12.6 Colligative Properties

Colligative properties are properties of a liquid that change when a solute is dissolved.

- Colligative properties depend only on the *number* of solute particles, **not** on the identity of the solute.

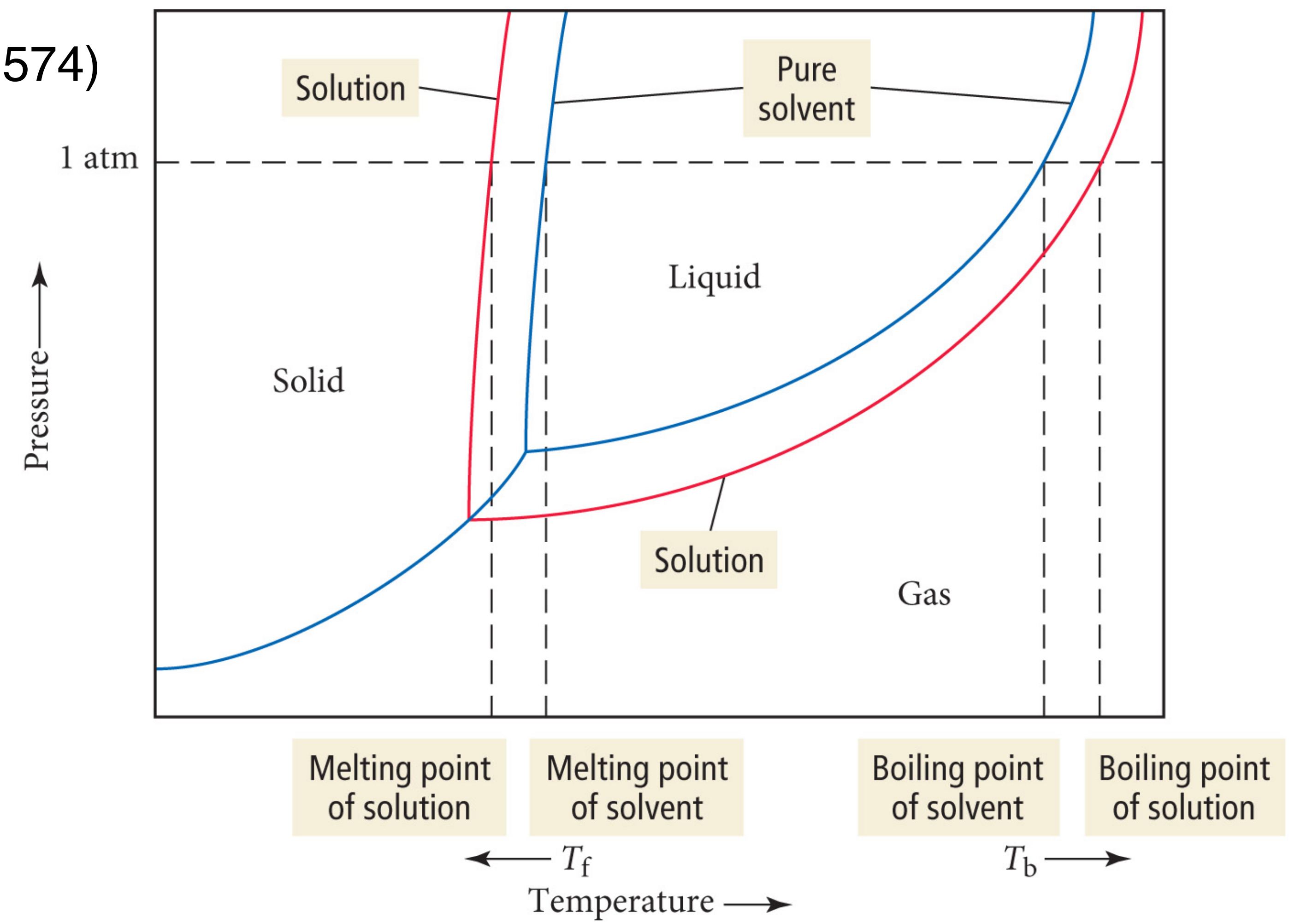
Four colligative properties:

1. **Vapor pressure lowering**
2. **Freezing point depression**
3. **Boiling point elevation**
4. **Osmotic pressure**

Colligative Properties

- A solution will have a higher boiling point and a lower freezing point than the pure liquid:

(p. 574)



Freezing Point Depression

- A solute **lowers** the freezing point of the solvent. The amount that the freezing temperature is reduced (ΔT_f) depends on the molality of the solute:

$$\mathbf{\Delta \mathit{T}_f = \mathit{K}_f \mathit{m}}$$

- K_f is the Freezing Point Depression constant, and depends on the solvent (1.86 °C/m for water).
- ΔT_f is always a *decrease* in temperature, so an aqueous solution will freeze at 0.0 °C – ΔT_f

Boiling Point Elevation

- Since a *non-volatile* solute lowers the V.P. of a solvent, it also **raises the boiling point**:

$$\mathbf{\Delta \mathit{T}_b = \mathit{K}_b \mathit{m}}$$

- K_b = 0.512 °C/m for water.
- The b.p. of a solution is the b.p. of the pure liquid + ΔT_b.

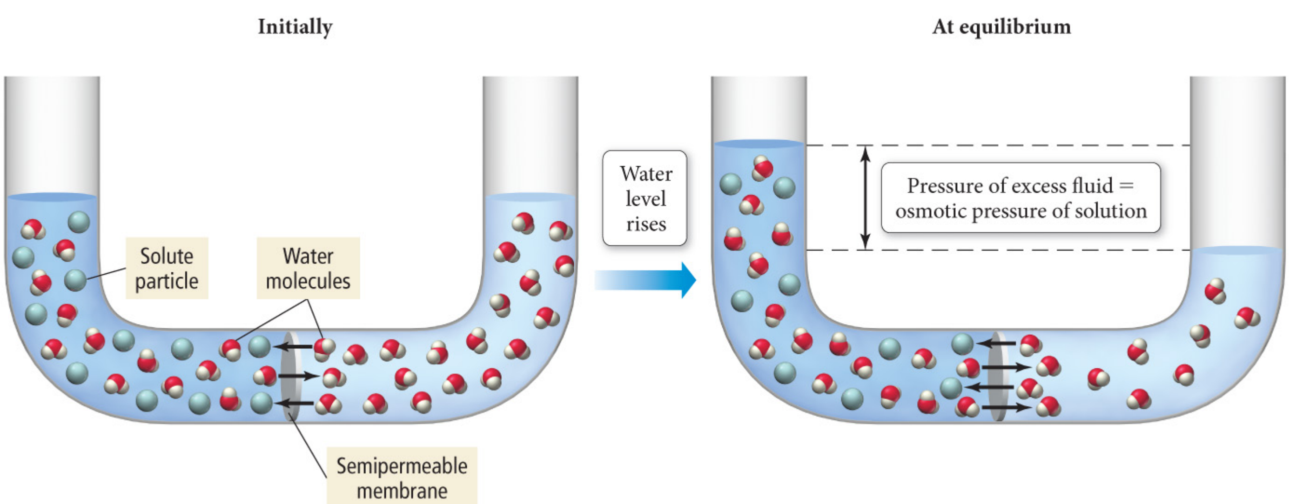
Osmotic Pressure

If aqueous solutions are separated by a "semipermeable membrane" which allows water but not solute to pass across it, osmosis will cause a net flow of water across the membrane **into the more concentrated solution**.

- This flow of water produces a pressure called the **osmotic pressure, Π**:

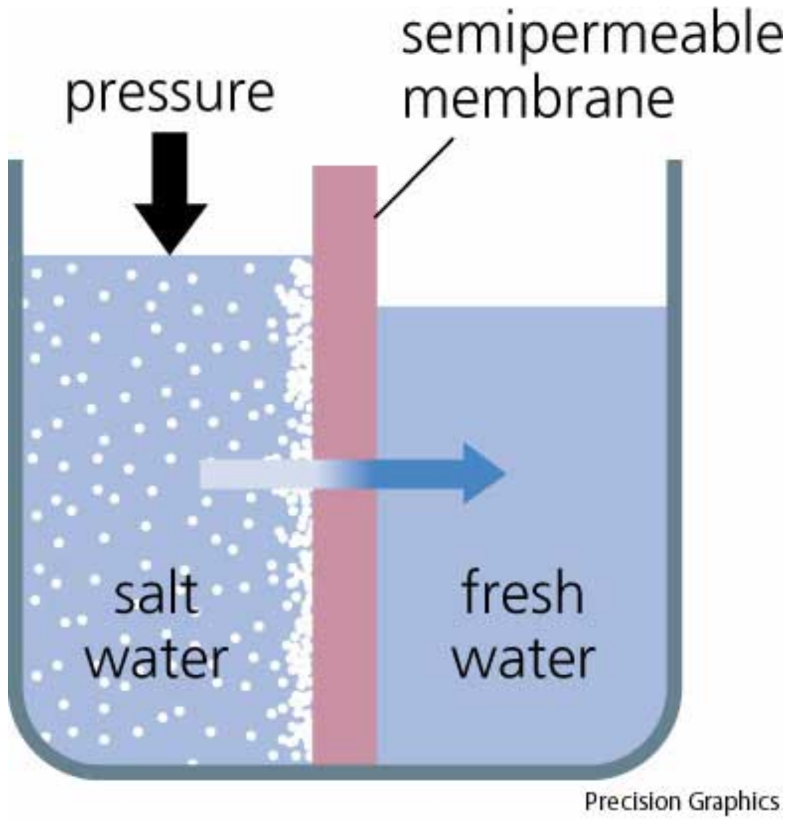
$$\Pi = MRT \quad (M = \text{molarity, R} = 0.08206\ \text{L•atm/mol•K})$$

Figure 12.16 **Osmosis and Osmotic Pressure**



Reverse Osmosis

- If a pressure **greater** than Π is applied to the more concentrated side, pure water will flow across the membrane. This is known as **reverse osmosis**, a method for purifying water.



12.7 Colligative Properties of Electrolytes

NaCl lowers the freezing point of water by almost twice the expected amount. Why? Because NaCl dissociates to Na^+ and Cl^- in solution:

$$NaCl\ (s) \rightarrow Na^+\ (aq) + Cl^-\ (aq)$$

- So for electrolytes: $\Delta T = i\, K\, m$
- i is called the **van't Hoff factor**, **the number of particles per formula unit** that the compound dissociates into in solution.

Colligative Properties of Electrolytes (contd.)

Many solutions are non-ideal due to association of ions, and have *i* less than the expected value, due to ion pairing.

TABLE 12.9 Van't Hoff Factors at 0.05 *m* Concentration in Aqueous Solution

Solute	*i* Expected	*i* Measured
Nonelectrolyte	1	1
NaCl	2	1.9
$MgSO_4$	2	1.3
$MgCl_2$	3	2.7
K_2SO_4	3	2.6
$FeCl_3$	4	3.4

Figure 12.17