

Silver Films on a Mica Crystal Face

We are submitting here microphotographs (Figs. 1 and 2) which may be of interest to some of your readers, particularly those working in the field of thin metal films. The microphotographs (by transmitted light) are of an agglomerated silver film on a mica crystal face. The film was prepared as follows: The mica sheet, approximately thirty microns in thickness, was split from the interior of a

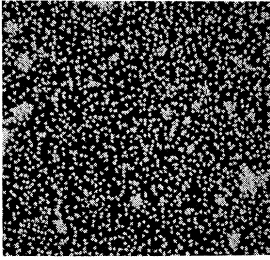


FIG. 1. Microphotograph by transmitted light. Mag. 81.5X.

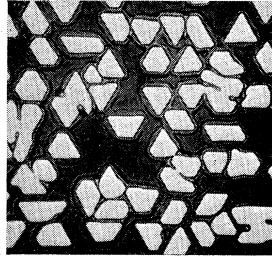


FIG. 2. Small section of Fig. 1. Mag. 531X.

heavier sheet and handled only on the margin with forceps, particular care being taken to avoid contamination. There was no preliminary cleaning of the mica slip prior to application of the silver film other than a two-hour bake in vacuum at 450°C. After cooling to room temperature the film was applied by evaporation from a silver bead located about one centimeter from the mica surface, so as to produce a range in film thickness over the sample of approximately 0.01–10.0 microns. Agglomeration was then effected by heating at 400°C for several hours. A vacuum of the order of 10^{-6} mm Hg was maintained during the whole process.

Ordinarily, in a film prepared in this manner, the openings or windows which appear during heat treatment show little evidence of regularity in shape or arrangement. However, in this particular film, the windows are essentially all bounded by straight lines parallel to one of three common hexagonal axes. The orientation of the silver crystals by atomic migration and a building onto the substrate crystal structure is most evident here and is exceptionally uniform over a relatively large area. The phenomenon is naturally most evident in a thickness range of approximately 0.1–0.2 micron. Regarding the crystalline nature of this particular piece of mica, we have no data. It is of the Indian variety of muscovite.

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The Binding Energy of $4n$ -Nuclei on the α -Particle Model

In various recent papers¹ the $4n$ -nuclei are regarded as consisting of α -particles which form a crystal lattice; this model is taken as a first approximation in contrast to the Hartree model. One argument in support of the α -particle model is thought to come from the fact that the binding

energy of the $4n$ -nucleus (n times the mass of the α -particle minus the mass of the nucleus) can in a certain approximation be written as a constant times the number of bonds between pairs of α -particles.² The outstanding exception to this rule is ${}^8\text{Be}$ which has almost zero binding energy instead of the predicted 2.5 Mev. Hafstad and Teller show that this discrepancy can not be explained by taking account of the zero-point vibrations of the α -particles.

It seems that the above difficulty with the α -particle model can be understood in another way. We set up a perturbation calculation by use of a Hartree method, which is fairly good for one α -particle,³ in that we consider the two protons and two neutrons comprising the α -particles as executing independent harmonic oscillations about the hypothetical lattice-points occupied by the α -particles. The nonorthogonality of the resulting system of antisymmetrical wave functions (constructed from Hermitian functions) can be approximately compensated for in the perturbation calculation. The first-order contribution gives a repulsion of the form $\sum E_m^1$ where m is to be summed over neighboring pairs of α -particles. The second-order calculation shows that it is not sufficient to consider only processes in which two α -particles participate but one must also include (e.g. in ${}^{12}\text{C}$), such a transition as the following: a proton from one α -particle and a neutron from another α -particle jump, under the influence of their nuclear force, into an excited state of the third. We write the perturbing potential as $H' = V - V_0$, where V is the nuclear interaction (taken as equal to $-a \exp[-b^2(r-r')^2] T_{ik}$ with $a > 0$ and T_{ik} an operator giving the spin and charge dependence) and V_0 is the fictitious zero-order potential. When antisymmetric combinations of oscillator functions are employed, the V^2 contribution to the energy can be evaluated exactly up to a final integral. Thus the above transition gives as its V^2 contribution to the binding energy:

$$-\frac{Ma^2(1-2\gamma)^3}{\hbar^2\alpha(1-e^{-\rho^2/2})} \int_0^1 \frac{dk}{k} \left\{ \frac{\exp[-\rho^2((1+k)(1+4\gamma^2k^2)/4(1+2\gamma k)) + \frac{3}{4} - \frac{3}{4}k]}{(1-4\gamma^2k^2)^{\frac{3}{2}}} - \exp[-\rho^2] \right\}$$

$Ma^2/\hbar^2\alpha$ is of the order of a nuclear binding energy, $1/\alpha^{\frac{3}{2}}$ is the average distance between two single particles in the same α -particle, $\gamma = b^2/(\alpha + 2b^2)$, $(1 - e^{-\rho^2/2})$ comes from normalization, $\rho = \alpha^{\frac{1}{2}}R$ where R is the "lattice spacing," and the integral is equivalent to a summation over intermediate states. This is to be compared with the V^2 contribution to the energy of a pure pair (as occurs in ${}^8\text{Be}$); one of the characteristic transitions of this type leads to the result:

$$-\frac{Ma^2(1-2\gamma)^3}{\hbar^2\alpha(1-e^{-\rho^2/2})} \int_0^1 \frac{dk}{k} \times \left\{ \frac{\exp[-\rho^2\{1-k/(1+2\gamma k)\}]}{(1-4\gamma^2k^2)^{\frac{3}{2}}} - e^{-\rho^2} \right\}$$

The two integrals are of the same order of magnitude as

can be seen from their series expansions. As a further check, a numerical integration was performed, by using⁸ $\gamma = \frac{1}{4}$ and $\rho = 1.7$, and the first integral is found to be eight-ninths of the second. Other V^2 terms are of the same order, and the V_0^2 , VV_0 contributions to the energy behave similarly. Consequently a more precise knowledge of the interaction between two α -particles will not provide an explanation of the binding energies of $4n$ -nuclei, in particular the difference between the binding of ${}^4\text{Be}^8$ and ${}^6\text{C}^{12}$.

Moreover, the perturbation energy of the second order can be written in the form $\sum E_m^{II}$ where m is to be summed over all configurations involving jumps between neighboring α -particles. Those terms which bring into play only pairs of α -particles just about cancel the corresponding terms in the first-order energy. Hence the other configurations are responsible for the binding energies; in ${}^6\text{C}^{12}$ a triangle, in ${}^8\text{O}^{16}$ four triangles and one tetrahedron, and so on (in the second-order matrix elements referring to more than four lattice-points cannot appear). Since the binding of ${}^8\text{O}^{16}$ is only twice that of ${}^6\text{C}^{12}$, the third-order perturbation energy must give an appreciable contribution (and presumably a repulsive one). This must be *à fortiori* true of heavier $4n$ -nuclei, to whose binding energy higher approximations must contribute. Taken together with the fact that even in second-order matrix elements between more than two α -particles are essential, this means that the model of an α -particle lattice is a very poor approximation. Instead of near-neighbor interaction between α -particles, one has essentially an interaction among all the constituents of the nucleus, i.e. the liquid-drop model.

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¹ W. Wefelmeier, Zeits. f. Physik **107**, 332 (1937); C. F. von Weizsacker, Naturwiss. **26**, 209, 225 (1938).

² L. H. Haistad and E. Teller, Phys. Rev. **54**, 684 (1938).

³ B. O. Grönblom, Zeits. f. Physik **110**, 37 (1938).

The Viscosity of Air

Within the past few years various authors have reported new determinations of the viscosity of air which point to a value somewhat higher than that published by me¹ in 1916, and on which Millikan placed great reliance when arriving at his value of e . While one or two very recent determinations are as yet unpublished the summary during the past year by Millikan² and by Robinson³ and direct correspondence to me may warrant at this time the following comments.

Although unable to recall any oversight or source of error of sufficient import to account for my result being as much too low as now assumed, I have continued to be much interested in this problem and ready to cooperate in the efforts made to secure an even higher precision in this most important constant. The inherent difficulties in obtaining an accurate value of this constant become obvious to anyone who studies the literature or works experimentally in this field. Even Houston's⁴ recently published

value (probably the best available) differs from that of Kellström⁵ by nearly the same amount that it differs from mine (0.36 percent) though all three determinations are by the same method.

The recent determinations appear to have been carried out with the utmost care, have had the advantage of instruments constructed with the high precision now possible, and refinements in theory and in method have received much attention. Hence it is reasonable to consider the values obtained very reliable. For reasons given in my report I still greatly prefer the cylinder method, and disapprove the use of suspensions in ribbon form or made of phosphor bronze (used by a recent observer). The cylinder used by Kellström was much smaller than that used by me or the one employed by Houston, a disadvantage, possibly. Houston's contribution of certain correction factors would seem to give added weight to his value of η . The uncertainties as to the end corrections, one of the objections to the capillary tube method, have been doubled by Rigden⁶ through his use of a pair of tubes for each run. The temperature control is always both critical and uncertain in this method. His result differs by 0.24 percent from that of his immediate predecessor in the work though it would appear to be close to the value now accepted.

Kellström's observation that any eccentricity of the inner cylinder lowers the apparent value of η might account in part for a low value since a defect in the clamping system required in the assembling of the apparatus might escape detection as it is impossible to check the alignment after the outer cylinder is in place. It seems unlikely that any large error of this sort could have entered into my results since the apparatus was so many times taken down and reassembled during the course of the experiments, and the value obtained closely checked that of Gilchrist who previously used the apparatus, and was checked later by Van Dyke, each using his own technique. Houston's corrections would hardly explain in full the discrepancy. Bearden has suggested that the main difficulty centers about the determination of the torque constant of the suspension. Assuming my value is too low I would suspect one or more of the factors mentioned in this paragraph to be responsible since the data obtained supported the accuracy claimed at that time.

As pointed out by Robinson, any of the recent values of η (mine included) if combined with the right oil drop data will yield a value of e acceptable to those in the x-ray field, but it would seem that the Houston-Millikan combination merits special confidence. While it would appear that the value of η has been determined with acceptable precision the writer would appreciate receiving information concerning any unpublished determination, whether completed or in progress.

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¹ E. L. Harrington, Phys. Rev. **8**, 738 (1916).

² R. Millikan, Ann. de. Physik **32**, 34 (1938).

³ H. R. Robinson, Nature **142**, 159 (1938).

⁴ W. V. Houston, Phys. Rev. **52**, 751 (1937).

⁵ G. Kellström, Phil. Mag. **23**, 313 (1937).

⁶ P. J. Rigden, Nature **141**, 82 (1938); Phil. Mag. **25**, 961 (1938).