Scaling Laws, Shell Effects, and Transient Times in Fission Probabilities *

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In a recent paper [1] we analyzed the intermediate mass fragment excitation functions for an extensive range of fragment atomic numbers, obtained for four different compound nuclei. A special way of plotting these data permits the ready observation of deviations from the transition state rates as a departure from a straight line. For over 70 excitation functions, the lack of deviations from the transition state null hypothesis both as a function of fragment Z and excitation energy led to the conclusion that the transition state rates were closely obeyed, and that no substantial transient time effects were present in these systems over the covered experimental energy and lifetime ranges.

In this work we extend the method to the fission of systems in the lead region, where lies the dramatic onset of the shell effects, and for which transient time effects have been claimed. Specifically we show the following: a) fission excitation functions for nuclei ranging from A=186 to 213 are rigorously scalable in terms of the transition state rates once the shell effects are accounted for; b) the shell corrections Δ_{shell} obtained from the data are in excellent agreement with those obtained from the ground state masses.

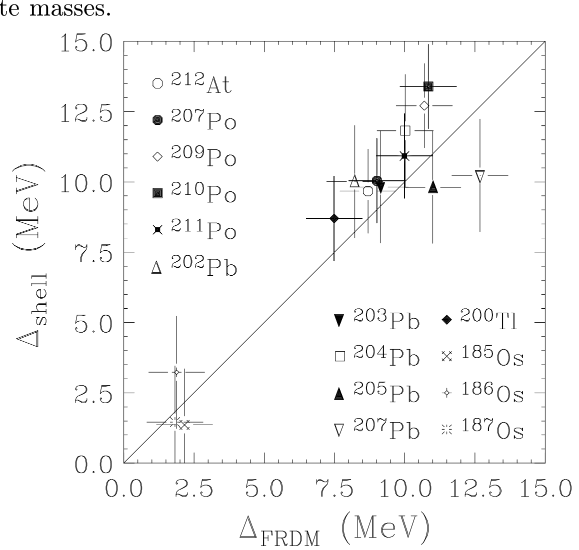

FIG. 1. Shell corrections Δ_{shell}, for the daughter nuclei (A_{CN} - n), extracted from fits to the fission excitation functions, plotted against the values determined from the ground state masses [2]. The diagonal line is to guide the eye.

In fig. 1 are shown the values of the ground state shell effect Δ_{shell} of the daughter nuclei after neutron emission, obtained by fitting the fission excitation functions with a transition state formalism in which Δ_{shell} is included in the expression of the level density of the residual nucleus. In this figure we plot these values of Δ_{shell} versus the corresponding values obtained as the difference of the ground state mass and the corresponding liquid drop value. The observed correlation is excellent. Note that the present shell effects are obtained in a totally independent way, which, in contrast to the standard procedure [2] is completely local, namely it depends only on the properties of the nucleus under consideration.

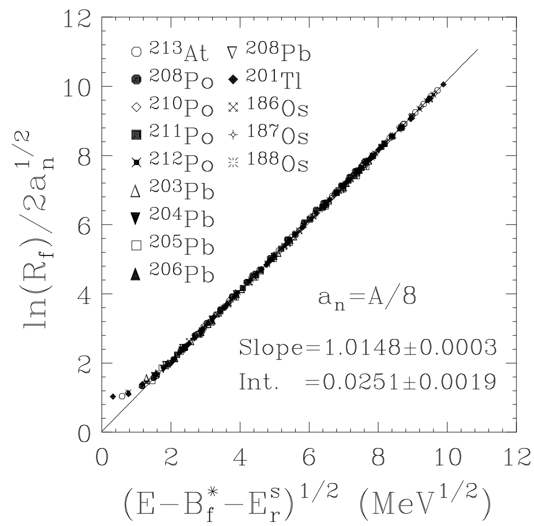

FIG. 2. The quantity $\ln(R_f)$ divided by $2a_n^{1/2}$ vs the square root of the intrinsic excitation energy over the saddle for fission of the fourteen compound nuclei indicated in the figure. The straight line is a linear fit to all but the lowest two or three data points.

As shown in fig. 2, all of the excitation functions for fourteen different compound nuclei reduce beautifully to a single straight line, according to the transition state predictions. This scaling extends well over seven orders of magnitude in the fission probability and is even better than that observed in ref.[1] for complex fragment emission, despite the fact that the systems cover a region in A and Z where shell effects vary dramatically. This indicates that the transition state fission rates hold extremely well. No evidence for the effects of transient times longer than 3×10^{-20} seconds is found.

* Excerpted from Phys. Rev. Lett. **75**, 4186 (1995).

[1] L.G. Moretto *et al.*,Phys. Rev. Lett. **74**, 3557 (1995).
[2] P. Möller *et al.*, LA-UR-3083 (1994).