Name _____ Date _____ Grade _____

Pre-Lab Questions: A Series of Chemical Reactions

The pre-lab questions MUST be completed before an experiment is started. To complete the pre-lab questions, read the introduction and procedure sections of this lab protocol. If you use another reference, please cite the source. Show all work and express answers to the correct number of significant figures with appropriate units.

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

Q2. Name any four techniques used for physical separation of materials.

Q3. What is the difference between 'decantation' and 'filtration'?

Q4. If you mix some chemicals in a flask that result in an *exothermic* reaction, what temperature change would you expect for this reaction?

Q5. If you mix some chemicals in a flask that result in an *endothermic* reaction, what temperature change would you expect for this reaction?

Q6. Define percent yield. How would you calculate percent yield in a chemical reaction?

Q7. For the chemical reaction in step 1 of this experiment, 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 Cu in the reaction?

Q8. In step 3, when $Cu(OH)_2(s)$ is heated, Copper (II) oxide and water are formed. Write a balanced equation for the reaction.

Q9. In step 4, 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 zinc are allowed to react, zinc sulfate and solid copper are formed. What type of reaction is this? Write a balanced equation for this reaction.

Experiment D: A Series of Chemical Reactions

Purpose

The purpose of this experiment is to carry out five different types of chemical reactions to convert copper from one form to another, and to see evidence of chemical changes and law of mass conservation.

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.

   e.g. $AgNO_3\,(aq) + NaCl\,(aq) \rightarrow NaNO_3\,(aq) + AgCl\,(s)$



Figure 1: Appearance of AgCl precipitate.

2. **Acid-Base reactions or Neutralization 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'.

   e.g. $HCl\,(aq) + NaOH\,(aq) \rightarrow NaCl\,(aq) + H_2O\,(l)$
   acid *base* *salt*

3. **Reduction-Oxidation or Redox reactions**: Electrons are transferred from one substance to another.

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

Redox reactions can be classified as many different types as shown below:

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. However, these are often not redox reactions.

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

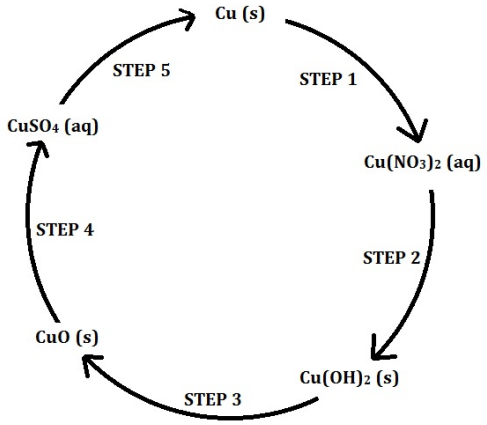
$$CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$$

In this experiment, you will run a series of reactions on a piece of copper wire that transforms copper into several different chemical compounds and, eventually, into an amount of copper powder. Some of the steps are quite interesting to observe, and they are excellent examples of some types of chemical reactions. In a simplified scheme, the reactions you will run can be summarized as follows:

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

Although you will start with copper solid (wire), the end-product is also copper solid (powder). This 'copper cycle' illustrates some of the principles of recycling.

Figure 2: The Copper Cycle



The detailed chemical reactions for each step are:

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

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

Step 3: $Cu(OH)_2\,(s) \triangleq CuO\,(s) + H_2O\,(l)$

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

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

During this experiment, you will be asked to classify the reactions taking place into one of the categories described in the 'Introduction'. 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 under Redox reactions, use that name in your classification (i.e., combination, decomposition, etc.).

Experimental Procedure

Safety Considerations for this experiment:

1. All steps in this experiment will be performed under the fume hood. Your instructor will turn on the fume hoods before you begin the experiment.
2. Be sure to wear your safety goggles and lab jacket at all times.
3. In this lab, you will be using concentrated HNO_3, 3M NaOH, and 6M H_2SO_4. Be mindful about the proper use of these acids and bases.
4. In case of a spill, notify your instructor immediately.
5. Clean all glassware used for the experiment before leaving the laboratory.
6. Place all solutions/precipitates/solids in the appropriate waste container.
7. Wash your hands before leaving the lab room.

Experiment

This experiment will involve:

1. Illustration of different types of chemical reactions,
2. Show how the quantity of an element can be carried through different chemical reactions without significant loss of mass, therefore, illustrating law of mass conservation,
3. Provide experience with fundamental laboratory procedures, such as transfer of reagents, decantation, filtration, washing, and dissolving a precipitate.

In this experiment, you will use a physical separation technique known as 'decantation'. Decantation is a process of carefully separating the liquid layer – called the supernatant fluid - from the precipitate in a reaction mixture. A **glass rod** is used to direct the liquid flow and to avoid splashing as shown in Figure 3.

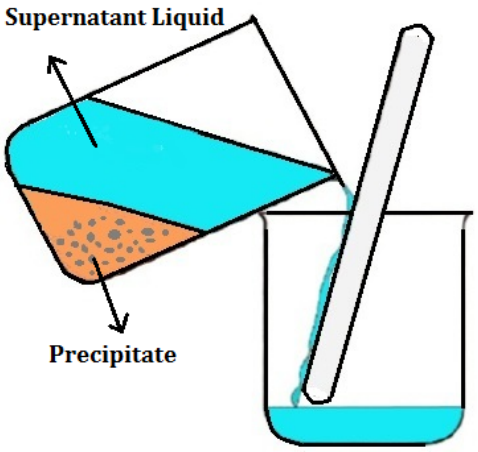


Figure 3: Decantation

Procedure

Step 1 (Must be completed in the fume hood)

1. Obtain a piece of pre-cut copper wire (about 0.25g) and weigh it to the nearest milligram. Record the mass in the data sheet.
2. Bend the copper wire 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. Using a pipet, transfer 2 mL of concentrated nitric acid into the beaker containing copper wire. Set the beaker down inside the fume hood as the NO_2 (gas) evolves. Swirl the beaker occasionally. Record what you observe in the data table.
4. If the gas evolution has ceased, and it appears that some of the copper has not dissolved, warm the beaker on the hot plate until gas begins to evolve again.
5. When the copper is all dissolved, add deionized water until the beaker is approximately half full.

Step 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 de-ionized water, and allow it to drain.

Step 3

1. Set up a hot plate at your lab bench to heat your reaction mixture.
2. Prepare some hot de-ionized water in a 125-mL beaker by placing it on a hot plate next to your reaction. Your hot plate can heat both the reaction and the water. *Caution: Do not leave your hot plate or the liquids on the hot plate unattended.*
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 (approximately 10 minute).
5. Turn off the heat, but continue stirring for a short period of time until the heat has evened out. Allow the solid to settle. Move the reaction to the benchtop with beaker tongs and fiberglass pad.
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.* 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.
7. Pour the liquid into a waste beaker (for proper disposal into a waste container).
8. Take your beaker to the hot plate that should have 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.

Step 4

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

Step 5 (Must be completed in the fume hood)

1. Place a piece of weighing paper on a balance, tare it out, and use your 'scoopula' or spatula to add about 1.0 g of fine mesh zinc metal.
2. Working in the fume hood, add the zinc to the beaker from step 4. Stir briskly until there are no more bubbles forming and the liquid is colorless. Decant the liquid into the waste container.
3. 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 waste container. Repeat this step one more times. Set the evaporating dish on a hot plate set to low. Allow the water to evaporate off.
4. 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.
5. Weigh the copper on the balance. Use weighing paper. To do this, make sure you zero out the mass of the weighing paper. Record the mass of the copper to the nearest milligram in the data sheet.
6. 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.
7. Use the smaller mass of copper in the calculations required in the experiment.
8. Show the copper to your instructor before disposing it in the ***"solid" waste container***.
9. Creasing the weighing paper before placing the copper on it helps the copper pour smoothly off of the paper.
10. Clean all glassware that was used before leaving the laboratory. Place all waste solutions/precipitates into proper waste containers.

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Name _____ Date _____ Grade _____

Data Sheet for Experiment: A Series of Chemical Reactions

Complete the following data table:

	Observations	Balanced Chemical Equation	Reaction Type
Step 1			
Step 2			
Step 3			
Step 4			
Step 5			

Percent Yield of Copper:

Original mass of copper wire _____ g

Recovered mass of copper powder _____ g (first weighing) _____ g (second weighing) _____ g (third weighing)

% recovered from original mass _____ %

Calculations:

In the space below, show calculations for % yield of copper.

Post-Lab Questions: A Series of Chemical Reactions

Please answer the following questions and show all work and units. Express all answers to the correct number of significant digits. **All completed questions must be submitted with your lab report.**

Q1. After zinc is added in step 5, 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. Based on your experimental data, 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. What is meant by the term limiting reagent?

Q7. Consider the combustion of methane, CH_4:

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

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 the given moles of methane and oxygen? How many grams of CO_2 is this?

Q8. 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?

Q9. How many milliliters of 6.0 *M* H_2SO_4 are required to react with 0.80 g of CuO according to step 4?

Q10. If 2.00 g of Zn is allowed to react with 1.75 g of $CuSO_4$ according to step 5, how many grams of Zn wil remain after the reaction is complete?