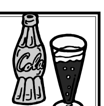
Chemistry 112

The Name Game

1. What is your name?
2. Where are you from?
3. What is your major?
4. What are your future plans?
5. What is your favorite movie?
6. What is the most exciting thing you have ever done?
7. What is something about you that people usually are surprised to learn?

A ***solution*** is a homogenous mixture of 2 or more substances



The ***solute*** is(are) the substance(s) present in the smaller amount(s)

The ***solvent*** is the substance present in the larger amount

Types of Solutions

Component 1	Component 2	State of Resulting Solution	Examples
Gas	Gas	Gas	Air
Gas	Liquid	Liquid	Soda water (CO_2 in water)
Gas	Solid	Solid	H_2 gas in palladium
Liquid	Liquid	Liquid	Ethanol in water
Solid	Liquid	Liquid	NaCl in water
Solid	Solid	Solid	Brass (Cu/Zn), solder (Sn/Pb)

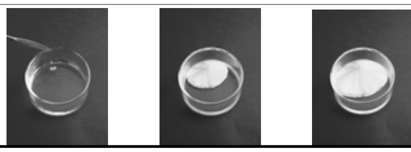
12.1

A ***saturated solution*** contains the maximum amount of a solute that will dissolve in a given solvent at a specific temperature.

An ***unsaturated solution*** contains less solute than the solvent has the capacity to dissolve at a specific temperature.

A ***supersaturated solution*** contains more solute than is present in a saturated solution at a specific temperature.

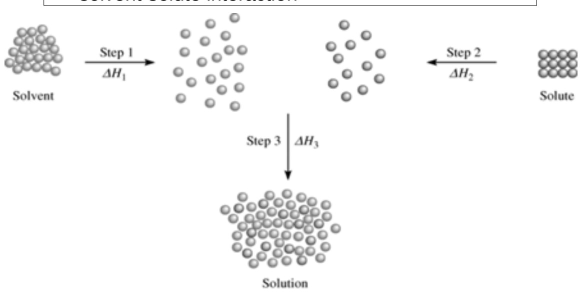
Sodium acetate crystals rapidly form when a seed crystal is added to a supersaturated solution of sodium acetate.



12.1

Three types of interactions in the solution process:

- solvent-solvent interaction
- solute-solute interaction
- solvent-solute interaction

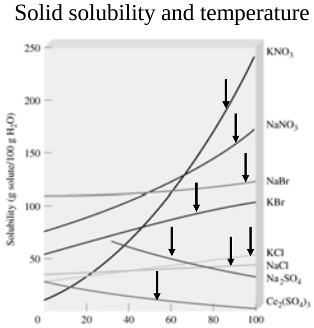


$$\Delta H_{soln} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

12.2

Temperature and Solubility

Solid solubility and temperature

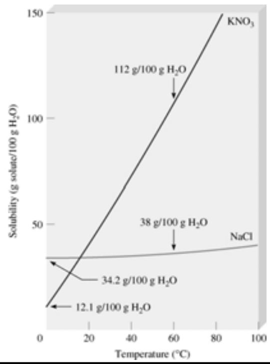


solubility increases with increasing temperature

solubility decreases with increasing temperature

12.4

Fractional crystallization is the separation of a mixture of substances into pure components on the basis of their differing solubilities.



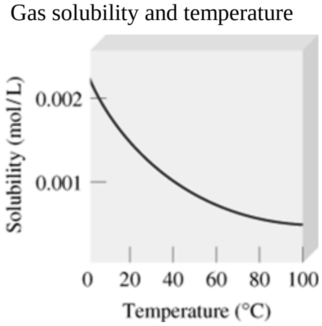
Suppose you have 90 g KNO_3 contaminated with 10 g NaCl.

Fractional crystallization:

1. Dissolve sample in 100 mL of water at 60^0C
2. Cool solution to 0^0C
3. All NaCl will stay in solution (s = 34.2g/100g)
4. 78 g of PURE KNO_3 will precipitate (s = 12 g/100g). 90 g – 12 g = 78 g

Temperature and Solubility

Gas solubility and temperature



solubility usually decreases with increasing temperature

Pressure and Solubility of Gases

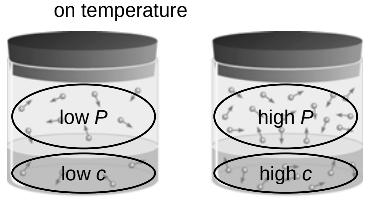
The solubility of a gas in a liquid is proportional to the pressure of the gas over the solution (***Henry's law***).

$c = kP$

c is the concentration (*M*) of the dissolved gas

P is the pressure of the gas over the solution

k is a constant (mol/L•atm) that depends only on temperature



12.5

Chemistry In Action: The Killer Lake

8/21/86
CO_2 Cloud Released
1700 Casualties

Lake Nyos, West Africa

Trigger?

- **earthquake**
- **landslide**
- **strong Winds**

"**like dissolves like**"

Two substances with similar ***intermolecular*** forces are likely to be soluble in each other.

- non-polar molecules are soluble in non-polar solvents

  CCl_4 in C_6H_6
- polar molecules are soluble in polar solvents

  C_2H_5OH in H_2O
- ionic compounds are more soluble in polar solvents

  NaCl in H_2O or NH_3 (*l*)

12.2

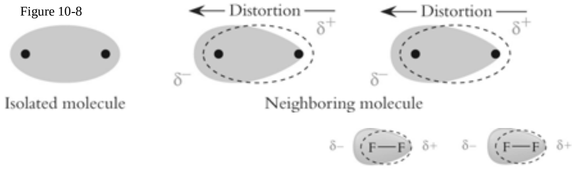
Intermolecular Forces

1. **London Forces (Dispersion Forces)**
2. **Dipole-Dipole Interactions**
3. **Ion-Dipole Interactions (Salt dissolving in solution)**
4. **Hydrogen Bonding**

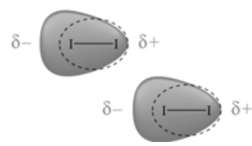
London Forces

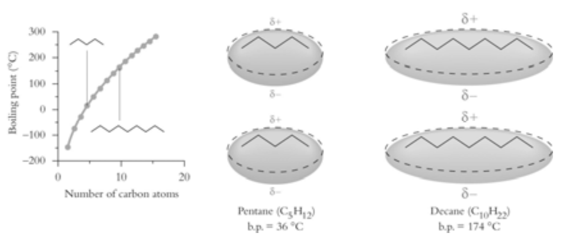
Occur between every compound and arise from the net attractive forces amount molecules which is produced from induced charge imbalances

Figure 10-8



The magnitude of the London Forces is dependent upon how easily it is to distort the electron cloud. The larger the molecule the greater it's London Forces are.



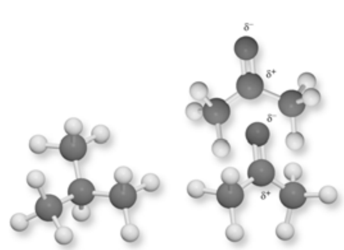


The boiling point of alkanes increase with the length of the carbon chain. Long-chain alkanes have larger dispersion forces because of the increased polarizability of their larger electron cloud.

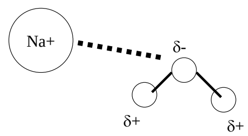
Dipolar Forces

Dipole Forces occur between molecules containing a dipole moment. The positive end of the dipole moment on one mole is attracted to the negative end of the dipole moment on a nearby molecule.

Consider 2-methyl propane (left) and acetone (right) Both compounds are about equal in size and shape thereby having similar London forces, but acetone contains an oxygen (red) and causes the molecule to have a dipole moment allowing it to have dipole forces and thus a higher boiling point



Ion-Dipole Forces



Hydrogen Bonding

Involves lone pairs of electrons of electrons on an electronegative atom one molecule and a polar bond to a hydrogen on a neighboring molecule

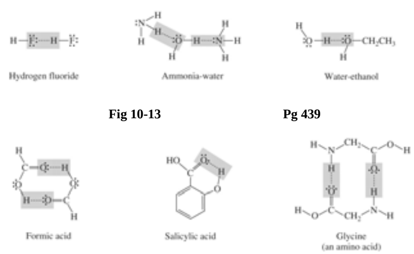
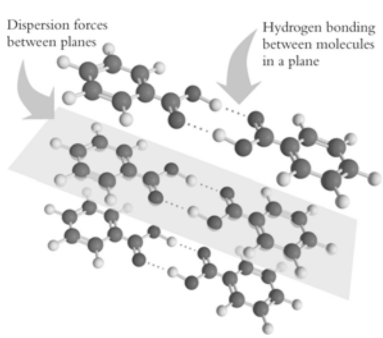


Fig 10-13 **Pg 439**

Examples of hydrogen bonding.



Crystals of benzoic acid contain pairs of molecules held together head to head by hydrogen bonds. These pairs then stack in planes which are held together by dispersion forces.

Courtesy Stephen Frisch

**Fig 10-16B
Pg 444**

Crystals of benzoic acid contain pairs of molecules held together head to head by hydrogen bonds. These pairs then stack in planes which are held together by dispersion forces.

Concentration Units

Molarity (M) = $\frac{\text{moles of solute}}{\text{liters of solution}}$

Molality (m) = $\frac{\text{moles of solute}}{\text{Kg of solvent}}$

Mass Percent (% w/w) = $\left(\frac{\text{mass of solute}}{\text{mass of solution}}\right)$ X 100

Mole Fraction (χ) = $\frac{\text{moles of solute}}{\text{total moles of solution}}$

Molarity Problem

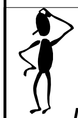
How many grams of KBr are required to make 250 mL Of a 0.40 M solution?

1. **Determine the amount of moles in solution**

$\frac{0.4 \text{ moles KBr}}{1 \text{ L}} \times 0.250 \text{ L} = 0.1 \text{ moles KBr}$

2. **Determine the mass of 0.1 moles of KBr**

$0.1 \text{ moles KBr} \times \frac{119 \text{ grams}}{1 \text{ mole KBr}} = 11.9 \text{ g KBr}$



What is the molality of a 5.86 *M* ethanol (C_2H_5OH) solution whose density is 0.927 g/mL?

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} \qquad M = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Assume 1 L of solution:
5.86 moles ethanol = 270 g ethanol
927 g of solution (1000 mL x 0.927 g/mL)

mass of solvent = mass of solution – mass of solute
= 927 g – 270 g = 657 g = 0.657 kg

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{5.86 \text{ moles } C_2H_5OH}{0.657 \text{ kg solvent}} = 8.92\ m$$

12.3

Test Your Skill

1. **What is weight percentage of a 0.15 m NaI solution?**
2. **What is molality of a 5% solution of C_2H_5OH?**
3. **What is the mole fraction of 0.15 m $C_{12}H_{22}O_{11}$?**

Dilutions

(Stock Conc) (volume) = (Diluted concentration)(volume)

$$M_1 * V_1 = M_2 * V_2$$

This equation is also used at the equivalence point in a titration

Dilution Problem 1

If 32 mL stock solution of 6.5 M H_2SO_4 is diluted to a volume of 500 mL
What would be the resulting concentration?

$$M_1*V_1 = M_2*V_2$$

$$(6.5M) * (32\ mL) = M_2 * (500.0\ mL)$$

$$M_2 = \frac{6.5\ M * 32\ mL}{500\ mL}$$

$$M_2 = 0.42\ M$$

Dilution Problem 2

How much of a 3.0 M solution of HNO_3 and how much water is needed to
Make 250 mL of a 0.5 M HNO_3 solution?

$$M_1*V_1 = M_2*V_2$$

$$(3M) * V_1 = (0.5\ M) * (250\ mL)$$

$$V_1 = \frac{0.5\ M * 250\ mL}{3\ M}$$

V1 = 42 mL

42 mL of 3.0 M HNO_3 and 208 mL of water is needed

Colligative Properties

A colligative property is a property that change depending upon
Relative numbers of solute and solvent particles.

There are four that you need to know:

Vapor pressure
Boiling point
Freezing point
Osmotic pressure

Colligative Properties of Nonelectrolyte Solutions

Colligative properties are properties that depend only on the **number** of solute particles in solution and not on the **nature** of the solute particles.

Vapor-Pressure Lowering

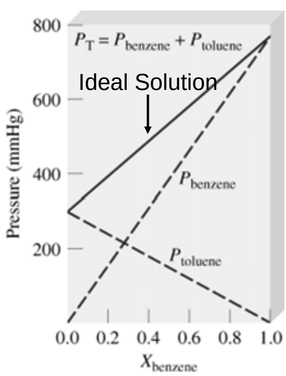
$$P_1 = X_1 P_1^0$$

Raoult's law

P_1^0 = vapor pressure of **pure** solvent

X_1 = mole fraction of the solvent

12.6



$P_A = X_A P_A^0$

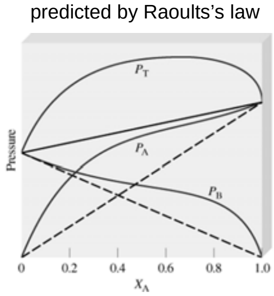
$P_B = X_B P_B^0$

$P_T = P_A + P_B$

$P_T = X_A P_A^0 + X_B P_B^0$

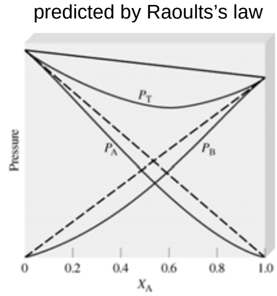
12.6

P_T is greater than predicted by Raoults's law



Force A-B < Force A-A & Force B-B

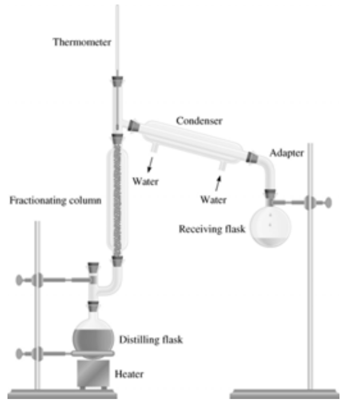
P_T is less than predicted by Raoults's law



Force A-B > Force A-A & Force B-B

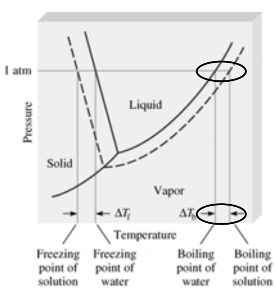
12.6

Fractional Distillation Apparatus



12.6

Boiling-Point Elevation



$\Delta T_b = T_b - T_b^0$

T_b^0 is the boiling point of the pure solvent

T_b is the boiling point of the solution

$T_b > T_b^0 \qquad \Delta T_b > 0$

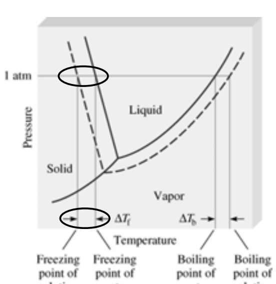
$$\Delta T_b = iK_b\, m$$

m is the molality of the solution

K_b is the molal boiling-point elevation constant (^{0}C/m)

12.6

Freezing-Point Depression



$\Delta T_f = T_f^0 - T_f$

T_f^0 is the freezing point of the pure solvent

T_f is the freezing point of the solution

$T_f^0 > T_f \qquad \Delta T_f > 0$

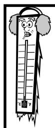
$$\Delta T_f = iK_f\, m$$

m is the molality of the solution

K_f is the molal freezing-point depression constant (^{0}C/m)

i = van't Hoff factor

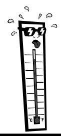
12.6



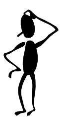
Molal Boiling-Point Elevation and Freezing-Point Depression Constants of Several Common Liquids

Solvent	Normal Freezing Point (°C)*	K_f (°C/*m*)	Normal Boiling Point (°C)*	K_b (°C/*m*)
Water	0	1.86	100	0.52
Benzene	5.5	5.12	80.1	2.53
Ethanol	−117.3	1.99	78.4	1.22
Acetic acid	16.6	3.90	117.9	2.93
Cyclohexane	6.6	20.0	80.7	2.79

*Measured at 1 atm.



12.6



What is the freezing point of a solution containing 478 g of ethylene glycol (antifreeze) in 3202 g of water? The molar mass of ethylene glycol is 62.01 g.

$\Delta T_f = K_f\, mi$ $\quad$ K_f water = 1.86 ^{0}C/m $\quad i = 1$

$$\boldsymbol{m} = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{478 \text{ g} \times \frac{1 \text{ mol}}{62.01 \text{ g}}}{3.202 \text{ kg solvent}} = 2.41\ m$$

$\Delta T_f = K_f\, m$ = 1.86 ^{0}C/m x 2.41 m = 4.48 ^{0}C

$\Delta T_f = T_f^0 - T_f$

$T_f = T_f^0 - \Delta T_f$ = 0.00 ^{0}C – 4.48 ^{0}C = -4.48 ^{0}C

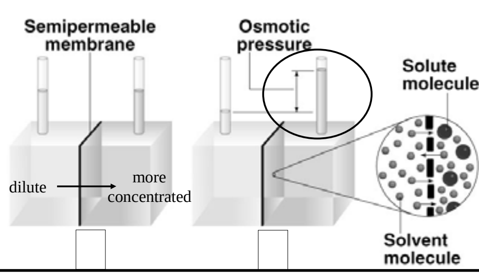
12.6

Osmotic Pressure (π)

Osmosis is the selective passage of solvent molecules through a porous membrane from a dilute solution to a more concentrated one.

A ***semipermeable membrane*** allows the passage of solvent molecules but blocks the passage of solute molecules.

Osmotic pressure (π) is the pressure required to stop osmosis.



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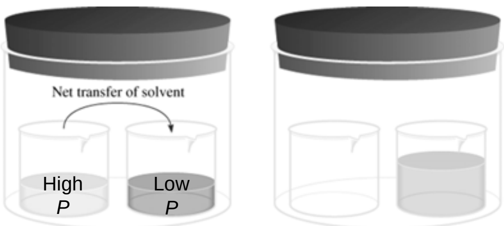
Osmotic Pressure (π)



$$\pi = iMRT$$

M is the molarity of the solution

R is the gas constant

i is the van't Hoff factor

T is the temperature (in K)

12.6

A cell in an:

isotonic solution

hypotonic solution

hypertonic solution

12.6

Colligative Properties of Electrolyte Solutions

0.1 *m* NaCl solution ⟶ 0.1 *m* Na^+ ions & 0.1 *m* Cl^- ions

Colligative properties are properties that depend only on the **number** of solute particles in solution and not on the **nature** of the solute particles.

0.1 *m* NaCl solution ⟶ 0.2 *m* ions in solution

van't Hoff factor (i) = $\dfrac{\text{actual number of particles in soln after dissociation}}{\text{number of formula units initially dissolved in soln}}$

	i should be
nonelectrolytes	1
NaCl	2
$CaCl_2$	3

12.7

A ***colloid*** is a dispersion of particles of one substance throughout a dispersing medium of another substance.

<u>Colloid versus solution</u>

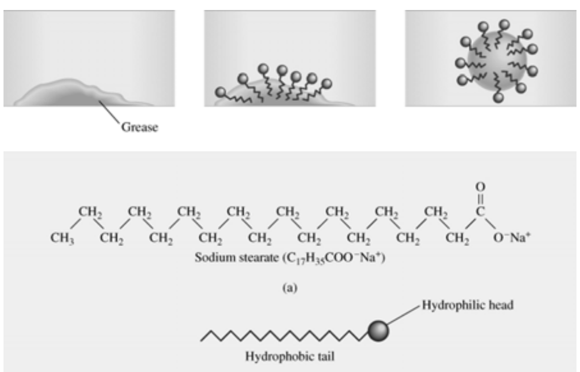
- collodial particles are much larger than solute molecules
- collodial suspension is not as homogeneous as a solution

Types of Colloids

Dispersing Medium	Dispersed Phase	Name	Example
Gas	Liquid	Aerosol	Fog, mist
Gas	Solid	Aerosol	Smoke
Liquid	Gas	Foam	Whipped cream
Liquid	Liquid	Emulsion	Mayonnaise
Liquid	Solid	Sol	Milk of magnesia
Solid	Gas	Foam	Plastic foams
Solid	Liquid	Gel	Jelly, butter
Solid	Solid	Solid sol	Certain alloys (steel), gemstones (glass with dispersed metal)

12.8

The Cleansing Action of Soap



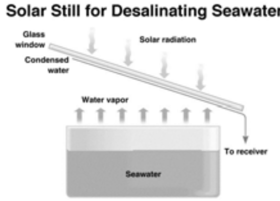
12.8

Chemistry In Action:
Desalination

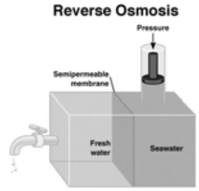
Composition of Seawater

Ions	g/kg of Seawater
Chloride (Cl^-)	19.35
Sodium (Na^+)	10.76
Sulfate (SO_4^{2-})	2.71
Magnesium (Mg^{2+})	1.29
Calcium (Ca^{2+})	0.41
Potassium (K^+)	0.39
Bicarbonate (HCO_3^-)	0.14

Solar Still for Desalinating Seawater



Reverse Osmosis



Which of the following salt solutions will have the highest vapor pressure?

A) 0.1M sodium acetate
B) 0.1M calcium phosphate
C) 0.1M potassium carbonate

A) 0.1 M $NaCH_3COO$