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Calculations of the Flattening of Idealized Nuclei During Head-On Collisions[*]

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When two nuclei closely approach each other they tend to flatten as a result of their mutual electrostatic forces. The amount they flatten depends upon the relative magnitudes of the electrostatic interaction (which is a function of their charges and separation) and of three of their fundamental nuclear properties: (1) stiffnesses against deformations, (2) inertias with respect to deformations, and (3) viscosities. If the electrostatic interaction is large enough, and each of these three properties is sufficiently small the nuclei will flatten appreciably; otherwise, they will remain essentially spherical. Since the liquid-drop model represents the average trends of nuclear masses in the periodic table,[1] liquid-drop stiffnesses are expected to also represent an average,[2-4] and a calculation of the flattening of colliding nuclei on the basis of the liquid-drop model should give the average flattening of nuclei throughout the periodic table. We therefore study the flattening that would be experienced by nonviscous idealized liquid drops in head-on collisions. This is done by integrating numerically the classical equations of motion describing the approach of two incompressible uniformly charged drops that are allowed to deform into spheroids and that are characterized by nonviscous irrotational hydrodynamical flow. Reference 5 contains the appropriate formulas.

In Fig. 1 the total center-of-mass kinetic energy E required during head-on collisions to bring two such idealized nuclei within range of their effective nuclear forces is plotted as a function of the atomic mass number A of the target (or projectile), for three choices of projectile (or target). [The target (or projectile) atomic number Z is taken to be related to A approximately according to the course of the line of beta stability.] The kinetic energy E is given in units of the energy V that would be required to bring two spherical drops (corresponding to infinite stiffnesses, infinite inertias, or infinite viscosities) within range of their nuclear forces, viz $V = Z_1Z_2e^2/[(R_1 + t) + (R_2 + t)]$. In this equation Z_1 and Z_2 are the target and projectile atomic numbers, e is the electronic charge, R_1 and R_2 are the target and projectile radii, and t is the distance beyond the nuclear radius to which nuclear forces are effective. The radius to the point where the density of nuclear matter has decreased to one-half its central value may be related to the atomic mass number according to $R = r_0A^{1/3}$, where $r_0 = (1.07 \pm 0.02)$ fm.[6] The distance t should be approximately independent of the mass number but would depend upon the method used to measure the point at which the nuclear force fields begin to interact. The five values chosen for t span the range of distances relevant to firm and gentle contacts. The ratio of the surface-energy constant to the Coulomb-energy constant, which enters these calculations, is taken from Green's analysis.[7] It is seen from the figure that the energy required to bring together two nonviscous idealized heavy nuclei is increased as a result of flattening by as much as 35% (about 200 MeV).

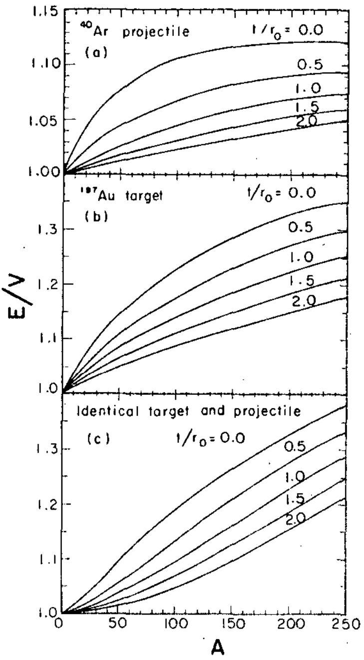

Fig. 1. The energy required to bring together the nuclear force fields of two nonviscous idealized nuclei.

Measurements of the flattening experienced during head-on collisions between pairs of nuclei throughout the periodic table would yield directly information concerning a certain combination of nuclear stiffnesses, inertias, and viscosities. Although estimates of the viscosity coefficient are available,[8] this quantity is known more poorly than the other two. Existing information concerning stiffnesses[3-4] and inertias[4] could therefore be used in conjunction with data on flattening to infer a value for the coefficient of nuclear viscosity. Although the accurate determination of this quantity would require calculations that use shell-affected stiffnesses and inertias, the present liquid-drop results may nevertheless prove useful in the study of transition nuclei (nonmagic spherical nuclei), whose stiffnesses are expected to equal approximately those of liquid drops.[2-4]

Footnotes and references:

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

1. W. D. Myers and W. J. Swiatecki, in Proceedings of the Lysekil Symposium, 1966 (to be published in Arkiv Fysik).
2. Liquid-drop model inertias are systematically too small.[4] This deficiency is important for many purposes but may not be too serious here since the flattening is not an extremely sensitive function of the inertia.
3. T. Honda, Prog. Theor. Phys., Suppl. 37 and 38 (1966) 451.
4. K. Alder et al., Rev. Mod. Phys. 28 (1956) 432.
5. J. R. Nix, UCRL-11338; J. R. Nix and W. J. Swiatecki, Nucl. Phys. 71 (1965) 1.
6. B. Hahn, D. G. Ravenhall, and R. Hofstadter, Phys. Rev. 101 (1956) 1131.
7. A. E. S. Green, Phys. Rev. 95 (1954) 1006.
8. L. Wilets, Theories of Nuclear Fission (Clarendon, Oxford, 1964), pp. 99-100.