Moles of Iron and Copper

The mole is a convenient unit for analyzing chemical reactions. The mole is equal to 6.02×10^{23} particles, or Avogadro's number of particles. More importantly, however, the mass of a mole of any compound or element is the mass in grams that corresponds to the molecular formula, or atomic mass. Simply stated, the atomic mass of copper is 63.5 u, which means that the mass of one mole of copper atoms is 63.5 g. Likewise, the molecular mass of water is 18.0 u, and the mass of one mole of water molecules is 18.0 g.

The mole is the common language in chemical reactions. In this experiment, you will observe the reaction of iron nails with a solution of copper(II) chloride and determine the number of moles involved in the reaction.

Iron and copper, along with gold, silver, lead, and antimony, were known in very early times. Iron and copper occur naturally in the earth's crust as oxides or sulfides. Chemical analysis and calculation of ore content is vital to the mining industry. Today an ore containing 3–4% copper is considered high-grade, while iron producers are little interested in ores containing less than 20–30% iron.

OBJECTIVES

1. to determine the number of moles of copper produced in the reaction of iron and copper(II) chloride
2. to determine the number of moles of iron used up in the reaction of iron and copper(II) chloride
3. to determine the ratio of moles of iron to moles of copper
4. to determine the number of atoms and formula units involved in the reaction.

MATERIALS

Apparatus

beakers (250 mL)
wash bottle
stirring rod
crucible tongs
centigram balance
drying oven
safety goggles
lab apron
plastic gloves
sandpaper or emery cloth
face shield

Reagents

copper(II) chloride
2 iron nails (approx. 5 cm)
1*M* hydrodhloric acid
distilled water

PROCEDURE

1. Find the mass of a clean, empty, dry 250 mL beaker. Record the mass to the nearest 0.01 g.
2. Add approximately 5 g of copper(II) chloride crystals to the beaker. Find the mass and record it in your notebook.
3. Add 25 mL of distilled water to the beaker. Swirl the beaker around to dissolve all of the copper(II) chloride crystals.
4. Obtain two clean, dry nails. If the nails are not clean, use a piece of sandpaper to make the surface of the nail shiny. Find the mass of the nails and record it in your notebook.

CAUTION: Copper(II) chloride is very poisonous and can kill you. Do not get it in your mouth. Do not swallow any.

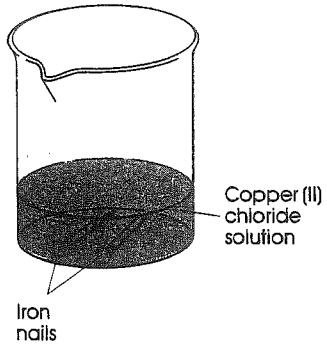
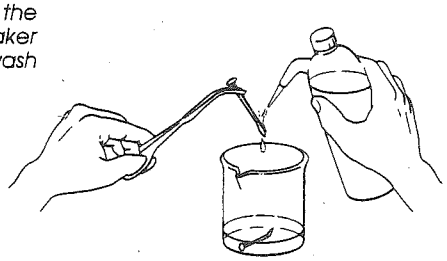


Figure 4B-1

5. Place the nails into the copper(II) chloride solution, as shown in Figure 4B-1. Leave them undisturbed for approximately 20 min. During that time, you should see the formation of copper in the beaker. At the same time, some of the iron will be used up.

6. Use the tongs to carefully pick up the nails, one at a time. Use distilled water in a wash bottle to rinse off any remaining copper from the nails before removing them completely from the beaker. (See Figure 4B-2.) If necessary, use a stirring rod to scrape any excess copper from the nails. Set the nails aside to dry on a paper towel.

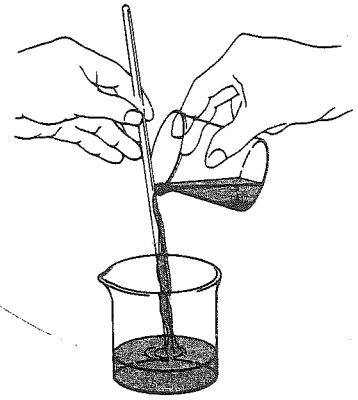
Figure 4B-2 *Any copper remaining on the nails may be washed back into the beaker with the use of distilled water from a wash bottle.*



7. After the nails are completely dry, find the mass of the nails and record it in your notebook.

8. *Decant* means to pour off only the liquid from a container that is holding both solid and liquid. Carefully decant the liquid from the solid. (See Figure 4B-3.) Pour the liquid into another beaker so that in case you overpour, you can still recover the solid.

Figure 4B-3 *When decanting, it is helpful to direct the liquid into the second beaker along a stirring rod, as shown here.*



9. After decanting, rinse the solid again with about ~~25~~ 10 mL of distilled water. Decant again. Repeat this step three or four more times.

10. Next, wash the solid with about ~~25~~ 10 mL of 1*M* hydrochloric acid. Decant again; then, once more, clean the solid with ~~25~~ 10 mL of distilled water.

11. After the final washing with water, place the copper in a drying oven to dry.

12. Allow the copper to become completely dry, then find the mass of the beaker plus the copper and record it in your notebook.

13. Clean up all of your materials. Before you leave the laboratory, wash your hands thoroughly with soap and water; use a fingernail brush to clean under your fingernails.

CAUTION: Hydrochloric acid is corrosive to skin, eyes, and clothing. When handling 1M hydrochloric acid, wear safety goggles, lab apron, and use a full face shield and gloves. Wash spills and splashes off your skin and clothing immediately using plenty of water. Call your teacher.

REAGENT DISPOSAL

Rinse all solutions down the drain with plenty of water. Place solids in the designated waste containers.

POST LAB DISCUSSION

In this experiment, you have reacted some of the iron from the nail at the same time as you have produced some copper. In order to find the moles of each of these substances, you will need to divide the mass of the iron used or the copper produced by the molar mass. You can also determine the moles of copper(II) chloride that you started with by dividing the mass of the copper(II) chloride by the molar mass. By multiplying by Avogadro's number, you will be able to determine the total number of atoms involved in the reaction. Finally, you will determine the ratio of moles of iron used to moles of copper produced.

DATA AND OBSERVATIONS

Before the reaction:

Mass of empty, dry beaker

Mass of beaker + copper(II) chloride

Mass of two iron nails

After the reaction:

Mass of two iron nails

Mass of beaker + copper (dry)

QUESTIONS AND CALCULATIONS

1. Find the following masses by doing the appropriate subtractions:
   a. mass of iron used in the reaction
   b. mass of copper(II) chloride used
   c. mass of copper produced
2. Find the number of moles of the following.
   a. moles of iron used
   b. moles of copper produced
3. Find the number of atoms of each of the substances involved in the reaction.
   a. atoms of iron used
   b. atoms of copper produced
4. Calculate the ratio of moles of copper produced to moles of iron used.
5. Was there any evidence that some of the copper(II) chloride was left in the beaker? Explain.

FOLLOW-UP QUESTIONS

1. Suppose that you have an unlimited supply of copper(II) chloride to react with iron. How many moles of copper would be produced by reacting 34.0 g of iron with the copper(II) chloride solution?
2. How many moles of iron would have been used up if 45.0 g of copper were to be produced?
3. How many atoms of copper would be involved in problem 2?
4. How many atoms of iron would be involved in problem 2?
5. How many grams of copper would be produced if 456 g of iron were reacted?

CONCLUSION

State the results of Objective 3.