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The most fundamental dimensionless quantity characterizing a nucleus is the mass number A. The reciprocal of the cube root of A is related to the ratio of the range of nuclear forces to the nuclear radius. The limit $A^{-1/3} \rightarrow 0$ represents the case of 'nuclear matter', and nuclear theory may be formulated as a Taylor expansion in powers of $A^{-1/3}$. This leads to the following hierarachy of effects:

Order	Typical energy	Effects
A	3000 MeV	Volume effects
$A^{2/3}$	600 MeV	Surface effects
$A^{1/3}$	50 MeV	Curvature and Compressibility
A^0	5 MeV	Single-particle effects.

A large part of nuclear spectroscopy and nuclear reaction theory operates at the level A^0. Most of nuclear many-body theory operates at the level A. The present work is concerned with a simple nuclear model which aims at describing approximately but comprehensively all effects short of the single-particle level, i.e. all <u>average nuclear properties</u> that do not depend on the discreteness of nucleons. The tool for constructing such a nuclear model is the Thomas-Fermi treatment, identical in its assumptions and range of validity with the Thomas-Fermi theory of atoms (taken without the gradient correction).

Our treatment follows closely that of Ref. 1. The nucleon-nucleon interaction is assumed to be a phenomenological Yukawa force. In order to ensure saturation its strength is assumed to decrease with increasing relative momentum $|\vec{p}_1 - \vec{p}_2|$ of the particles, changing sign at a critical value p_c:

$$V(r_{12}) = -C(1 - |\vec{p}_1 - \vec{p}_2|^2/p_c^{\ 2}) \frac{\exp(-r_{12}/a)}{r_{12}/a} \quad .$$

The strength parameter C, range a, and p_c are adjustable parameters of the theory. The total energy of a Fermi gas of particles (with $N = Z$ and no Coulomb energy) interacting according to the above law of force was made stationary with respect to variations in the density distribution of nucleons. This led to a Thomas-Fermi (integral) equation which was solved by iteration. The parameters C, a and p_c were adjusted to reproduce the binding and density of nuclear matter as well as the nuclear surface tension, as given in Ref. 2. ($C = 328.7$ MeV, $a = 0.6256$ fm, $p_c^{\ 2}/2$ (nucleon mass) = 82.03 MeV.) Three examples of the resulting density distributions are shown in Fig. 1. Note that an (uncharged) medium-weight nucleus would have a central density higher than either a very heavy or a very light nucleus. Note also the asymmetry in the density fall-off in the surface: a slow (approximately exponential) approach to the central density but a short-tailed approach to zero density. Some idea of the degree of reliability of the present treatment is provided by the prediction of a ten-to-ninety skin thickness of 2.00 fm, approximately the experimental value.

In Fig. 2 the nuclear energy per particle is plotted as a function of $A^{-1/3}$. The equation for the energy was found to be (in MeV):

$$E = -15.677\,A + 18.56\,A^{2/3} + (28.74 - 19.42 - 2.34)A^{1/3} - 12.3\,A^{0} + \cdots .$$

The last number in the coefficient of $A^{1/3}$ is the compressibility correction due to the squeezing of the nucleus by the surface tension. (The incompressibility coefficient E_v'' predicted by our theory is 295 A MeV.) The sum of the other two coefficients of $A^{1/3}$ is the curvature correction. The first represents the effect of the increased exposure (fewer neighbors) for particles close to the curved surface, the second that of the reduced number of exposed particles per unit area of the curved surface. The net result is a predicted increase in the surface tension of a curved nuclear surface by a factor $1 + \ell\kappa$, where κ is the total curvature and ℓ is 0.303 fm. Note in Fig. 2 the close representation of the energy per particle, down to $A \approx 4$, by the volume and surface energies alone (indicated by the straight line).

The nuclear Thomas-Fermi equation for a mixture of neutrons and charged protons (with $N \neq Z$) may also be solved (see Ref. 1). This introduces a fourth parameter, related to the symmetry energy coefficient. We are in the process of working out the detailed consequences of this theory.

FOOTNOTES AND REFERENCES

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

[†] Submitted to the Nucl. Structure Conference, Tokyo, Japan, Sept. 7-13, 1967.

1. R. G. Seyler and C. H. Blanchard, Phys. Rev. 124, 227 (1961); 131, 355 (1963).
2. W. D. Myers and W. J. Swiatecki, Nuclear Phys. 81, 1 (1966).

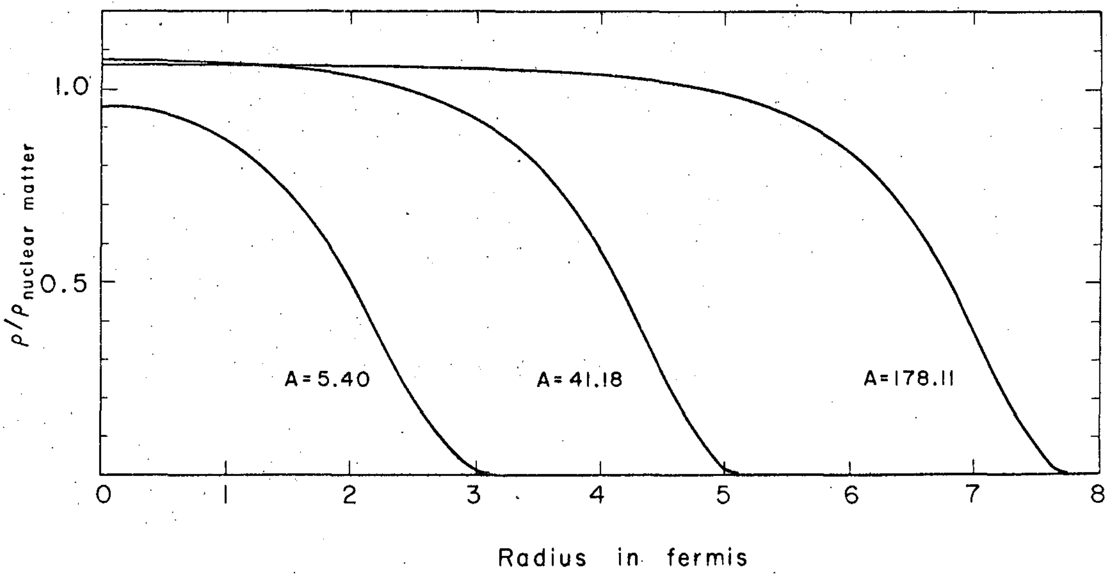

Fig. 1. Nuclear densities.

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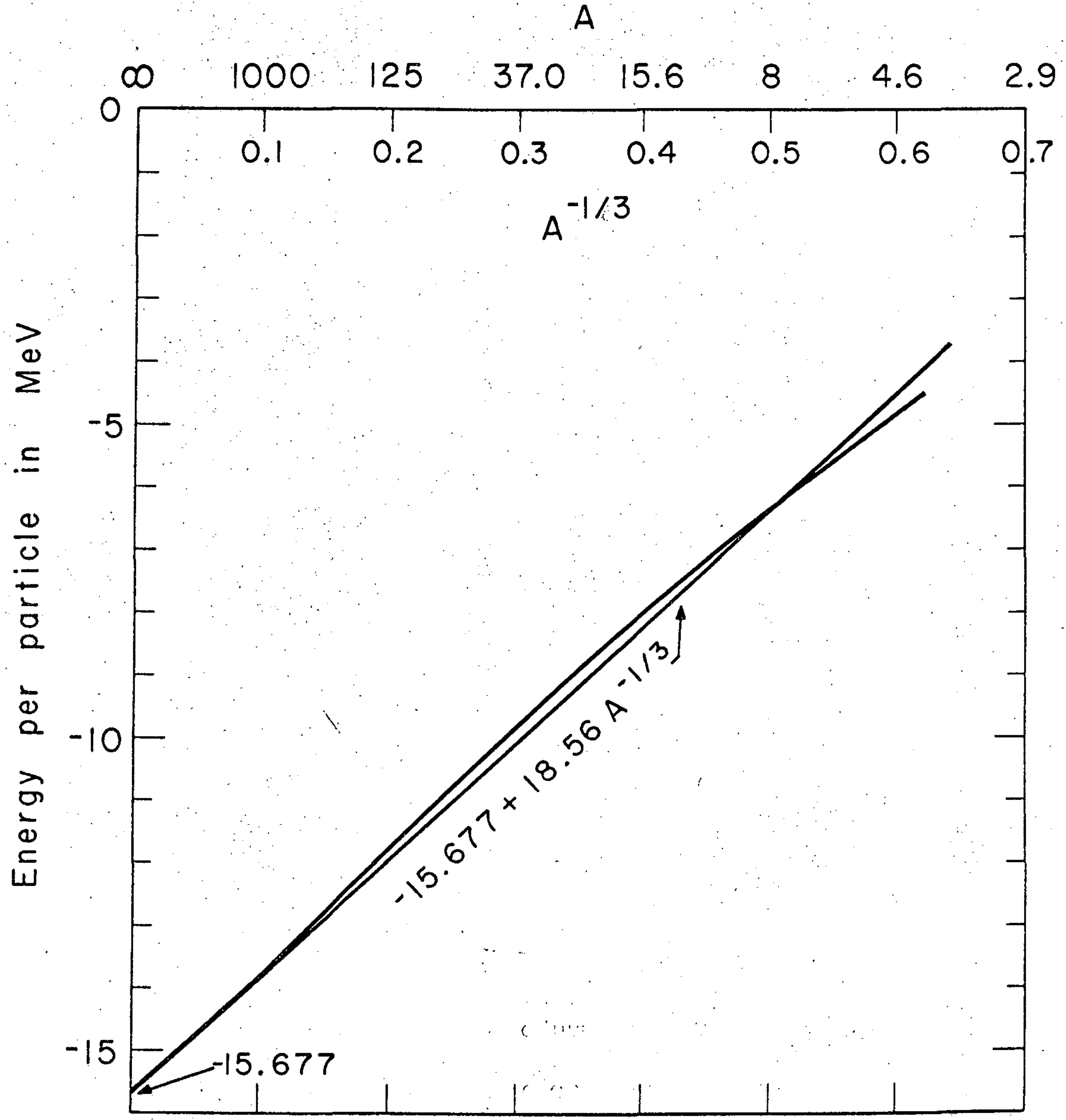

Fig. 2. Energy per particle. XBL 676-3351