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Charles A. Sorrell

Missouri University of Science and Technology

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Liquid Viscosity Measurement Using a Buret

An instructional technique

The viscosity of a liquid is a fundamental property, related to intermolecular forces in the liquid state, and consequently has an important place in the elementary or physical chemistry course. For the classroom or laboratory situation, demonstration of variations in viscosity using standard techniques requires some specialized glassware and investment of time. The results are generally discussed in terms of well known equations whose terms are related to the geometry of the viscometer but in actuality are obtained as values relative to a standard liquid.

The simplified technique, using a buret, described here circumvents some of the problems associated with classroom demonstration in that it is suitable for large classes and requires no specialized equipment. It has the added benefit of requiring the student to depart from standard procedure, as outlined in a laboratory manual, and to consider more thoroughly the assumptions involved in measuring relative viscosities. Although the data obtained by this method seem to be surprisingly accurate, the method is described not as a substitute for the standard method but with the hope that the method and associated ideas will be of some value in instructional situations.

The Poiseuille Method

Viscosities of relatively fluid liquids are generally determined by measurement of flow times through an Ostwald viscometer and solution of the Poiseuille equation. Derivation of the equation, description of the viscometer, and more or less thorough treatments of corrections necessary for calculation of absolute viscosities are included in most physical chemistry texts.

In brief, the Ostwald viscometer consists of a small reservoir located above a capillary tube; the capillary is connected through a U-tube to a larger reservoir. A measured volume of liquid is placed into the viscometer and drawn by suction into the upper, smaller reservoir and then allowed to flow by gravity; the time required for the meniscus to move between two marks on the capillary is measured. The level of the lower, larger reservoir is of course below the lower mark on the capillary at all times.

The Poiseuille equation expresses the viscosity as

$$\eta = \frac{\pi p r^4}{8 v l} t \quad (1)$$

where η = coefficient of viscosity, poises, dyne sec cm^{-2} ($\text{g cm}^{-1} \text{sec}^{-1}$); p = driving pressure, dyne cm^{-2} ($\text{g cm}^{-1} \text{sec}^{-2}$); r = radius of capillary, cm; v = volume of liquid, cm^3 ; l = distance between markers, cm; and t = time, sec.

The equation assumes that flow is perfectly laminar, that the driving pressure is solely that necessary to

maintain a steady rate of flow, that all the potential energy of the liquid is converted to thermal energy by viscous friction, and that interaction between the liquid and the capillary wall is confined to the first molecular layer of the liquid. None of the assumptions is strictly valid, though resultant error is small. The chief source of error is in measuring the dimensions of the viscometer, and because of this viscosities are most commonly measured relative to that of a standard liquid whose absolute viscosity has been determined accurately over a range of temperatures.

If the experiment is conducted with both ends of the viscometer open, the driving pressure is

$$p = \rho g h \quad (2)$$

where ρ = density of the liquid; g = acceleration of gravity; and h = difference in height between the liquid levels in the two reservoirs. The Poiseuille equation can thus be written

$$\eta = \frac{\pi r^4 g h}{8 v l} \rho t \quad (3)$$

For a given volume of liquid and a given viscometer the equation may be simplified to

$$\eta = A \rho t \quad (4)$$

where A is an instrumental constant with the dimensions, $\text{cm}^2 \text{sec}^{-2}$. If the coefficient of viscosity, η_1 , of a standard liquid is known, the coefficient, η_2 , of a second liquid may be determined from

$$\frac{\eta_2}{\eta_1} = \frac{\rho_2 t_2}{\rho_1 t_1} \quad (5)$$

where t_2 and t_1 are the measured flow times of equal volumes of the two liquids through the same viscometer. The instrumental constant need not be calculated in this case.

Measurements with an Ostwald viscometer may be tedious and time consuming because of the necessity of introducing carefully measured volumes of each liquid and of cleaning the capillary thoroughly between measurements of flow times of different liquids. The results are very sensitive to dust or organic material in the capillary. Because of the variation of viscosity with temperature, the viscometer is normally immersed in a constant temperature bath.

The Buret Method

The geometric constraints and evaluation of all the experimental variables related to the Ostwald viscometer have made possible accurate measurement of absolute viscosities. Any experimental method involving flow times could be used, theoretically, to determine viscosities if all the variables could be identified and

evaluated. Equation (5) may be used for other flow conditions, without evaluation of the instrumental constant, if additional variables are independent. If the additional variables are not independent, but are functions of one or more other variables, viscosity cannot be determined by comparison with one standard liquid, in accordance with eqn. (5). In this case, however, viscosity may be determined by comparison with several standard liquids, with the equation for relative viscosity rewritten as

$$\frac{\eta_2}{\eta_1} = X \frac{\rho_2 t_2}{\rho_1 t_1} \quad (6)$$

where t_1 is the measured flow time for one of the standard liquids having density ρ_1 and coefficient of viscosity η_1 , and X is the calibration term, a function of unevaluated variables. The simplest way to express X is as a function of the experimental measurement, t .

The method described here consists of measurement of flow times of relatively large volumes of liquids from a buret into a breaker, preparation of a flow time calibration curve, and calculation of viscosities in accordance with eqn. (5).

The 100-ml buret used had a column radius of 0.75 cm. The length between the 0 and 100 ml marks was 56.9 cm, and between the 100 ml mark and the orifice was 12.6 cm. The tapered portion was ~ 9.8 cm long. Flow times were measured between the 10 and 80 ml marks, a length of 39.8 cm. The buret was mounted vertically on a ring stand with two clamps and all measurements were made at room temperature, between 24° and 26°C, during a three day period. Liquid temperature was determined prior to each flow time measurement with a mercury thermometer; this was necessary because of evaporative cooling of the tube after each measurement.

The liquids of interest were aqueous solutions of acetone, ethanol, and l-propanol. Accurate data for ethanol-water solutions were obtained by Bingham and Jackson (1) and were useful for testing the validity of the procedure. Solutions were prepared at 10% (molar) increments in 250-ml quantities, with each component measured by volume to the nearest 0.1 ml, and stored in capped bottles for several days prior to measurement. Acetone, methanol, water, ethanol, l-propanol, and ethylene glycol, for which viscosity and density data are available (2), were used as standard liquids. Densities of ethanol-water and l-propanol-water solutions were taken from the literature (3, 4); densities of acetone-water solutions were measured by the pycnometer method.

Flow times were measured by visual observation of the meniscus between the 10 and 80 ml marks and a push-button electric timer, accurate to the nearest 0.1 sec. Four replicate measurements were made for each sample; maximum deviation from the mean was 0.2 sec. After completion of four measurements for one sample, the buret was rinsed with a portion of the next sample to be measured; no other cleaning procedures were found necessary.

The measured flow-time for water was taken as the zero correction point of the calibration curve. Calculated flow times for the other standard liquids were obtained by solution of eqn. (5) using known viscosities of water and the other standards. The calculated flow

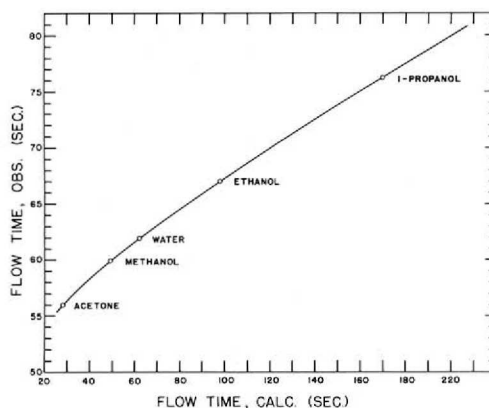


Figure 1. Calibration curve relating flow times for buret method to those calculated from known viscosities. Flow time for water was taken as the standard.

times were plotted versus observed flow times to obtain the calibration curve shown in Figure 1. If a single instrumental constant were involved, as is the case with the Ostwald viscometer, calculated and observed flow times would be equal for all the standard liquids. This is not the case, however, for the buret method. The calibration term X , as used in eqn. (6), can be evaluated as a function of t by fitting the calibration curve to an equation, or, alternatively, a calculated flow time for each observed flow time may be obtained from the calibration curve and the viscosity can be calculated using eqn. (5).

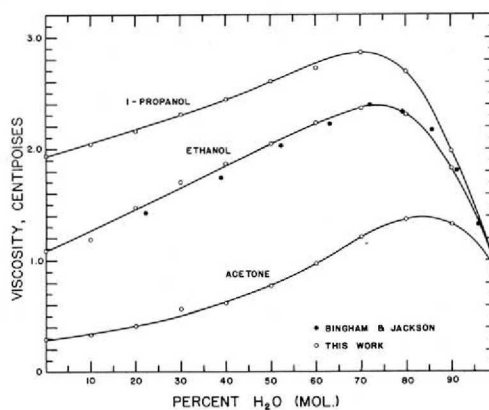


Figure 2. Viscosities of water-organic solutions obtained by buret method.

The latter method was used for calculation of viscosities of the organic-water solutions. The results are shown in Figure 2, with the ethanol-water data of Bingham and Jackson (1) plotted for comparison. The data appear to be sufficiently accurate for many purposes.

Uses of the Buret Method

The buret method has some advantages over the Poiseuille method, even though it depends on availability of accurate absolute viscosities measured by that method. It is considerably less time-consuming than the Poiseuille method, is relatively insensitive to contamination of the tube, to positioning of the buret, and can be accomplished with standard laboratory glassware. The chief disadvantage is one of temperature control; variations of viscosity with temperature would be exceedingly difficult to measure without an elaborately engineered temperature bath.

The chief value of such an unorthodox method could

be considered educational. Measurement of viscosity with an Ostwald viscometer as a laboratory exercise is certainly worthwhile, but it does not require a great deal of thought about the terms included in the Poiseuille equation. Use of the buret method provides a ready means of comparing instrumental and physical variables and their effects on the experimental measurements themselves. A challenging laboratory exercise, for example, would require the student to study the Poiseuille method and then to develop an experimental and analytical method for viscosity measurement based on measurement of flow times through a buret, as described here, or through another geometric arrangement of flow paths.

Because viscosity is a fundamental property of a liquid, related to molecular interactions, it is worthwhile to relate measurements to the other fundamental properties of the same liquids. All the data necessary for calculation of partial molal volume, for example, are available upon completion of analysis of the viscosity data for solutions. Samples prepared for viscosity measurements may subsequently be used for surface tension measurements and the relationships between viscosity and specific conductance could also be considered.

In short, laboratory exercises that demonstrate to the student that elaborate experimental preparation is not always necessary provide him with an opportunity to exercise originality in developing a new technique, however insignificant, and encourage him to relate a number of fundamental properties to a physical phenomenon, are well worth the effort.

Bibliography of Selected General References

- DANIELS, F., AND ALBERTY, R. A., "Physical Chemistry," John Wiley & Sons, Inc., New York, 1955.
- DANIELS, F., WILLIAMS, J. W., BENDER, P., ALBERTY, R. A., AND CORNWELL, C. D., "Experimental Physical Chemistry," (6th ed), McGraw-Hill Book Co., Inc., New York, 1962.
- HATSCHEK, E., "The Viscosity of Liquids," George Bell and Sons, Ltd., London, 1928.
- REILLY, J., AND RAY, W. N., "Physico-Chemical Methods," D. Van Nostrand Co., Inc., New York, 1953.

Literature Cited

- (1) BINGHAM, E. C., AND JACKSON, R. F., *Bull. Bur. Std.*, **14**, 59 (1918-19).
- (2) WEAST, R. C. (*Editor*), "Handbook of Chemistry and Physics" (50th ed.), Chemical Rubber Co., Cleveland, 1969-70.
- (3) HODGMAN, C. D., WEAST, R. C., AND SELBY, S. M. (*Editors*), "Handbook of Chemistry and Physics" (42nd ed.), Chemical Rubber Co., Cleveland, 1960-61.
- (4) PERRY, J. H. (*Editor*), "Chemical Engineer's Handbook" (3rd ed.) McGraw-Hill Book Co., Inc., New York, 1950.

