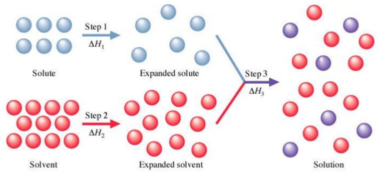
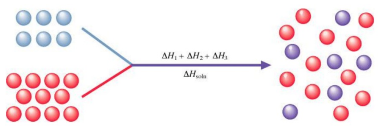
The Solution Process

Chemist believe that the process in making a solution is composed of three steps.



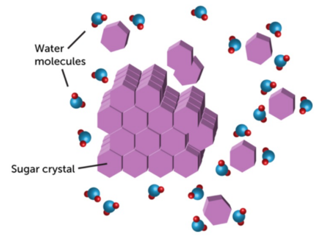
Step-by-Step Process



Composite Process

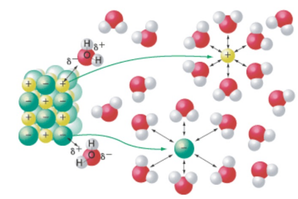
Page 1

Solvation vs. Dissociation



Solvation is a process by which a substance (the solvent) dissolves the solute by surrounding it.

Dissociation is a process by which an ionic substance is broken into it's ions by solvation.



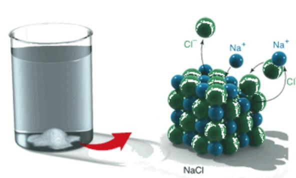
Page 2

Like Dissolves Like

"Like dissolves like" is an expression used by chemists to predict how and whether two substances will be dissolved in each other.

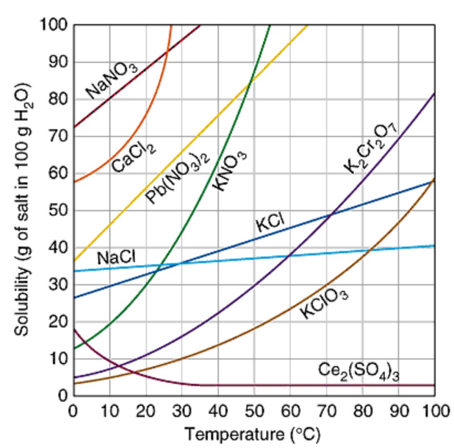
Factors which affect solubility:

1. Like Dissolves Like
2. Temperature
3. Pressure (Henry's Law)



Page 3

Solubility Curves



saturated
unsaturated
supersaturated

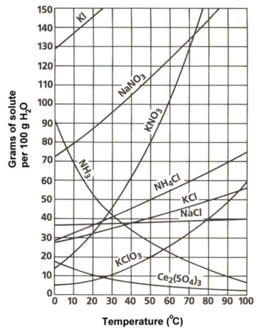
discuss gas solubility

Page 4

Example Problems

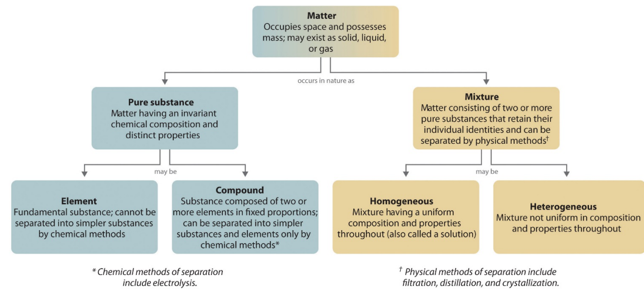
1. How many grams of KCl can be dissolved in 100g of water at 80°C?

2. How many grams of NaCl can be dissolved in 100g of water at 90°C?



3. A chemist adds 120 grams of KCl into a test tube which contains 100 grams of water. The temperature of the water is 80°C. How much of the solute will be left undissolved at the bottom of the test tube?

Types of Mixtures



True Solutions

Colloids Suspensions

1. percent by weight: grams of solute per 100 grams of solution

How many grams of sulfate ion are there in 300.0 grams of a solution that is 22.2% by weigh $Al_2(SO_4)_3$?

2. percent by volume: ml of solute per 100 ml of solution - usually restricted to liquid-liquid solutions

Common rubbing alcohol is 70.0% by volume isopropyl alcohol in water. If a bottle contains 340 mL of the alcohol, how many milliliters of solution are there in the bottle?

3. parts per million (ppm) - grams of solute/million grams of solution

- used for very dilute solutions
- may also use milliliters of solute per million milliliters of soln

If the allowable level of lead in tap water cannot exceed 4.2 ppm, how many atoms of lead could be present in a 25.0-mL sample of tap water?

4. molarity - (M) moles of solute/liter of solution

- used when quantity of solute is important
- neither identity of solvent nor the amount of solvent is important
- used in equilibrium problems, osmotic pressure, acid-base titrations

What is the molarity of solution if 3.00 grams of solid sodium carbonate are added to enough water

to make 225 ml of solution? What are the [CO_3^{2-}] and [Na^+]?

5. molality - (*m*) - moles of solute/kilogram of solvent

- used in colligative properties - FPD / BPE
- how the solute affects the properties of the solvent

How many grams of water are needed if a student wants to make a 2.49-molal solution by using 136 grams of sodium chloride?

6. mole fraction – χ_A - moles of A / total number of moles

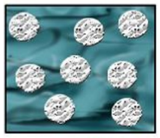
- used in colligative properties - vapor pressure lowering

What is the mole fraction of nitrogen gas in a sample of air, if the percent composition of air is assumed to be 78.1% nitrogen, 20.8% oxygen, 0.50% argon, and 0.50% water vapor?

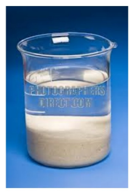
Colloids/Suspensions/Tyndall Effect

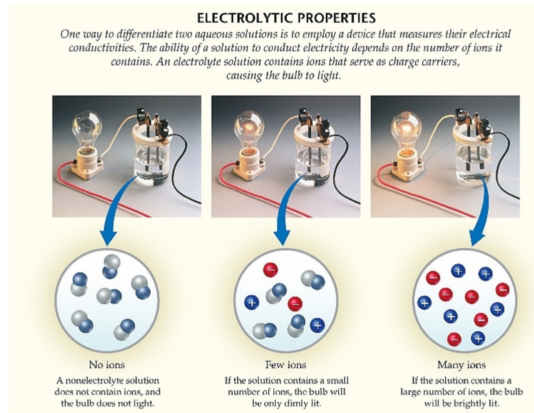
Solution

Colloid



Suspension





Electrolytes are substances that conduct electricty because they produce ions in solution when dissolved.

Classifying Electrolytes (Strong & Weak) and Nonelectrolytes

Strong Electrolytes

Weak Electrolytes

Nonelectrolytes

Electrolytes (Strong vs. Weak) & Nonelectrolytes The Van't Hoff Factor

The van 't Hoff factor (i) is the ratio between the actual concentration of particles produced when the substance is dissolved, and the concentration of a substance as calculated from its mass.

Nonelectrolytes: i = 1 (no ions in solution)

Strong Electrolytes: i = number of ions in 1 formula unit (n)

Weak Electrolytes: must know percent dissociation

$$i = 1 + \alpha(n - 1) \qquad \alpha = \frac{1 - i}{1 - n}$$

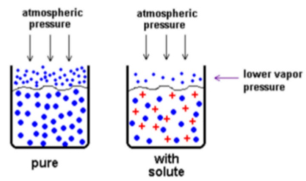
Colligative Properties

Definition: properties of solutions that depend upon the ratio of the number of particles to the number of solvent molecules in solution.

These depend on the number of particles NOT the identity of the particles

Four types of colligative properties:

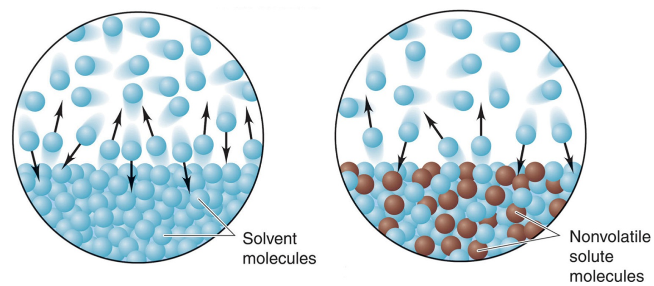
1. vapor pressure lowering
2. boiling point elevation
3. freezing point depression
4. osmotic pressure



How is vapor pressure lowered?

Page 17

Vapor Pressure Lowering: A Visual/Mathematical Explanation



Raoult's Law: $P_{soln} = \chi_{solv}P_{solv}$

Page 18

Boiling Point Elevation and Freezing Point Depression

Both properties relate to the effect that the solute has on the properties of the solvent

Remember: Colligative properties are independent of the identity of the substance

Conceptual: What do these properties mean?

Page 19

BPE and FPD Equations

$\Delta T_f = i \cdot m \cdot k_f$ **freezing point depression**

$\Delta T_b = i \cdot m \cdot k_b$ **boiling point elevation**

Can be used to determine molecular weights (most of the time for macromolecules):

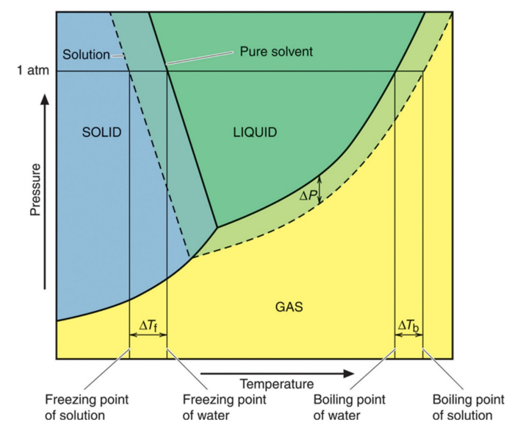
Page 20

Molal Boiling Point Elevation and Freezing Point Depression Constants of Several Solvents

Solvent	Boiling Point (^{0}C)*	K_b (^{0}C/m)	Melting Point (^{0}C)	K_b (^{0}C/m)
Acetic acid	117.9	3.07	16.6	3.90
Benzene	80.1	2.53	5.5	4.90
Carbon disulfide	46.2	2.34	-111.5	3.83
Carbon tetrachloride	76.5	5.03	-23	30.
Chloroform	61.7	3.63	-63.5	4.70
Diethyl ether	34.5	2.02	-116.2	1.79
Ethanol	78.5	1.22	-117.3	1.99
Water	100.0	0.512	0.0	1.86

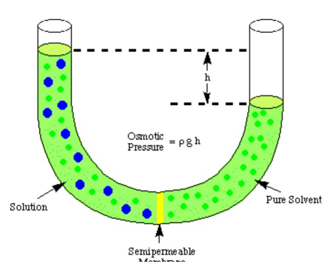
*at 1 atm.

BP Elevation and FP Depression: A graphical approach



Osmotic Pressure

Define: the pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane



$\pi = i$*M*R*T

Practice 1 (FPD and BPE)

A chemist adds 45 grams of sodium chloride to 500 grams of water, what will the melting and boiling points be of the resulting solution?

$\Delta T_b = i m K_b$

$= (2)(1.5\ m)(0.512\ °C/m)$

$= 1.5°C$

$T_{b,new} = 101.5°C$

Practice 2

What is the molecular weight of a nonvolatile, nonelectrolyte, if 2.450 grams of this substance, when dissolved into 32.00 grams of water drops the freezing point to -2.45°C?

$$MW = \frac{g_{solu} \cdot K_f}{kg_{solv} \cdot \Delta T_f} = \frac{2.450\,g \cdot 1.86\,°C/m}{0.03200\,kg \cdot 2.45\,°C}$$

$$MW = 58.13\ g/mol$$

Page 25

Example 3

An 0.844-molal aqueous solution of hydrosulfuric acid (a weak acid) has a freezing point of -2.23°C. (a) What is the van't Hoff factor (*i*) for this solution? (b) What is the percent dissociation?

$$\Delta T_f = i m K_f \Rightarrow i = \frac{\Delta T_f}{m K_f} = \frac{2.23\,°C}{0.844\,m \cdot 1.86\,°C/m}$$

$$i = 1.42$$

$$\alpha = \frac{1-i}{1-n} = \frac{1-1.42}{1-3}$$

$$\alpha = 0.21$$

21%

Page 26

Example 4

A solution is prepared by dissolving 35.0 g of hemoglobin in enough water to make up 1.00 L in volume. The osmotic pressure of the solution is found to be 10.0 mmHg at 25.0 °C. Calculate the molar mass of hemoglobin.

$$\pi = iMRT$$

$$10.00\,mmHg = (1)\left(\frac{35}{x}\right)\left(62.4\,\frac{L \cdot mmHg}{mol \cdot K}\right)(298)$$

$= 65410$

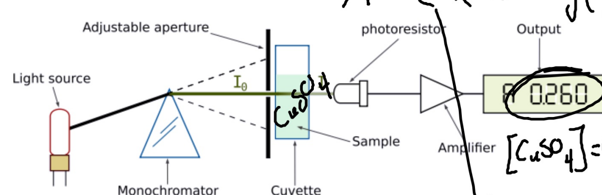
$65041\ g/mol$

Page 27

Spectrophotometer

$$A = \varepsilon l c = \log\left(\frac{1}{T}\right)$$

$cm^{-1}M^{-1}$



$[CuSO_4] = 0.15M$

$\varepsilon = 0.862$ (Molar absorptivity)

$$C = \frac{A}{l\varepsilon} = \frac{0.260}{2.00\,cm \cdot 0.862\,M^{-1}cm^{-1}}$$

Page 28

Page 29