Metallic Bonds and Metallic Properties

Metals are made up of closely packed cations rather than neutral atoms. The valence electrons of metal atoms can be modeled as a sea of electrons. That is, the valence electrons are mobile and can drift freely from one part of the metal to another. Metallic bonds consist of the attraction of the free-floating valence electrons for the positively charged metal ions. These bonds are the forces of attraction that hold metals together.

The sea-of-electrons model explains many physical properties of metals. For example, metals are good conductors of electrical current because electrons can flow freely in them. As electrons enter one end of a bar of metal, an equal number leave the other end. Metals are ductile—that is, they can be drawn into wires, as shown in Figure 7.12. Metals are also malleable, which means that they can be hammered or forced into shapes.
Section 7.3 (continued)

Metals vs. Ionic Compounds

Purpose
Students compare copper metal and a copper compound.

Materials
- Copper metal or alloy
- Copper-containing ionic compound

Procedure
Show the class a small sample of elemental copper or a copper alloy and a sample of a copper-containing crystalline ionic mineral such as chalcocite (Cu₂S). Wearing safety glasses and standing far from the students, smash both samples with a hammer. Discuss why the two substances respond differently to the stress of the hammer blow.

Expected Outcomes
The elemental copper will flatten but not break because the cations and electrons are mobile; the crystal will shatter.

Crystalline Structure of Metals

Use Visuals

Figure 7.14 Lead a class discussion on the concept of “closest packing” of metal cations in pure metals. Use the three different closest packing arrangements shown in Figure 7.14 as a reference. Emphasize that the concept of closest packing also relates to more than just metal atoms. Have the students describe other examples of closest packing.

Both the ductility and malleability of metals can be explained in terms of the mobility of valence electrons. A sea of drifting valence electrons insulates the metal cations from one another. When a metal is subjected to pressure, the metal cations easily slide past one another like ball bearings immersed in oil. In contrast, if an ionic crystal is struck with a hammer, the blow tends to push the positive ions close together. They repel, and the crystal shatters.
Alloys

Although every day you use metallic items, such as spoons, very few of these objects are pure metals. Instead, most of the metals you encounter are alloys. Alloys are mixtures composed of two or more elements, at least one of which is a metal. Brass, for example, is an alloy of copper and zinc. Alloys are important because their properties are often superior to those of their component elements. Sterling silver (92.5% silver and 7.5% copper) is harder and more durable than pure silver but still soft enough to be made into jewelry and tableware. Bronze is an alloy generally containing seven parts of copper to one part of tin. Bronze is harder than copper and more easily cast. Nonferrous (non-iron) alloys, such as bronze, copper-nickel, and aluminum alloys, are commonly used to make coins.

The most important alloys today are steels. The principal elements in most steel, in addition to iron and carbon, are boron, chromium, manganese, molybdenum, nickel, tungsten, and vanadium. Steels have a wide range of useful properties, such as corrosion resistance, ductility, hardness, and toughness. Table 7.3 lists the composition of some common alloys.

Table 7.3 Composition of Some Common Alloys

<table>
<thead>
<tr>
<th>Name</th>
<th>Composition (by mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterling silver</td>
<td>Ag 92.5% Cu 7.5%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>Fe 96% C 4%</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>Fe 80.0% Cr 18.0% C 0.4%</td>
</tr>
<tr>
<td>Spring steel</td>
<td>Fe 98.6% Cr 1.0% C 0.4%</td>
</tr>
<tr>
<td>Surgical steel</td>
<td>Fe 67% Cr 18% Ni 12% Mo 3%</td>
</tr>
</tbody>
</table>

Alloys can form from their component atoms in different ways. If the atomic sizes are quite different, the smaller atoms can fit into the interstices (spaces) between the larger atoms. Such an alloy is called an interstitial alloy. In the various types of steel, for example, carbon atoms occupy the interstices (spaces) between the larger atoms. Such an alloy is called an interstitial alloy. In the various types of steel, for example, carbon atoms occupy the interstices (spaces) between the larger atoms. Such an alloy is called an interstitial alloy.

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Building With Alloys

Explain that materials for a building must be able to withstand the stresses that a building undergoes. Discuss with students several different types of stress. Tensile stress can be observed when a building beam sags. The bottom of the beam undergoes tensile stress as it is slightly stretched. The top of the beam undergoes compression stress, which results when two forces push toward each other through a solid. The top of the beam is compressed as it is slightly shortened. A building undergoes shear stress in a strong wind. In shear stress, forces are applied from different directions, and the building might twist or break. Ask, Which of these buildings are most likely to undergo shear stress? (The Atomium, the Chrysler Building)

Metals are used as building materials because of strength and durability, but other properties might determine the use of a metal in a building. Ask, What property of a metal might make it useful on the outside of a building? (Answers might include luster when a shiny appearance is desired, malleability when the metal covers another material, or the ability of a certain metal to form a compound that protects the rest of the metal or other materials under it.) What metal was chosen for each of these buildings? Why do you think that alloy was used? (Possible answers: the Atomium—aluminum alloy; shiny, corrosion resistant, light, malleable; the Chrysler Building—steel; shiny, malleable, corrosion-resistant; the Jewish Museum Berlin—zinc-titanium alloy: corrosion resistant, light)

Facts and Figures

A Good Foundation

Concrete itself is not strong enough to be a good framing material. Reinforcing the concrete by pouring it over steel rods that have been laid out in a grid adds a considerable amount of strength to the concrete. When exceptionally strong concrete is needed, it is poured over steel cables that are stretched. After the concrete dries, the rods are released, and the concrete is compressed as the rods return to their original length. This exceptionally strong concrete is called prestressed concrete.
Making an Alloy

Purpose
Students observe how to make an alloy from copper and zinc.

Materials
penny, fine sandpaper, granulated zinc, dilute NaOH solution,
evaporating dish, tongs, hot plate, teaspoon

Safety
Be sure to use adequate ventilation and have no skin contact with the NaOH solution. Do not touch hot objects.

Procedure
Use the sandpaper to clean any tarnish from the penny. Add a teaspoon of zinc to the evaporating dish, and cover the zinc with NaOH solution. Place the penny on the zinc, being sure the penny is also covered by the solution. Heat the dish until the penny changes to a silvery color. Using the tongs, remove and rinse the penny. Place the penny on the hot plate, which should be set to medium heat. When the penny turns a gold color, use tongs to remove it from the hot plate.

Expected Outcome
A gold-colored alloy forms from copper and zinc. Ask, Why did the penny turn a silver color? (Zinc was deposited on the penny.) At what point was an alloy formed? (An alloy was formed when the copper and zinc on the penny were heated to a golden color.) Why was the penny heated to form the alloy? (Heat increases the kinetic energy of the atoms, allowing them to mix more freely.)