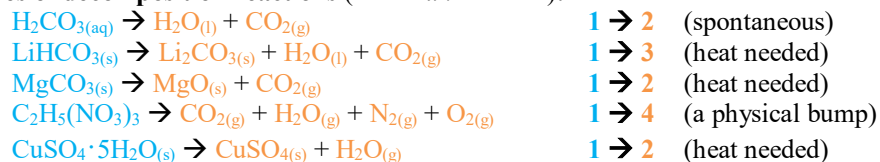


Types of Reactions:

Like everything else in chemistry, reaction types can be broken down into different categories and you will need to be able to recognize what type of reaction you are working with based only upon the given reactants. The six types of reactions that you will need to be able to recognize are **decomposition**, **combination**, **combustion**, **single replacement**, **double replacement**, and **neutralization** reactions. The good news is that each of these reactions has typical characteristics that make them easily identifiable. The bad news is that you actually need to know what to look for and how to predict the products of each reaction.

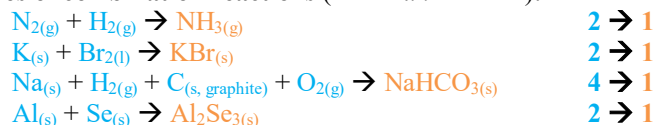
For a **decomposition** reaction, you are looking for a single compound that is breaking apart into multiple compounds. This type of reaction might be spontaneous (takes place without outside help) or might need a kick-start to get going (heat or a physical change). Either way, you start with **one reactant** and end with **multiple products**.

Examples of decomposition reactions (all are *unbalanced*):



Combination reactions typically have **multiple reactants** that go to form a **single product**, essentially the opposite of a decomposition reaction. The reactants for combination reactions are usually all elements, which makes this type of reaction easily identifiable.

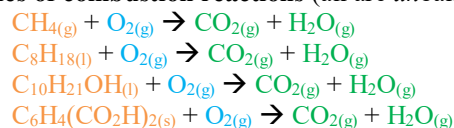
Examples of combination reactions (all are *unbalanced*):



The only combination reactions that you will need to be able to predict are those between non-VOS metals and nonmetals, the product of which is always a neutral ionic compound.

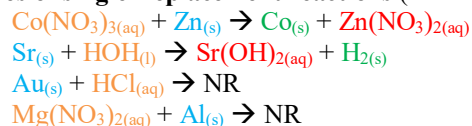
Pretty much everything can burn and when something burns it is through a **combustion** reaction. Combustion is basically the reaction of a substance with **elemental oxygen**. The combustion reactions that we are concerned with typically involve compounds made of **carbon and hydrogen** or **carbon, hydrogen and oxygen** though like I said, pretty much anything can burn. You are responsible for remembering that combustion reactions must have $\text{O}_2(\text{g})$ present as a reactant (in addition to what is being burned).

Examples of combustion reactions (all are *unbalanced*):



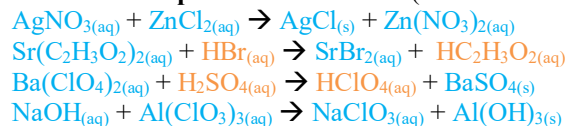
Single-Replacement reactions are identified as having an **element** and a **compound** as the reactants. Remember, in order to determine whether a given single-replacement reaction will actually take place, you must use the activity series. It is also important to remember that if a given single-replacement reaction does take place, the products will be a different compound and a different element than that with which you started.

Examples of single-replacement reactions (all are *unbalanced*):



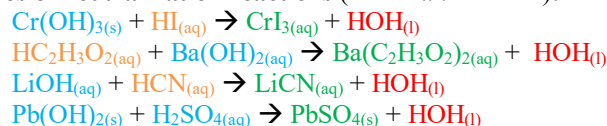
Double-Replacement reactions are the most common reactions we will do in this class. The reactants in a double-replacement reaction are either **two ionic compounds** or **an ionic compound** and **an acid** and the products will be the same. Nothing that participates in a double-replacement reaction changes its charge, which helps when trying to predict products. These reactions take place in a water environment.

Examples of double-replacement reactions (all are *unbalanced*):



Finally we come to the **neutralization** reactions. As far as we are concerned in here, neutralization reactions are really just a special type of double-replacement involving an **acid** and **base**. The **base** is typically in the form of a **metal-hydroxide** such as **NaOH**, making this a reaction between an **ionic compound** and an **acid**. The products of a neutralization reaction are always a **new ionic compound** and **water**. This is an important reaction type and we will spend an entire chapter on acid/base chemistry later in the semester, so make sure you can recognize them!

Examples of neutralization reactions (all are unbalanced):



Chemical equations and balancing reactions:

You need to be proficient in balancing reactions in order to be successful in chemistry. That is all good and well, but what does it mean to be a balanced chemical reaction? Remember, the Law of Conservation of Matter states, "Matter cannot be created or destroyed." For balancing chemical equations, this translates to mean that you must have the same amount of each atom before and after a reaction takes place. You can perform any chemical reaction you want, rearrange the atoms in any way you need to, but you must start and finish with the same amount of matter. Essentially, it means that there is the SAME number of EACH atom on BOTH sides of the equation. No big deal right? It starts of pretty easy, but can get tough, so follow along with the examples, and try to understand what each step is doing and why it is being done. Some hints for you: Make a table listing all the elements (or ions) for each side of the reaction. If polyatomic ions are present and are EXACTLY the same on both sides, then they can be balanced as one piece (see the examples below for... well. examples of this). Make one column for the reactants (before) side, and one column for the products (after) side. Make sure the elements or ions are listed in the same order in both columns, and ALWAYS make hydrogen next to last and oxygen last. It will always be easier to balance oxygen last. Here we go...

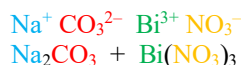
Examples:

- a) Example: Give the balanced equation for the reaction for sodium carbonate mixed with bismuth (III) nitrate

Translate:



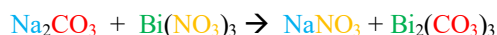
Write ONE of each ion above products:



Copy ions to reactant side, swapping anions:



Balance CHARGES of products:



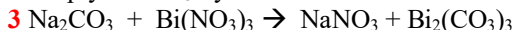
NO MORE TOUCHING THE SUBSCRIPTS!!!!!!!

Balance the equation:

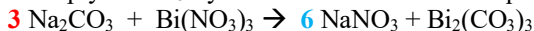
(ONLY CHANGE COEFFICIENTS TO BALANCE EQUATION!!!)



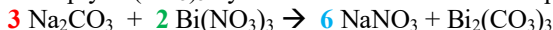
Trial 1: Multiply Na_2CO_3 by **3** so that the carbonates are equal on both sides.



Trial 2: Multiply NaNO_3 by **6** so that the nitrates are equal on both sides.



Trial 3: Multiply $\text{Bi}(\text{NO}_3)_3$ by **2** so that the bismuths are equal on both sides.



		Reactants				Products	
	Initial	Trial 1	Trial 3		Initial	Trial 2	
Na	2	6	6	Na	1	6	
CO ₃	1	3	3	CO ₃	3	3	
Bi	1	1	2	Bi	2	2	
NO ₃	3	3	6	NO ₃	1	6	

b) Example: Give the balanced equation for the reaction for potassium sulfate with barium nitrate

Translate: $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2$

Write ONE of each ion above products: $\text{K}^+ \text{SO}_4^{2-} \text{Ba}^{2+} \text{NO}_3^-$
 $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2$

Copy ions to reactant side, swapping anions: $\text{K}^+ \text{SO}_4^{2-} \text{Ba}^{2+} \text{NO}_3^- \quad \text{K}^+ \text{NO}_3^- + \text{Ba}^{2+} \text{SO}_4^{2-}$
 $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2$

Balance CHARGES of products: $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2 \rightarrow \text{KNO}_3 + \text{BaSO}_4$

Balance the equation: **(ONLY CHANGE COEFFICIENTS TO BALANCE EQUATION!!!)**

Start off by making a table of the elements and ions involved (because the nitrate and sulfate ions are on both sides of the equation, you can list them as the ions rather than sulfur, nitrogen and oxygen separately):

Initial equation: $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2 \rightarrow \text{KNO}_3 + \text{BaSO}_4$

Trial 1: Multiply KNO_3 by **2** so that the potassium atoms are equal on both sides
 $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2 \rightarrow \textbf{2} \text{KNO}_3 + \text{BaSO}_4$

Reactants		Products		
	Initial		Initial	Trial 1
K	2	K	1	2
SO ₄	1	SO ₄	1	1
NO ₃	2	NO ₃	1	2
Ba	1	Ba	1	1

In the initial column, compare the number of potassium atoms on the reactant side to the number of potassium atoms on the product side. There are two on the reactant and one on the product side. To fix this, put a 2 in front of the KNO_3 on the product side. The 2 you just placed in front of the KNO_3 is called a coefficient. Remember, when you are balancing, you can ONLY use coefficients; you cannot EVER change subscripts. Because of this, the coefficient changes not only the number of potassium atoms on the product side, but also the number of nitrate ions. In other words, putting the number in front of a molecule multiplies ALL the atoms in the molecule by that number. So putting a 2 in front of KNO_3 give you 2 K and 2 nitrates. Now that the columns on both the reactant product sides are equal, the equation is balanced.

The answer is: $\text{K}_2\text{SO}_4 + \text{Ba}(\text{NO}_3)_2 \rightarrow \textbf{2} \text{KNO}_3 + \text{BaSO}_4$

c) Example: Give the balanced equation for the reaction for aluminum hydroxide and nitric acid

Translate: $\text{Al}(\text{OH})_3 + \text{HNO}_3$

Write ONE of each ion above products: $\text{Al}^{3+} \text{OH}^- \text{H}^+ \text{NO}_3^-$
 $\text{Al}(\text{OH})_3 + \text{HNO}_3$

Copy ions to reactant side, swapping anions: $\text{Al}^{3+} \text{OH}^- \text{H}^+ \text{NO}_3^- \quad \text{Al}^{3+} \text{NO}_3^- + \text{H}^+ \text{OH}^-$
 $\text{Al}(\text{OH})_3 + \text{HNO}_3$

Balance CHARGES of products: $\text{Al}(\text{OH})_3 + \text{HNO}_3 \rightarrow \text{Al}(\text{NO}_3)_3 + \text{HOH}$

Balance the equation: **(ONLY CHANGE COEFFICIENTS TO BALANCE EQUATION!!!)**

Same steps as above, start off by making a table, then work your way through (nitrate and hydroxide are the same on both sides, so you can list them as the ion instead of nitrogen hydrogen and oxygen separately).

Initial equation: $\text{Al}(\text{OH})_3 + \text{HNO}_3 \rightarrow \text{Al}(\text{NO}_3)_3 + \text{HOH}$

Multiply reactant side HNO_3 by **3** to get the same number of nitrates on both sides.
 Trial 1 $\text{Al}(\text{OH})_3 + \textbf{3} \text{HNO}_3 \rightarrow \text{Al}(\text{NO}_3)_3 + \text{HOH}$

Multiply product side water by **3** to get the same number of hydroxides on both sides.

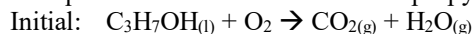


Reactants			Products		
	Initial	Trial 1		Initial	Trial 2
Al	1	1	Al	1	1
NO ₃	1	3	NO ₃	3	3
H	4	6	H	2	6
O	3	3	O	1	3

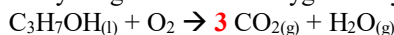
After trial two, both the products and reactants had the same number of each atom and ion, so the equation is balanced. The final answer is $\text{Al}(\text{OH})_3 + 3 \text{HNO}_3 \rightarrow \text{Al}(\text{NO}_3)_3 + 3 \text{HOH}$

NOTE: Remember that any molecule in the equation that does not have a coefficient in front is assumed to be 1. So the equation in example b) can also be written $1 \text{Al}(\text{OH})_3 + 3 \text{HNO}_3 \rightarrow 1 \text{Al}(\text{NO}_3)_3 + 3 \text{HOH}$.

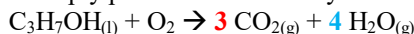
- d) Balance the equation for the combustion of isopropyl alcohol, $\text{C}_3\text{H}_7\text{OH}$



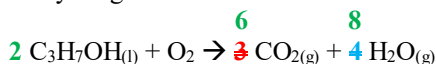
Trial 1: Multiply product side CO_2 by **3** to get same number of carbons on both sides (remember, start with everything that is NOT oxygen or hydrogen).



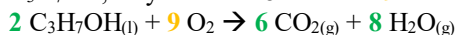
Trial 2: Multiply product side water by **4** to balance the hydrogens.



Trial 3: You now have a situation where you have the diatomic oxygen molecule in the equation and an odd number of oxygens on one side and an even number on the other. When this happens, **double** everything other than the diatomic element.



Trial 4: You now need a total of 20 oxygens on the reactant side. There are 2 oxygens from the $2 \text{C}_3\text{H}_7\text{OH}$, so you need 18 more. A **9** in front of the O_2 takes care of that and we are balanced!



Reactants				Products				
	Initial	Trial 3	Trial 4		Initial	Trial 1	Trial 2	Trial 3
C	3	6	6	C	1	3	3	6
H	8	16	16	H	2	2	8	16
O	3	4	20	O	3	7	10	20

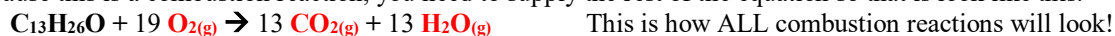
Predicting Reaction Products, Part 2:

You will need to be able to predict the products of several different types of reactions. All but one of these reactions will be covered here. Some reactions are relatively straightforward and will not require much time to memorize, while others will require a little bit more thought. Remember that reactions in which a solid is formed are called **precipitation reactions** while reactions in which there is a transfer of electrons are called redox reactions.

We will start with the combustion reactions because it is straight memorization. If you are told that something that is burned or combusted, you need to add oxygen gas as a reactant (remember, oxygen is needed for something to burn) and you need to add carbon dioxide and water as products. That is it. Once you have the unbalanced reaction written, you then balance it and you are done.

Example: Write the balanced chemical equation for the combustion of $\text{C}_{13}\text{H}_{26}\text{O}$.

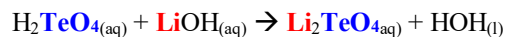
Because this is a combustion reaction, you need to supply the rest of the equation so that it looks like this:



The next type of reaction you need to know is the neutralization reaction. These are recognizable because they always involve an acid and a base (usually a hydroxide). A neutralization reaction will always produce water and a salt. This salt, which is just another word for ionic compound, will be made up from the cation of the base and the anion of the acid.

Example: Write the balanced equation for the reaction between telluric acid and lithium hydroxide.

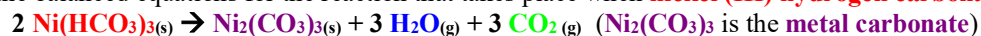
First, we can identify this as a neutralization reaction because it involves a base (hydroxide) and an acid. The unbalanced equation would then be:



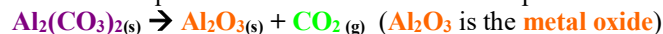
This is how ALL neutralization reactions will look!

You will need to be able to predict the products for 2 different types of decomposition reactions: the decomposition of **metal hydrogen carbonates** and the decomposition of **metal carbonate**. The reactions are quite similar, so don't mix them up! **Metal hydrogen carbonates** will produce the **metal carbonate**, **water**, and **CO₂**, while the **metal carbonate** will yield the **metal oxide** and **CO₂**.

Example: Give the balanced equations for the reaction that takes place when **nickel (III) hydrogen carbonate** is heated.



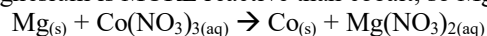
Example: Give the balanced equations for the reaction that takes place when aluminum carbonate is heated.



Finally, you need to be able to predict the products, (if there are any) of a single replacement reaction. For this, you will use the activity series. The activity series tells you which of the elements involved are the most reactive and will therefore be found in a compound. If the most active metal in the reactants is already in a compound, then there will be no reaction. If the most reactive metal is not in a compound, then the reaction will go forward with the more active metal replacing the less active metal.

Example: Solid manganese is placed into a cobalt (III) nitrate solution.

Magnesium is MORE reactive than cobalt, so Mg will replace Co in the compound:



Example: Solid silver is placed into a sodium nitrate solution.

Silver is LESS reactive than sodium, so Ag will NOT replace Na in the compound (the more active element is already in the compound)



PRACTICE

- decomposition of lithium carbonate
 - carbonic acid and ammonium hydroxide react
 - diphosphorous pentoxide is formed when phosphorous and oxygen gas react with each other
 - silver hydrogen carbonate is heated and decomposes
 - calcium nitrate decomposes when heated to form calcium nitrite and oxygen gas
 - sulfuric acid and aluminum metal
 - zinc is placed in an aqueous lead (II) nitrate solution
 - cadmium is placed in an aqueous iron (III) sulfate solution
 - aluminum oxide and manganese are the products when manganese (IV) oxide reacts with aluminum
 - titanium (IV) chloride and water react to make titanium (IV) oxide and hydrogen chloride gas
- sulfuric acid is mixed with aluminum hydroxide
 - lead (II) nitrate is added to iron (III) bromide
 - acetic acid is poured onto solid calcium carbonate making calcium acetate, water, and carbon dioxide
 - copper (II) sulfide is reacted with tin (IV) bromate
 - propanol (C₃H₇OH) is burned
 - solid sodium bicarbonate is mixed with phosphoric acid → sodium phosphate, water, and carbon dioxide
 - benzene is burned (C₆H_{6(l)})
 - zinc chloride and potassium hydroxide are reacted with each other
 - cobalt (III) sulfate and selenic acid are poured together
 - ammonium phosphate is mixed with nickel (II) nitrate
 - the combustion of pentene (C₅H₁₀)
 - nitric acid is neutralized with magnesium hydroxide
 - solid bismuth (III) sulfide and hydrochloric acid react
 - antimony (III) iodide reacts with ammonium sulfide
 - heptane (C₇H₁₆) is combusted
 - The PRODUCTS of a reaction are solid bismuth (IV) chromate and sodium nitrate.

Write a balanced chemical equation for the combustion of each of the following hydrocarbons:

- decane – C₁₀H₂₂
- nonene – C₉H₁₈