Paper : Physical Chemistry (IA)
Topic : Physical Properties of Liquids

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A mathematical relationship between surface tension of a liquid and its temperature is given by W. Ramsay and J. Shields :

$$\gamma \left(\frac{M}{\rho}\right)^{2/3} = k\,(t_c - t - 6)$$

where k is a constant (temperature coefficient), t_c is critical temperature and t any other temperature. $(M/\rho)^{2/3}$ represents molar surface energy of the liquid.

The table given below shows the surface tensions of some liquids at various temperatures (in dynes cm^{-1})

Liquid	20°C	40°C	60°C	80°C
Water	72.75	69.56	66.18	62.61
Ethyl alcohol	22.27	20.60	19.01	—
Methyl alcohol	22.6	20.9	—	—
Acetone	23.7	21.2	18.6	16.2
Toluene	28.43	26.13	23.81	21.53
Benzene	28.9	26.3	23.7	21.3

Determination of Surface Tension :→

The methods commonly employed for the determination of surface tension are :

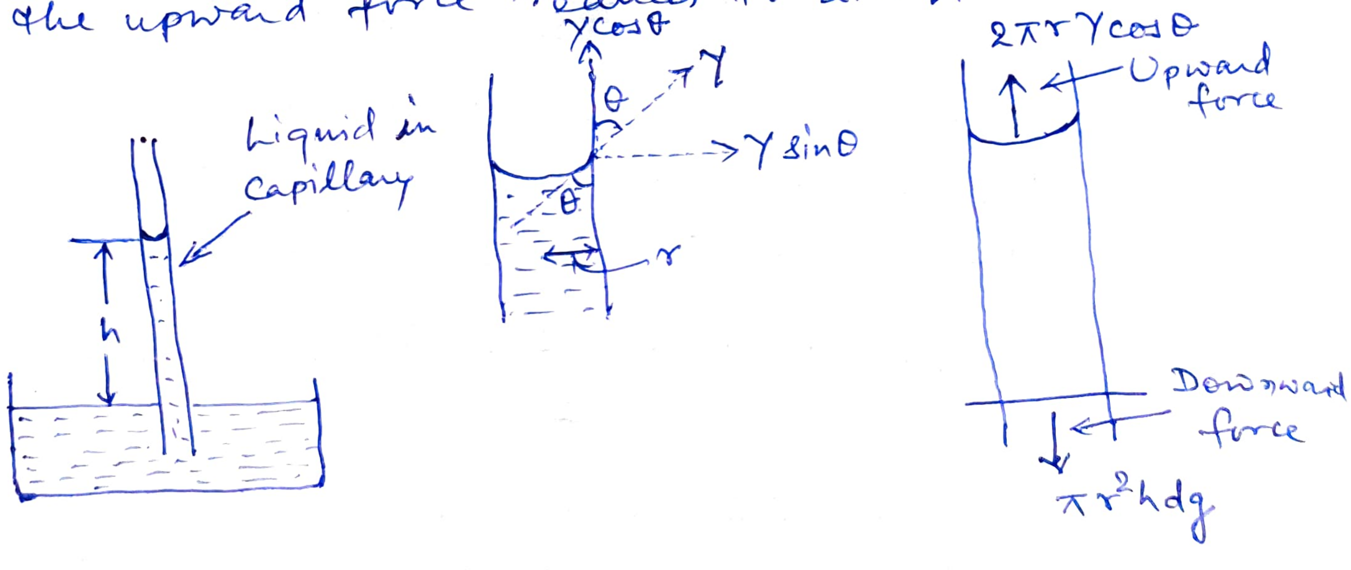
(1.) Capillary-rise Method :–

A capillary tube of radius r is vertically inserted into a liquid. The liquid rises to a height h and forms a concave meniscus. The surface tension (γ) acting along the inner circumference of the tube exactly supports the weight of the liquid column.

By definition, surface tension is force per 1 cm acting at a tangent to the meniscus surface. If the angle between the tangent and the tube wall is θ, the vertical component of surface tension is $\gamma \cos\theta$. The total surface tension along the circular contact line of meniscus is $2\pi r$ times. Therefore,

$$\text{Upward force} = 2\pi r \gamma \cos\theta$$

where r is the radius of the capillary. For most liquids, θ is essentially zero, and $\cos\theta = 1$. Then the upward force reduces to $2\pi r\gamma$.



The downward force on the liquid column is due to its weight which is mass x gravity.

Thus,

$$\text{Downward force} = \pi r^2 h d g$$

where d is the density of the liquid.

But since

$$\text{Upward force} = \text{Downward force}$$

or, $$2\pi r \gamma = \pi r^2 h d g$$

or, $$\gamma = \frac{r h d g}{2} \text{ dynes/cm}$$

In order to know the value of γ, the value of h is found with the help of a travelling microscope and the density (d) with pyknometer.

Example : A capillary tube of internal diameter 0.21 mm is dipped into a liquid whose density is 0.79 g cm^{-3}. The liquid rises in this capillary to a height of 6.30 cm. Calculate the surface tension of the liquid ($g = 980$ cm/sec^2).

Sol. : We know that

$$\gamma = \frac{h r d g}{2} \text{ dynes/cm}$$

Substituting the values (given) as

$h = 6.30$ cm ; $r = \frac{0.21}{2} \times \frac{1}{10}$ cm $= 0.0105$ cm

$d = 0.79$ g cm^{3} ; $g = 980$ cm sec^{-2}, we have

$$\gamma = \frac{6.30 \times 0.0105 \times 0.79 \times 980}{2} \text{ dynes/cm}$$

$$= 25.6 \text{ dynes/cm}$$

Thus the surface tension of the given liquid is 25.6 dynes/cm.

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