels are equally likely to be populated and are thus governed by the factors such as the density of final states and barrier penetration factors. In this theoretical framework of statistical model code neutron multiplicity calculations has been performed considering that the system forms a fully equilibrated CN and there is negligible contribution from non-compound nuclear processes (e.g. QF, DIC, PEF). The main ingredients of statistical model are 1) level density parameter, 2) Bohr-Wheeler (BW) fission width and 3) Kramer's fission width. The standard form of level density formula can be written as [5]:

$$\rho(E^*, \iota) = \frac{2\iota+1}{24}[\frac{\hbar 2}{2\mathfrak{I}}]^{\frac{3}{2}} \frac{\sqrt{a}}{E^*2} \exp(2\sqrt{aE^*})$$

here $\mathfrak{I}$ is the rigid body moment of inertia and ℓ is the angular momentum of the CN, 'a' is the level density parameter and is related to the nuclear temperature 'T' according to the Fermi gas model as E*= aT^2. Bohr-Wheeler fission width is used in order to obtain fission probability and is given by the equation [5]:

$$\Gamma_{BW} = \frac{1}{2\pi\rho(E^*)} \int_0^{E^*-V_B} d\varepsilon \rho^*(E^* - V_B - \varepsilon)$$

The Kramer's fission width in which effect of dissipation is included is given as [6]:

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

In this paper we undertake the theoretical calculations for $^{52}Cr + {}^{208}Pb$ and $^{58}Ni + {}^{208}Pb$ reactions based on statistical model code approach and calculated the values of pre-scission neutron multiplicities (M_{pre}) with lab energies ranging from 270MeV to 345MeV.

Results and Discussion

In the present study we are reporting the M_{pre} values for the super heavy compound nuclei ^{260}Sg at lab energies of (E_{lab}) = 270,275,280,285 MeV and for ^{266}Ds at E_{lab} values of 330, 335,340,345 MeV. The pre-scission neutron multiplicity values are calculated for these two systems using both the BW and Kramer's widths for the different values of reduced dissipation strength 'β'. Fig 1 and 2 shows the statistical model predicted results only since no experimental data exist for M_{pre} for both these systems. These are the exploratory calculations and thus provides an estimation of pre-scission neutron multiplicities that can be obtained from the planned experiment.

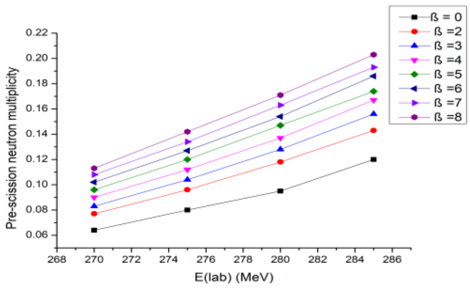

Fig.1 Pre-scission neutron multiplicities calculated using the BW fission width and Kramer's width for the $^{52}Cr + {}^{208}Pb \rightarrow {}^{260}Sg$ system.

The reduced dissipation strength β is usually treated as a free parameter and its value is obtained from fitting of experimental data. From the graph it is clear that M_{pre} values increases with increasing values of lab energies because at higher excitation energies the emission of particles (n, p, α) becomes significant and is strongly related to reduced dissipation strength. Also the SM calculations for super-heavy nuclei are highly speculative where the fission widths are calculated under the assumption that the LDM barrier is much larger than the shell correction.

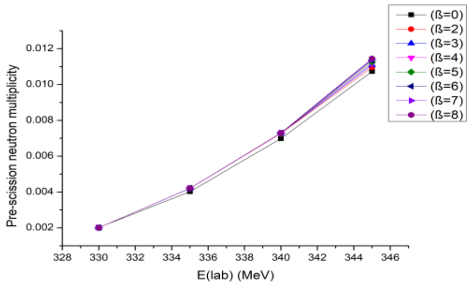

Fig. 2 Pre-scission neutron multiplicities calculated for the $^{58}Ni + {}^{208}Pb \rightarrow {}^{266}Ds$ system using BW fission width and Kramer's width

For super-heavy nuclei there is hardly any LDM barrier hence for the location of shell model barrier and its height shell model calculations are required. The combined dynamical Langevin calculations with the statistical model must be taken into consideration while calculating the neutron emission.

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Electronic address: shrutinarang.sn@gmail.com