AIP The Journal of Chemical Physics

# The Viscosity of Monolayers: Theory of the Surface Slit Viscosimeter

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Citation: J. Chem. Phys. **6**, 53 (1938); doi: 10.1063/1.1750123
View online: http://dx.doi.org/10.1063/1.1750123
View Table of Contents: http://jcp.aip.org/resource/1/JCPSA6/v6/i1
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# LETTERS TO THE EDITOR

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## The Viscosity of Monolayers: Theory of the Surface Slit Viscosimeter

The surface viscosimeter which makes use of the flow of a film through a rectangular capillary slit possesses many advantages in comparison with other types. Perhaps the greatest of these is the fact that, since it has no moving parts, no motion is imparted to the substrate (usually aqueous) by the instrument. Since surface viscosimeters which utilize moving rings or disks impart such a motion, their theory is thus made much more complicated.

A surface slit viscosimeter has been used by Harkins and Myers [1] who also gave the first term on the right of Eq. (2) given below. Since this neglects the effects of the viscosity of the water carried along by the film, it is essential to develop the more complete theory, and this has been done by one of us (Kirkwood). This adds the last term in Eq. (2).

The hydrodynamical problem may be solved for an incompressible film of viscosity coefficient, $\eta$, and a fluid substrate of viscosity coefficient, $\eta_0$, flowing through a rectangular slit of width $a$ and depth $h$. If $\alpha$ is the film pressure gradient $(f_2-f_1)/l$, the area flux, $A$ is calculated to be

$$A=\frac{8\alpha a^3}{\pi^4}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^4[\eta+(a\eta_0/\pi n)\coth(\pi nh/a)]}. \quad (1)$$

If the ratio $h/a$ of depth to breadth is large relative to unity, Eq. (1) leads to the following approximation, which is doubtless adequate for all practical purposes.

$$\eta=\alpha a^3/12A-a\eta_0/\pi. \quad (2)$$

The substrate correction to be applied to the earlier formula is thus equal to $a\eta_0/\pi$. In the above equations, no end corrections have been made, but they will be negligible if the ratio of the slit length, $l$, to the slit width, $a$, is made large.

On water at 20°C the corrections in surface poises are for different diameters of slit.

$$1\text{ mm}=0.00032,$$
$$0.5\text{ mm}=0.00016,$$
$$0.1\text{ mm}=0.00003.$$

The correction terms to be applied to the values of Harkins and Myers are smaller than those given above, since they used a slit of negligible depth. Thus the value of 0.0018 surface poises, given as the viscosity of a film of arachidic acid, when corrected is close to 0.0017, a change within the experimental error. However, the values given earlier for extremely fluid films, such as that formed by oleic acid, should be considered as only upper limiting values. The exact values of the viscosities are now being determined.

A capillary slit was used by Bresler and Talmud[2] but they did not determine viscosities from rates of flow, and their theory is different from ours.

On account of the theoretical and practical merits of the surface slit viscosimeter, and its great simplicity of construction and use, it should be adopted as the standard for all surface viscosimetry.

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November 16, 1937.

[1] W. D. Harkins and R. J. Myers, Nature **140**, 465 (1937). R. J. Myers and W. D. Harkins, J. Chem. Phys. **5**, 601–3 (1937).
[2] S. E. Bresler, B. A. Talmud, and D. L. Talmud, Physik. Zeits. Sowjetunion **4**, 864 (1933).