A Series of Chemical Reactions

INTRODUCTION

There are millions of different chemical reactions taking place in our world. Many of them fall into categories that display similar chemical processes. Three common processes are:

1. **Precipitation reactions**: Two soluble ionic compounds react to form an insoluble compound.

$$AgNO_3\ (aq)\ +\ NaCl\ (aq)\ \rightarrow\ NaNO_3\ (aq)\ +\ AgCl\ (s)$$

2. **Acid-Base reactions**: The H^+ from an acid reacts with the OH^- from a base to form water, while the remaining cation and anion form a salt.

$$HCl\ (aq)\ +\ NaOH\ (aq)\ \rightarrow\ NaCl\ (aq)\ +\ H_2O\ (l)$$

3. **Redox reactions**: Electrons are transferred from one substance to another.

$$MnO_2\ (s) + H_2C_2O_4\ (aq) + H_2SO_4\ (aq) \rightarrow\ MnSO_4\ (aq) + 2\ CO_2\ (g) + 2H_2O\ (l)$$

Many different types of reactions can be classified in the following:

A. **Combination reactions**: Two elements combine to form one product.

$$2\ Na\ (s)\ +\ Cl_2\ (g)\ \rightarrow\ 2\ NaCl\ (s)$$

B. **Decomposition reactions**: One substance breaks down into two or more elements.

$$2\ H_2O\ (l)\ \rightarrow 2\ H_2\ (g)\ +\ O_2\ (g)$$

C. **Single replacement reactions**: One element in a compound is replaced with another.

$$2\ AgNO_3\ (aq)\ +\ Zn\ (s)\ \rightarrow\ Zn(NO_3)_2\ (aq)\ +\ 2\ Ag\ (s)$$

$$2\ NaI\ (aq)\ +\ Cl_2\ (g)\ \rightarrow\ 2\ NaCl\ (aq)\ +\ I_2\ (s)$$

D. **Combustion reactions**: An element or compound reacts with oxygen to produce heat and light. A few other substances besides oxygen can also be found in combustion reactions.

$$CH_4\ (g)\ +\ 2\ O_2\ (g)\ \rightarrow\ CO_2\ (g)\ +\ 2\ H_2O\ (g)$$

There are also combination and decomposition reactions that involve compounds, rather than elements. These are often not redox reactions.

$$NH_3\ (g)\ +\ HCl\ (g)\ \rightarrow\ NH_4Cl\ (s)$$

$$CaCO_3\ (s)\ \rightarrow\ CaO\ (s)\ +\ CO_2\ (g)$$

In today's experiment, you will run a series of reactions on a piece of copper wire that will turn it from a wire into a pile of copper powder. Some of the steps are quite interesting to observe. You will be asked to classify the reactions taking place into one or another of the categories described above. In a greatly simplified diagram, the reactions you will run can be summarized as follows:

$$Cu\ (s) \rightarrow Cu(NO_3)_2\ (aq) \rightarrow Cu(OH)_2\ (s) \rightarrow CuO\ (s) \rightarrow CuSO_4\ (aq) \rightarrow Cu\ (s)$$

Detailed reactions for each step are as follows:

1) $8\ HNO_3\ (aq) + 3\ Cu\ (s) + O_2\ (g) \rightarrow 3\ Cu(NO_3)_2\ (aq) + 4\ H_2O\ (l) + 2\ NO_2\ (g)$

2) $Cu(NO_3)_2\ (aq) + 2\ NaOH\ (aq) \rightarrow Cu(OH)_2\ (s) + 2\ NaNO_3\ (aq)$

3) $Cu(OH)_2\ (s) \rightarrow CuO\ (s) + H_2O\ (l)$

4) $CuO\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + H_2O\ (l)$

5) $CuSO_4\ (aq) + Zn\ (s) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$

The steps of the experiment are numbered according to the above reactions. The data table asks that you assign to each reaction one of the types from this page. When you classify each reaction, you might find it helpful to do so on this page, and then transfer your answers to the data table. If the reaction falls into one of the sub-groups listed, use that name in your classification.

Name ______________________________________ Date _______ Grade ____

Pre-lab Assignment: A Series of Chemical Reactions.
MUST be completed before an experiment is started. The COPY pages will be collected as you enter the lab.

Q1. Give three examples, other than the ones listed in this experiment, of redox reactions.

Q2. When will reactions proceed to completion?

Q3. Define percent yield in general terms.

Q4. Name six methods of separating materials.

Q5. Give criteria in terms of temperature changes for exothermic and endothermic reactions.

Q6. If 1.65 g of $Cu(NO_3)_2$ are obtained from allowing 0.93 g of Cu to react with excess HNO_3, what is the percent yield of the reaction?

Q7. What is meant by the terms *decantation* and *filtration*?

Q8. When $Cu(OH)_2(s)$ is heated, Copper (II) oxide and water are formed. Write a balanced equation for the reaction.

Q9. When sulfuric acid and copper (II) oxide are allowed to react, copper (II) sulfate and water are formed. Write a balanced equation for this reaction.

Q10. When copper (II) sulfate and aluminum are allowed to react, aluminum sulfate and copper are formed. What kind of reaction is this? Write a balanced equation for this reaction.

EXPERIMENTAL PROCEDURE

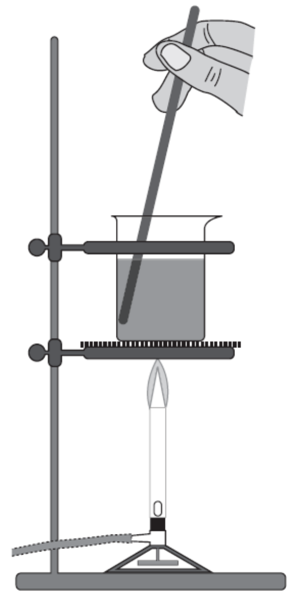
Supplies:
From your locker: 1-150 ml beaker, 1-100 ml beaker, 1 stirring rod, 1-50 mL and 1-10 mL graduated cylinder, 1 evaporating dish, 1 wire gauze, 1 beaker tongs
From the lab: 1 ring stand, 2 rings (greater diameter than 150 ml beaker), 1 Bunsen burner.
Special supplies: 1 copper wire (It will weigh about 0.25g)
Next to balances: Zinc metal
From the fume hoods (get as needed)
- concentrated HNO3.....................**CAUTION**
- 3 M NaOH....................................**CAUTION**
- 6 M H2SO4..................................**CAUTION**
- methanol

Be mindful of safety throughout the experiment. Caustic reagents will be used.

Procedure:
Safety: Carry out all steps that produce fumes in the hoods as described. Be especially careful with acids and bases. Wear your goggles at all time.
Part 1.
1) Obtain a piece of pre-cut copper wire (about 0.5g) and weigh it to the nearest milligram. Record the mass.
2) Bend it in half. Place it in the 150-mL beaker. Use a pencil to write your initials on the white area of the beaker. Erase any old marks. Take the beaker to the fume hood.
3) Transfer 2 mL of concentrated nitric acid into the beaker. Set the beaker down as the NO_2 gas evolves. Swirl the beaker occasionally. Record what you observe in the data table.
4) If it appears that some of the copper has not dissolved, and gas evolution has ceased, warm the beaker on the hot plate until gas begins to evolve once more.
5) When the copper is all dissolved, add deionized water until the beaker is half full. Use the 100-ml beaker to carry deionized water to the fume hood. After the water is added, you may take the beaker back to your work area for the rest of the experiment.

Part 2.
1) Obtain 15 ml of 3 M NaOH solution in a 50-ml graduated cylinder. Pour this into the beaker containing the copper solution while stirring constantly. Record your observations.
2) Rinse the graduated cylinder with tap water, then with deionized water, and allow it to drain.

Part 3.



1) Set up an apparatus as shown in the figure. Use a hot flame.
2) Also prepare some hot de-ionized water in a 125-mL placed on a hot plate.
3) Stir gently and constantly to prevent "bumping" (a phenomenon caused by local overheating in thick solutions or solutions containing solids).
4) Heat the solution until the blue color is entirely converted to black. This will occur before the solution boils.
5) Turn off the burner, but continue stirring for a short period of time until the heat has evened out. Allow the solid to settle.
6) Use beaker tongs to hold the beaker while you carefully pour off as much liquid from the solid as you can without losing any solid. This is called *decanting*.
7) *Pour the liquid into a waste beaker (for proper disposal into a waste container).*
8) When you grasp the beaker with the tongs, have the spout of the beaker facing in the direction in which you would point it if you were holding the beaker in your hand. This avoids awkward turning of your wrist to the outside or dipping your whole arm down to pour towards the front.
9) Take your beaker to the hot plate holding the large flask containing hot deionized water. Use the hot pads to pour water into the beaker to somewhere near the 125 ml mark on the beaker. Ask for help if the flask seems too heavy. This rinses side products of the reaction off of the CuO. Allow to settle, and then decant. Record your observations.

Part 4.

1) Use a 10-ml graduated cylinder to measure 7 ml of 6 M H_2SO_4 solution. Add this to the beaker while stirring. Record your observations.

Part 5.

1) Place a piece of weighing paper on a balance, tare it out, and use your scoopula to add about 1.0 g of fine mesh zinc metal.
2) Working in the fume hood, add the zinc to the beaker. Stir briskly until there are no more bubbles forming and the liquid is colorless. Decant the liquid into the waste container marked "Zinc Waste."
3) Use a sharpie to write your initials on an evaporating dish. Transfer the copper to the evaporating dish using a rubber policeman. Add about 5 ml of deionized water. Stir, allow to settle, then decant the water rinse into the sink. Repeat this step two more times. Then add 5 ml of methanol, stir, allow to settle, and pour the methanol into the waste container marked "Methanol Waste." Pour off as much as possible.
4) Set the evaporating dish on a hot plate set to low. Allow the methanol to evaporate off (this step must be done in the fume hood).
5) Check to see if the copper is dry. Poke it with a stirring rod to see if it seems dry. Do not heat it too long or the copper will oxidize.
6) Weigh the copper on the balance. Use weighing paper. Make sure you zero out the mass of the

weighing paper. Record the mass of the copper to the nearest milligram.
7) Spread the copper out on the weighing paper, and after you have finished with the observations, record the weight in data table. Weigh it again on another piece of creased* weighing paper to see if the mass remained constant. If it has not, this means that the copper is still wet. There is not enough time in this lab to bring the copper “to constant weight”, a technique commonly used to ensure that a sample is dry. Drying and weighing is repeated until the mass remains constant.
8) Use the smaller mass of copper in the calculations required in the experiment.
9) Place the copper in the container provided, label it, and show it to the instructor.

*Creasing the weighing paper before placing the copper on it helps the copper pour smoothly off of the paper.

Clean-Up. Clean all glassware that was used before leaving the laboratory. Place all waste solutions/precipitates into proper waste containers.

A Series of Chemical Reactions

Name ______________________________ Date ________ Grade ____

Partner's Name __________________________

DATA

Original mass of copper wire ___________ g

Recovered mass of copper powder ___________ g (first weighing) ___________ g (second weighing)

% recovered from original mass ___________ %

Observations	**Rewrite equations and Give Reaction Type**
Part 1	
Part 2	
Part 3	
Part 4	
Part 5	

Name ______________________________ **Date** ________ **Grade** ____

Post-Laboratory Questions and Exercises
(Due after completing lab. Show all your work. Report to correct number of significant figures and include appropriate units!)

Q1. In part 5, after the zinc is added, not only does copper metal appear, as is shown in the chemical equation given, but bubbles also appear. This is due to a single replacement reaction between Zn(s) and H_2SO_4(aq). Write out this balanced equation.

Q2. Zinc also reacts with HCl(aq). Write out this balanced equation.

Q3. Give reasons as to why you might expect your percent yield to be low. Give reasons as to why you might expect the percent yield to be high. Explain why your percent yield is high (>100%) or low (<100%)?

Q4. Reaction 4 is a variation of an acid-base reaction. Protons are transferred from an acid to the oxygen on CuO. Another common variation occurs when protons are transferred to a carbonate ion. Carbon dioxide and water form. Complete the following reaction:

$CaCO_3$ (s) + 2 HCl(aq) $\rightarrow$

Q5. Acid-base reactions are also called neutralization reactions. Write out and balance the neutralization reaction between NaOH and H_2SO_4. Also show the neutralization reaction between $Ca(OH)_2$ and HNO_3.

Q6. Consider the combustion of methane, CH_4:

$$CH_4(g) \quad + \quad 2\ O_2(g) \quad \text{----->} \quad CO_2(g) \quad + \quad 2\ H_2O(g)$$

Suppose 2 moles of methane is allowed to react with 3 moles of oxygen.

a) What is the limiting reagent? (show work)

b) How many moles of CO_2 can be made from this mixture? How many grams of CO_2?

Q7. Suppose 8.00 g of CH_4 is allowed to burn in the presence of 6.00 g of oxygen. How much (in grams) CH_4, O_2, CO_2, and H_2O remain after the reaction is complete?

Q8. How many milliliters of 6.0 *M* H_2SO_4 are required to react with 0.80 g of CuO according to Equation [4]?

Q9. If 2.00 g of Zn is allowed to react with 1.75 g of $CuSO_4$ according to Equation [5], how many grams of Zn will remain after the reaction is complete?

Q10. What is meant by the term limiting reagent?