Section 5

Bonding in Metals

Objectives

After this lesson, students will be able to

L.1.5.1 Describe how metal atoms are bonded in solid metal.

L.1.5.2 Explain how metallic bonding results in useful properties of metals.

Target Reading Skill

Relating Cause and Effect Explain that cause is the reason for what happens. The effect is what happens because of the cause. Relating cause and effect helps students relate the reason for what happens to what happens as a result.

Answers

Graphic organizers should show that metallic bonding causes the properties of metals, which include electrical conductivity, heat conductivity, ductility, malleability, and luster.

All in One Teaching Resources

- Transparency L13

Preteach

Build Background Knowledge

L2

Inferring Properties of Metals

Have students name common objects containing metal and infer properties of metals based on the objects. Ask: **What common objects are made wholly or mostly of metal?** *(Sample answers: Jewelry, aluminum foil, wires, pots and pans)* **Based on the uses of metals in these objects, what do you think are some properties of metals?** *(Sample answers: Flexibility, ability to conduct heat and electricity)*

Section 5 · Tech & Design ·

Bonding in Metals

Reading Preview

Key Concepts

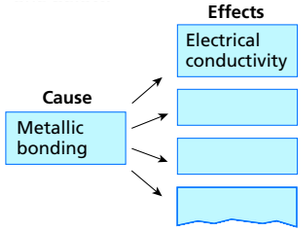
- How are metal atoms bonded in solid metal?
- How does metallic bonding result in useful properties of metals?

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.

Lab zone Discover Activity

Skills Focus Inferring L1

Materials small pieces of three different metals

Time 10 minutes

Tip Make sure the pieces of metal do not have sharp edges.

Expected Outcome Students are expected to be able to bend and fold the materials and reshape them in other ways.

Think It Over The metals must be able to be bent, flattened into thin sheets, or pulled into strands.

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.

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

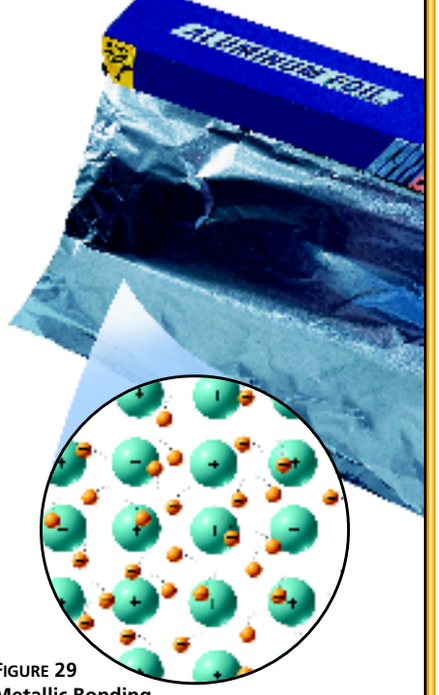


FIGURE 29
Metallic Bonding
Solid metals consist of positively charged ions surrounded by a loose "sea" of valence electrons.
Problem Solving *Why would nonmetals be unlikely to have the type of bonding shown here?*

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.

Go Online NSTA SCILINKS
For: Links on metallic bonding
Visit: www.SciLinks.org
Web Code: scn-1215

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Modified Cloze
Create a paragraph with the boldface sentences and the sentence containing the boldface term on this page. Leave some terms blank, and give students a list of the terms. After doing a sample sentence, have students fill in the blanks with terms from the list. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Modified Cloze Use the same paragraph and list of terms as in the Beginning strategy, but add some wrong choices to the list. **learning modality: verbal**

Instruct

Metallic Bonding

Teach Key Concepts L2

Understanding the Nature of Metallic Bonds

Focus Have students look at Figure 29.

Teach Ask: **What holds the atoms of metals together?** *(Attraction between positively charged ions and the electrons around them)*

Apply Ask: **Which are stronger, metallic bonds or ionic bonds? Why?** *(Ionic bonds, because the attraction between two ions is stronger)* **learning modality: visual**

All in One **Teaching Resources**
- Transparency L14

Metallic Properties

Teach Key Concepts L2

Explaining Properties of Metals

Focus Tell students metallic bonds explain the properties of metals.

Teach Say that electrons and ions in metals can move, so metals are flexible and can conduct heat and electricity.

Apply Have students read why metals have luster. **learning modality: verbal**

Go Online NSTA SCILINKS
For: Links on metallic bonding
Visit: www.SciLinks.org
Web Code: scn-1215
Download a worksheet that will guide students' review of Internet sources on metallic bonding.

Independent Practice L2

All in One **Teaching Resources**
- Guided Reading and Study Worksheet: *Bonding in Metals*

Student Edition on Audio CD

Monitor Progress L2

Answers

Figure 29 Because valence electrons are strongly held in atoms of nonmetals

Reading Checkpoint An attraction between a positive metal ion and the electrons around it

Lab zone **Build Inquiry** L2

Making Judgments About the Uses and Properties of Metals

Time 10 minutes

Focus Guide students in judging how the properties of metals suit their uses.

Teach Lead the class in brainstorming a list of metal objects, using Figure 30 as a starting point. On the board, list the objects that students name. Then, for each object, have students identify which metallic properties make metal well suited for use in that object. For example, electrical conductivity and ductility make metal well suited for use in electric wire, and malleability and luster make metal well suited for use in jewelry.

Apply Ask: **What other materials might be used in these objects?** *(Students might identify other materials, such as wood or plastic, that could be used in some of the objects.)* **How well suited would these other materials be? Why?** *(Generally, other materials would not be as well suited as metals because they lack metals' properties.)* **learning modality: verbal**

Lab zone **Teacher Demo** L2

How Objects Demonstrate Properties of Metals

Materials aluminum objects such as a beverage can, baking pan, foil wrap, ornament

Time 10 minutes

Focus Have students identify how aluminum objects demonstrate the properties of metals.

Teach Show students the objects, and explain that they are made from aluminum, a metal. Review the properties of metals, and challenge students to describe uses of the aluminum objects that demonstrate each property. Accept all reasonable responses. *(Sample answer: A beverage can that is chilling in a cooler demonstrates heat conductivity.)*

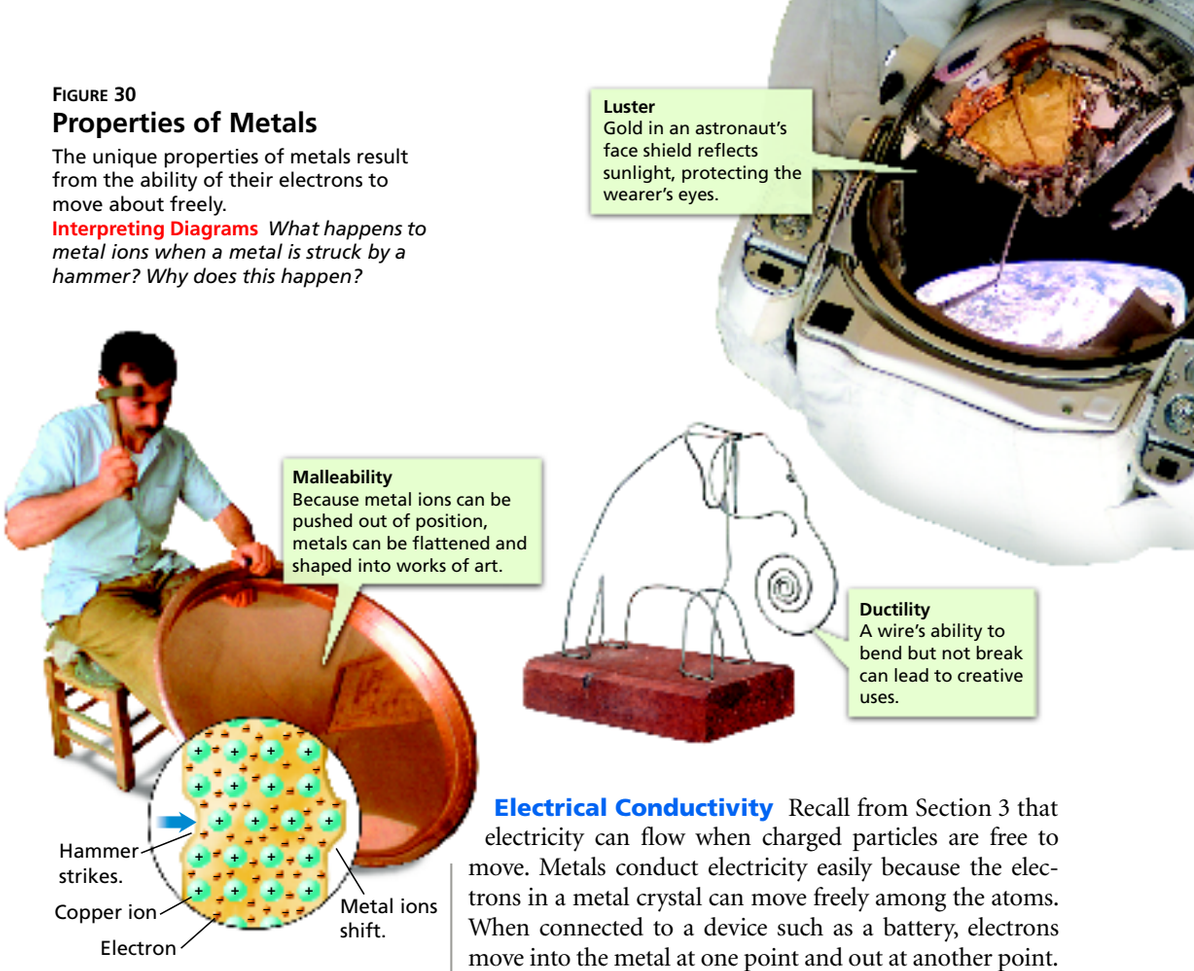
Apply Ask: **What other properties of aluminum make it useful for these purposes?** *(Students might say that aluminum is also useful because it is also lightweight, strong, recyclable, and rustproof.)* Make sure students understand that these other properties of aluminum do not necessarily characterize all metals. For example, iron is much heavier than aluminum and rusts easily. **learning modality: visual**

FIGURE 30

Properties of Metals

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

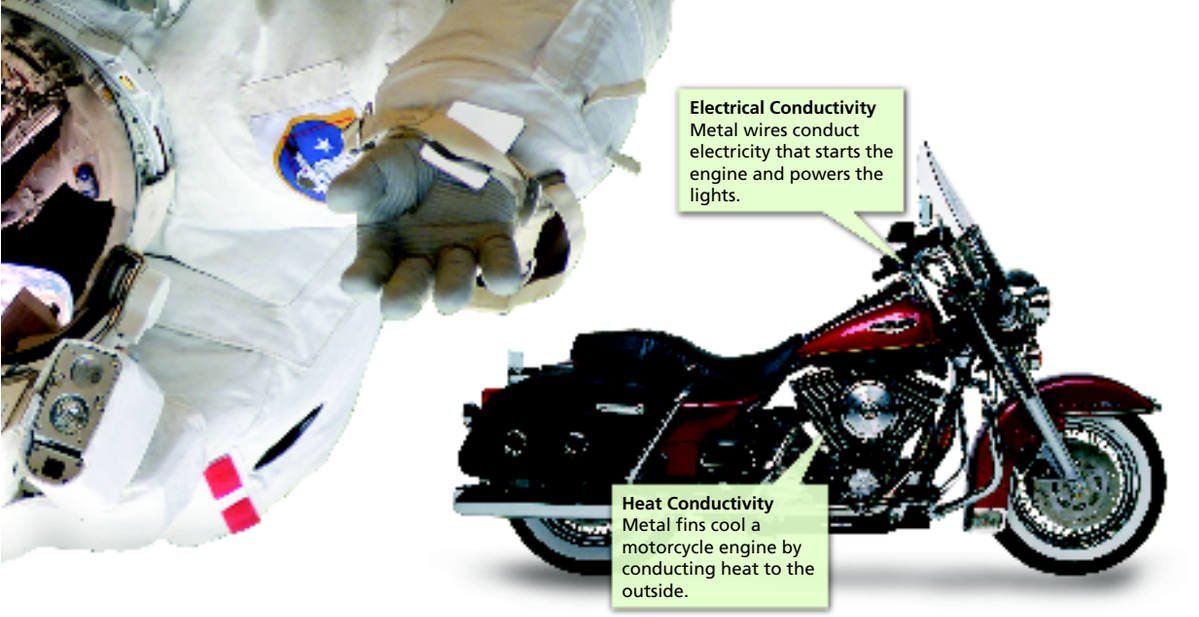
Interpreting Diagrams *What happens to metal ions when a metal is struck by a hammer? Why does this happen?*



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.

Monitor Progress L2

Answers

Figure 30 Metal ions are pushed out of position, because the ions are not attracted to other ions, only to the loose electrons surrounding them.

Reading Checkpoint Because their valence electrons absorb light and then give it off again

Assess

Reviewing Key Concepts

1. a. A metal crystal consists of positively charged metal ions embedded in a "sea" of valence electrons. **b.** Each metal atom contributes a positive ion and one or more loosely held valence electrons. Attractions between valence electrons and positive ions hold metal atoms together. **c.** A metallic bond is the attraction between a positive metal ion and the electrons around it. An ionic bond is the attraction between positive and negative ions.

2. a. Five properties are: heat conductivity, electrical conductivity, ductility, malleability, and luster. The loosely held valence electrons, which allow ions and valence electrons in metals to move, account for these properties. **b.** Heat travels through metals as increased motion of particles in hotter parts of the metal is passed along to particles in cooler parts. **c.** A metal spoon would conduct heat to your hand, possibly causing a burn.

Reteach L1

Call on students to name properties of metals. Call on other students to describe an example of each property.

Performance Assessment L2

Drawing Have students draw a diagram to illustrate metallic bonding.

Students can keep their diagrams in their portfolios. Portfolio

All in One Teaching Resources

- Section Summary: *Bonding in Metals*
- Review and Reinforcement: *Bonding in Metals*
- Enrich: *Bonding in Metals*

Lab zone Chapter Project

Keep Students on Track Tell students to explain in their presentations how they modeled atoms and bonds and why they chose the materials they did.

Writing in Science

Writing Mode Persuasion

Scoring Rubric

4 Exceeds criteria
3 Meets criteria
2 Includes a label but explains only two properties of metals and/or contains some errors
1 Includes only a general description of only one property and/or contains serious errors