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THE SURFACE ENERGY AND THE COMPRESSIBILITY †

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†Prepared for the "Sixth Winter Workshop on Nuclear Dynamics", Jackson Hole, Wyoming, 17-24 February 1990

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The surface energy and the compressibility are closely related since, after all, the surface energy arises in part from the fact that there is a loss of binding associated with reduced density, and the compressibility coefficient K_∞ is the quantity that governs this effect for small density deviations. In fact, we find in our work [1] (which is the continuation of a series of Thomas-Fermi calculations using the Seyler-Blanchard interaction)[2] that the value of K_∞ is determined by the combined requirement that the surface diffuseness correspond to the one measured in electron scattering and the surface energy is the one that corresponds to a fit of the model to nuclear masses. The effect on the surface energy of varying the diffuseness b or the compressibility K_∞ can be seen in fig. 1.

Even though K_∞ has been determined, the effective value of the compressibility K_{eff} for a finite nucleus can be quite a bit smaller because the resistance of the nucleus to changes in scale consists not only of a bulk effect but depends also on surface, curvature and higher order effects. In fig. 2 the calculated values for the binding energy per particle E/A and the effective stiffness K_{eff} for a wide range of $N = Z$ nuclei (without Coulomb energy) are compared. In both cases the values are plotted versus $A^{-1/3}$ so that a curve through the points will intersect the ordinate at the nuclear matter value of the quantity in question. The slope of the line gives the dependence on surface area and the other terms are associated with higher order effects. It is interesting to note that in both parts of this figure the higher order terms in the power series expansion tend to cancel. What this means for the quantity E/A is that a simple Liquid Drop Model consisting only of a volume and surface term can be expected to work very well. For the quantity K_{eff} it means that there is probably little point in trying to go beyond a simple two term description of the effective stiffness in terms of volume and surface effects.

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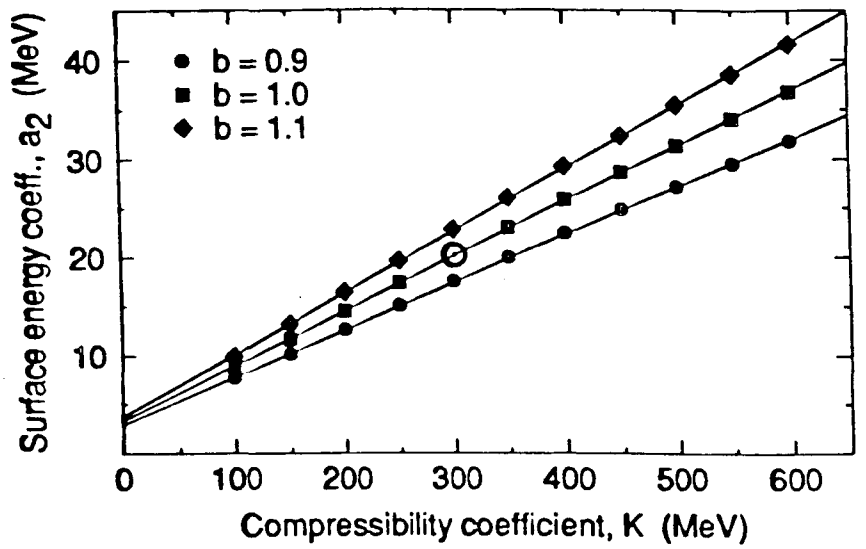

Fig. 1 The value of the surface energy coefficient a_2 is plotted against K_∞ for three different values of the nuclear diffuseness b. The point corresponding to our choice of parameters is in the circle in the center of the figure.

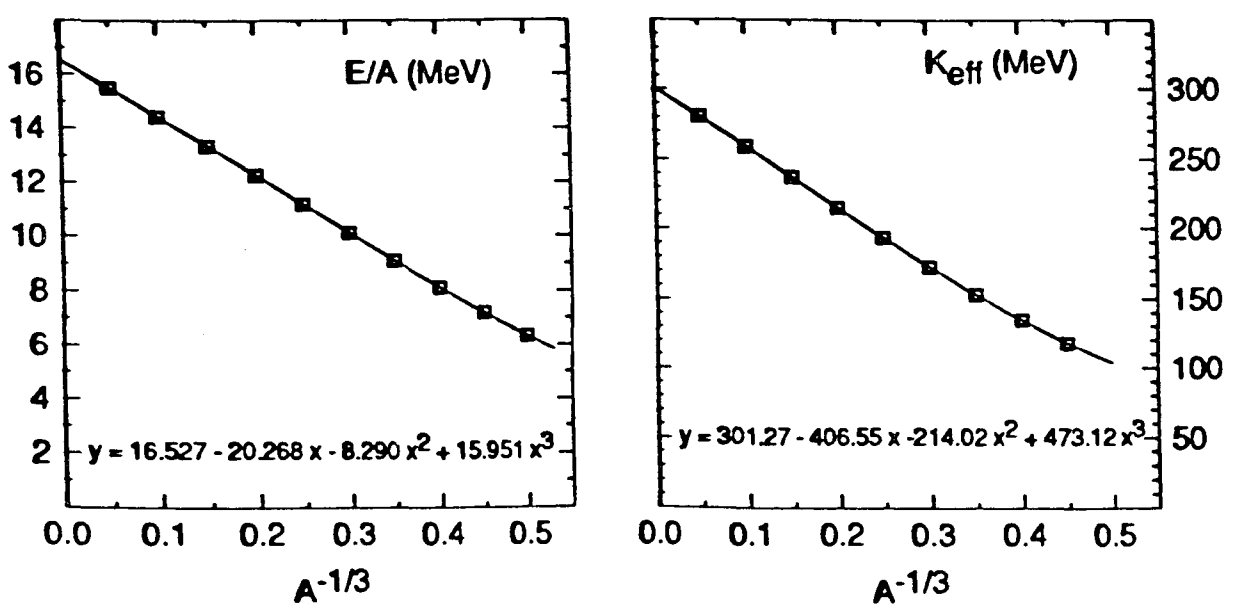

Fig. 2 A plot of the calculated energy per particle E/A versus $A^{-1/3}$ for finite $N = Z$ nuclei (without Coulomb energy) is compared with a similar plot for the quantity K_{eff}.

The effective compressibility depends not only on the size of the nucleus but also on its composition. In fig. 3 the calculated value of K_{eff} for a number of nuclei has been plotted versus the mass number A for three different cases. The open triangles correspond to values similar to those in fig. 2 with $N = Z$ and no Coulomb energy. The circles correspond to the K_{eff} values that would result if the composition of each nucleus was changed to the neutron-proton ratio holding at β-stability. The square symbols correspond to also including the effect of the Coulomb energy. The effect of the neutron excess and the Coulomb repulsion can be clearly seen.

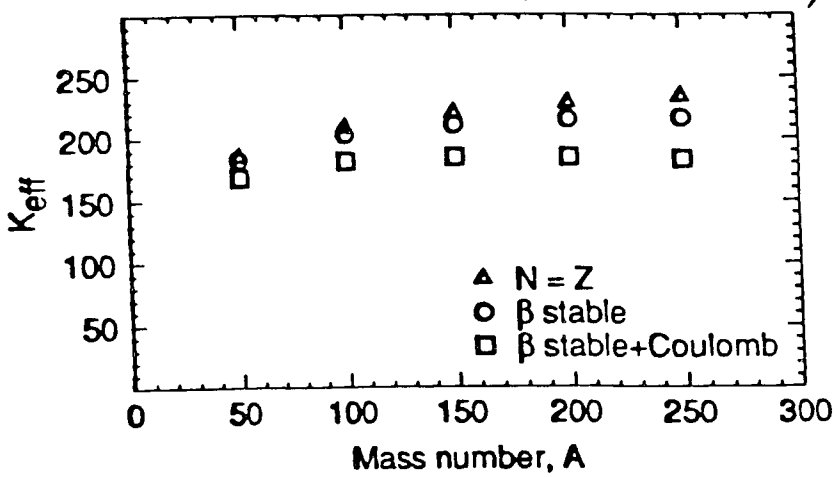

Fig. 3 The effective value of the compressibility K_{eff} for a number of nuclei is plotted versus their mass number A. The triangles correspond to $N = Z$ and have the same values as in fig. 2. The circles show the reduction that occurs when the N, Z ratio is changed to correspond to β stability. The effect of adding the Coulomb repulsion is indicated by the square symbols.

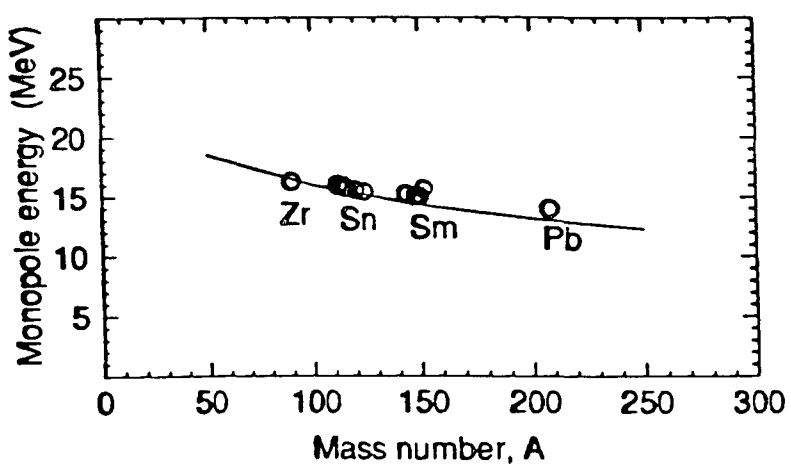

Fig. 4 The solid line corresponds to our estimate of the energy of the Giant Monopole Resonance using the hydrodynamical expression above. The circles correspond to measured values[3)] whose errors are claimed to be smaller than the size of the symbols.

In addition, in fig. 4 we show our prediction for the energy of the Giant Monopole Resonance based on these values of K_{eff} and the simple hydrodynamical expression $E_{GMR} = \hbar\frac{\pi}{\sqrt{15}}\sqrt{K_{eff}/B}$, where $B = m\langle r^2\rangle$, $\langle r^2\rangle = \frac{3}{5}R^2 + 3b^2$, $R = 1.13\,A^{1/3}\,\mathrm{fm}$ and $b = 1\,\mathrm{fm}$.[4] This expression was derived from eq. (6A-50) in ref.[5], which is $\omega = \pi u_c/R_o$, where $u_c = \sqrt{\frac{K}{9m}}$. To arrive at our expression, which includes a diffuseness correction, we replaced R_o by $\sqrt{\frac{5}{3}\langle r^2\rangle}$.

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