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DYNAMICAL CALCULATIONS OF THE DIVISION OF IDEALIZED NUCLEI

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Dynamical Calculations of the Division of Idealized Nuclei*

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We study the dynamics of the division of nuclei idealized as incompressible uniformly charged liquid drops with constant surface tension and nonviscous irrotational hydrodynamical flow. The shape of the nuclear surface is specified with six degrees of freedom, in terms of three smoothly joined portions of quadratic surfaces of revolution (e.g. two spheroids connected by a hyperboloidal neck). The potential energy is calculated in a standard way, whereas the kinetic energy is calculated by the approximate method of Werner and Wheeler.[1-3] The resulting classical equations of motion are solved numerically.

Figure 1 illustrates for three values of the fissility parameter x the sequences of shapes from the saddle point to scission, for initial conditions at the saddle point corresponding to 1 MeV of kinetic energy in the fission mode and 1 MeV in the mass-asymmetry mode. The parameter x is defined as $\frac{1}{2}E_c^{(0)}/E_s^{(0)}$, where $E_s^{(0)}$ and $E_c^{(0)}$ denote respectively the surface and Coulomb energies of the original spherical drop (with a sharp surface); the nuclei that correspond approximately to these values of x are indicated in parentheses.[4] We observe that: (1) The time from saddle to scission increases substantially with increasing x. (2) For small values of x the motion consists primarily of a constriction of the drop's neck, whereas for large x the drop also elongates substantially. (3) The mass-asymmetric component of motion is not amplified into a large mass asymmetry during the descent as proposed by Hill[5] and by Hill and Wheeler,[6] but instead represents stable oscillations about a symmetrical division. This means that within the limitation of a parameterization that permits only binary division, the liquid-drop model does not suggest an explanation of the observed mass asymmetry in fission.

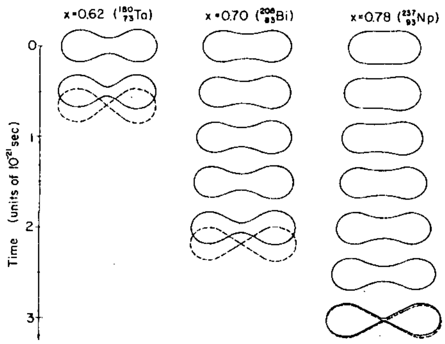

Fig. 1. Illustrations of the descent from saddle to scission.

In Fig. 2 we compare as a function of x the calculated (solid curve) and experimental most-probable total translational kinetic energies of fission fragments at infinity. (According to classical statistical mechanics, the most probable division occurs when the system starts from rest at the saddle point.) The dashed curve represents approximately the translational kinetic energy acquired by the fragments from their Coulomb repulsion after scission. The energy difference between the solid and dashed curves gives the translational kinetic energy acquired by the fragments prior to scission. The increase in this quantity as x increases above ~ 0.7 reflects the increased distance from saddle to scission and the greater pre-scission elongation at larger values of x.[7] The experimental data are most-probable (open symbols) and average (solid symbols) fragment kinetic energies from a variety of sources but include only cases in which the mass distribution is symmetrical. The calculations (with no adjustable parameters[4]) reproduce both the correct order of magnitude and the correct trend with x of the kinetic energies, but a systematic difference of about 5% is evident.

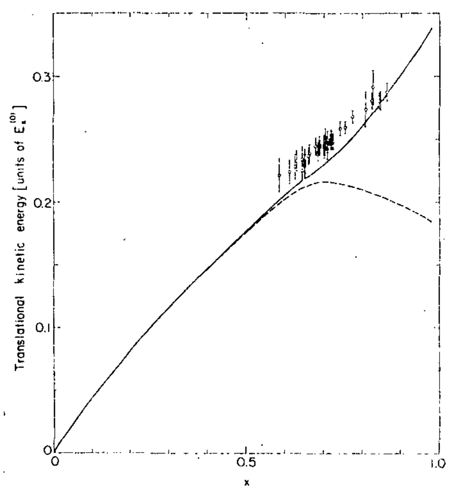

Fig. 2. Calculated and experimental fission-fragment kinetic energies.

The widths of the distributions in mass, translational kinetic energy, and excitation energy are now being calculated as functions of x.

Footnotes and references:

* This work was performed under the auspices of the U.S. Atomic Energy Commission.

1. F. G. Werner and J. A. Wheeler, unpublished manuscript.
2. J. R. Nix, UCRL-11338; J. R. Nix and W. J. Swiatecki, Nucl. Phys. 71 (1965) 1.
3. I. Kelson, Phys. Rev. 136 (1964) B1667.
4. In converting from natural liquid-drop units to conventional units, and vice versa, we use the latest semiempirical mass-formula constants of W. D. Myers and W. J. Swiatecki, in Proceedings of the Lysekil Symposium, 1966 (to be published in Arkiv Fysik).
5. D. L. Hill, Ph. D. dissertation, Princeton University, April 1951.
6. D. L. Hill and J. A. Wheeler, Phys. Rev. 89 (1953) 1102.
7. The calculated translational kinetic energies at scission for the fission of ^{236}U and ^{252}Cf essentially agree with the values deduced from experimental data on long-range alpha particles emitted during fission. See I. Halpern (preprint) and Y. Boneh, Z. Fraenkel and I. Nebenzahl, Phys. Rev. 156 (1967) 1305.