

Properties of Solutions

Colligative

Colligative Properties

- **Colligative properties** are properties whose value depends only on the number of solute particles, and not on what they are.
 - Value of the property depends on the concentration of the solution.
- The difference in the value of the property between the solution and the pure substance is generally related to the different attractive forces and solute particles occupying solvent molecules positions.

Colligative Properties

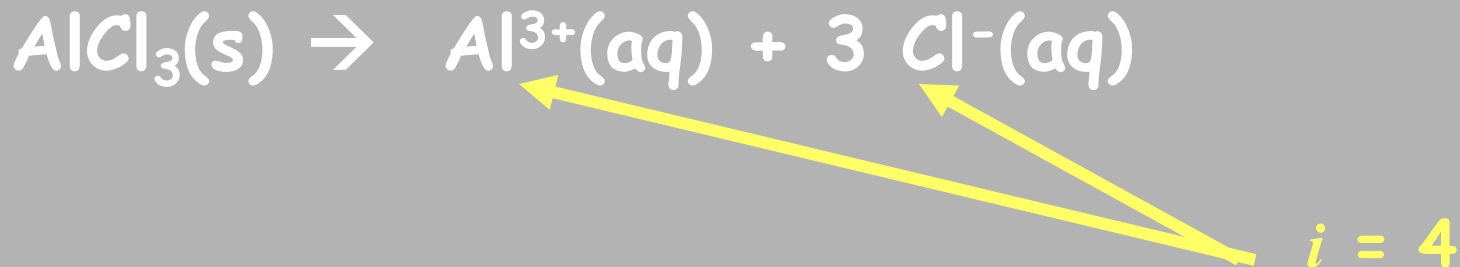
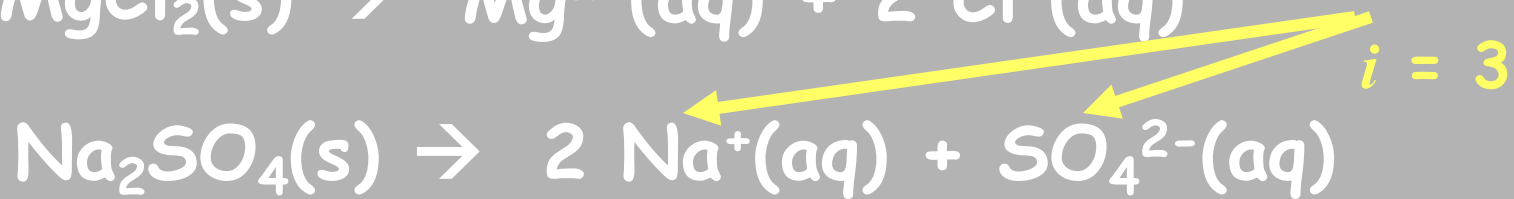
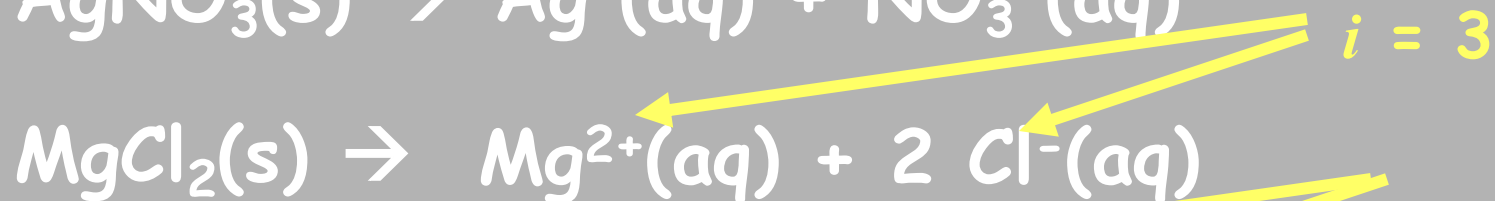
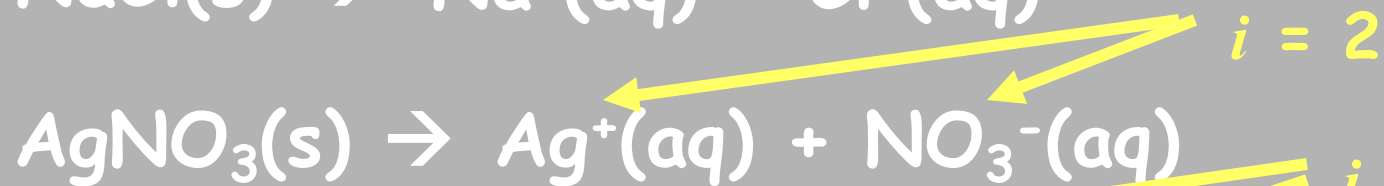
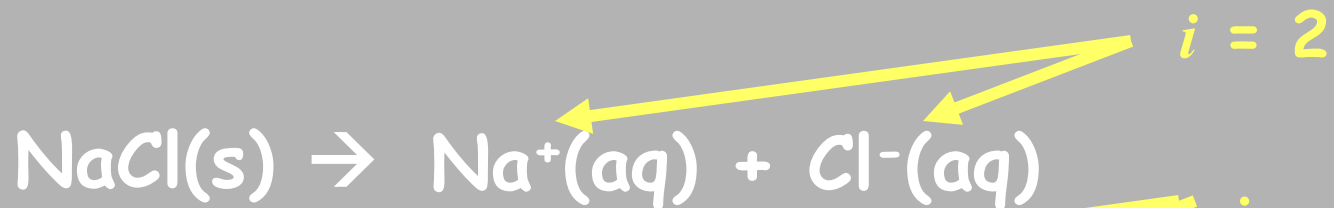
Colligative properties are those that depend on the concentration of particles in a solution, not upon the identity of those properties.

- ❑ Boiling Point Elevation
- ❑ Freezing Point Depression
- ❑ Osmotic Pressure

The van't Hoff Factor, i

Electrolytes may have two, three or more times the effect on boiling point, freezing point, and osmotic pressure, depending on its dissociation.

Dissociation Equations and the Determination of i



Ideal vs. Real van't Hoff Factor

The ideal van't Hoff Factor is only achieved in VERY DILUTE solution.

Solute	Molality, m					
	1.0	0.10	0.010	0.0010	...	Inf dil*
NaCl	1.81	1.87	1.94	1.97	...	2
MgSO ₄	1.09	1.21	1.53	1.82	...	2
Pb(NO ₃) ₂	1.31	2.13	2.63	2.89	...	3

Freezing Point Depression

Each mole of solute particles lowers the freezing point of 1 kilogram of water by 1.86 degrees Celsius.

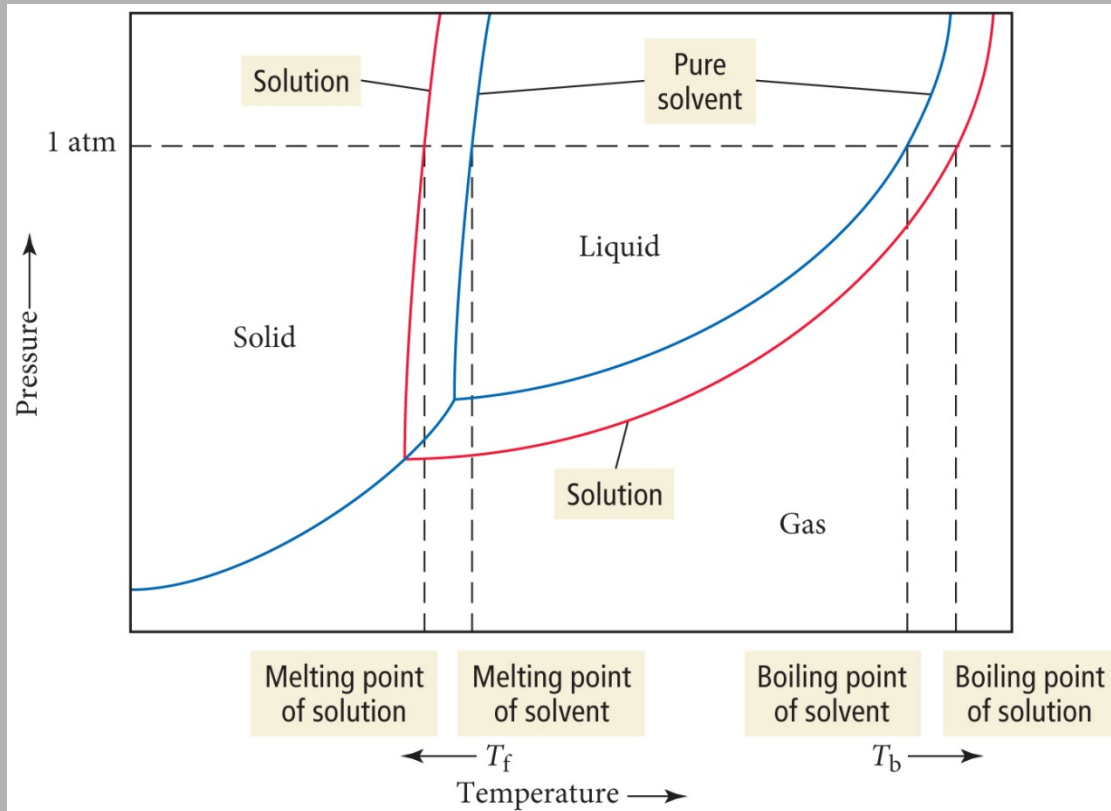
$$\Delta T = i \cdot K_f \cdot m_{\text{solute}}$$

$$K_f = 1.86 \text{ } ^\circ\text{C} \cdot \text{kilogram/mol}$$

m = molality of the solution

i = van't Hoff factor

Freezing Point Depression and Boiling Point Elevation



Boiling Point Elevation

Each mole of solute particles raises the boiling point of 1 kilogram of water by 0.51 degrees Celsius.

$$\Delta T = i \cdot K_b \cdot m_{\text{solute}}$$

K_b = 0.51 °C · kilogram/mol

m = molality of the solution

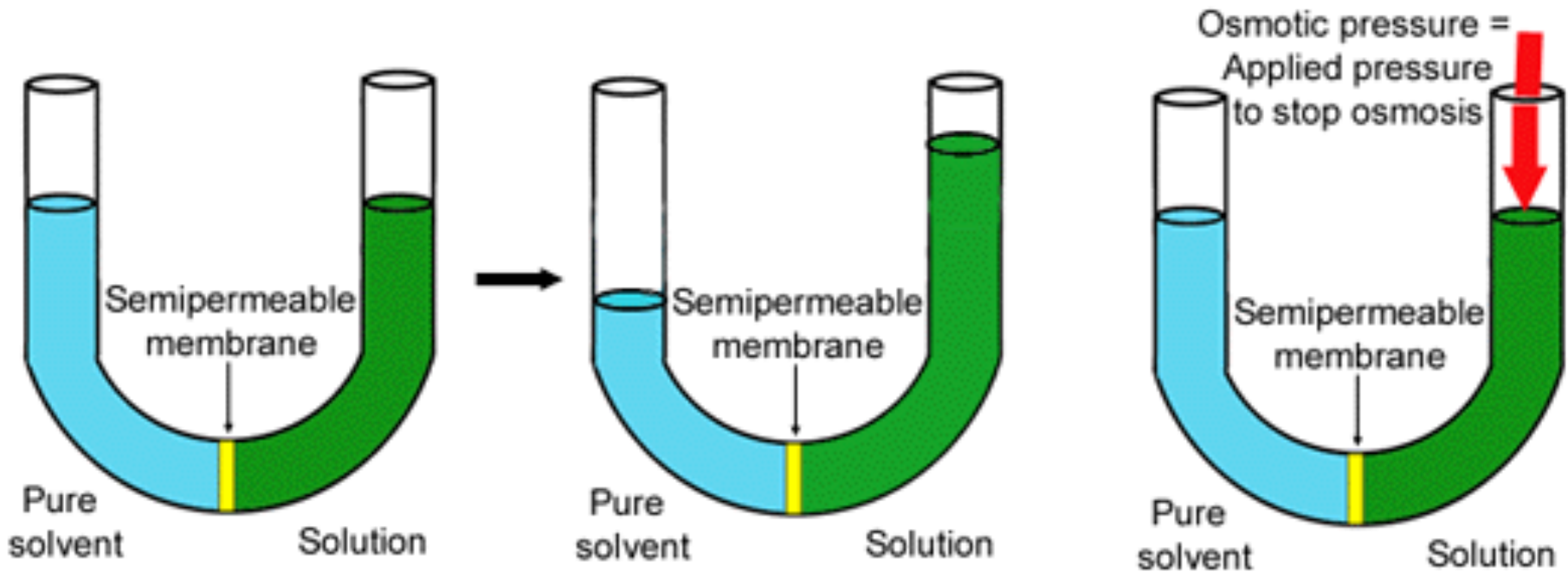
i = van't Hoff factor

Freezing Point Depression and Boiling Point Elevation Constants, °C/m

Solvent	K_f	K_b
Acetic acid	3.90	3.07
Benzene	5.12	2.53
Nitrobenzene	8.1	5.24
Phenol	7.27	3.56
Water	1.86	0.512

Osmotic Pressure

The minimum pressure that stops the osmosis is equal to the osmotic pressure of the solution



Osmotic Pressure Calculations

$$\Pi = iMRT$$

Π = Osmotic pressure

M = Molarity of the solution

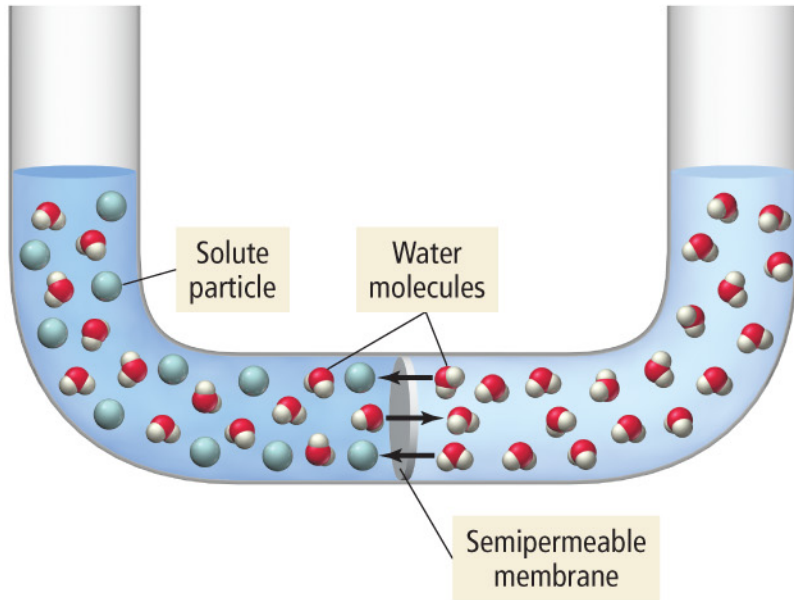
R = Gas Constant = 0.08206 L·atm/mol·K

T = Absolute Temperature

An Osmosis Cell

Osmosis and Osmotic Pressure

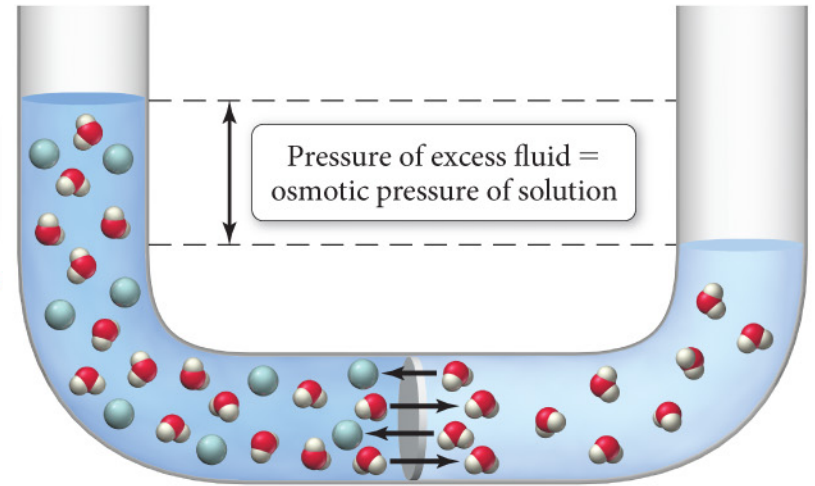
Initially



Water level rises



At equilibrium



Suspensions and Colloids

Suspensions and colloids are NOT solutions.

Suspensions: The particles are so large that they settle out of the solvent if not constantly stirred.

Colloids: The particles intermediate in size between those of a suspension and those of a solution.

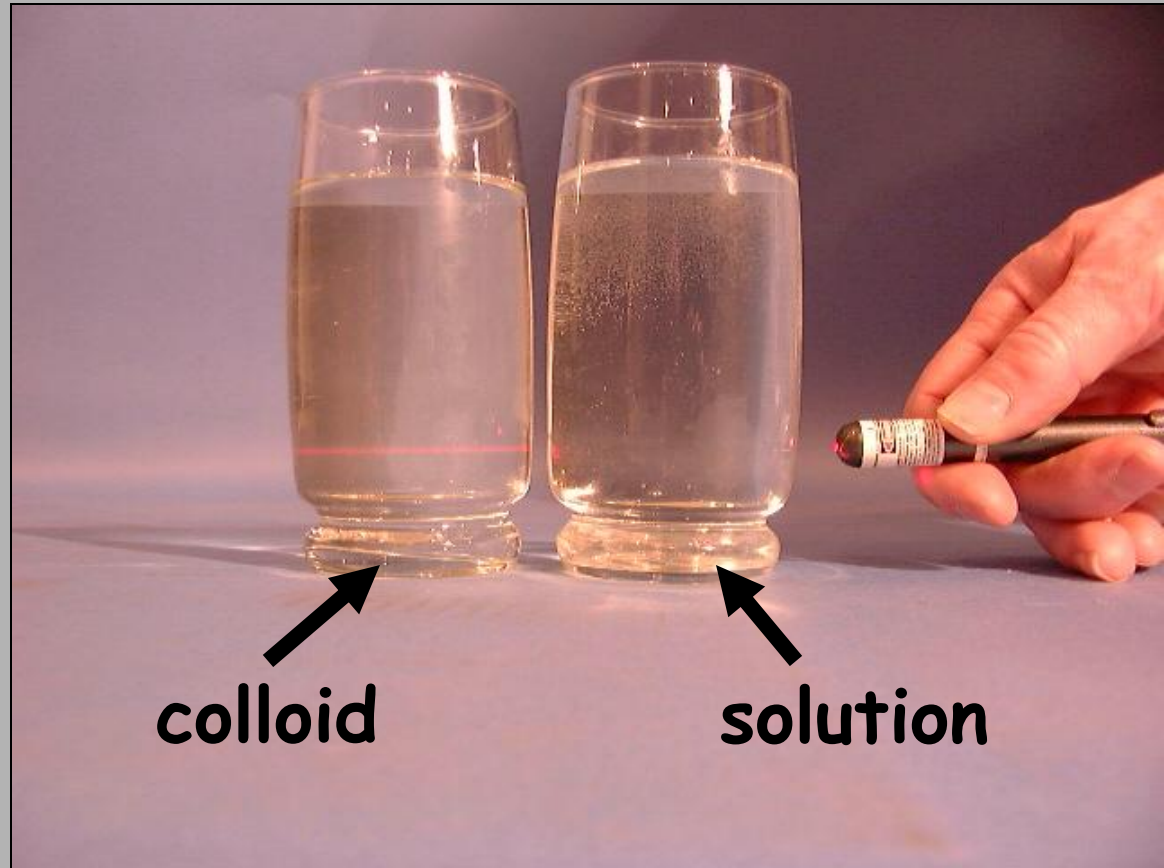
Types of Colloids

Examples	Dispersing Medium	Dispersed Substance	Colloid Type
Fog, aerosol sprays	Gas	Liquid	Aerosol
Smoke, airborne germs	Gas	Solid	Aerosol
Whipped cream, soap suds	Liquid	Gas	Foam
Milk, mayonnaise	Liquid	Liquid	Emulsion
Paint, clays, gelatin	Liquid	Solid	Sol
Marshmallow, Styrofoam	Solid	Gas	Solid Foam
Butter, cheese	Solid	Liquid	Solid Emulsion
Ruby glass	Solid	Solid	Solid sol

The Tyndall Effect

Colloids scatter light, making a beam visible. Solutions do not scatter light.

Which glass contains a colloid?



All of the following are colligative properties except:

-  **A** Osmotic Pressure
-  **B** Boiling Point elevation
-  **C** Freezing Point depression
-  **D** Density elevation
-  **E** None of these

Henry's Law (removed from AP)

- The solubility of a gas (S_{gas}) is directly proportional to its partial pressure, (P_{gas}).






$$S_{\text{gas}} = k_{\text{H}} P_{\text{gas}}$$

- k_{H} is called the **Henry's law constant**.

**TABLE 12.4 Henry's Law
Constants for Several Gases in
Water at 25 °C**

Gas	k_{H} (M/atm)
O ₂	1.3×10^{-3}
N ₂	6.1×10^{-4}
CO ₂	3.4×10^{-2}
NH ₃	5.8×10^1
He	3.7×10^4

A correct statement of Henry's law is:

-  the concentration of a gas in solution is inversely proportional to temperature.
-  the concentration of a gas in solution is directly proportional to the mole fraction of solvent.
-  the concentration of a gas in solution is independent of pressure.
-  the concentration of a gas in a solution is inversely proportional to pressure.
-  none of these

The solubility of O_2 in water is 0.590g/L at an oxygen pressure of around 14.7 atm . What is the Henry's Law constant for O_2 (in units of $\text{L}\cdot\text{atm/mol}$)?



4.01E^{-2}



1.25E^{-3}



7.97E^2



2.71E^{-1}



None of them are within 5% of the correct answer

121.2 g of NaCl completely dissolve (producing Na^+ and Cl^- ions) in 1.00 Kg of water at 25°C . The vapor pressure of pure water at this temperature is 23.8 torr. Determine the vapor pressure of the solution



22.1 torr



22.9 torr



20.6 torr



19.9 torr



23.8 torr

At 40°C, heptane has a vapor pressure of about 92.0 torr and octane has a vapor pressure of about 31.2 torr. Assuming ideal behavior, what is the vapor pressure of a solution that contains twice as many moles of heptane as octane?

-  **A** 61.3 torr
-  **B** 51.5 torr
-  **C** 71.7 torr
-  **D** 82.1 torr
-  **E** None of these

A 7.12 g sample of a compound is dissolved in 250. grams of benzene. The freezing point of this solution is 1.02°C below that of pure benzene. What is the molar mass of this compound? (K_f benzene = $5.12^{\circ}\text{C}/\text{m}$). Ignor sig. figs.

A 35.7 g/mol

B 143 g/mol

C 286 g/mol

D 5.67 g/mol

E 71.5 g/mol

What is the boiling point change for a solution containing 0.681 moles of naphthalene (a nonvolatile, nonionizing compound) in 250. g of liquid benzene? ($K_b = 2.53 \text{ }^\circ\text{C}/m$ for benzene)



6.89 $^\circ\text{C}$



0.93 $^\circ\text{C}$



3.72 $^\circ\text{C}$



1.723 $^\circ\text{C}$



0.431 $^\circ\text{C}$

Determine the Osmotic Pressure of a solution that contains 0.017 g of a hydrocarbon solute (molar mass = 340 g/mol) dissolved in benzene to make 350-ml solution. The temperature is 20.0°C



0.18 torr



0.9 torr



1.2 torr



2.6 torr



2.4 torr