Since the Middle Ages, when ancient physicians attempted to find a magical substance that would cure all diseases, humans have been fascinated with chemical reactions. In order to effectively describe these changes, a system for and series of short hand notation was developed to aid ancient and now modern chemists classify chemical reactions.

The names of the basic building blocks of matter (elements) have historically interesting names such as Ytterbium, named after a cute little town in Sweden, and Plumbus, named after a metal (lead) that was used for water pipes in ancient Rome. The names of compounds, or combinations of different elements, are much more complicated. To simplify matters, chemists use one or two letter abbreviations for the elements. Writing a compound is simplified by using a chemical formula, or a series of symbols that represent the elements present in the compound.

Chemical compounds, as we will learn, have definite, whole number ratios of various. Typically, the atoms in a compound are listed in the formula in the order (from left to right) that the elements appear on the periodic table. The number ratios of the atoms in a compound are shown by using subscripts (little numbers that are lower than the rest of the text) just to the right of the element. Examples of formulas are shown below.

NaCl sodium chloride, with 1 sodium atom and 1 chlorine atom
CO2 carbon dioxide, with 1 carbon atom for every 2 oxygen atoms
HCl hydrochloric acid, with 1 hydrogen atom for each chlorine atom

A chemical reaction involves elements and/or compounds combining, separating or changing partners in various ways. Again, describing such a complicated process in words is difficult, so a chemical reaction equation is used. The equation shows the chemical formula(s) of the starting compound(s), called reactants, and the final compound(s), called products. The reactants are always shown on the left, and the products on the right, and they are separated by an arrow to ensure that no one is confused on which direction the reaction is going. A general chemical reaction equation for a reaction called combination is shown below, and a specific example follows.

reactant A + reactant B \rightarrow product C  
C (s) + O2 (g) \rightarrow CO2 (g) 

If you would like to read the equation aloud, this is what the general reaction #1 would say: A reacts with B to make C. Equation 2 would read: Carbon reacts with oxygen to make carbon dioxide. The funny letters in parentheses in equation 2 represent the physical state that the matter is in, such as gas (g), liquid (l), solid (s), or dissolved in water (aq).

In order to aid chemists in recognizing and describing reactions, several types of reactions are classified into groups. Equation 2 is an example of a combination reaction, where two reactants combine to form 1 product. Examples of other types of reactions are listed below:

Decomposition, where one reactant decomposes or separates into 2 or more simpler products:

H2CO3 \rightarrow CO2 (g) + H2O (l)

Carbonic acid decomposes in water to make carbon dioxide gas and water.
Combustion, where a fuel (typically a compound with C and H atoms) reacts with oxygen (O₂) to make water, carbon dioxide and heat.

\[
\text{Fuel} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{heat} \\
C_3H_8(\text{g}) + O_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})
\]
Propane reacts with oxygen gas to make carbon dioxide gas and water.

Single replacement, where an element in a compound is replaced by another pure element. The products are the new compound, and a new element.

\[
\text{Compound} + \text{element 1} \rightarrow \text{new compound} + \text{element 2} \\
\text{CuSO}_4(\text{aq}) + \text{Zn (s)} \rightarrow \text{ZnSO}_4(\text{aq}) + \text{Cu (s)}
\]
Copper sulfate solution reacts with zinc metal to make zinc sulfate solution and copper metal.

Double replacement, where partners in two compounds switch places to make two new compounds.

\[
\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB} \\
\text{AgNO}_3(\text{aq}) + \text{NaCl (aq)} \rightarrow \text{AgCl (s)} + \text{NaNO}_3(\text{aq})
\]
Silver nitrate (aq) reacts with sodium chloride (aq) to make solid silver chloride and sodium nitrate (aq).

Precipitation reactions cause a solid to form, and this type of reaction can be just like the single or double replacement reaction types, since they can cause solids to form.

Detecting chemical changes.
Several obvious signs may be evident to show that a chemical reaction has occurred. These changes can be color, odor, temperature, appearance, or change of state.

Experiment

Materials: 14 stations labeled with station number, chemicals, and chemical amounts as indicated in the procedure below.

Hypothesis: What happens when you cause one or more chemicals to react?

Carry out the reactions as instructed. Record all of your observations. Be sure to use all of your senses! Look for changes such as color changes, sounds, temperature change and precipitates forming. Keep in mind the types of chemical reactions, because you will eventually classify the reactions that you see. If no reaction seems to be occurring, write NAR, short for No Apparent Reaction. Give each of the reactions several minutes before deciding on a result of NAR. After finishing the chemical reactions, we will work as a class on balancing the reactions, which means that each of the reactant atoms can be accounted for in the products. The capital M is a way chemists describe the how many of a compound are in 1 liter of water.
The Reactions:

1. In a test tube, mix 2 mL (½ inch) of 0.1 M calcium chloride [CaCl$_2$] with 2 mL of 0.1 M sodium phosphate [Na$_3$PO$_4$].

2. Heat a test tube containing ½ inch of copper sulfate pentahydrate [CuSO$_4$·(H$_2$O)$_5$]. Save this tube for later.

3. Add a few drops of water to a test tube containing ¼ inch of anhydrous copper sulfate [CuSO$_4$].

4. After it has cooled a bit, add a few drops of water to the test tube in #2.

5. Add a 1 inch piece of zinc [Zn] ribbon to a test tube containing 1 inch of 6 M hydrochloric acid [HCl]. If a gas evolves, test the identity of the gas by quickly inserting a burning wooden splint into the test tube.

6. In a test tube, mix ½ inch 2 M hydrochloric acid [HCl] and ½ inch of 1 M sodium carbonate [Na$_2$CO$_3$]. Again, if a gas forms, check the identity of the gas with a lit wooden splint.

7. Add a spatula tip full of manganese (IV) oxide [MnO$_2$] to a test tube containing 1.5 inches of 6% hydrogen peroxide [H$_2$O$_2$]. Check the identity of the gas.

8. Mix 1 inch 6 M HCl with 1 inch of 3 M NaOH.

9. Add 1 inch of sodium sulfate decahydrate [Na$_2$SO$_4$·(H$_2$O)$_{10}$] to a test tube and add a small bit of water.

10. Mix ½ inch of 3 M sulfuric acid [H$_2$SO$_4$] with 1 inch of 3 M sodium hydroxide [NaOH].

11. Mix 1 inch 0.1 M calcium chloride [CaCl$_2$] with 1 inch of 1 M Na$_2$CO$_3$.

12. Add a 1 inch piece of Zn ribbon to a test tube with 1 inch of 0.1 M CuSO$_4$.

13. Add a piece of copper (Cu) to a test tube with 1 inch of 0.1 M zinc sulfate [ZnSO$_4$].

14. Mix ½ inch 0.1 M CaCl$_2$ with ½ inch 0.1 M sodium nitrate NaNO$_3$.
**Experiment 17-Chemical Reactions Lab Report**

Name: ________________________________  Section: ___________________

For this lab, you need to balance each equation, and classify the reaction according to the types of reactions listed in the lab handout using C (combination), D (decomposition), Cu (combustion), S (single replacement), DR (double replacement) and P (precipitation).

<table>
<thead>
<tr>
<th>Type of Reaction</th>
<th>Equation</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. [ \text{CaCl}_2 (aq) + \text{Na}_3\text{PO}_4 (aq) \rightarrow \text{Ca}_3(\text{PO}_4)_2 (s) + \text{NaCl (aq)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>2. [ \text{CuSO}_4 (\text{H}_2\text{O})_5 + \text{heat} \rightarrow \text{CuSO}_4 (s) + \text{H}_2\text{O (g)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>3. [ \text{CuSO}_4 (s) + \text{H}_2\text{O (l)} \rightarrow \text{CuSO}_4 (\text{H}_2\text{O})_5 (s) ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>4. this is the same reaction as #3</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>5. [ \text{Zn (s)} + \text{HCl (aq)} \rightarrow \text{ZnCl}_2 (aq) + \text{H}_2 (g) ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>[ ___\text{H}_2 (g) + ___\text{O}_2 (g) \rightarrow ___\text{H}_2\text{O (g)} ]</td>
<td>The “popping” reaction induced with the match</td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>6. [ \text{HCl(aq)} + \text{Na}_2\text{CO}_3(aq) \rightarrow ___\text{CO}_2(g) + ___\text{NaCl(aq)} + ___\text{H}_2\text{O(l)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>7. [ ___\text{H}_2\text{O}_2(aq) \rightarrow ___\text{O}_2(g) + ___\text{H}_2\text{O(l)} ] (the MnO\textsubscript{2} is a catalyst, it does not react)</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>8. [ \text{HCl (aq)} + ___\text{NaOH (aq)} \rightarrow ___\text{NaCl (aq)} + ___\text{H}_2\text{O (l)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>9. [ ___\text{Na}_2\text{SO}_4 (\text{H}<em>2\text{O})</em>{10} \rightarrow ___\text{Na}_2\text{SO}_4 (aq) + ___\text{H}_2\text{O (l)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>10. [ ___\text{H}_2\text{SO}_4 (aq) + ___\text{NaOH} \rightarrow ___\text{H}_2\text{O (l)} + ___\text{Na}_2\text{SO}_4 (aq) ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>11. [ ___\text{CaCl}_2 (aq) + ___\text{Na}_2\text{CO}_3 (aq) \rightarrow ___\text{NaCl (aq)} + ___\text{CaCO}_3 (s) ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>12. [ ___\text{Zn (s)} + ___\text{CuSO}_4 (aq) \rightarrow ___\text{ZnSO}_4 (aq) + ___\text{Cu (s)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>13. [ ___\text{Cu (s)} + ___\text{ZnSO}_4 (aq) \rightarrow ___\text{CuSO}_4 (aq) + ___\text{Zn (s)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
<tr>
<td>14. [ ___\text{CaCl}_2 (aq) + ___\text{NaNO}_3 (aq) \rightarrow ___\text{Ca(NO}_3)_2 (aq) + ___\text{NaCl (aq)} ]</td>
<td></td>
<td>[ ___ ]</td>
</tr>
</tbody>
</table>
Fill in the table of compounds

<table>
<thead>
<tr>
<th></th>
<th>Br&lt;sup&gt;-&lt;/sup&gt;</th>
<th>S&lt;sup&gt;2-&lt;/sup&gt;</th>
<th>PO&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;3-&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>K&lt;sup&gt;+&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca&lt;sup&gt;2+&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe&lt;sup&gt;3+&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. What does the symbol (aq) mean?

2. What are the definitions of: atom, element, and compound?

3. Why do chemists classify reactions?

4. What is the difference between a product and a reactant?

Practice Balancing Equations Worksheet-Please balance the following equations, and classify the reaction. Answers are on next page (don’t peak until you’re done).

1) _____ Co(s) + _____ O<sub>2</sub>(g) \( \rightarrow \) _____ Co<sub>2</sub>O<sub>3</sub>(s)

2) _____ LiClO<sub>3</sub>(s) \( \rightarrow \) _____ LiCl(s) + _____ O<sub>2</sub>(g)

3) _____ Cu(s) + _____ AgC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>(aq) \( \rightarrow \) _____ Cu(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>(aq) + _____ Ag(s)

4) _____ C<sub>3</sub>H<sub>7</sub>OH(l) + _____ O<sub>2</sub>(g) \( \rightarrow \) _____ CO<sub>2</sub>(g) + _____ H<sub>2</sub>O(g)

5) _____ H<sub>2</sub>SO<sub>4</sub>(aq) + _____ Al(OH)<sub>3</sub>(aq) \( \rightarrow \) _____ Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>(aq) + _____ H<sub>2</sub>O(l)

6) _____ H<sub>2</sub>CO<sub>3</sub>(aq) + _____ NH<sub>4</sub>OH(aq) \( \rightarrow \) _____ (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>(aq) + _____ HOH(l)

7) _____ C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>(s) + _____ O<sub>2</sub>(g) \( \rightarrow \) _____ CO<sub>2</sub>(g) + _____ H<sub>2</sub>O(g)

8) _____ LiNO<sub>3</sub>(s) \( \rightarrow \) _____ LiNO<sub>2</sub>(s) + _____ O<sub>2</sub>(g)

9) _____ Pb(s) + _____ O<sub>2</sub>(g) \( \rightarrow \) _____ PbO(s)

10) _____ NaOH(aq) + _____ HCl(aq) \( \rightarrow \) _____ NaCl(aq) + _____ H<sub>2</sub>O(l)
These are the answers to the practice balancing problems.

1) \(4 \text{Co(s)} + 3 \text{O}_2(g) \rightarrow 2 \text{Co}_2\text{O}_3(s)\)

2) \(2 \text{LiClO}_3(s) \rightarrow 2 \text{LiCl(s)} + 3 \text{O}_2(g)\)

3) \(\text{Cu(s)} + 2 \text{AgC}_2\text{H}_3\text{O}_2(aq) \rightarrow \text{Cu(C}_2\text{H}_3\text{O}_2)_2(aq) + 2 \text{Ag(s)}\)

4) \(2 \text{C}_3\text{H}_7\text{OH(l)} + 9 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 8 \text{H}_2\text{O(g)}\)

5) \(3 \text{H}_2\text{SO}_4(aq) + 2 \text{Al(OH)}_3(aq) \rightarrow \text{Al}_2(\text{SO}_4)_3(aq) + 6 \text{H}_2\text{O(l)}\)

6) \(\text{H}_2\text{CO}_3(aq) + 2 \text{NH}_4\text{OH(aq)} \rightarrow (\text{NH}_4)_2\text{CO}_3(aq) + 2 \text{H}_2\text{O(l)}\)

7) \(\text{C}_6\text{H}_12\text{O}_6(s) + 6 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 6 \text{H}_2\text{O(g)}\)

8) \(2 \text{LiNO}_3(s) \rightarrow 2 \text{LiNO}_2(s) + \text{O}_2(g)\)

9) \(2 \text{Pb(s)} + \text{O}_2(g) \rightarrow 2 \text{PbO(s)}\)

10) \(\text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}\)