Section 5 · Tech & Design ·

Bonding in Metals

Reading Preview

Key Concepts

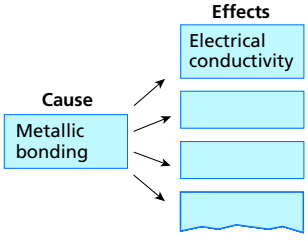
- How are metal atoms bonded in solid metal?
- How does metallic bonding result in useful properties of metals?

Key Terms

- metallic bond
- alloy
- ductile
- malleable

Target Reading Skill

Relating Cause and Effect As you read, identify the properties of metals that result from metallic bonding. Write the information in a graphic organizer like the one below.



Lab zone Discover Activity

What Do Metals Do?

1. Your teacher will give you pieces of different metals. Examine each metal and try changing its shape by bending, stretching, folding, or any other action you can think of. **CAUTION:** *Handle metal pieces with sharp edges carefully.*
2. What properties are common to these metals? What properties are different?
3. What properties make each metal suitable for its use?

Think It Over

Inferring Paper clips (made mostly of iron), aluminum foil, and copper wire are made from large chunks of metals. What properties must these metals have to be made into these products?

Why would you choose metal to cover the complex shape of the building in Figure 28? You couldn't cover the building with brittle, crumbly nonmetals such as sulfur or silicon. What physical properties make metal an ideal material for making furniture, musical instruments, electrical wire, pots and pans, eating utensils, and strong beams for buildings? Why do metals have these physical properties?

FIGURE 28
Metal in Architecture
The Guggenheim Museum in Bilbao, Spain, provides a dramatic example of some properties of metals. The museum's shiny outer "skin" is made of the lightweight metal titanium, which can be pressed into large, thin, flexible sheets.

Metallic Bonding

The properties of solid metals can be explained by the structure of metal atoms and the bonding between those atoms. Recall that most metals have 1, 2, or 3 valence electrons. When metal atoms combine chemically with atoms of other elements, they usually lose valence electrons, becoming positively charged metal ions. Metals lose electrons easily because their valence electrons are not strongly held.

The loosely held electrons in metal atoms result in a type of bonding that is characteristic of metals. Like many solids, metals exist as crystals. The metal atoms are very close together and in specific arrangements. These atoms are actually positively charged ions. Their valence electrons are free to drift among the ions. Each metal ion is held in the crystal by a **metallic bond**—an attraction between a positive metal ion and the electrons surrounding it. Look at Figure 29. **A metal crystal consists of positively charged metal ions embedded in a "sea" of valence electrons.** The more valence electrons an atom can add to the "sea," the stronger the metallic bonds within the crystal will be.

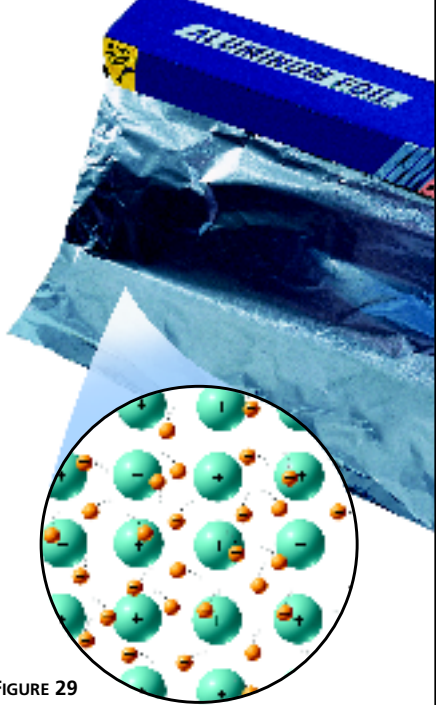


FIGURE 29
Metallic Bonding
Solid metals consist of positively charged ions surrounded by a loose "sea" of valence electrons.
Problem Solving *Why would nonmetals be unlikely to have the type of bonding shown here?*

Reading Checkpoint **What is a metallic bond?**

Metallic Properties

Metallic bonding explains many of the common physical properties of metals and their alloys. An **alloy** is a material made of two or more elements that has the properties of a metal.

Suppose that you placed one hand on an unheated aluminum pan and the other hand on a wooden tabletop. The aluminum pan would feel cooler than the tabletop even though both are at the same temperature. You feel the difference because aluminum conducts heat away from your hand much faster than wood does. **The "sea of electrons" model of solid metals explains their ability to conduct heat and electricity, the ease with which they can be made to change shape, and their luster.**

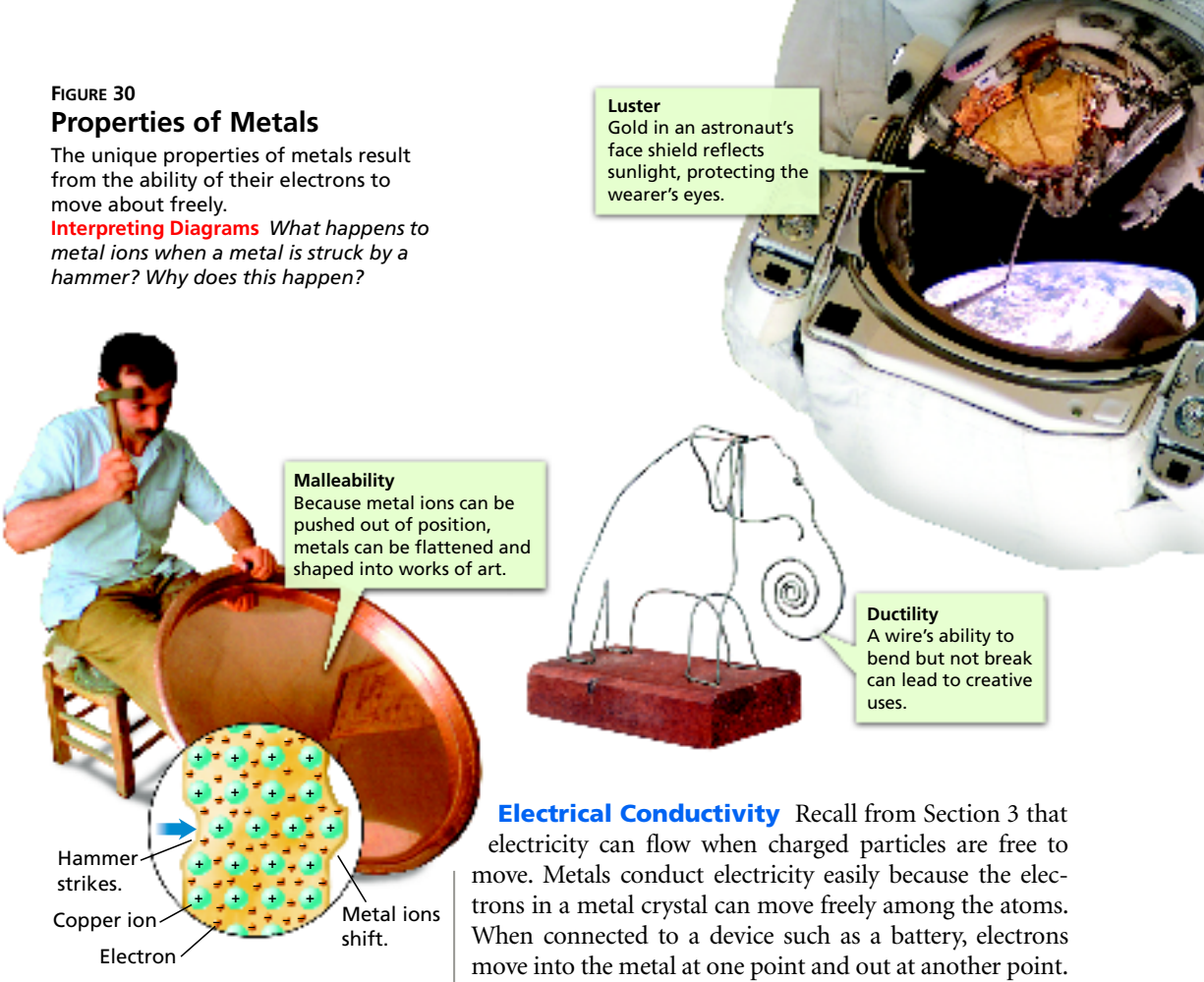
Heat Conductivity Heat travels through materials as the increased motion of the particles in the hotter parts of the material are passed along to the particles in the cooler parts. The freedom of motion of electrons in metals makes it easy for thermal energy to be transferred along the crystal.

FIGURE 30

Properties of Metals

The unique properties of metals result from the ability of their electrons to move about freely.

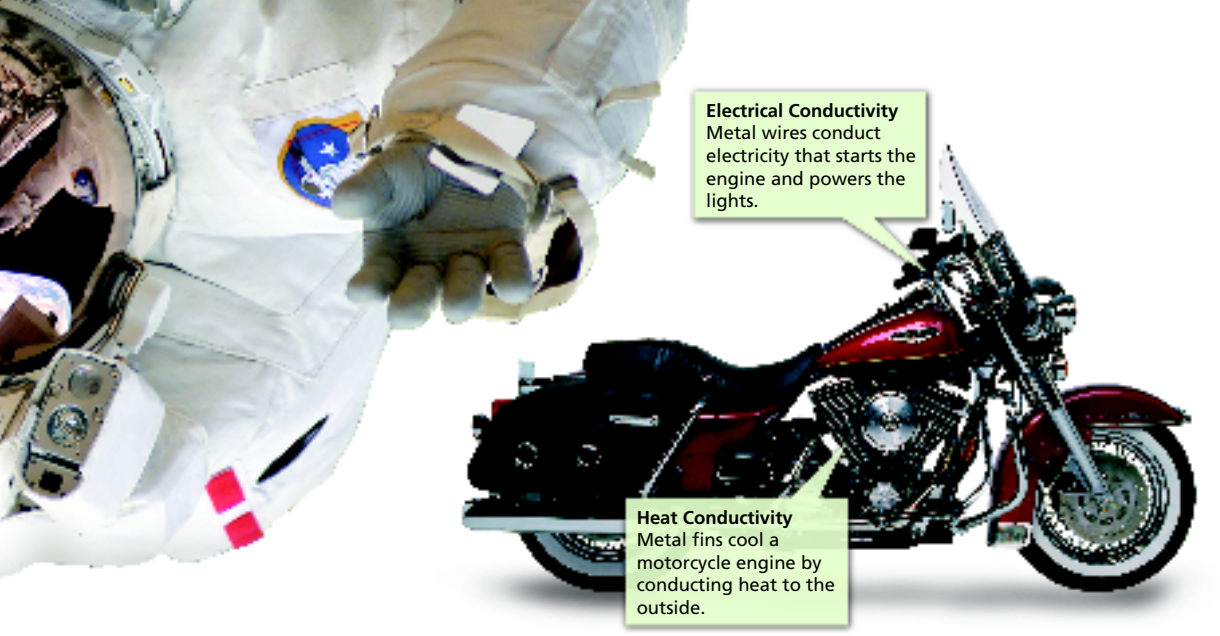
Interpreting Diagrams *What happens to metal ions when a metal is struck by a hammer? Why does this happen?*



Electrical Conductivity Recall from Section 3 that electricity can flow when charged particles are free to move. Metals conduct electricity easily because the electrons in a metal crystal can move freely among the atoms. When connected to a device such as a battery, electrons move into the metal at one point and out at another point.

Changes in Shape A metal's ability to conduct electricity would not be very useful if the metal couldn't be made into thin wires that could bend. Most metals are flexible and can be reshaped easily. They can be stretched, pushed, or compressed into different shapes without breaking. Metals act this way because the ions in metal crystals are not attracted to other ions as in ionic crystals. Instead, they are attracted to the loose electrons all around them. As a result, the ions can be pushed out of position, as shown in Figure 30.

Because the metal ions in a crystal move easily, metals are **ductile,** which means that they can be bent easily and pulled into thin strands or wires. Metals are also **malleable**—able to be rolled into thin sheets, as in aluminum foil, or beaten into complex shapes.



Luster Polished metals exhibit luster, that is, they are shiny and reflective. A metal's luster is due to its valence electrons. When light strikes these electrons, they absorb the light and then give it off again. This property makes metals useful for making products as varied as mirrors, buildings, jewelry, and astronaut helmets.

Reading Checkpoint **Why do metals exhibit luster?**

Section 5 Assessment

Target Reading Skill **Relating Cause and Effect** Refer to your graphic organizer about metallic properties to help you answer Question 2 below.

Reviewing Key Concepts

1. **a.** **Describing** Describe the structure of a metal crystal.
   b. **Relating Cause and Effect** Explain how metal atoms form metallic bonds in crystals. What role do the valence electrons play?
   c. **Comparing and Contrasting** Review what you learned about ionic bonds in Section 3. How does a metallic bond differ from an ionic bond?
2. **a.** **Listing** Name five properties of metals. What accounts for these properties?
   b. **Explaining** Explain how heat travels through metals.
   c. **Applying Concepts** Why is it safer to use a nonmetal mixing spoon when cooking something on a stove?

Writing in Science

Product Label Choose a familiar metal object and create a "product label" for it. Your label should describe at least two of the metal's properties and explain why it exhibits those properties. You can include illustrations on your label as well.