LESSON **23**

Chemical Reactions Involving Metals

CORBIS/DIGITAL STOCK

The ancient Egyptians made part of Tutankhamen's throne from gold. Gold is valued for its scarcity. If gold is so scarce, why was it one of the first metals to be used?

INTRODUCTION

Earth's crust contains large amounts of many different metals, but pure chunks of metals are rarely found. Aluminum, for example, is the most common metal in Earth's crust, but it is never found naturally as a piece of aluminum metal. Aluminum exists naturally only combined with other elements, as aluminum compounds. You know that iron reacts with oxygen in the air. Would you expect to find a lot of pure iron metal lying around? Some metals, such as copper and gold, can be found as nuggets of pure metal. Why is it possible to find a rare metal, such as gold, in the form of pure nuggets, but not a common metal, such as magnesium? In this lesson, you will investigate the differences in the chemical properties of some metals. After this lesson, you may be able to answer some of these questions.

OBJECTIVES FOR THIS LESSON

Conduct an inquiry to compare how different metals react with acid.

Discuss how differences in the chemical properties of metals affect how they are extracted from their ores and used.

Design and conduct an experiment to compare how different metals corrode.

Getting Started

1. You know that metals have many properties in common. But do metals also have properties that differ from one another? Discuss with the members of your group how metals may differ in their properties. Be prepared to contribute your ideas to a class discussion.

2. Use the information you collected in Table 1 on Student Sheet 21.1a and your observations from Inquiry 22.2 to find out how one of the following metals reacts with oxygen in the air: copper, iron, magnesium, sodium, aluminum, zinc, calcium, and tin. Your teacher will assign a metal to your group.

3. Report on your findings. After your teacher lists your results, write the list in your science notebook. You will use this list later in the lesson.

MATERIALS FOR LESSON 23

For you

- 1 copy of Student Sheet 23.1: Comparing the Reaction of Different Metals With Acid
- 1 copy of Student Sheet 23.2: Investigating Corrosion
- 1 pair of safety goggles

For you and your lab partner

- 1 test tube rack
- 4 test tubes
- 1 lab scoop
- 1 bottle containing dilute hydrochloric acid
- 1 thermometer
- 1 metric ruler

For your group

- 1 jar of magnesium ribbon pieces
- 1 jar of granular zinc
- 1 jar of copper filings
- 1 jar of iron filings
- 1 plastic container
- 1 black marker
- 2 cotton balls
- 1 bottle of vegetable oil
- 5 labels
- Access to boiled water
- Access to anhydrous calcium chloride

Inquiry 23.1
Comparing the Reactions of Different Metals With Acid

PROCEDURE

1. One student from your group should collect a plastic box containing the materials.

2. Check the items against the materials list.

3. Remove the materials from the plastic box that you and your lab partner will use. You will share the jars of elements with the other pair in your group.

4. Pass around the jars and examine the elements. Your teacher will ask you some questions about the characteristic properties of the substances in the jars.

SAFETY TIPS

You must wear your safety goggles *throughout the lesson*.

You will be handling dilute hydrochloric acid. If you spill it on your clothes or your skin, wash it off immediately with lots of water. If you get some in your eyes, wash it out with lots of water. If you spill it on the bench, immediately inform your teacher.

Immediately inform your teacher of any accidents you have involving acid.

5. Listen carefully while your teacher reviews Steps 6 through 11 below. Reread the procedure before starting the experiment.

6. Place the four test tubes in the test tube rack.

7. Pour hydrochloric acid into each tube to a depth of 5 cm. Use your ruler to measure the acid in the test tube.

8. Add two lab scoops of iron filings to the first test tube. Immediately place the thermometer in the tube and measure the temperature (see Figure 23.1).

9. Carefully observe what happens in the test tube. After a few minutes, measure the temperature again.

Figure 23.1 *Watch what happens in the test tube. Carefully measure any temperature changes.*

10. Record your observations and temperature measurements in Table 1 on Student Sheet 23.1.

11. Repeat Steps 8 through 10 with another metal and a new test tube containing acid. Perform the same procedure with the remaining two metals.

12. Use your observations and measurements to help you answer the following questions on Student Sheet 23.1: Did any chemical reactions take place? What evidence was there that chemical reactions were occurring? Did all the metals react with the acid? Of those that did react, did they all behave in the same way? Did the products of the reactions look the same? Were there any temperature changes? If so, did the temperature increase or decrease? Were the temperature changes the same for all of the metals?

13. Your teacher will conduct a demonstration with the metals you used in this inquiry.

14. The metal that reacts the fastest with the acid is the most reactive. Use your results from Table 1, your answers to the questions in the student sheet, and your observations of the demonstration to complete Table 2 on Student Sheet 23.1.

15. Is there any similarity between the information in Table 2 and the information you collected in "Getting Started"? Write your answer on Student Sheet 23.1.

16. Clean up your work area. Pour the acid and any remaining metal into the bucket provided by your teacher. *Do not pour it down the sink.* Wash out the test tubes with lots of water before returning them, with the other materials, to the plastic box.

Inquiry 23.2
Investigating Corrosion

PROCEDURE

1. In this inquiry you will be working in your group. Discuss with the other members of your group what you think the word "corrode" means. Your teacher will ask you for your definition.

2. Think about the following questions and then discuss your ideas with the other members of your group:

   A. Do metal objects that are placed outdoors corrode?

   B. What causes corrosion?

   C. Do all metals corrode?

3. In this inquiry, you will consider how to design an experiment to compare how typical environmental conditions (that is, exposure to air and water) cause different metals to corrode. The metals you will investigate are the same ones you used in Inquiry 23.1: magnesium, zinc, iron, and copper. Discuss with the members of your group how you could set up an inquiry to determine the effects of air and water on one of these metals. Look at the apparatus in the plastic box to give you some ideas. Think about the following questions:

   A. What conditions will you need to create to show that both air and water affect the corrosion of metals?

   B. How will you create these conditions?

   C. How will you ensure that all comparisons you make are fair?

4. After 5 minutes of group discussion, your teacher will conduct a brainstorming session of your ideas.

5. Use the class procedure to complete the first two columns of Table 1 on Student Sheet 23.2.

6. Your group will set up the apparatus to investigate the corrosion of one of the metals. Your teacher will assign a metal to your group. Write the name of the metal on the student sheet.

7. Using the labels and a marker, label each test tube with the numbers used in column 1 of Table 1. Also label the plastic container with the names of the members of your group and the name of the metal you are investigating.

8. As you set up each test tube, stand it in the plastic container. Place the container in the designated storage place (see Figure 23.2). You will look at the results of this experiment in about 4 days.

9. After about 4 days, record your observations in Table 1 on Student Sheet 23.2.

10. Discuss the results with the other members of your group and write in Table 1 your conclusions and any other notes you may have for each tube.

11. Your teacher will help you collect the results for all the metals from different groups. Summarize the class results in Table 2 on Student Sheet 23.2. Write your own conclusions for each metal.

12. Use the class results to answer the following questions on Student Sheet 23.2: Did all the metals corrode? Did all the metals corrode to the same extent? What is the relationship between the rate at which a metal corrodes in the presence of air and water and the rate at which it reacts with acid?

Figure 23.2 *Place the numbered tubes in the labeled container and put them in the place designated by your teacher.*

REFLECTING ON WHAT YOU'VE DONE

1. Review the results from both inquiries as well as the information you collected in "Getting Started." Do you recognize any similarities between the data obtained from the two inquiries? Be prepared to contribute your ideas about the chemical reactivity of metals to a class discussion.

2. On your student sheet, write a short paragraph about what you have found out about the chemical reactivity of metals (see Figure 23.3) and how this knowledge can be applied to choosing metals to do specific jobs (for example, use of copper to make water pipes).

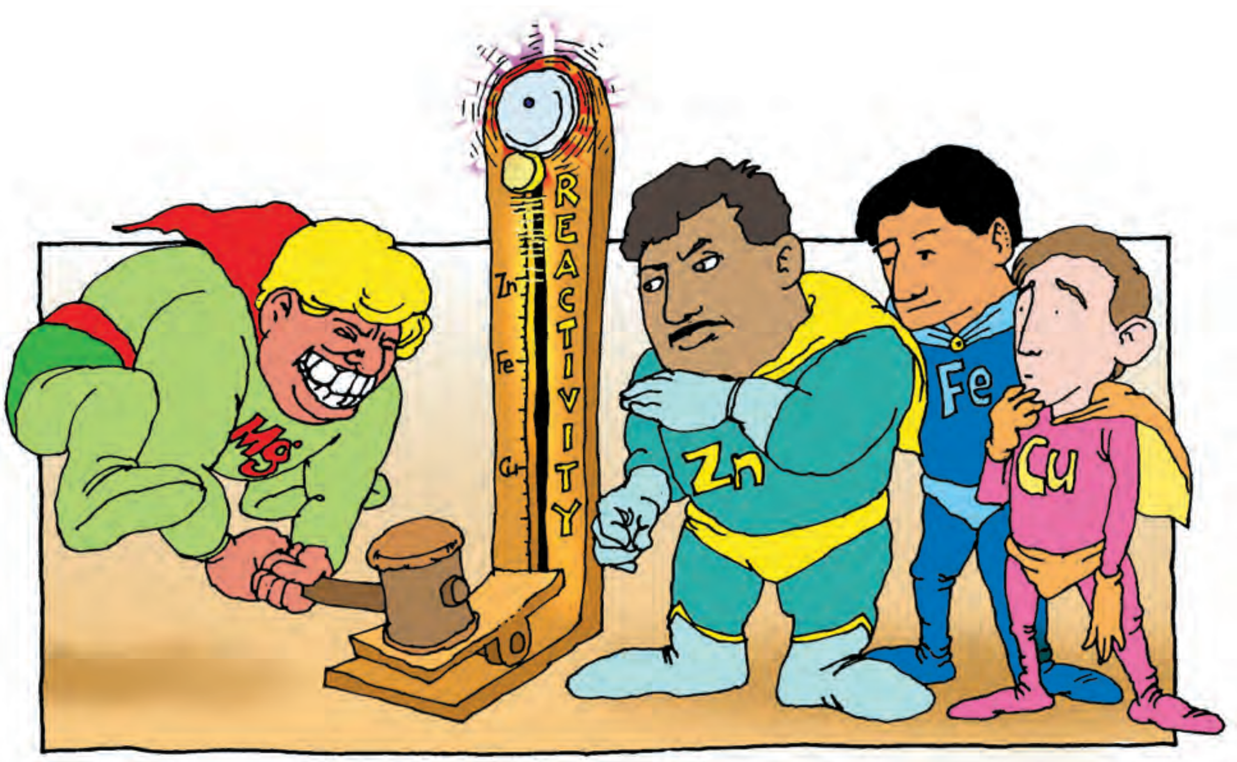

Figure 23.3 *Magnesium is the most reactive of the four metals.*

Reactivity and Free Metals

KEN HAMMOND/USDA

Copper is more reactive than gold. Sometimes it is found as nuggets as shown in this picture, but most copper is obtained by smelting copper ores. During smelting, the metal is extracted from the metal ore. The exact process depends on the type of ore. For example, if the ore is copper carbonate or copper oxide, smelting is achieved by roasting the ore with carbon, usually in the form of coke. A chemical reaction takes place that produces copper metal and carbon dioxide gas.

Gold is valued for its scarcity and for its lack of reactivity. Because it does not react with other elements, such as oxygen, it can be found in its pure form as nuggets. Metals that are not combined with other substances are called free metals. Gold's lack of reactivity also means that it stays shiny and does not corrode. This makes it ideal for use in jewelry and in electrical contacts (for example, the plugs on a computer cable).

Copper is a much more common metal than gold is, and sometimes nuggets of pure copper can be found. Copper can remain shiny for a long time, and it is also used to make jewelry. However, eventually it reacts with other elements, particularly oxygen in the air, and slowly corrodes (a process called tarnishing).

Iron is more reactive than copper. Because of its reactivity, iron is almost always found in Earth's crust combined with other elements. Rocks containing large amounts of iron compounds are called iron ore. Iron is extracted from these ores by a process called smelting. Chunks of natural iron are sometimes found, but these originate from outer space. Meteorites that fall to Earth are often composed mainly of iron. They can last thousands of years, but they also eventually corrode. □

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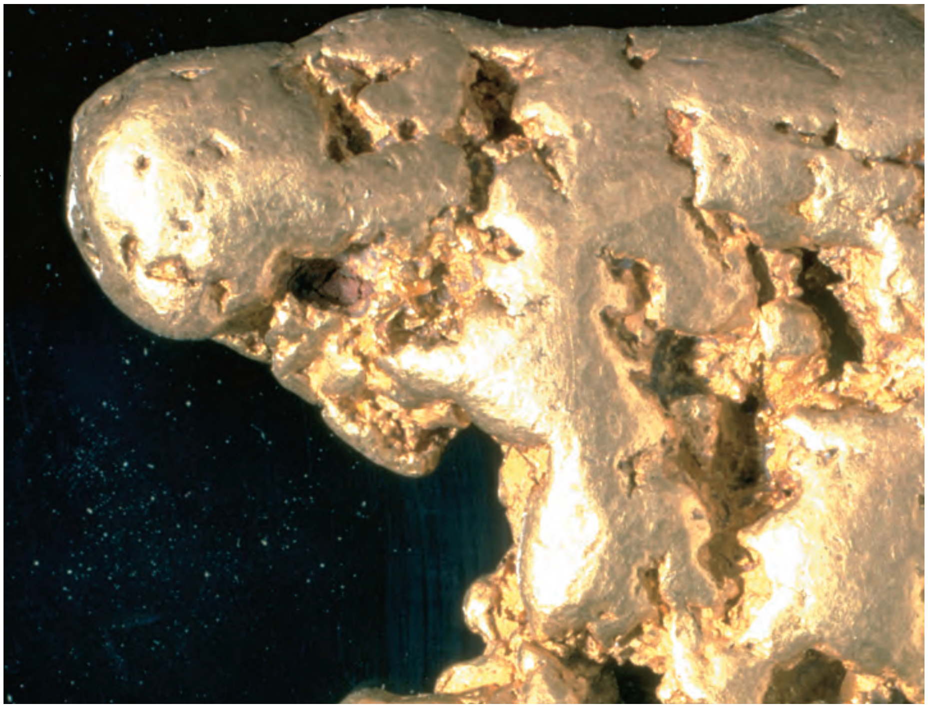

The low reactivity of gold explains why it can be found as metal nuggets. Most other metals exist as ores.

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This giant iron meteorite is in the form of pure iron, which is rarely found on Earth. Why can iron exist in space but not for very long on the surface of Earth?

Making Metals by Mistake

© ROBERT FRERCK/WOODFIN CAMP & ASSOCIATES

This Mochica mask from northern Peru is made of copper. Although the Mochica civilization lasted for 1000 years, its smiths never mastered the production of iron. Why did early cultures make objects from less reactive metals such as copper, silver, and gold?

Are you the sort of person who does things by trial and error? For example, if you get a new video game, do you put it in your machine and then try to play without reading the instruction manual? If so, you are in good company. Trial and error is a technique that has been used since prehistoric times. It is still used today because it works.

Consider the way people figured out how to make metals. Before about 5000 B.C., the only metals that people used came from nuggets of gold, silver, and copper. Nobody knew that metals were locked inside rocks. Nobody, that is, until someone probably made a very hot fire on top of some greenish rocks and saw molten copper trickling out.

Today, it is known that those greenish rocks contained copper combined with oxygen and other elements. Heating the rocks with a wood fire to several hundred degrees caused a chemical reaction. The rock turned to copper oxide, and the oxygen broke loose from the copper and combined with carbon from the wood. Carbon dioxide floated away. The copper stayed behind.

Of course, early people didn't know any of this. But that didn't stop them from experimenting. How much rock should be used? Which rocks work? Where are the rocks found? How hot does the fire have to be? Does the type of wood matter? Does the phase of the moon make a difference? Would it help to add some dirt? If rocks can be changed to copper, can copper be turned into gold? After a few centuries of trials—and almost as many errors—people knew a lot about making copper and it became widely available.

The copper was not very hard. It could be made into pots and pans. It could be shaped into fancy jewelry. But it was too soft to make good tools or weapons. People needed tools and weapons, and more trial and error eventually led to the next big discovery.

In about 3800 B.C., a copper maker in the Middle East mixed tin ore with copper ore and heated them up. The resulting metal was very different from tin and from copper. This

Early armor, such as these Cypriot helmets, was made from alloys of less reactive metals. Bronze, an alloy of tin and copper, was used to make these helmets.

new metal, an alloy called bronze, was lighter in color than copper. It was also much harder than either copper or tin. This new alloy was used to make axes, spears, knives, armor, and other tools.

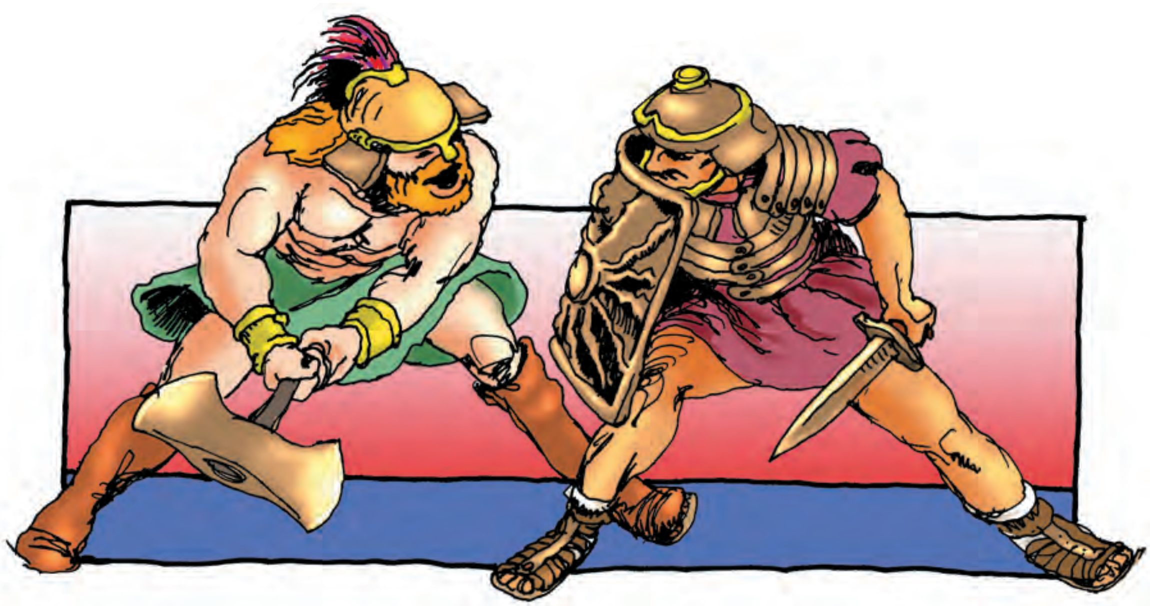
The secrets of making bronze soon spread to the Far East. By 1500 B.C., Chinese bronze makers had discovered, by trial and error, that the hardest bronze is exactly 85 percent copper and 15 percent tin. They had no idea why this particular mixture was so hard. But by experimenting, watching carefully, and recording results, they found the best way to make bronze.

Iron was probably discovered by mistake, in much the same way as copper. However, iron ore requires a much hotter fire than that used to extract copper from ore. Can you think of the reason why the fire needs to be so hot?

Iron is much harder than bronze. Tools and weapons made of iron were much harder than those made from bronze. The techniques for extracting and improving the quality of iron were refined through trial and error, and the new technology spread quickly. The Iron Age had begun. ☐

QUESTION

Iron was discovered after copper and tin because it is more difficult to extract from its ore. What are the modern processes for extracting iron metal from its ores? Use information from the library and the Internet to find out more about these processes. Write a paragraph about the techniques involved, and illustrate your answer with a diagram.



Bronze is harder than either tin or copper—hard enough to use for armor in battle.