Fission Transient Times from Fission Probabilities of Neighboring Isotopes

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The evolution of a fissioning nucleus from an assumed spherical shape towards the fission saddle, and eventually to the scission point, has been studied extensively. If the transient time (τ_D) that a nucleus takes to evolve from a ground state shape to the saddle point is longer than the characteristic time for compound nucleus decay ($\tau_{\rm CN}$), then the fission probability is expected to be suppressed. Since the transient time has a strong and direct effect on the fission probability, a value for τ_D can be determined from an analysis of the fission probabilities.

We present a new method to estimate the fission transient time by utilizing the cumulative fission probabilities of neighboring Os isotopes. The fission probabilities were determined as the ratio of the measured fission cross sections to the Bass Model fusion cross sections.

Assuming a step function for the transient time effects, the fission decay width can be written as

$$\Gamma_f = \Gamma_f^{(\infty)} \int_0^\infty \zeta(t)\, \frac{N(t)}{N_0}\, \lambda_{\rm CN}\, dt = \Gamma_f^{(\infty)} \int_{\tau_D}^\infty \frac{N(t)}{N_0}\, \frac{dt}{\tau_{\rm CN}}, \tag{1}$$

where $\zeta(t) = 0$ ($t<\tau_D$) and $\zeta(t) = 1$ ($t \geq \tau_D$); τ_D is the fission transient time; $N(t)$ is the number of remaining compound nuclei at time t (starting with N_0 compound nuclei at t=0); $\lambda_{\rm CN}$ is the total decay constant of the compound nucleus, and $\tau_{\rm CN} = 1/\lambda_{\rm CN}$ is the compound nucleus lifetime; $\Gamma_f^{(\infty)}$ denotes the transition-state fission width, or the fission width expected when no transient time effects are present.

We consider a decay with only two open channels, fission and n emission. Starting from the compound nucleus (Z, A) with excitation energy E, multiple chance fission contributes to the overall fission cross section as:

$$\sigma_f = \sum_{i=0} \sigma_f^{(i)} = \sum_{l=0}^{l=l_{\max}} \sum_{i=0} \sigma_l P_f^{(i)}(l) \tag{2}$$

where $\sigma_f^{(i)}$ is the fission cross section after i neutrons have been emitted, σ_l is the angular momentum distribution of the fusion cross section, and $P_f^{(i)}(l)$ is the fission probability after the emission of i neutrons from a compound nucleus of initial angular momentum l and for a finite value of τ_D [1].

A global fit procedure based upon these concepts has been constructed [2] and applied to the fission cross sections in Fig. 1. The fits of the total fission cross section for the five neighboring $^{185-189}$Os compound nuclei (produced in ^{3}He/^{4}He-induced reactions on separated isotope W targets) are shown by the solid line. The first-chance

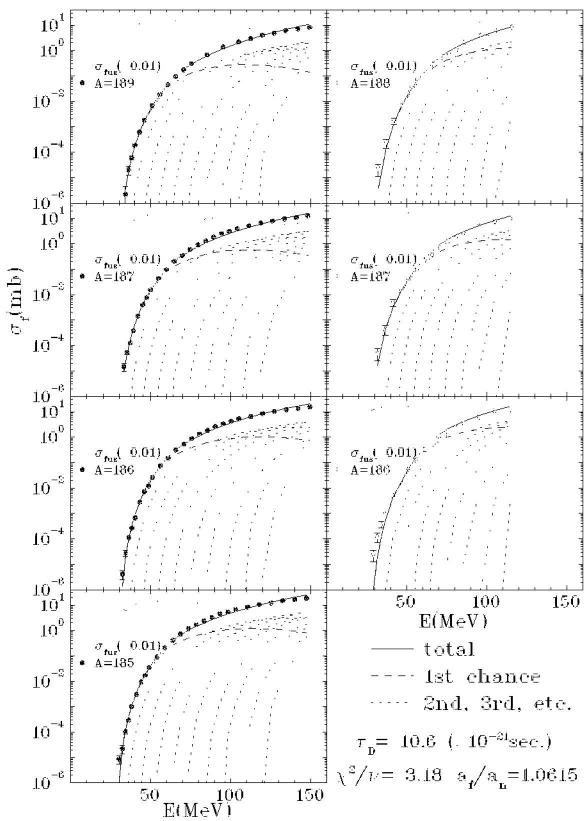

FIG. 1. Measured fission excitation functions for five adjacent Os compound nuclei produced in ^{3}He($\bullet$)/^{4}He($\diamond$)-induced reactions on W targets. The fusion cross sections ($\times$) are the Bass Model predictions. For each excitation function, the contributions from 1st, 2nd, 3rd, $\cdots$ chance fission to the total fit (solid line) are shown. The τ_D value obtained from this simultaneous fit to seven excitation functions is $\approx 10\times10^{-21}$ sec, and a_f/a_n is 1.062.

fission cross section is given by the dashed lines. Good fits give a transient time τ_D of $< 25\times10^{-21}$ seconds, and the best fit gives $\tau_D \approx 10\times10^{-21}$ seconds. This value is consistent with the recent τ_D values reported in [3–6].

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