Chapter 7: Chemical Reactions

A chemical reaction: a process in which at least one new substance is formed as the result of a chemical change.

$$A + B \rightarrow C + D$$

Reactants Products

Evidence that a chemical reaction has occurred:

- Color change
- Formation of a solid (in a previously clear solution)
- Formation of a gas
- Emission of light
- Emission or absorption of heat

A chemical equation: a written statement the uses symbols and formulas instead of words to describe the changes that occur in a chemical reaction

Ex.

$$MgO + C \rightarrow CO + Mg$$

Special symbols are often used in chemical equations to express the state of reactants and products

(s) = solid
(l) = liquid
(g) = gas
(aq) = aqueous

substance dissolved in H_2O

Ex.

$$Mg(OH)_{2(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\ H_2O_{(l)}$$

Balanced Chemical Equations

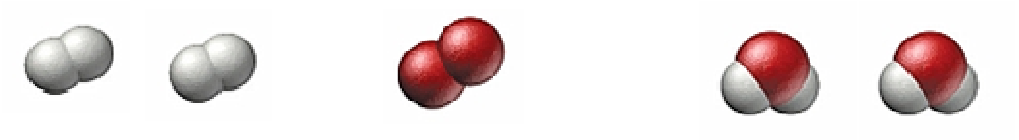
For a chemical equation to be valid:

1) It must be consistent with experimental facts. **<u>Accurate formulas MUST be used in the equation.</u>**
2) It must be consistent with the law of the conservation of mass. **The equation MUST BE BALANCED.**

Recall: **The Law of the Conservation of Mass** - mass is neither created nor destroyed in an ordinary chemical reaction.

Total mass before the reaction	=	Total mass after the reaction

$$2\ H_2 \quad + \quad O_2 \quad \rightarrow \quad 2\ H_2O$$



A balanced chemical equation has the **<u>same number of atoms of EACH ELEMENT</u>** involved in the reaction on <u>each side of the equation.</u>

Equation above can mean: **2 moles** of hydrogen react with **1 mole** of oxygen to produce **2 moles** of water

Writing and Balancing Chemical Equations

1st step: Write the correct formulas for reactants and products (use your knowledge from Ch 5 & 6). Use subscripts to indicate the state (s, l, g, aq) if necessary.

Ex. Solid iron(III) oxide reacts with hydrogen gas to produce iron metal and liquid water

2nd step: Balance the chemical equation by changing the coefficients in the equation.

- Coefficients are the **numbers to the left of the formula** that denote the amount of the substance

$$\_\_\_Fe_2O_{3(s)} + \_\_\_ H_{2(g)} \rightarrow \_\_\_ Fe_{(s)} + \_\_\_H_2O_{(l)}$$

Balance the following chemical equation:

$$\_\_\_\_Fe + \_\_\_\_S \rightarrow \_\_\_\_Fe_2S_3$$

Guidelines for Balancing Equations

1. The **coefficients** in a balanced equation are always the **<u>smallest set of whole numbers</u>** (fractions shouldn't be present in the final balanced equation).
2. It is helpful to consider polyatomic entities as units (if they stay together during the reaction).

Ex. ___$BaCl_2$ + ___$(NH_4)_2SO_4$ → ___$BaSO_4$ + ____NH_4Cl

3. Subscripts must <u>NEVER</u> be altered to balance a chemical equation.

   ex.

   K_2SO_4 + $HgCl_2$ → KCl + $HgSO_4$

   to balance this equation above you **<u>CAN NOT</u>** write:

   K_2SO_4 + $HgCl_2$ → K_2Cl_2 + $HgSO_4$

4. Balance elemental substances **<u>LAST</u>**.

___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O

5. If an element appears in one compound on each side, **<u>balance that element first</u>** (finding the <u>L</u>east <u>C</u>ommon <u>M</u>ultiple on both sides) Note: the LCM of 3 & 4 is 12

__ H_3PO_3 → __ H_3PO_4 + __ PH_3

Balancing Equations

Balance the following chemical equations:

a) ___Cu_2O + _____Cu_2S → **____Cu + ____SO_2**

b) ____Na_2SO_4 + ___$Pb(NO_3)_2$ → ___$NaNO_3$ + ____$PbSO_4$

c) _____$KClO_3$ → ____KCl + ____O_2

d) ____C_4H_{10} + ____O_2 → ____CO_2 + ____H_2O

e) ____$N_2H_{4(l)}$ + ___$H_2O_{2(l)}$ → ___$N_{2(g)}$ + ___$H_2O_{(g)}$

Write and balance the chemical equation for the following description of a reaction:

Liquid ammonia (NH_3) is reacted with oxygen gas to produce nitrogen monoxide gas and liquid water.

Aqueous Solutions

Many times, the chemicals we react are dissolved in water

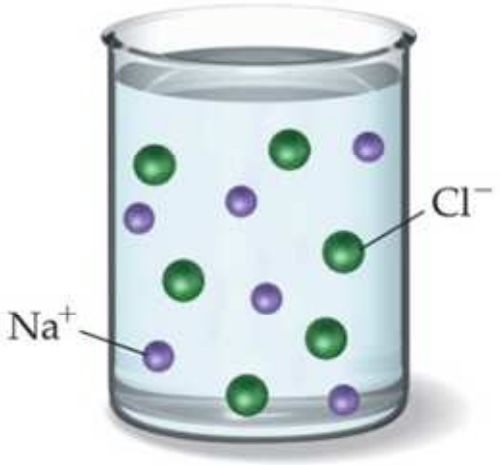
- A chemical dissolved in water is called an **aqueous solution**

Dissolving chemicals in water helps them to react faster

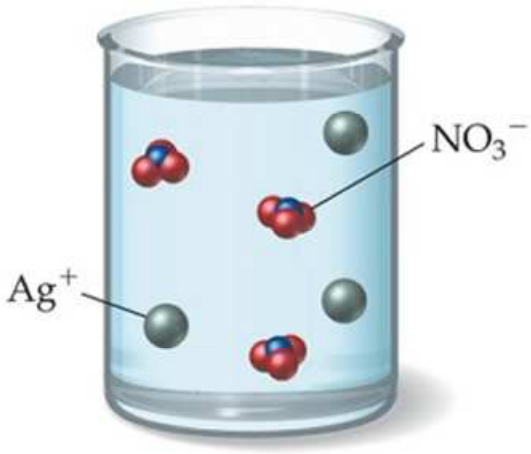
- The water separates the chemicals into individual molecules or ions
- The separate, free-floating particles come in contact more frequently so the reaction speeds up

When **ionic compounds** dissolve in water, the anions and cations separate from each other.
(The ionic compound **dissociates**)

- Note: not all ionic compounds are soluble in water



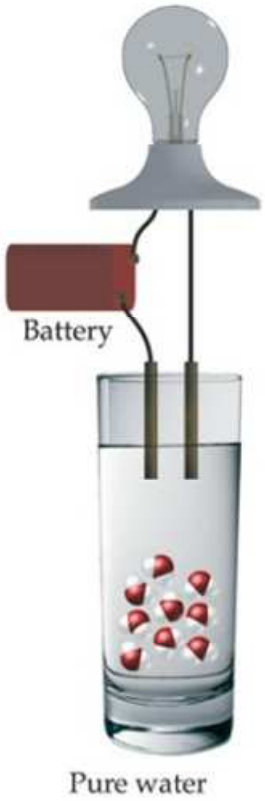
When compounds containing **polyatomic ions dissociate**, the polyatomic group stays together as one ion.



Electrolytes

Electrolytes are substances whose water solution is a **conductor of electricity**

ALL electrolytes have ions dissolved in water.

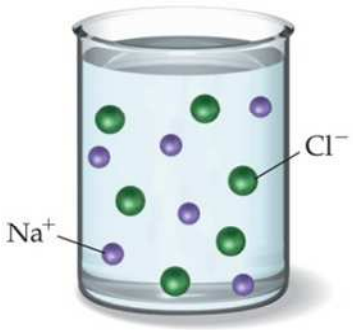


- S**trong** electrolyte - **ALL** the formula units are separated into ions.
- W**eak** electrolyte - a **small percentage** of the formula units are separated into ions.
- N**on**electrolytes - **NONE** of the formula units (or molecules) are separated into ions.

Solubility of Ionic Compounds

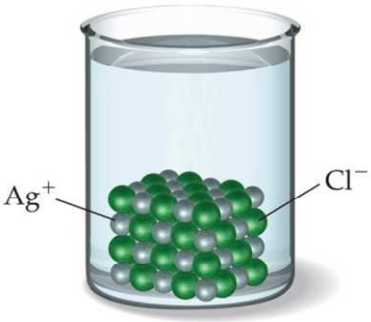
An ionic compound is **soluble** in a liquid if it dissolves in that liquid.

- NaCl is soluble in water



An ionic compound is **insoluble** if a significant amount does not dissolve in the liquid.

- AgCl is insoluble in water.



Solubility of Ionic Compounds

We can't easily predict which ionic compounds will be soluble and insoluble in H_2O, so we need to use the **Solubility Rules** (Table 7.2, pg 210 in your text)

Solubility Rules for Ionic Compounds

The following table will be given on the exam **as shown below.**

Compounds Containing the Following Ions Are Mostly Soluble	**Exceptions**
Li^+, Na^+, K^+, NH_4^+	None
nitrate, acetate	None
chloride, bromide, iodide	When any of these ions pairs with Ag^+, Hg_2^{2+}, or Pb^{2+}, the compound is insoluble
sulfate	When sulfate pairs with Sr^{2+}, Ba^{2+}, Pb^{2+}, or Ca^{2+} the compound is insoluble
Compounds Containing the Following Ions Are Mostly Insoluble	**Exceptions**
hydroxide, sulfide	When either of these ions pairs with Li^+, Na^+, K^+, or NH_4^+, the compound is soluble
	When sulfide pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the compound is soluble
	When hydroxide pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the compound is slightly soluble (for many purposes, these may be considered insoluble)
carbonate, phosphate	When either of these ions pairs with Li^+, Na^+, K^+, or NH_4^+, the compound is soluble

Predict whether the following compounds are soluble or insoluble in water:

Na_3PO_4 $Ca_3(PO_4)_2$

CaI PbI_2

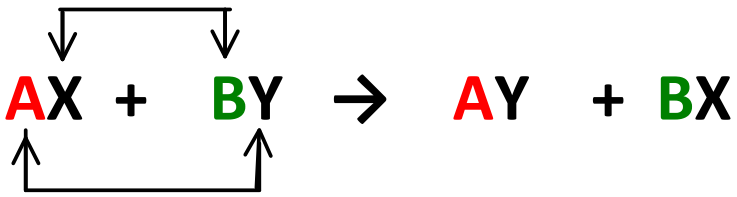
$Fe(OH)_3$ $Ca(OH)_2$

K_2CO_3 $CuCO_3$

Exchange Reactions

- also called **Double Replacement** Reactions

AX & BY are ionic compounds dissolved in water to produce aqueous solutions



A and B exchange partners

The driving force for exchange reactions is the formation of:

a) precipitate, or
b) water, or
c) a gas

Note: we will skip the "Gas Evolution Reactions" (Section 7.8 p 218)

Precipitation Reactions (an exchange reaction)

When two aqueous solutions of ionic compounds are mixed together, sometimes a precipitate is formed if one of the products is an insoluble salt.

$$Ba(NO_3)_{2(aq)} + Li_2CO_{3(aq)} \rightarrow BaCO_{3(s)} + 2\,LiNO_{3(aq)}$$

A precipitate (insoluble)

How do we know which products are soluble (aq subscript) and which are insoluble and form a ppt?

Precipitation Reactions

Use the Solubility Rules to determine which exchange product (IF ANY) is the precipitate.

Ex. Write the balanced chemical equation for the reaction of aqueous solutions of nickel(II) chloride and silver nitrate that form a precipitate

1st: Write the formulas of the reactants (with subscripts):

$NiCl_{2(aq)} + AgNO_{3(aq)} \rightarrow$

2nd: Write ion pairs for the reactants

Ni^{2+} and Cl^- Ag^+ and NO_3^-

3rd: Swap ions, making new +/- pairs, writing cation FIRST
(make formulas for possible new products from new ion pairs)

$Ni(NO_3)_2$ $AgCl$

4th: Write the chemical equation with new possible products and BALANCE THE EQUATION IF NECESSARY

$NiCl_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow Ni(NO_3)_2 + 2\ AgCl$

5th: Determine phase labels of products: (s) = ppt; (aq) = soluble

$NiCl_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow Ni(NO_3)_{2(aq)} + 2\ AgCl_{(s)}$

(Note: Order of 4th and 5th step can be swapped)

Precipitation Reactions

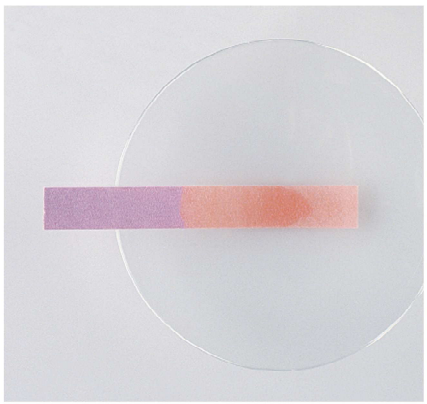
Write the balanced chemical equation for the reaction of lead(II) nitrate and lithium bromide solutions.

Write the balanced chemical equation for the reaction of sodium sulfate and ammonium phosphate solutions.

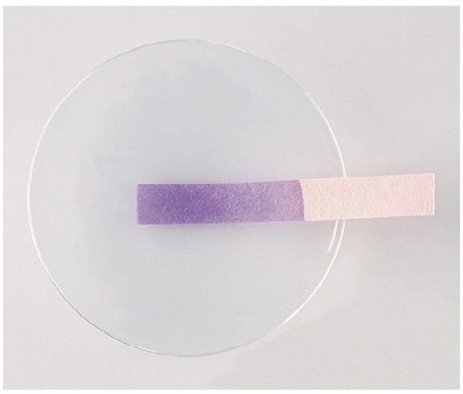
IMPORTANT: We will skip Section 7.7 - Writing Complete Ionic and Net Ionic Equations

Acid-Base Reactions

- Acids taste sour and bases taste bitter
- Simple way to test whether something is acidic or basic - litmus paper



Blue litmus paper turn red if acidic



Red litmus paper turn blue if basic

Many bases have the hydroxide ion as the anion

- Common Bases: NaOH, LiOH, KOH, $Ca(OH)_2$, $Ba(OH)_2$

When an acid and a base react to form WATER and a SALT it is called a **NEUTRALIZATION** reaction.

Ex.

$$HCl_{(aq)} + KOH_{(aq)} \rightarrow H_2O_{(l)} + KCl_{(aq)}$$

Acid -Base Reactions are also EXCHANGE REACTIONS

Neutralization Reactions

Write the balanced chemical equation for the reaction of sulfuric acid and aqueous calcium hydroxide.

Note: Procedure for writing balanced acid-base reactions similar to precipitation reactions. However, the formation of H_2O is driving force rather than formation of a precipitate.

Topics in Ch 7 we will not cover and WILL NOT be on the Exam:

Writing Complete and Net Ionic Reactions - All of Section 7.7 p 215-216

Gas Evolution Reactions - in Section 7.8 p 218

Oxidation-Reduction Reactions - in Section 7.9 p 220

Classifying Chemical Reactions - All of Section 7.10

Combustion Reactions

- In a combustion reaction a compound reacts with O_2 to form oxygen containing product(s).
- Combustion of hydrocarbons (contain C&H) and C, H, O containing compounds are an important type of combustion reaction. Very exothermic reactions - flame produced!

CH or CHO + O_2 → CO_2 + H_2O

containing compound — carbon dioxide — water

The products of a complete combustion reaction of **ANY** CH or CHO containing compound with **O_2** will be **CO_2** and **H_2O.**

Write a balanced chemical equation for the complete combustion of propane, C_3H_8.