# 6A Stoichiometric Analysis of an Iron-Copper Single Replacement Reaction

Stoichiometry is an important field of chemistry that uses calculations to determine quantities such as the masses of reactants and products in chemical reactions. The word *stoichiometry* is derived from two Greek words: *stoicheion* (meaning "element") and *metron* (meaning "measure"). In other words, it is a very mathematical part of chemistry. We can find examples of its use in many chemical industries. Chemical engineers regularly use stoichiometry to estimate how much gold is present at a mine site or how much fertilizer can be manufactured from a given amount of polluting sulfur dioxide gas.

The reaction that occurs in this experiment is called a single replacement reaction and is described by the following balanced chemical equation:

$$Fe(s) + CuCl_2(aq) \rightarrow FeCl_2(aq) + Cu(s)$$

In this experiment, you will determine the moles of iron atoms reacted and moles of copper atoms produced, then calculate the corresponding mole ratio.

The mining industry often utilizes similar reactions to recover valuable metals from solutions that have formed in ponds at or near mine sites. Also, chemical analysis and calculation of ore content is vital to the industry. Even though iron and copper, along with gold, silver, lead, and antimony, were known metals in very early times, it has only been in modern times that chemists have been able to determine accurate analyses of their presence. Iron and copper occur naturally in the earth's crust typically as oxides or sulfides. Today an ore containing 4% copper is considered high-grade, while iron producers have little interest in ores containing less than 20-30% iron.

## OBJECTIVES

1. to determine the number of moles of iron reacted
2. to determine the number of moles of copper produced
3. to calculate the ratio of moles of copper to moles of iron

## SUPPLIES

**Equipment**
2 beakers (250 mL)
crucible tongs
centigram balance
plastic teaspoon
stirring rod
wash bottle
sandpaper
hot plate
heat resistant mat
lab apron
safety goggles

**Chemical Reagents**
copper(II) chloride crystals
2 iron nails (approx. 5 cm)

## PROCEDURE

### Part I: Determining the Mass of Iron Reacted

1. Put on your lab apron and safety goggles.
2. Measure and record the mass of a clean, dry 250 mL beaker in your copy of Table 1 in Experimental Results. This mass will be needed at the end of the experiment.
3. Add one level scoop (plastic teaspoon) of copper(II) chloride crystals to the beaker. Add approximately 50 mL of water to the beaker and use a stirring rod to dissolve all the copper(II) chloride crystals.
4. Obtain two clean nails and use a piece of sandpaper to remove any coating from each nail's surface. Measure and record the combined mass of the nails.
5. Place the nails into the copper(II) chloride solution and let them sit for about 20 min. (See Figure 6A-1.) Observe what happens as the reaction proceeds. Look for solid copper forming while the iron nails react. Record your qualitative observations.
6. Use crucible tongs to hold one nail at a time above the beaker. Use water in a wash bottle to rinse off any remaining copper from the nails before removing them completely from the beaker. (See Figure 6A-2.) If necessary, use a stirring rod to scrape any excess copper from the nails and rinse the copper back into the beaker. Set the nails aside to dry on a paper towel. Also, wash and dry the metal tongs to prevent the tongs from reacting!
7. After the nails have completely dried, measure and record the mass of the nails.

**CAUTION**

Copper(II) chloride is poisonous. Wash any spills off skin or clothing with plenty of water.

**Figure 6A-1** *Reacting the nails*

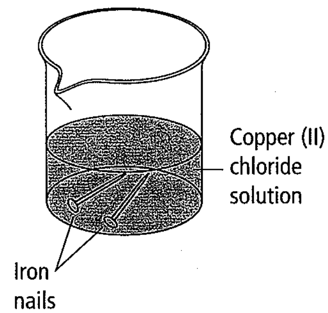
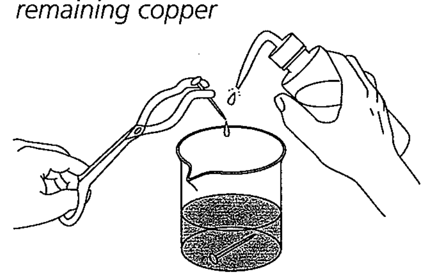



**Figure 6A-2** *Rinsing the nails to remove remaining copper*



### Part II: Determining the Mass of Copper Produced

1. *Decant* means to pour off only the liquid and leave the solid behind from a container that is holding both solid and liquid. Carefully decant the liquid from the solid into a second 250 mL beaker. (See Figure 6A-3.) Rinse with water and decant again.
2. Place the beaker containing the wet copper on a hot plate set at medium. Heat gently until the copper appears to have dried. Set the beaker on a heat resistant mat to cool.

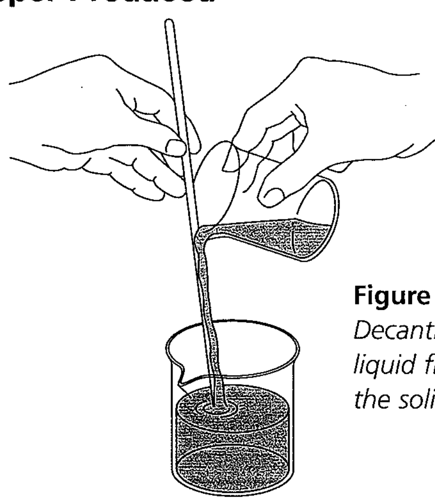


**Figure 6A-3** *Decanting the liquid from the solid*

3. Measure and record the mass of the beaker containing the copper.
4. Clean up all of your materials.
5. Before leaving the laboratory, wash your hands thoroughly with soap and water.

## REAGENT DISPOSAL

Rinse all solutions down the sink with copious amounts of water. Any solid waste should go into the designated waste container.

## POST LAB CONSIDERATIONS

The chemical reaction in this experiment has been:

$$Fe(s) + CuCl_2(aq) \rightarrow FeCl_2(aq) + Cu(s)$$

Therefore, it will be interesting to see if your ratio of copper produced to moles of iron reacted matches the mole ratio in the above balanced equation. These mole values will simply be calculated from the mass in grams of the chemicals consumed and produced.

## EXPERIMENTAL RESULTS

**Table 1**

| | Mass (g) |
|---|---|
| empty, dry beaker | |
| two iron nails (before the reaction) | COMPLETE IN YOUR NOTEBOOK |
| two iron nails (after the reaction) | |
| beaker + copper (dry) | |

Qualitative observations

## ANALYSIS OF RESULTS

1. Use your data to determine the mass of iron reacted.
2. Calculate the number of moles of atoms of iron reacted.
3. Use your data to determine the mass of copper produced.
4. Calculate the number of moles of atoms of copper produced.
5. Calculate the ratio of moles of copper produced to moles of iron reacted. Under ideal conditions, what should have been expected? (Hint: Refer to the equation in the Post Lab Considerations.)

## FOLLOW-UP QUESTIONS

1. If the tongs used in the experiment were made of pure iron, what might happen if the tongs were allowed to remain in contact with the $CuCl_2$ solution?

2. A student carelessly allows some aluminum tongs to sit in a beaker containing $CuCl_2$ solution for a period of time and a reaction occurs.

| | |
|---|---|
| Original mass of tongs | 85.1 g |
| Final mass of tongs | 73.2 g |

   a. Write the balanced chemical equation for the reaction.
   b. Calculate the moles of atoms of aluminum that reacted.
   c. Calculate the number of atoms of aluminum that reacted.
   d. Calculate the moles of atoms of copper that are produced.
   e. Calculate the mass of copper that is produced.

## CONCLUSION

State the results of Objective 3.