A CELL FOR THE MEASUREMENT OF CATAPHORESIS OF ULTRAMICROSCOPIC PARTICLES.

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In a recent publication Northrop[1] describes a convenient cell for microscopic cataphoresis measurements which can easily be made by cementing together microscopic slides. The writer has modified the cell so that it can be employed for measurements of cataphoresis of particles of ultramicroscopic size such as colloidal gold, etc. The modification consists in cementing slides in such a manner as to make it possible for a strong beam of light to pass through the front edge of the cell. The diagrams in Fig. 1 show the construction of the cell. The slides are lettered alphabetically in the order in which they are cemented together by means of de Khotinsky cement. Slide *d* is perforated and is made from an ordinary thick slide which has a circular flat depression in the middle. This depression is easily cut away by means of a glass cutter and one edge of the slide is then ground off, leaving a space of 1 mm. between the perforation and the edge.

Construction of the Cell.—Slide *b* is cemented on top of Slide *a*, leaving about 1.5 cm. of Slide *a* exposed. Slide *c* comes on top of *b*, and then Slide *d* on top of Slide *c*, taking care that the ground edge of *d* coincides in the same vertical plane with the exposed edge of Slide *a*. The long front edge of the cell is ground smooth, and Slide *e* is cemented to it. On top of Slide *e* come the blocks *f* and *g*, leaving about 2 cm. of the middle portion of Slide *e* exposed. The ends of the cell are then ground smooth, the inside of the cell is cleaned by means of lens paper and acetone, and end-tubes are then cemented on. The end-tubes consist of two short pieces (4 to 5 cm. long) of thick-walled glass tubing, one end of which is widened and flat-

[1] Northrop, J. H., *J. Gen. Physiol.*, 1921–22, iv, 629.

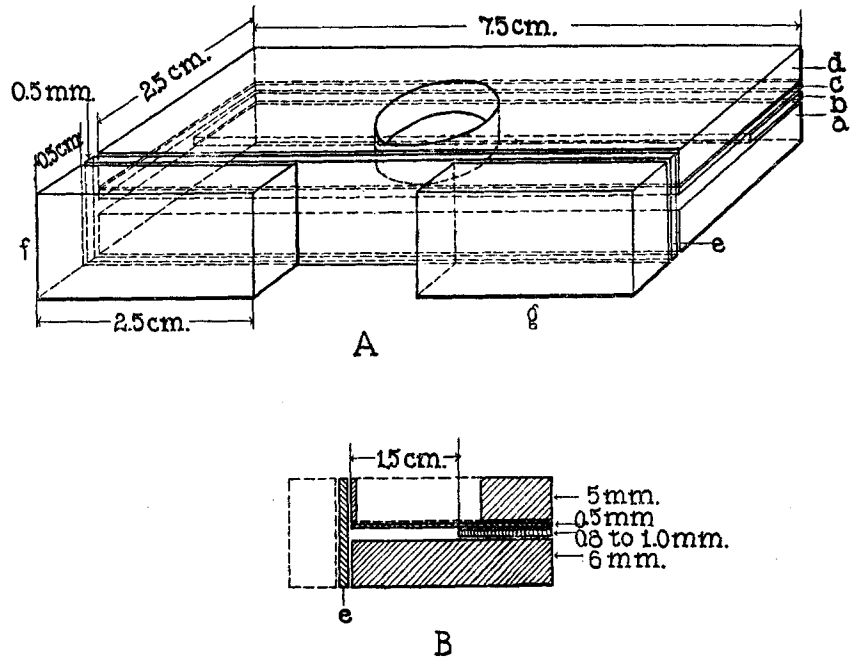

FIG. 1. *A*, perspective view of the cell. *B*, transverse section through the middle of the cell.

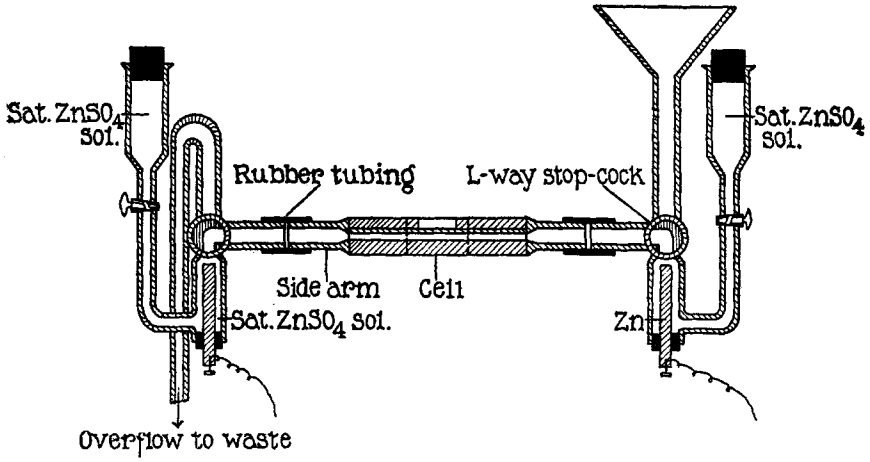

FIG. 2. Longitudinal section through the cataphoresis apparatus.

tened and then ground smooth so as to fit well to the end of the cell. As in the case of Northrop's arrangement, non-polarizable Zn-$ZnSO_4$ electrodes are employed. The electrodes designed by Northrop were slightly modified by adding reservoirs for saturated $ZnSO_4$ solution, thus making it possible to renew readily the $ZnSO_4$ solution around the zinc electrodes. Fig. 2 gives a sectional view of the whole cell assembled, together with the modified zinc electrodes.

Calibration of the Cell.—In employing the apparatus for cataphoresis measurements it is necessary to know the drop in potential per cm. length of the part of the cell where the observations are made, when a known E.M.F. is applied to the terminals of the zinc electrodes. The drop of potential per cm. length of the cell proper can be calculated, with an approximation sufficient for the accuracy of cataphoresis experiments, from the actual measurements of the lengths and the inner cross-sectional areas of all the parts of the apparatus used in the electric circuit, with the exception of the parts containing saturated $ZnSO_4$ solution. The resistance of saturated $ZnSO_4$ solution is very small in comparison with the electrolytes usually employed in cataphoresis measurements; hence the potential drop across the $ZnSO_4$ portions of the circuit can be neglected. The calculation of the drop per cm. length of the cell is based on the principle that the drop per cm. length of a conductor of a non-uniform cross-section is inversely proportional to the cross-sectional area of any part of the conductor. If e_c and e_1 are the drops per cm. length of the cell, whose cross-sectional area is A_c, and of any other part of the apparatus, whose cross-sectional area is A_1, then $e_1 = e_c \frac{A_c}{A_1}$.

Hence

$$\text{the total drop } E = e_c \left(L_c + L_1 \times \frac{A_c}{A_1} + L_2 \times \frac{A_c}{A_2} + \ldots\ldots \right)$$

in which L_c, L_1, L_2, respectively, are the lengths in cm. of the various parts of apparatus. If $L_1 \times \frac{A_c}{A_1}$ and $L_2 \times \frac{A_c}{A_2}$ respectively, are designated as the equivalent lengths of the various parts of the apparatus in terms of the length L_c of the cell proper, then the drop

per unit length of the cell is equal to the total P.D. as measured by a voltmeter connected across the terminals of the zinc electrodes divided by the sum of all the equivalent lengths, or

$$e_c = \frac{E}{L_c + L_1 \times \frac{A_c}{A_1} + L_2 \times \frac{A_c}{A_2} + \ldots\ldots}$$

Another formula for calculating the value of e_c is given by Northrop in his publication mentioned before, where the reader may find more details as to the technique of operating the apparatus as well as to the method employed in determining the actual velocity of electrical migration of suspended particles.

The cell described here has been successfully employed for several months, using a simplified Zsigmondy[2] arrangement for obtaining a strong beam of light, which consists, (1) of a small Leitz arc lamp which is using 4 to 5 amperes and which is provided with a clock mechanism for leading the carbons,[3] (2) of a double-convex lens, and (3) of a microscope objective (Zeiss A) attached to a microscope barrel. This is mounted in a horizontal position on a stand which can be raised or lowered by means of a fine screw. A microscope provided with a Zeïss objective of 16 mm. focal length and a No. 12 compensating ocular, in which a cross-sectional microscale is placed, is used for taking observations.

The cell can also be used for ordinary microscopic cataphoresis measurements by allowing light to reach the bottom of the cell as usual. But the writer has found the ultramicroscopic method to be of advantage even in cases of large microscopic particles, as it is much easier to focus and less tiresome for the eye to make many observations when the ultramicroscope method is employed than using an ordinary microscope method.

[2] Zsigmondy, R., Kolloidchemie, Leipsic, 2nd edition, 1918.

[3] The arc lamp has been recently replaced in this laboratory, at the kind suggestion of Dr. L. Waldo, by a convenient incandescent lamp supplied by the Pathescope Company of America, Aeolian Hall, New York.