CAPILLARITY

- The phenomenon of rise or fall of liquid in a capillary tube is called capillarity or capillary action.
- The rise or fall of liquid in a capillary tube is given by

$$h = \frac{2S\cos\theta}{r\rho g} = \frac{2S}{R\rho g} \qquad \left(\because \cos\theta = \frac{r}{R}\right)$$

where S is the surface tension of the liquid, θ is the angle of contact, ρ is the density of liquid, r is the radius of capillary tube, R is the radius of the meniscus and g is the acceleration due to gravity.
  - If $\theta < 90°$, *i.e.*, **meniscus is concave**, h will be positive, *i.e.*, the liquid will rise in the capillary.
  - If $\theta > 90°$, *i.e.*, **meniscus is convex**, h will be negative, *i.e.*, the liquid will fall in a capillary tube.
  - If $\theta = 90°$, *i.e.*, **meniscus is plane**, $h = 0$, so no phenomenon of capillarity.
- If a capillary tube is of insufficient length as compared to height to which liquid can rise in the capillary tube, then the liquid rises upto the full length of capillary tube but there is no overflowing of the liquid in the form of fountain. It is so because the liquid meniscus adjusts its radius of curvature so that hR = constant *i.e.* $hR = h'R'$.

Variation in Surface Tension

- The surface tension of the liquid decreases with rise in temperature and becomes zero at the critical temperature.
- A highly soluble substance like sodium chloride (common salt) when dissolved in water, increases the surface tension of water.
- When a sparingly soluble substance like phenol, dissolved in water, reduces the surface tension of water.
- When a detergent or soap is mixed with water, the surface tension of water decreases.

Illustration 16

Air is pushed into a soap bubble of radius r to double its radius. If the surface tension of the soap solution is S, the work done in the process is

(a) $8\pi r^2S$ (b) $12\pi r^2S$

(c) $16\pi r^2S$ (d) $24\pi r^2S$

Soln. (d) : A soap bubble has two surfaces, hence its surface potential energy is

$U_0 = 2(4\pi r^2)S = 8\pi r^2 \cdot S$

If the radius of the soap bubble is doubled, then its surface potential energy.

$U_f = 2(4\pi(2r)^2)S = 32\pi r^2 \cdot S$

The work done in this process is $\Delta U = U_f - U_o = 24\pi r^2 \cdot S$

$\Rightarrow$ (d) is correct.

Illustration 17

Two soap bubbles of radii a and b combine to form a single bubble of radius c. If P is the external pressure, then the surface tension of the soap solution is

(a) $\frac{P(c^3 + a^3 + b^3)}{4(a^2 + b^2 - c^2)}$ (b) $\frac{P(c^3 - a^3 - b^3)}{4(a^2 + b^2 - c^2)}$

(c) $Pc^3 - 4a^2 - 4b^2$ (d) $Pc^2 - 2a^2 - 3b^2$

Soln. (b) : As the total mass of the air inside the bubble and the temperature remains constant, we can say,

$P_aV_a + P_bV_b = P_cV_c$

As pressure inside the soap bubble is $\frac{4\sigma}{r}$ more than the external pressure, (here σ is the surface tension)

$$\left(P + \frac{4\sigma}{a}\right)\cdot\left(\frac{4}{3}\pi a^3\right) + \left(P + \frac{4\sigma}{b}\right)\cdot\left(\frac{4}{3}\pi b^3\right) = \left(P + \frac{4\sigma}{c}\right)\cdot\left(\frac{4}{3}\pi c^3\right)$$

$\Rightarrow \quad P(a^3 + b^3 - c^3) = 4\sigma(c^2 - a^2 - b^2)$

or $\quad \sigma = \frac{P(c^3 - a^3 - b^3)}{4(a^2 + b^2 - c^2)}$

$\Rightarrow$ (b) is correct.

Illustration 18

How much work is done in doubling a soap bubble of radius r and surface tension T?

Soln.: $W = 2 \times T \times \Delta A = 2 \times T \times [4\pi \times (2r)^2 - (4\pi r^2)]$
$= 2T \times 4\pi \times 3r^2 = 24\pi r^2T$.

HEAT

- Heat is the form of energy that flows between a body and its surrounding medium by virtue of temperature difference between them.
- The SI unit of heat is joule.
- The practical unit of heat is calorie.
- 1 calorie is the amount of heat required to raise the temperature of 1 g of water from 14.5°C to 15.5°C.
- Joule found that when mechanical work (W) is converted into heat (Q), the ratio of W and Q is always constant, represented by J,

  i.e. $\frac{W}{Q} = J$ or $W = JQ$

  where J is Joule's mechanical equivalent of heat. J is not a physical quantity but a conversion factor involved when work is converted into heat or vice-versa. The value of
  J = 4.186 joule/calorie
  i.e. 1 calorie = 4.186 joule.

TEMPERATURE

- Temperature is basically a measure of degree of hotness or coldness of a body.