

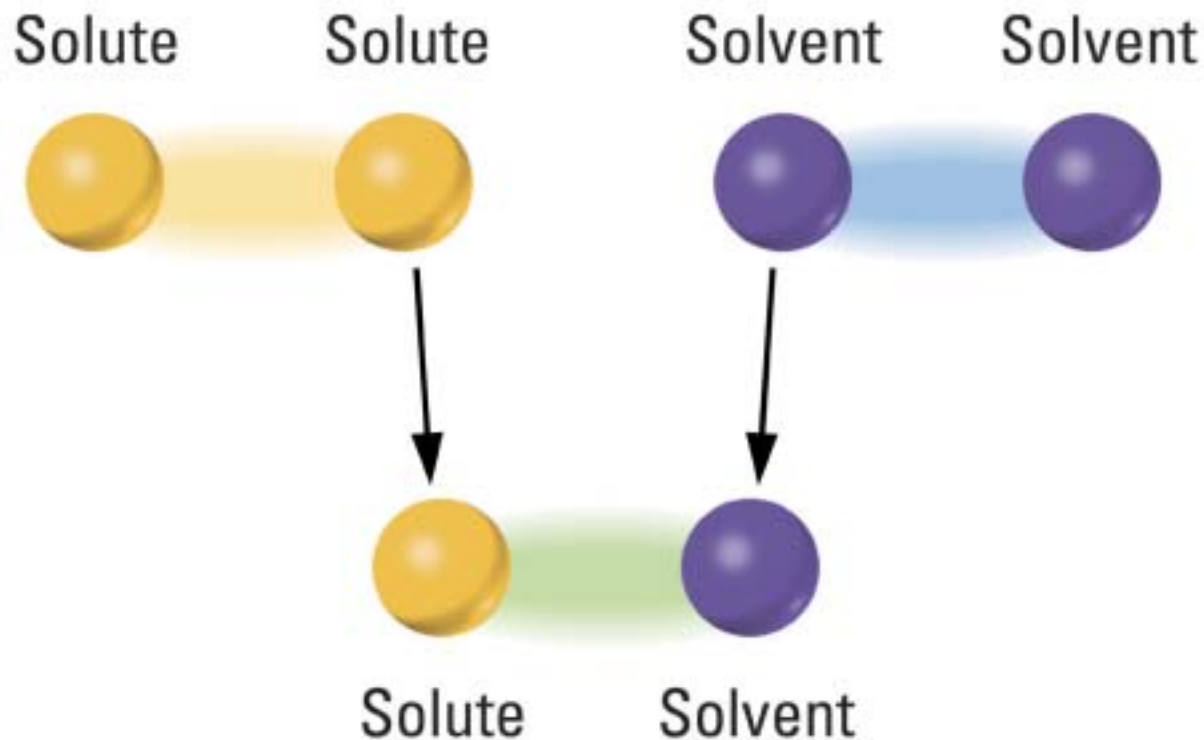
# Chapter 15

## The Chemistry of Solutes and Solutions

# Solution Terminology

- Solute: one or more substance(s) dispersed in the solution
- Solvent: majority substance in a solution

## Solute - Solvent Interactions



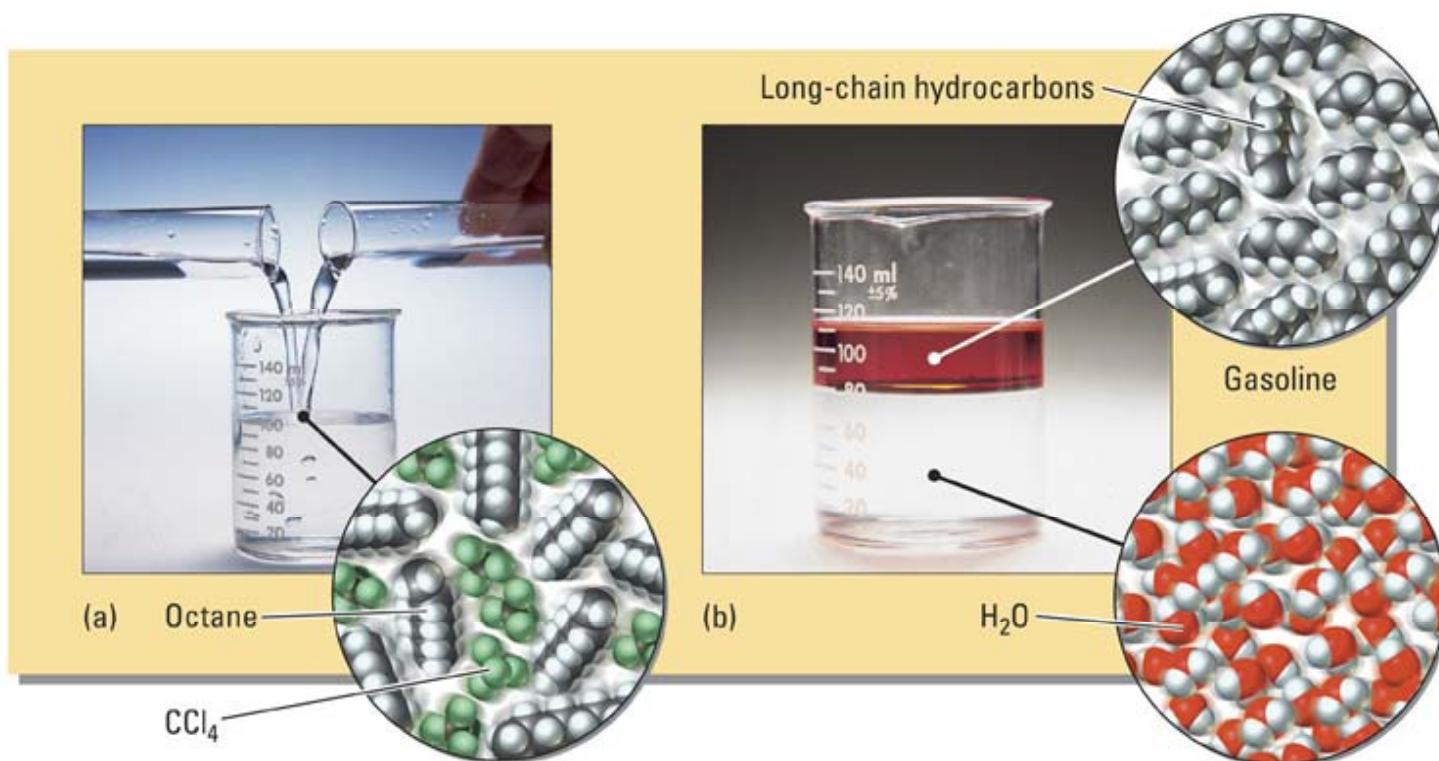
# Types of Solutions

**TABLE 15.1** Types of Solutions

Type of solution	Example
Gas in gas	Air — a mixture principally of $\text{N}_2$ and $\text{O}_2$ but containing other gases as well
Gas in liquid	Carbonated beverages ( $\text{CO}_2$ in water)
Gas in solid	Hydrogen in palladium metal
Liquid in liquid	Motor oil—a mixture of liquid hydrocarbons; coffee with cream; tea with lemon juice
Solid in liquid	The oceans (dissolved $\text{Na}^+$ , $\text{Cl}^-$ , and other ions)
Solid in solid	Bronze (copper and tin); pewter (tin, antimony, and lead)

# Miscible vs. Immiscible

- miscible - liquids that dissolve in each other
- immiscible - liquids that do not dissolve in each other due to differences types of interactions



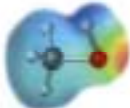


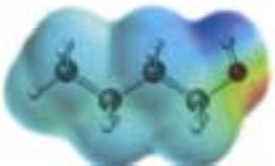

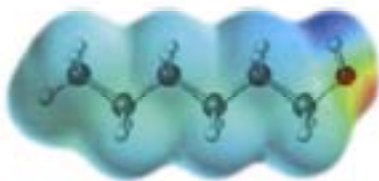


# “Likes Dissolve Likes”

- substances with similar noncovalent forces are likely to be soluble in each other
- solutes do not readily dissolve in solvents whose noncovalent forces are quite different from their own
- stronger solute-solvent attractions favor solubility, stronger solute-solute or solvent-solvent attractions reduce solubility

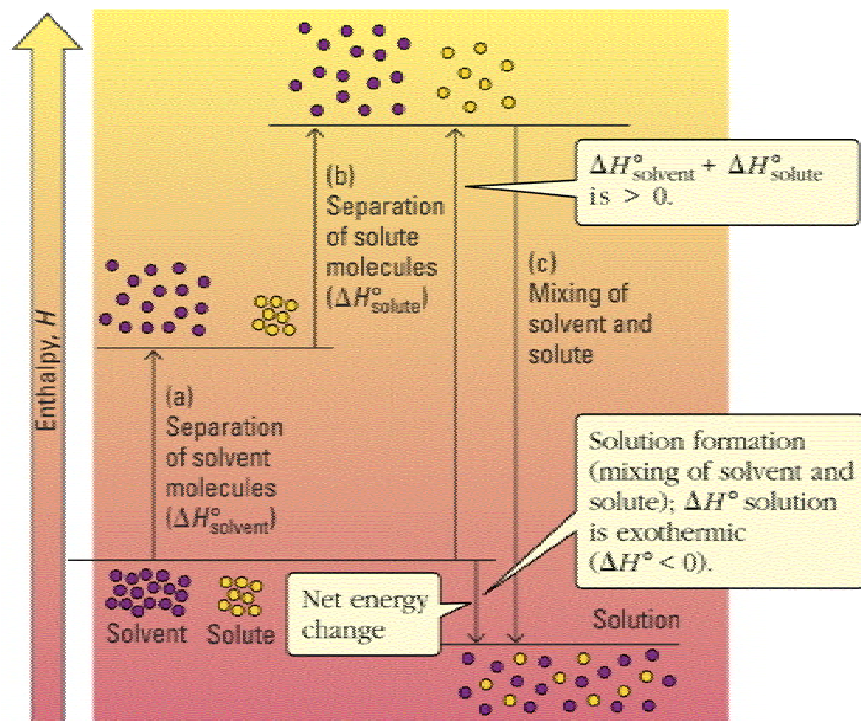
# Solubilities of Some Alcohol

**TABLE 15.2** Solubilities of Some Alcohols in Water

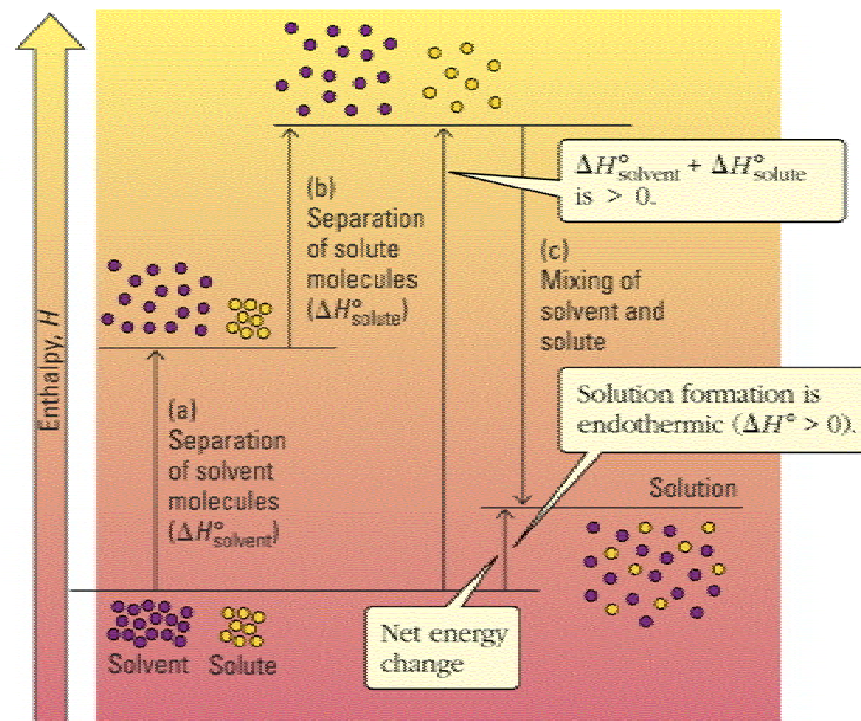
Name	Formula	Solubility in water (g/100 g H <sub>2</sub> O at 20 °C)	Models
Methanol	CH <sub>3</sub> OH	Miscible	
Ethanol	CH <sub>3</sub> CH <sub>2</sub> OH	Miscible	
1-Propanol	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> OH	Miscible	
1-Butanol	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> OH	7.9	
1-Pentanol	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> OH	2.7	
1-Hexanol	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>5</sub> OH	0.6	

# The Solution Making Process

An exothermic solution-making process



An endothermic solution-making process



# Solution Terminology

saturated

- solution containing undissolved solute in equilibrium with the solution

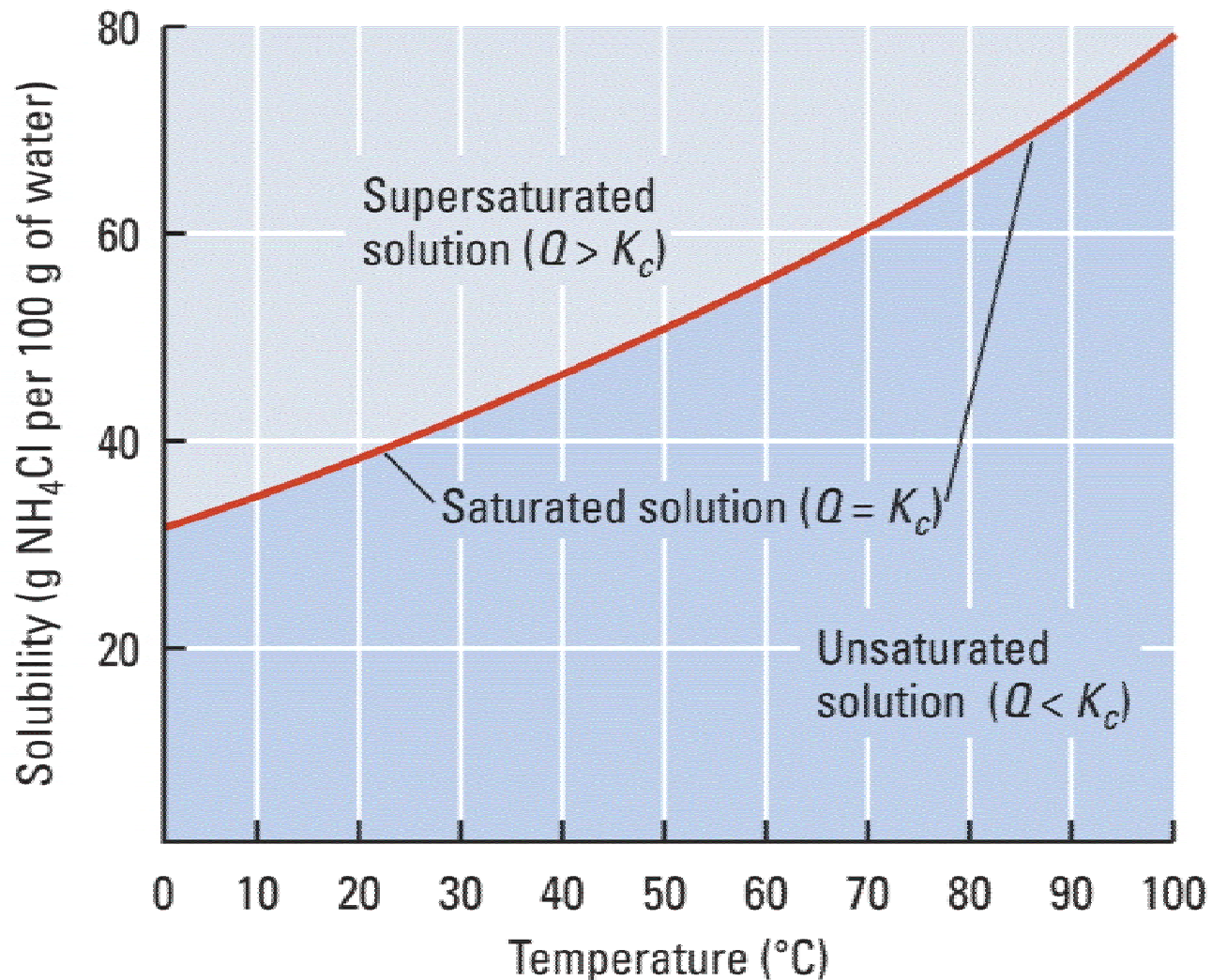
unsaturated

- solution containing less than the maximum amount of solute

supersaturated

- solution containing more solute than is normally allowed

# Types of Solutions



# Supersaturated Solution



(a)



(b)



(c)



(d)

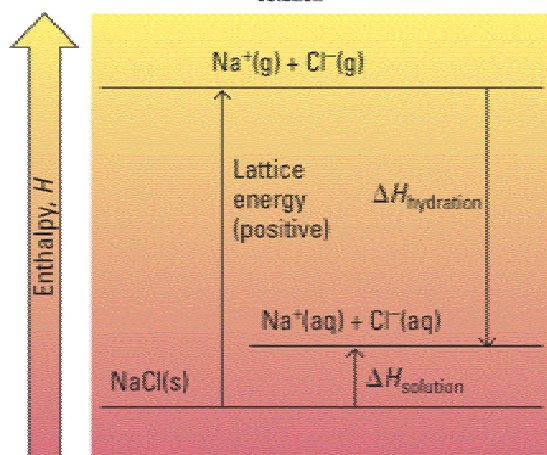


(e)

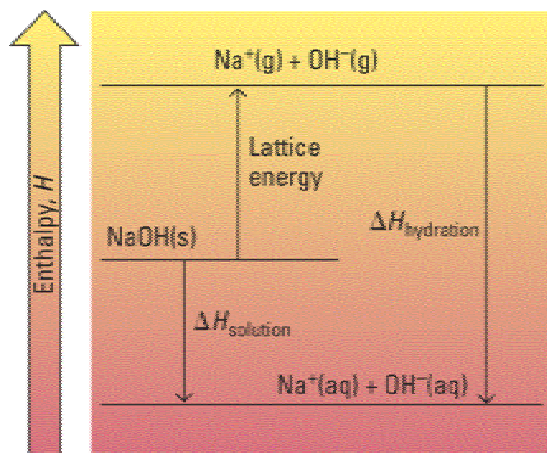


# Heats of Solution

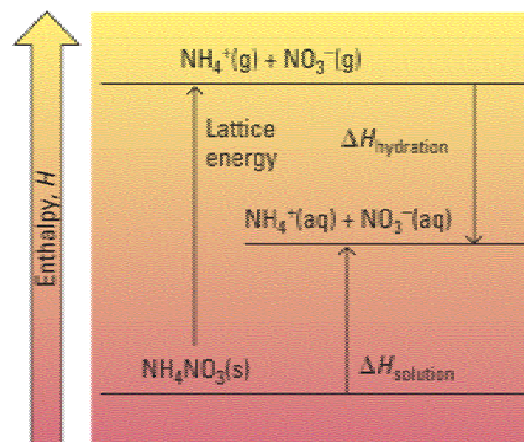
Small endothermic  $\Delta H_{\text{solution}}$



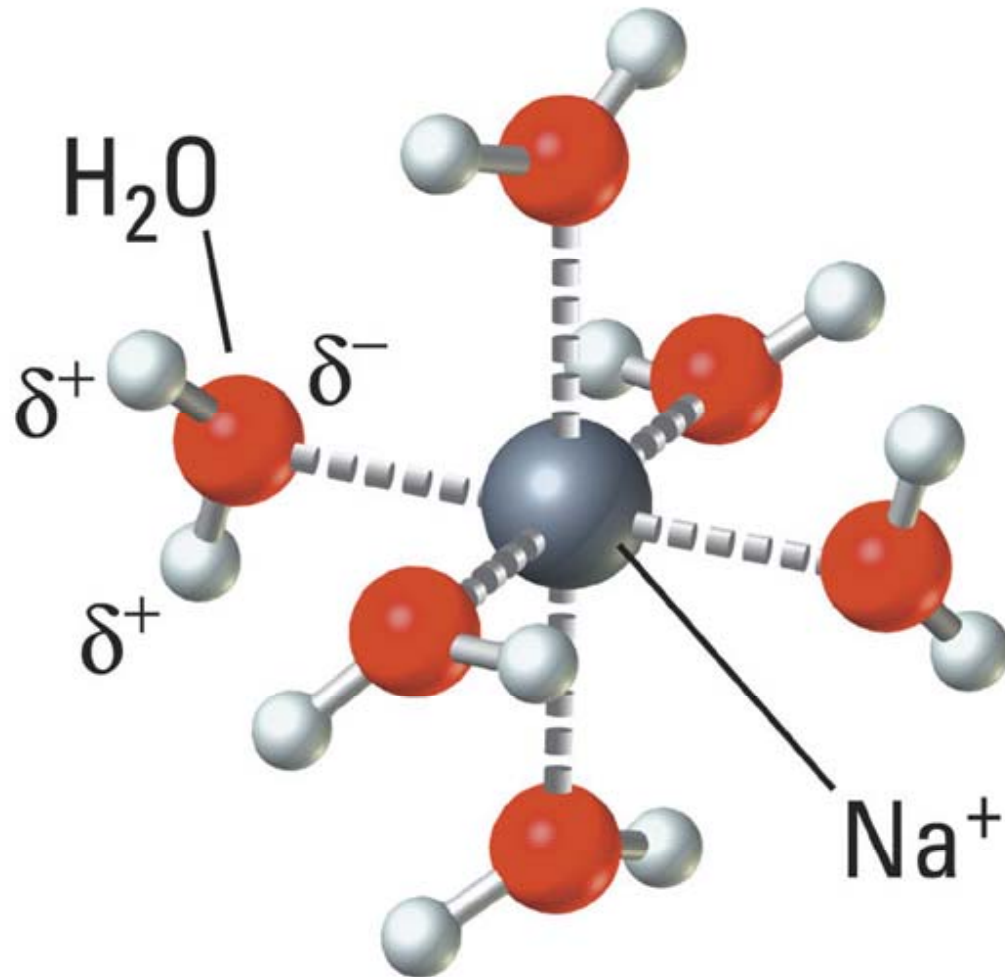
Large exothermic  $\Delta H_{\text{solution}}$



Large endothermic  $\Delta H_{\text{solution}}$

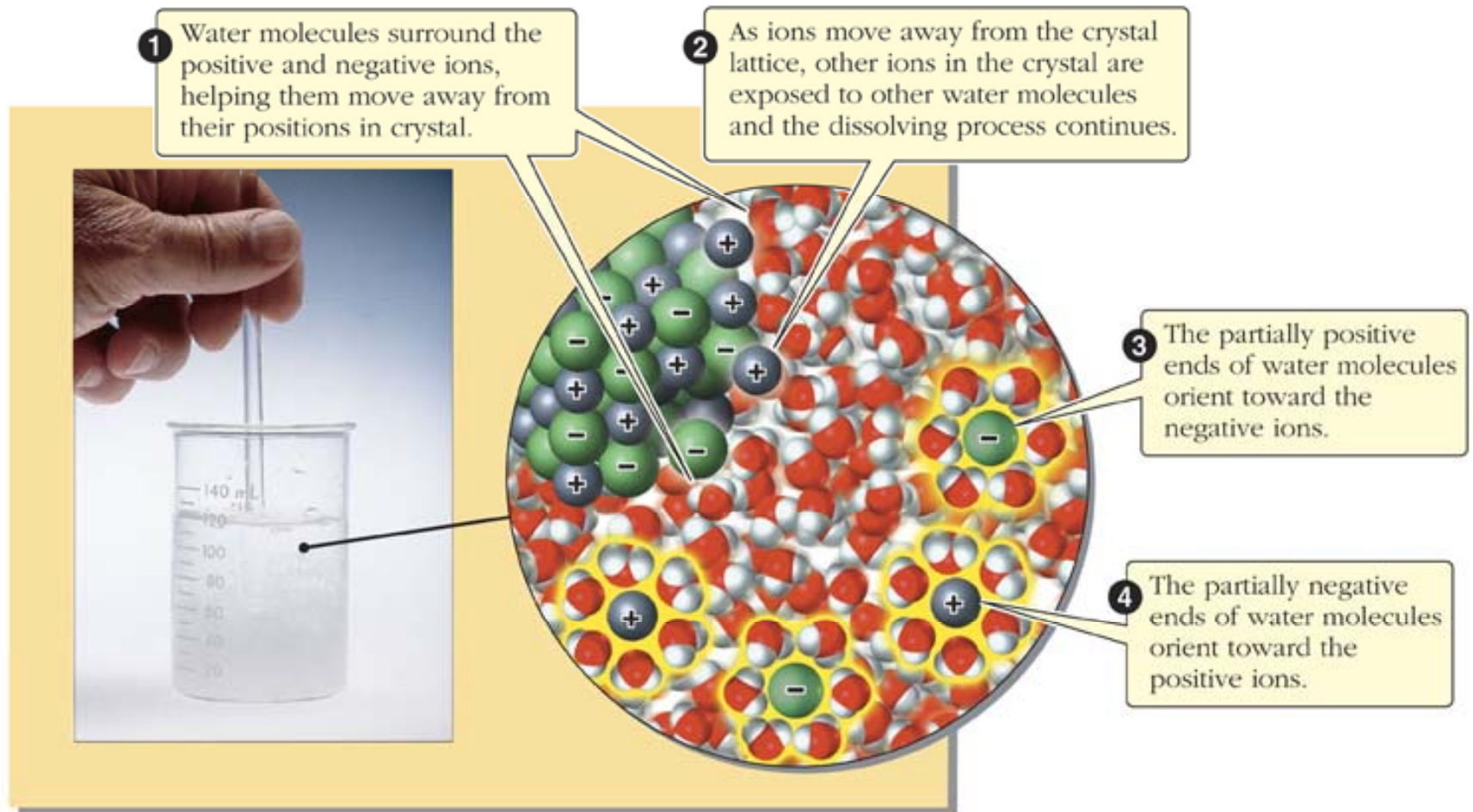


# Hydration of a Sodium Ion

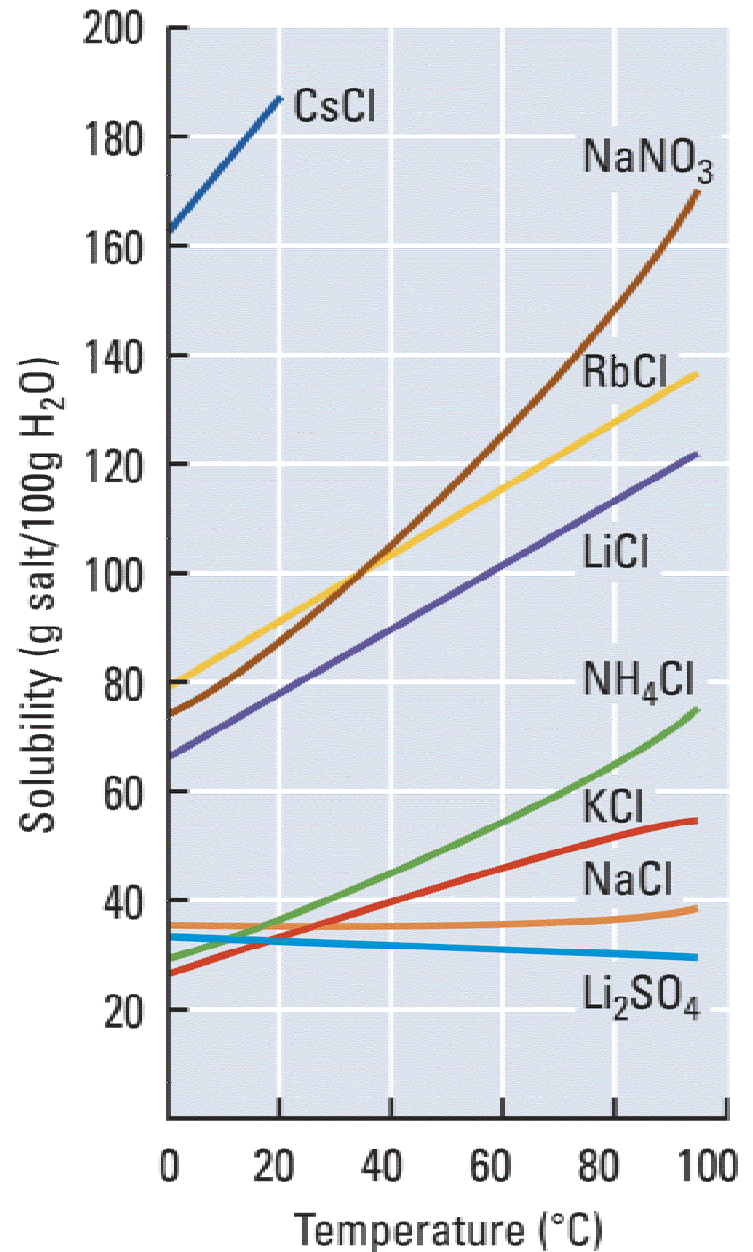




# Water Dissolving An Ionic Solute



# Solubility of Ionic Compounds and Temperature



# Weight Percent

$$\text{wt \%} = \frac{\text{\#g of solute}}{\text{\#g of solution}} \times 10^2$$

# Parts per Million (ppm)

$$\text{ppm} = \frac{\text{\#g of solute}}{\text{\#g of solution}} \times 10^6 = \frac{\text{\#mg of solute}}{\text{\#kg of solution}}$$

$$\text{ppm} = \frac{\text{\#micro-L solute}}{\text{\#L of solution}}$$

# Molarity

The number of moles of solute per liter of solution.

molarity  $\Leftrightarrow$  M

$$M = \frac{\text{moles of solute}}{\text{liter of solution}}$$

units: moles/liter = M

# Molality

- number of moles of solute particles (ions or molecules) per kilogram of solvent

$$m = \frac{\text{\#moles solute}}{\text{\#kilograms of solvent}}$$

# Mole Fraction

$$X_i = \frac{\text{\#moles of component i}}{\text{total number of moles}}$$

# Mass Fraction

# Comparison of Concentration Terms

**TABLE 15.4** Comparison of Concentration Terms

Concentration term	Units of concentration	Advantages	Disadvantages
Mass fraction	None	Independent of temperature; used in special applications	Density must be known to convert mass fraction to molarity
Weight percent	Percent	Independent of temperature; useful in wide range of applications	Density must be known to convert weight percent to molarity
Parts per million, parts per billion, parts per trillion	ppm, ppb, ppt	Temperature independent; widely used in environmental applications	Must be determined by very exacting analytical methods
Molarity	$\frac{\text{Moles solute}}{\text{liter solution}}$	Volume measurements are easy and the results readily used in stoichiometric calculations	Temperature dependent; density must be known to determine solvent mass

# Colligative Properties

- properties that depend on the number of particles not on the identity of the particles

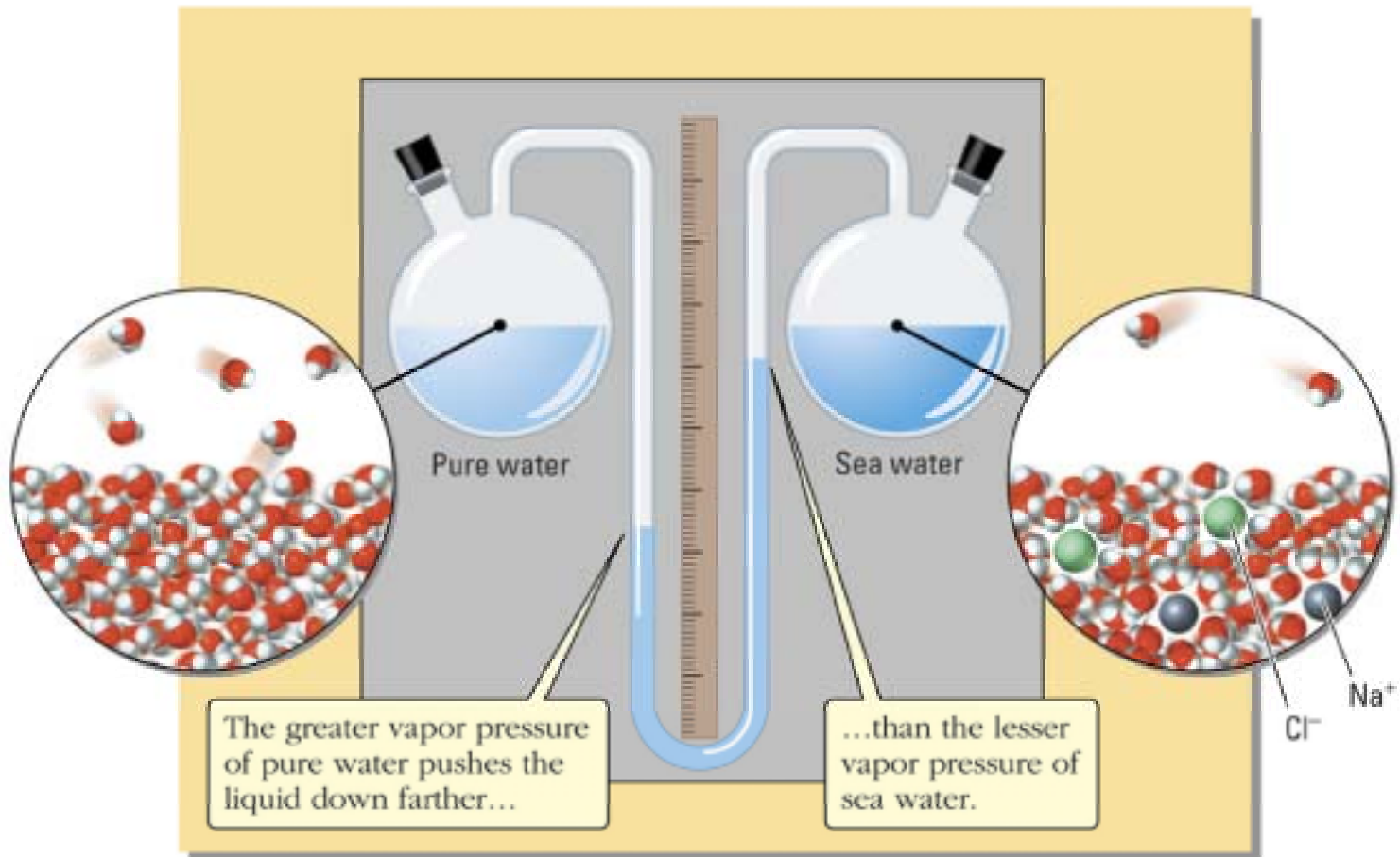
Raoult's Law

$$P_1 = X_1 P_1^\circ$$

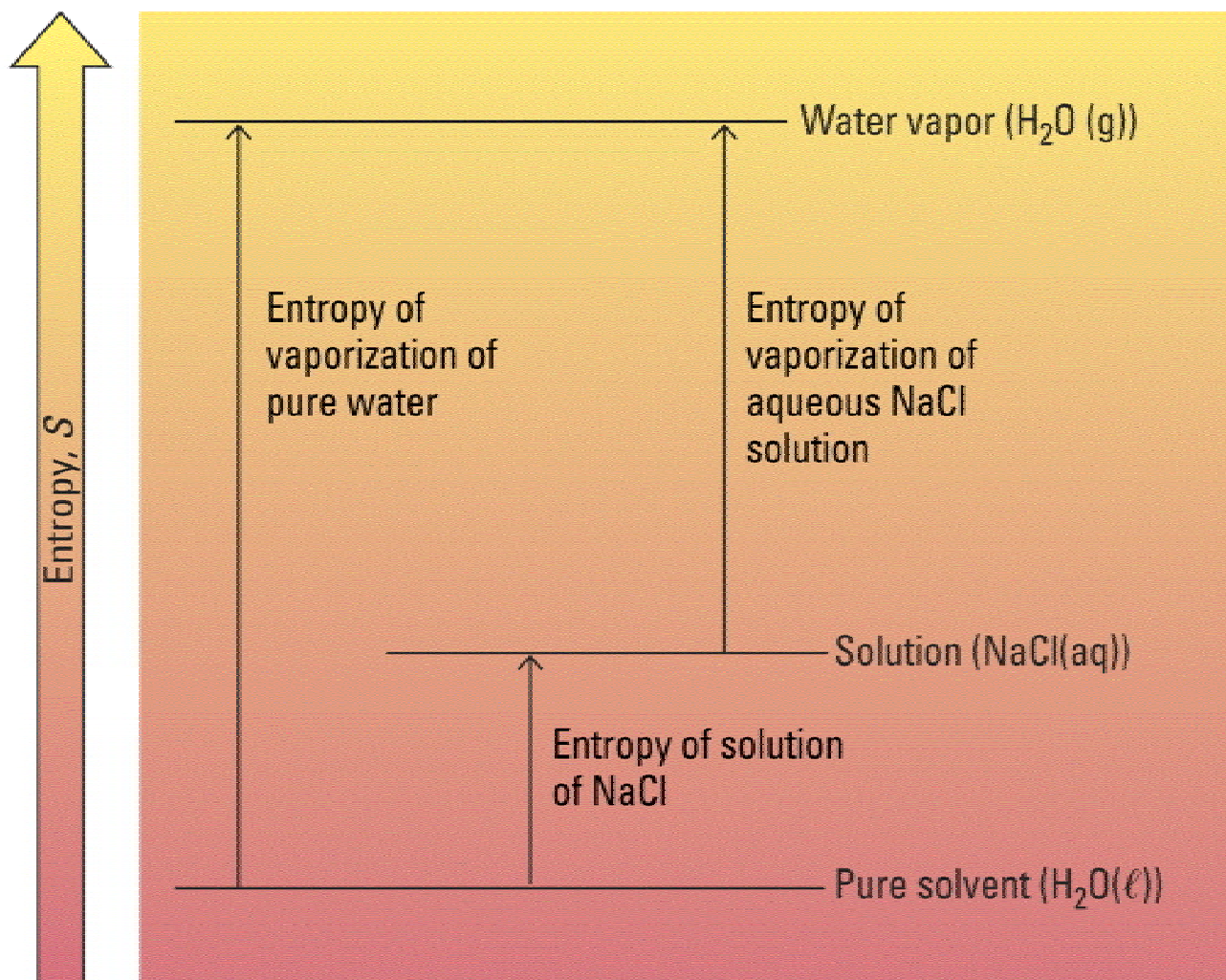
- vapor pressure lowering



# Vapor Pressure of Pure Water vs. Sea Water



# Vapor Pressure Lowering



# Boiling Point Elevation

$$\Delta T = T_{\text{final}} - T_{\text{initial}}$$

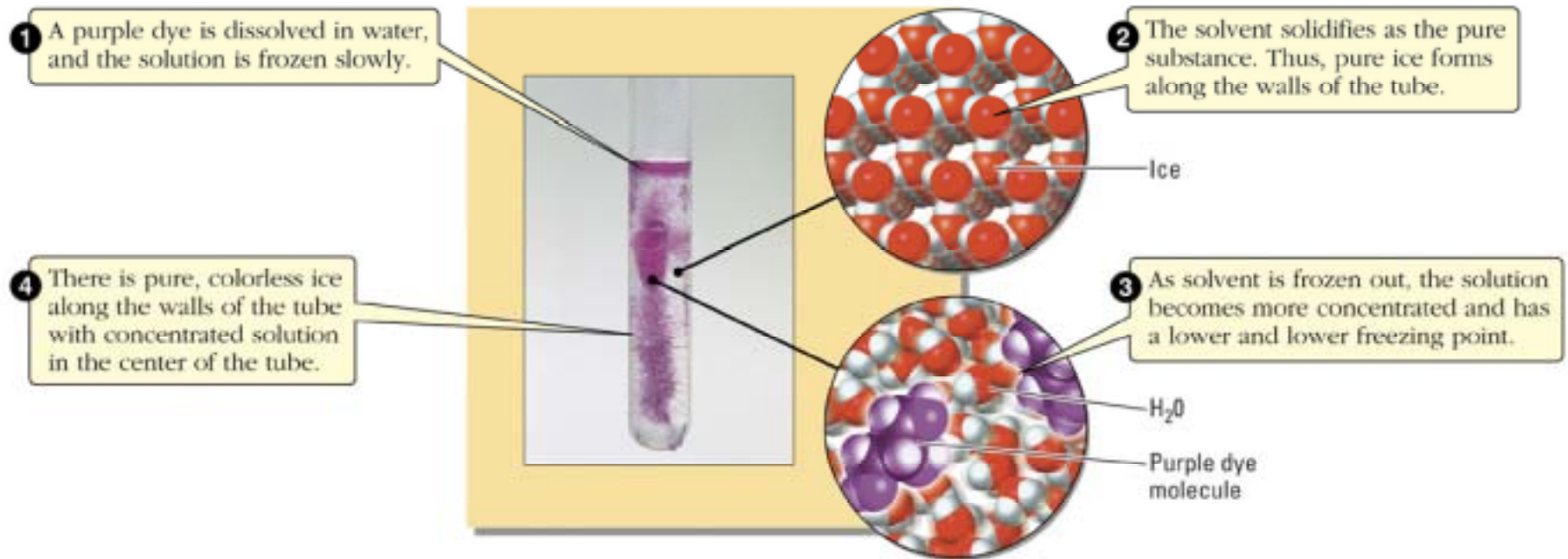
$$(\Delta T_b = bp_{\text{solution}} - bp_{\text{pure solvent}})$$

$$\Delta T_b = k_b \times m$$

where  $k_b \Rightarrow$  boiling point elevation constant

$m \Rightarrow$  molality of all solutes in solution

# Solvent Freezing



# Freezing Point Depression

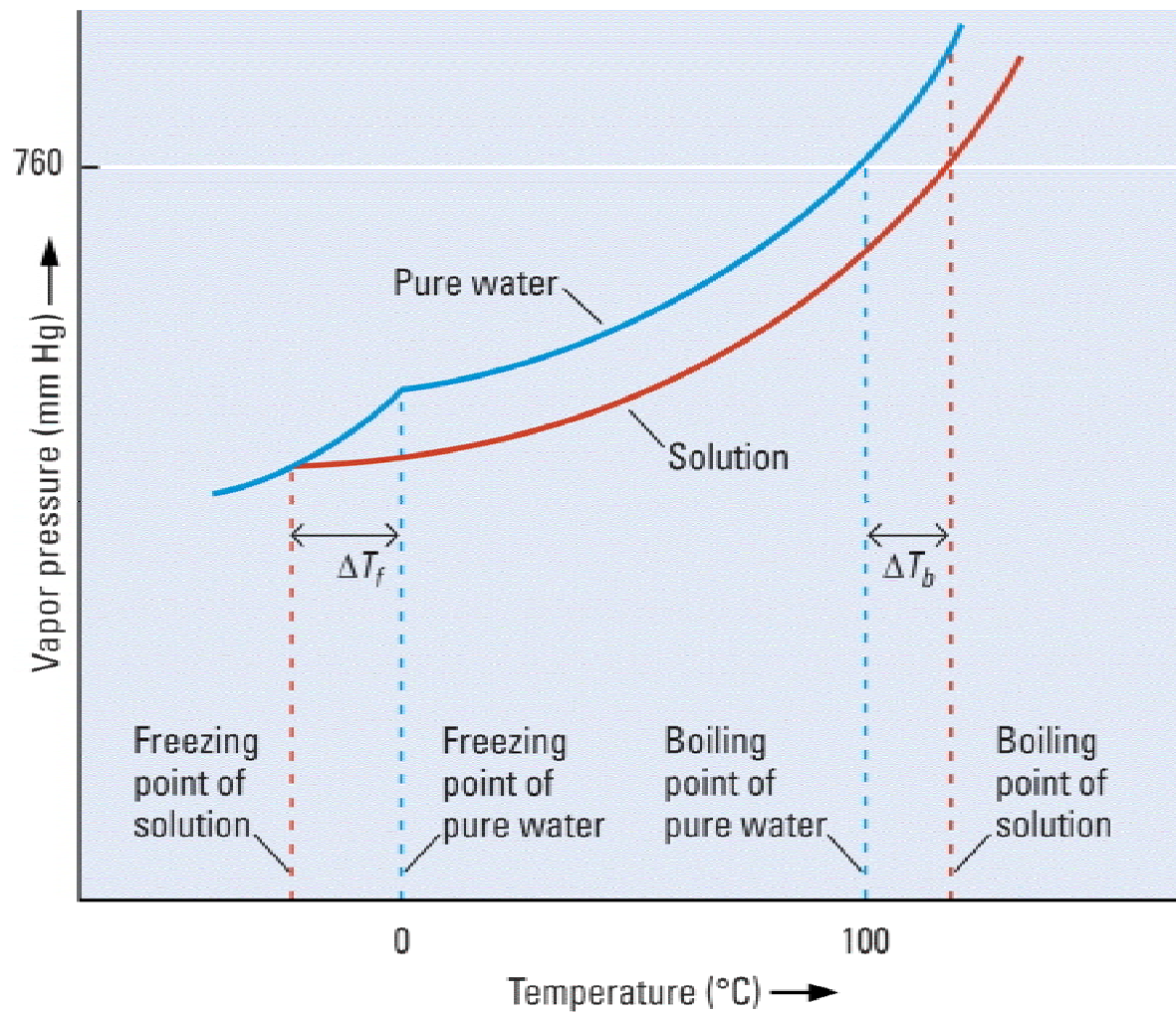
$$\Delta T = T_{\text{final}} - T_{\text{initial}}$$

$$(\Delta T_f = \text{fp}_{\text{pure solvent}} - \text{fp}_{\text{solution}})$$

$$\Delta T_f = k_f \times m$$

where  $k_f \Rightarrow$  freezing point depression  
constant

$m \Rightarrow$  molality of all solutes in solution





# Colligative Properties of Electrolytes

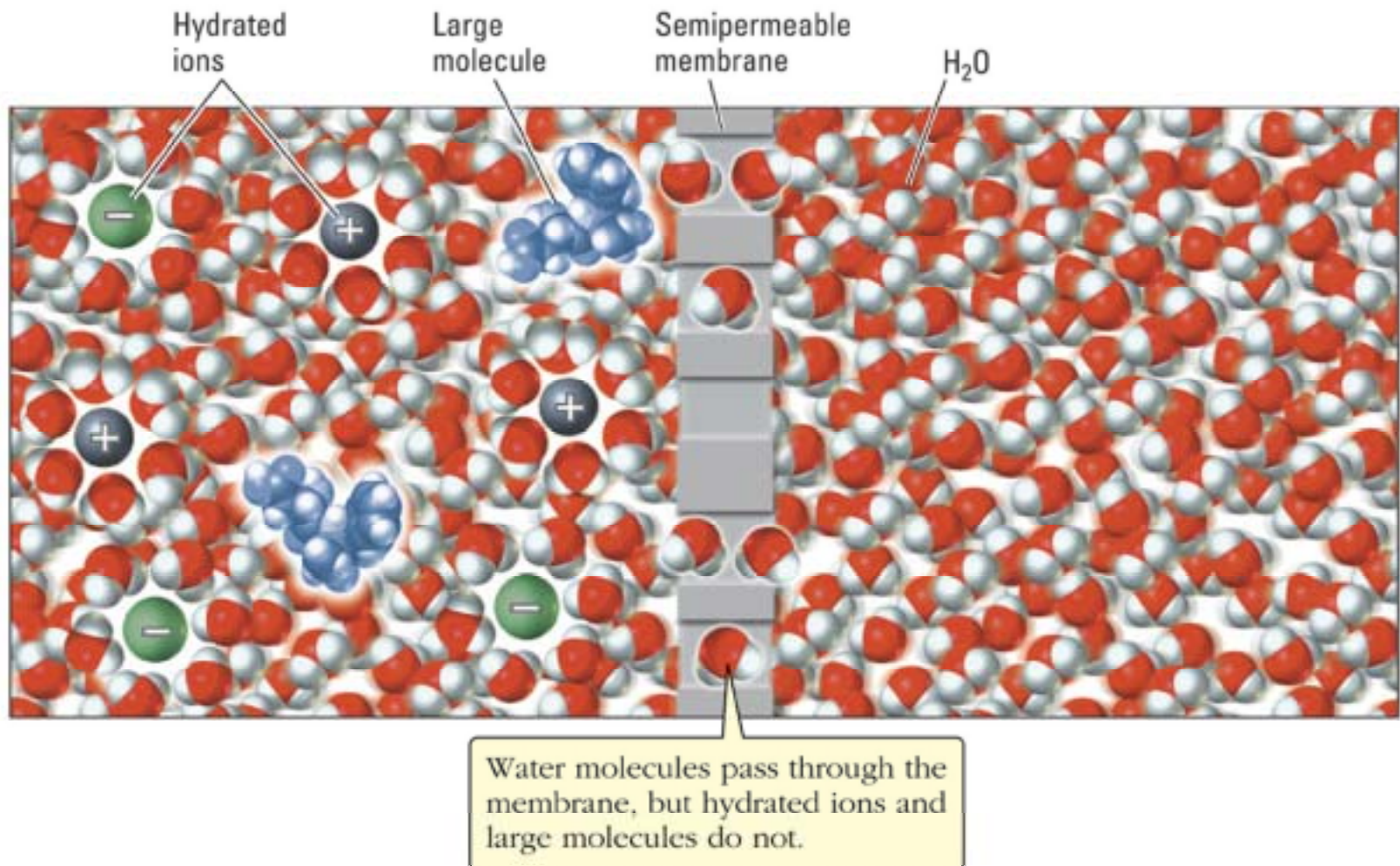
$$vp_{\text{water}} > vp_{1\text{M sucrose}} > vp_{1\text{M NaCl}} > vp_{1\text{M CaCl}_2}$$

1 mole sucrose = 1 mole molecules

1 mole NaCl = 2 mole of ions

1 mole  $\text{CaCl}_2$  = 3 moles ions

# Osmosis





# Osmotic Pressure

$$\Pi = cRTi$$

where  $\Pi \Rightarrow$  osmotic pressure

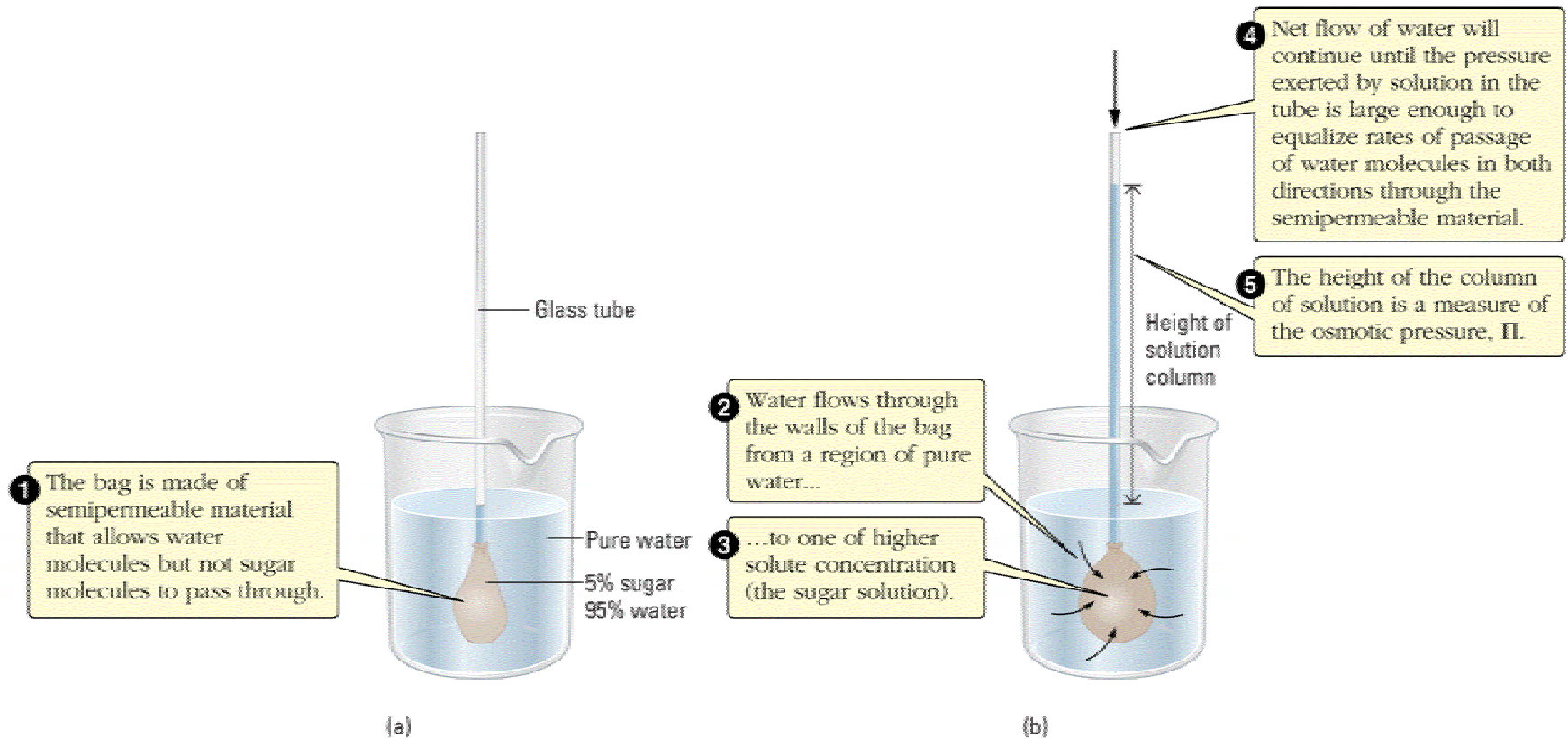
$c \Rightarrow$  concentration

$R \Rightarrow$  gas constant

$T \Rightarrow$  absolute temperature

$i \Rightarrow$  number of particles per formula unit

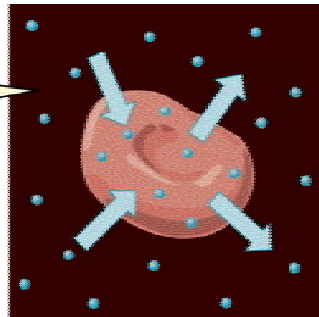
# Measuring Osmotic Pressure



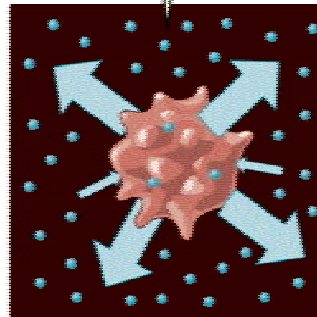
# Osmosis and the Cell

In a *hypertonic* solution, the concentration of solutes outside the cell is greater than inside. There is a net flow of water out of the cell, causing the cell to dehydrate, shrink, and perhaps die.

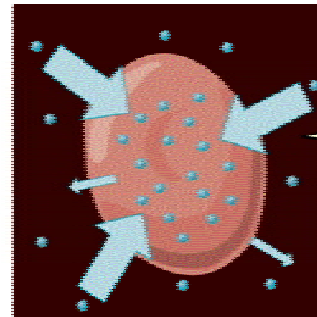
In an *isotonic* solution, the *net* movement of water in and out of the cell is zero because the concentration of solutes inside and outside the cell is the same.



(a) Isotonic solution



(b) Hypertonic solution



(c) Hypotonic solution

In a *hypotonic* solution, the concentration of solutes outside the cell is less than inside. There is a net flow of water into the cell, causing the cell to swell and perhaps to burst.

# Normal vs. Reverse Osmosis

