EXPERIMENT 12

Types of Chemical Reactions

Performance Goals

12–1 Carry out various chemical reactions.

12–2 Demonstrate that during chemical reactions mass is conserved.

CHEMICAL OVERVIEW

Chemical reactions can be classified as:

a. Combination or synthesis reactions in which two or more substances combine to form a single product.

b. Decomposition reactions, which are the opposite of the combination reactions, in that a compound breaks down into simpler substances.

c. Complete oxidation (burning) of organic compounds. In these reactions an organic compound reacts with oxygen yielding carbon dioxide, $CO_2(g)$, and water, $H_2O(g)$ or $H_2O(l)$.

d. Precipitation reactions, when the cation from one compound reacts with the anion of another compound yielding a solid product (precipitate). These reactions are also called double replacement or ion combination reactions since ions of the two reactants appear to change partners.

e. Oxidation–reduction reactions, during which one of the reactants gives off electrons (gets oxidized) and the other gains electrons (gets reduced).

f. Acid–base reactions, also called neutralization reactions, in which an acid reacts with a base yielding a salt and (usually) water.

In this experiment, we will carry out several different reactions, starting and ending with metallic copper. These reactions can be summarized as follows:

$$Cu \xrightarrow{HNO_3} Cu(NO_3)_2 \xrightarrow{NaOH} Cu(OH)_2 \xrightarrow{heat} CuO \xrightarrow{HCl} CuCl_2 \xrightarrow{Zn} Cu$$

SAFETY PRECAUTIONS

In this experiment you will use fairly concentrated acids and bases. When in contact with skin, most of these chemicals cause severe burns if not removed promptly. Always wear goggles when working with these chemicals. Reacting metal with nitric acid should *only* be carried out *in the hood.* Be careful when using a boiling water bath. Replenish the water from time to time as it becomes necessary.

PROCEDURE

1. Dissolution of Copper

A. Weigh a clean and dry 25 -mL Erlenmeyer flask on a milligram balance. Record this value on the work page.

B. Place about 100 mg of metallic copper (wire or granules) into the flask. Weigh the metal and flask to the milligram and record the mass.

C. *In the hood*, add 2 mL of 6 M nitric acid, HNO_3, to the flask and warm the contents on a hot plate. Brown vapors will form as the metal dissolves. Continue heating until no more brown fumes exist over the solution. Be sure not to evaporate all liquid. If needed, add two more milliliters of HNO_3. Allow the solution to cool to room temperature, then add 2 mL of deionized water.

2. Preparation of Copper(II) Hydroxide

To the solution prepared above, carefully add 6 M sodium hydroxide, NaOH, drop by drop, until the solution is basic to litmus (red paper turns blue). You can use magnetic stirring or swirl the contents of the flask while adding the NaOH. Do not dip the litmus paper directly into the solution. Instead, stir the solution with a glass rod and then touch the wet end of the rod to the paper. You should see a blue spot on the red paper when the solution is basic.

3. Preparation of Copper(II) Oxide

A. While stirring, heat the flask and its contents in a boiling water bath or on a magnetic stirring hot plate. In about 5 minutes, the blue $Cu(OH)_2$ will be converted to the black copper(II) oxide. If this does not occur, check your solution; it may not be basic enough. Swirl your solution and add more NaOH, then check with the litmus paper.

B. Allow the mixture to cool to room temperature. Remove the magnetic stirrer, if used. Rinse with a small amount of deionized water, collecting the rinse in the Erlenmeyer flask.

C. Set up a vacuum filtration apparatus using a small Büchner funnel (see Figure 31.2). Place a small filter paper into the funnel, moisten it with a small amount of deionized water, and start the vacuum. This will ''seat'' the filter paper and eliminates leakage around its edges. After this point, *do not* shut off the vacuum until the filtration is finished.

D. Transfer the black precipitate into the funnel, rinse the flask with 1 to 2 mL of deionized water, and pour into the funnel. The filtration may be a bit slow toward the end, due to small particles plugging up the filter paper pores. Wash the precipitate with 1 to 2 mL of deionized water. Discard the filtrate.

4. Converting Copper(II) Oxide to Copper(II) Chloride

Pour 6 mL of 6 M hydrochloric acid, HCl, into a 50-mL beaker. Using a spatula, transfer the black precipitate *and* the filter paper to the acid solution. Do not let the metal spatula come in contact with the acid. Stir the mixture with a glass stirring rod until the precipitate is completely dissolved. If needed, heat the solution on a hot plate. Remove the filter paper, using the glass rod, and rinse it with 1 to 2 mL of deionized water, adding the rinse to the green solution. *Do not* use metal forceps or tweezers because they will contaminate the solution. If some precipitate is stuck on the funnel, hold it over the beaker and rinse it with 1 to 2 mL of 6 M hydrochloric acid solution. Rinse the funnel with 1 to 2 mL of deionized water. This rinse should also be collected in the beaker.

5. Recovering the Metallic Copper

A. Weigh about 200 mg of zinc powder on a piece of preweighed weighing paper.

B. *In the hood*, **very** slowly, add a small amount of zinc powder to the copper(II) chloride solution. Stir after each addition. You will observe the formation of copper metal particles and vigorous evolution of hydrogen gas. This step is very critical, because too rapid formation of copper globules tends to enclose some of the unreacted zinc powder. This will result in an unrealistically high yield for the experiment.

C. Test for completeness of the reaction by adding 2 to 3 drops of your solution to 10 drops of concentrated ammonia, NH_3, in a small test tube. If a blue color appears, the reaction is not yet complete. Add a few more *small* portions of zinc powder and test again. Another indication that all the copper has been removed is the fact that the green solution turns colorless.

D. After the reaction is complete, add 5 mL of 3 M hydrochloric acid to the solution in the beaker and stir with a glass rod. This will hasten the removal of excess zinc present in your mixture. Metallic copper does not react with hydrochloric acid. Allow the solution to stand for 5 minutes, stirring occasionally.

E. Place a small funnel into a 250-mL Erlenmeyer flask or secure it with a clamp over a beaker. Weigh a piece of filter paper and place it in the funnel. First, pour the solution into the funnel, then transfer the solid copper. Use deionized water to rinse the beaker and be sure that all solid has been collected in the funnel. Wash the copper twice with 2-mL portions of deionized water.

F. Remove the filter paper and copper from the funnel, spread it out on a watch glass, and allow it to air dry. At the beginning of the next laboratory period weigh the copper and filter paper to the milligram and record the mass on the work page. Calculate the percentage of recovery (yield).

Name ______________________ Date ____________ Section ____________

Experiment 12

Advance Study Assignment

1. Balance each of the following equations and classify the reactions:

   a. $Cu(s) + HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O + NO_2(g)$

   ____

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

   ____

   c. $Cu(OH)_2(s) \rightarrow CuO(s) + H_2O$

   ____

   d. $CuO(s) + HCl(aq) \rightarrow CuCl_2(aq) + H_2O$

   ____

   e. $CuCl_2(aq) + Zn(s) \rightarrow Cu(s) + ZnCl_2(aq)$

   ____

2. Define a precipitation reaction.

3. If you started with 0.108 g of copper and at the end of the experiment you had recovered 0.099 g, calculate the percent recovery.

Name ______ Date ______ Section ______

Experiment 12

Work Page

Mass Data

Mass of flask (g)	
Mass of flask + Cu (g)	
Mass of weighing paper (g)	
Mass of weighing paper + Zn (g)	
Mass of filter paper (g)	
Mass of filter paper + Cu (g)	

Results

Mass of Cu, initial (g)	
Mass of Zn (g)	
Mass of Cu, recovered (g)	
Percent recovery	

Show all your calculations below:

Classify each reaction as a double replacement, synthesis, decomposition, precipitation, neutralization, or oxidation–reduction reaction:

Part 1. ______________________________

Part 2. ______________________________

Part 3. ______________________________

Part 4. ______________________________

Part 5. ______________________________

Name ______ *Date* ______ *Section* ______

Experiment 12

Report Sheet

Mass Data

Mass of flask (g)	
Mass of flask + Cu (g)	
Mass of weighing paper (g)	
Mass of weighing paper + Zn (g)	
Mass of filter paper (g)	
Mass of filter paper + Cu (g)	

Results

Mass of Cu, initial (g)	
Mass of Zn (g)	
Mass of Cu, recovered (g)	
Percent recovery	

Show all your calculations below:

Classify each reaction as a double replacement, synthesis, decomposition, precipitation, neutralization, or oxidation–reduction reaction:

Part 1. ______________________________

Part 2. ______________________________

Part 3. ______________________________

Part 4. ______________________________

Part 5. ______________________________