Section 6.1

1 FOCUS

Objectives

6.1.1 **Recognize** stable electron configurations.

6.1.2 **Predict** an element's chemical properties using number of valence electrons and electron dot diagrams.

6.1.3 **Describe** how an ionic bond forms and how ionization energy affects the process.

6.1.4 **Predict** the composition of an ionic compound from its chemical formula.

6.1.5 **Relate** the properties of ionic compounds to the structure of crystal lattices.

Reading Focus

Build Vocabulary L2

Word Forms Have students think of word forms related to *crystals* such as *crystalline* and *crystallize.* Have them discuss ways people commonly use these words—and the word *crystal*—and compare those usages to the way *crystals* is defined in Section 6.1.

Reading Strategy L2

a. Form a cation **b.** Form an anion

2 INSTRUCT

Stable Electron Configurations

Integrate Social Studies L2

In 1902, G.N. Lewis proposed "the theory of the cubical atom." He illustrated his theory with drawings of cubes with valence electrons placed at their corners. In his classic 1916 paper, "The Atom and the Molecule," Lewis simplified his diagrams by using dots to represent electrons and a symbol to represent the kernel of an atom.

Recreate the cube models for lithium and beryllium on the board or overhead projector. (Draw cubes with one and two corners circled, respectively.) Explain that each circle represents a valence electron. Then, have students refer to Figure 2 and draw their own cube models for boron, carbon, nitrogen, oxygen, and fluorine. **Logical, Visual**

6.1 Ionic Bonding

Reading Focus

Key Concepts

- When is an atom unlikely to react?
- What is one way in which elements can achieve stable electron configurations?
- How does the structure of an ionic compound affect its properties?

Vocabulary

- electron dot diagram
- ion
- anion
- cation
- chemical bond
- ionic bond
- chemical formula
- crystals

Reading Strategy

Sequencing Copy the concept map. As you read, complete the concept map to show what happens to atoms during ionic bonding.

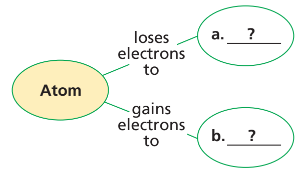


Figure 1 The handle and body of this titanium mug were welded together in an argon atmosphere. If titanium is allowed to react with oxygen in air, the compound that forms makes the weld more brittle and more likely to break.

The handle of the titanium mug in Figure 1 was joined to the body by welding. The pieces were heated until their surfaces fused together. The welding of titanium does not take place in air. At the temperature at which welding occurs, titanium becomes hot enough to react with oxygen in the air, forming an oxide. The oxide makes the weld more brittle and likely to break. Because titanium does not react with a noble gas such as argon, the welding of titanium usually takes place in an argon atmosphere.

Argon's name is a reminder of its inactivity. It comes from the Greek word *argos,* which means "idle" or "inert." Why is argon very inactive yet oxygen is highly reactive? Chemical properties, such as reactivity, depend on an element's electron configuration.

Stable Electron Configurations

The highest occupied energy level of a noble gas atom is filled. **When the highest occupied energy level of an atom is filled with electrons, the atom is stable and not likely to react.** The noble gases have stable electron configurations with eight valence electrons (or two in the case of helium).

The chemical properties of an element depend on the number of valence electrons. Therefore, it is useful to have a model of atoms that focuses only on valence electrons. The models in Figure 2 are electron dot diagrams. An **electron dot diagram** is a model of an atom in which each dot represents a valence electron. The symbol in the center represents the nucleus and all the other electrons in the atom.

Section Resources

Print

- ***Reading and Study Workbook With Math Support,*** Section 6.1
- ***Math Skills and Problem Solving Workbook,*** Section 6.1
- ***Transparencies,*** Chapter Pretest and Section 6.1

Technology

- ***Interactive Textbook,*** Section 6.1
- ***Presentation Pro CD-ROM,*** Chapter Pretest and Section 6.1
- ***Go Online,*** NSTA SciLinks, Ionic bonds

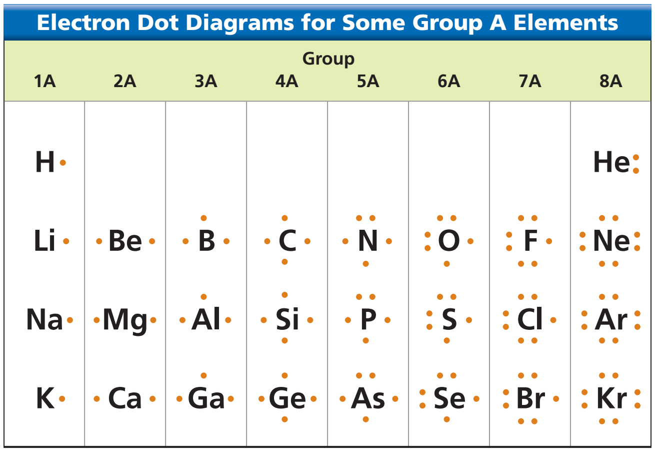


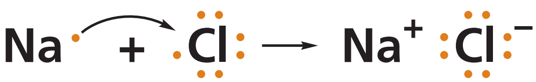
Figure 2 In an electron dot diagram, each dot represents a valence electron. **Observing** ***How many valence electrons do sodium and chlorine have?***

Ionic Bonds

Elements that do not have complete sets of valence electrons tend to react. By reacting, they achieve electron configurations similar to those of noble gases. **Some elements achieve stable electron configurations through the transfer of electrons between atoms.**

Transfer of Electrons Look at the electron dot diagram for chlorine in Figure 2. A chlorine atom has one electron fewer than an argon atom. If the chlorine atom were to gain a valence electron, it would have the same stable electron arrangement as argon. Look at the electron dot diagram for sodium. A sodium atom has one more electron than a neon atom. If a sodium atom were to lose this electron, its highest occupied energy level would have eight electrons. It would then have the same stable electron arrangement as neon.

What happens at the atomic level when sodium reacts with chlorine? An electron is transferred from each sodium atom to a chlorine atom. Each atom ends up with a more stable electron arrangement than it had before the transfer.



Formation of Ions When an atom gains or loses an electron, the number of protons is no longer equal to the number of electrons. The charge on the atom is not balanced and the atom is not neutral. An atom that has a net positive or negative electric charge is called an **ion.** The charge on an ion is represented by a plus or a minus sign. Notice the plus sign next to the symbol for sodium and the minus sign next to the symbol for chlorine.

Go Online NSTA SCiLINKS

For: Links on ionic bonds
Visit: www.SciLinks.org
Web Code: ccn-1061

Build Science Skills

L2

Predicting Emphasize that, except for hydrogen and helium, the dots in an electron dot diagram do not represent all of the electrons in an atom, just the valence electrons.

Have students look at Figure 2. Ask them to predict the electron dot diagrams for rubidium, strontium, indium, tin, antimony, tellurium, iodine, and xenon. *(These elements—Rb, Sr, In, Sn, Sb, Te, I, and Xe—have the same valence electron configurations as the elements directly above them in the periodic table.)*
Logical, Visual

Ionic Bonds

Address Misconceptions

L2

Many students think that objects become positively charged because they gain protons. Challenge this misconception by explaining that electrons are the only subatomic particles that can be transferred from an atom during a chemical change. Have students recall how electrons can move to higher energy levels when an atom absorbs energy. Remind students of the location of protons in the nuclei of atoms.
Logical

FYI

Once an ion has been defined as a charged particle, the term *atom* can be reserved for the neutral particle.

Go Online NSTA SCiLINKS

Download a worksheet on ionic bonds for students to complete, and find additional teacher support from NSTA SciLinks.

Customize for Inclusion Students

Visually Impaired
Have interested students listen to a recording of *Ionisation,* a musical work scored for percussion and sirens in 1931 by French-American composer Edgard Varèse (1883–1965). There is no melody or harmony, just blocks of sound produced by instruments including cymbals, maracas, and drums. The noises are supposed to represent what happens to electrons as ionization occurs. Let students state their reactions to the music. Ask them to discuss how appropriate the title is for this piece of music.

Answer to . . .

Figure 2 *Sodium has one valence electron. Chlorine has seven.*

Data Analysis

What Determines the Size of an Atom or Ion? L2

Answers
1. Within a period, the atomic radius decreases as the atomic number increases.
2. Within these groups, the atomic radius increases as the atomic number increases.
3. When the next higher energy level is occupied, there is a significant increase in the atomic radius.
4. The ionic radius for potassium is much smaller than its atomic radius. The ionic radius for bromine is much larger than its atomic radius.
5. With the loss of valence electrons, the radius decreases. With the addition of valence electrons, the radius increases.
6. An energy level that was occupied is no longer occupied and the size decreases.

For Extra Help L1

Explain that attractions between protons and electrons largely determine the atomic radius of a specific atom.
Verbal

FYI

Because an electron cloud does not have an outer edge, the radius for elements that form diatomic molecules is calculated by measuring the distance between the two nuclei in the molecule and dividing by two.

Data Analysis

What Determines the Size of an Atom or Ion?

Scientists use atomic radii to compare the sizes of atoms of different elements. Remember from mathematics that the radius of a sphere is the distance from the center of the sphere to its outer edge. The radius is half the diameter of the sphere. Because atomic radii are extremely small, these distances are expressed in units called picometers (pm). As a comparison, there are one billion (10^9) picometers in a millimeter.

The table shows the atomic radius and ionic radius for six metals and six nonmetals. You will use the data to relate the size of an element's atoms to the element's location on the periodic table. You also will use the data to compare the sizes of atoms and their ions.

Atomic and Ionic Radii

1A	2A	6A	7A
Li: atomic 152; ionic (1+) 60	Be: atomic 112; ionic (2+) 31	O: atomic 66; ionic (2–) 140	F: atomic 64; ionic (1–) 136
Na: atomic 186; ionic (1+) 95	Mg: atomic 160; ionic (2+) 65	S: atomic 103; ionic (2–) 184	Cl: atomic 99; ionic (1–) 181
K: atomic 227; ionic (1+) 133	Ca: atomic 197; ionic (2+) 99	Se: atomic 117; ionic (2–) 198	Br: atomic 114; ionic (1–) 195

Atomic radius
Ionic radius

1. **Using Tables** Within a period, what happens to the atomic radius as the atomic number of the elements increases?
2. **Using Tables** Within Groups 1A, 2A, 6A, and 7A, what happens to the atomic radius of elements as the atomic number increases?
3. **Inferring** How does adding an occupied energy level affect the atomic radius? (*Hint:* Lithium is a Period 2 element and sodium is a Period 3 element.)
4. **Comparing and Contrasting** Compare the atomic and ionic radii for potassium (K), and for bromine (Br).
5. **Making Generalizations** What happens to the radius of an atom when the atom loses electrons? When the atom gains electrons?
6. **Relating Cause and Effect** Explain the difference in size between a metal atom and its cation.

The ion that forms when a chlorine atom gains an electron has 17 protons and 18 electrons. This ion has a charge of 1– because it has one extra electron. The symbol for the ion is written Cl^{1-}, or Cl^{-} for short. An ion with a negative charge is an **anion** (AN eye un). Anions like the Cl^{-} ion are named by using part of the element name plus the suffix *–ide.* Thus, Cl^{-} is called a *chloride* ion.

A sodium ion has 11 protons and 10 electrons. Because it has one extra proton, the sodium ion has a charge of 1+. The symbol for the ion is written Na^{1+}, or Na^{+} for short. An ion with a positive charge is a **cation** (KAT eye un). Naming a cation is easy. You just use the element name, as in the *sodium* ion.

Formation of Ionic Bonds Remember that a particle with a negative charge will attract a particle with a positive charge. When an anion and a cation are close together, a chemical bond forms between them. A **chemical bond** is the force that holds atoms or ions together as a unit. An **ionic bond** is the force that holds cations and anions together. An ionic bond forms when electrons are transferred from one atom to another.

Facts and Figures

Atomic and Ionic Radii The radius of an atom decreases from left to right across a period because valence electrons are shielded from the nucleus by electrons in lower energy levels. The amount of positive nuclear charge experienced by valence electrons is mainly determined by the difference in charge between the nucleus and the inner (or core) electrons. Because the number of core electrons does not change across a period, as the number of protons increases the charge experienced by valence electrons increases and the atomic radius decreases.

The radius of an anion is larger than the radius of its corresponding atom. Adding electrons to the highest occupied energy level increases the repulsions among electrons. The increase in repulsions causes the electrons to spread out more in space.

Ionization Energy An electron can move to a higher energy level when an atom absorbs energy. Cations form when electrons gain enough energy to escape from atoms. The energy allows electrons to overcome the attraction of the protons in the nucleus. The amount of energy used to remove an electron is called ionization energy. It varies from element to element. The lower the ionization energy, the easier it is to remove an electron from an atom.

Figure 3 shows two trends for ionization energy. Ionization energies tend to increase from left to right across a period. It takes more energy to remove an electron from a nonmetal than from a metal in the same period. Ionization energies tend to decrease from the top of a group to the bottom. In Group 1A, potassium has a lower ionization energy than sodium. So it is easier to remove an electron from potassium than from sodium, and potassium is more reactive than sodium.

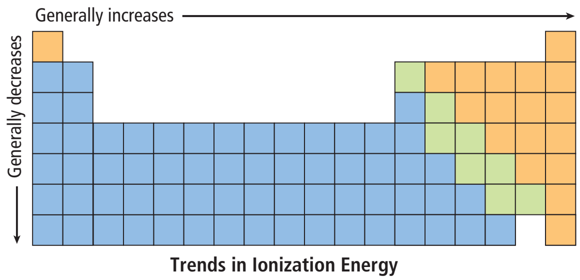


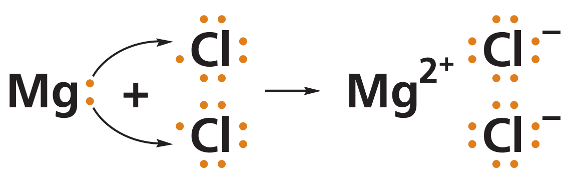
Figure 3 Ionization energies generally increase from left to right across a period. **Interpreting Diagrams** ***What is the trend for ionization energy within a group?***

Reading Checkpoint ***What is ionization energy?***

Ionic Compounds

Compounds that contain ionic bonds are ionic compounds, which can be represented by chemical formulas. A **chemical formula** is a notation that shows what elements a compound contains and the ratio of the atoms or ions of these elements in the compound. The chemical formula for sodium chloride is NaCl. From the formula, you can tell that there is one sodium ion for each chloride ion in sodium chloride.

Based on the diagram in Figure 4, what would the formula for magnesium chloride be? A magnesium atom cannot reach a stable electron configuration by reacting with just one chlorine atom. It must transfer electrons to two chlorine atoms. After the transfer, the charge on the magnesium ion is 2+ and its symbol is Mg^{2+}. The formula for the compound is $MgCl_2$. The 2 written to the right and slightly below the symbol for chlorine is a subscript. Subscripts are used to show the relative numbers of atoms of the elements present. If there is only one atom of an element in the formula, no subscript is needed.



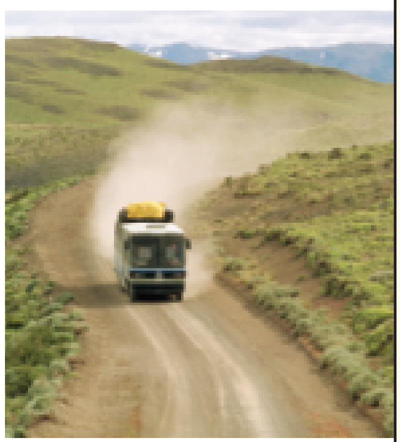


Figure 4 Magnesium chloride forms when magnesium atoms transfer electrons to chlorine atoms. Magnesium chloride is used to control dust that is stirred up by traffic on unpaved roads.

Facts and Figures

Ionization Energy Ionization energy varies for each valence electron in an atom. These energies are referred to as first ionization energy, I_1, second ionization energy, I_2, and so forth. An I_2 is always greater than an I_1 for a given element because the second electron is being removed from a positively charged ion. Because the positive charge continues to increase with each subsequent removal of an electron, an I_3 is greater than an I_2.

FYI

Memory aids may help students distinguish cations and anions. Tell students that *cation* means "to go down," which might make them think of losing an electron, and that *anion* means "to go up," which might make them think of gaining an electron. Students could also think of related terms that start with the same letter, such as *cast off* for cation and *accept* for anion. Finally, students could associate the phrase <u>A</u> <u>N</u>egative <u>ION</u> with anion.

Use Visuals L1

Figure 3 Emphasize the difference between the trend in ionization energy across a period and the trend within a group. Ask, **According to Figure 3, which element has a greater ionization energy, sodium or magnesium?** *(Magnesium)* **Which element has a greater ionization energy, potassium or cesium?** *(Cesium)* **Logical**

Ionic Compounds

Build Reading Literacy L1

KWL Refer to page **124D** in **Chapter 5**, which provides the guidelines for a KWL.

Before students read Ionic Compounds, have students construct a KWL chart with three columns entitled, What I Know, What I Want to Know, and What I Learned. Have them fill out the final column after they have read pp. 161–164. **Intrapersonal**

Build Math Skills L1

Ratios and Proportions When elements combine to form compounds, they do so in specific whole number ratios. For example, water, or H_2O, has a hydrogen to oxygen ratio of 2:1. Ask students to calculate the following ratios: sodium to chlorine in sodium chloride, NaCl; magnesium to chlorine in magnesium chloride, $MgCl_2$; and sodium to oxygen in sodium oxide, Na_2O. *(1:1; 1:2; 2:1)* **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Answer to . . .

Figure 3 *It generally decreases from top to bottom within a group.*

Reading Checkpoint *The amount of energy needed to remove an electron from an atom*

Integrate Earth Science L2

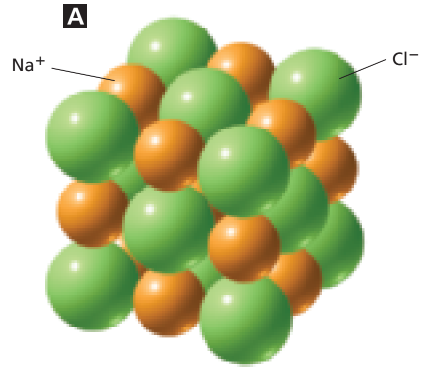
Geologists use a system to classify minerals similar to the one used by chemists to classify compounds. Ask students to use the library or Internet to find photographs of minerals that have cubic crystals (like sodium chloride) or hexagonal crystals (like ruby). Some students may also want to find examples of tetragonal, monoclinic, triclinic, and orthorhombic crystals.
Visual

Use Visuals L1

Figure 5 Have students examine Figure 5. Ask, **How are sodium ions represented in the figure?** *(Sodium ions are represented by the smaller, orange spheres.)* **How are chloride ions represented in the figure?** *(Chloride ions are represented by the larger, green spheres.)* **What do you notice about the pattern of the locations of positive and negative ions in the diagram?** *(No two neighboring ions have the same charge.)* **What similarity do you notice between the diagram and the photograph of sodium chloride crystals?** *(The structures in both the diagram and the photograph have a cubic shape.)*
Visual

Build Science Skills L2

Applying Concepts Help students understand the structure of a crystal lattice by encouraging them to think of three-dimensional analogies for lattices, such as scaffolding on a building or cups and saucers stacked on a tray in a restaurant.
Visual, Logical



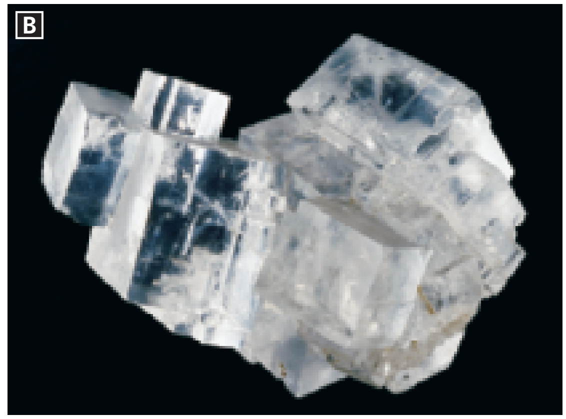


Figure 5 The structure and shape of a crystal are related. **A** In a sodium chloride crystal, each ion is surrounded by six oppositely charged ions. **B** Sodium chloride crystals are shaped like cubes.

Crystal Lattices A chemical formula for an ionic compound tells you the ratio of the ions in the compound. But it does not tell you how the ions are arranged in the compound. If you looked at a sample of sodium chloride with a hand lens or microscope, you would be able to see that the pieces of salt are shaped like cubes. This shape is a clue to how the sodium and chloride ions are arranged in the compound.

Figure 5A shows that the ions in sodium chloride are arranged in an orderly, three-dimensional structure. Each chloride ion is surrounded by six sodium ions and each sodium ion is surrounded by six chloride ions. Each ion is attracted to all the neighboring ions with an opposite charge. This set of attractions keeps the ions in fixed positions in a rigid framework, or lattice. The repeating pattern of ions in the lattice is like the repeating pattern of designs on the wallpaper in Figure 6.

Solids whose particles are arranged in a lattice structure are called **crystals.** Compare the cubic shape of the sodium chloride crystals in Figure 5B to the arrangement of ions in Figure 5A. The shape of an ionic crystal depends on the arrangement of ions in its lattice. In turn, the arrangement of the ions depends on the ratio of ions and their relative sizes. Crystals are classified into groups based on the shape of their crystals. Crystals of ruby have a six-sided, hexagonal shape. The How It Works box on page 163 describes one way to make rubies.

Reading Checkpoint ***What shape are sodium chloride crystals?***

Figure 6 This wallpaper displays a repeating pattern of flower and fruit designs. **Using Analogies** ***How is this arrangement of designs similar to the arrangement of ions in a crystal?***

Facts and Figures

Crystal Systems Crystals are classified into seven different crystal systems, which are described by geometric figures with six faces. The figures are distinguished by the angles at which the faces meet and by how many edges on a face are equal in length. Cubic: three equal edges, three 90° angles; tetragonal: two equal edges, three 90° angles; orthorhombic: no equal edges, three 90° angles; monoclinic: no equal edges, two 90° angles; triclinic: no equal edges, no 90° angles; hexagonal: two equal edges, two 90° angles, one 120° angle; rhombohedral: three equal edges, two 90° angles.

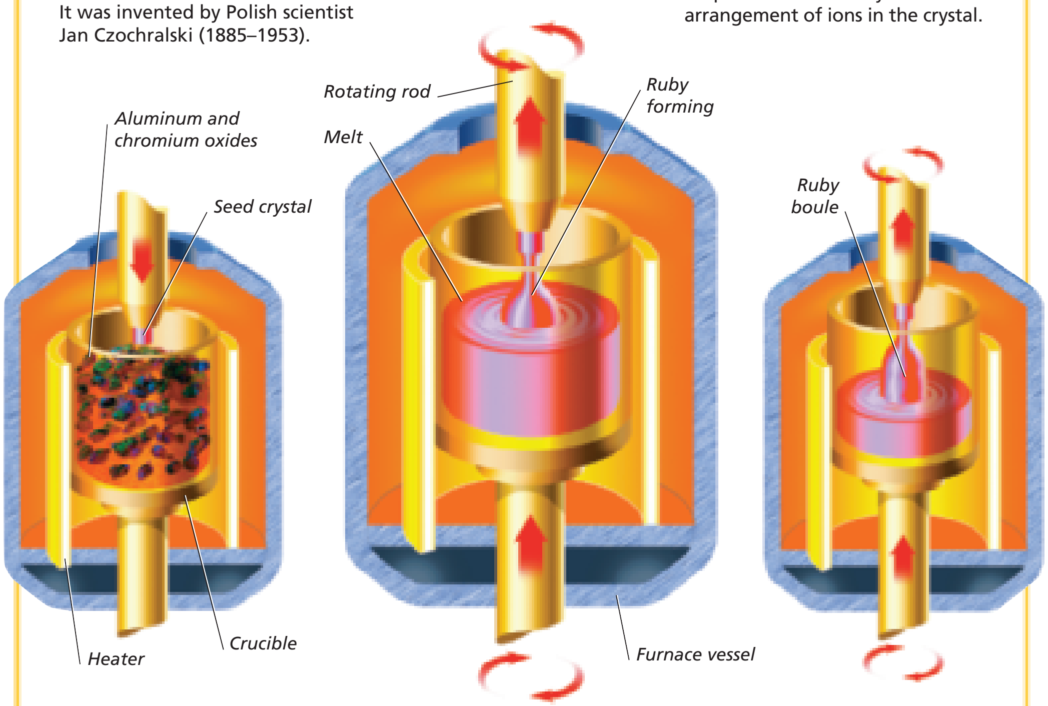
HOW It Works

Synthetic Rubies

Rubies are mainly aluminum oxide, which is white. The substitution of a small percentage of chromium ions for aluminum ions gives rubies their distinctive red color. Because natural rubies are rare, rubies are often manufactured. **Interpreting Diagrams** ***What substances are in the mixture used to make rubies?***

Synthetic ruby
A synthetic ruby boule has a hexagonal crystal structure identical to the natural ruby gemstone. Its shape is determined by the arrangement of ions in the crystal.

Making synthetic rubies
One way of making synthetic rubies is called the pulled-growth method. It was invented by Polish scientist Jan Czochralski (1885–1953).



1 **Seed crystal** Aluminum oxide and chromium(VI) oxide are melted. A tiny piece of ruby, called a seed crystal, is attached to a rod and placed above the molten mixture (melt).

2 **Lowering into the melt** The rod is lowered until the seed crystal touches the melt. The rod is slowly lifted, and ions in the melt begin to attach themselves to the seed crystal to form a ruby.

3 **Forming a boule** As the rod is lifted higher, an oblong-shaped crystal called a boule grows from the end. Once cooled, the boule can be cut into different shapes.

HOW It Works

Synthetic Rubies L2

Another technique used to create synthetic rubies was first used in 1902. It is called the Verneuil flame-fusion process. It differs from the more expensive Czochralski pulled-growth process described in the text in that the mixture of aluminum and chromium oxides is heated in open air with a flame instead of melted in a crucible.

The mineral corundum consists of aluminum oxide mixed with chromium, iron, or other mineral impurities. The color of a corundum crystal depends on the type and amount of impurities. Crystals of red corundum are called rubies, while crystals of other colors are called sapphires. In addition to the familiar use of synthetic rubies in jewelry, some lasers use synthetic rubies to produce light of a specific frequency.

Interpreting Diagrams Oxides of aluminum and chromium
Visual

For Enrichment L3

Interested students can make a poster presentation for the class explaining other methods for synthesizing gemstones. Some common methods besides the flame-fusion and pulled-growth methods include the flux-growth method, the solution-growth process, and horizontal crystallization.
Visual, Portfolio

Answer to . . .

Figure 6 *The pattern of design elements in the wallpaper repeats the way the arrangement of ions repeats in a crystal lattice.*

Reading Checkpoint *They are cubes.*

Section 6.1 (continued)

FYI

Real crystals are not perfect. Sites in a lattice may be vacant, sites may be occupied by impurities, and occupied sites may be squeezed in between regular sites in the lattice (an interstitial defect). In an ionic compound, a cation vacancy is balanced by a nearby anion vacancy or by an interstitial cation (which maintains an overall balance of charge). Crystal defects are largely responsible for how crystals fracture under stress.

Use Visuals L1

Figure 7 Have students compare the before-and-after diagrams. Ask, **When the hammer hits the crystal, what happens to the positions of the ions?** *(Ions with similar charge are pushed near one another.)* **How do objects with the same charge behave?** *(They repel.)* **Visual**

3 ASSESS

Evaluate Understanding L2

Have students describe the formation of anions, cations, and ionic bonds.

Reteach L1

Use the diagram at the bottom of p. 161 to review the formation of cations, anions, and ionic bonds.

Connecting Concepts

Potassium is more reactive than calcium because the amount of energy needed to remove a single valence electron from a potassium atom is much smaller than the amount of energy needed to remove two valence electrons from a calcium atom.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 6.1.

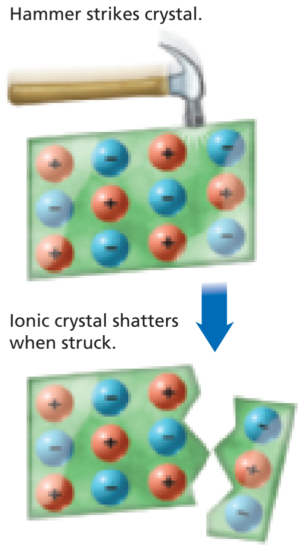


Figure 7 When an ionic crystal is struck, ions are moved from their fixed positions. Ions with the same charge repel one another and the crystal shatters.

Properties of Ionic Compounds The properties of sodium chloride are typical of an ionic compound. It has a high melting point (801°C). In its solid state, sodium chloride is a poor conductor of electric current. But when melted, it is a good conductor of electric current. Sodium chloride crystals shatter when struck with a hammer. **The properties of an ionic compound can be explained by the strong attractions among ions within a crystal lattice.**

Recall that the arrangement of particles in a substance is the result of two opposing factors. The first factor is the attractions among particles in the substance. The second factor is the kinetic energy of the particles. The stronger the attractions among the particles, the more kinetic energy the particles must have before they can separate.

For an electric current to flow, charged particles must be able to move from one location to another. The ions in a solid crystal lattice have fixed positions. However, when the solid melts, the lattice breaks apart and the ions are free to flow. Melted, or molten, sodium chloride is an excellent conductor of electric current.

Rock salt contains large crystals of sodium chloride. If you tapped a crystal of rock salt sharply with a hammer, it would shatter into many smaller crystals. Figure 7 shows what happens to the positions of the ions when the crystal is struck. Negative ions are pushed into positions near negative ions, and positive ions are pushed into positions near positive ions. Ions with the same charge repel one another and cause the crystal to shatter.

Section 6.1 Assessment

Reviewing Concepts

1. When is an atom least likely to react?
2. Describe one way an element can achieve a stable electron configuration.
3. What characteristic of ionic bonds can be used to explain the properties of ionic compounds?
4. Use ionization energy to explain why metals lose electrons more easily than nonmetals.
5. Why is a rock salt crystal likely to shatter when struck?

Critical Thinking

6. **Making Generalizations** What will the ratio of ions be in any compound formed from a Group 1A metal and a Group 7A nonmetal? Explain your answer.
7. **Drawing Conclusions** Why do ionic compounds include at least one metal?
8. **Predicting** Based on their chemical formulas, which of these compounds is not likely to be an ionic compound: KBr, SO_2, or $FeCl_3$? Explain your answer.

Connecting Concepts

Reactivity of Metals Use what you know about how ionic bonds form to explain the difference in reactivity between potassium and calcium. If necessary, reread the description of Group 1A and Group 2A properties in Section 5.3.

Section 6.1 Assessment

1. When the highest occupied energy level of an atom is filled with electrons
2. Through the transfer of electrons between atoms
3. The strong attractions among ions within a crystal lattice
4. Metals have lower ionization energies than nonmetals. The lower the ionization energy, the easier it is to remove an electron from an atom.
5. When ions with the same charge are pushed close together, they repel one another.
6. The ratio will be one to one because a Group 1A metal loses one electron and a Group 7A nonmetal gains one electron to achieve a stable electron configuration.
7. One element in an ionic compound must form cations, but nonmetals tend to form anions.
8. SO_2 because sulfur and oxygen are both nonmetals and unlikely to form cations