Types of Reactions:

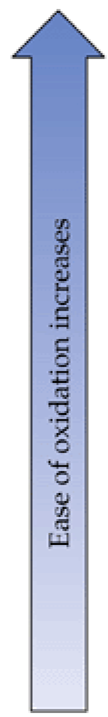
In many situations, one can predict the type of reaction which will occur if two substances are combined with each other (or whether a reaction will not take place). For each of the four most common types of reactions certain rules allow us to make these predictions:

1. **Synthesis:** reaction will occur provided the two elements involved are capable of demonstrating opposite valences. Example: $Zn^{2+} + Cl^{1-}{}_2 \rightarrow ZnCl_2$

2. **Decomposition:** reaction will occur provided conditions are supplied (such as change in temperature) Example: $2HgO \xrightarrow{\Delta} 2Hg + O_2$

3. **Single displacement** (replacement): reaction will occur if the element or cation that is going to displace or exchange is more active (see activation chart)

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$



Example #1:

$Ag + Cu(NO_3)_2 \rightarrow NR$

Because copper is the more active element

Example #2:

tin and copper(II)sulphate

$Sn + CuSO_4 \rightarrow Cu + SnSO_4$

Tin is higher on the activity chart than copper

4. **Double displacement** (replacement): reaction has similar criteria to single replacement reactions but is dependent on solubility (we will look at this in the next unit in more depth).

   Example: $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaNO_3$

5. **Combustion:** a reaction between a hydrocarbon and oxygen; always producing water and carbon dioxide.

   Example: $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

Word and formula equations

1. Two types of equations are written by chemists:
- word equations: describe the substances that react in a chemical reaction (termed reactants), and the products that are formed, along with their states
- formula equations: a shorthand method used to describe the same reactions. These are of two types:
  - **Skeleton equations:** (unbalanced) which lists the correct formula of each reacting substance and product substances, and their states.
  - **Balanced equations:** which list the correct formulas, states and balances the equation for the number of atoms present. That is it takes into account the Law of Conservation of Mass, and makes sure there is the same number and type of atom in the reactant and product. In Chemistry 30 we should only use balanced equations.

2. We balance equations by changing the coefficients or numbers in front of the substance.
WE NEVER CHANGE THE FORMULAS OF SUBSTANCES IN ORDER TO BALANCE.

3. Counting the atoms correctly is therefore critical. The balance (coefficient) we use is always multiplied by the subscripts used in each formula, to indicate how many atoms are represented. If atoms are in two different reactants or product compounds, they are added together to determine how many are present in total.

Reactants	number of each atom
$2\ SO_2 + O_2$	2 Sulfur
	4 + 2 = 6 Oxygen
$4\ CO_2 + 6\ H_2O$	4 Carbon
	8 + 6 = 14 Oxygen
	12 Hydrogen

Balancing by Inspection

Balancing equations is basically a process of trial and error, called inspection, but a few hints can help.

1. Balance atoms that ***appear only once*** in reactant and product first, and atoms that appear more than once last.

Example #1:

	Reactant		Product
	____C_3H_8 (g)+ ____O_2 (g)	→	____CO_2 (g) + ____H_2O (g)
Step 1	Balance atoms that appear only once first (C and H) ___C_3H_8 (g)+ ____O_2 (g)	→	___CO_2 (g) + ___H_2O (g)
Step 2	Balance atoms that appear more than once last (O) ___C_3H_8 (g)+ ___O_2 (g)	→	___CO_2 (g) + ___H_2O (g)

2. Balance ***polyatomic ions*** as a group, for example $SO_4{}^{2-}$ ion. Caution: The ion must remain the same in reactant and product.

Example #2:

	Reactant		Product
	____$Ca(NO_3)_2$ (aq) + ____Na_3PO_4 (aq)	→	____$Ca_3(PO_4)_2$ (s) + ____$NaNO_3$ (aq)
Step 1	Balance atoms that appear only once (Ca , Na) ____$Ca(NO_3)_2$ (aq) ____Na_3PO_4 (aq)	→	____$Ca_3(PO_4)_2$ (s) + ____$NaNO_3$ (aq)
Step 2	Balance atoms in ions as groups (PO_4 ; NO_3) ____$Ca(NO_3)_2$ (aq) + ____Na_3PO_4 (aq)	→	____$Ca_3(PO_4)_2$ (s) + ___$NaNO_3$ (aq)

3. In some cases the # of atoms of an element in the reactants may be odd, while the # in the products will always be even (due to an even subscript). **In this case you need to double the balance of all atoms already balanced and continue the balancing**. Example #3:

	Reactant		Product
	____$CuFeS_2$ (s) + ____O_2 (g)	→	____Cu (s) + ____FeO (s) + ____SO_2 (g)
Step 1	Balance atoms that appear only once first ___$CuFeS_2$ (s) + ____O_2 (g)	→	___Cu (s) + ___FeO (s) + ___SO_2 (g)
Step 2	Balance oxygen now. Notice that there are five atoms in the products but the reactants will always be even. To balance, double all balances already made.		
	___$CuFeS_2$ (s) + ___O_2 (g)	→	___Cu (s) + ___FeO (s) + ___SO_2 (g)

Writing Net Ionic Equations

- Sometimes a product that is shown on the product side of the equation does not really appear in the physical chemical reaction. The reason for this has to do with the solubility of ionic substances in water.
- If a particular product is soluble, it will stay dissolved in the aqueous solution. If a product is insoluble, it will appear as a solid precipitate in the test vessel. It is important to know which products stay dissolved in water, so we can make proper identification of the precipitates that do form as the result of chemical reactions.
- Ionic equations are more realistic representations of these reactions that take place in aqueous solution. Ionic equations show the individual ions that exit in solution. When we take an ionic displacement reaction and remove the information that is misleading, we produce a net ionic equation.
- Ions that don't change or enter into a chemical change are called spectator ions.
- In order to write **net ionic reactions** we need to do the following steps:
  1. balance the equation for atoms.
  2. write out the dissolved chemical species as they exist in solution. Precipitates, liquids and gases **are not written as ions.** This is called a total ionic equation.
  3. remove common aqueous ions, (ions that are in both the reactant and product). The resulting equation is called the net ionic equation.

Writing Net Ionic Equations (all three steps)

A solution of Barium chloride combines with a solution of Sodium Carbonate to form a precipitate of Barium Carbonate and a solution of Sodium Chloride

Step #1: **Write the formula equations and balance**

___$BaCl_2$ (aq) + ___Na_2CO_3 (aq) → ___$BaCO_3$ (s) + _2__NaCl (aq)

Step #2: **Write the aqueous substances as separate ions. Leave solids, liquids and gases unchanged.**

_Ba^{2+}(aq) + 2Cl^- (aq) + 2Na^+(aq) + CO_3^{2-}(aq) → ___$BaCO_3$ (s) + 2Na^+(aq) + 2Cl^- (aq)

Step #3: **Cancel common aqueous ions. (Net Ionic Equations**)

Ba^{2+} (aq) + CO_3^{2-} (aq) → $BaCO_{3(s)}$

1.4 Assignment

1) *Determine the # of atoms of each type present in the following reactants.*

Reactants	# of each atom
$PbS + 2\ PbO$	Pb =
	S =
	O =
$2\ NH_4NO_3 + H_2S$	N =
	H =
	O =
	S =
$Fe(NO_3)_3 + 3\ LiOH$	Fe =
	N =
	O =
	Li =
	H =
$Ca_3(PO_4)_2 + 3\ H_2SO_4$	Ca =
	P =
	O =
	H =
	S =

2) Balance the following chemical equations by inspection ;

a) ____K_2O + ____H_2O -------> _____KOH

b) ____KOH +____ H_3PO_4 -------> ____K_3PO_4 + ____H_2O

c) ____$CaCl_2$ + ____HNO_3 -------> ____$Ca(NO_3)_2$ + ____HCl

d) ____$FeCl_3$ + ____KOH -------> ____KCl + ____$Fe(OH)_3$

e) ____.NaClO + ____H_2S -------> ____NaCl + ____H_2SO_4

f) ____Ag_2S + ____HNO_3 -------> ____$AgNO_3$ + ____NO + ____S + ____H_2O

g) ____I_2 + _____$Na_2S_2O_3$ -------> ____ $Na_2S_4O_6$ + ____NaI

h) ____Fe + ____$CuNO_3$ -------> ____$Fe(NO_3)_2$ + ____Cu

i) ____$MgCl_2$ + ____NH_4NO_3 -------> ____$Mg(NO_3)_2$ + ____NH_4Cl

j) ____Al + ____H_2SO_4 -------> ____$Al_2(SO_4)_3$ + ____H_2

3) **Write the total and net ionic equations for the following using the procedure above.**

a) ____Zn (s) +____ HCl (aq) ----->____ $ZnCl_2$ (aq) + ____H_2 (aq)

b) ____$FeCl_3$ (aq) +____ $AgNO_3$ (aq) ------>____ AgCl (s) +____ $Fe(NO_3)_3$ (aq)

c) ____KOH (aq) + ____H_3PO_4(aq) ------>____ K_3PO_4(aq) +____ H_2O (l)

d) ____HCl (aq) + ____ Na_2CO_3 (aq) -----> ____ H_2O(l) + ____CO_2(g) + ____NaCl (aq)

e) ____$Ba(OH)_2$ (aq) + ____$Fe_2(SO_4)_3$ (aq) -----> ____ $Fe(OH)_3$ (s) + ____ $BaSO_4$ (aq)

4) For each of the following problems, tell:
   i) What type of reaction might be expected (5 choices)
   ii) Whether the reaction will occur or not (assume that all double displacements will go ahead)
   iii) If not, why it will not occur
   iv) If so, what the balanced equation for the reaction is

a) tin and copper (II) sulphate

b) iron (III) nitrate and sodium chromate

c) calcium and iodine

d) magnesium and hydrochloric acid

e) calcium oxide $\xrightarrow{\textit{electrolyzed}}$

f) carbon and oxygen

g) sodium carbonate and sulfuric acid

h) iron (II)sulfide $\xrightarrow{\textit{electrolyzed}}$

i) platinum and lead(II) nitrate

j) propane and oxygen gas