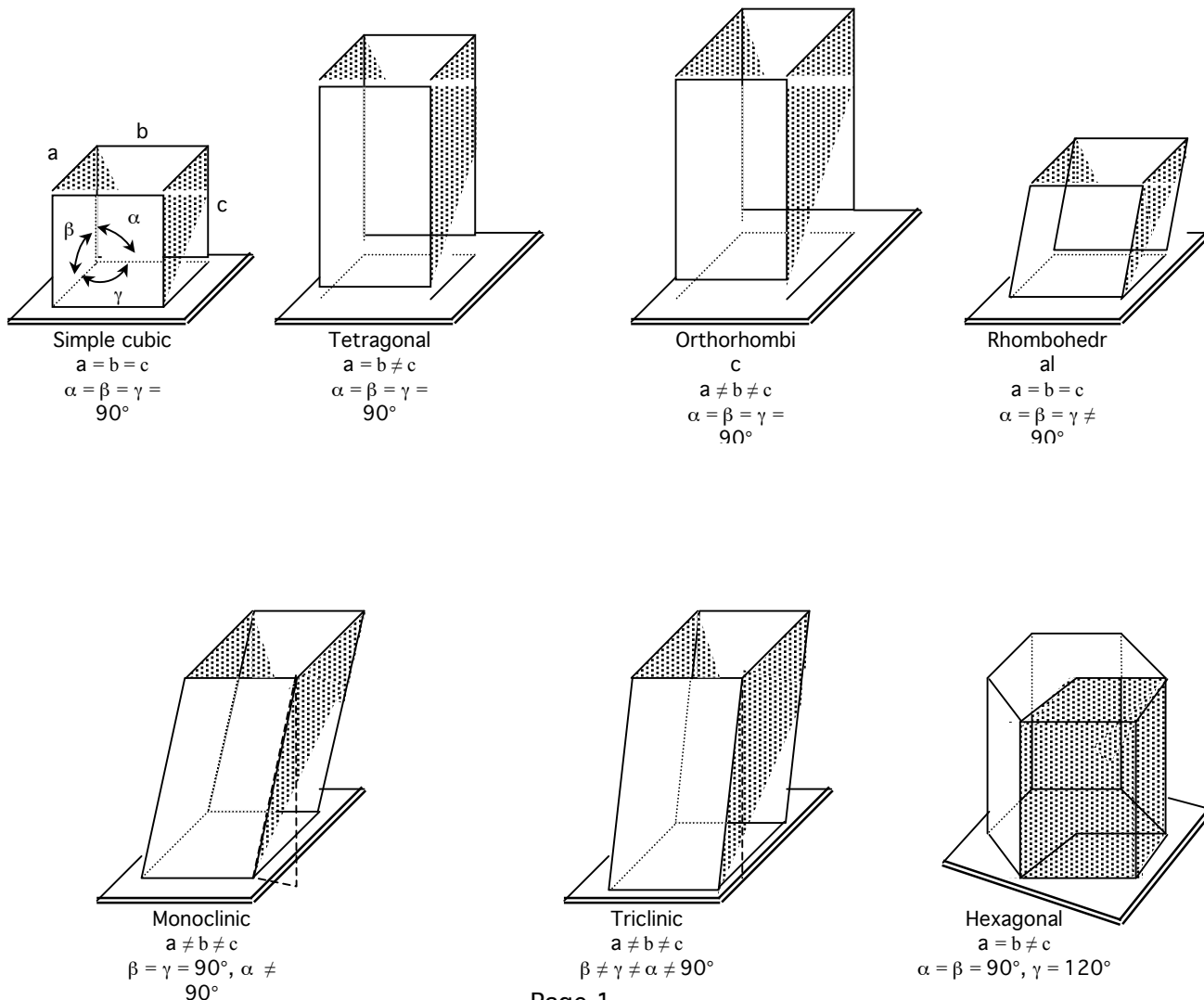CHEMISTRY 111 LECTURE
EXAM III Material
Part 1 SOLIDS
VI. Crystalline Solids: Unit Cells and Basic Structures
A. Types
1. Crystalline Solid
Crystalline solids have a highly ordered arrangement of particles (ions, atoms, and molecules)
2. Amorphous Solid
Amorphous solids have considerable disorder in their structure.

B. Crystalline Solids
1. Crystalline lattice
A three dimensional array of lattice points in a pattern that defines a crystal.

2. Unit Cell
The Unit cell is the basic repeating unit of the lattice.
3. Coordination Number
The coordination number of a particle in a crystal is thenumber of nearest neighbors .
4. Lattice Points
The points in a lattice occupied by atoms, ions or molecules.
5. Kinds of Lattice

Simple cubic
$a = b = c$
$\alpha = \beta = \gamma = 90°$

Tetragonal
$a = b \neq c$
$\alpha = \beta = \gamma = 90°$

Orthorhombic
$a \neq b \neq c$
$\alpha = \beta = \gamma = 90°$

Rhombohedral
$a = b = c$
$\alpha = \beta = \gamma \neq 90°$

Monoclinic
$a \neq b \neq c$
$\beta = \gamma = 90°, \alpha \neq 90°$

Triclinic
$a \neq b \neq c$
$\beta \neq \gamma \neq \alpha \neq 90°$

Hexagonal
$a = b \neq c$
$\alpha = \beta = 90°, \gamma = 120°$

5. <u>Geometry</u>

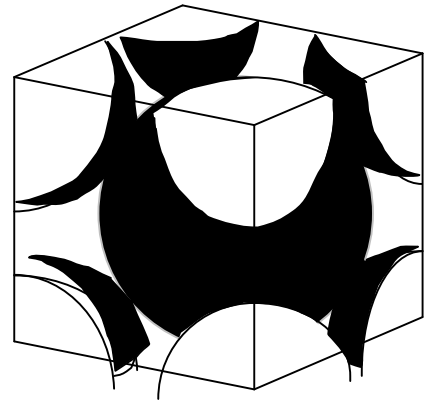6.   <u>Simple Cubic</u>

  a. Calculate the volume of the unit cell
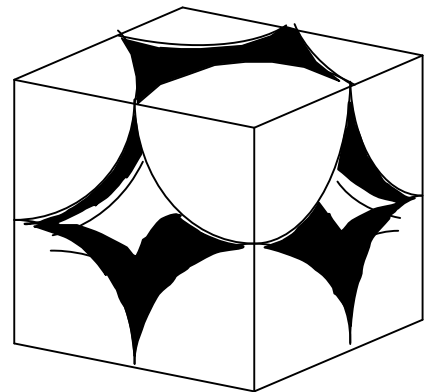
  b. Calculate the volume of the spheres

c. Calculate the percent occupied (packing efficiency)
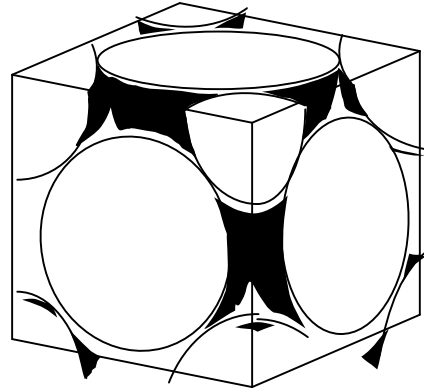
Body Centered Cubic

a. Calculate the volume of the unit cell

b. Calculate the volume of the spheres

c. Calculate the percent occupied (packing efficiency)

6. Face Centered Cubic

a. Calculate the volume of the unit cell

b. Calculate the volume of the spheres

c. Calculate the percent occupied (packing efficiency)

Problems:
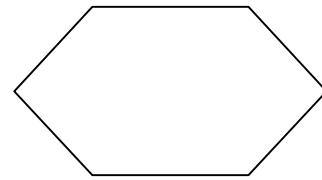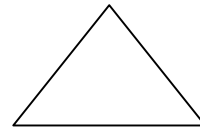
1. Molybdem has an atomic radius of 136 pm and crystallizes in a body centered cubic system.
    a. What is the length of the edge of a unit cell.
    b. Calculate the density of molybdem

2. Aluminum crystallizes in the face-centered cubic system, and the edge of a unit cell is 287.5 pm. Calculate the atomic radius of Al.

8. Packing Efficiency

a. Closest cubic packing

b. Hexagonal
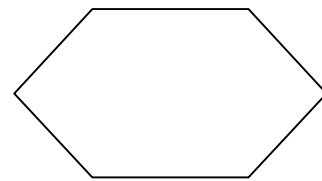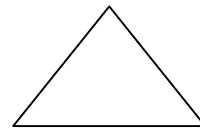
Part V Types of Solids

	IONIC SOLIDS	MOLECULAR SOLIDS	NONBONDING SOLIDS	NETWORK COVALENT	METALLIC SOLIDS
PARTICLES AT LATTICE POINTS	cations and anions [positive and negative ions]	polar or nonpolar covalent molecules	atoms	atoms	metallic cations [positive metallic ions]
BONDING BETWEEN PARTICLES (attractive forces)	electrostatic attractions [ionic bond]	intermolecular forces dipole-dipole, hydrogen bond, london forces	dispersion forces	covalent bonds	metallic bonds between positive metal ions and mobile electrons
PROPERITIES	high M.P. high B.P. nonconductors brittle hard/brittle	moderate to low M.P. moderate to low B.P. nonconductors or semi conductors soft	low M.P. low B.P. nonconductors	high M.P. high B.P. nonconductors brittle hard	variable M.P. variable B.P. malleable and ductile
EXAMPLES	NaCl KBr LiNO$_3$	H$_2$O SO$_2$ NH$_3$ C$_2$H$_5$OH	Xe Ar	C (diamond) SiC SiO$_2$	Au Cu Fe Na Hg

Part 2 SOLUTIONS   Chapter 12

I. Solutions are homogeneous mixtures

II. Components of a solution:

III. Solubility-Review:

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

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

ex. $\dfrac{79.5 \text{ g NaBr}}{100 \text{ g H}_2\text{O}}$ vs $\dfrac{0.00015 \text{ g Fe(OH)}_3}{100 \text{ g H}_2\text{O}}$

b. <u>Past solubility</u> $\Rightarrow$ Additional solute will not dissolve

c. <u>Concentration of solutions</u>

    1)   Dilute solutions contains a small amount of solute

    2)   Concentrated solutions contains a large amount of solute

d. <u>Solubility terms for **solids** as the solute</u>

    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. <u>Solubility terms for solids as the solute</u>

        Saturated, Unsaturated, or supersaturated solution?

f. <u>Solubility terms for **liquids** as the solute</u>

    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-review

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-review
      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)

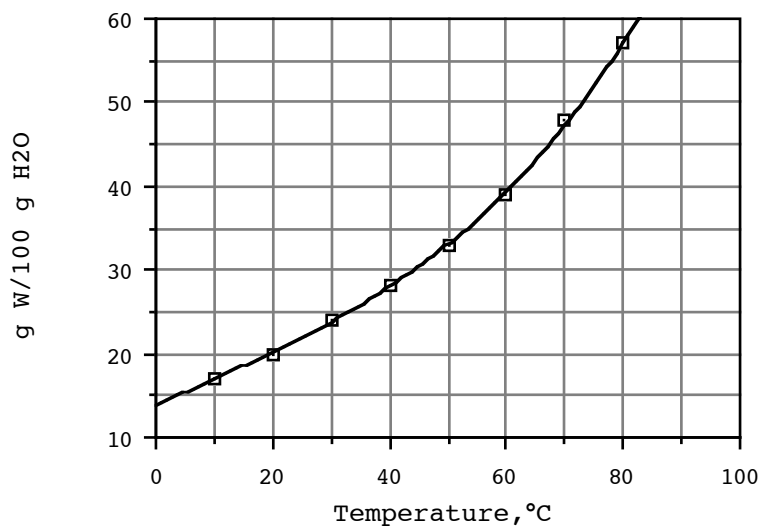   3) Nature of the Solute/Solvent   "like dissolves like"
          a.

          b.

          c.

g. Solubility curves-review

Solubility of compound "W"

IV. Solution Formation
<u>The solution process:</u>

The attraction between ions and water is called <u>**hydration**</u>. 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 enthalphy 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-Review
A. Percent solute

1. % by weight = $\dfrac{\text{g solute}}{\text{g solution}}$ x 100

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

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

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

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

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

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

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

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

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 = $\dfrac{\text{moles } A}{\text{total moles of solution}}$

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:

$$M_1 V_1 = M_2 V_2$$

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

Solution Problems-Review

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.

$$2 \, HNO_3 \, (aq) \quad 3 \, H_2S(aq) \quad \rightarrow \quad 2 \, NO(g) \; + \; 3 \, S(s) \; + \; 4 \, H_2O(l)$$
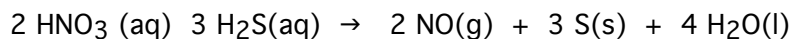
2. What is the molarity of a 50.0 mL sample of sulfuric acid that will completely react with 40.0 mL of 0.200 M $Mg(OH)_2$?

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.

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

Net Ionic equations shows the species that are reacting in solution

Un-ionized equation - the bookkeeping equation

Total ionic equation - Shows substances in their predominant form

Net-Ionic equation - Shows the only species that underwent a chemical reaction. [Spectator ions have been eliminated]
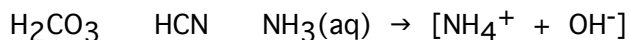
How to write net-ionic equations
1. Write a balanced equation (correct chemical formulas)

2. Write a total ionic equation:
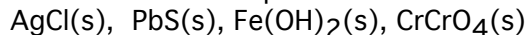   a. Write the following in the ionized form:

		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:
   $$H_2CO_3 \quad HCN \quad NH_3(aq) \rightarrow [NH_4^+ + OH^-]$$

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

   (3) Molecules
   $$H_2O(aq) \ H_2(g) \ H_2S(g)$$
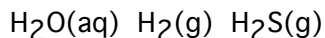
3. Write the net-ionic equation by eliminating all spectator ions. (The unreacting species)
   The net-ionic equaiton must be in the simplest ratio possible

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_____

Concentration of Ions after a Limiting Reactant Reaction

   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.

The balanced eqn.: $3\ Na_2CO_3(aq)\ +\ 2\ NiCl_3(aq)\ \rightarrow\ Ni_2(CO_3)_3(s)\ +\ 6\ NaCl(aq)$

The total ionic eqn.:

Calculations:

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:

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

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

IV. <u>RAOULT'S LAW-PARTIAL PRESSURE CURVES</u>

A. An <u>IDEAL SOLUTION</u> follows Raoult's law. The intermolecular forces between component A and B are the same as between A-A and B-B
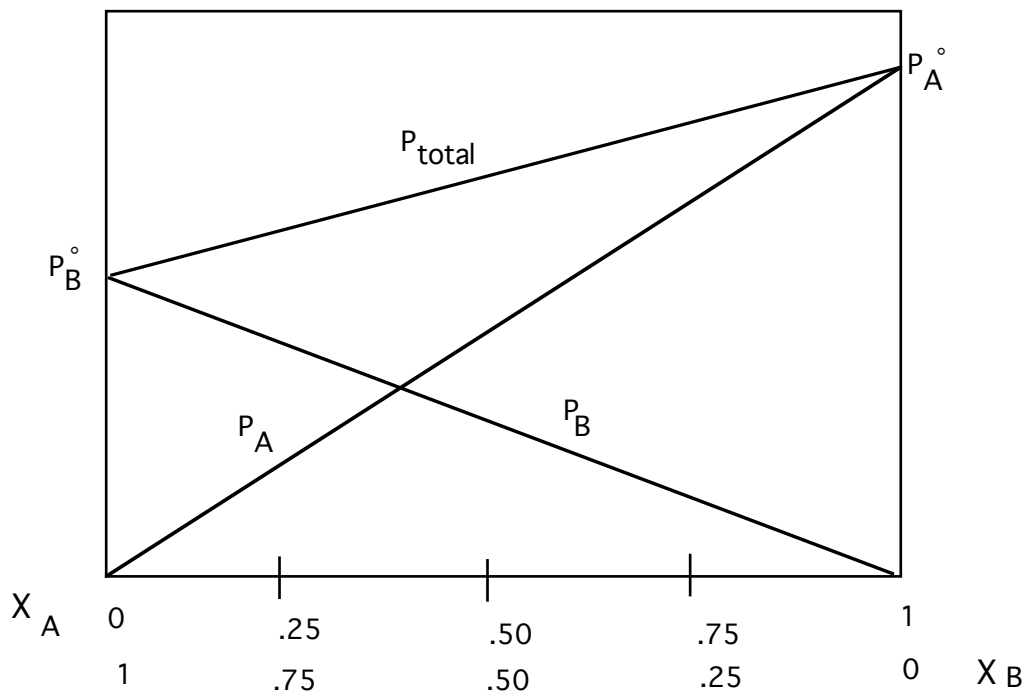
B. A <u>**POSTIVE DEVIATION FROM RAOULT'S LAW**</u>: The partial pressure of A and B and total pressure above the solution are HIGHER than expected. The intermolecular forces between component A and B are weaker than between A-A and B-B
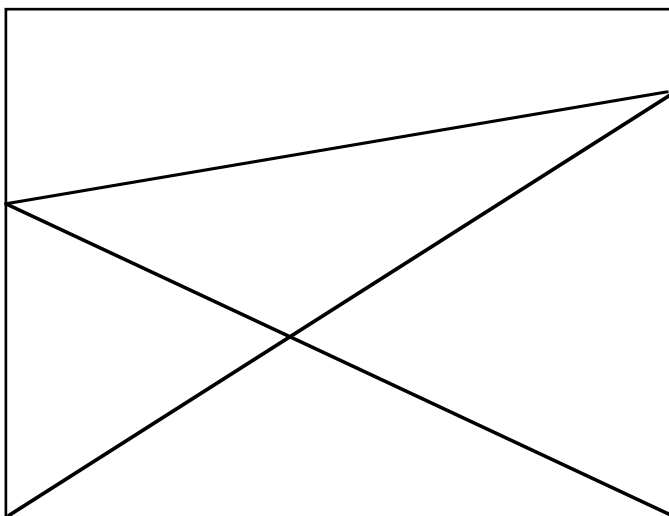
C. A <u>**NEGATIVE DEVIATION FROM RAOULT'S LAW**</u>: The partial pressure of A and B and total pressure above the solution is LOWER than expected. The intermolecular forces between component A and B are stronger than between A-A and B-B
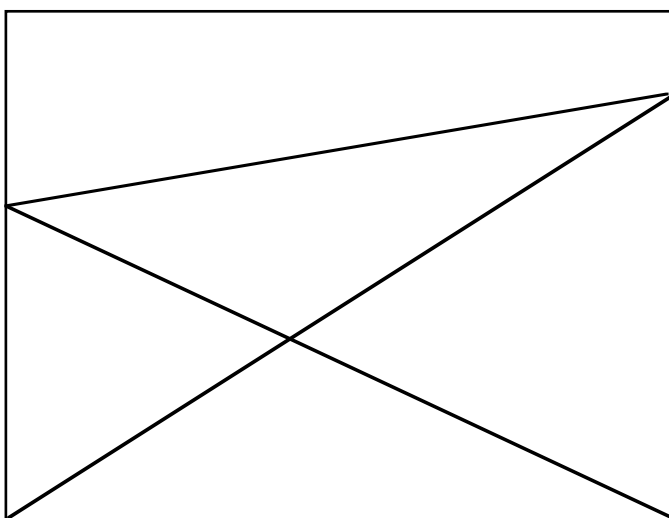
Part 9 COLLIGATIVE PROPERTIES

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.

$$\Delta T = iK_b m$$

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

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

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.

$$\Delta T = iK_f m$$

Where:

K_f = molal freezing point depression constant for the solvent Units of K_f are: $\dfrac{^{\circ}C \cdot kg}{mole}$.

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

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 from a high solute concentration through a semi-permeable membrane to a lower solute concentration.

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

$$\pi = iMRT$$

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

Part 4 COLLOIDS

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

<div align="center">COLLIOD</div>

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

COMPARISION: <u>TRUE SOLUTION</u>   <u>COLLOID</u>   <u>SUSPENSION</u>

Particle size: < 1 nm   1 - 100 nm   > 100 nm

C. PROPERTIES OF COLLOIDS
   1. TYNDALL EFFECT
      The Tyndall effect is the scattering of light by colloidal particles.

   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.

drophilic Colloidal Systems

    a. Macromolecules - The colloidal particles are macromolecules which are more attracted to water (the dispersing phase) than each other.
      Macromolecules disperse in water due to the presence of polar groups in the molecule which are strongly attracted to water

H   H

hydrocarbon portion
(oil attracting)

Polar group or
salt group
(Water-attracting)
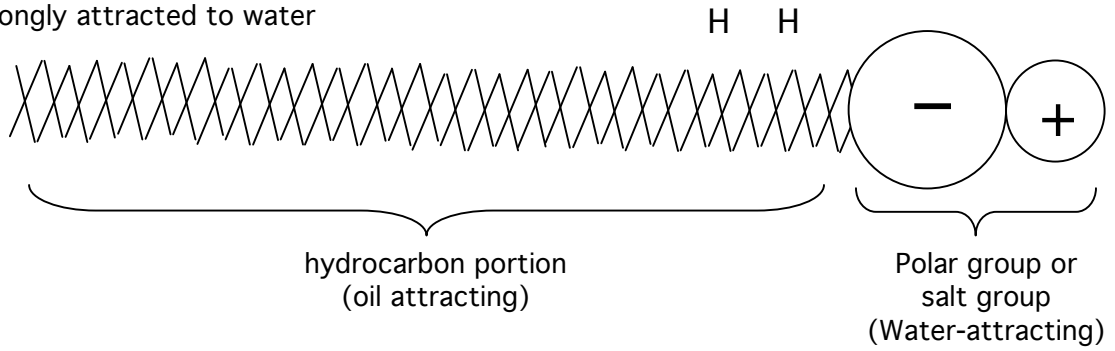
      Macromolecules disperse in water due to the molecules clustering together to form a colloidal particle, where, the polar groups of the molecules are on the outside and are strongly attracted to water (the nonpolar groups are on the inside).

palmitate anion

sodium ion

micelle

water