EXPERIMENT 12

AIM

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

APPARATUS AND MATERIAL REQUIRED

A glass/plastic capillary tube, travelling microscope, beaker, cork with pin, clamps and stand, thermometer, dilute nitric acid solution, dilute caustic soda solution, water, plumb line.

PRINCIPLE

When a liquid rises in a capillary tube [Fig. E 12.1], the weight of the column of the liquid of density ρ below the meniscus, is supported by the upward force of surface tension acting around the circumference of the points of contact. Therefore

$2\pi rT = \pi r^2 h\rho g$ (approx) for water

or $T = \dfrac{h\rho gr}{2}$

where T = surface tension of the liquid,

h = height of the liquid column and

r = inner radius of the capillary tube

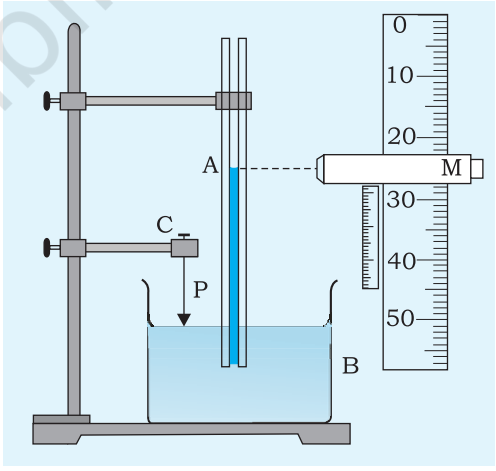

Fig.E 12.1: *Rise of liquid in a capillary tube*

PROCEDURE

1. Do the experiment in a well-lit place for example, near a window or use an incandescent bulb.
2. Clean the capillary tube and beaker successively in caustic soda and nitric acid and finally rinse thoroughly with water.
3. Fill the beaker with water and measure its temperature.
4. Clamp the capillary tube near its upper end, keeping it above the beaker. Set it vertical with the help of a plumbline held near it.

Move down the tube so that its lower end dips into the water in the beaker.

5. Push a pin P through a cork *C*, and fix it on another clamp such that the tip of the pin is just above the water surface as shown in Fig. E 12.1. Ensure that the pin does not touch the capillary tube. Slowly lower the pin till its tip just touches the water surface. This can be done by coinciding the tip of the pin with its image in water.

6. Now focus the travelling microscope M on the meniscus of the water in capillary A, and move the microscope until the horizontal crosswire is tangential to the lowest point of the meniscus, which is seen inverted in M. If there is any difficulty in focussing the meniscus, hold a piece of paper at the lowest point of the meniscus outside the capillary tube and focus it first, as a guide. Note the reading of travelling microscope.

7. Mark the position of the meniscus on the capillary with a pen. Now carefully remove the capillary tube from the beaker, and then the beaker without disturbing the pin.

8. Focus the microscope on the tip of the pin and note the microscope reading.

9. Cut the capillary tube carefully at the point marked on it. Fix the capillary tube horizontally on a stand. Focus the microscope on the transverse cross section of the tube and take readings to measure the internal diameter of the tube in two mutually perpendicular directions.

OBSERVATIONS

Determination of h

Least count (L.C.) of the microscope = ... mm

Table E 12.1 : Measurement of capillary rise

S. No.	Reading of meniscus h_1 (cm)			Reading of tip of pin touching surface of water h_2 (cm)			$h = h_1 - h_2$
	M.S.R. S (cm)	V.S.R. n	$h_1 = (S + n \times \text{L.C.})$	M.S.R. S' (cm)	V.S.R. n'	$h_2 = (S' + n' \times \text{L.C.})$ (cm)	
1							
2							
3							

Table E 12.2 : Measurement of diameter of the capillary tube

S. No.	Reading along a diameter (cm)		Diameter $d_1 (x_2 - x_1)$	Reading along perpendicular diameter		Diameter $d_2 (y_2 - y_1)$	Mean diameter $d = \frac{d_1 + d_2}{2}$
	One end	other end	(cm)	One end	other end	(cm)	
1	x_1	x_2		y_1	y_2		
2							
3							

Mean radius r = ... cm; Temperature of water θ = ... °C;

Density of water at $0°$ C = ... g cm^{-3}

CALCULATION

Substitute the value of h and r and ρg in the formula for T and calculate the surface tension.

RESULT

The surface tension of water at ... °C = ... ± ... Nm^{-1}

PRECAUTIONS

1. To make capillary tube free of contamination, it must be rinsed first in a solution of caustic soda then with dilute nitric acid and finally cleaned with water thoroughly.
2. The capillary tube must be kept vertical while dipping it in water.
3. To ensure that capillary tube is sufficiently wet, raise and lower water level in container by lifting or lowering the beaker. It should have no effect on height of liquid level in the capillary tube.
4. Water level in the capillary tube should be slightly above the edge of the beaker/dish so that the edge does not obstruct observations.
5. Temperature should be recorded before and after the experiment.
6. Height of liquid column should be measured from lowest point of concave meniscus.

SOURCES OF ERROR

1. Inserting dry capillary tube in the liquid can cause gross error in the measurement of surface tension as liquid level in capillary tube may not fall back when the level in container is lowered.

2. Surface tension changes with impurities and temperature of the liquid.

3. Non-vertical placement of the capillary tube may introduce error in the measurement of height of the liquid column in the tube.

4. Improper focussing of meniscus in microscope could cause an error in measurement of the height of liquid column in the capillary tube.

DISCUSSION

1. In a fine capillary tube, the meniscus surface may be considered to be semispherical and the weight of the liquid above the lowest point of the meniscus as $\frac{1}{3}\rho r^3 \pi g$. Taking this into account, the formula for surface tension is modified to $T = \frac{1}{2}\rho g r\left(h + \frac{r}{3}\right)$. More precise calculation of surface tension can be done using this formula.

2. If the capillary is dry from inside the water that rises to a certain height in it will not fall back, so the capillary should be wet from inside. To wet the inside of the capillary tube thoroughly, it is first dipped well down in the water and raised and clamped. Alternatively, the beaker may be lifted up and placed down.

SELF ASSESSMENT

1. Suppose the length of capillary tube taken is less than the height upto which liquid could rise. What do you expect if such a tube is inserted inside the liquid? Explain your answer.

2. Two match sticks are floating parallel and quite close to each other. What would happen if a drop of soap solution or a drop of hot water falls between the two sticks? Explain your answer.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Experiment can be performed at different temperatures and effect of temperature on surface tension can be studied.

2. Experiment can be performed by adding some impurities and effect of change in impurity concentration (like adding NaCl or sugar) on surface tension can be studied.

3. Study the effect of inclination of capillary tube on height of liquid rise in the capillary tube.