## *Chapter 13. The Properties of Solutions.*

***Chapter Overview:***
In this chapter, we address two questions:

1.

2.

We're especially interested in _____ _____.

*Colligative properties:*

***Review of terms***

solution

aqueous solution

solute vs. solvent

solubility

saturated vs. unsaturated

*Important:* In a *saturated* solution an _____ exists between solid solute and dissolved solute.

supersaturated

miscible

immiscible

solvation

hydration

electrolytes vs. nonelectrolytes

volatile vs. nonvolatile

## *The Solution Process*

Important Question: What is the _____ _____?

The "Solubility Rule":

This means:

To understand the _____ _____ in the solution process, we need to focus on three factors:

1.

2.

3.

### *1. Understand the Intermolecular Forces that occur between solute and solvent particles in solutions.*

1.

2.

3.

4.

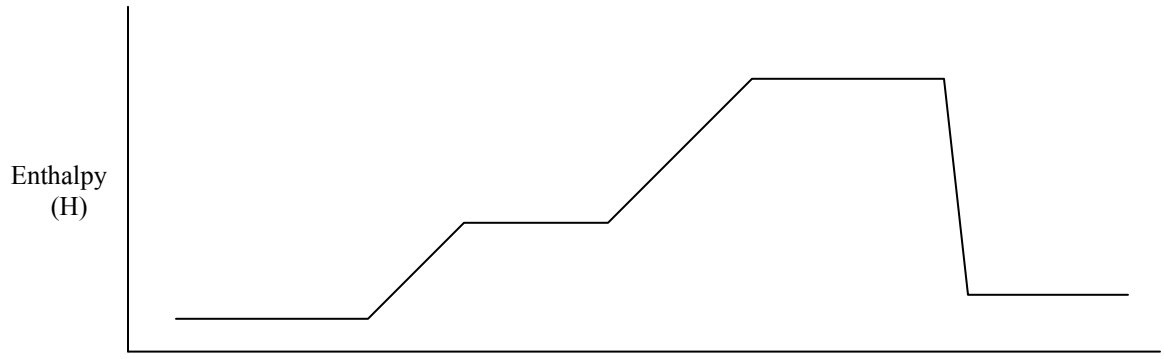
5.

6.

### *2. Energetics of the Solution Process*

**Key principle:**

**Thought experiment:** (compare figures 13.4 and 13.5, p. 396-397)



- This reminds us of a key principle from last semester:

  Bond breaking is _____; bond formation is _____.

- So, in order for solutions to form, $\Delta H_3 \approx$

  $\Delta H_{soln} =$

  $\Delta H_{soln}$ can be endothermic or exothermic:

  $NaOH(s)$, $\Delta H_{soln} =$

  $NH_4NO_3$, $\Delta H_{soln} =$

***3. Entropy***

Some substances, such as $NH_4NO_3$, have an _____ heat of solution.

Since enthalpy ($\Delta H_{soln}$) cannot explain why substances such as $NH_4NO_3$ dissolve, what must be the driving force?

## *Properties of Solutions*

***Effect of temperature on solubility***

• The solubility of *solids* in liquids:

• The solubility of *gases* in liquids:

One important application:

***Effect of pressure on solubility***

• The solubility of *solids* in liquids:

• The solubility of *gases* in liquids:

Henry's law:

An important application:

***Units of Concentration***

"Dilute" vs "Concentrated"

**Molarity (M)**

- Five things to know about molarity:

  1) M x V =

  2) You can always replace "M" with _____

  3) Molarity can be used as a _____ _____

4) Molarity is _____ _____

5) Important shortcut:

**Molality (m)**

• Important: Molality is *not* _____ _____

and that's why we use molality for _____ and _____

**Mass Percent**

• mass percent is also called:

**Mole Fraction ($X_A$)**

• "Junior High definition" of percent:

• "Junior High definition" of fraction:

**Example:** A 0.750 M $H_2SO_4$ solution has a density of 1.046 g/mL. Given that the molar mass of $H_2SO_4$ is 98.08 g/mol, determine a) the mole fraction of $H_2SO_4$; b) the mass percent of $H_2SO_4$; c) the molality of $H_2SO_4$.

## *Colligative Properties*

Definition of Colligative Properties:

We will consider 4 colligative properties:

1)

2)

3)

4)

### *Vapor Pressure Lowering*

*Make sure you understand the concept of Vapor Pressure. Quick Review:*

- Thought experiment:

- Def'n of Vapor Pressure:
- The _____ the intermolecular attractive forces, the _____ the vapor pressure.
- For a given liquid, vapor pressure _____ with temperature.
- "Volatile" –

**Raoult's Law (General Form):**

$P_A$ =

where $P_A$ =

$X_A$ =

$P^o_A$ =

### *Case 1: Nonvolatile Solute in a Volatile Solvent*

If A is the solvent,

A demonstration:

**Example**: What is the vapor pressure of an aqueous solution formed by dissolving 20.0 g of glucose ($C_6H_{12}O_6$, a nonvolatile nonelectrolyte) in 100.0 g of water at 25ºC? (Given: the vapor pressure of pure water is 23.756 at 25ºC.)

***Case 2: A Solution with Two Volatile Components***

If A and B are both volatile,

By Raoult's Law: $P_A =$

$P_B =$

Dalton's Law of Partial Pressure: $P_{tot} =$

where $P_{tot} =$

$P_{tot} =$

Positive deviation from Raoult's law results when

Negative deviation from Raoult's law results when

**Example**: What is the vapor pressure of a solution formed by mixing 6.00 mol of methanol with 8.00 mol of propanol at 40.ºC? (At 40.ºC the vapor pressures of pure methanol and pure propanol are 303 and 44.6 torr, respectively.)

**Example**: A certain methanol/propanol mixture has a vapor pressure of 205 torr at 40.ºC. Describe the composition of this solution in terms of the mole fraction of each component.

***Boiling point elevation***

Review definition of Boiling Point:

Phase diagram of pure water and an aqueous solution:

$\Delta T_b$ =

***Freezing Point Depression***

$\Delta T_f$ =

***Osmotic Pressure***

Thought experiment:

semipermeable membrane:

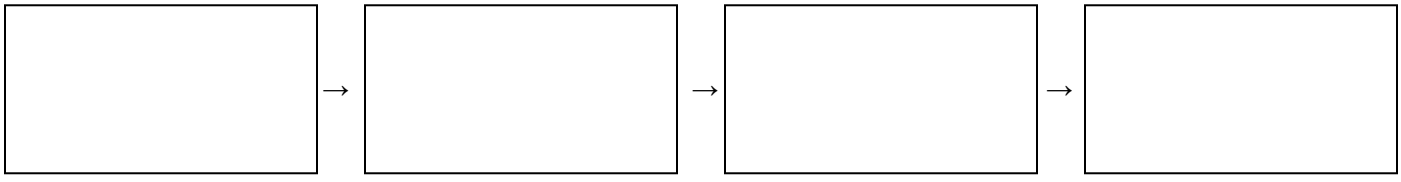
osmosis:

$\Pi$ =

where

***Using Colligative Properties to Determine the Molar Mass of an Unknown Solute***

Four steps:



**Example**: A solution of an unknown non-volatile nonelectrolyte was prepared by dissolving 0.250 g of unknown in 40.0 g of $CCl_4$. The new boiling point was: 76.97ºC. What is the molar mass of the unknown solute?
(Given: $K_b$ for $CCl_4$ = 5.02 ºC/m; $T_b$ for $CCl_4$ = 76.60ºC)

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***Colligative Properties of Electrolyte Solutions***

Review these definitions:

**Colligative Properties**: Properties of solutions that depend on _____

and not on _____.

**Strong electrolytes:**

Up until now we have focused on the colligative properties of non-electrolyte solutions. For electrolyte solutions, we must take into account:

**Examples**: Given that $K_f$ for water is 1.86 ºC/m, determine:

a) the freezing point of 1.00 m glucose (a non-volatile nonelectrolyte)

b) the freezing point of 1.00 m NaCl *assuming complete dissociation*

c) the freezing point of 1.00 m $MgCl_2$ *assuming complete dissocation*

**Example**: Assuming complete dissociation, which of the aqueous solutions below is expected to have the lowest boiling point?

a) 0.080 m glucose (a non-electrolyte)
b) 0.060 m $Na_3PO_4$
c) 0.15 m KCN
d) 0.10 m $LiClO_4$
e) 0.12 m $Mg(NO_3)_2$

*The van't Hoff i factor*

$i$ =