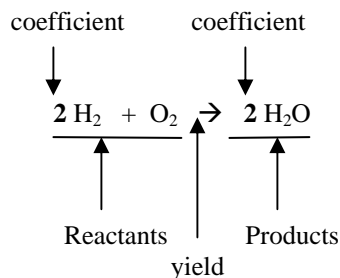


Chemical Equations Reactions

Like everything else in chemistry, chemical equations follow a few basic patterns. Today we will begin to look at the first of these patterns and practice predicting the products in a chemical reaction. First, let's identify the different parts of a chemical equation. Look at the equation below.



Coefficients - the numbers written in front of the chemical formulas. You wrote coefficients when you balanced equations.

Reactants - the elements or compounds on the left hand side of the equation before the \rightarrow are known as the reactants.

Products - the elements or compounds on the right side of the equation after the \rightarrow are known as the products.

Yield(\rightarrow) - this arrow is called a yield sign. It separates the reactants from the products.

How we read an equation is important also. The equation above would be read as follows. Two moles of diatomic hydrogen react with one mole of diatomic oxygen to yield 2 moles of water. Even if there is no coefficient in front of a formula, it still means there is one mole of the substance.

The word **diatomic** is used above when we read the equation. A **diatomic molecule** is made up of **two atoms of the same element**. These elements never exist as one naturally. When writing chemical equations you must always remember to write a subscript of two when these elements are by themselves. (When they are bonded to other elements they **do not** necessarily have a subscript of 2.) There are seven diatomic elements; they are listed in the chart to the right. This same chart is on the back of your periodic table. I highly recommend that you memorize these seven diatomic elements. You can see that they kind of form a pattern on the periodic table.

Diatomic Elements

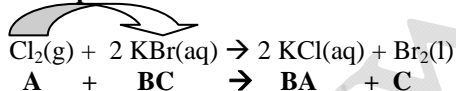
H₂ N₂ O₂
F₂ Cl₂ Br₂ I₂

Single Replacement Reactions

In a single displacement reaction one element replaces another element in a compound. They follow one of the following two patterns: $A + BC \rightarrow BA + C$ or $A + BC \rightarrow AC + B$

The most important thing to remember with single displacement reactions is **elements that form cations can only replace cations and elements that form anions can only replace anions**. See the two examples below.

Example #1:

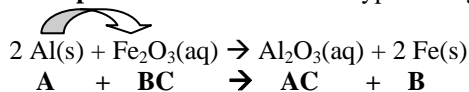


There are a few things we must be aware of in the above equation. First, chlorine is an element that forms an anion, so it can only replace an element that forms an anion, in this case bromine. Second, chlorine and bromine are both **diatomic molecules** and must be written with a subscript of 2 when they are alone. Do not be confused by the letters in parenthesis after each molecule's formula. They tell you the state that each molecule is in. There is a key below to help you.

s: solid **l:** liquid **g:** gas
aq: aqueous (dissolved in water) In order for a reaction to occur, ionic compounds must be dissolved in water.

Note: There are 11 elements that are **gases at room temperature**. They are: **H, N, O, F, Cl, He, Ne, Ar, Kr, Xe, Rn**. There are two elements that are **liquid at room temperature**. They are: **Hg and Br**. All other elements are solid at room temperature.

Example #2: Look at the other type of single displacement equation below:



In the equation above, the element that is all by itself is **aluminum**. Aluminum forms a cation, so it can only replace iron (Fe), which also is a cation.

Not all single replacement reactions can occur. Before we can write the products for any single displacement equation, we **MUST** check the activity series to see if the displacement is possible. There is a cation and an anion activity series. I listed both to the right. They can also both be found on the back of your periodic table.

<u>Anion Activity Series</u>
F ₂
Cl ₂
Br ₂
I ₂

<u>Cation Activity Series</u>
Li
K
Rb
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Co
Ni
Sn
Pb
H
Cu
Hg
Ag
Pt
Au

Elements higher on the chart can replace elements below it, but elements lower on the chart cannot replace elements higher on the chart. For example, as we saw above in our two examples, chlorine, Cl, can replace bromine, Br, and aluminum, Al, can replace iron, Fe. Look at your charts. Note that on the Anion Activity Series, chlorine is higher than bromine. Note on the Cation Activity Series chart that aluminum is higher than iron. **If an element cannot replace the other element, the reaction is labeled N.R. for no reaction.** See below for an example.

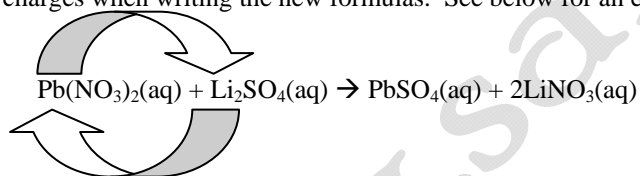
If I tried to reverse the reaction in example #2, let's see what would happen.
 $\text{Fe(s)} + \text{Al}_2\text{O}_3\text{(aq)} \rightarrow \text{N.R.}$

Since iron is lower on the activity series chart than aluminum, it cannot replace it. When this occurs we label it N.R. for no reaction.

One more important issue: In a single replacement reaction, whenever you see the formula for water, H₂O, you should treat it as a compound formed between **H (cation) and OH (anion)**. It would be best for you to change the formula to HOH.

Double Replacement Reactions

In the single displacement problems that we studied last class, one single element displaced another that was in a compound. In a double displacement problem, we begin with two compounds and we switch the cations of each. **There is no need to check the activity series when solving double displacement reactions.** All you need to remember is to switch cations and cross charges when writing the new formulas. See below for an example.



One more note, **if a multivalent (an element with more than one charge) element (like lead above) is used, you must use the same charge once you switch the cations.** In other words, if we use lead(II) as a reactant, we must also use lead(II) as a product. You cannot switch to lead(IV). The general pattern of a double displacement reaction is $\text{AB} + \text{CD} \rightarrow \text{CB} + \text{AD}$

Don't forget, once you switch cations, you must again write the charges as superscripts and then cross them.

Synthesis Reactions

In a synthesis reaction you start out with two separate elements on the reactants side and then combine them to form a compound on the products side. The general pattern of a synthesis reaction is: $\text{A} + \text{B} \rightarrow \text{AB}$. Look at the example below.

- Ex: A strip of aluminum foil is placed in liquid bromine.
 $2\text{Al} + 3\text{Br}_2 \rightarrow 2\text{AlBr}_3$

Decomposition Reactions

A decomposition equation is the opposite of a synthesis equation. You are given a compound as the reactant and it is strongly heated. To find the product, you split the compound into the individual elements, usually. The general pattern of a decomposition equation is: $\text{AB} \rightarrow \text{A} + \text{B}$. Look at the example below.

- Ex: Sodium chloride is strongly heated
 $2\text{NaCl(s)} \rightarrow 2\text{Na(s)} + \text{Cl}_2\text{(g)}$

Remember to make diatomic elements diatomic when they are alone.

Other Decomposition Reactions

There are three other decomposition reactions you need to know. The first is the **decomposition of a hydrate**. When a hydrate decomposes, water is removed. See below for the decomposition of.

- Ex: Barium iodide dihydrate is strongly heated
 $\text{BaI}_2 \cdot 2\text{H}_2\text{O}(s) \rightarrow \text{BaI}_2(s) + 2\text{H}_2\text{O}(l)$

Another decomposition reaction is the **decomposition of carbonates**. When a carbonate decomposes, carbon dioxide gas is produced. The other product is the metal oxide. You must still remember to cross charges between the metal and oxygen. Finish the equation by balancing it. See below the decomposition of.

- Ex: Calcium carbonate is strongly heated
 $\text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g)$

The last type of decomposition is the **decomposition of a chlorate**. When a chlorate decomposes, oxygen gas is produced. The other product is a metal chloride. For example, the decomposition of is shown below.

- Ex: Magnesium chlorate is strongly heated
 $\text{Mg}(\text{ClO}_3)_2(s) \rightarrow \text{MgCl}_2(s) + 3\text{O}_2(g)$

Note that once the oxygen gas is removed you are left with the ionic compound magnesium chloride. You should still go through the steps of crossing charges between magnesium (2+) and chlorine (1-) to get MgCl_2 .

Combustion Reactions

To combust is to react with oxygen. These reactions often involve a hydrocarbon. The key way to identify these reactions is by seeing the words **burned in air**. Depending on the reactants a number of different products can be formed.

If the compound contains:	A product will generally be:
a metal	the metal oxide
carbon	carbon dioxide, CO_2
hydrogen	water, H_2O
phosphorus (P_4)	tetraphosphorus decoxide (P_4O_{10})
sulfur	sulfur dioxide, SO_2

- Ex: Propene (C_3H_6) is burned in air.
 $2\text{C}_3\text{H}_6 + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
- Ex: Solid copper(II) sulfide is strongly heated in air.
 $2\text{CuS} + 3\text{O}_2 \rightarrow 2\text{CuO} + 2\text{SO}_2$
- Ex: Pure solid phosphorus (white form) is burned in air.
 $\text{P}_4 + 5\text{O}_2 \rightarrow \text{P}_4\text{O}_{10}$

Homework- Write the balanced chemical equation using the elements and compounds below as your reactants.

1. In the following equation, circle the coefficients, underline the reactants and put a box around the products.



2. List the seven diatomic molecules.

3. True or False (Circle One) The seven elements that form diatomic molecules ALWAYS have a subscript of two, even when they are bonded to other atoms.

4. When we use the compound water in this chapter, we will not write H_2O . Instead, we will write the formula as _____ and _____ will be the cation and _____ will be the anion.

5. What do each of the following abbreviation represent when they appear in a chemical equation?

- | | |
|--------|-------|
| a. aq: | c. l: |
| b. s: | d. g: |

6. What is the rule for whether an element can be replaced in a single replacement reaction?

7. True or False (Circle One) A cation can only replace a cation but an anion can replace a cation or an anion.

8. What is the most active cation? What is the most active anion?

9. What do you write as the product for a reaction that cannot occur?

10. **Single Replacement Reactions.** Write complete balance chemical reaction for each of the following.

a. A strip of magnesium metal is placed in a solution of iron(II) chloride.

b. A strip of aluminum is placed in a solution of lithium nitrate

c. A piece of cadmium metal is oxidized by adding it to a solution of copper(II) chloride.

d. Chlorine gas is bubbled into a solution of sodium bromide.

e. Solid potassium fluoride is added to liquid iodine.

f. A piece of solid sodium is added to a beaker of water.

11. **Double Replacement.** Write complete balance chemical reaction for each of the following.

a. Solutions of zinc bromide and silver nitrate are combined.

b. Solutions of barium chloride and potassium fluoride are mixed together.

c. A solution of aluminum nitrate is added to a solution of sodium hydroxide

d. A solution of calcium chloride is added drop by drop to a solution of sodium carbonate.

e. A solution of nickel(II) bromide is added to a solution of potassium hydroxide.

12. **Synthesis:** Write complete balance chemical reaction for each of the following.

- a. Hydrogen gas and oxygen gas are heated together

- b. Solid sodium is added to liquid bromine

- c. A strip of aluminum is heated in chlorine gas

- d. Solid pieces of potassium and iodine are heated strongly

- e. Solid iron and sulfur are heated strongly together

13. **Decomposition:** Write complete balance chemical reaction for each of the following.

- a. Solid calcium chloride is heated strongly.

- b. Electricity is passed through water causing it to decompose.

- c. Solid sodium chlorate is strongly heated.

- d. Solid copper(II) sulfate pentahydrate is heated strongly.

- e. Solid calcium carbonate is strongly heated.

14. **Combustion:** Write complete balance chemical reaction for each of the following.

- a. Solid nickel(II) sulfide is strongly heated in air.

- b. Hexane (C_6H_{14}) is combusted in air.

- c. Propanone(CH_3COCH_3) is burned in air.

- d. Sulfur in its standard state is burned in air.

15. Modified True/False. If a statement is true, circle true. If a statement is false, circle false and rewrite the statement making it true.:

- a. **True or False** (Circle One) When solving double displacement equations, you must look at the activity series to see if the reaction can occur.
- b. **True or False** (Circle One) In order for a combustion reaction to occur, oxygen is needed as a reactant.
- c. **True or False** (Circle One) Decomposition reactions never have compounds in their products.
- d. **True or False** (Circle One) In the decomposition of a hydrate, the water is removed from the hydrate and is written as a separate product.
- e. **True or False** (Circle One) In the decomposition of a chlorate, carbon dioxide is always one of the products.
- f. **True or False** (Circle One) When using a multivalent cation, you can use a different charge in your reactant and your product

16. Mixed Problems. For each of the following reactions, write a balanced equation for the reaction. Coefficients should be in terms of lowest whole numbers.

- a. Magnesium metal is burned in nitrogen gas.
- b. Lead foil is immersed in silver nitrate solution.
- c. A solution of ammonium sulfate is added to a solution of barium hydroxide.
- d. Ethanol(C_2H_5OH) is completely burned in air.
- e. Solutions of zinc sulfate and sodium phosphate are mixed.
- f. Solutions of silver nitrate and lithium bromide are mixed.
- g. A solution of ammonium thiocyanate is added to a solution of iron(II) chloride.
- h. Carbon disulfide vapor is burned in excess oxygen.
- i. A solution of sodium hydroxide is added to a solution of ammonium chloride.