13. SOLUTIONS

Homogeneous mixtures of two components

Why is the study of solutions important?

What solutions are used in the home?

TYPES OF SOLUTIONS

Solid dental fillings, 14 K gold, alloys

Liquid saline, vinegar, sugar water

Gas air

DEFINITIONS

Solvent

component in greatest amount

Solute

component in smaller amount

Aqueous Solution (aq)

water as solvent

THE SOLUTION PROCESS

Dissolution

solute particles surrounded & dispersed by solvent

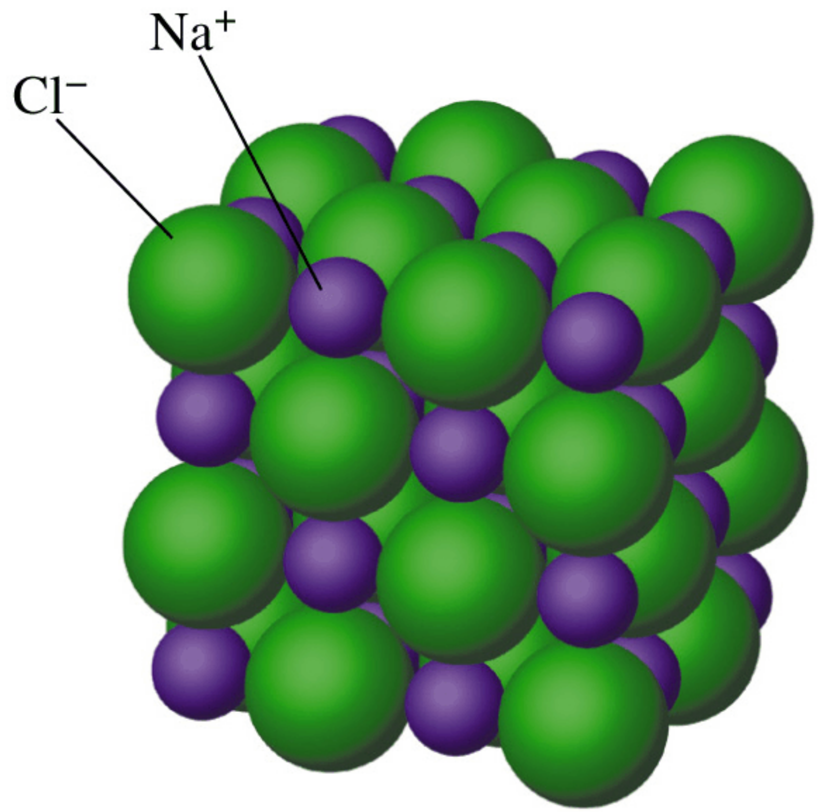
Solute particles solvated

$$NaCl\ (s) \rightarrow NaCl\ (aq)$$

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

THE SOLUTION PROCESS

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



SOLUBILITY

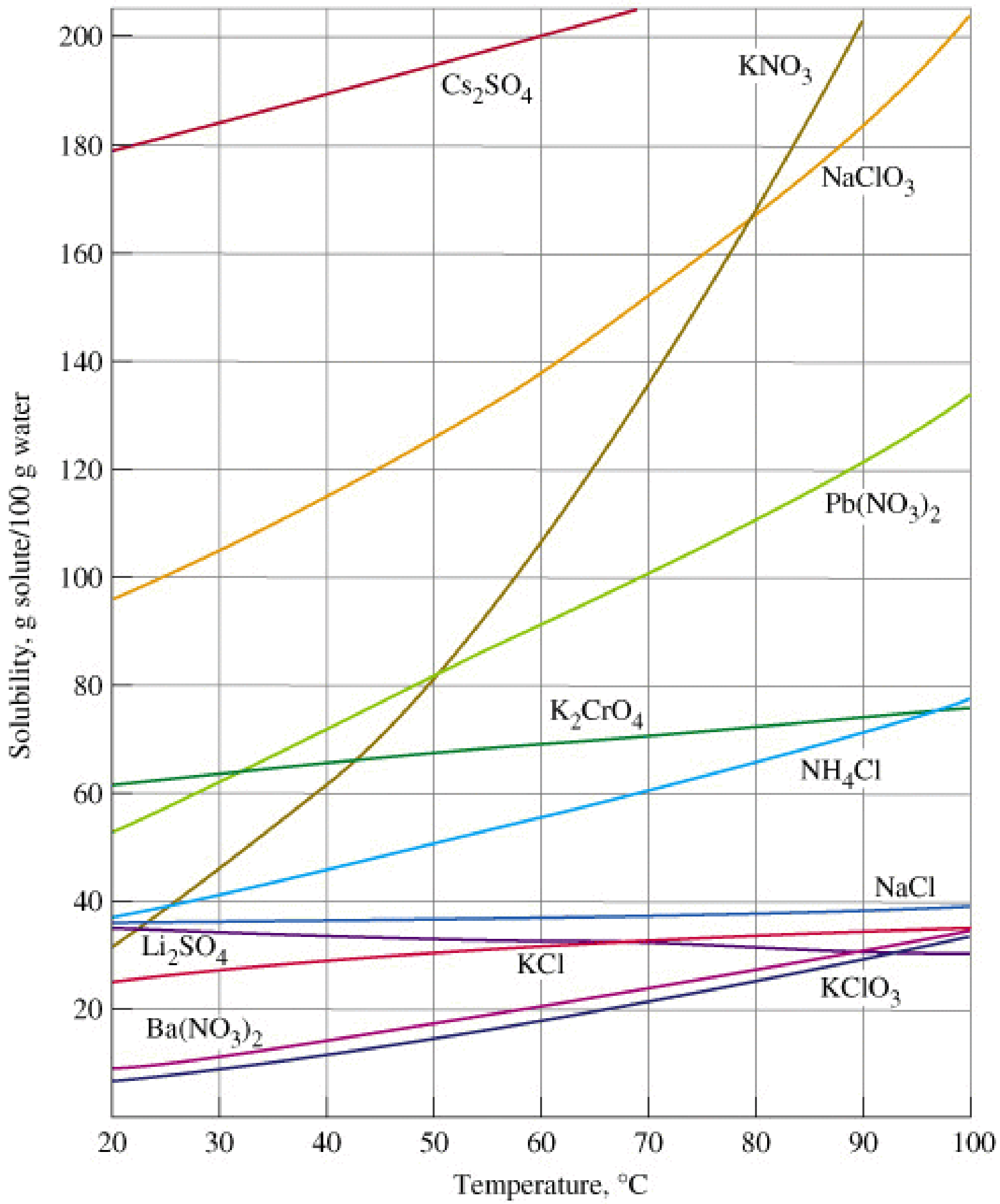
Quantity of solute that dissolves in specific quantity of solvent at specific temperature

At 25°C

36.2 g NaCl dissolves in 100 g water

Saturated   Unsaturated   Supersaturated

Solubility: Effect of Temperature



Solids

solubility increases with temp

Not all substances soluble

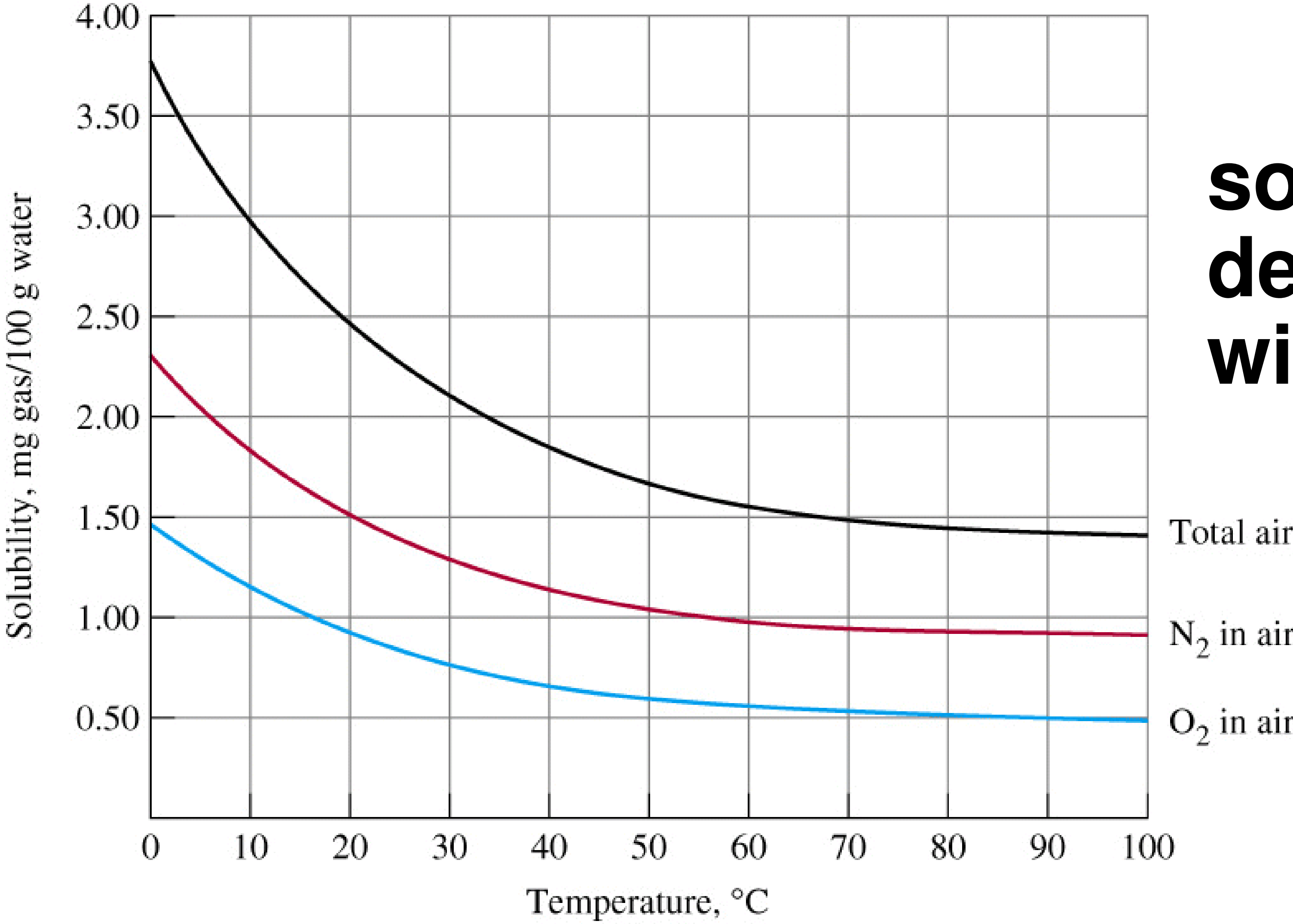
barium sulfate settles

Solubility of Gases

Nonpolar gases only slightly soluble in water

Solubility increases with polarizability of gas molecule

SOLUBILITY: EFFECT OF TEMPERATURE



Gases

solubility decreases with temp

Solubility: Effect of Pressure

Gases

Solubility increases with pressure of gas

Henry's Law

$$M_g = kP_g$$

Gases from a solid

<u>AUSCHWITZ</u>

Zyklon B, hydrogen cyanide in a solid support plus a warning agent

> 1 million people killed

Forensic analysis confirms presence of cyanide in the buildings

AUSCHWITZ

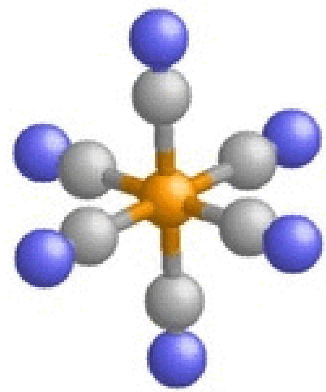
HCN gas reacts with iron to form blue compound

Prussian Blue staining

Forensic analysis confirms presence of cyanide in the buildings

SOLUBILITY

$$Fe(OH)_3 + 6CN^- \rightarrow 3OH^- + Fe(CN)_6^{3-}$$



MYSTERY OF LAKE NYOS

CONCENTRATION

Amount of solute in solution

Mass percent

Mole fraction

Molarity

Molality

Concentration

Mass percentage: % of solute by mass

$$\%A = \frac{\text{mass of A}}{\text{mass of solution}} \times 100\%$$

CONCENTRATION

Mole fraction: (χ) moles of solute divided by moles of solution

$$\chi_A = \frac{\text{moles of A}}{\text{Total moles of solution}}$$

CONCENTRATION

Molarity: (M) moles of solute per liter of solution

$$M_A = \frac{\text{moles of A}}{\text{Liters of solution}}$$

Concentration

Molality: (m) moles of solute per kilogram of solvent

$$m_A = \frac{\text{moles of A}}{\text{Kilograms of solvent}}$$

Solution Calculations

A saturated solution of NaCl has 35.7 g of NaCl per 100.0 g water.

Calculate:
1. Mass %
2. Mole fraction
3. Molality

1. Mass %

$$\% = \frac{\text{mass of A}}{\text{mass of solution}} \times 100\%$$

$$= \frac{35.7 \text{ g}}{100.0 + 35.7 \text{ g}} \times 100\% = 26.3\%$$

SOLUTION CALCULATIONS

2. Mole fraction of NaCl

Convert masses of NaCl & water to moles

$$mol_{NaCl} = \frac{35.7\ g}{58.44\ g\ NaCl} = 0.611\ mol\ NaCl$$

$$mol_{water} = \frac{100.0\ g}{18.02\ g\ water} = 5.549\ mol\ water$$

Next find fraction of each

Solution Calculations

2. Mole fraction of NaCl

Add moles of NaCl & water

0.611 mol NaCl
5.549 mol water
―――――――――――
6.160 mol solution

$$\frac{0.611 \text{ mol NaCl}}{6.160 \text{ mol solution}} = 0.0992$$

SOLUTION CALCULATIONS

3. Molality   mol NaCl ÷ kg of solvent

$$\frac{0.611 \text{ mol NaCl}}{0.1000 \text{ kg}} = 6.11 \text{ mol/kg}$$

or 6.11 m

Solution Calculations

Molality

Ionic substances have greater effect per mole than covalent due to ionization

1 mol sugar (s) → 1 mol sugar (aq)

1 mol NaCl (s) → 1 mol Na^+ (aq) + 1 mol Cl^- (aq)

→ 2 mol of ions

Colligative Properties

Physical properties of solutions relative to pure solvent

Vapor pressure

Boiling point

Freezing point

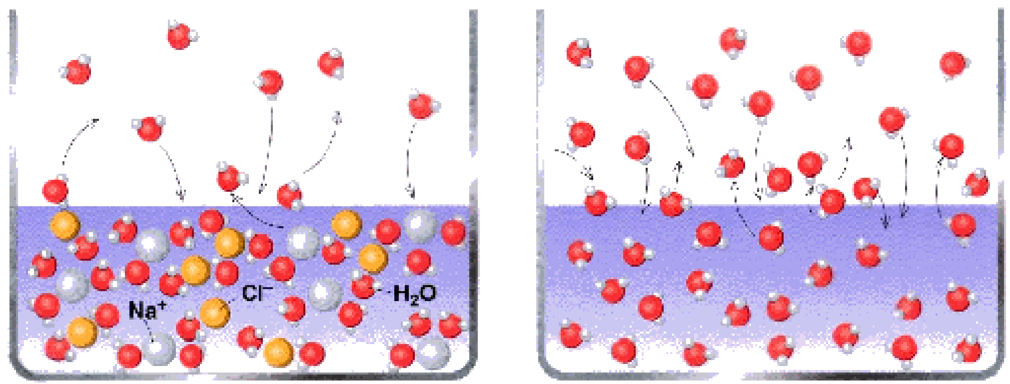
Osmotic pressure

Effects depend on concentration, not identity

COLLIGATIVE PROPERTIES

1. Vapor pressure lowering

Raoult's Law



sea water **pure water**

Vapor pressure of solvent proportional to its mole fraction

COLLIGATIVE PROPERTIES

1. Vapor pressure lowering

Raoult's Law

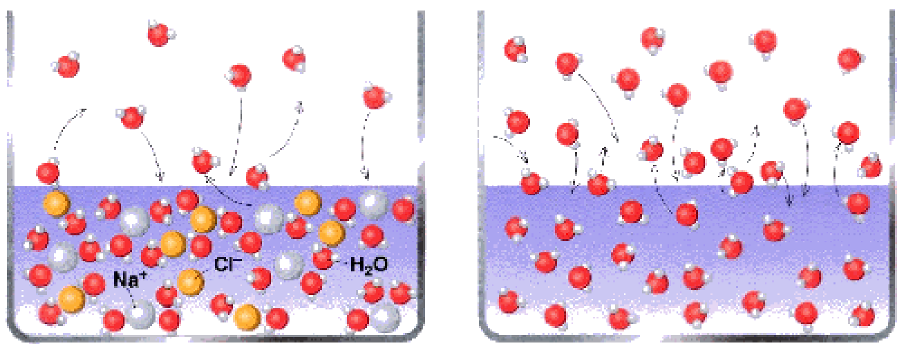
$$P = X_{solvent}P^{\circ}$$

VP of solution | **VP of pure solvent**

COLLIGATIVE PROPERTIES

2. Boiling point elevation

VP lowering affects BP elevation



sea water **pure water**

BP

COLLIGATIVE PROPERTIES

2. Boiling point elevation

Difference in BP called ΔT

$$\Delta T = T_b - T_b^{\circ}$$

BP solution

BP solvent

$$\Delta T = K_b\, m$$

K_b = boiling point elevation constant,

m = molality

Colligative Properties

2. Boiling point elevation

$$\Delta T = K_b\, m$$

K_b = depends on solvent

= 0.52 °C/m for water

See table 13.2

Calculations

What is the boiling point of a solution of 2.00 mol of sucrose in 175 g of water

$$m = \frac{\text{mol sucrose}}{\text{Kg solvent}} = \frac{2.00 \text{ mol}}{0.175 \text{ kg}}$$

$$= 11.4 \text{ m}$$

CALCULATIONS

What is the boiling point of a solution of 20.0 mol of sucrose in 175 g of water

$\Delta T = K_b\, m$

$= 0.52\ ^\circ C/m \times 11.4\ m = 5.9\ ^\circ C/m$

$\Delta T = T_b - T_b^\circ \Rightarrow T_b = \Delta T + T_b^\circ$

$= 100.00 + 5.9\ ^\circ C$

$= 105.9\ ^\circ C$

Colligative Properties

Can use ΔT to find molecular mass of solutes

see example 13.9, p. 422

Colligative Properties

3. Freezing point depression

Difference in FP called ΔT

$\Delta T = T_f - T_f^\circ$ $\Delta T = K_f m$

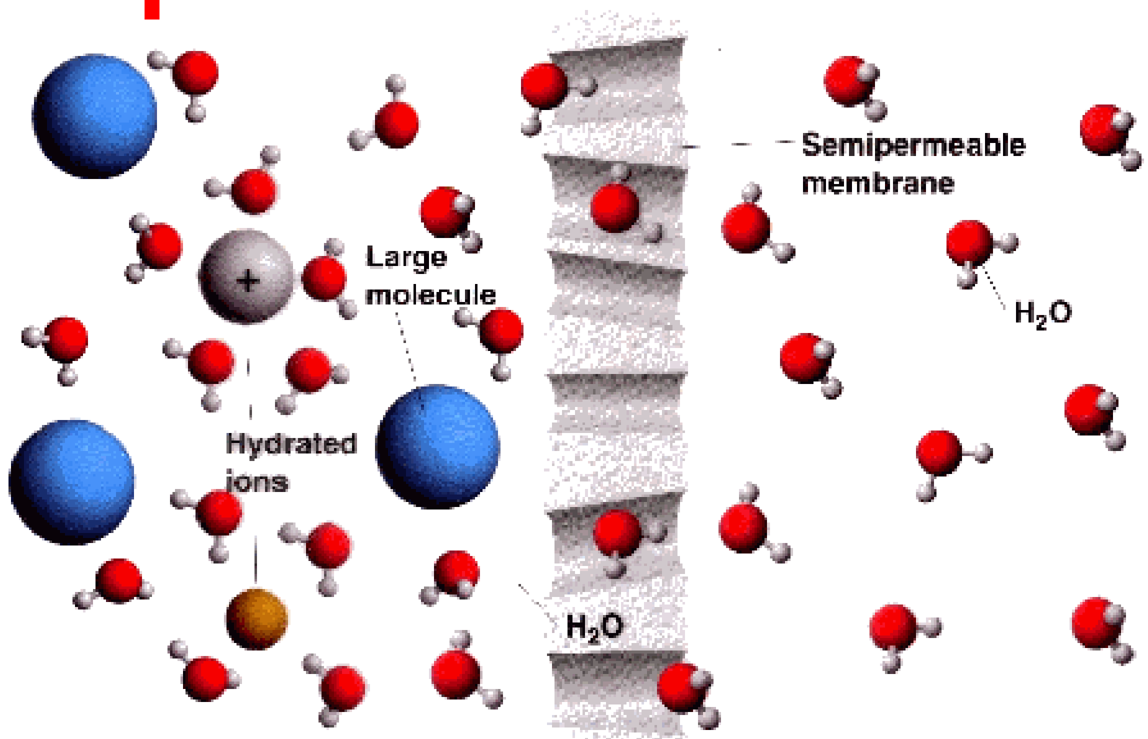
K_f = freezing point elevation constant,
m = molality

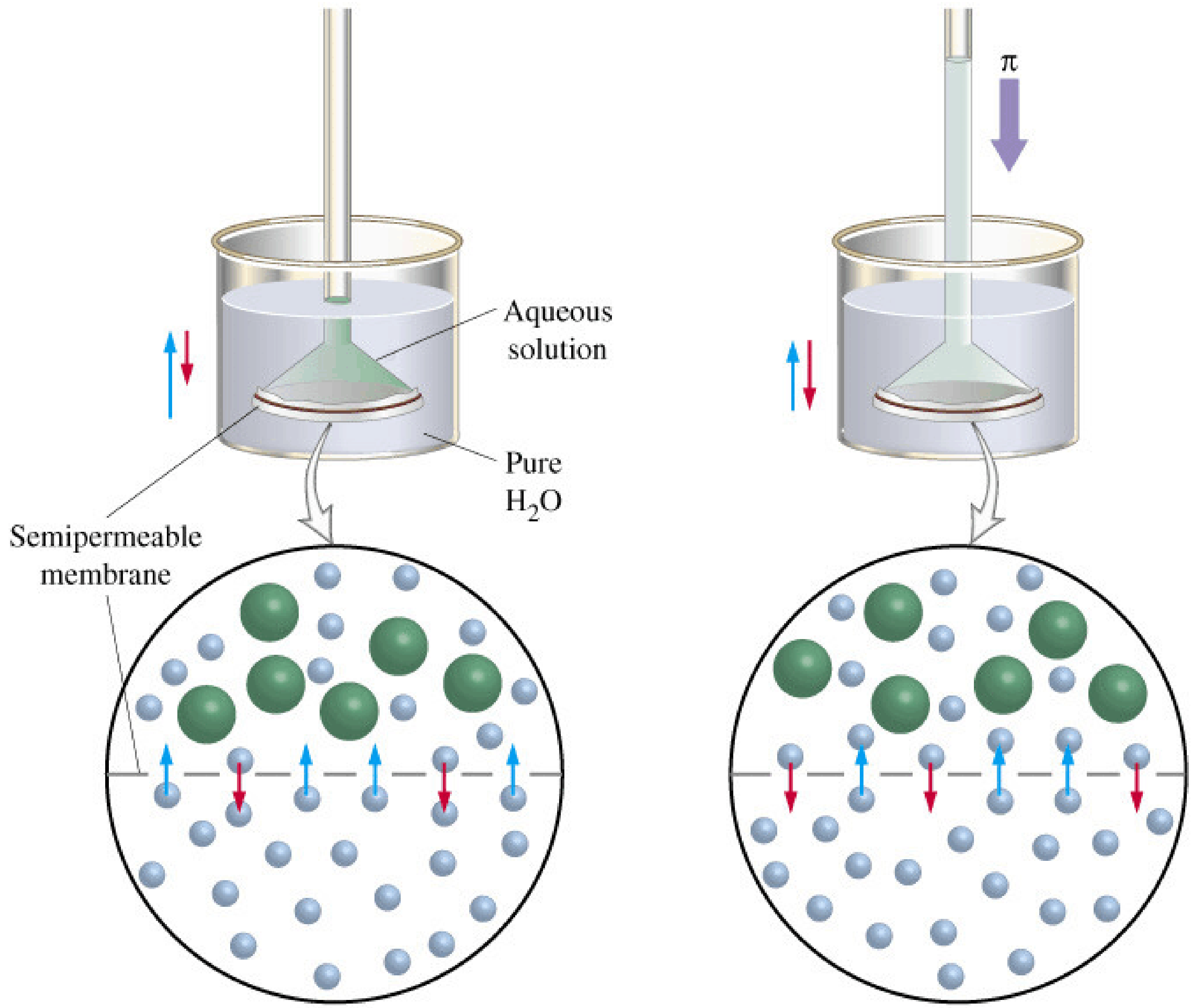
FP of solution always lower than pure solvent

COLLIGATIVE PROPERTIES

4. Osmosis

Selective passage through semipermeable membranes





(a) **(b)**

COLLIGATIVE PROPERTIES

4. Osmosis

$$\pi = MRT$$

π: osmotic pressure
M: molarity
R: gas law constant
T: temp in Kelvin

Reverse Osmosis

Drinking Water
Ice-Making
Car Wash Water
Reclamation
Photography
Pharmaceuticals
Kidney Dialysis

Reverse Osmosis