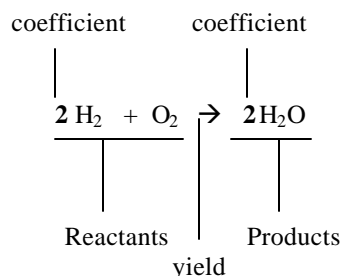


Chemical Equations & Single Displacement Reactions

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. 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. Remember, 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 we are 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** have to 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

H_2	N_2	O_2
F_2	Cl_2	Br_2
		I_2

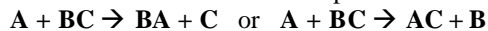
Lets practice writing some equations. Write the balanced chemical equations for each of the following word equations.

- iron + sulfur \rightarrow iron(III) sulfide
- cesium + cupric sulfate \rightarrow cesium sulfate + copper
- barium bromide dihydrate \rightarrow barium bromide + water
- potassium chlorate \rightarrow potassium chloride + oxygen
- water \rightarrow hydrogen + oxygen
- mercury(II) oxide \rightarrow mercury + oxygen
- potassium iodide + lead(II) nitrate \rightarrow lead(II) iodide + potassium nitrate
- chlorine + sodium bromide \rightarrow sodium chloride + bromine
- octane (C_8H_{18}) + oxygen \rightarrow carbon dioxide + water
- sodium carbonate \rightarrow sodium oxide + carbon dioxide

Now we will begin to look at some of the patterns in chemical equations. Please note that on your homework and exam you will be given the reactants and be expected to predict the products formed and also balance the final equation.

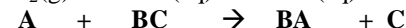
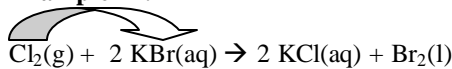
Single Displacement

In a single displacement reaction one element replaces another element in a compound. They follow one of the following two patterns:



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 or cr: solid or crystalline (used for ionic compounds)

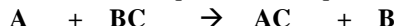
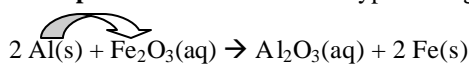
l: liquid

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.

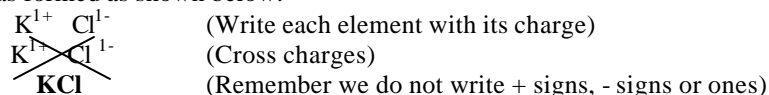
Not all single replacement reactions can occur. Before we can write the products for any single displacement equation, we **MUST** check the activity series to see if the displacement is possible. There is a cation and an anion activity series. I listed both to the right. They can also both be found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

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.

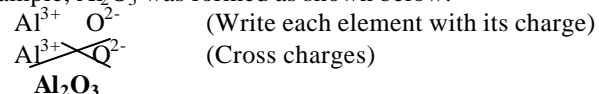
If I tried to reverse the reaction in example #2, let's see what would happen.
 $\text{Fe}(\text{s}) + \text{Al}_2\text{O}_3(\text{aq}) \rightarrow \text{N.R.}$

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.

Now look at the compounds formed in each of the products of example one and two. These formulas are determined by crossing charges of the cation and anion as we had done earlier this year when we first started writing formulas. In the first example, KCl was formed as shown below:



In the second example, Al_2O_3 was formed as shown below.



One more important issue: Whenever you see the formula for water, H_2O , you should treat it as a compound formed between **H (cation) and OH (anion)**. In fact, it would be helpful to you to change the formula to HOH whenever you see H_2O .

Anion Activity Series

F₂
Cl₂
Br₂
I₂

Cation Activity Series

Li
Rb
K
Cs
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Ni
Sn
Pb
H₂
Cu
Hg
Ag
Pt
Au

Now lets go step by step. Predict the products when solid sodium reacts with water.

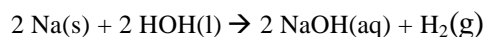
Description of Action	Action
1. Write the formulas for the reactants you are given.	1. $\text{Na(s)} + \text{HOH(l)} \rightarrow$ Remember, water is now HOH! Unless it is stated otherwise, water is always a liquid (l).
2. Once you recognize that this is a single replacement problem, determine whether the non-bonded element is a cation or anion. Then determine which element it will replace. Remember cations can only replace cations and anions can only anions.	2. Sodium is our non-bonded element and it is a cation . Therefore, it will try to replace Hydrogen, the cation in the compound.
3. Check your activity series chart to see if this replacement is possible. If the reaction cannot occur, label it N.R. If it can occur, go to step 4.	3. Sodium is higher up on the activity series chart than hydrogen so this replacement can occur.
4. Switch the appropriate elements and write the elements with their charges as superscripts. If the element that is being replaced is diatomic, be sure to write it with a two for its subscript.	4. $\text{Na(s)} + \text{HOH(l)} \rightarrow \text{Na}^{1+}(\text{OH})^{1-}(\text{aq}) + \text{H}_2(\text{g})$ All ionic compounds are crystalline. H_2 is a gas at room temperature.
5. Cross charges and remove any + signs, - signs and ones.	5. $\text{Na(s)} + \text{HOH(l)} \rightarrow \text{NaOH(aq)} + \text{H}_2(\text{g})$
6. Balance the equation.	6. $2\text{Na(s)} + 2\text{HOH(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(\text{g})$

You try one. Predict the products when chlorine gas reacts with aqueous lithium iodide.

Description of Action	Action
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.

Homework:

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:

e. s:

b. cr:

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 are the 11 elements that are gases at room temperature?

9. What are the only two elements that are liquid at room temperature?

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

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

12. Predict the products for each of the following reactants. Assume all ionic compounds are aqueous.

a. aluminum and lithium nitrate

b. copper and silver nitrate

c. hydrogen and gold(III) sulfide

d. water and barium

e. sodium iodide and bromine

f. zinc and hydrogen chloride

g. aluminum and copper(I) sulfate

h. hydrogen and ferric oxide

i. lead and cesium oxide

j. potassium fluoride and iodine

k. sodium chloride and fluorine

l. chlorine and magnesium bromide