

What You Will Learn

- Explain how ionic bonds form.
- Describe how positive ions form.
- Describe how negative ions form.
- Explain why ionic compounds are neutral.

Vocabulary

ionic bond
ion
crystal lattice

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

ionic bond a bond that forms when electrons are transferred from one atom to another, which results in a positive ion and a negative ion

ion a charged particle that forms when an atom or group of atoms gains or loses one or more electrons

Ionic Bonds

Have you ever accidentally tasted sea water? If so, you probably didn't enjoy it. What makes sea water taste different from the water in your home?

Sea water tastes different because salt is dissolved in it. One of the salts in sea water is the same as the salt that you eat. The chemical bonds in salt are ionic (ie AHN ik) bonds.

Forming Ionic Bonds

An **ionic bond** is a bond that forms when electrons are transferred from one atom to another atom. During ionic bonding, one or more valence electrons are transferred from one atom to another. Like all chemical bonds, ionic bonds form so that the outermost energy levels of the atoms in the bonds are filled.

Figure 1 shows another substance that contains ionic bonds.

Charged Particles

An atom is neutral because the number of electrons in an atom equals the number of protons. So, the charges of the electrons and protons cancel each other. A transfer of electrons between atoms changes the number of electrons in each atom. But the number of protons stays the same in each atom. The negative charges and positive charges no longer cancel out, and the atoms become ions. **Ions** are charged particles that form when atoms gain or lose electrons. An atom normally cannot gain electrons without another atom nearby to lose electrons (or cannot lose electrons without a nearby atom to gain them). But it is easier to study the formation of ions one at a time.

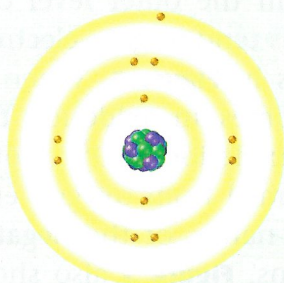
✓ Reading Check Why are atoms neutral? (See the Appendix for answers to Reading Checks.)

Figure 1 Calcium carbonate in this snail's shell contains ionic bonds.

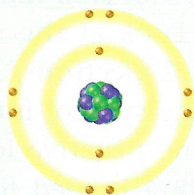


Figure 2 Forming Positive Ions

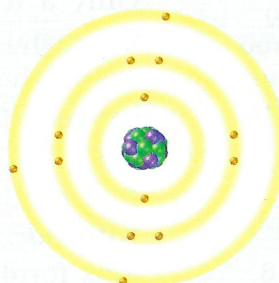
Here's How It Works: During chemical changes, a sodium atom can lose its 1 electron in the third energy level to another atom. The filled second level becomes the outermost level, so the resulting sodium ion has 8 valence electrons.



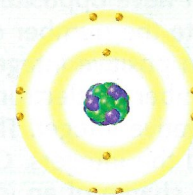
Sodium atom (Na)	
11+	protons
11-	electrons
0	charge



Sodium ion (Na⁺)	
11+	protons
10-	electrons
1+	charge



Aluminum atom (Al)	
13+	protons
13-	electrons
0	charge



Aluminum ion (Al³⁺)	
13+	protons
10-	electrons
3+	charge

Forming Positive Ions

Ionic bonds form during chemical changes when atoms pull electrons away from other atoms. The atoms that lose electrons form ions that have fewer electrons than protons. Because the positive charges outnumber the negative charges, these ions have a positive charge.

Metal Atoms and the Loss of Electrons

Atoms of most metals have few valence electrons. Metal atoms tend to lose these valence electrons and form positive ions. Look at the models in **Figure 2**. When a sodium atom loses its only valence electron to another atom, the sodium atom becomes a sodium ion. A sodium ion has 1 more proton than it has electrons. So, the sodium ion has a 1+ charge. The chemical symbol for this ion is written as Na⁺. Notice that the charge is written to the upper right of the chemical symbol. **Figure 2** also shows a model for the formation of an aluminum ion.

The Energy Needed to Lose Electrons

Energy is needed to pull electrons away from atoms. Only a small amount of energy is needed to take electrons from metal atoms. In fact, the energy needed to remove electrons from atoms of elements in Groups 1 and 2 is so small that these elements react very easily. The energy needed to take electrons from metals comes from the formation of negative ions.

SCHOOL to HOME

Studying Salt

Spread several grains of salt on a dark sheet of construction paper. Use a magnifying lens to examine the salt. Ask an adult at home to examine the salt. Discuss what you saw. Then, gently tap the salt with a small hammer. Examine the salt again. Describe your observations in your **science journal**.

ACTIVITY

MATH PRACTICE

Calculating Charge

Calculating the charge of an ion is the same as adding integers (positive or negative whole numbers and 0) that have opposite signs. You write the number of protons as a positive integer and the number of electrons as a negative integer. Then, you add the integers. Calculate the charge of an ion that contains 16 protons and 18 electrons. Write the ion's symbol and name.

Forming Negative Ions

Some atoms gain electrons from other atoms during chemical changes. The ions that form have more electrons than protons. So, these ions have a negative charge.

Nonmetal Atoms Gain Electrons

The outermost energy level of nonmetal atoms is almost full. Only a few electrons are needed to fill the outer level of a nonmetal atom. So, atoms of nonmetals tend to gain electrons from other atoms. Look at the models in **Figure 3**. When an oxygen atom gains 2 electrons, it becomes an oxide ion that has a 2- charge. The symbol for the oxide ion is O^{2-} . Notice that the name of the negative ion formed from oxygen ends with *-ide*. This ending is used for the names of the negative ions formed when atoms gain electrons. **Figure 3** also shows a model of how a chloride ion is formed.

The Energy of Gaining Electrons

Energy is given off by most nonmetal atoms when they gain electrons. The more easily an atom gains an electron, the more energy the atom releases. Atoms of Group 17 elements give off the most energy when they gain an electron. These elements are very reactive. An ionic bond will form between a metal and a nonmetal if the nonmetal releases more energy than is needed to take electrons from the metal.


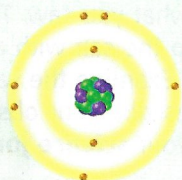
 **Reading Check** Atoms of which group on the periodic table give off the most energy when forming negative ions?

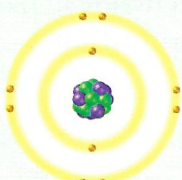
Figure 3 Forming Negative Ions

Here's How It Works: During chemical changes, an oxygen atom gains 2 electrons in the second energy level from another atom. An oxide ion that has 8 valence electrons is formed. Thus, its outermost energy level is filled.

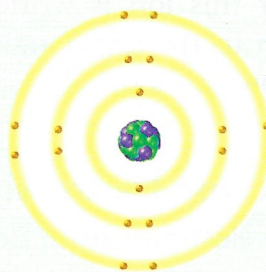
Here's How It Works: During chemical changes, a chlorine atom gains 1 electron in the third energy level from another atom. A chloride ion that has 8 valence electrons is formed. Thus, its outermost energy level is filled.



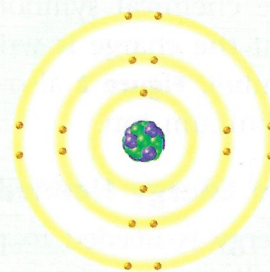
Oxygen atom (O)	
8+	protons
8-	electrons
<hr/>	
0	charge



Oxide ion (O^{2-})	
8+	protons
10-	electrons
<hr/>	
2-	charge



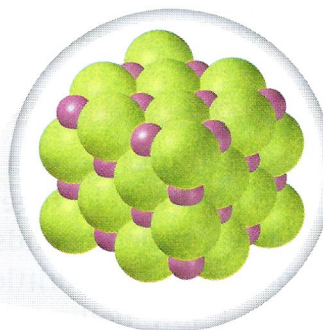
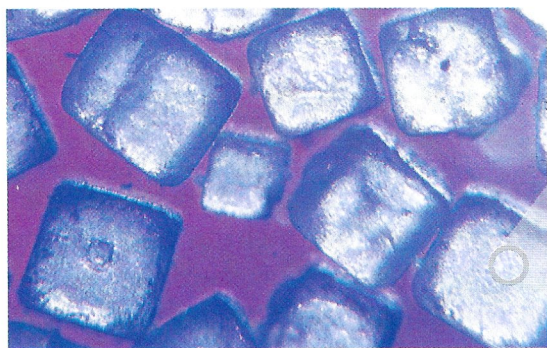
Chlorine atom (Cl)	
17+	protons
17-	electrons
<hr/>	
0	charge



Chloride ion (Cl^{-})	
17+	protons
18-	electrons
<hr/>	
1-	charge

Ionic Compounds

When ionic bonds form, the number of electrons lost by the metal atoms equals the number gained by the nonmetal atoms. The ions that bond are charged, but the compound formed is neutral because the charges of the ions cancel each other. When ions bond, they form a repeating three-dimensional pattern called a **crystal lattice** (KRIS tuh-l LAT is), like the one shown in **Figure 4**. The strong attraction between ions in a crystal lattice gives ionic compounds certain properties, which include brittleness, high melting points, and high boiling points.



crystal lattice the regular pattern in which a crystal is arranged

Figure 4 This model of the crystal lattice of sodium chloride, or table salt, shows a three-dimensional view of the bonded ions. In the model, the sodium ions are pink and the chloride ions are green.

SECTION Review

Summary

- An ionic bond is a bond that forms when electrons are transferred from one atom to another. During ionic bonding, the atoms become oppositely charged ions.
- Ionic bonding usually occurs between atoms of metals and atoms of nonmetals.
- Energy is needed to remove electrons from metal atoms. Energy is released when most nonmetal atoms gain electrons.

Using Key Terms

1. Use the following terms in the same sentence: *ion* and *ionic bond*.
2. In your own words, write a definition for the term *crystal lattice*.

Understanding Key Ideas

3. Which types of atoms usually become negative ions?
 - a. metals
 - b. nonmetals
 - c. noble gases
 - d. All of the above
4. How does an atom become a positive ion? a negative ion?
5. What are two properties of ionic compounds?

Math Skills

6. What is the charge of an ion that has 12 protons and 10 electrons? Write the ion's symbol.

Critical Thinking

7. **Applying Concepts** Which group of elements gains two valence electrons when the atoms form ionic bonds?
8. **Identifying Relationships** Explain why ionic compounds are neutral even though they are made up of charged particles.
9. **Making Comparisons** Compare the formation of positive ions with the formation of negative ions in terms of energy changes.

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Topic: Types of Chemical Bonds
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