Exploring Chemical Equations and Reactions

Objective #1: Know the parts of a Chemical Equation

Below is a balanced chemical equation of a chemical reaction between sodium (Na) and iodine (I).

$$\underline{2}\ Na + \underline{1}\ I_2 \rightarrow \underline{2}\ NaI$$

Reactants: substances present _________________________ a chemical reaction occurs

Products: substances present _________________________ a chemical reaction has occurred

** From reactants to products, the chemical reaction allows bonds to breaks apart, rearrange atoms, and forms new bonds to produce "new" substances with different properties.*

Coefficient: whole number _______________________ that get distributed to each atom in a chemical formula

- Coefficients are ____________________________ units

Subscript: a whole number that follows an atom to indicate atoms that are ________________________ together in a chemical formula

Objective #2: Balancing Equations

In a balanced chemical reaction, the ____________________and ____________________ of atoms that are present at the beginning of a reaction must be equal to the number and type of atoms present at the end.

To balance an equation…

1) Determine what elements are present in the reaction on BOTH the reactant and product side.
2) Count the starting number of atoms for each element on BOTH sides of the equation
3) Use coefficients (whole number multipliers) in front of chemical symbols or formulas to balance the numbers between the reactants and the products
4) The reaction is balanced when the type and number of atoms is the same on BOTH sides

** * Disclaimer: Balancing chemical equations simply takes time and practice to master!!***

Sum of Coefficients

Ex. #1 ___H_2 + ___O_2 → ___H_2O _____

Ex. #2 ___Zn + ___HCl → ___$ZnCl_2$ + ___H_2 _____

Ex #3 ___$KClO_3$ → ___KCl + ___O_2 ______

Ex #4 ___$CoBr_3$ + ___$CaSO_4$ → ___$CaBr_2$ + ___$Co_2(SO_4)_3$ ______

Ex #5 ___P_2O_5 + ___H_2O → ___H_3PO_4 ______

Balancing Chemical Equations

1. If an equation is balanced properly, both sides of the equation must have the same number of
   1) atoms 2) coefficients 3) molecules 4) moles of molecules

2. Given the unbalanced equation: __Al + __$CuSO_4$ → __$Al_2(SO_4)_3$ + __Cu When the equation is balanced using the smallest whole-number coefficients, what is the coefficient of Al?
   1) 1 2) 2 3) 3 4) 4

3. Given the unbalanced equation: __$Mg(ClO_3)_2(s)$ → __$MgCl_2(s)$ + __$O_2(g)$ What is the coefficient of O_2 when the equation is balanced correctly using the smallest whole number coefficients?
   1) 1 2) 2 3) 3 4) 4

4. Given the unbalanced equation: __$CaSO_4$ + __$AlCl_3$ →___$Al_2(SO_4)_3$ + __$CaCl_2$ What is the coefficient of $Al_2(SO_4)_3$ when the equation is completely balanced using the smallest whole-number coefficients?
   1) 1 2) 2 3) 3 4) 4

5. Given the unbalanced equation:__Fe_2O_3 + __CO →__Fe + __CO_2 When the equation is correctly balanced using the smallest whole-number coefficients, what is the coefficient of CO?
   1) 1 2) 2 3) 3 4) 4

6. Given the incomplete equation: $4Fe + 3O_2 \rightarrow 2X$ Which compound is represented by X?
   1) FeO 2) Fe_2O_3 3) Fe_3O_2 4) Fe_3O_4

7. Given the incomplete equation: $2\ N_2O_5(g) \rightarrow$? Which set of products completes and balances the incomplete equation?
   1) $2\ N_2(g) + 3\ H_2(g)$ 2) $2\ N_2(g) + 2\ O_2(g)$ 3) $4\ NO_2(g) + O_2(g)$ 4) $4\ NO(g) + SO_2(g)$

Objective #3: Classifying Reactions

Five basic chemical reactions exist in chemistry. Given a reaction, you will need to be able to classify the type of reaction, and later on predict the products (or reactants) when given.

1) Decomposition (D)

   There is only ___________ reactant, and it breaks down to form two or more single elements

   - General formula: ____________________________

   - Example:

2) Synthesis (S) (this reaction is also sometimes known as a _________________________ reaction)

   Two or more single elements combine and react to form only __________ product

   - General formula: ____________________________

   - Example:

3) Combustion (C)

   The reactants are ALWAYS contain a ____________ compound that reacts with __________,

   and the products are ALWAYS _____________________________ and _________________

   - General Formula: ____

   - Example:

4) Single Replacement (SR)

   A reaction in which an __________________ replaces another element in a _____________________.

   - General Formula: ____

   - Example:

5) Double Replacement (DR)

   A reaction in which two ______________________ switch ions and form two new compound products.

   - General Formula: ____

   - Example:

Classify the following reactions as S, D, C, SR or DR

Reaction	**Type**	**Reaction**	**Type**
$H_2 + Br_2 \rightarrow 2\ HBr$		$Cl_2 + 2\ KI \rightarrow 2\ KCl + I_2$	
$2\ LiNO_3 + Ca \rightarrow Ca(NO_3)_2 + 2\ Li$		$Li_2S + Fe(NO_3)_2 \rightarrow 2\ LiNO_3 + FeS$	
$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$		$2\ NO \rightarrow N_2 + O_2$	
$2\ Li_2O \rightarrow 4\ Li + O_2$		$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$	

Classifying Reactions

1. Given the balanced equations representing two chemical reactions:

$$Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$$
$$2NaCl \rightarrow 2Na + Cl_2$$

Which type of chemical reactions are represented by these equations?

1) single replacement and decomposition
2) single replacement and double replacement
3) synthesis and decomposition
4) synthesis and double replacement

2. Which balanced equation represents a single-replacement reaction?

1) $Mg + 2AgNO_3 \rightarrow Mg(NO_3)_2 + 2Ag$
2) $2Mg + O_2 \rightarrow 2MgO$
3) $MgCO_3 \rightarrow MgO + CO_2$
4) $MgCl_2 + 2AgNO_3 \rightarrow 2AgCl + Mg(NO_3)_2$

3. Given the balanced equation representing a reaction: $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ Which type of chemical reaction is represented by this equation?

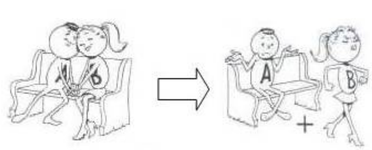
1) double replacement 2) single replacement 3) combustion 4) synthesis

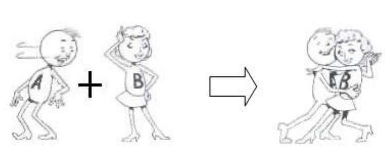
4. Given the balanced equation: $AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$ This reaction is classified as

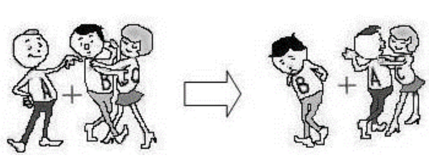
1) synthesis 2) decomposition 3) single replacement 4) double replacement

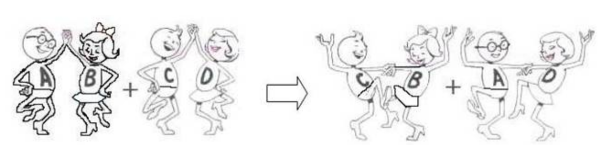
5. What type of reaction is shown to the right? $F_2(g) + CaBr_2(g) \rightarrow CaF_2(g) + Br_2(g)$

1) synthesis 2) decomposition 3) single replacement 4) double replacement









Objective #4: Determining the missing substance(s) in a reaction

a) Decomposition Reaction

In some decomposition reactions, one reactant breaks down into its corresponding elements that made up the compound in the first place. When determining the parts of a decomposition reaction, be sure to remember that there are seven elements that are diatomic when they are alone (un-bonded) in nature.)

Example 1: ___CO_2 → ___ ________________ + ___ ________________

Example 2: ___ ________________ → ___Sr + ___O_2

Example 3: ___ Pb_3P_2 → ___ ________________ + ___ ________________

b) Synthesis Reaction

In some synthesis reactions, two or more solitary elements combine to make one product. When determining the parts of a synthesis reaction, be sure to remember that there are seven elements that are diatomic when they are alone (un-bonded) in nature.)

Example 1: ___Na + ___Cl_2 → ___ ________________

Example 2: ___ ________________ + ___ ________________ → ___ Fe_2O_3

Example 3: ___ ________________ + ___ ________________ → ___ SO_2

Decomposition and Synthesis Reactions

1. What are the products for the following decomposition reaction? 2 Al_2O_3 → ?

   1) 4 Al + O_3 2) 2 Al_2 + O_3 3) 4 Al + 3 O_2 4) 4 Al + 6 O

2. What are the reactants for the following synthesis reaction? ? → 2 ArF_3

   1)2 Ar + F_3 2) 2 Ar + 2 F_3 3) 2 Ar + 3 F_2 4) 2 Ar + 6 F

3. Given the incomplete equation: 4Fe + 3O_2 → 2X Which compound is represented by X?

   1) FeO 2) Fe_2O_3 3) Fe_3O_2 4) Fe_3O_4

c) Single Replacement Reactions:
A reaction can occur if the element to be replaced is the same charge as the element trying to replace it

ex. A positive ion can only replace another positive ion in a compound
A negative ion can only replace another negative ion in a compound **AND/OR**

- The element being replaced is less reactive than the element trying to replace it
  - **Use Table J: Activity Series**
    - If the single element reactant is higher on Table J than the element it is trying to replace, a reaction WILL occur
    - If the single element reactant is lower on Table J than the element it is trying to replace, a reaction WILL NOT occur

Single Replacement Reactions

1. Based on Reference Table J, which of the following elements will replace Pb from $Pb(NO_3)_2(aq)$?
1) Mg 2)Au 3) Cu 4) Ag

2. According to Reference Table J, which pair will react in a single replacement reaction?
1) $Cu + H_2O$ 2) $Ca + H_2O$ 3) $Au + H_2O$ 4) $Ag + H_2O$

3. Referring to Reference Table J, which single replacement reaction will not occur under standard conditions?
1) $Sn(s) + 2\,HCl(aq) \rightarrow SnCl_2(ag) + H_2(g)$
2) $Cu(s) + 2\,HCl(aq) \rightarrow CuCl_2(aq) + H_2(g)$
3) $Ba(s) + 2\,HCl(aq) \rightarrow BaCl_2(aq) + H_2(g)$
4) $Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Examples:

1) ___Al + ___HCl → ___ _______________ + ___ _______________

2) ___Ag + ___$MgCl_2$ → ___ _______________ + ___ _______________

3) ___Cr + ___ $Pb(NO_3)_4$ → ___ _______________ + ___ _______________

4) ___Cl_2 + ___ NaI → ___ _______________ + ___ _______________

5) ___ I_2 + ___ HF → ___ _______________ + ___ _______________

d) Double Replacement Reactions

Rules to complete a double replacement reaction:

a) Look up the charges of the elements in the compounds on the reactant sides
b) Ions will switch partners and form a bond with the other oppositely charged ion available
c) Use new subscripts if necessary to insure that each new formula has a net charge of zero
d) Determine the phases of the elements using Reference Table F.

Table F
Solubility Guidelines for Aqueous Solutions

Ions That Form *Soluble* Compounds	Exceptions
Group 1 ions (Li^+, Na^+, etc.)	
ammonium (NH_4^+)	
nitrate (NO_3^-)	
acetate ($C_2H_3O_2^-$ or CH_3COO^-)	
hydrogen carbonate (HCO_3^-)	
chlorate (ClO_3^-)	
halides (Cl^-, Br^-, I^-)	when combined with Ag^+, Pb^{2+}, or Hg_2^{2+}
sulfates (SO_4^{2-})	when combined with Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, or Pb^{2+}

Ions That Form *Insoluble* Compounds*	Exceptions
carbonate (CO_3^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
chromate (CrO_4^{2-})	when combined with Group 1 ions, Ca^{2+}, Mg^{2+}, or ammonium (NH_4^+)
phosphate (PO_4^{3-})	when combined with Group 1 ions or ammonium (NH_4^+)
sulfide (S^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
hydroxide (OH^-)	when combined with Group 1 ions, Ca^{2+}, Ba^{2+}, Sr^{2+}, or ammonium (NH_4^+)

*compounds having very low solubility in H_2O

(aq) — This column contains negative ions that always form soluble compounds (aq)

(s) — This column contains exceptions to the previous column and if any of these ions are also in the compound the compound is now insoluble (s)

(s) — This column contains negative ions that when in compounds will not dissolve in water and are insoluble (s)

(aq) — This column contains exceptions to the previous column and if any of these ions are also in the compound is now soluble (aq)

Examples:

1) ___NaBr (aq) + ___$AgNO_3$ (aq) → ___ __________________( ) + ___ __________________( )

2) ___$Ba(NO_3)_2$ (aq) + ___Na_2SO_4 (aq) → ___ __________________( ) + ___ __________________( )

3) ___$AgNO_3$ (aq) + ___Na_2CrO_4 (aq) → ___ ________________( ) + ___ ________________( )

4) ___K_2CO_3 (aq) + ___$CaSO_4$ (aq) → ___ ________________( ) + ___ ________________( )

5) ___$Mg(NO_3)_2$ (aq) + ___LiOH(aq) → ___ ________________( ) + ___ ________________( )

Objective #5: Writing Net Ionic Equations

A net ionic equation shows only those particles involved in the formation of a solid (s) in a double replacement reaction and is balanced with respect to mass and charge. You can predict the formation of a precipitate (solid) by using the general rules for solubility of ionic compounds with respect to Reference Table F.

Example 1:

Write the net ionic equation for the following reaction: $Sr(NO_3)_2$ (aq) + K_2SO_4 (aq) →

a) Finish and balance the double replacement reaction:

___ ______________ + ___ ______________ → ___ ______________ + ___ ______________

b) Write out the "Total Ionic Equation"; cross out spectator ions – those ions that are the same on the reactant and product sides:

____

c) Net Ionic Equation – what's left over: d) Spectator Ions – what was crossed out above:

____________________________________ ____________________________________

Example 2:

Write the net ionic equation for the following reaction: KI (aq) + $Pb(NO_3)_2$ (aq) $\rightarrow$

a) Finish and balance the double replacement reaction:

___ _______________ + ___ _______________ $\rightarrow$ ___ _______________ + ___ _______________

b) Write out the "Total Ionic Equation"; cross out spectator ions – those ions that are the same on the reactant and product sides:

____

c) Net Ionic Equation – what's left over: d) Spectator Ions – what was crossed out above:

____ ____________________________________

Stoichiometry

Stoichiometry is the study of amounts in chemical reactions. When doing stoichiometry problems, you must always begin with a ____. You will then use the whole number _______________________________ as molar quantities for each compound, which will help to determine how much of each reactant is needed to produce the given products.

Objective #1: Determining Mole Ratios from balanced equations

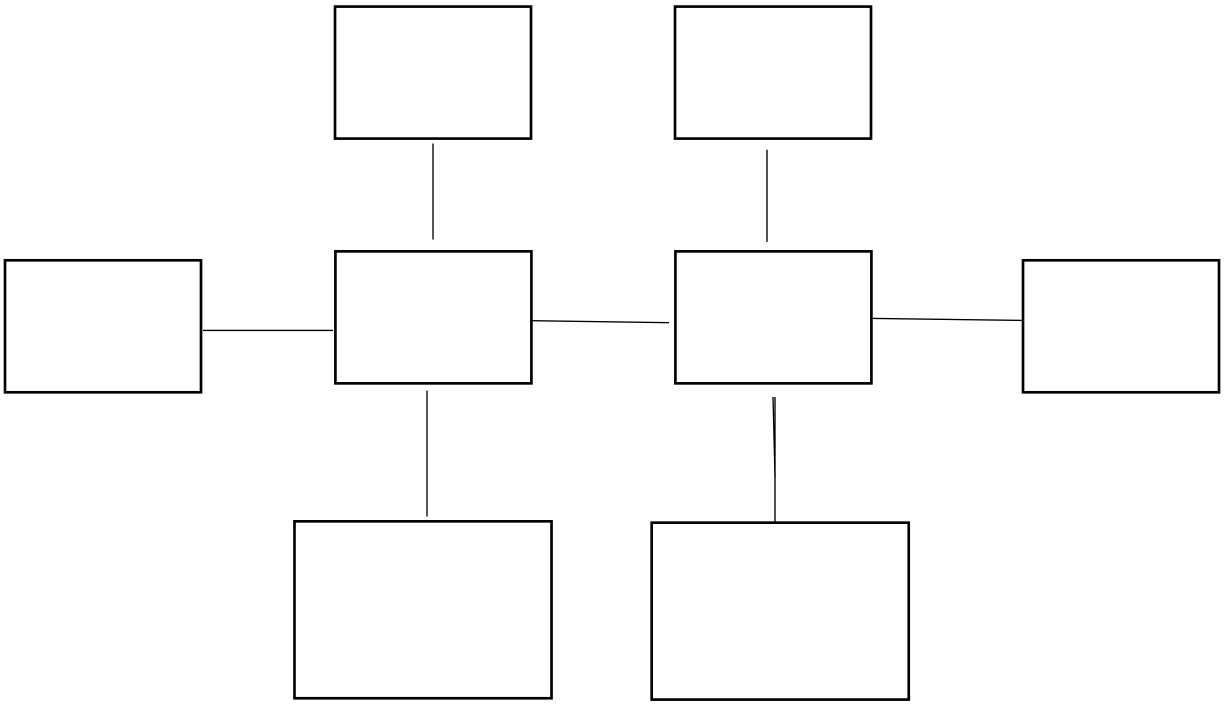
From a balanced equation, you can create mole ratios between two substances.

a) $2\ H_2 + 1\ O_2 \rightarrow 2\ H_2O$
Mole ratios:

b) $1\ Zn + 2\ HCl \rightarrow 1\ H_2 + 1\ ZnCl_2$
Mole ratios:

These mole ratios show the relationship between molar quantities of one compound to molar quantities of another compound

Objective #2: Using the Stoichiometry Mole Map
Shows the relationship when converting between molar units AND between moles of one substance to moles of another substance.



1) **1 step stoichiometry calculations (mole – mole calculations)**
   This is the simplest type of stoichiometry calculation. These are mole-mole calculations, in which you are trying to determine how many moles of one substance there are related to another substance. (Use a one-step dimensional analysis setup to solve.) Using the mole ratio of the two substances being asked about, you will create a setup as below to solve these problems.

   Example 1:
   Given the following balanced equation: 1 Zn + 2 HCl → 1 H_2 + 1 $ZnCl_2$
   How many moles of H_2 would be produced if there was 7.3 moles of HCl?

   Example 2:
   Given the following balanced equation: N_2 + 3 H_2 → 2 NH_3
   How many moles of H_2 are needed to produce 0.8 moles of NH_3?

2) 2 – step stoichiometry calculations

In a two-step calculation, you will be comparing moles of one substance to grams, liters or molecules of another substance in a balanced chemical equation. One step will be to convert the grams (or liters or atoms/molecule) to moles, and the other step will be to compare moles of one substance to moles of another substance using the mole ratios. This will require a two-step dimensional analysis setup.

Example 1:

Given the following balanced equation: $1\ Zn + 2\ HCl \rightarrow 1\ H_2 + 1\ ZnCl_2$
How many moles of H_2 would be produced if there was 25.0 grams of Zn used?

Example 2:

Given the following balanced equation: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$
How many liters of NH_3 would be produced if there was 5.5 moles of N_2?

Example 3:

Given the following balanced equation: $2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$
How many moles of $KClO_3$ would be needed to produce 2.60×10^{23} molecules of O_2?

3) 3 – step stoichiometry calculations

In a three-step calculation, you will be comparing grams/atoms/molecules/liters of one substance to grams, liters, atoms or molecules of another substance in a balanced chemical equation. You will follow the mole map road and use a three-step dimensional analysis setup.

Example 1:

Given the following balanced equation: $1\ Zn + 2\ HCl \rightarrow 1\ H_2 + 1\ ZnCl_2$
How many grams of $ZnCl_2$ would be produced if there was 37.0 grams of Zn used?

Example 2:

Given the following balanced equation: 1 N_2 + 3 H_2 → 2 NH_3

How many molecules of N_2 would be needed to produce 125.0 L of NH_3?

Example 3:

Given the following balanced equation: 2 $KClO_3$ → 2 KCl + 3 O_2

How many liters of O_2 would be produced if the reaction began with 20.0 grams of $KClO_3$?

Objective #3: Determining Limiting Reactants

The limiting reactant in a chemical reaction is the substance that is _________________________ consumed when the chemical reaction is complete. The amount of product formed is limited by this reactant, since the reaction cannot continue without it. If one or more other reactants are present in excess of the quantities required to react with the limiting reactant, they are described as _________________ reactants.

The limiting reactant must be identified in order to calculate the percentage yield of a reaction, since the _________________________yield is defined as the amount of product obtained when the limiting reactant reacts completely. Given the balanced chemical equation, which describes the reaction, there are several equivalent ways to identify the limiting reactant and evaluate the excess quantities of other reactants.

Example #1: Limiting Reactant Calculation

A 2.00 g sample of ammonia is mixed with 4.00 g of oxygen. How many grams of H_2O will be produced? Which reactant is the limiting reactant?

$$4\ NH_{3(g)} + 5\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$$

Example 2: Limiting Reactant Calculation
90.0 g of $FeCl_3$ reacts with 52.0 g of H_2S. How many liters of HCl will be produced? Which reactant is the limiting reactant?

$$2\ FeCl_{3(s)} + 3\ H_2S_{(g)} \rightarrow Fe_2S_{3(s)} + 6\ HCl_{(g)}$$

Objective #4: Percent Yield

The theoretical yield is the maximum amount of product you would expect from a reaction based on the amount of limiting reagent. In practice, however, chemists don't always obtain the maximum yield for many reasons. Since chemists know that the actual yield might be less than the theoretical yield, we report the actual yield using percent yield, which tells us what percentage of the theoretical yield we obtained. The percent yield is determined using the following equation:

$$\text{Percent Yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Example #1: A 2.00 g sample of ammonia is mixed with 4.00 g of oxygen for the following reaction:

$$4\ NH_{3(g)} + 5\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$$

At the completion of the reaction, 2.35 grams of H_2O were produced. What is your percent yield?

Example #2: 90.0 g of $FeCl_3$ reacts with 52.0 g of H_2S for the following reaction:

$$2\ FeCl_{3(s)} + 3\ H_2S_{(g)} \rightarrow Fe_2S_{3(s)} + 6\ HCl_{(g)}$$

At the completion of the reaction, 29.5 L of HCl were produced. What is your percent yield?