Effect of fission barrier shell correction on fission dynamics

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Introduction

Measurement of pre-scission neutron multiplicity (ν_{pre}) provides important insight about the time scales associated with fission [1, 2] and has been an excellent tool to study the dissipative mechanism involved. Dissipation is included in statistical model calculation by considering a constant dissipation coefficient β to explain the experimental ν_{pre}. However a consistent description of the friction over wide mass range of the fission nuclei remains unaccomplished [3, 4]. In Langevin dynamical model calculation, the dissipation coefficient is not a free parameter but is calculated as a function of the shape of the fissioning nuclei. In this work, we have analyzed ν_{pre} for fourteen reactions (detail given in table I), distributed over a compound nucleus mass (A_{CN}) of $168 - 248$, using Langevin dynamical model to obtain a consistent description of dissipation without many free parameters.

Result and Analysis

For the analysis, dynamical evolution of the nuclear fission in one degree of freedom (elongation parameter c) has been considered. Funny Hills shape parametrization has been used for describing the shape of the nucleus and the time evolution of c is taken from the Langevin equations [11].

TABLE I: Details of reactions used in the present study.

S.N.	Reaction (CN)	ref
1	^{18}O + ^{150}Sm (^{168}Yb)	[2]
2	^{19}F + ^{159}Tb (^{178}W)	[2]
3	^{19}F + ^{181}Ta (^{200}Pb)	[2]
4	^{18}O + ^{186}W (^{204}Pb)	[6]
5	^{12}C + ^{194}Pt (^{206}Po)	[7]
6	^{18}O + ^{192}Os (^{210}Po)	[2]
7	^{1}H + ^{238}U (^{239}Np)	[8, 9]
8	^{7}Li + ^{232}Th (^{239}Np)	[10]
9	^{11}B + ^{232}Th (^{243}Am)	[5]
10	^{12}C + ^{232}Th (^{244}Cm)	[5]
11	^{12}C+^{204}Pb (^{216}Ra)	[2]
12	^{16}O + ^{197}Au (^{213}Fr)	[2]
13	^{16}O + ^{232}Th (^{248}Cf)	[5]
14	^{11}B+^{237}Np (^{248}Cf)	[5]

$$\frac{dp}{dt} = -\frac{p^2}{2}\frac{\partial}{\partial c}\left(\frac{1}{\mathcal{M}(c)}\right) - \frac{\partial F}{\partial c} - \eta(c)p + g\Gamma(t),$$
$$\frac{dc}{dt} = \frac{p}{\mathcal{M}(c)} \qquad (1)$$

Here, p is the momenta conjugate to c and $\mathcal{M}(c)$ is the moment of inertia which is function of the shape of the nucleus. One body dissipation with wall and window friction is used for all the calculations. The contribution of wall friction (k_s) was varied in the calculation in order to reproduce the experimental ν_{pre} values and all other parameters were kept unchanged.

Calculated results are compared with the available experimental ν_{pre} and are shown in fig.1. The value of k_s, required for the best agreement with experimental result is men-

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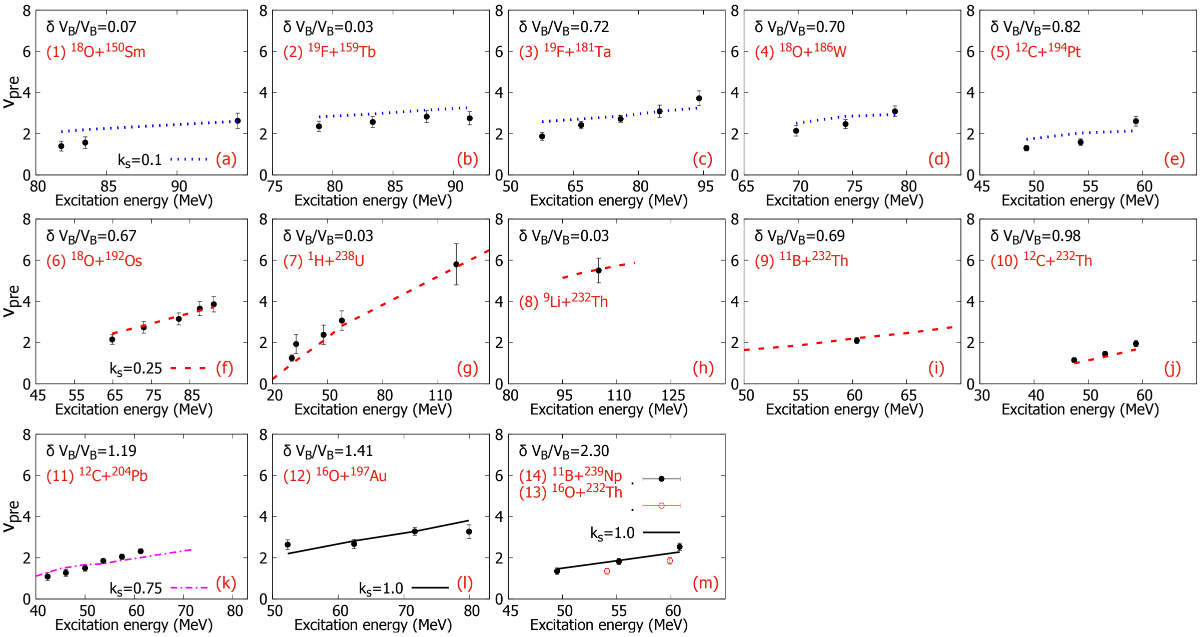

FIG. 1: Experimental and calculated pre-scission neutron multiplicity for reactions, mentioned in Table I. Symbols represent experimental data and lines show calculated values. Blue dot and red dashed lines show calculations with $k_s = 0.1$ and 0.25. Magenta dot dashed line and black solid lines show calculations with $k_s = 0.75$ and 1.0, respectively.

tioned in the plots. It was observed that no single value of k_s could explain all the experimental ν_{pre} data over the entire studied mass range. For reactions, forming light compound nuclei ($A_{CN} < 210$) small contribution from wall (k_s=0.1) could explain the experimental data as can be seen in fig.1(a-e). In case of reactions with $A_{CN} > 210$, higher value of $k_s \geq 0.25$ was needed. The required value of k_s in $A_{CN} > 210$ region was not same for all the fissioning nuclei and amount of the shell correction on the fission barrier (δV_B) was found to play an important role. The value of fractional change in liquid drop barrier due to shell correction ($\delta V_B/V_B$, where V_B is liquid drop barrier and δV_B is shell correction in the barrier) plays a decisive role. These values are mentioned with each plot. For reactions with $\delta V_B/V_B < 1.0$ and $A_{CN} > 210$, $k_s = 0.25$ explained experimental ν_{pre} irrespective of the CN mass in the mass range of 210 – 244 (shown in fig. 1(f-j)). On the other hand, if $\delta V_B/V_B > 1.0$ a higher value of $k_s(0.25 \leq k_s \leq 1.0)$ was needed. These reaction are shown in Fig.1(k-m). The value of k_s is 0.75 for ^{19}F+^{197}Au which has $\delta V_B/V_B = 1.19$ (Fig. 1(k)) but for higher $\delta V_B/V_B$, $k_s = 1.0$ is needed. This study indicates effect of shell correction on the disipative mechanism of nuclear fission.

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