CHEMISTRY 111 LECTURE

Unit III Material

Part 1 Solutions, colloids, and suspensions

COMPARISION:	TRUE SOLUTION	COLLOID	SUSPENSION
Particle size:	< 1 nm	1 - 100 nm	> 100 nm

Part 2 COLLOIDS

A. **COLLOID** is a homogeneous mixture. Particles of one substance are dispersed throughout another substance.
COMPONENTS:

COLLIOD

Colloid particle	Continuous phase
Dispersed phase	Dispersing medium

B. TYPES OF COLLOIDS

Colloids are classified according to the state (solid, liquid, gas) of the dispersed phase and the state of the continuous phase.

DISPERSED PHASE	CONTIUOUS PHASE	NAME OF COLLOID	EXAMPLES
LIQUID	GAS	LIQUID AEROSOL	➘FOG ➘MIST ➘CLOUD
SOLID	GAS	SOLID AEROSOL	➘SMOKE ➘DUST
GAS	LIQUID	FOAM	➘BEER FROTH ➘SAP SUDS ➘WHIPPED CREAM
LIQUID	LIQUID	EMULSION	➘MILK (CREAM IN MILK) ➘MAYONAISE (OIL DISPERSED IN WATER)
SOLID	LIQUID	SOL	➘AgCl PPT IN H2O ➘PAINT ➘INK ➘MILK OF MAGNESIA
GAS	SOLID	SOLID FOAM	➘PUMICE ➘PLASTIC ➘MARSHMALLOW
LIQUID	SOLID	SOLID EMULSION	➘CHEESE ➘BUTTER ➘JELLY
SOLID	SOLID	SOLID SOL	➘RUBY (GLASS WITH DISPERSED METAL) ➘ALLOYS

C. PROPERTIES OF COLLOIDS

1. TYNDALL EFFECT
   The Tyndall effect is the scattering of light by colloidal particles.

2. BROWNIAN MOVEMENT
   Brownian movement is the random motion of colloidal particles in a dispersing medium.
   This was the first visual proof showing the kinetic molecular theory.

3. FILTRATION & GEL PENETRATION
   Most colloidal particles will pass through filter paper but will not pass through a gel.
   All solute particles in a solution will pass through both filter papers and gels.

4. RATE OF SETTLING
   Very dense dispersed colloidal particles do not sink but may remain dispersed in the dispersing medium indefinitely. Colloidal systems can remain stable indefinitely.

5. ADSORPTION
   Colloidal particles have a tremendous amount of surface area. This large area makes it particularly efficient in attracting and holding molecules, atoms, and ions.

D. FORMATION OF COLLOIDAL SYSTEMS

1. Dispersion method
   Large peieces of substances are broken into smaller particles of colloidal size and is dispersed through a continuous phase.

2. Condensation method
   Small molecules, ions or atoms are made to cluster together to form particles of "colloidal" size. These colloidal particles are dispersed through a continuous phase.

E. LIQUID COLLOIDAL SYSTEMS-Colloidal systems in which a liquid is the dispersing (continuous) medium

1. Lyophilic Colloid
   a. Lyophilic colloid - The colloidal particles are more attracted to the dispersing medium than to each other.
      The effect: This prevents the colloidal particles from coagulating (clumping) together to form large particles which will settle out.

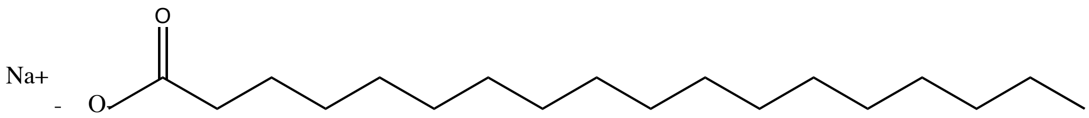
   b. Hydrophilic colloid - A lyophilic colloid in which the continuous (dispersing) medium is water.

2. Lyophobic Colloid
   a. Lyophobic colloid - The colloidal particles are more attracted to each other than the dispersing medium.
      The effect:: Colloidal particles will coagulate (clump) together to form large particles which will settle out.

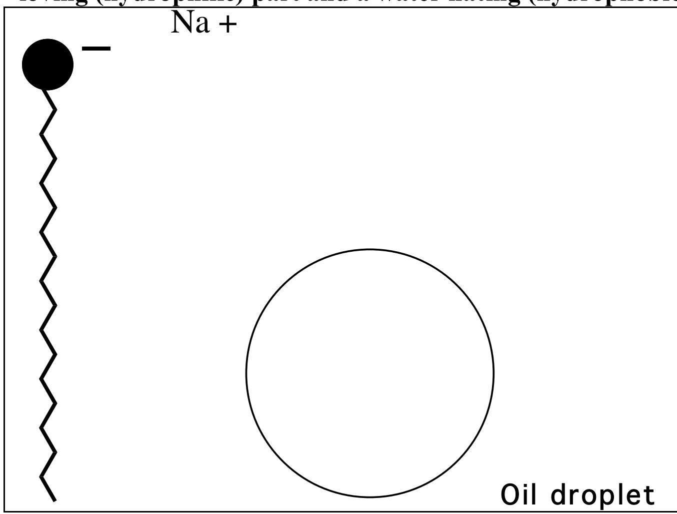
   b. Hydrophobic colloid - A lyophobic colloid in which the continuous (dispersing) medium is water.

3. Examples of Hydrophilic Colloidal Systems

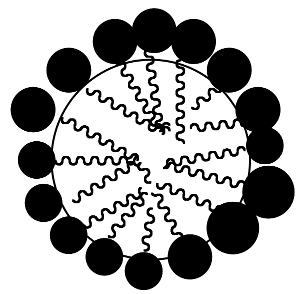
Soap

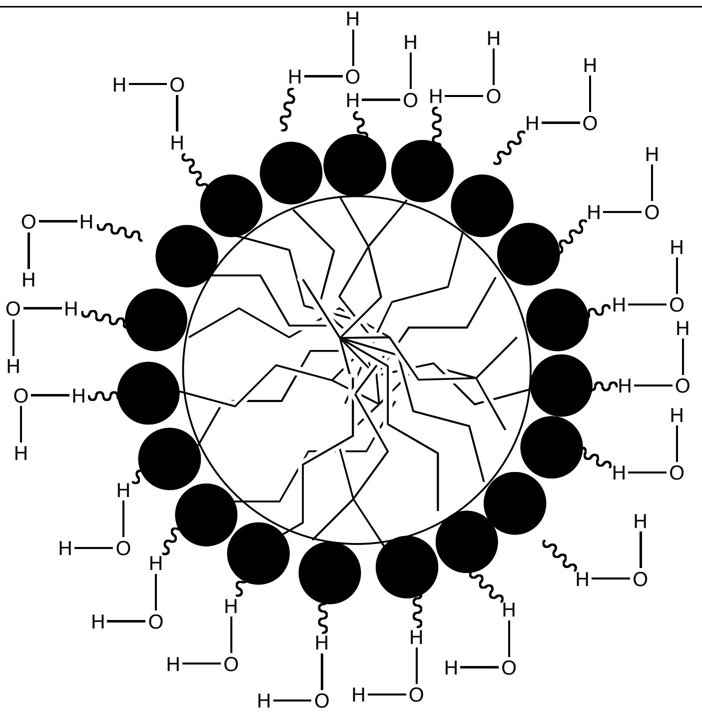


Soap is the salt of a fatty acid. It is unique because it has an ionic end and a long tail that is nonpolar. So it has both a water loving (hydrophilic) part and a water hating (hydrophobic) part.



The polar "head" will be attracted to water. The nonpolar "tail" will be attracted to oil. This is how soap is able to wash away oil from skin or dishes.



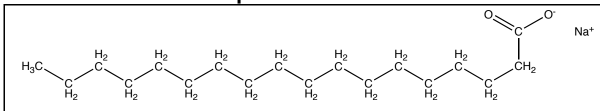
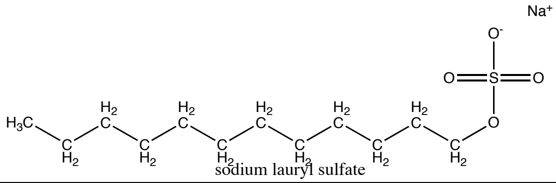
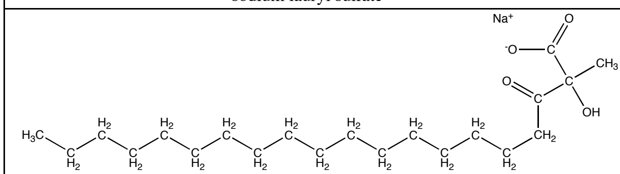


A soap Micelle

Non polar ends of molecules at the center are attracted to the circular nonpolar material. The negativiely charged groups on the surface are attracted to the water molecules

water

Some other important molecules with similar properties to soap:

 sodium stearate	**This is the soap molecule made from NaOH and pig fat. It forms a "bridge" between oil and water. It "fools" them into making a sort of mixture called an emulsion. Emulsions are not solutions but are mixtures of things that don't "like" to be mixed such as oil and water.**
 sodium lauryl sulfate	**This is the emulsifier you find in toothpaste and shampoo. Look on the labels to many household products and you will find sodium lauryl sulfate and many compounds similar to it.**
 sodium stearoyl lactylate	**Foods also need emulsifiers to keep the nonpolar and polar molecules mixed. You would not want your Twinkie to separate! This molecule is similar in structure to soap. It is found in small amounts in many foods to keep them mixed. Egg yolks can do a similar job because they, too contain emulsifiers, but eggs don't sit on a shelf very well for very long. This long molecule also has some fat characteristics in that it makes the "creamy" filling of Twinkies creamy, without any real cream! It gives fillings the smooth texture. And it is all made in a test tube!**

F. HYDROPHOBIC COLLOIDAL DISPERSIONS

Hydrophobic colloidal systems are unstable. The colloidal particles are more attracted to each other than the dispersing medium, therefore, they will coagulate into larger particles which will settle out. The hydrophobiccolloidal system must be stabilized.

1. Stabilization by adsorption of ions

2. Stabilization by a protective colloid

G. COAGULATION OF HYDROPHOBIC COLLOIDS

1. Heating - heating increases the kinetic energy of the particles. The colloidal particles collide with sufficient energy to over come the repulsion between the colloidal particles due to the adsorbed ions

2. Adding an electrolyte - Ions are added to remove the adsorbed ion layers. Colloidal particles can then
coagulate (ppt).

A **flocculant/flocculating agent** - A substance that causes particles to coagulate (destroys the colloid)

3. Mixing of two colloidal dispersions whose particles are oppositely charged causes them to coagulate (ppt).

4. Applying an electrical current, electrophoresis - When an electrical current is applied, the charged dispersed colloidal particles moves toward the electrode with the opposite charge. When the charged particles reach the electrodes they are neutralized and the particles will coagulate into larger particles and will settle out (ppt).

PART 3 SOLUTION CHEMISTRY

I. Solutions are homogeneous mixtures

II. Components of a solution:

III. Solubility:

The amount of solute that dissolves in a given amount of solvent at a given T^o and Pressure

a. In: $\frac{\text{g solute}}{\text{100 g solvent}}$

$$\text{ex. } \frac{79.5 \text{ g NaBr}}{100 \text{ g } H_2O} \quad \text{vs} \quad \frac{0.00015 \text{ g } Fe(OH)_3}{100 \text{ g } H_2O}$$

b. Past solubility ⇒ Additional solute will not dissolve

c. Concentration of solutions

1) Dilute solutions contains a small amount of solute

2) Concentrated solutions contains a large amount of solute

d. Solubility terms for **solids** as the solute

1) In an **unsaturated solution** additional solute will dissolve

2) In a **saturated solution** additional solute will **not** dissolve

3) A **supersaturated solution** is a solution that has been prepared to hold more solute than its solubility limit

e. Solubility terms for solids as the solute

Saturated, Unsaturated, or supersaturated solution?

f. Solubility terms for **liquids** as the solute

1) Miscible-2 liquids that form a solution in all proportions

2) Immiscible - 2 liquids that do not form a solution

SOLUBILITY RULES FOR IONIC COMPOUNDS

Ion contained in the Compound	Solubility	Exceptions
Group IA	soluble	
NH_4^+	soluble	
$C_2H_3O_2^-$	soluble	
NO_3^-	soluble	
Cl^-, Br^-, and I^-	soluble	Ag^+, Pb^{2+}, Hg_2^{2+}
SO_4^{2-}	soluble	Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
CO_3^{2-}, PO_4^{3-}, SO_3^{2-}	insoluble	group IA and NH_4^+
S^{2-}	insoluble	group IA, IIA, and NH_4^+
OH^-	insoluble	group IA, Ca^{2+}, Ba^{2+}, Sr^{2+}

STRONG ACIDS AND BASES

STRONG BASES

LiOH	NaOH
KOH	RbOH
CsOH	$Sr(OH)_2$
$Ba(OH)_2$	$Ca(OH)_2$

STRONG ACIDS

HNO_3	H_2SO_4
$HClO_4$	HCl
HBr	HI

f. Factors that Effect Solubility

1) Temperature -

a. Solids - In general the solubility of a solid increases with increasing temperature (depends if the solution process is an endo- or exothermic process)

b. Gases - In general the solubility of a gas decreases with increasing temperature.

2) Pressure

a. solids and liquids – Pressure has little / no effect on the solubility of solids.

b. Gases - The solubility of a gas increases when the partial pressure of the gas over the solution is increased (Henry's law)

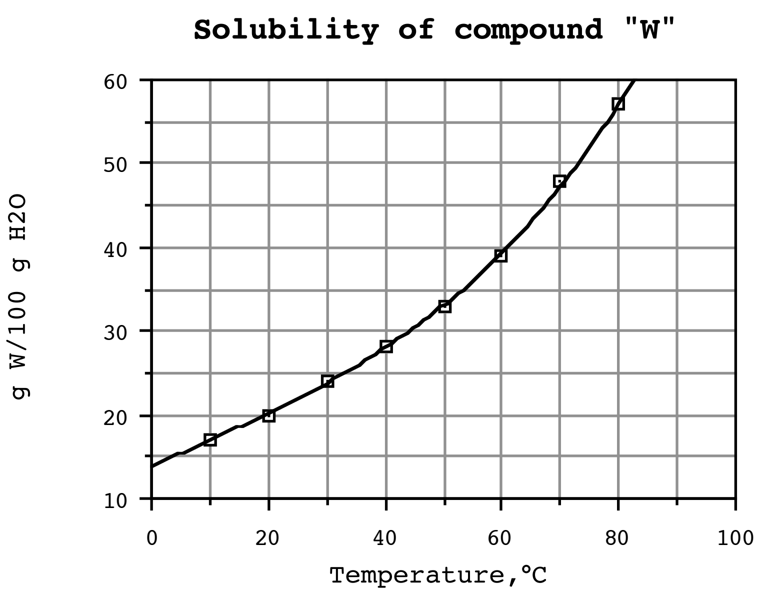
3) Nature of the Solute/Solvent "like dissolves like"

a.

b.

c.

g. Solubility curves



IV. Solution Formation

The solution process:

The attraction between ions and water is called **hydration**. This is due to an ion-dipole interaction where the polar water molecules are attracted to the surface of an ionic crystalline lattice. The ion-dipole attractions formed allow the ions to escape from the crystal and are essentially "dissolved" in water. All ions are hydrated in water solution.

V. Heat of solution

Heat can be released or absorbed when a solute dissolves in a solvent (the solvation process).
The enthalpy change, ΔH_{soln}, depends upon the energy required to break solute-solute bonds and the energy released when solute-solvent bonds are formed.

A. An exothermic process:

B. An endothermic process:

VI. Concentrations

A. Percent solute

1. % by weight = $\frac{\text{g solute}}{\text{g solution}} \times 100$

$$\frac{\text{g solute}}{\text{100 g solution}}$$

2. % by volume = $\frac{\text{ml solute}}{\text{g solution}} \times 100$

$$\frac{\text{ml solute}}{\text{100 ml solution}}$$

3. Wt-Vol % = $\frac{\text{g solute}}{\text{ml solution}} \times 100$

$$\frac{\text{g solute}}{\text{100 ml solution}}$$

B. Molarity = M = $\frac{\text{moles solute}}{\text{Liter solution}}$

Problem: What is the molar concentration of a solution that has 10.3 g of sodium bromide in 251 mL of solution?

C. Molality = $\frac{\text{moles solute}}{\text{Kg solvent}}$

Problem: What is the molality of a solution that has 10.3 g sodium bromide that has been dissolved in 300. mL of water?

D. Mole Fraction = $X_A = \frac{\text{moles }_A}{\text{total moles of solution}}$

Problem: What is the mole fraction of sodium bromide when the solution contains 10.3 g sodium bromide dissolved in 300. mL of water?

VII Dilutions:

$$M_1V_1 = M_2V_2$$

Dilution Problem

1. 25ml of a 8.0 M HCl solution is diluted to 1 liter. What is the final molarity?

Solution Problems

1. How many grams of S can be produced from the reaction of 30.0 mL of 12.0 M HNO_3 with an excess of 0.035 M H_2S.

$$2\ HNO_3\ (aq)\ \ 3\ H_2S(aq) \rightarrow 2\ NO(g) + 3\ S(s) + 4\ H_2O(l)$$

2. What is the molarity of a 50.0 mL sample of sulfuric acid that will completely react with 40.0 mL of 0.200 M $Mg(OH)_2$?

3. The density of a 88.00 % (wt/wt) methanol (CH_3OH) solution is 0.8274 g/ml. What is the molarity of the solution?

4. An aqueous solution of acetic acid is 0.796 m and has a density of 1.004 g/ml. What is the molarity of the solution?

5. Calculate the molality of a 14.0 % by mass nitric acid solution.

6. 20.00 mL of a 0.100 M sodium carbonate solution is mixed with 40.00 mL of a 0.800 M nickel (III) chloride solution.

a) Calculate the number of grams of nickel (III) carbonate produced.
b) Calculate the molarity of all the species in solution after the reaction has taken place.

$$3\ Na_2CO_3(aq) + 2\ NiCl_3(aq) \rightarrow Ni_2(CO_3)_3(s) + 6\ NaCl(aq)$$

The balanced eqn.:

The total ionic eqn.:

Calculations:

7. 5.0 g of zinc are reacted with 1855 mls of 0.250 F hydrochloric acid. How many grams of hydrogen gas are produced? Calculate the molarity of all species left in solution after the reaction has taken place.

The balanced eqn.:

The total ionic eqn

Calculation:

Part 6 ELECTROLYTES

I. ELECTROLYTES- A substance that is a conductor of electricity in water due to the movement of ions in solution:

A. Strong, Weak, and Nonelectrolytes

1. Strong Electrolytes:

a. Substances which are strong conductors of electricity in an aqueous solution.

b. Substances that are 100% ionized in solution

c. Substances which are strong electrolytes:

(1) Soluble ionic compounds

(2) Strong Acids

(3) Strong Bases

2. Weak Electrolytes:

a. Substances which are weak conductors of electricity in an aqueous solution.

b. Substances which ionize very little in solution

c. Substances which are weak electrolytes:

(1) Weak Acids

(2) Weak Soluble Bases

(3) Slightly soluble ionic compounds

3. Nonelectrolytes:

a. Substances which do not conduct electricity in solution.

b. Substances which do not ionize in solution.

c. Substances which are nonelectrolytes:

Soluble substance that only exists as molecules in water

Part 7 NET-IONIC EQUATIONS

Net Ionic equations shows the species that are reacting in solution

<u>Un-ionized equation</u> - the bookkeeping equation

<u>Total ionic equation</u> - Shows substances in their predominant form

<u>Net-Ionic equation</u> - Shows the only species that underwent a chemical reaction. [Spectator ions have been eliminated]

How to write net-ionic equations

1. Write a balanced equation (correct chemical formulas)
2. Write a total ionic equation:
   a. Write the following in the ionized form:

		Write As:
Soluble Salt	$FeCl_2(aq)$	$Fe^{2+}(aq) + 2Cl^-(aq)$
Strong Acid	$HCl(aq)$	$H^+(aq) + Cl^-(aq)$
Strong Base	$NaOH(aq)$	$Na^+(aq) + OH^-(aq)$

   b. Write the following in the unionized form:

   (1) Weak acids and bases:
   H_2CO_3 HCN $NH_3(aq) \rightarrow [NH_4^+ + OH^-]$

   (2) Insoluble ionic compounds
   $AgCl(s)$, $PbS(s)$, $Fe(OH)_2(s)$, $CrCrO_4(s)$

   (3) Molecules
   $H_2O(aq)$ $H_2(g)$ $H_2S(g)$

3. Write the net-ionic equation by eliminating all spectator ions. (The unreacting species)
   The net-ionic equaiton must be in the simplest ratio possible

If all species on both sides are spectator ions → N.R.

EXAMPLES:

1. Oxalic acid is poured into a solution of potassium hydroxide.

Molecular equation____

Total ionic____

Net ionic____

2. Solutions of Iron (II) chloride and cesium hydroxide are mixed together

Molecular equation____

Total ionic____

Net ionic____

3. Aqueous sodium phosphate and sulfuric acid are mixed.

Molecular equation____

Total ionic____

Net ionic____

4. . lead (II) cyanide and potassium carbonate solutions are mixed

Molecular equation____

Total ionic____

Net ionic____

Part 8 VAPOR PRESSURE OF SOLUTIONS

I. VAPOR PRESSURE

If a solution is composed of more than 1 volatile component, the total pressure of gases about the solution is the sum of the partial pressure of all of the gases:

$$P_{total} = P_A + P_B + P_C \text{ ...+...etc.}$$

Where:
- P_A = partial vapor pressure of A
- P_B = partial vapor pressure of B
- P_C = partial vapor pressure of C

II. PARTIAL PRESSURES - RAOULT'S LAW

The partial pressure of a component is found by:

$$P_A = X_A P_A^\circ$$

Where:
- P_A = partial vapor pressure of A over the solution.
- P_A° = vapor pressure of A over a pure solution of A
- X_A = The mole fraction of A in solution.

THEREFORE:

$$P_{total} = P_A + P_B + P_C$$

$$P_{total} = X_A P_A^\circ + X_B P_B^\circ + X_C P_C^\circ$$

III. PROBLEMS

1. VAPOR PRESSURE OF SOLUTION CONTAINING A NONVOLATILE, NONIONIZING SOLUTE

   100 0 g of glycerin, $C_3H_8O_3$(MM= 92.1 g/mol), a nonvolatile nonelectrolyte is added to 200.0 mL of water 25.0°C. The vapor pressure of pure water at 25.0°C is 23.8 torr. What is the vapor pressure of the resulting solution?

2. <u>VAPOR PRESSURE OF SOLUTION WITH TWO OR MORE VOLATILE COMPONENTS</u>

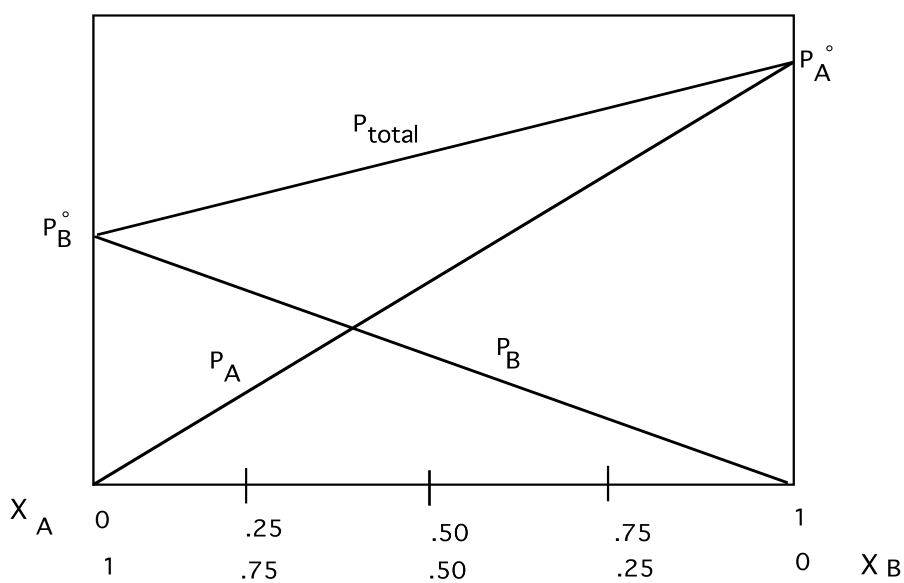
Equal masses (100.0 g) of Ethanol (C_2H_5OH, MM= 46.0) and water (, MM= 18.0) are mixed at 63.5 °C and an ideal solution is formed. At 63.5°C The vapor pressure of ethanol and water is 400.0 torr and 175 torr, respectively. Calculate the Vapor pressure over the solution

Benzene, C_6H_6 and toluene, C_7H_8, form ideal solutions. At 90°C, the vapor pressure of pure benzene is 1.326 atm, and the vapor pressure of pure toluene is 0.532 atm. What is the mole fraction of toluene in a solution that boils at 90°C and 1.000 atm pressure?

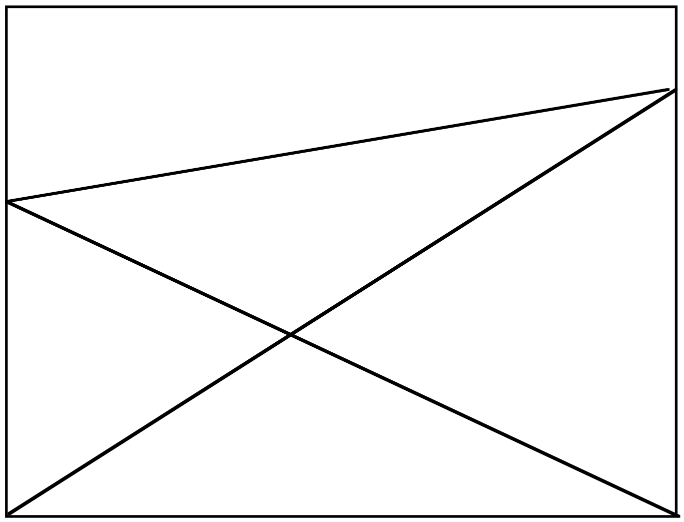
A solution prepared from 96.0 g of a nonvolatile, nondissociating solute n 5.25 mole of toluene has a vapor pressure of 0.161 atm at 60 °C. What is the moledular weight of the solute? The vapor pressure of pure toluene at 60.0 °C is .184 atm.

IV. RAOULT'S LAW-PARTIAL PRESSURE CURVES

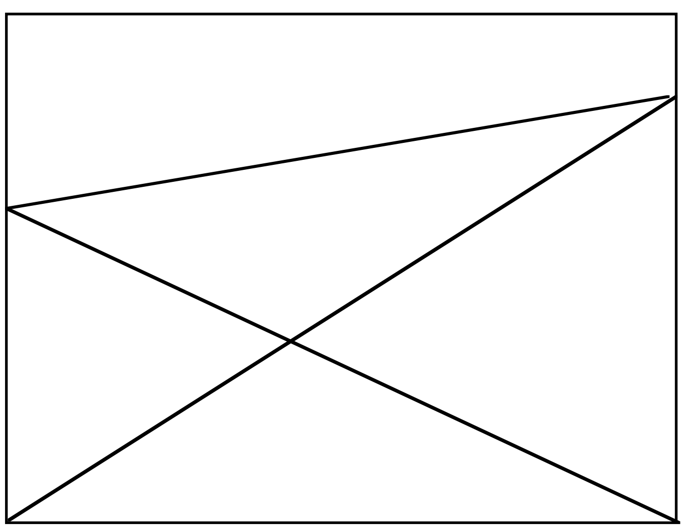
A. An IDEAL SOLUTION follows Raoult's law. The intermolecular forces between component A and B are the same as between A-A and B-B



B. A **<u>POSTIVE DEVIATION FROM RAOULT'S LAW</u>**: The partial pressure of A and B and total pressure above the solution are HIGHER than expected. The intermolecular forces between component A and B are weaker than between A-A and B-B



C. A **<u>NEGATIVE DEVIATION FROM RAOULT'S LAW</u>**: The partial pressure of A and B and total pressure above the solution is LOWER than expected. The intermolecular forces between component A and B are stronger than between A-A and B-B



Part 9 COLLIGATIVE PROPERTIES

The **colligative properties** of solutions are properties that depend primarily upon the number of dissolved particles present (concentrations), rather than upon the nature of these particles.
Colligative properties include: Boiling point elevation, freezing point lowering, and osmotic pressure.

I. BOILING POINT ELEVATION

The boiling point of a liquid is the temperature at which its vapor pressure equals the atmospheric pressure. The normal boiling point is when the vapor pressure equals the atomospheric pressure of 1. The addition of a solute decreases the vapor pressure above the liquid. Therefore, an increase of temperature is required to achieve a vapor pressure of 1 atm. This increase in the boiling temperature when a solute is added is called Boiling Point Elevation.

The boiling point elevation, ΔT_f, is the difference between the boiling point of the solvent and the boiling point of the solution.

$$\Delta T = K_b m$$

Where: K_b = molal boiling point elevation constant for the solvent Units of K_f are: $\frac{^oC\ kg}{mole}$.

m = the molality of the solution = $\frac{\text{moles solute}}{\text{kg solvent}}$

II. FREEZING POINT DEPRESSION

The addition of a solute to a solvent will decrease the freezing point (temperature) of the solvent. The freezing point depression, ΔT, is the difference between the freezing point of the solvent and the freezing point of the solution.

$$\Delta T = K_f m$$

Where:

K_f = molal freezing point depression constant for the solvent Units of K_f are: $\frac{^oC\ kg}{mole}$.

m = the molality of the solution = $\frac{\text{moles solute}}{\text{kg solvent}}$

Problems:

1. An aqueous solution is 0.0222 m glucose. What is the freezing point of this solution?

2. Camphor melts at 179.5 °C with a freezing point depression constant of 40°C/m.
   a) A 1.07 mg sample of an unknown compound was dissolved in 78.1 mg of camphor. The solution melted at 176.0°C. What is the molecular weight of the compound?

   b) If the empirical formula of the unknown compound is CH, what is the molecular formula

III. OSMOSIS

Osmosis is the phenomenon of solvent flowing through a semi-permeable membrane from the side of lower solute concentration to the side of higher solute concentration.

The colligative property, OSMOTIC PRESSURE, is the pressure applied to the solution that stops osmosis from occurring.

$$\pi = MRT$$

π = osmotic pressure
M = molarity
R = Gas constant
T = temperature

Problem:
Calculate the osmotic pressure at 25°C. When 0.798 g of starch (MM= is 3.24×10^4 on the average) is dissolved to produce 100.0 ml of solution.

IV. COLLIGATIVE PROPERITIES OF IONIC SOLUTIONS

Coligative properities depend only upon the number of particles in the solution. NaCl dissociates in solution into two ions. Therefore the ΔT_f, or ΔT_b, for a 1 M NaCl solution would be twice that of 1 M glucose solution, a nonelectrolyte.

$$\Delta T_b = iK_b m$$
$$\Delta T_f = iK_f m$$
$$\pi = iMRT$$

Where: i = the van't Hoff factor