A COMPACT INSTRUMENT FOR THE MEASUREMENT OF SURFACE TENSION OF LIQUIDS

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ABSTRACT. An instrument for the measurement of surface tension of liquids by a null method is described. The method of balancing the downward force of surface tension on the edge of a thin glass plate by the upward hydrostatic pressure of the liquid is used. The instrument is quite compact, handy and sensitive and can be used for rapid measurement on a number of samples.

INTRODUCTION

Except perhaps du Nouy's tensiometer, compact instruments for the measurement of surface tension are not available. Invariably it is required to assemble a number of loose pieces and it is difficult to obtain accurate results unless extreme care is taken in their manipulation.

Meier (1949) has described a method on which the present instrument is based. He balanced the downward pull due to surface tension on a vertical wire immersed in water by the upthrust of water. Vankataraman (1955) has investigated the scope of the method in detail and found that it is capable of giving results with an accuracy of less than 0.1%. It was thought desirable, therefore, to devise a compact instrument, which should have an advantage of sensitivity, accuracy and rapidity.

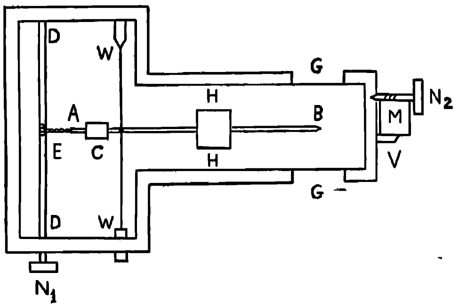

Fig. 1

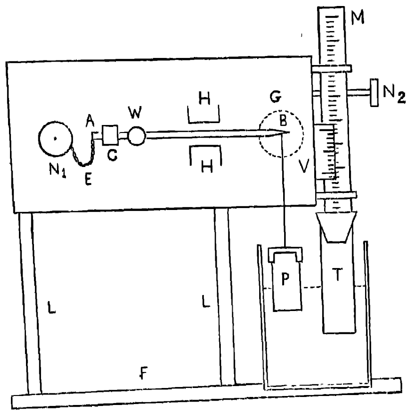

Fig. 2.

DESCRIPTION OF THE INSTRUMENT

The instrument is described in figures 1 and 2. WW is the torsion wire. AB is the torsion arm fixed at the centre of the wire. The glass plate P is suspended from the end B. C is the compensating weight.

Since the instrument is generally kept closed to avoid disturbances due to draught, etc., it was inconvenient to adjust the weight C every time to restore the horizontality of the torsion arm A light metal chain E was wound on the rod DD and its other end was attached to the end A of the torsion arm. By turning the knob N_1, the chain could be wound or unwound, thus decreasing or increasing a slight weight on the end A. The supports HH are fixed in the box to allow the torsion arm to deflect in a restricted range. A rod M with a centimetre scale marked on it and a vernier V are attached at the end of the instrument. The vernier is fixed while the rod M can be moved up and down by the rack and pinion motion with the help of the knob N_2. A glass tube T with a flat bottom is attached to the rod M through a rubber cork as shown in figure 2. The whole assembly rests on the pillars LL fixed to the base F.

OPERATION OF THE INSTRUMENT

The glass plate P is suspended from the end B and the weight C adjusted to keep the arm nearly horizontal. (Once adjusted, this position of the weight is not to be disturbed so long as the glass plate is the same.) The knob N_1 is then rotated until the arm is exactly horizontal. The glass plates GG are put to illuminate the end B. Although we used a microscope to see the image of B, the observation could be taken without it. For this a small horizontal line is marked at the centre of each glass plate. The end B is observed from the side and the knob N_1 is turned until the lines and the end B are one behind the other. The liquid is then poured in the beaker until its level is just near the lower edge of B. The glass tube is lowered by turning the knob N_2 so that the liquid level just touches the lower edge of P. This reading (H_1) on the scale M is noted. When the liquid level touches the plate, the latter is drawn downward by the force of surface tension. This force is balanced by the upthrust of the liquid by raising the level of the liquid sufficiently. This is done by lowering the glass tube T until the end B is restored to its original position. The reading (H_2) on the scale is again noted and the difference H_2–H_1 is found.

When the torsion arm is restored to its horizontal position, the forces of surface tension and upthrust are equal.

$$\therefore \quad \gamma \cdot 2\,(l+t) = \rho g h \cdot lt \qquad \ldots \quad (1)$$

where γ is the surface tension of the liquid, l the length of the edge of the glass plate in contact with water, t the thickness of the plate, ρ the density of the liquid and h the height through which the liquid level is raised.

The height h is connected with H $(= H_2 - H_1)$ by the relation

$$h\,[\,\pi\,(R^2 - r^2) - l \cdot t\,] = \pi\, r^2 H \qquad \ldots \quad (2)$$

where R = radius of the beaker and r = radius of the glass tube T.

$$\therefore \quad h = \frac{\pi\, r^2 H}{\pi\,(R^2 - r^2) - l \cdot t} \qquad \ldots \quad (3)$$

Substituting this value of h in eq. (1) we get

$$\gamma \cdot 2\,(l+t) = \frac{\rho\, glt \cdot \pi\, r^2 H}{\pi\,(R^2 - r^2) - lt}$$

or

$$\gamma = \frac{\rho\, g\, l\, t \cdot \pi\, r^2 H}{2\,(l+t)\,[\,\pi\,(R^2 - r^2) - lt\,]} \qquad \ldots \quad (4)$$

The above equation can be written as

$$\gamma/\rho = C \cdot H \quad \text{for a given instrument} \qquad \ldots \quad (5)$$

where

$$C = \frac{\pi\, r^2 \cdot g\, l\, t}{2(l+t)\,[\,\pi\,(R^2 - r^2) - lt\,]}$$

Thus by drawing a graph of γ/ρ against H for different known liquids the constant C of the instrument can be determined. Such a graph drawn from observation on some known liquids like benzene, carbon disulphide, chloroform is shown in figure 3.

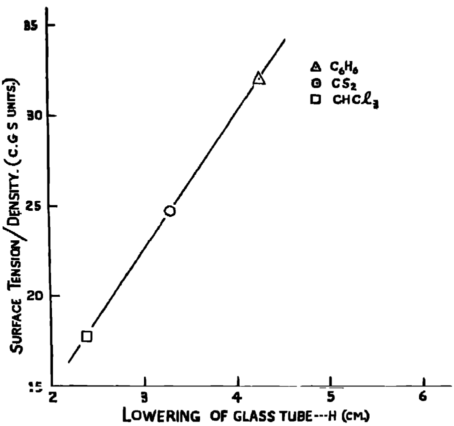

Fig. 3.

Typical observations on benzene are given below :

Temperature of the liquid = 26°C
Radius of the tube $T = r$ = 1.22 cms.
Radius of the beaker = R = 3.28 cms.
Mean $H_2 - H_1 = H$ = 4.280 cms.
Length of the plate = l = 1.550 cms.
Thickness of the plate = t = 0.101 cm.
Density of benzene = ρ = 0.875 gm./c.c.
g = 980 cm./Sec^2
Surface tension = γ = 28.08 ($\pm$ 0.088) dynes/cm. from equation (4).

The accuracy of our method (0.32%) may be compared with that obtained by Sugden (1921) with the capillary tube method where it is stated that the possible errors in the method may amount to 0.3%.

REFERENCES

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