EXPERIMENT

AIM

To determine the surface tension of water by capillary rise method.

MATERIAL REQUIRED

3 capillary tubes, a travelling microscope, dish, tap water, HNO_3 dil. caustic soda, glass strip, fine adjustable stand, metallic plate, pin, clamp, thermometer and rubber band.

DIAGRAM

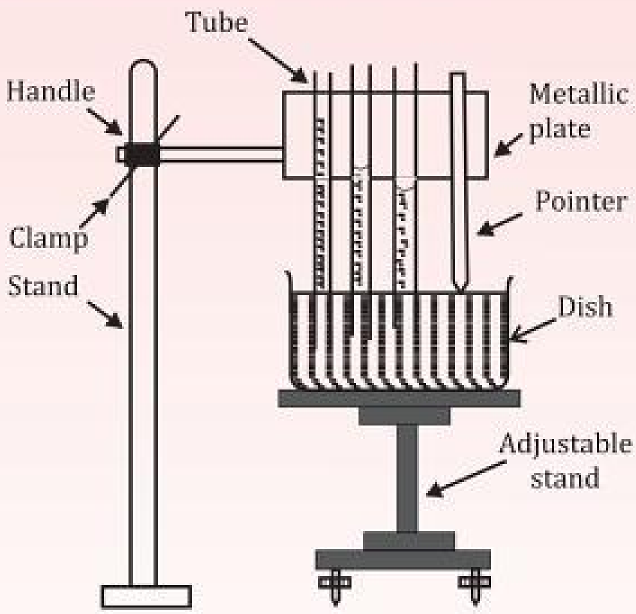


Fig. Measurement of surface tension by capillary rise.

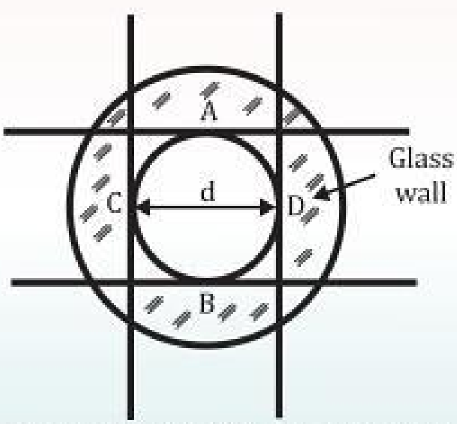


Fig. Measurement of internal diameter of capillary tube.

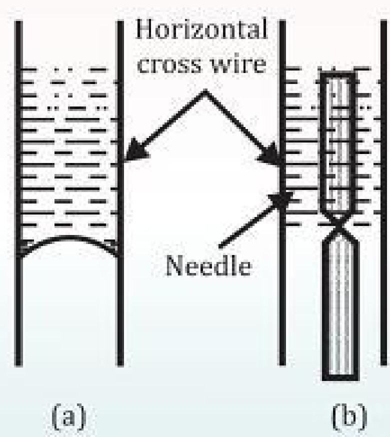
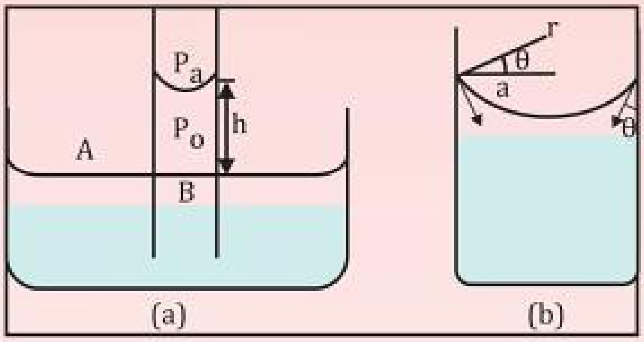


Fig. Water meniscus through microscope.

THEORY

FORMULA USED

If one end of an open capillary tube is inserted in a liquid having surface tension T and density ρ, then the liquid column raises the capillary tube through a height h. The surface tension T acts as shown in the figure. The angle of contact is denoted by α.



For internal radius 'r' of capillary tube, force acting upwards on meniscus around the contact,

$$F = T\cos\alpha + 2\pi r = \text{Weight of liquid column}$$

Now, Weight = Volume of liquid in the column (v) × density (ρ) × acceleration due to gravity (g).
or,

$$F = W = V\rho g$$

Now,

Volume = Volume of column + [(Volume of cylinder at meniscus $- \frac{1}{2}$ (Volume of sphere at meniscus)]

$$= \pi r^2 h + [\pi r^2 \times r - \frac{1}{2}(\frac{4}{3}\pi r^3)]$$

Therefore, cylinder at meniscus has height r as shown in figure,

$$= \pi r^2 h + \frac{1}{3}\pi r^3 = \pi r^2\left(h + \frac{r}{3}\right)$$

$$W = V\rho g = \pi r^2 \rho g\left(h + \frac{r}{3}\right)$$

Thus,

$$T\cos\alpha \times 2\pi r = \pi r^2 \rho g\left(h + \frac{r}{3}\right)$$

$$T = \frac{r\rho g}{2\cos\alpha}\left(h + \frac{r}{3}\right)$$

For small value of angle of contact (α), $\cos\alpha$ ------------ h and $\frac{r}{3}$ can be neglected.

$$T = \frac{rh\rho g}{2}$$

PROCEDURE

A. Setup of the apparatus

1. Position the adjustable height stand on the table and level its base using leveling screws.
2. Fill an open dish with water that is free from dirt and grease, and place it on the stand.
3. Select three capillary tubes with varying radii (ranging from 0.05 mm to 0.15 mm).
4. Clean and dry the capillary tubes, then secure them in a metallic plate in ascending order of radius. Attach a pointer after the third capillary tube.
5. Secure the horizontal handle of the metallic plate on a vertical stand, ensuring that the capillary tubes and the pointer align vertically.

6. Adjust the height of the metallic plate so that the capillary tubes immerse in the water in the open dish.
7. Align the pointer so that its tip just touches the water surface.

B. Measurement of capillary rise

8. Determine the least count of the traveling microscope for both the horizontal and vertical scales; record these values.
9. Adjust the microscope to an appropriate height, maintaining its axis horizontally and directed towards the capillary tubes.
10. Bring the microscope in front of the first capillary tube (with the maximum rise).
11. Align the horizontal crosswire with the central part of the concave meniscus (appearing convex through the microscope).
12. Record the position of the microscope on the vertical scale.
13. Move the microscope horizontally to the second capillary tube.
14. Lower the microscope and repeat steps 11 and 12.
15. Repeat steps 11 and 12 for the third capillary tube.
16. Lower the stand to reveal the pointer tip.
17. Move the microscope horizontally to the pointer.
18. Lower the microscope, ensuring the horizontal crosswire touches the pointer tip.
19. Repeat step 12.

C. Measurement of the internal diameter of the capillary tube

20. Place the first capillary tube horizontally on the adjustable stand.
21. Focus the microscope on the water-dipped end, observing a white circle (inner bore) surrounded by a green circular strip (glass cross-section).
22. Align the horizontal crosswire with the inner circle at A. Record the microscope reading on the vertical scale.
23. Raise the microscope to align the horizontal crosswire with the circle at B. Note the reading (the difference provides the vertical internal diameter AB of the capillary tube).
24. Move the microscope horizontally to make the vertical crosswire touch the inner circle at C. Record the microscope reading on the horizontal scale.
25. Shift the microscope rightward to align the vertical crosswire with the circle at D. Note the reading (the difference gives the horizontal internal diameter CD of the capillary tube).
26. Repeat steps 19 to 24 for the remaining two capillary tubes.
27. Record the temperature of the water in the dish.
28. Document your observations as outlined further.

OBSERVATIONS

At room temperature:

Density of water, ρ = __________ kg/m^3.

Room temperature, t = __________ °C.

Vernier constant of travelling microscope:

Along vertical axis = __________ cm.

Along horizontal axis = ____________ cm.

RADIUS OF CAPILLARY TUBE

S. No.	Reading of meniscus (x)			Reading of needle tip (y)			h = x – y (cm)
	MSR	VSR	Total (cm)	MSR	VSR	Total (cm)	
1.							
2.							
3.							

TABLE FOR HEIGHT OF LIQUID RISE

S. No.	Horizontal diameter			Vertical diameter			Mean d = (cm)	Radius, $r = \frac{d}{2}$ (cm)
	Left end	Right end	Diameter D_1 (cm)	Upper end	Lower end	Diameter D_2 (cm)		
1.								
2.								
3.								
4.								
5.								
6.								

Mean radius = _________ cm.

CALCULATIONS

Surface tension, $S = \frac{rh\rho g}{2}$ = _________ N/m.

RESULT

Surface tension of water at t °C = _________ Nm^{-1}.

PRECAUTIONS

1. Clean the tube thoroughly.
2. Don't use distilled water in the dish, as it is greasy.
3. Tube and pin should be vertical over the water surface.
4. Careful reading of microscope scale should be taken.
5. Effect of backlash error should be avoided by turning screw in one direction.
6. Apparatus should be set in brightly illuminated room.

SOURCES OF ERROR

1. Capillary tube may not be of uniform bore.
2. Tap water may contain dirt or grease.

VIVA VOCE

Q1. What is meant by surface tension?

Ans. The property of a liquid by virtue of which it tends to acquire the least surface area and behaves like a stretched membrane is called surface tension.

Q2. What is the nature of intermolecular forces which cause surface tension?

Ans. The intermolecular forces are electrostatic forces acting between same molecules as well as different molecules.

Q3. Why does mercury column have convex meniscus while water column has concave meniscus?

Ans. The force of cohesion between water and glass is less than force of adhesion. So, it has concave meniscus. However, this is just the opposite case, i.e., force of adhesion between mercury and glass is less than force of cohesion. So, mercury column has convex meniscus.

Q4. Water rises in a capillary tube, but not in an ordinary tube. Why?

Ans. The capillary tube has a very thin diameter. So, rise in height is more. In wide bore tube, the height of rise of water is less, so not easily detectable.

Q5. Which has greater angle of contact with glass mercury or water? Why?

Ans. Mercury has greater angle of contact with glass. The angle of contact of mercury is an obtuse angle, while water has negligible angle of contact. This is because in mercury, force of cohesion is more than force of adhesion.

Q6. Why should we take clean water in this experiment?

Ans. The surface tension increases due to presence of soluble impurities in water and decreases due to insoluble partially soluble impurities in water. In both cases, accuracy of experimental measurement is affected.

Q7. State the formula used to determine surface tension for water?

Ans. Surface tension,

$$T = \frac{rh\rho g}{2}$$

Where, r = radius of capillary tube,

h = height of water level, x

ρ = density of water at room temperature,

g = acceleration due to gravity.

Q8. What determines the height to which water level rises in capillary tube?

Ans. Weight of water column should be equal to upward pull created due to surface tension.