

# Elements and Chemical Bonds

## Ionic and Metallic Bonds

### ..... Before You Read .....

**What do you think?** Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	5. Losing electrons can make some atoms more chemically stable.	
	6. Metals are good electrical conductors because they tend to hold onto their valence electrons very tightly.	

### ..... Read to Learn .....

## Understanding Ions

As you read in Lesson 2, the atoms of two or more nonmetals form compounds by sharing valence electrons. However, when a metal and a nonmetal bond, they do not share electrons. Instead, one or more valence electrons transfer from the metal atom to the nonmetal atom. After electrons transfer, the atoms bond and form a chemically stable compound. Transferring valence electrons results in atoms with the same number of valence electrons as a noble gas.

When an atom loses or gains a valence electron, it becomes an ion. *An ion is an atom that is no longer electrically neutral because it has lost or gained valence electrons.* Because electrons have a negative charge, gaining or losing an electron changes the overall charge of the atom. An atom that loses valence electrons becomes an ion with a positive charge. This is because after an atom loses an electron, the atom has more protons than electrons. The atom is now an ion with a positive charge. An atom that gains valence electrons becomes an ion with a negative charge. This is because the number of protons is now less than the number of electrons. ✓

### Key Concepts

- What is an ionic compound?
- How do metallic bonds differ from covalent and ionic bonds?

### Study Coach

**Write a Quiz** As you read, write one question for each paragraph on one side of a sheet of paper. Write the answers on the back of the paper. Exchange quizzes with a partner and take each other's quiz.

### Reading Check

**1. Explain** Why does an atom that gains an electron become an ion with a negative charge?

---



---



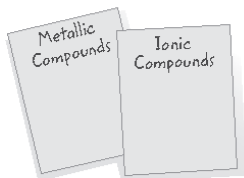
---



---

## FOLDABLES®

Make two quarter-sheet note cards to summarize information about ionic and metallic compounds.



### Losing Valence Electrons

Sodium (Na) is a metal. Its atomic number is 11. This means each sodium atom has 11 protons and 11 electrons. Sodium is in group 1 on the periodic table. Therefore, sodium atoms have one valence electron and are chemically unstable.

Metal atoms, such as sodium, become more stable when they lose valence electrons and form a chemical bond with a nonmetal. The figure below describes the process of losing and gaining valence electrons. When a sodium atom loses one valence electron, the electrons in the next-lower energy level become the new valence electrons. The sodium atom then has eight valence electrons, the same as the noble gas neon (Ne). The sodium atom is chemically stable.

### Gaining Valence Electrons

In Lesson 2, you learned that nonmetal atoms can share valence electrons with other nonmetal atoms. Nonmetal atoms can also gain valence electrons from metal atoms. Either way, they achieve the electron arrangement of a noble gas. The nonmetal chlorine (Cl) has an atomic number of 17. Chlorine atoms have seven valence electrons, as shown in the figure below. If a chlorine atom gains one valence electron, it will have eight valence electrons. It will then have the same electron arrangement as the stable noble gas argon (Ar).

When a sodium atom loses a valence electron, it becomes a positively charged ion. This is shown by a plus (+) sign. When a chlorine atom gains a valence electron, it becomes a negatively charged ion. This is shown by a negative (-) sign. ✓

### ✓ Reading Check

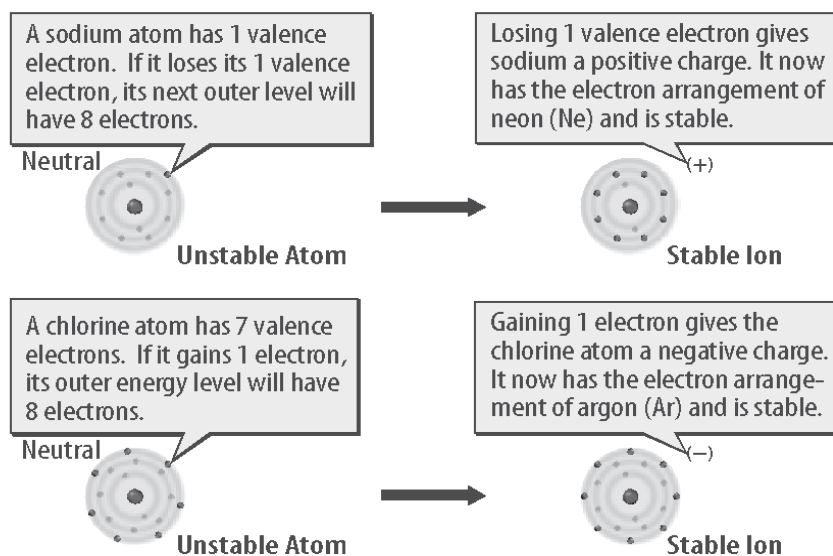
**2. Predict** Are atoms of a group 16 element more likely to gain or lose valence electrons?

---

### ✓ Visual Check

**3. Identify** What would an ion's charge be if the atom gained two electrons?

---




## Determining an Ion's Charge

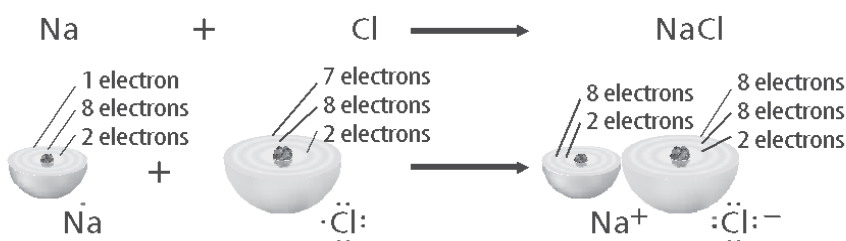
Atoms are electrically neutral because they have the same number of protons (+) and electrons (-). Once an atom gains or loses electrons, it becomes a charged ion. For example, the atomic number for nitrogen (N) is 7. This means that each N atom has 7 protons and 7 electrons. It is electrically neutral. When forming an ionic bond, N atoms gain 3 electrons. The N ion then has 10 electrons. To determine the charge of the ion, subtract the number of electrons in the ion from the number of protons.

$$7 \text{ protons} - 10 \text{ electrons} = -3 \text{ charge}$$

A nitrogen ion has a  $-3$  charge. This is written as  $\text{N}^{3-}$ .

## Ionic Bonds—Electron Transferring

Recall that metal atoms lose valence electrons and nonmetal atoms gain valence electrons. When forming a chemical bond, the nonmetal atoms gain the electrons lost by the metal atoms. In (NaCl), or table salt, a sodium atom loses one valence electron. The electron is transferred to a chlorine atom. The sodium atom is now a positively charged ion. The chlorine atom is now a negatively charged ion. These ions attract each other and form a stable ionic compound, as shown below. *The attraction between positively and negatively charged ions in an ionic compound is an ionic bond.* 



## Ionic Compounds

The ions of ionic compounds are strongly attracted to each other. As a result, ionic compounds are usually solid and brittle at room temperature. They have relatively high melting and boiling points. Water that contains dissolved ionic compounds is a good conductor of electricity. This is because an electrical charge can pass from ion to ion in the solution.

## Comparing Ionic and Covalent Compounds

Recall that in a covalent bond, two or more nonmetal atoms share electrons and form a unit, or molecule. Covalent compounds are made up of many molecules. However, when nonmetal ions bond to metal ions in an ionic compound, there are no molecules. Instead, there is a large collection of ions with opposite charges. The ions are all attracted to each other and are held together by ionic bonds.

## Math Skills

An atom's radius is measured in picometers (pm), 1 trillion times smaller than a meter. When an atom becomes an ion, its radius either increases or decreases. For example, the radius of a sodium (Na) atom is 186 pm. The radius of a  $\text{Na}^+$  ion is 102 pm. By what percentage does the radius change as the ion forms?

- Subtract the ion's radius from the atom's radius.  
 $102 \text{ pm} - 186 \text{ pm} = -84 \text{ pm}$
- Divide the difference by the atom's radius.  
 $-84 \text{ pm} \div 186 \text{ pm} = -0.45$
- Multiply the answer by 100 and add a % sign.  
 $-0.45 \times 100 = -45\%$

A negative value means a decrease in size. A positive value means an increase.

## 4. Calculate Percentage

The radius of an oxygen (O) atom is 73 pm. The radius of an oxygen ion ( $\text{O}^{2-}$ ) is 140 pm. By what percentage does the radius change? Show your work.

---

---

---

## Key Concept Check

**5. Explain** What holds ionic compounds together?

---

---

---

### Key Concept Check

**6. Specify** How do metal atoms bond with one another?

---

---

### ACADEMIC VOCABULARY


#### conduct

(verb) to serve as a medium through which something can flow

### Visual Check

**7. Identify** Circle the bond that results in a compound that conducts thermal energy well.

## Metallic Bonds—Electron Pooling

Recall that metal atoms typically lose valence electrons when forming compounds. Metal atoms form compounds with one another by combining, or pooling, their valence electrons, as shown in the table below. A **metallic bond** is a bond formed when many metal atoms share their pooled valence electrons. In aluminum (Al), atoms lose their valence electrons and become positive ions. The negatively charged valence electrons move from ion to ion. Valence electrons in metals do not bond to one atom. Instead, a “sea of electrons” surrounds the positive ions. 

### Properties of Metallic Compounds

Metals are good conductors of thermal energy and electricity. Because the valence electrons can move from ion to ion, they can easily conduct an electric charge. When a metal is hammered into a sheet or drawn into a wire, it does not break. The metal ions can slide past one another in the electron sea and move to new positions. Metals are shiny because the valence electrons at the surface interact with light. The table below compares the covalent, ionic, and metallic bonds that you studied in this chapter.

Type of Bond	What is bonding?	Properties of Compounds
<b>Covalent</b> —share valence electrons	nonmetal atoms; nonmetal atoms	<ul style="list-style-type: none"><li>• gas, liquid, or solid</li><li>• low melting and boiling points</li><li>• often not able to dissolve in water</li><li>• poor conductors of thermal energy and electricity</li><li>• dull appearance</li></ul>
<b>Ionic</b> —transfer valence electrons	nonmetal ions; metal ions	<ul style="list-style-type: none"><li>• solid crystals</li><li>• high melting and boiling points</li><li>• dissolves in water</li><li>• solids are poor conductors of thermal energy and electricity</li><li>• ionic compounds in water solutions conduct electricity</li></ul>
<b>Metallic</b> —pool valence electrons	metal ions; metal ions	<ul style="list-style-type: none"><li>• usually solid at room temperature</li><li>• high melting and boiling points</li><li>• do not dissolve in water</li><li>• good conductors of thermal energy and electricity</li><li>• shiny surface</li><li>• can be hammered into sheets and pulled into wires</li></ul>

## ..... After You Read .....

### Mini Glossary

**ion:** an atom that is no longer electrically neutral because it has lost or gained valence electrons

**metallic bond:** a bond formed when many metal atoms share their pooled valence electrons

**ionic bond:** the attraction between positively and negatively charged ions in an ionic compound

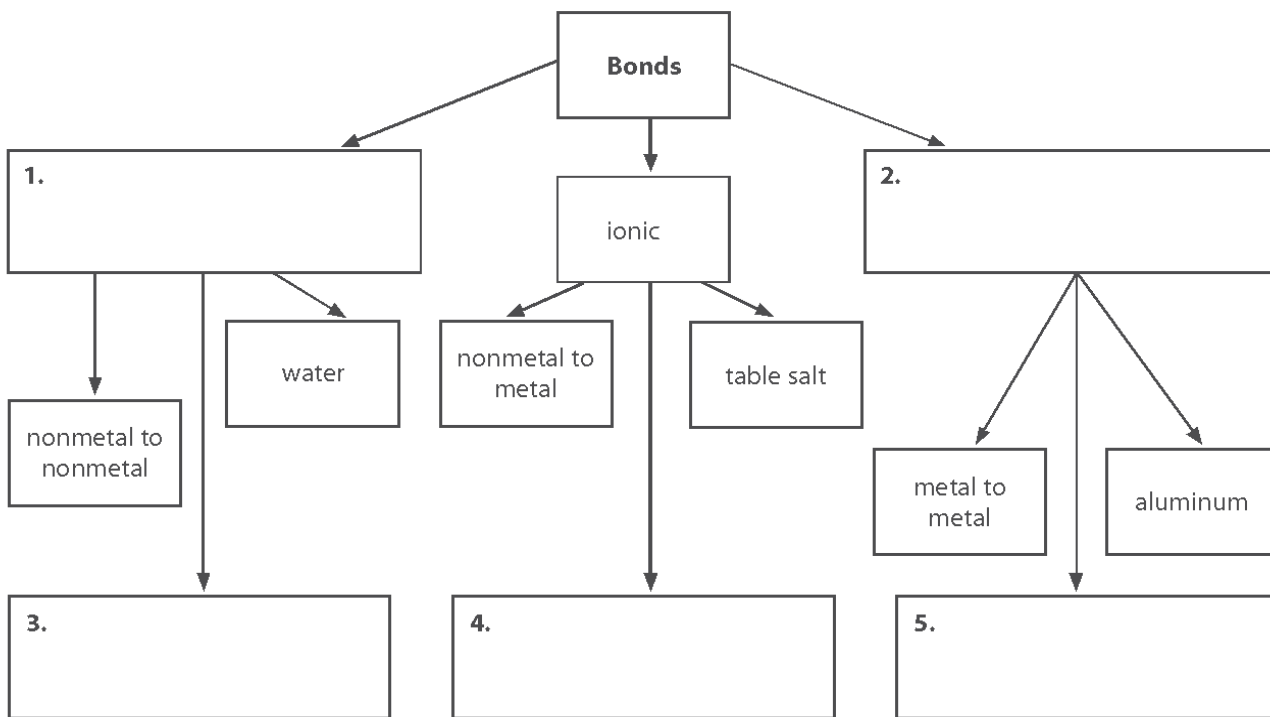
- Review the terms and their definitions in the Mini Glossary. Write two sentences that describe the difference between a positively charged ion and a negatively charged ion.

---



---

- Fill in the organizer below with the following terms to compare the three types of bonding that you learned about in this chapter: *ionic*, *metallic*, and *covalent*. In each bottom box, identify the type of bond by writing *transfer valence electrons*, *pool valence electrons*, or *share valence electrons*.



Copyright © McGraw-Hill Education.

### What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?



Log on to [ConnectED.mcgraw-hill.com](http://ConnectED.mcgraw-hill.com) and access your textbook to find this lesson's resources.

END OF LESSON