* Start before lab

EXPERIMENT

Analysis of a Penny

OBJECTIVES

- To become familiar with the evidence for chemical reaction.
- To translate word equations into balanced chemical equations.
- To determine the percentages of copper and zinc in a "zinc penny."
- To gain experience in observing evidence for chemical reactions.

DISCUSSION

Most ordinary chemical reactions can be classified as one of five basic types. The first type of reaction occurs when two or more **reactants** combine to form a single **product**. This type of reaction is called a *combination reaction.*

$$A + Z \rightarrow AZ$$

A second type of reaction occurs when a single compound breaks down into two or more simpler substances, often with the use of a **catalyst** to speed up the reaction. This type is called a *decomposition reaction.*

$$AZ \rightarrow A + Z$$

A third type of reaction occurs when one element displaces another. For this to occur, a more active element that is higher in the **activity series**, displaces an element that is lower in the series. This type is called a *single-replacement reaction.*

$$A + BZ \rightarrow AZ + B$$

A fourth type of reaction occurs when two substances in **aqueous solution** switch partners; that is, an anion of one substance exchanges with another. Usually one of the products is an insoluble **precipitate**. This type is called a *double-replacement reaction.*

$$AX + BZ \rightarrow AZ + BX$$

A fifth type of reaction occurs when an acid and a base react to form a salt and water. This is a special type of double-replacement reaction, and is called a *neutralization reaction.*

$$HX + BOH \rightarrow BX + HOH$$ (water)

Notice that the hydrogen ion in the acid neutralizes the hydroxide ion in the base to form water. If water is written as HOH, the neutralization is obvious and the equation may be easier to balance.

In this experiment, you will carefully observe and record evidence for a chemical reaction. Evidence for a reaction may include any of the following: (1) a gas is produced; (2) a precipitate is formed; (3) a color change is observed; (4) an energy change is noted. In order to describe the reaction, we use various symbols in the chemical equation. Table 10.1 lists some of these.

Table 1 Symbols in Chemical Equations

Symbol	*Translation*
→	produces, yields (the arrow separates reactants from products)
+	added to, reacts with (separates two or more reactants or products)
Δ	heat (written above →)
NR	no reaction (written after →)
(s)	solid or precipitate
(l)	liquid
(g)	gas
(aq)	aqueous solution

In order to write a chemical equation, it is necessary to predict the products from a reaction. Initially, this may be a difficult task. To aid you in writing chemical equations, the products are given for each reaction. You only need to translate the given word equations into balanced chemical equations. The following examples will illustrate.

Combination Reaction

calcium(s) + oxygen(g) → calcium oxide(s)

$$2\,Ca(s) + O_2(g) \rightarrow 2\,CaO(s)$$

Decomposition Reaction

lithium hydrogen carbonate(s) → lithium carbonate(s) + water(g) + carbon dioxide(g)

$$2\,LiHCO_3(s) \rightarrow Li_2CO_3(s) + H_2O(g) + CO_2(g)$$

Single-Replacement Reaction

tin(s) + hydrochloric acid(aq) → tin(II) chloride(aq) + hydrogen(g)

$$Sn(s) + 2\,HCl(aq) \rightarrow SnCl_2(aq) + H_2(g)$$

Double-Replacement Reaction				
potassium carbonate(aq)	+ calcium chloride(aq)	→	calcium carbonate(s)	+ potassium chloride(aq)
$K_2CO_3(aq)$	+ $CaCl_2(aq)$	→	$CaCO_3(s)$	+ $2\ KCl(aq)$

Neutralization Reaction				
nitric acid(aq)	+ barium hydroxide(aq)	→	barium nitrate(aq)	+ water
$2\ HNO_3(aq)$	+ $Ba(OH)_2(aq)$	→	$Ba(NO_3)_2(aq)$	+ $2\ HOH(l)$

Analysis of a "Zinc Penny"

In 1982 the United States Mint stopped making copper pennies because of the high price of copper, and began phasing in pennies made of zinc. The U.S. Mint cast the penny from pure zinc and electroplated the zinc with a layer of copper only 0.01 mm thick! The resulting "zinc penny" has the same appearance as a copper penny, however, it is about 20% lighter in mass.

In this experiment you will cut a "zinc penny" to expose the zinc and drop the penny into sulfuric acid. Although copper does not react with acid, zinc does react with sulfuric acid and leaves a thin copper shell. The chemical equations for the two reactions are:

$$Cu(s) + H_2SO_4(aq) \rightarrow NR$$

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

The following example exercise illustrates the calculation for the percentages of copper and zinc in a "zinc penny."

Example Exercise 1 • Percent Composition of a "Zinc Penny"

A 1995 penny having a mass of 2.536 g is cut to expose the zinc and dropped into sulfuric acid. After the zinc has reacted, the copper shell is found to have a mass of 0.063 g. Calculate the percentages of copper and zinc in the "zinc penny."

Solution: The percentage of copper is simply the ratio of the mass of Cu metal to the mass of the penny; that is,

$$\frac{0.063\ \cancel{g}}{2.536\ \cancel{g}} \times 100\% = 2.5\%\ Cu$$

The percentage of zinc is the ratio of the mass of Zn metal to the mass of the original penny. The mass of Zn corresponds to the mass loss of the penny: 2.536 g − 0.063 g = 2.473 g. Thus,

$$\frac{2.473\ \cancel{g}}{2.536\ \cancel{g}} \times 100\% = 97.52\%\ Zn$$

Experimentally, the 1995 "zinc penny" is 2.5% Cu and 97.52% zinc.

Students often ask if it is illegal to destroy a coin. According to a U.S. Treasury official: *"the law provides criminal penalties for anyone who **fraudulently** alters, defaces, mutilates, impairs, diminishes, falsifies, scales or lightens any of the coins coined at the mints of the United States."* Since we are not intending to defraud, this experiment is **legal**.

EQUIPMENT and CHEMICALS

A. Instructor Demonstrations

- crucible tongs
- deflagrating spoon
- magnesium, Mg ribbon
- sulfur, S powder

B–F. Student Experiments

- 13 × 100 mm test tubes (6)
- test tube holder
- test tube brush
- wash bottle with distilled water
- 250-mL Erlenmeyer flask
- 100-mL beaker
- copper(II) sulfate pentahydrate, solid $CuSO_4 \cdot 5H_2O$
- sodium hydrogen carbonate, solid $NaHCO_3$
- wooden splints
- copper, Cu wire
- magnesium, Mg turnings
- calcium, Ca turnings
- hydrochloric acid, 0.1 *M* HCl
- silver nitrate, 0.1 *M* $AgNO_3$
- copper(II) nitrate, 0.1 *M* $Cu(NO_3)_2$
- aluminum nitrate, 0.1 *M* $Al(NO_3)_3$
- potassium carbonate, 0.5 *M* K_2CO_3
- sodium phosphate, 0.5 *M* Na_3PO_4
- nitric acid, 0.1 *M* HNO_3
- sulfuric acid, 0.1 *M* H_2SO_4
- phosphoric acid, 0.1 *M* H_3PO_4
- sodium hydroxide, 0.5 *M* NaOH
- phenolphthalein acid-base indicator
- "zinc penny" (post-1982 mint date)
- dilute sulfuric acid, 3 *M* H_2SO_4
- acetone, C_3H_6O

PROCEDURE

General Directions: For Procedures A–E, record your observations in the Data Table. Since the "zinc penny" may require three hours to react completely, it is advisable to first perform Procedure F, and then begin Procedures A–E.

A. Combination Reactions—Instructor Demonstrations

1. Hold a 2-cm strip of magnesium ribbon with crucible tongs, and ignite the metal in a hot burner flame.
2. Put about 1 g of sulfur in a deflagrating spoon. Dim the lights and ignite the powder with a hot burner flame. Place the burning sulfur under a fume hood to avoid the pungent odor of the sulfur dioxide gas.

Note: The Instructor should demonstrate or closely supervise each of these exothermic reactions.

B. Decomposition Reactions

1. Put a pea-sized portion of copper(II) sulfate pentahydrate crystals into a dry test tube. Grasp the test tube with a test tube holder and heat with a burner. Note the color change, and observe the inside surface at the top of the test tube.
2. Add sodium hydrogen carbonate (baking soda) into a 250-mL Erlenmeyer flask so as to cover the bottom of the flask. Support the flask on a ring stand, using a wire gauze.
   (a) Hold a flaming splint in the mouth of the flask, and record how long it burns.
   (b) Heat the flask strongly with the laboratory burner until moisture is observed; hold a flaming splint in the mouth of the flask, and record how long it burns.

C. Single-Replacement Reactions

1. Put 20 drops of silver nitrate solution into a test tube, and add a small piece of copper wire. Allow a few minutes for reaction and then record your observation.
2. Put 20 drops of hydrochloric acid into a test tube, and add a small piece of magnesium metal. Record your observation.
3. Put 20 drops of distilled water into a test tube, and add a small piece of calcium metal. Record your observation. (ABOUT 1mL OF DISTILLED WATER)

D. Double-Replacement Reactions

1–3. Put 10 drops of silver nitrate, copper(II) nitrate, and aluminum nitrate solutions into separate test tubes #1–3. Add a few drops of potassium carbonate solution to test tubes #1, #2, and #3. Observe the reactions, and record your observations.

4–6. Put 10 drops of silver nitrate, copper(II) nitrate, and aluminum nitrate solutions into separate test tubes #4–6. Add a few drops of sodium phosphate solution to test tubes #4, #5, and #6. Observe the reactions, and record your observations.

E. Neutralization Reactions

1. Put 10 drops of nitric acid, sulfuric acid, and phosphoric acid into separate test tubes #1–3. Add one drop of phenolphthalein to each of the test tubes. Add drops of dilute sodium hydroxide solution into test tube #1 until a permanent color change is observed.

   Note: Phenolphthalein is an acid–base indicator that is colorless in acidic and neutral solutions, and pink in basic solutions.

2. Add drops of dilute sodium hydroxide solution to test tube #2 until a permanent color change is observed.
3. Add drops of dilute sodium hydroxide solution to test tube #3 until a permanent color change is observed.

F. Percentages of Copper and Zinc in a Penny

1. Obtain a post-1982 penny, and record the mint date. Use metal shears to cut the coin as shown in Figure 1.
2. Accurately weigh the penny on a balance, and record the mass.

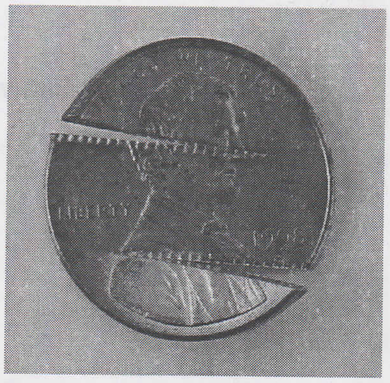

Figure 1 Exposing Zinc in a Penny A "zinc penny" should be cut as shown to ensure a rapid and complete reaction with sulfuric acid.

3. Drop the penny into a 100-mL beaker, and add about 20 mL of dilute sulfuric acid. The reaction requires about 3 hours for the zinc in the coin to react completely.

   Caution: If acid contacts your skin, wash immediately with water.

4. When the coin stops producing gas bubbles, discard the sulfuric acid in the sink.
5. Wash the coin with distilled water, and discard the wash solution. Rinse the coin with acetone, and discard the rinse solution. When the coin appears dry, weigh the copper shell and record the mass in the Data Table.
6. Calculate the percentages of copper and zinc in the penny.

NAME ____________________

DATE ____________________ SECTION ____________________

*PRELABORATORY ASSIGNMENT**

1. In your own words, define the following terms:

   activity series

   catalyst

   precipitate (ppt)

   product

   reactant

2. Explain the meaning of the following symbols:

   $\rightarrow$

   $+$

   Δ

   NR

   (g)

   (l)

   (s)

   (aq)

3. List four observations that are evidence of a chemical reaction.

   (a)

   (b)

   (c)

   (d)

4. What color is phenolphthalein acid-base indicator in:

   (a) an acidic solution? Clear

   (b) a basic solution? Pink

5. What is the acceptable range of mint dates for a "zinc penny"?

   After 1982

6. A 1990 penny has a mass of 2.545 g and produces a copper shell with a mass of 0.064 g. Refer to Example Exercise 1 and calculate the percentage of (a) copper metal and (b) zinc metal in the penny.

   $\frac{0.064}{2.545} \times 100 = 2.5\%$ Copper (2 SF)

   $2.545 - .064 = 2.481$ [illegible]

   $\frac{2.481}{2.545} \times 100 =$ (4 SF)

   97.49%

7. What safety precautions must be observed in this experiment?

NAME ____________________

DATE ____________________ SECTION ____________________

DATA TABLE

Procedure	*Observation*
A. Combination Reactions—Instructor Demonstrations	
1. $Mg + O_2 \xrightarrow{\Delta}$	
2. $S + O_2 \xrightarrow{\Delta}$	
B. Decomposition Reactions	
1. $CuSO_4 \cdot 5H_2O \xrightarrow{\Delta}$	
2. (a) $NaHCO_3$	
(b) $NaHCO_3 \xrightarrow{\Delta}$	
C. Single-Replacement Reactions	
1. $Cu + AgNO_3 \rightarrow$	
2. $Mg + HCl \rightarrow$	
3. $Ca + H_2O \rightarrow$	
D. Double-Replacement Reactions	
1. $AgNO_3 + K_2CO_3 \rightarrow$	
2. $Cu(NO_3)_2 + K_2CO_3 \rightarrow$	
3. $Al(NO_3)_3 + K_2CO_3 \rightarrow$	
4. $AgNO_3 + Na_3PO_4 \rightarrow$	
5. $Cu(NO_3)_2 + Na_3PO_4 \rightarrow$	
6. $Al(NO_3)_3 + Na_3PO_4 \rightarrow$	
E. Neutralization Reactions	
1. $HNO_3 + NaOH \rightarrow$	
2. $H_2SO_4 + NaOH \rightarrow$	
3. $H_3PO_4 + NaOH \rightarrow$	

Translating Word Equations into Balanced Chemical Equations

A. Combination Reactions—Instructor Demonstrations

1. magnesium(s) + oxygen(g) $\xrightarrow{\Delta}$ magnesium oxide(s)

   $Mg(s) + O_2(g) \xrightarrow{\Delta}$

2. sulfur(s) + oxygen(g) $\xrightarrow{\Delta}$ sulfur dioxide(g)

   $S(s) + O_2(g) \xrightarrow{\Delta}$

B. Decomposition Reactions

1. copper(II) sulfate pentahydrate(s) $\xrightarrow{\Delta}$ copper(II) sulfate(s) + water(g)

   $CuSO_4 \bullet 5H_2O(s) \xrightarrow{\Delta}$

2. sodium hydrogen carbonate(s) $\xrightarrow{\Delta}$ sodium carbonate(s) + water(g) + carbon dioxide(g)

   2 $NaHCO_3(s) \xrightarrow{\Delta}$

C. Single-Replacement Reactions

1. copper(s) + silver nitrate(aq) $\rightarrow$ copper(II) nitrate(aq) + silver(s)

   $Cu(s) + AgNO_3(aq) \rightarrow$

2. magnesium(s) + hydrochloric acid(aq) $\rightarrow$ magnesium chloride(aq) + hydrogen(g)

   $Mg(s) + HCl(aq) \rightarrow$

3. calcium(s) + water(l) $\rightarrow$ calcium hydroxide(s) + hydrogen(g)

   $Ca(s) + H_2O(l) \rightarrow$

F. Percentages of Copper and Zinc in a Penny **Mint Date** ________

mass of "zinc penny" ____________ g

mass of copper ____________ g

mass of zinc ____________ g

Show the calculation for the percentage of copper in the penny (see Example Exercise 1).

Percentage of copper ____________ %

Show the calculation for the percentage of zinc in the penny.

Percentage of zinc ____________ %

NAME ____________________

DATE ____________________ SECTION ____________________

POSTLABORATORY ASSIGNMENT

1. Provide the chemical formula for the following substances produced during the experiment.

   (a) the white smoke produced from reaction **A.1** ________

   (b) the colorless gas produced from reaction **B.1** ________

   (c) the flame-extinguishing gas produced from reaction **B.2** ________

   (d) the gray solid produced from reaction **C.1** ________

   (e) the colorless gas produced from reaction **C.2** ________

   (f) the cream ppt produced from reaction **D.1** ________

   (g) the blue ppt produced from reaction **D.2** ________

   (h) the white ppt produced from reaction **D.3** ________

2. Convert the following word equations to balanced chemical equations.

   (a) copper metal(s) + oxygen(g) $\xrightarrow{\Delta}$ copper(II) oxide(s)

   $2Cu + O_2 \xrightarrow{\Delta} 2CuO$

   (b) iron(III) carbonate(s) $\xrightarrow{\Delta}$ iron(III) oxide(s) + carbon dioxide(g)

   $Fe_2(CO_3)_3 \rightarrow Fe_2O_3 + 3CO_2$

   (c) sodium metal(s) + water(l) → sodium hydroxide(aq) + hydrogen(g)

   $2Na + 2H_2O \rightarrow 2NaOH + H_2$

   (d) aluminum metal(s) + sulfuric acid(aq) → aluminum sulfate(aq) + hydrogen(g)

   $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

   (e) barium chloride(aq) + lithium chromate(aq) → barium chromate(s) + lithium chloride(aq)

   $BaCl_2 + Li_2CrO_4 \rightarrow BaCrO_4 + 2LiCl$

   (f) acetic acid(aq) + calcium hydroxide(aq) → calcium acetate(aq) + water(l)

   $2CH_3COOH + Ca(OH)_2 \rightarrow Ca(C_2H_3O_2)_2 + H_2O$

F. Percentages of Copper and Zinc in a Penny **Mint Date** ________

mass of "zinc penny" ____________ g

mass of copper ____________ g

mass of zinc ____________ g

Show the calculation for the percentage of copper in the penny (see Example Exercise 1).

Percentage of copper ____________ %

Show the calculation for the percentage of zinc in the penny.

Percentage of zinc ____________ %

NAME ____________________

DATE ____________________ SECTION ____________________

POSTLABORATORY ASSIGNMENT

1. Provide the chemical formula for the following substances produced during the experiment.

   (a) the white smoke produced from reaction **A.1** __________

   (b) the colorless gas produced from reaction **B.1** __________

   (c) the flame-extinguishing gas produced from reaction **B.2** __________

   (d) the gray solid produced from reaction **C.1** __________

   (e) the colorless gas produced from reaction **C.2** __________

   (f) the cream ppt produced from reaction **D.1** __________

   (g) the blue ppt produced from reaction **D.2** __________

   (h) the white ppt produced from reaction **D.3** __________

2. Convert the following word equations to balanced chemical equations.

   (a) copper metal(s) + oxygen(g) $\xrightarrow{\Delta}$ copper(II) oxide(s)

   $2Cu + O_2 \rightarrow 2CuO$

   (b) iron(III) carbonate(s) $\xrightarrow{\Delta}$ iron(III) oxide(s) + carbon dioxide(g)

   $Fe_2(CO_3)_3 \rightarrow Fe_2O_3 + 3CO_2$

   (c) sodium metal(s) + water(l) → sodium hydroxide(aq) + hydrogen(g)

   $2Na + 2H_2O \rightarrow 2NaOH + H_2$

   (d) aluminum metal(s) + sulfuric acid(aq) → aluminum sulfate(aq) + hydrogen(g)

   $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

   (e) barium chloride(aq) + lithium chromate(aq) → barium chromate(s) + lithium chloride(aq)

   $BaCl_2 + Li_2CrO_4 \rightarrow BaCrO_4 + 2LiCl$

   (f) acetic acid(aq) + calcium hydroxide(aq) → calcium acetate(aq) + water(l)

   $2CH_3COOH + Ca(OH)_2 \rightarrow Ca(C_2H_3O_2)_2 + H_2O$

3. Complete and balance the following single-replacement reactions. If there is no reaction, write the symbol NR.

(a) $Zn(s)$ + $Ni(NO_3)_2(aq)$ → $Zn(NO_3)_2$ + Ni

(b) $Zn(s)$ + $Mg(NO_3)_2(aq)$ → $Zn(NO_3)_2$ + Mg

(c) $K(s)$ + $H_2O(l)$ → K_2O + $2H_2$

(d) $Mg(s)$ + $H_2SO_4(aq)$ → $MgSO_4$ + H_2

4. Circle the following compounds that are insoluble in water.

(a) $BaCl_2$

(c) $Zn(NO_3)_2$

(e) K_2S

(g) $(NH_4)_2CrO_4$

(i) $Ca(C_2H_3O_2)_2$

(b) $Al(OH)_3$
(d) $MgCO_3$
(f) $Co_3(PO_4)_2$
(h) $PbSO_4$
(j) Hg_2I_2

5. (optional) A 1980 penny weighing 3.072 g is dissolved in nitric acid, and copper metal is electroplated from the resulting solution. If the mass of electroplated copper is 2.918 g, what are the percentages of copper and zinc in the 1980 penny?

$Cu = \frac{2.918\,g}{3.072\,g} \times 100 = 94.9\%$

94.99 % Cu

$Zn = \frac{.154\,g}{3.072\,g} \times 100 = 5.0\%$

5.013 % Zn