

## 1.8.4 Osmotic Pressure

The solute particles present in a solution behave almost in the same way as the molecules of a gas do. Similar to gases, solutions also exhibit the phenomenon of **diffusion**. When a pure solvent is taken over a solution, the solute particles diffuse from the solution into the solvent. In fact, diffusion exhibited by solutions is a *bilateral process* in which solute molecules move into the solvent and at the same time the solvent molecules move into the solution as shown in Fig. 1.16. The process continues till the system becomes homogeneous. The diffusion of solute also takes place when two solutions of different concentration are kept in direct contact. Thus, *solutions possess a tendency to equalise concentration in all parts and this tendency is responsible for the diffusion of solute*. The tendency of a solution to equalise concentration in all its parts gives rise to another important phenomenon known as **osmosis**. The phenomenon of osmosis is related to an important colligative property of solutions called **osmotic pressure**. In the forthcoming discussion we shall study osmosis and osmotic pressure in somewhat detail.

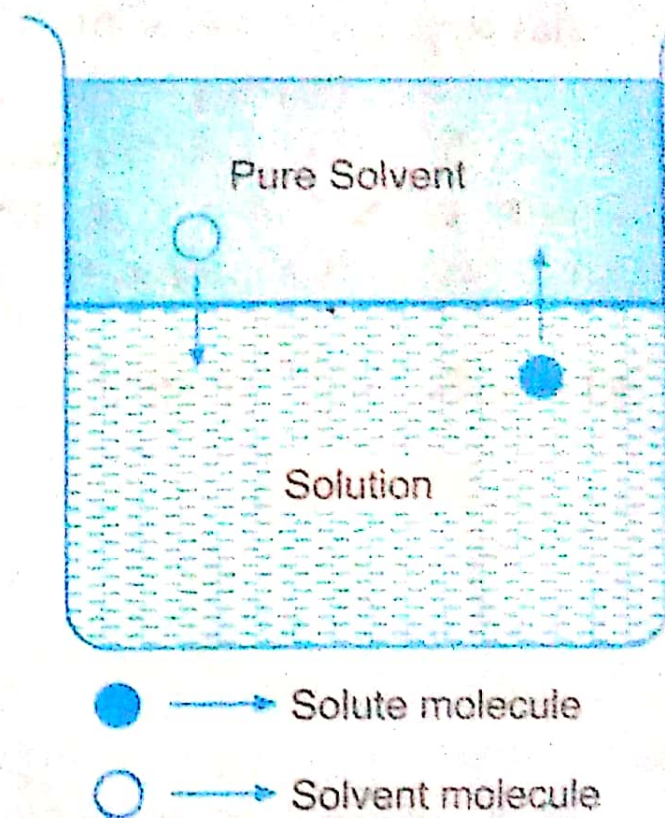


Fig. 1.16 Diffusion in solution.

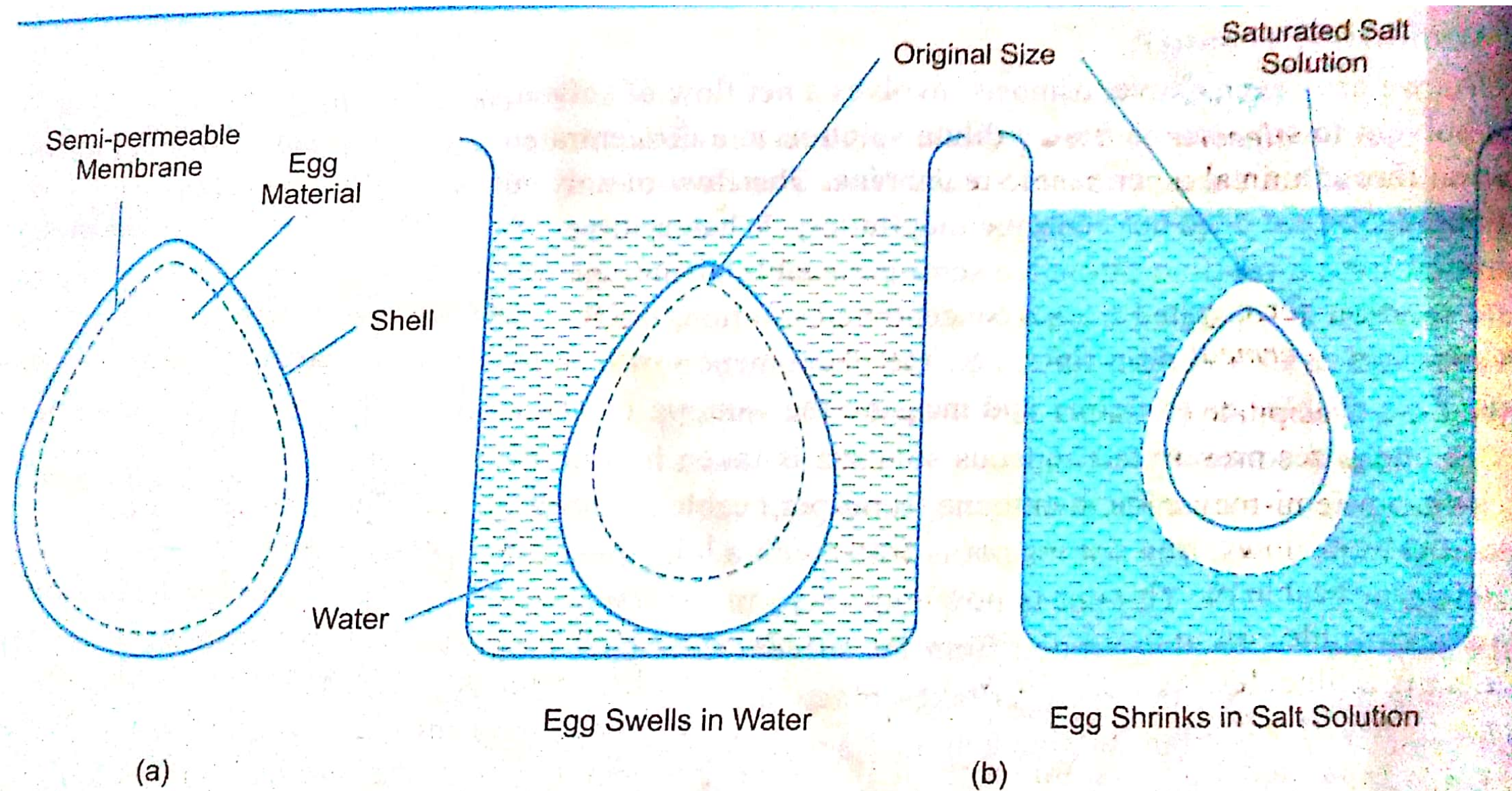


Fig. 1.18 (a) Structure of an egg (b) Demonstration of the phenomenon of osmosis.

**Table 1.10 Difference between Diffusion and Osmosis**

<b>Diffusion</b>	<b>Osmosis</b>
<p>Diffusion involves the free mixing of the solution without a semi-permeable membrane.</p> <p>In diffusion, both solvent and solute molecules move directly into each other. Thus, it is a bilateral process.</p> <p>In diffusion, solute particles move from higher concentration to lower concentration while the solvent molecules move from lower concentration to higher concentration.</p> <p>It is shown by solutions as well as by gases.</p> <p>It can neither be stopped nor can be reversed.</p>	<ol style="list-style-type: none"><li>1. Osmosis involves the use of a semi-permeable membrane.</li><li>2. In osmosis, only solvent molecules move through the semi-permeable membrane. The movement of solute particles is checked by the semi-permeable membrane.</li><li>3. In osmosis, the net flow of solvent molecules is from lower concentration to higher concentration.</li><li>4. It is shown by solutions only.</li><li>5. It can be stopped or reversed by applying external pressure on the solution having a higher concentration.</li></ol>

*The osmotic pressure of a solution at a particular temperature may be defined as the hydrostatic pressure which builds up when the solution is separated from the solvent by a semi-permeable membrane and which is just sufficient to stop the phenomenon of osmosis.*

## (D) Laws of Osmotic Pressure and van't Hoff's Equation

van't Hoff (1877) established that *the solute particles present in a solution behave exactly like the molecules of a gas and the osmotic pressure of a dilute solution is equal to the pressure which the solute would exert if it were a gas at the same temperature and occupying the same volume as that of the solution.* He also found that the ordinary laws obeyed by gases are also obeyed by dilute solutions. The ordinary gas laws when applied to solutions are referred to as **laws of osmotic pressure.** These are as follows.

(i) **Boyle-van't Hoff law** : According to this law, *the osmotic pressure of a dilute solution is directly proportional to its concentration provided temperature remains constant.*

Let  $\pi$  be the osmotic pressure and  $C$  the concentration of a dilute solution. According to this law,

$$\pi \propto C \text{ (at constant temperature)} \quad (1.41)$$

If concentration of solution is expressed in moles per litre and  $V$  is the volume containing one mole of the solute,  $C = 1/V$ . Therefore relation 1.41 can be written as

$$\pi \propto \frac{1}{V} \text{ (at constant temperature)} \quad (1.42)$$

This relationship is similar to the Boyle's law for gases and is known as **Boyle-van't Hoff law.**

(ii) **Charles'-van't Hoff law** : According to this law, *the osmotic pressure of a dilute solution is directly proportional to the absolute temperature if concentration of the solution is kept constant.* Mathematically,

$$\pi \propto T \text{ (at constant concentration)} \quad (1.43)$$

This relationship is similar to the Charles' law for gases and is known as **Charles'-van't Hoff law.**

(iii) **Avogadro-van't Hoff law** : According to this law, *equal volumes of solutions contain equal number of moles (molecules) of solute provided their osmotic pressures and temperatures are the same.*

This statement is similar to the Avogadro's law for gases and is known as **Avogadro-van't Hoff law.**

**van't Hoff Equation**  
We have already seen that according to Boyle-van't Hoff law

$$\pi \propto \frac{1}{V} \text{ (at constant temperature)} \quad \dots (i)$$

and according to Charles'-van't Hoff law

$$\pi \propto T \text{ (at constant concentration)} \quad (1)$$

Combining (i) and (ii), we have

$$\pi \propto \frac{T}{V}$$

or,

$$\pi = S \frac{T}{V}$$

or,

$$\pi V = ST \quad (1.44)$$

In this equation  $S$  is a constant known as **solution constant**. van't Hoff showed that the value of solution constant ( $S$ ) is equal to that of the gas constant,  $R$ , i.e.,

$$S = R$$

Hence, Eq. 1.44 can be written as

$$\pi V = RT \quad (1.45)$$

This equation is similar to the gas equation ( $PV = RT$ ) and is known as **van't Hoff equation**. For  $n$  moles of the solute dissolved in  $V$  litres of the solution, van't Hoff equation can be written as

$$\pi V = nRT \quad (1.46)$$

**Osmotic pressure is a colligative property :**

From Eq. 1.46, we have

$$\pi = \frac{n}{V} RT$$

If temperature is kept constant,

$$\pi \propto \frac{n}{V}$$

Thus, **osmotic pressure of a solution depends upon the number of moles of solute dissolved in a definite volume of solution. It does not depend upon the nature of solute.** Hence, osmotic pressure is a colligative property.