

## Ionic Bonds

## Reading Preview

## Key Concepts

- What are ions, and how do they form bonds?
- How are the formulas and names of ionic compounds written?
- What are the properties of ionic compounds?

## Key Terms

- ✓ ion ✓ polyatomic ion
- ✓ ionic bond ✓ ionic compound
- ✓ chemical formula ✓ subscript
- crystal

## Target Reading Skill

**Previewing Visuals** Before you read, preview Figure 9. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

## Formation of an Ionic Bond

Q. What is an ionic bond?

A.

Q.

Lab zone

## Discover Activity

## How Do Ions Form?

1. Place three pairs of checkers (three red and three black) on your desk. The red represent electrons and the black represent protons.
2. Place nine pairs of checkers (nine red and nine black) in a separate group on your desk.
3. Move a red checker from the smaller group to the larger group.
4. Count the number of positive charges (protons) and negative charges (electrons) in each group.
5. Now sort the checkers into a group of four pairs and a group of eight pairs. Repeat Steps 3 and 4, this time moving two red checkers from the smaller group to the larger group.



## Think It Over

**Inferring** What was the total charge on each group before you moved the red checkers (electrons)? What was the charge on each group after you moved the checkers? Based on this activity, what do you think happens to the charge on an atom when it loses electrons? When it gains electrons?

You and a friend walk past a market that sells apples for 40 cents each and pears for 50 cents each. You have 45 cents and want an apple. Your friend also has 45 cents but wants a pear. You realize that if you give your friend a nickel, she will have 50 cents and can buy a pear. You will have 40 cents left to buy an apple. Transferring the nickel gets both of you what you want. Your actions model, in a simple way, what can happen between atoms.

If you transfer a nickel to your friend, both of you will have the money you need.

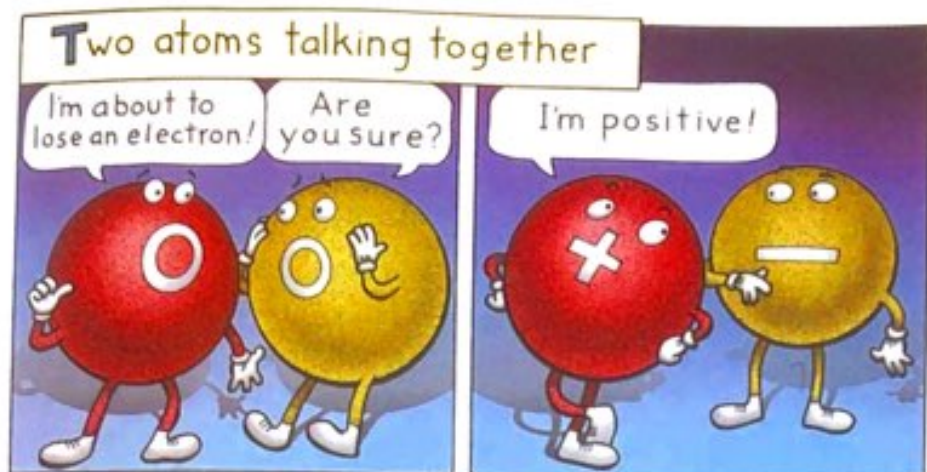


FIGURE 7

### How Ions Form

When an atom loses one of its electrons, it becomes a positively charged ion. The atom that gains the electron becomes a negatively charged ion.

## Ions and Ionic Bonds

Atoms with five, six, or seven valence electrons usually become more stable when this number increases to eight. Likewise, most atoms with one, two, or three valence electrons can lose electrons and become more stable. When these two types of atoms combine, electrons are transferred from one type of atom to the other. The transfer makes both types of atoms more stable.

**How Ions Form** An **ion** (EYE ahn) is an atom or group of atoms that has an electric charge. **When an atom loses an electron, it loses a negative charge and becomes a positive ion. When an atom gains an electron, it gains a negative charge and becomes a negative ion.** Figure 8 lists some ions you will often see in this book. Use this table as a reference while you read this section and other chapters.

**Polyatomic Ions** Notice in Figure 8 that some ions are made of several atoms. For example, the ammonium ion is made of nitrogen and hydrogen atoms. Ions that are made of more than one atom are called **polyatomic ions** (pahl ee uh TAHM ik). The prefix *poly* means “many,” so *polyatomic* means “many atoms.” You can think of a polyatomic ion as a group of atoms that reacts as a unit. Like other ions, polyatomic ions have an overall positive or negative charge.



**Reading Checkpoint**

How does an ion with a charge of 2+ form?

FIGURE 8

Ions are atoms that have lost or gained electrons. **Interpreting Tables** How many electrons does a sulfur atom gain when it becomes a sulfide ion?

| Ions and Their Charges |        |                               |
|------------------------|--------|-------------------------------|
| Name                   | Charge | Symbol or Formula             |
| Lithium                | 1+     | Li <sup>+</sup>               |
| Sodium                 | 1+     | Na <sup>+</sup>               |
| Potassium              | 1+     | K <sup>+</sup>                |
| Ammonium               | 1+     | NH <sub>4</sub> <sup>+</sup>  |
| Calcium                | 2+     | Ca <sup>2+</sup>              |
| Magnesium              | 2+     | Mg <sup>2+</sup>              |
| Aluminum               | 3+     | Al <sup>3+</sup>              |
| Fluoride               | 1-     | F <sup>-</sup>                |
| Chloride               | 1-     | Cl <sup>-</sup>               |
| Iodide                 | 1-     | I <sup>-</sup>                |
| Bicarbonate            | 1-     | HCO <sub>3</sub> <sup>-</sup> |
| Nitrate                | 1-     | NO <sub>3</sub> <sup>-</sup>  |
| Oxide                  | 2-     | O <sup>2-</sup>               |
| Sulfide                | 2-     | S <sup>2-</sup>               |
| Carbonate              | 2-     | CO <sub>3</sub> <sup>2-</sup> |
| Sulfate                | 2-     | SO <sub>4</sub> <sup>2-</sup> |
| Phosphate              | 3-     | PO <sub>4</sub> <sup>3-</sup> |

FIGURE 9

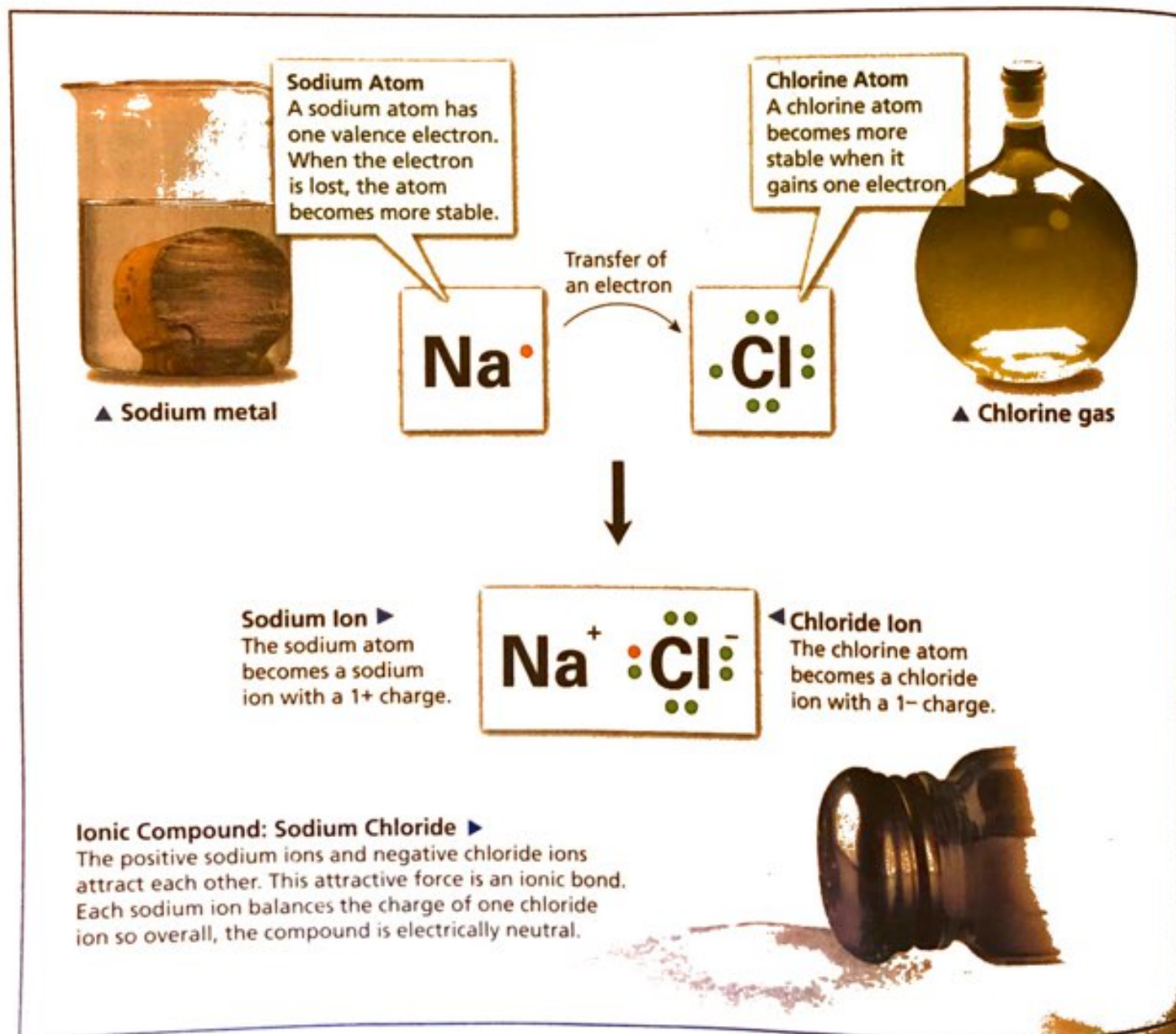
## Formation of an Ionic Bond

Reactions occur easily between metals in Group 1 and nonmetals in Group 17. Follow the process below to see how an ionic bond forms between a sodium atom and a chlorine atom.

**Relating Cause and Effect** Why is sodium chloride electrically neutral?

**Ionic Bonds** Look at Figure 9 to see how sodium atoms and chlorine atoms combine to form sodium chloride (table salt). Notice that sodium has one valence electron and chlorine has seven valence electrons. When sodium's valence electron is transferred to chlorine, both atoms become ions. The sodium atom becomes a positive ion ( $\text{Na}^+$ ). The chlorine atom becomes a negative ion ( $\text{Cl}^-$ ).

Because oppositely charged particles attract, the positive  $\text{Na}^+$  ion and the negative  $\text{Cl}^-$  ion attract each other. An **ionic bond** is the attraction between two oppositely charged ions. **Ionic bonds form as a result of the attraction between positive and negative ions.** A compound that consists of positive and negative ions, such as sodium chloride, is called an **ionic compound**.



## Chemical Formulas and Names

Compounds can be represented by chemical formulas. A **chemical formula** is a combination of symbols that shows the ratio of elements in a compound. For example, the formula for magnesium chloride is  $\text{MgCl}_2$ . What does the formula tell you?

**Formulas of Ionic Compounds** From Figure 8 you know that the charge on the magnesium ion is  $2+$ . **When ionic compounds form, the ions come together in a way that balances out the charges on the ions. The chemical formula for the compound reflects this balance.** Two chloride ions, each with a charge of  $1-$  will balance the charge on the magnesium ion. That's why the formula of magnesium chloride is  $\text{MgCl}_2$ . The number "2" is a subscript. A **subscript** tells you the ratio of elements in the compound. For  $\text{MgCl}_2$ , the ratio of magnesium ions to chloride ions is 1 to 2.

If no subscript is written, the number 1 is understood. For example, the formula  $\text{NaCl}$  tells you that there is a 1 to 1 ratio of sodium ions to chloride ions. Formulas for compounds of polyatomic ions are written in a similar way. For example, calcium carbonate has the formula  $\text{CaCO}_3$ .

**Naming Ionic Compounds** Magnesium chloride, sodium bicarbonate, sodium oxide—where do these names come from? **For an ionic compound, the name of the positive ion comes first, followed by the name of the negative ion.** The name of the positive ion is usually the name of a metal. But, a few positive polyatomic ions exist, such as the ammonium ion ( $\text{NH}_4^+$ ). If the negative ion is a single element, as you've already seen with sodium chloride, the end of its name changes to *-ide*. For example,  $\text{MgO}$  is named magnesium oxide. If the negative ion is polyatomic, its name usually ends in *-ate* or *-ite*, as in Figure 8. The compound  $\text{NH}_4\text{NO}_3$ , named ammonium nitrate, is a common fertilizer for gardens and crop plants.



**Reading Checkpoint**

What is the name of the ionic compound with the formula  $\text{K}_2\text{S}$ ?

**FIGURE 10**

### Calcium Carbonate

The white cliffs of Dover, England, are made of chalk formed from the remains of tiny sea organisms. Chalk is mostly an ionic compound, calcium carbonate.

Lab  
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## Skills Activity

### Interpreting Data

Use the periodic table and Figure 8 to identify the charges of the ions in each ionic compound listed below. Then write the formula for each compound.

- sodium bromide
- lithium oxide
- magnesium sulfide
- aluminum fluoride
- potassium nitrate
- ammonium chloride


How did you know how many of each ion to write in the formula?



## Try This Activity

## Crystal Clear

Can you grow a salt crystal?

1.  Add salt to a jar containing about 200 mL of hot tap water and stir. Keep adding salt until no more dissolves and it settles out when you stop stirring.
2. Tie a large crystal of coarse salt into the middle of a piece of thread.
3. Tie one end of the thread to the middle of a pencil.
4. Suspend the other end of the thread in the solution by laying the pencil across the mouth of the jar. Do not allow the crystal to touch the solution.
5. Place the jar in a quiet, undisturbed area. Check the size of the crystal over the next few days.

**Observing** Does the salt crystal change size over time? What is its shape? What do you think is happening to the ions in the solution?

## Properties of Ionic Compounds

Table salt, baking soda, and iron rust are different compounds with different properties. You wouldn't want to season your food with either iron rust or baking soda. However, these compounds are alike in some ways because they are all ionic compounds. **In general, ionic compounds are hard, brittle crystals that have high melting points. When dissolved in water or melted, they conduct electricity.**

**Ionic Crystals** Figure 11 shows a chunk of halite, or table salt, NaCl. Pieces of halite have sharp edges, corners, flat surfaces, and a cubic shape. Equal numbers of  $\text{Na}^+$  and  $\text{Cl}^-$  ions in solid sodium chloride are attracted in an alternating pattern, as shown in the diagram. The ions form an orderly, three-dimensional arrangement called a **crystal**.

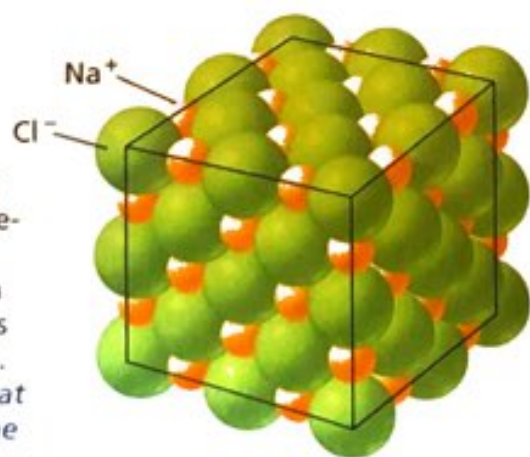
In an ionic compound, every ion is attracted to ions of opposite charge that surround it. It is attracted to ions above, below, and to all sides. The pattern formed by the ions remains the same no matter what the size of the crystal. In a single grain of salt, the crystal pattern extends for millions of ions in every direction. Many crystals of ionic compounds are hard and brittle, due to the strength of their ionic bonds and the attractions among all the ions.

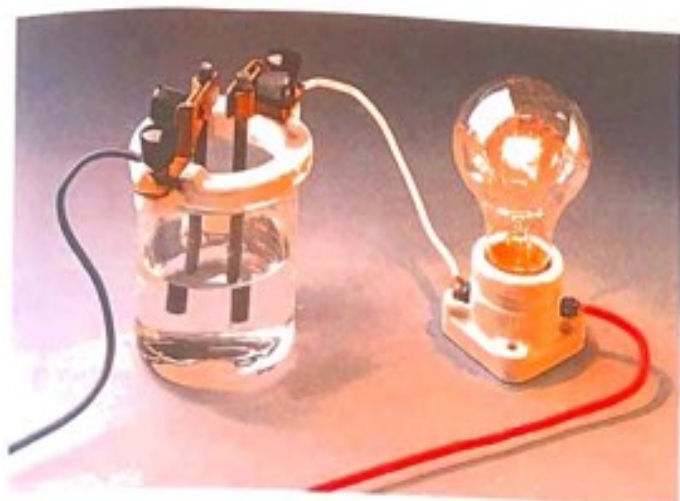
**High Melting Points** What happens when you heat an ionic compound such as table salt? When you heat a substance, its energy increases. When ions have enough energy to overcome the attractive forces between them, they break away from each other. In other words, the crystal melts to a liquid. Because ionic bonds are strong, a lot of energy is needed to break them. As a result, ionic compounds have high melting points. They are all solids at room temperature. Table salt must be heated to  $801^\circ\text{C}$  before the crystal melts.

FIGURE 11  
Ionic Crystals

The ions in ionic compounds are arranged in specific three-dimensional shapes called crystals. Some crystals have a cube shape like these crystals of halite, or sodium chloride.

**Making Generalizations** What holds the ions together in the crystal?





**FIGURE 12**  
**Ions in Solution**  
A solution of sodium chloride conducts current across the gap between the two black rods of a conductivity tester. As a result, the bulb lights up.

**Electrical Conductivity** Electric current is the flow of charged particles. When ionic crystals dissolve in water, the bonds between ions are broken. As a result, the ions are free to move about, and the solution conducts current. Likewise, after an ionic compound melts, the ions are able to move freely, and the liquid conducts current. In contrast, ionic compounds in solid form do not conduct current well. The ions in the solid crystal are tightly bound to each other and cannot move from place to place. If charged particles cannot move, there is no current.



**Reading  
Checkpoint**

What is a crystal?

**Go Online**

SCILINKS<sup>SM</sup>  
NSTA

For: Links on ionic compounds  
Visit: [www.SciLinks.org](http://www.SciLinks.org)  
Web Code: scn-1213

## Section 2 Assessment

**Target Reading Skill Previewing Visuals**  
Compare your questions and answers about Figure 9 with those of a partner.

### Reviewing Key Concepts

- a. Reviewing** What are the two basic ways in which ions form from atoms?

**b. Comparing and Contrasting** Contrast sodium and chloride ions, including how they form. Write the symbol for each ion.

**c. Relating Cause and Effect** What holds the ions together in sodium chloride? Indicate the specific charges that are involved.
- a. Identifying** What information is given by the formula of an ionic compound?

**b. Explaining** The formula for sodium sulfide is  $\text{Na}_2\text{S}$ . Explain what this formula means.

**c. Applying Concepts** Write the formula for calcium chloride. Explain how you determined this formula.

- a. Listing** List three properties of ionic compounds.

**b. Making Generalizations** Relate each property that you listed to the characteristics of ionic bonds.

### Writing in Science

**Firsthand Account** Pretend that you are the size of an atom, observing a reaction between a potassium atom and a fluorine atom. Write an account of the formation of an ionic bond as the atoms react. Tell what happens to the valence electrons on each atom and how each atom is changed by losing or gaining electrons.