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**- Student Activity -**

**The Five Types of Chemical Reactions**

In this activity, you will learn that many of the chemical reactions that are part of your lives can be classified as one of five basic reactions. Once you are proficient with recognizing and classifying the five reactions, you will be ready to predict the products of a chemical reaction. In additional to learning the types of chemical reactions, you will also learn how to **balance** chemical reactions.

**Synthesis Reaction**

A synthesis reaction (also called a combination reaction) is where two or more elements or compounds combine to form a more complex product. This type of reaction is easy to recognize because you will always see two or more reactants on the left side of a chemical equation, but only one product on the right side. The generic equation for this reaction can be written as:

**A + B AB**

A simple example of this type of reaction is when solid calcium is combined with solid sulfur to form solid calcium sulfide. This can be written as:

**Ca(s) + S(s) CaS(s)**

Now you try one. Write the reaction for solid magnesium reacting with gaseous oxygen to form solid magnesium oxide. Note, oxygen is a diatomic element. Also remember your rules for figuring out the formulas for ionic compounds from their names.

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You may notice that something about the equation looks wrong. If you were to count the number of oxygen atoms on the left, there are two. However, the number of oxygen atoms on the right is only one. This seems to violate the law of conservation of matter. That is because we are not finished yet.

Now we need to **balance** the equation. This means we will add numbers in front of the reactants/products in order to make sure that the number of atoms on the left of the reaction is equal to the number of atoms on the right.

Here was what you should have written on the previous page:

**Mg(s) + O2(g) MgO(s)**

To balance the number of oxygens, we will need to put a "2" in front of the MgO(s) like this.

**Mg(s) + O2(g) 2MgO(s)**

However, now we have a new problem. We have the two magnesium atoms on the right, but only one on the left. Once again, to fix this we will need another "2." But this time, we will put it in front of the Mg(s) like this:

**2Mg(s) + O2(g) 2MgO(s)**

Now the equation is balanced. There are two magnesiums and two oxygens on the left and on the right of the reaction. These numbers that we are inserting in front of the reactants/products are called **coefficients.** In **c**hemistry, the coefficient is the number in front of the formula or an element or a compound that tells you how many of a given formula are present. It is important to note that the coefficient can represent a number of atoms, molecules, ions and even moles.

**Now your teacher will demonstrate this reaction!**

Let's try another one. This time, write out the complete **balanced equation** for the following reaction: Solid aluminum will react with liquid bromine to form solid aluminum bromide. (Don't forget that bromine is diatomic).

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**Decomposition Reaction**

A decomposition reaction is where a single chemical species (a reactant) is broken down into two or more simpler elements or compounds. This type of reaction is easy to recognize because you will always see two or more products on the right side of a chemical equation, but only one reactant on the left side. The generic equation for this reaction can be written as:

**AB A + B**

A simple example of this type of reaction is when gaseous carbon dioxide is decomposed into solid carbon and gaseous oxygen. This can be written as:

**CO2(g) C(s) + O2(g)**

Now you try one. Write the reaction for the decomposition of solid magnesium nitride into solid magnesium and gaseous nitrogen. Don't forget about diatomic elements, and remember to balance your reaction.

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Now let's try a trickier one. Write out and balance the following reaction:

Liquid potassium chlorate will break down into solid potassium chloride and gaseous oxygen.

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**Now your teacher will demonstrate this reaction!**

Note that in order for this reaction to work, we must first melt the potassium chlorate. And to really see the results of this reaction, something combustible will be added to the test tube so you can see that oxygen was indeed produced.

Please write down at least three observations from this reaction on the next page.

**Observations of the decomposition of potassium chlorate**

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The reason for the flame is because sugar is combustible and the contents were not only extremely hot but filled with oxygen. Oxygen helps burning occur. Did you notice that the fire was kind of light purple in color? Please explain what caused this color.

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What you witnessed was actually two reactions: a decomposition, followed by a combustion. But we will discuss combustion a little later on.

Eventually, you will be required to determine the products of these types of reactions. Can you see why oxygen was one of the products of this reaction? Oxygen is a relatively stable diatomic element. Stability plays a key roll in the formation of products. Both oxygen and potassium chloride are stable compounds. Potassium chlorate is little more unstable. Which is why it is so easily decomposed.

What do you think would happen if we attempted this same experiment with sodium chlorate? Would we make the exact same products? Would they be at least similar? And what about the color… would that be the same as well? Think about it!

**Single Replacement Reaction**

A single replacement reaction is where a single element reacts with a compound creating a new compound and a new element. The generic equation for this reaction can be written as:

**A + BX AX + B**

As you can see from the above reaction, the element **A** has replaced the element **B** in the compound **BX** creating new compound **AX** and the new element **B**.

Now let's look at a real reaction. When solid lithium reacts with a solution of sodium chloride, a solution of lithium chloride and solid sodium are produced.

Li(s) + NaCl(aq) LiCl(aq) + Na(s)

In the above reaction, the metal lithium replaced the metal sodium within sodium chloride to produce lithium chloride and sodium. You can think of it as a substitution of one element for another. The replaced element does not always have to be the metal.

Try this one on your own. When chlorine gas is mixed with aqueous potassium iodide, the products that are formed are aqueous potassium chloride and solid iodine. (Don't forget that halogens are diatomic and make sure you balance this one).

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So how do you know which element to replace? Metals replace metals and non-metals replace non-metals. Or the more electropositive elements replace each other and the more electronegative elements replace each other.

Now you can to do your own experiment. On your table is a bottle of aqueous copper(II) sulfate. Using a pipette, squirt in a couple of mL of this solution into a test tube. Using your scooplula, add a little bit of solid iron powder to the solution. Stopper the test tube and gently shake the test tube. Wait about a minute. Look at the contents of your test tube now. Pour off the liquid portion of the test tube and examine the new solid. Can you figure out what you just made? Write out the reaction as follows: Aqueous copper(II) sulfate and solid iron powder make aqueous iron(II) sulfate and solid copper.

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Did you notice that the metal was no longer dark brown in color? That's because it's not iron anymore, it's copper! And what about the pretty blue copper(II) sulfate? Did the color change to a more a greenish hue? That's because the product, iron(II) sulfate is yellow, but not all of the copper(II) sulfate was used up. So what color do you get when extra blue solution mixes with a yellow solution?



**Double Replacement Reaction**

A double replacement reaction is where two compounds in solution trade cations (positive ions) to form two new compounds.

The generic equation for this reaction can be written as:

**AX + BY BX + AY**

As you can see from the above reaction, the **A** and **B** have switched places.

Try to figure this one out on your own. And remember to balance it.

An aqueous solution of magnesium chloride and an aqueous solution of sodium carbonate will produce a solution of sodium chloride and a solid precipitate of magnesium carbonate.

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Now you can to do your own experiment.

On your table is a bottle of aqueous cadmium(II) nitrate and a bottle of aqueous sodium sulfide. Using a pipette, squirt in a couple of mL of each solution into a test tube. (Make sure you don't use the same pipettes. We don't want to contaminate the solutions). Your products are aqueous sodium nitrate and a precipitate of cadmium(II) sulfide.

See next page.

Cd(NO3)2(aq) + Na2S(aq) NaNO3(aq) + CdS(s)

Oh no! I've spoiled your fun… I've already written the answer. But wait… Is it balanced?

Guess what you have to do?

\_\_\_\_ Cd(NO3)2(aq) + \_\_\_\_ Na2S(aq) \_\_\_\_\_ NaNO3(aq) + \_\_\_\_\_ CdS(s)

**Combustion Reaction**

A combustion reaction is technically any reaction that is burned in oxygen. Heated high enough, almost anything can burn. However, for our purposes, when we talk about combustion, we will limit it to the burning of any compound that contains only carbon and hydrogen (and sometimes oxygen). When such a compound is burned in oxygen, the same two products are always produced: carbon dioxide and water. So the generic reaction would look like this:

 hydrocarbon + O2(g) CO2(g) + H2O(g)

Here is a specific example: When gaseous methane is burned it produces carbon dioxide and water vapor.

 CH4(g) + 2O2(g) CO2(g) + 2H2O(g)

Now let's do something cool…I mean hot…

Butane is a flammable gas with the formula C4H10. When burned in oxygen it produces… well you already know that. Write out this reaction. This one will be a little harder to balance.

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Observe the demonstration of what happens when different volumes of butane gas (C4H10) are placed in an 850.0 mL tennis ball canister and ignited with a an electric spark. Observe what is happening in the reaction

**Observations**

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Why does this reaction not work when the volume of butane used was increased to 60.0 mL?

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Now you try one more. Glucose can also be burned in oxygen. Write out and balance the combustion reaction for glucose.

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