# Fission width for different mass fragmentation from Langevin equations

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At present dynamical models are necessary to calculate the fission fragment mass distribution in heavy-ion induced fusion-fission reactions [1]. Alternatively, for a faster calculation, the fragment mass distribution can be obtained from a statistical model provided the fission probabilities corresponding to different mass divisions of fragments are known. With this objective, we calculate the fission widths for different fragment-mass divisions using the two dimensional Langevin equations. We then propose a Kramers-like formula for fission into specific mass ratios and compare it with the widths from the Langevin dynamical calculation.

We use two-dimensional Langevin equations[1]

$$\frac{dp_i}{dt} = -\frac{p_j p_k}{2}\frac{\partial}{\partial q_i}\left(m^{-1}\right)_{jk} - \frac{\partial V}{\partial q_i} -\beta_{ij}\left(m^{-1}\right)_{jk} p_k + g_{ij}\gamma_j\left(t\right), \quad (1)$$

$$\frac{dq_i}{dt} = \left(m^{-1}\right)_{ij} p_j$$

where $q_1$ and $q_2$ stands for the elongation ($c$) and mass asymmetry parameter ($\alpha$) and $p_i$s represent the respective momentum. $V$ is the finite-range rotating liquid drop model potential and $m_{ij}$ and $\beta_{ij}$ are the shape-dependent collective inertia and dissipation tensors respectively. The time-correlation property of the random force follows the relation

$$< \gamma_k(t)\gamma_l(t') >= 2\delta_{kl}\delta(t-t'). \quad (2)$$

The strength ($g_{ij}$) of the random force is related to the compound nuclear temperature

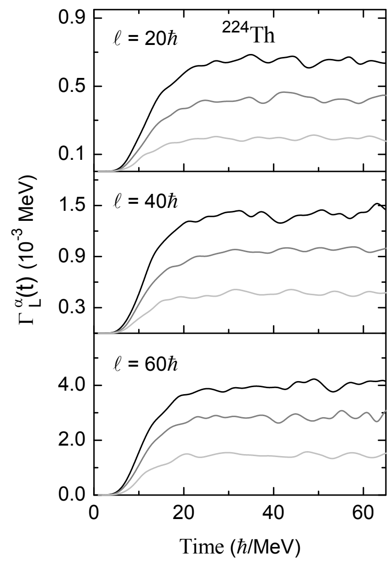


FIG. 1: $\Gamma_L^\alpha$ as a function of time for $\alpha = 0.0$ (black lines), 0.35 (gray lines) and 0.60 (light-gray lines).

($T$) and dissipation through the fluctuation-dissipation theorem. $T$ is determined from the excitation energy using a shape-dependent level density parameter. The Langevin equations are solved to get the asymmetry coordinate distribution along the scission line for the fission events. The fragment mass distribution is subsequently obtained from this asymmetry coordinate distribution. The fission width ($\Gamma_L^\alpha$) for a specific mass ratio is obtained by counting the number of events contributing to that mass ratio. In Fig.1 the $\Gamma_L^\alpha$ is shown for $^{224}$Th at an initial $T$ equal to $2MeV$. It is evident from this figure that $\Gamma_L^\alpha$ reaches a stationary value after a certain interval for all spin and asymmetry values.

Guided by the Kramers' work [2] on fission

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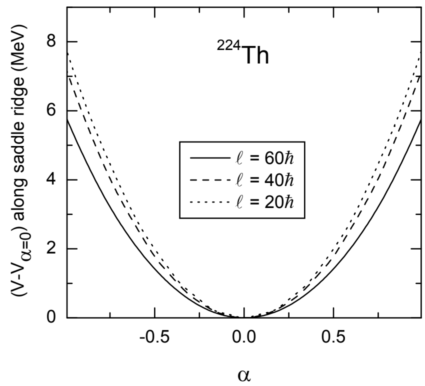


FIG. 2: Potential profile along the saddle ridge for different values of $\ell$.

width for one-dimensional motion, we next propose the following fission width for a specific fragment mass asymmetry

$$\Gamma_K = C \exp\left(-V_b/T\right) \tag{3}$$

where fission of a given spin $\ell$ is considered. The fission barrier $V_b$ is the barrier for the particular mass asymmtery $\alpha$ as shown in Fig.2. It is given by the profile along the saddle ridge (locus of conditional saddle points). $T$ is the temperature at the ground state configuration of the compound nucleus while $C$ is a constant which can be obtained through proper normalization. In order to verify if Eq.(3) correctly represents the stationary widths shown in Fig.1, the ratios of these stationary widths with respect to the width corresponding to $\alpha = 0$ are then plotted as a function of $\alpha$ in Fig.3. The same ratios calculated using Eq.(3) are also plotted in Fig.3. We find that Eq.(3) agrees remarkably well with the Langevin dynamical results. This opens up the possibility of performing statistical model calculations for fission fragment mass distribution where the fission widths for specific fragment mass ratios can be used at par with other competing decay channels such as particle and $\gamma$ evaporation.

In conclusion we have shown that the fission width corresponding to different fragment mass divisions of a highly excited heavy nucleus can be obtained from the Langevin dynamical calculation and its relative magnitude can be predicted from a equation like the Kramers' formula.

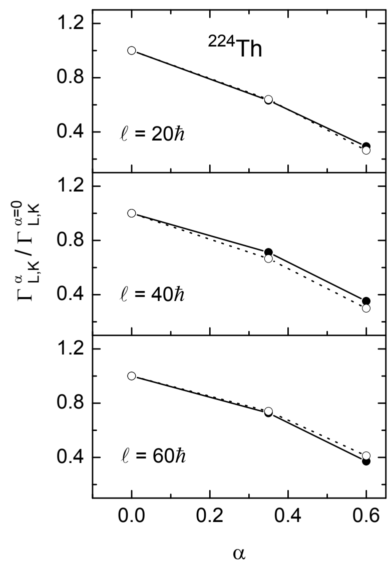


FIG. 3: Fission width ratios $\Gamma_L^{\alpha}/\Gamma_L^{\alpha=0}$ (filled symbols) and $\Gamma_K^{\alpha}/\Gamma_K^{\alpha=0}$ (open symbols). Lines are drawn to guide the eye.

## References


[1] A. V. Karpov *et al.*, Phys. Rev. C **63**, 054601(2001).

[2] H. A. Kramers, Physica (Amsterdam) **7**, 284 (1940).