Solutions

- **solution**: a homogeneous mixture

Solution Terminology:
- **solute**: substance that is dissolved
- **solvent**: substance that does the dissolving (often water)
ex. in a solution of salt water, salt is the solute and water is the solvent
- **concentration**: the amount of solute in a given amount if solution
- **molarity** is another word for concentration

Determination of Concentration

- concentration can be calculated according to the following equation:

$$C = \frac{n}{V}$$

C = concentration (M)
n = number of moles (mol)
V = volume of solution (L)

- concentration is expressed in unites of mol/L or Molar (M)

ex. What is the concentration of a 2.0 L solution that contains 0.026 mol of NaCl?

*don't confuse Molar (M) with moles (mol)!

ex. What is the volume of a 0.022 M solution that contains 0.11 mol of HCl?

ex. How many grams of $ZnCl_2$ does 650 mL of a 2.40 M solution contain? How many molecules are present?

Standard Solutions

- standard solution: a solution of known concentration

Preparation of a Standard Solution

ex. Describe how to prepare 100 mL of a 0.10 M solution of $C_{12}H_{22}O_{11}$.

Solution Dilution

- solutions of a certain concentration are often prepared by diluting solutions of a higher concentration
- **dilution**: decreasing the concentration of a solution by adding more solvent (ie. more water)

Dilution Calculations

- the moles of solute before dilution must equal the moles of solute following dilution (this is because *no solute is added; only solvent is added*)

recall, $C = \frac{n}{V}$ therefore, $n = CV$

initial moles of solute = final moles of solute

$n_1 = n_2$

$C_1V_1 = C_2V_2$

where: C_1 = initial concentration (M)
V_1 = initial volume (L)
C_2 = final concentration (M)
V_2 = final volume (L)

ex. 2.0 L of 0.24 M solution of KBr is diluted to a final volume of 4.8 L. Calculate the final concentration. Calculate the mass of KBr present in the solution.

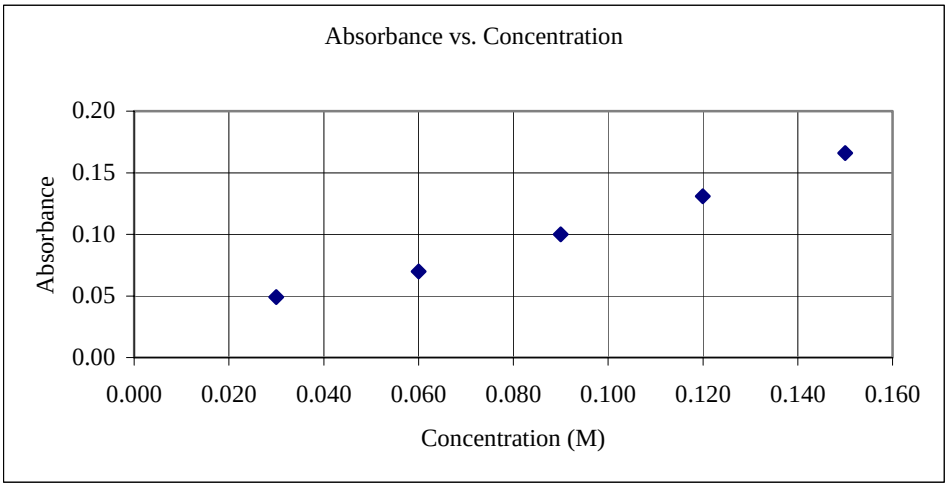
ex. 450 mL of solution contains 100 g of $CaCl_2$. What is the final concentration if 200 mL of water are added to the solution?

Spectrophotometry

- the concentration of solutions can be measured using a technique called spectrophotometry
- to determine the concentration of a solution, light of a given wavelength is sent through the solution (the wavelength used is "opposite" to the colour of the solution)
- as the light is sent through the solution, some of it is absorbed and some of it passes through
- the brightness of the light after it passes through the solution is then compared with the brightness of the light before it passed through the solution (the less light that is absorbed, the brighter the light will be after it passes through the solution)
- the less concentrated a solution is, the less light it will absorb; the more concentrated a solution is, the more light it will absorb
- in an experiment, the absorbance is measured for solutions with known concentrations and this data is plotted to create a calibration curve and a "line of best fit" is drawn
- the absorbance of a solution with unknown concentration is then measured and from the calibration curve, the concentration can be determined

ex. Absorbance data for copper (II) sulphate at 600 nm

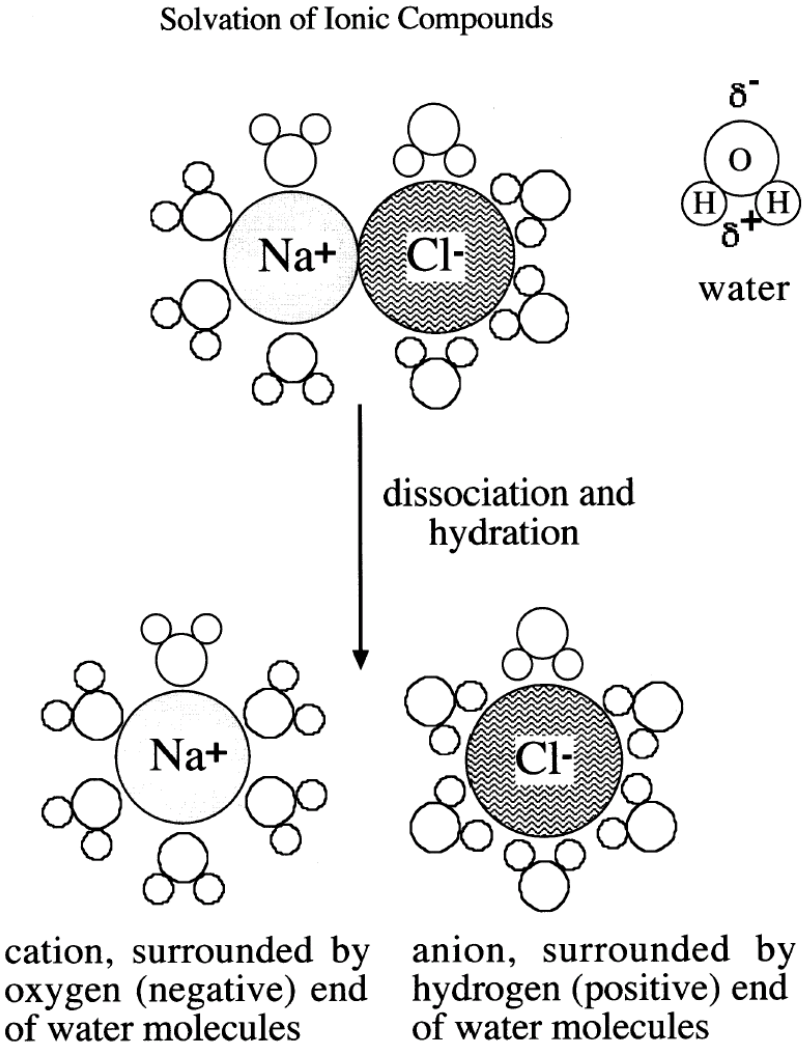
Concentration (M)	**Absorbance**
0.030	0.049
0.060	0.070
0.090	0.100
0.120	0.131
0.150	0.166



ex. If a solution gave an absorbance reading of 0.15, what would the concentration be?

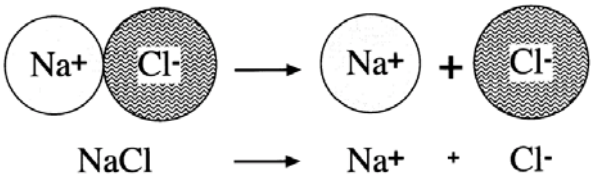
Solvation of Ionic Compounds

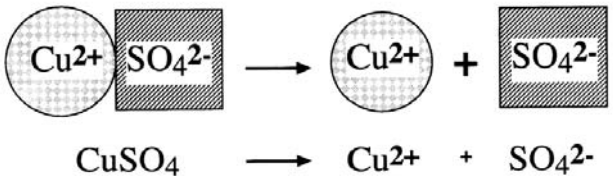
- **solvation**: the interactions between solute and solvent (water)
- ionic compounds dissolve in water
- as an ionic compound dissolves in water, the positive cation of the ionic compound interacts with the oxygen end of the water molecule (negative end) and the negative anion of the ionic compound interacts with the hydrogen end of the water molecule (positive end)
- these interactions result in **dissociation**: the separation of an ionic compound into its constituent ions
- the ions undergo **hydration**: the become surrounded by water molecules

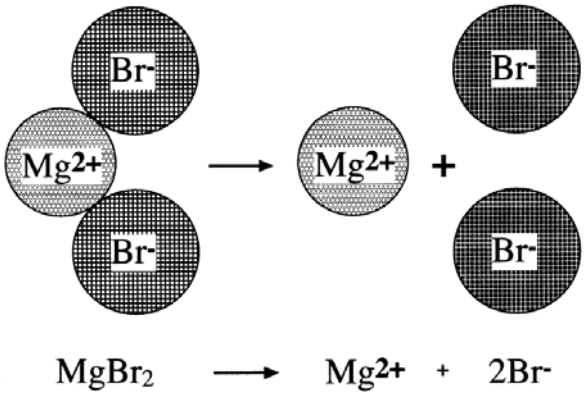


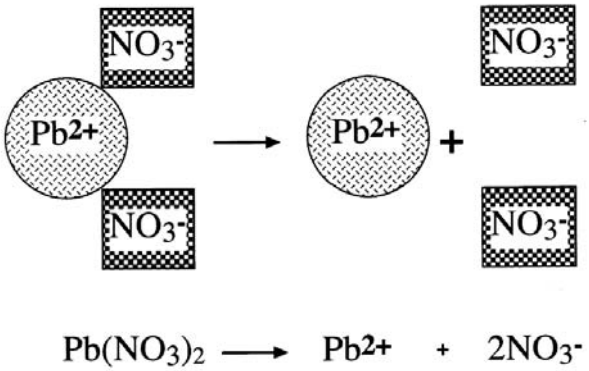
Dissociation Equations

Dissociation of Ionic Compounds









ex. write the dissociation equation for $BaCl_2$

ex. write the dissociation equation for scandium chlorate

Concentration of Ions in Solution

ex. Calculate the concentration of each ion in a 0.26 M solution of $Al(NO_3)_3$

ex. Calculate the concentration of each ion in a 0.0540 M solution of iron (III) sulphate

Concentration of Ions when Two Solutions are Mixed

ex. Calculate the concentration of each ion resulting from mixing 40 mL of 0.012 M potassium iodate with 55 mL of 0.018 M magnesium chloride, given that no reaction occurs

ex. Calculate the concentration of each ion resulting from mixing 2.5 L of 0.48 M ammonium chloride with 1.4 L of 0.52 M ammonium sulphate, given that no reaction occurs

Solubility

- **solubility**: the amount of solute that will dissolve in a solvent at a given temperature to form a saturated solution
- **saturated**: solution: a solution in which no more solute can be dissolved
- **unsaturated**: solution: a solution in which more solute can be dissolved
- the solubility for different solutes in water varies
- for example the solubility of NaCl in water (at 25 ºC) is 6.0 M whereas the solubility of AgCl in water (at 25 ºC) is 0.000010 M
- compounds that have high solubilites are said to be **soluble** in water; compounds that have low solubilities are said to be **insoluble** in water
- **soluble**: more that 0.10 M (more than 0.10 moles of a solute dissolves in 1 L of water)
- **insoluble**: less that 0.10 M (less than 0.10 moles of a solute dissolves in 1 L of water)
- when compounds are insoluble in solution, they form a precipitate
- **precipitate**: a solid compound that has low solubility in a solvent and therefore does not dissolve in that solvent

- solubility data for various combination of anions and cations is available on solubility tables
- note: in general, the solubility of a compound increases with increased temperature

ex. Classify the following compounds as soluble (S) or insoluble (IN) in water

(a) PbI_2 (b) MgS (c) $Al(OH)_3$ (d) Li_2CO_3 (e) $CuCl_2$

Solubility Table
Soluble >0.1 M at 25 °C
Insoluble <0.1 M at 25 °C

Anion	Cation	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^- or Chlorate, ClO_3^- or Hypochlorite, ClO^- or Perchlorate, ClO_4^- or Acetate, $C_2H_3O_2^-$	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Insoluble
Fluoride, F^-	All others	Soluble
	Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Insoluble
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Insoluble
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Ba^{2+}, Sr^{2+}	Soluble
	All others	Insoluble
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Insoluble
Oxalate, $C_2O_4^{2-}$ or Phosphate or PO_4^{3-} Carbonate, CO_3^{2-}, or Sulphite SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Insoluble

Solubility and Reactions

- solutions of ionic compounds can react to form a precipitate
- this reaction can be written in three forms
(1) the **formula equation**
(2) the **complete ionic equation**
(3) the **net ionic equation**

ex. write the formula equation, complete ionic equation, and net ionic equation for the reaction between $Pb(NO_3)_2$ and NaI

- the ions which do not participate in the reaction are called **spectator ions**

ex. write the formula equation, complete ionic equation, and net ionic equation for the reaction between $MgSO_4$ and Na_3PO_4

Selective Precipitation

ex. A solution contains Ca^{2+} and Cu^{+} ions. Describe a procedure to separate each of the ions from solution.

ex. A solution contains Br^{-}, F^{-}, and S^{2-} ions. Describe a procedure to separate each of the ions from solution.

Solution Stoichiometry

ex. 100 mL of 0.300 M barium chloride reacts with 200 mL of sodium sulphate.
(a) What concentration of sodium sulphate solution is required?
(b) What would be the mass of each of the products?

ex. 150 mL of 0.150 M lead (II) nitrate reacts with 205 mL of 0.250 M potassium iodide solution.
(a) Which reactant is limiting and which is excess?
(b) What would be the mass of each of the products?
(c) Write the net ionic equation for the formation of the precipitate.