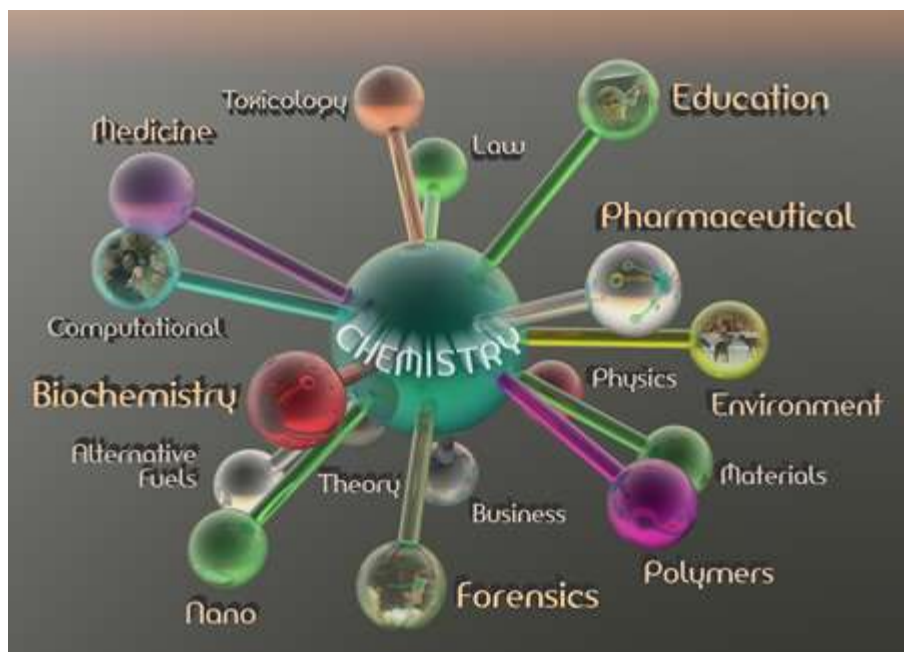


Chapter 11: Chemical Reactions

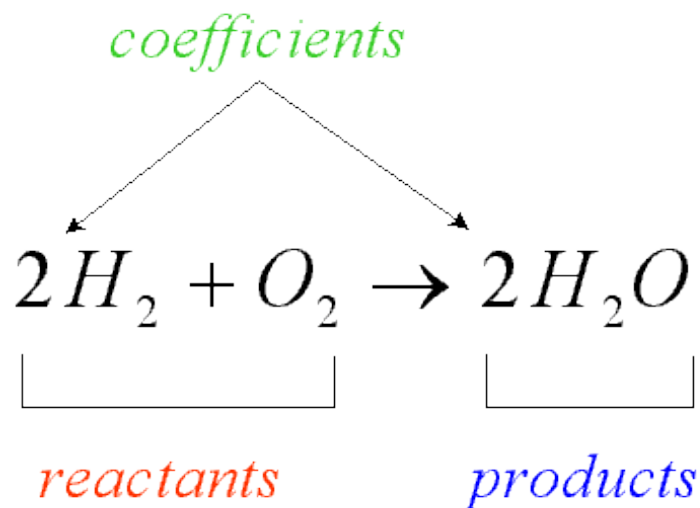
Jennie L. Borders



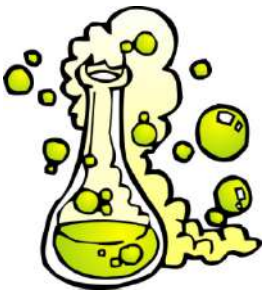
Section 11.1 – Describing Chemical Reactions

- In a chemical reaction, the reactants are written on the left and the products on the right.
- The arrow that separates them is called yield.

Reactants → Products



Symbols in Equations

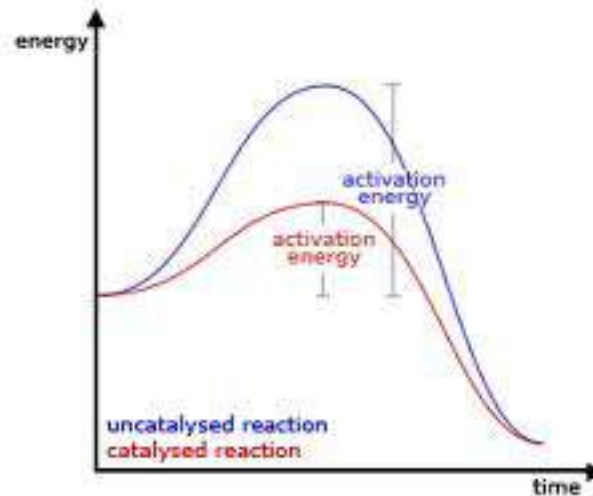
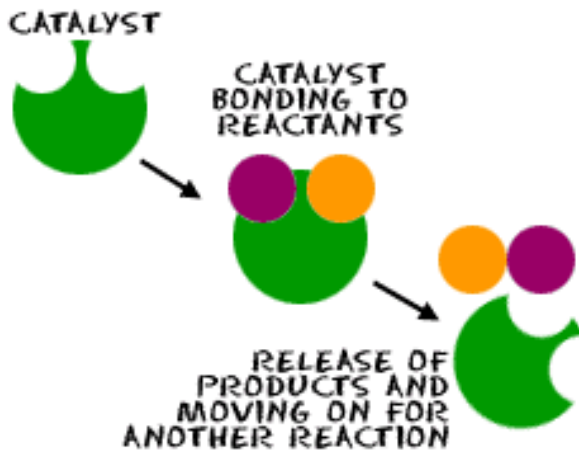


Symbol	Meaning
\rightarrow	yields
\rightleftharpoons	reversible reaction
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous
$\xrightarrow{\text{Pt}}$	catalyst
$\xrightarrow{\Delta}$	heat



Catalyst

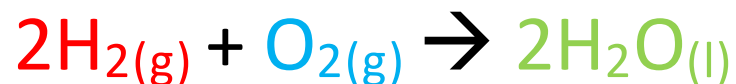
- A catalyst is a substance that speeds up a reaction but is not used up in the reaction.
- A catalyst is neither a reactant nor a product, so its formula is written above the arrow in a chemical equation.



Word Equations

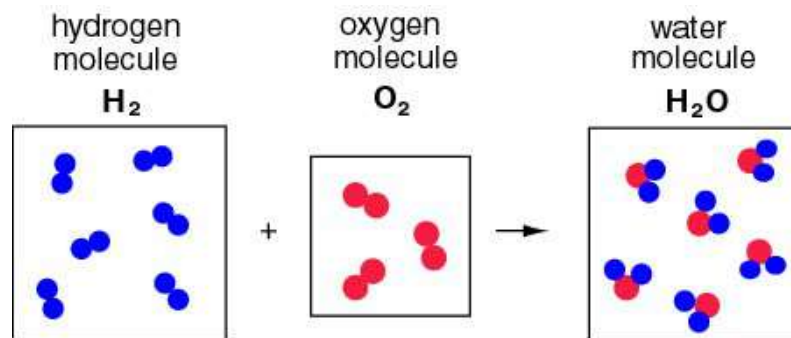
- To write a word equation, write the names of the reactants and products in a sentence form.

Ex: chemical equation



Ex: word equation

Hydrogen gas and oxygen gas react to form liquid water.



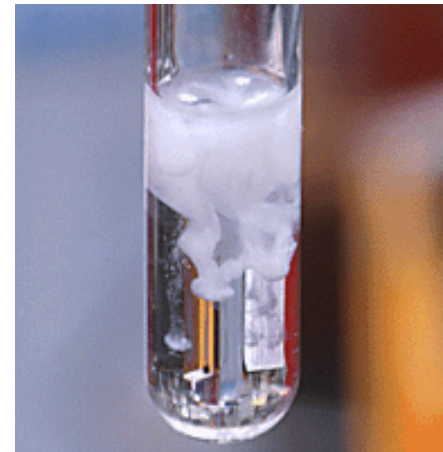
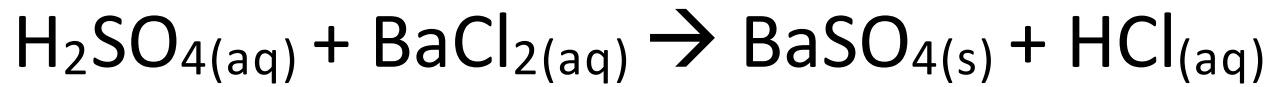
Sample Problem #1

- Write a sentence that describes this chemical reaction:



Practice Problem #1

- Write a sentence that describes this reaction:



Sample Problem #2



- Write the chemical equation for the following reaction:

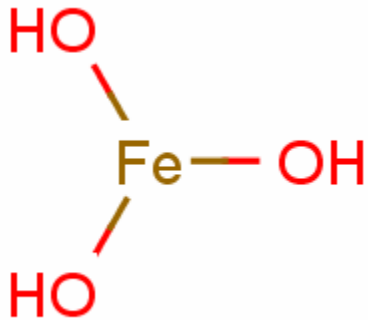
Hydrochloric acid and solid sodium hydrogen carbonate react to produce aqueous sodium chloride, water, and carbon dioxide.

Hint: Acids will always be aqueous unless otherwise stated.

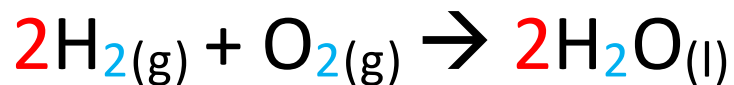
Practice Problem #2

- Write the chemical equation for the following reaction:

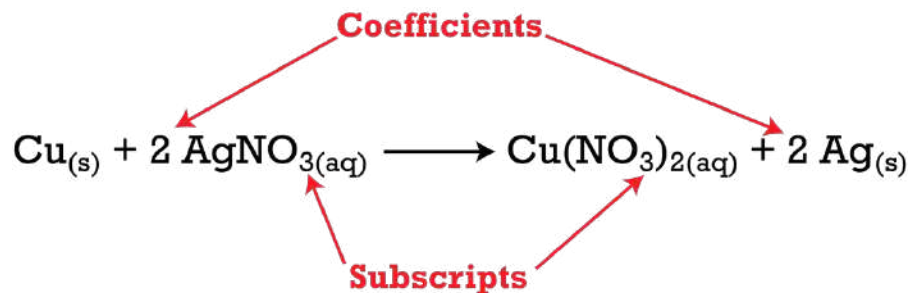
Solid iron(III)hydroxide is heated to form solid iron(III)oxide and water



Balancing Chemical Equations



- **Coefficients** are the numbers in front of a chemical formula.
- **Subscripts** are numbers that show the number of atoms in a compound.
- When balancing reactions, you can only change the coefficients, **not** the subscripts.
- A skeleton equation is an equation that has no coefficients.



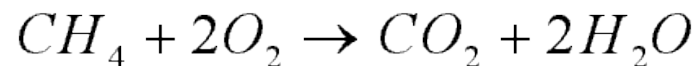
Balancing Chemical Equations

- To balance a chemical equation, you add coefficients to the substances so that the reactant and product side of the equation contain equal numbers and types of atoms.
- Coefficients are added so that the equation follows the law of conservation of mass.



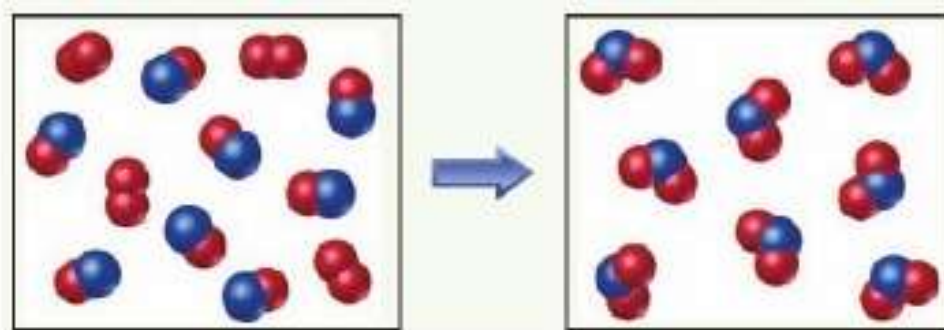
Rules for Balancing Equations

- Balance hydrogen and oxygen last.
- Count a polyatomic ion as a single unit if it appears unchanged on both sides of the equation.
- If you end up with an odd number, you can double all of the coefficients.
- Make sure to reduce the coefficients to the lowest whole-number ratio.
- A coefficient of one is understood and does not need to be written.



Sample Exercise

1. The following diagram represents a chemical reaction in which the red spheres are oxygen atoms and the blue spheres are nitrogen atoms.



- a. Write the chemical formulas for the reactants and products.

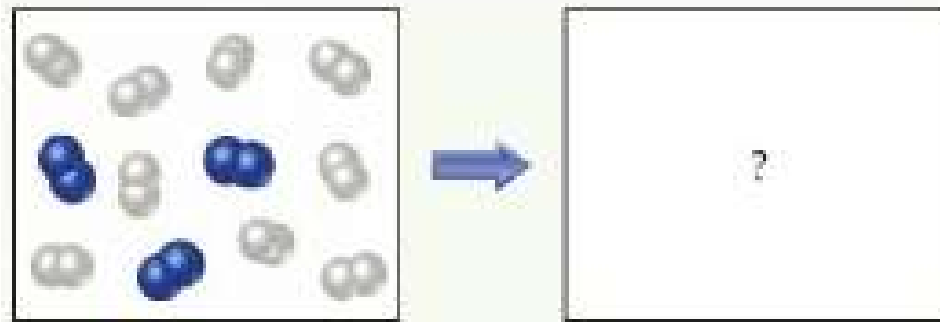
Sample Exercise

b. Write the balanced equation for the reaction.

c. Is the diagram consistent with the law of conservation of mass?

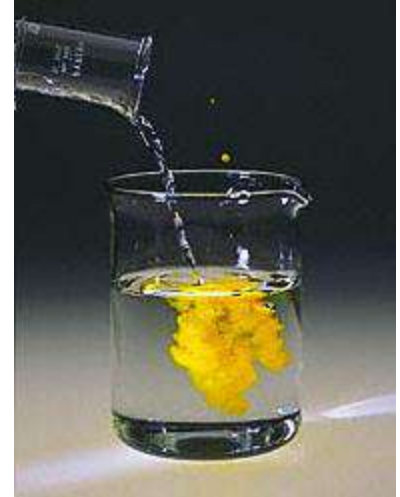
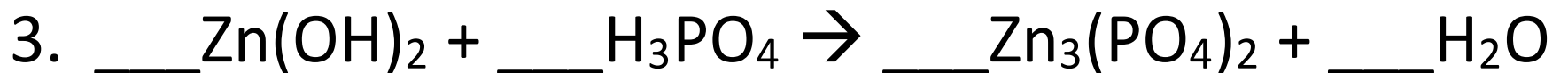
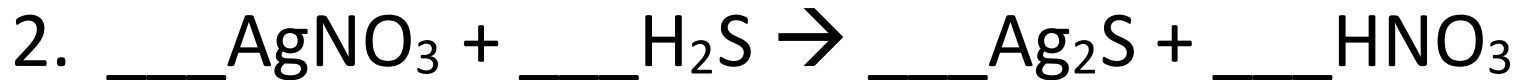
Practice Exercise

- In the following diagram, the white spheres represent hydrogen atoms, and the blue sphere represent nitrogen atoms. To be consistent with the law of conservation of mass, how many NH_3 molecules should be shown in the right box?

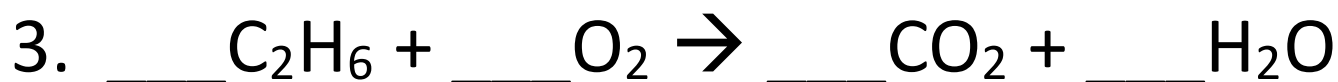


Sample Problems

Balance the following equations:



Practice Problems



Section 11.1 Assessment

1. Describe the steps in writing a balanced chemical equation.
2. Write the skeleton equation for the following reactions:
 - a. Heating solid copper(II)sulfide in the presence of oxygen gas produces pure copper and sulfur dioxide gas.
 - b. Iron metal and chlorine gas react to form solid iron(III)chloride.

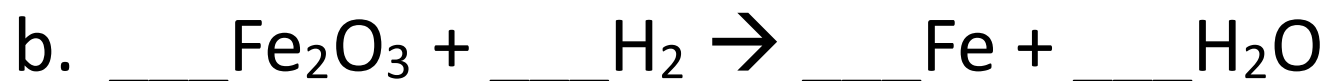
Section 11.1 Assessment

- c. Solid aluminum carbonate decomposes to form solid aluminum oxide and carbon dioxide gas.

- d. Solid magnesium reacts with aqueous silver(I)nitrate to form solid silver and aqueous magnesium nitrate.

Section 11.1 Assessment

3. Balance the following equations:



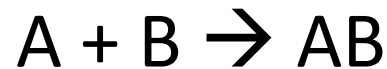
Section 11.2 – Types of Chemical Reactions

- The five general types of reactions are synthesis, decomposition, single displacement, double displacement, and combustion.

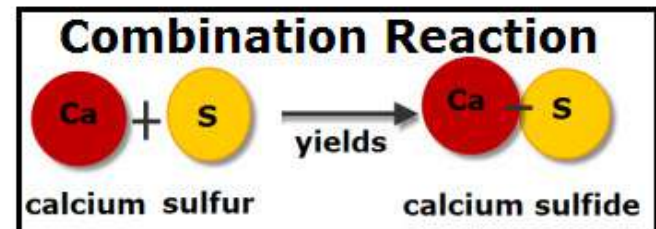
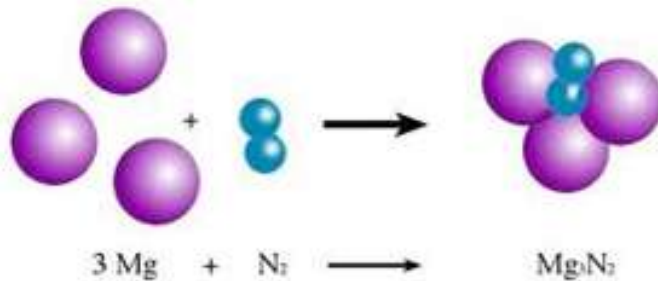
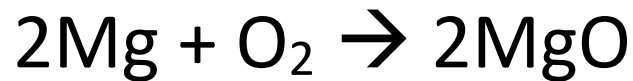


Synthesis Reactions

- In a synthesis reaction, two or more substances react to form one product. Synthesis reactions are also called combination reactions.
- Generic Reaction:



- Actual Example:



Predicting Products

- Predict the products for the following reaction:



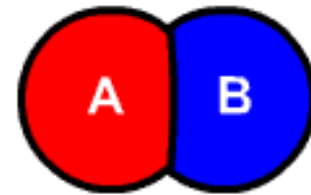
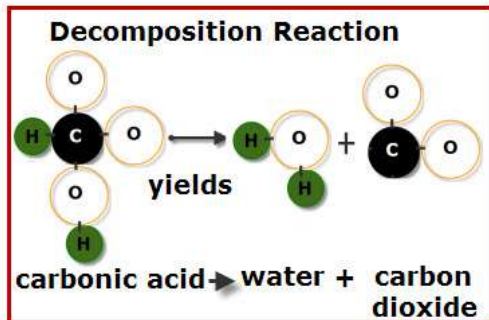
- Write the balanced equation for the combination reaction that occurs when lithium metal and fluorine gas react.
- Write the balanced equation for the reaction that occurs when the surface of aluminum metal undergoes a combination reaction with oxygen in the air.

Decomposition Reactions

- A decomposition reaction occurs when a single reactant breaks down into two or more products.
- Generic Reaction:



- Actual Example:



Predicting Products

- Predict the products for the following reaction:



- Write the balanced equation for the decomposition reaction that occurs when solid barium carbonate is heated to form barium oxide and carbon dioxide.
- Write the balanced equation for the reaction that occurs when solid mercury(II)sulfide decomposes into elements when heated.

Single Displacement Reactions

- A single displacement reaction occurs when one element replaces a second element in a compound.
- Generic Reaction:



- Actual Example:

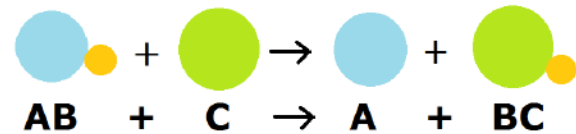


Figure 2.5

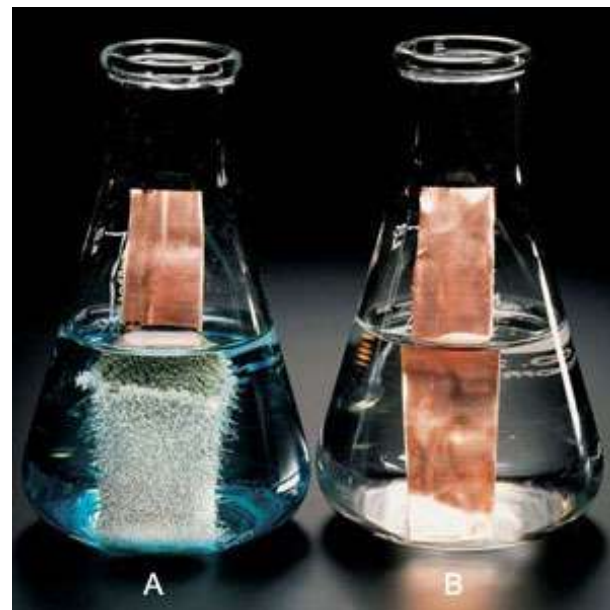
Predicting Products

- Predict the products for the following reactions:



The Activity Series

- A list of metals arranged in order of decreasing ease of oxidation is called an activity series.
- Active metals are at the top of the series and are most easily oxidized.
- Noble metals are at the bottom of the series and are not very reactive.
- Any metal on the list can be oxidized by the ions of elements below it.



Activity Series

Metal	Oxidation Reaction
Lithium	$\text{Li}(s) \longrightarrow \text{Li}^+(aq) + e^-$
Potassium	$\text{K}(s) \longrightarrow \text{K}^+(aq) + e^-$
Barium	$\text{Ba}(s) \longrightarrow \text{Ba}^{2+}(aq) + 2e^-$
Calcium	$\text{Ca}(s) \longrightarrow \text{Ca}^{2+}(aq) + 2e^-$
Sodium	$\text{Na}(s) \longrightarrow \text{Na}^+(aq) + e^-$
Magnesium	$\text{Mg}(s) \longrightarrow \text{Mg}^{2+}(aq) + 2e^-$
Aluminum	$\text{Al}(s) \longrightarrow \text{Al}^{3+}(aq) + 3e^-$
Manganese	$\text{Mn}(s) \longrightarrow \text{Mn}^{2+}(aq) + 2e^-$
Zinc	$\text{Zn}(s) \longrightarrow \text{Zn}^{2+}(aq) + 2e^-$
Chromium	$\text{Cr}(s) \longrightarrow \text{Cr}^{3+}(aq) + 3e^-$
Iron	$\text{Fe}(s) \longrightarrow \text{Fe}^{2+}(aq) + 2e^-$
Cobalt	$\text{Co}(s) \longrightarrow \text{Co}^{2+}(aq) + 2e^-$
Nickel	$\text{Ni}(s) \longrightarrow \text{Ni}^{2+}(aq) + 2e^-$
Tin	$\text{Sn}(s) \longrightarrow \text{Sn}^{2+}(aq) + 2e^-$
Lead	$\text{Pb}(s) \longrightarrow \text{Pb}^{2+}(aq) + 2e^-$
Hydrogen	$\text{H}_2(g) \longrightarrow 2\text{H}^+(aq) + 2e^-$
Copper	$\text{Cu}(s) \longrightarrow \text{Cu}^{2+}(aq) + 2e^-$
Silver	$\text{Ag}(s) \longrightarrow \text{Ag}^+(aq) + e^-$
Mercury	$\text{Hg}(l) \longrightarrow \text{Hg}^{2+}(aq) + 2e^-$
Platinum	$\text{Pt}(s) \longrightarrow \text{Pt}^{2+}(aq) + 2e^-$
Gold	$\text{Au}(s) \longrightarrow \text{Au}^{3+}(aq) + 3e^-$



Sample Exercise

- Will an aqueous solution of iron (II) chloride oxidize magnesium metal? If so, write the balanced equation for the reaction.

Practice Exercise

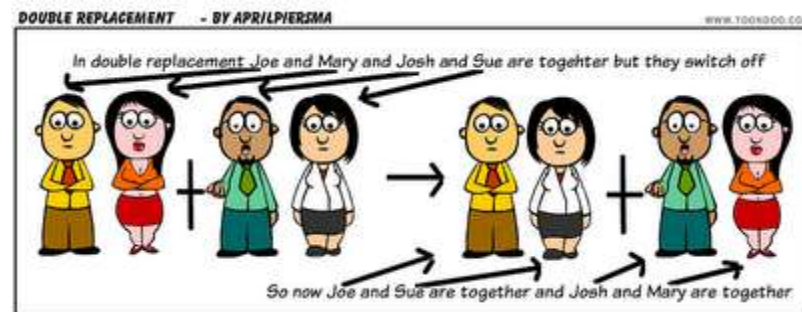
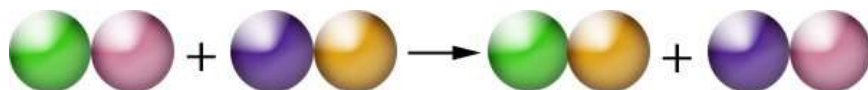
- Which of the following metals will be oxidized by $\text{Pb}(\text{NO}_3)_2$: Zn, Cu, Fe?

Double Displacement Reactions

- A double displacement reaction involves the exchange of two positive ions between two compounds.
- Generic Reaction:

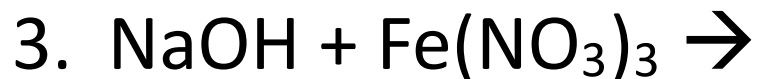
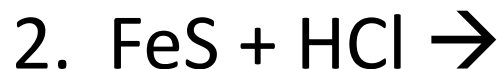
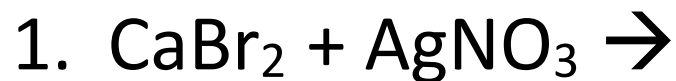


- Actual Example:



Predicting Products

- Predict the products for the following reactions:



Relationships and Reactions

Chemical Reactions

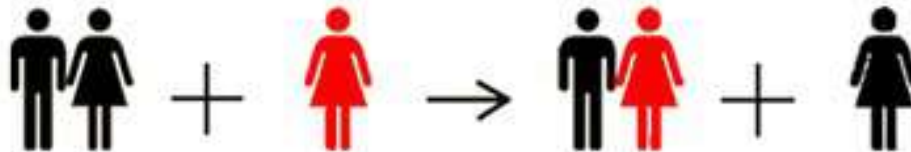
Synthesis:



Decomposition:



Single Displacement:

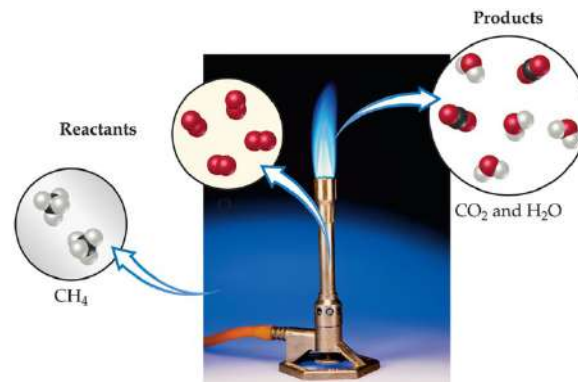
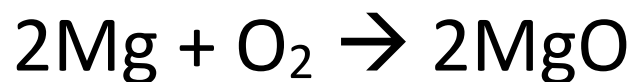


Double Displacement:



Combustion Reactions

- A combustion reaction occurs when a substance burns in oxygen and produces a lot of heat and light.
- Examples:



Combustion Reactions

- Many combustion reactions involve a hydrocarbon burning in air, and the products are CO_2 and H_2O as long as the combustion is complete.
- Generic Reaction:

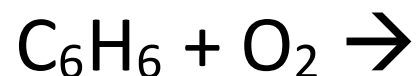


- Actual Example:



Predicting Products

- Predict the products for the following reaction:

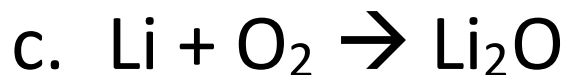
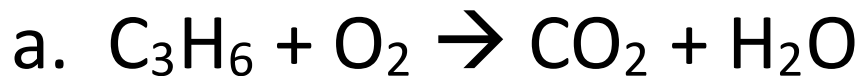


- Write the balanced equation for the reaction that occurs when methanol, CH_3OH is burned in air.
- Write the balanced equation for the reaction that occurs when ethanol, $\text{C}_2\text{H}_5\text{OH}$, is burned in air.

Section 11.2 Assessment

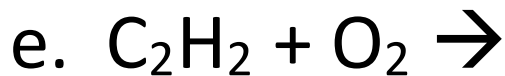
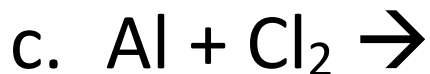
1. What are the five types of chemical reactions?

2. Classify the following skeleton reactions:



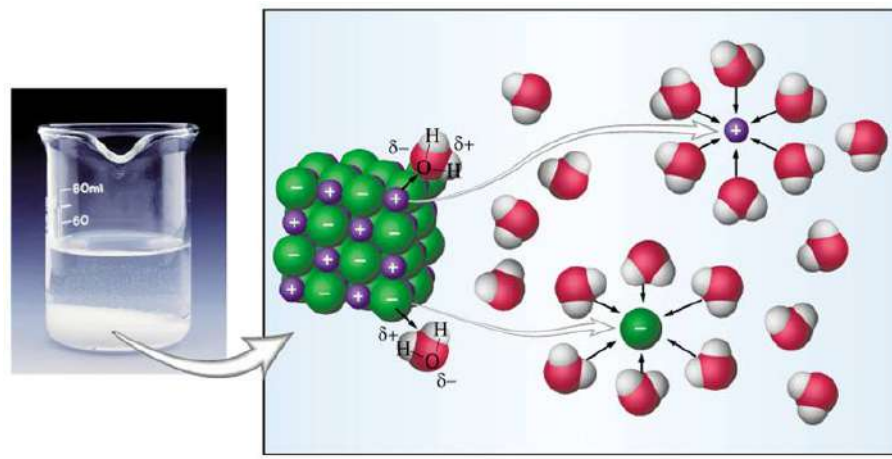
Section 11.2 Assessment

1. Complete and balance each equation:



Section 11.3 – Reactions in Aqueous Solution

- A complete ionic equation is an equation that shows dissolved ionic compounds as dissociated free ions.
- A spectator ion is an ion that is not directly involved in a reaction.
- Compounds that are aqueous will break into ions, and compounds that are solid will remain bonded.



Aqueous Ions

- When a compound is aqueous it breaks into its ions.

- Ex:

$\text{NaCl} =$

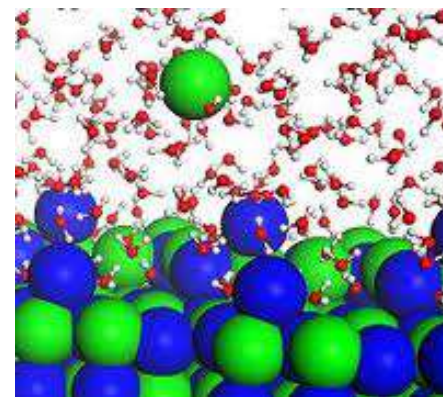
$\text{MgBr}_2 =$

$\text{Al}_2\text{O}_3 =$

$\text{LiNO}_3 =$

$\text{K}_2\text{CO}_3 =$

$\text{Sr}(\text{NO}_2)_2 =$



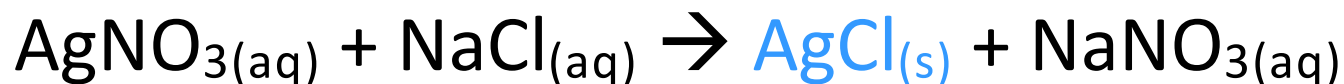
Rules for Writing Complete Ionic Equations

1. Balance the equation.
2. Separate all aqueous substances into ions.
3. Leave any non-aqueous substances or precipitates together.

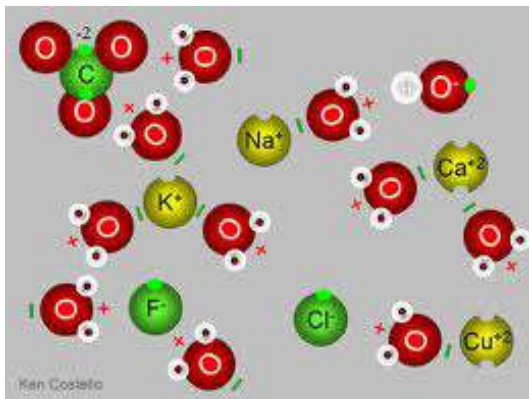
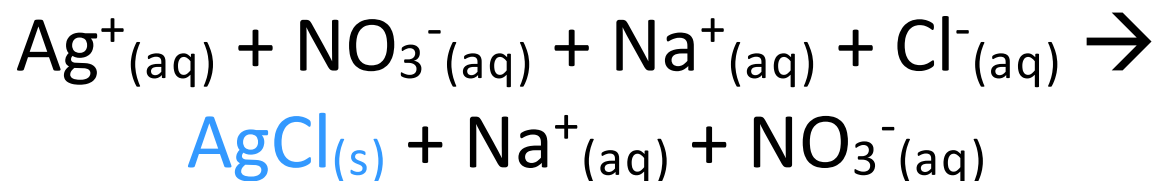


Complete Ionic Equations

- Regular Equation:



- Complete Ionic Equation:



If every ion in a complete ionic equation is a spectator, then no reaction occurs.

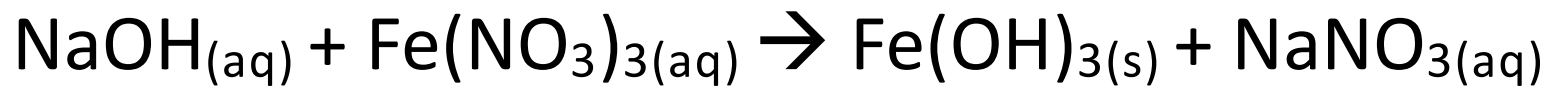
Sample Problem

- Write the complete ionic equation for the following reaction:



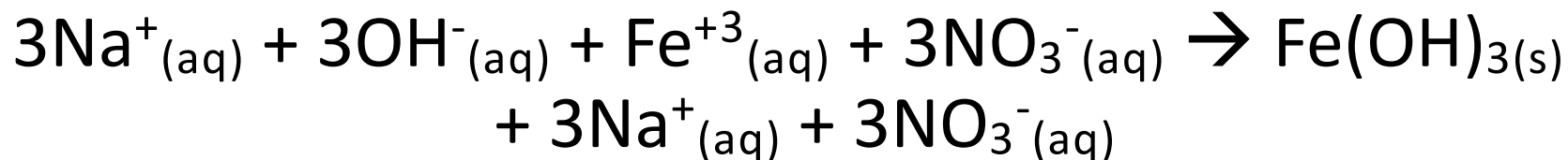
Practice Problems

- Write the complete ionic equation for the following reaction:

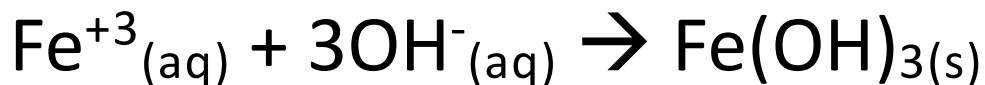


Net Ionic Equations

- A net ionic equation shows only those particles involved in the reaction.
- The spectator ions have been removed.
- Ex: complete ionic equation

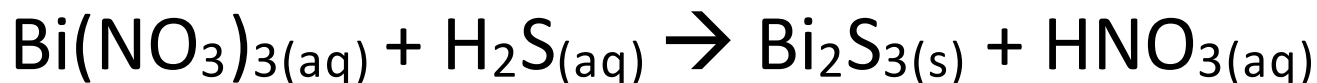


- When the spectator ions are removed, you are left with the net ionic equation:

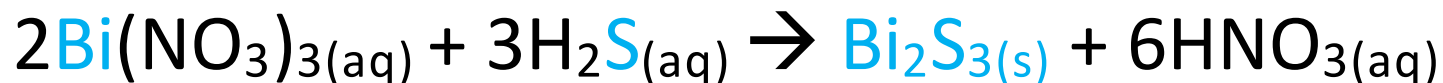


Sample Problems

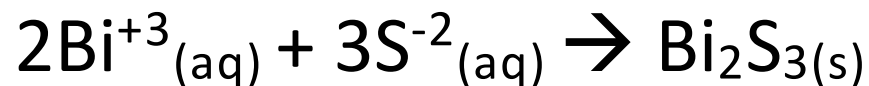
- To write a net ionic equation, you only consider non-aqueous substances and the ions that form them.



- First, balance the equation:

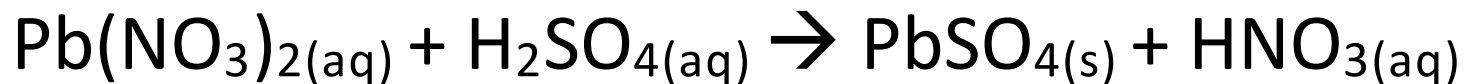


- Write only the ions involved in the reaction:

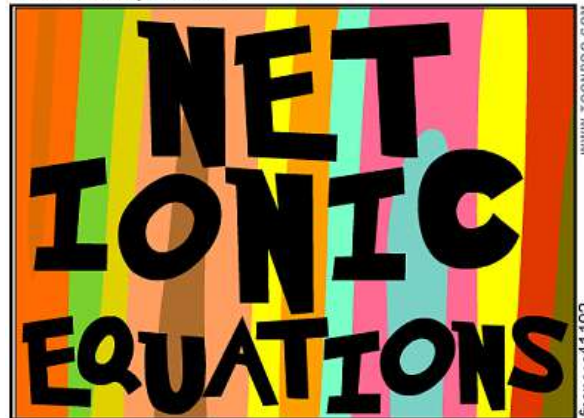


Practice Problems

1. Write the net ionic equation for the following reaction:

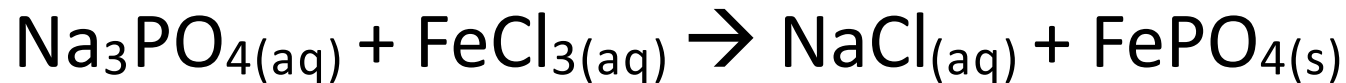


NET IONIC EQUATIONS



Practice Problems

- Write the net ionic equation for the following equation:



Gas Formation

- The sulfide ion and the carbonate ion will react with acids to form gases.



- Ex: S^{2-}



- Ex: CO_3^{2-}



So ...



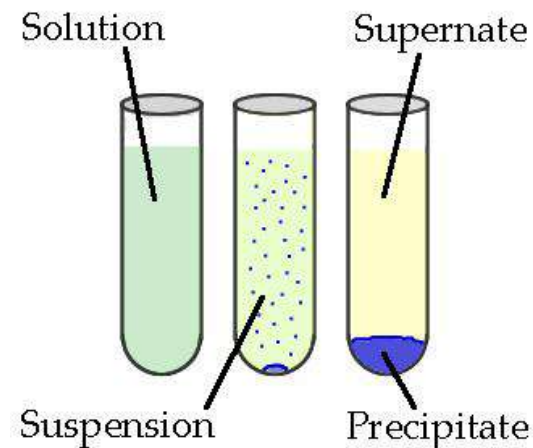
Predicting Precipitates

- You can predict whether a precipitate forms by using solubility rules.
- If a substance is soluble, then it will dissolve in water and be aqueous.
- If a substance is insoluble, then it will bond with another ion and will be a solid.



Solubility Rules

alkali metals - Group 1	soluble
NH_4^+	soluble
NO_3^-	soluble
ClO_3^-	soluble
SO_4^{2-} (except with Pb^{2+} , Ag^+ , Hg_2^{2+} , Ba^{2+} , Sr^{2+} , and Ca^{2+})	soluble
Cl^- (exception Ag^+ , Pb^{2+} , Hg_2^{2+})	soluble
CO_3^{2-} , PO_4^{3-} , CrO_4^{2-} , S^{2-} , and OH^-	insoluble



Soluble or Insoluble?

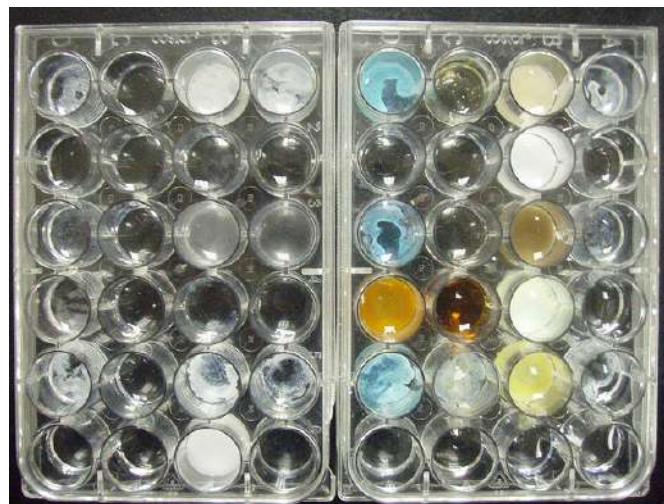
- If any part of a compound is soluble, then the compound will be soluble.
- NH_4Cl
- BaSO_4
- Na_2SO_4
- $\text{Ca}(\text{OH})_2$
- K_3PO_4
- $\text{Mg}(\text{NO}_3)_2$
- AgCl
- NiCrO_4



Predicting Precipitates

Rules for Predicting Precipitates

1. Form products and balance charges where necessary.
2. Balance the equation.
3. Identify whether the products are solid, liquid, gas, or aqueous.



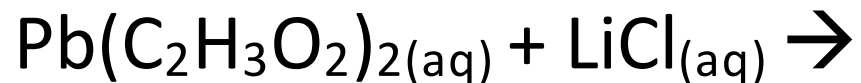
Sample Problem

- Predict the products for the following reaction:



Practice Problems

1. Predict the products for the following reaction:



Practice Problems

2. Predict the products for the following reaction:



Sample Exercise

- Write the net ionic equation for the precipitation reaction that occurs when solutions of calcium chloride and sodium carbonate are mixed.

Practice Exercise

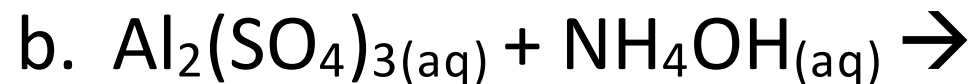
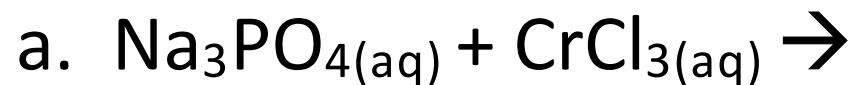
- Write the net ionic equation for the precipitation reaction that occurs when aqueous solutions of silver (I) nitrate and potassium phosphate are mixed.

Section 11.3 Assessment

1. What is a net ionic equation?
2. How can you predict the formation of a precipitate in a double displacement reaction?
3. Write the net ionic equation for the following reactions:
 - d. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{PbCl}_2(\text{s}) + \text{HC}_2\text{H}_3\text{O}_2(\text{aq})$
 - e. $(\text{NH}_4)_2\text{S}(\text{aq}) + \text{Co}(\text{NO}_3)_2(\text{aq}) \rightarrow \text{CoS}(\text{s}) + \text{NH}_4\text{NO}_3(\text{aq})$

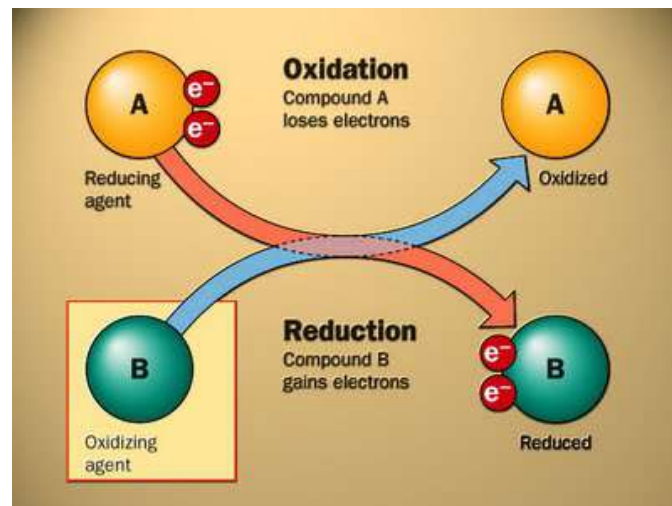
Section 11.3 Assessment

4. Predict the products for the following reactions:



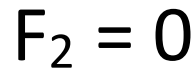
Oxidation-Reduction Reactions

- Oxidation-reduction reactions (redox reactions) are reactions in which electrons are transferred between reactants.
- Oxidation is loss of electrons.
- Reduction is gain of electrons.
- Oxidation and reduction always occur together.



Rules for Oxidation Numbers

1. For an atom in its elemental form, the oxidation number is always zero.



2. For any monatomic ion the oxidation number equals the charge on the ion.



3. The oxidation number of hydrogen is usually +1 when bonded to nonmetals and -1 when bonded to metals



Rules for Oxidation Numbers

4. The oxidation number of oxygen is usually -2 (except in peroxide, O_2^{2-} , where it is -1).

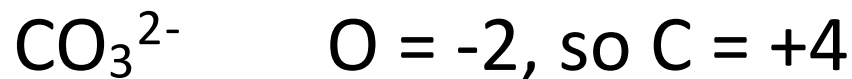
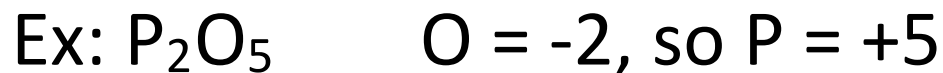


5. The oxidation number of fluorine is -1 in all compounds. The other halogens have an oxidation number of -1 except when combined with oxygen in oxyanions.



Rules for Oxidation Numbers

6. The sum of the oxidation numbers of all atoms in a neutral compound is zero. The sum of the oxidation numbers in a polyatomic ion equals the charge of the ion.

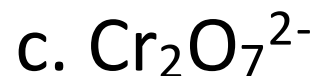
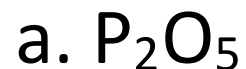


Sample Exercise

- Determine the oxidation number of sulfur in each of the following:
 - a. H_2S
 - b. S_8
 - c. SCl_2
 - d. Na_2SO_3
 - e. SO_4^{2-}

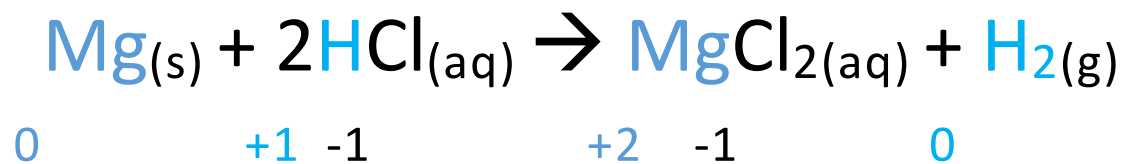
Practice Exercise

- What is the oxidation state of each element in the following:



Oxidation of Metals

- Many metals undergo displacement reactions with acids to form salts and hydrogen gas.



- Write the oxidation numbers for each element to determine which element is oxidized and which is reduced.
- Since **Mg** goes from **0** to **+2**, it is oxidized. Since **H** goes from **+1** to **0**, it is reduced.

Sample Exercise

- Write the balance equation and net ionic equation for the reaction of aluminum with hydrobromic acid.

Practice Exercise

- a. Write a balanced equation and net ionic equation for the reaction between magnesium and cobalt (II) sulfate.
- b. What is oxidized and what is reduced in the reaction?