Section 3

Ionic Bonds

Objectives

After this lesson, students will be able to

L.1.3.1 Describe ions, and explain how they form bonds.

L.1.3.2 Explain how the formulas and names of ionic compounds are written.

L.1.3.3 Identify the properties of ionic compounds.

Target Reading Skill

Previewing Visuals Explain that looking at the visuals before they read helps students activate prior knowledge and predict what they are about to read.

Answers

Sample questions and answers:

Formation of an Ionic Bond

What is an ionic bond? *(An ionic bond is the attraction between two oppositely charged ions.)* **What is the overall charge on an ionic compound?** *(Overall, an ionic compound is electrically neutral.)*

All in One Teaching Resources

- Transparency L6

Preteach

Build Background Knowledge

L2

Electrons and Electrical Charge

Guide students in recalling what they have learned about electrons and electrical charge as a review of the knowledge needed to understand how elements become ions and form ionic bonds. Ask: **What charge does an electron have?** *(1–)* **What is the overall charge on the atom of an element?** *(Overall, an atom is neutral in charge.)* **What charges attract each other?** *(Positive and negative charges)* **Elements in which group have one valence electron?** *(Group 1)* **Elements in which group have seven valence electrons?** *(Group 17)* Tell students that these facts about electrons and electrical charge will help them understand ionic bonds, which they will read about in this section.

Section 3

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

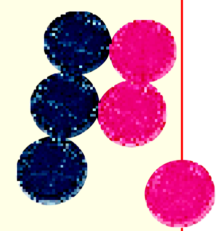
Previewing Visuals Before you read, preview Figure 17. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Formation of an Ionic Bond

Q.	What is an ionic bond?
A.	
Q.	

Lab zone Discover Activity

How Do Ions Form?

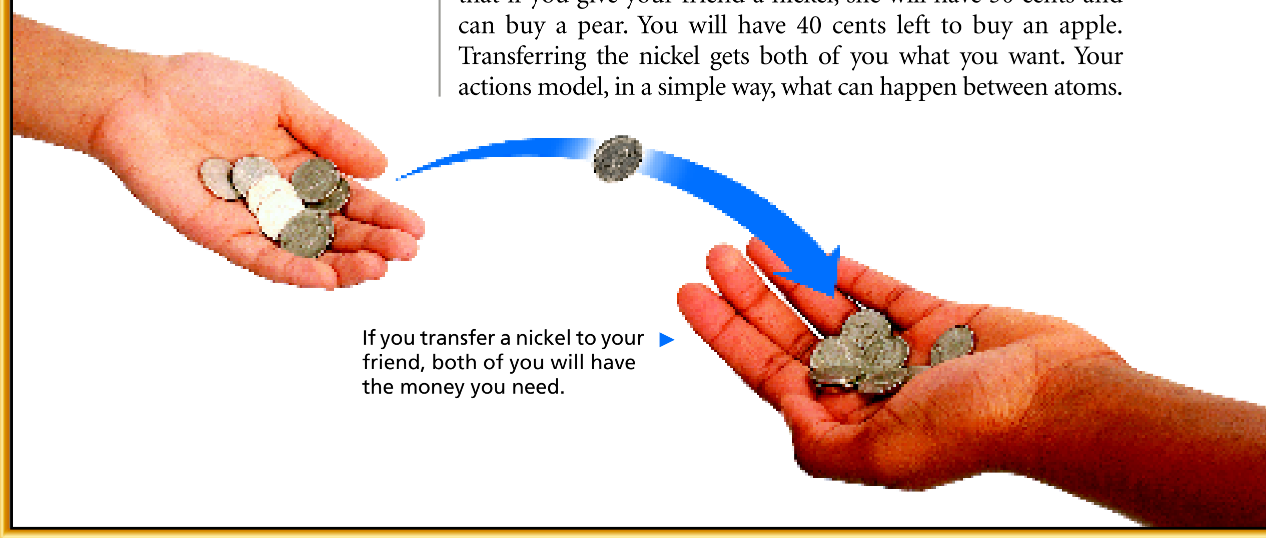


1. Place three pairs of checkers (three red and three black) on your desk. The red represent electrons and the black represent protons.
2. Place nine pairs of checkers (nine red and nine black) in a separate group on your desk.
3. Move a red checker from the smaller group to the larger group.
4. Count 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.

Lab zone Discover Activity

Skills Focus Inferring L1

Materials 12 red checkers, 12 black checkers

Time 15 minutes

Tip Remind students that each electron (red checker) has a charge of 1– and each proton (black checker) has a charge of 1+.

Expected Outcome Students simulate the transfer of electrons between atoms.

Think It Over Before the red checkers (electrons) were moved, each group was electrically neutral. The group that gained one or two red checkers had a charge of 1– or 2–. The group that lost one or two red checkers had a charge of 1+ or 2+. An atom becomes positively charged when it loses electrons and negatively charged when it gains electrons.

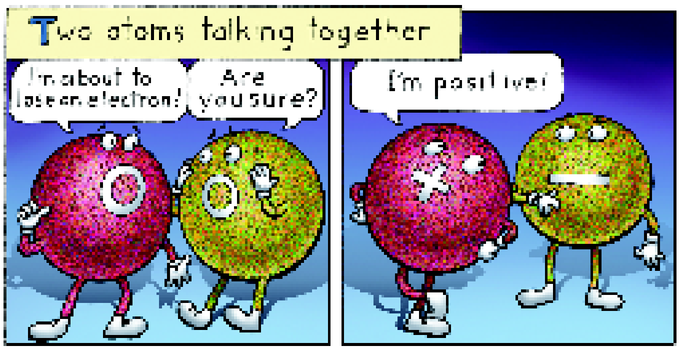


FIGURE 15
How Ions Form
When an atom loses one of its electrons, it becomes a positively charged ion. The atom that gains the electron becomes a negatively charged ion.

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 16 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 16 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?

Ions and Their Charges

Name	Charge	Symbol or Formula
Lithium	1+	Li^+
Sodium	1+	Na^+
Potassium	1+	K^+
Ammonium	1+	NH_4^+
Calcium	2+	Ca^{2+}
Magnesium	2+	Mg^{2+}
Aluminum	3+	Al^{3+}
Fluoride	1–	F^-
Chloride	1–	Cl^-
Iodide	1–	I^-
Bicarbonate	1–	HCO_3^-
Nitrate	1–	NO_3^-
Oxide	2–	O^{2-}
Sulfide	2–	S^{2-}
Carbonate	2–	CO_3^{2-}
Sulfate	2–	SO_4^{2-}
Phosphate	3–	PO_4^{3-}

FIGURE 16
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?*

Differentiated Instruction

Gifted and Talented L3

Modeling Polyatomic Ions Challenge students to draw electron dot diagrams for several of the more complex polyatomic ions listed in Figure 16, such as ammonium, aluminum, bicarbonate, and phosphate. Encourage students to share their completed diagrams with the class by drawing them on the board. Have them explain how they determined the correct way to represent each ion. **learning modality: logical/mathematical**

Instruct

Ions and Ionic Bonds

Teach Key Concepts L2

Formation of Ions

Focus Use the cartoon in Figure 15 to help students understand how ions form.

Teach Have students read the cartoon. Ask: **In the first frame, what do the zeroes represent?** *(Neutrality of atoms)* **Why does one atom become positive and the other atom become negative?** *(The positive atom loses an electron, and the negative atom gains an electron.)* **What do the atoms represent in the second frame?** *(Ions)*

Apply Challenge students to write an operational definition of the term *ion* based on the cartoon. *(Atoms that have an electric charge)* **learning modality: visual**

Use Visuals: Figure 16 L3

Common Ions and Their Charges

Focus Introduce common ions that students will see throughout the book.

Teach In Figure 16, point out how positively charged ions are listed first, followed by negatively charged ions, and how, within each charge group, the ions are listed by order of increasing charge.

Apply Suggest that students mark this page with a self-sticking note for easy referral, because they will use Figure 16 throughout this and later chapters. **learning modality: visual**

All in One Teaching Resources
- Transparency L7

Independent Practice L2

All in One Teaching Resources
- *Guided Reading and Study Worksheet: Ionic Bonds*

Student Edition on Audio CD

Monitor Progress L2

Skills Check Ask students to predict the charge of bromide, an ion that forms from bromine in Group 17. Remind students that Group 17 elements have seven valence electrons.

Answers

Figure 16 Two electrons

Reading Checkpoint By losing two electrons

Use Visuals: Figure 17 L2

Formation of Ionic Bonds

Focus Guide students in using the diagram to learn how ionic bonds form.

Teach Instruct students to study Figure 17. Ask: **Why do sodium and chloride ions bond together?** *(They have opposite charges, and opposite charges attract.)*

Apply Ask: **How would another Group 1 metal, such as potassium, and another Group 17 nonmetal, such as bromine, form a bond?** *(The same way as sodium and chlorine)* **learning modality: visual**

All in One Teaching Resources

- Transparency L8

Lab zone Build Inquiry L2

Predicting How Ions Will Bond

Materials list of positive ions and negative ions (Figure 16)

Time 5 minutes

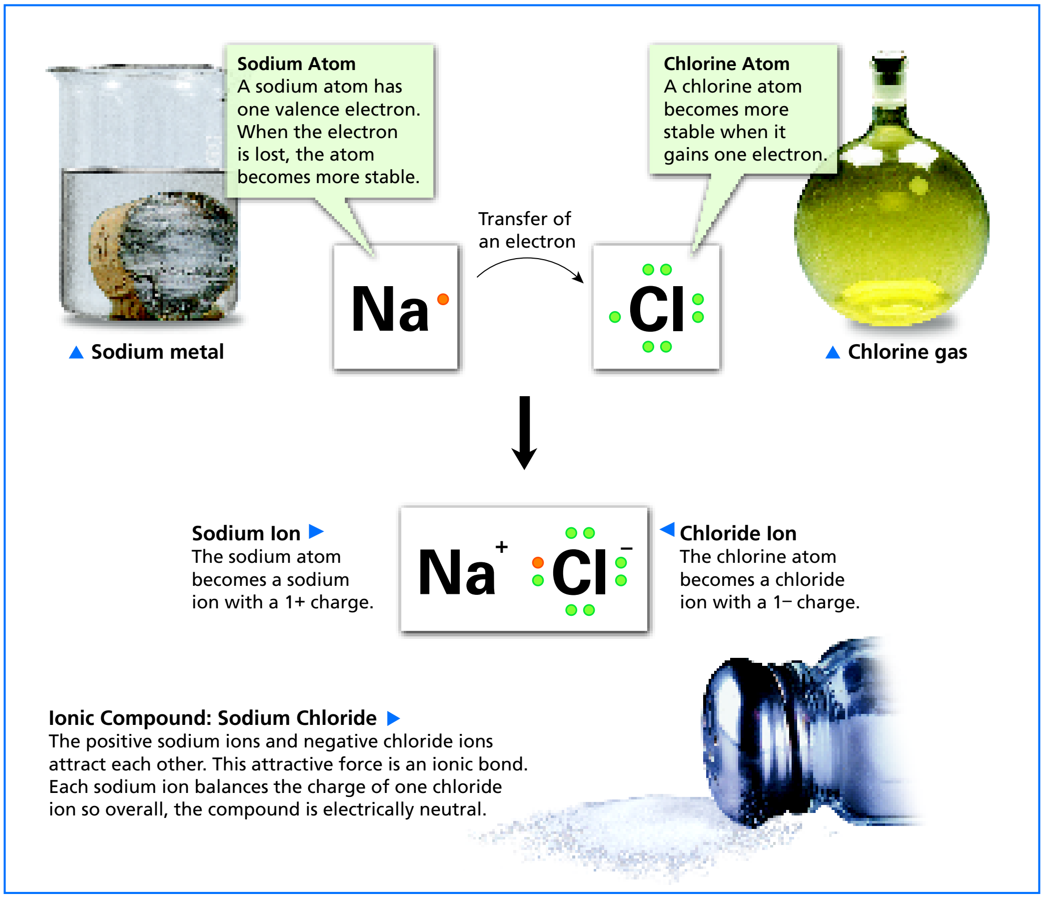
Focus Have students predict how positive and negative ions listed in Figure 16 might form ionic compounds together. Tell them that the correct compounds are electrically neutral, so the positive and negative charges must balance. *(Students are likely to name combinations of positive and negative ions in which the positive charge balances the negative charge to form a neutral ionic compound. Sample answer: A calcium ion, Ca^{2+}, and a carbonate ion CO_3^{2-} might form the ionic compound calcium carbonate, $CaCO_3$.)*

Apply Ask: **How many sodium ions do you predict there would be in the ionic compound sodium phosphate? Why?** *(There would be three sodium ions to balance the 3– charge of the phosphate ion.)* **learning modality: logical/mathematical**

Ionic Bonds Look at Figure 17 to see how sodium atoms and chlorine atoms combine to form sodium chloride (table salt). Notice that sodium has 1 valence electron and chlorine has 7 valence electrons. When sodium's valence electron is transferred to chlorine, both atoms become ions. The sodium atom becomes a positive ion (Na^+). The chlorine atom becomes a negative ion (Cl^-).

Because oppositely charged particles attract, the positive Na^+ ion and the negative 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.**

FIGURE 17
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?*



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 $MgCl_2$. What does the formula tell you?

Formulas of Ionic Compounds From Figure 16 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 $MgCl_2$. The number "2" is a subscript. A **subscript** tells you the ratio of elements in the compound. For $MgCl_2$, 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 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 $CaCO_3$.

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 (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, MgO is named magnesium oxide. If the negative ion is polyatomic, its name usually ends in *-ate* or *-ite*, as in Figure 16. The compound NH_4NO_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 K_2S?**

Lab zone Skills Activity

Interpreting Data

Use the periodic table and Figure 16 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?

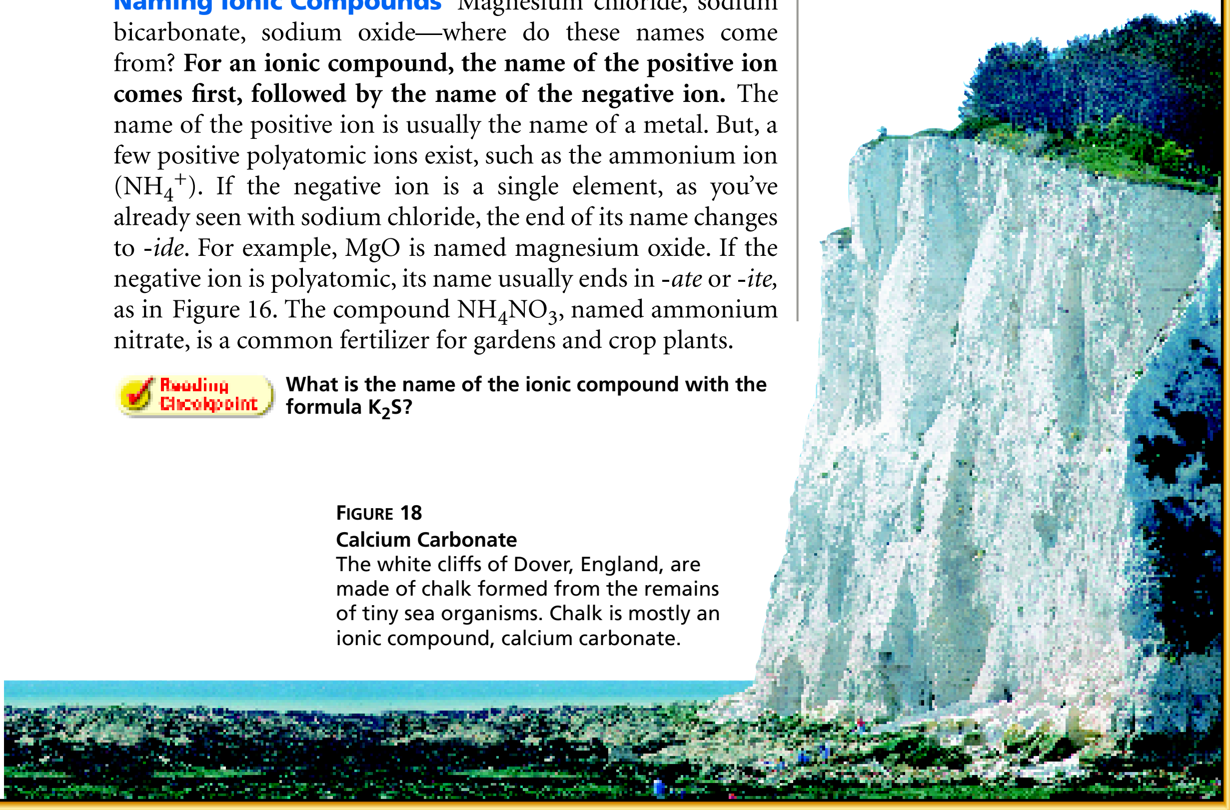


FIGURE 18
Calcium Carbonate
The white cliffs of Dover, England, are made of chalk formed from the remains of tiny sea organisms. Chalk is mostly an ionic compound, calcium carbonate.

Lab zone Skills Activity

Skills Focus Interpreting data L2

Materials periodic table, Figure 11, and Figure 16

Time 15 minutes

Tip Remind students that bromine is in the same group as fluorine in the periodic table, and that bromine forms an ion with the same charge as fluoride.

Expected Outcome Students are expected to pair positive and negative ions in ratios that result in neutral ionic compounds: NaBr, Li_2O, MgS, AlF_3, KNO_3, NH_4Cl.

Extend Encourage students to find ionic compounds listed as ingredients in household products. **learning modality: visual**

Chemical Formulas and Names

Teach Key Concepts L2

Explaining Chemical Formulas

Focus Explain how chemical formulas reflect the composition of ionic compounds.

Teach On the board, write *calcium ion* and *chloride ion*. Ask: **What is the charge of a calcium ion?** *(2+)* **What is the charge of a chloride ion?** *(1–)* Write the charges on the board next to the ions. Ask: **If calcium and chloride formed a compound, how many chloride ions would be needed to balance the charge of the calcium ion?** *(Two)* **What is the formula for calcium chloride?** *($CaCl_2$)* Write the formula on the board.

Apply Have students practice writing chemical formulas by doing the Skills Activity on this page. **learning modality: verbal**

Monitor Progress L2

Skills Check On the board, write Na O. Call on students to add any missing subscripts needed to make it a balanced formula for an ionic compound. Call on another student to name the compound.

Answers

Figure 17 The 1+ charge of the sodium ion is balanced by the 1– charge of the chloride ion.

Reading Checkpoint Potassium sulfide

Properties of Ionic Compounds

Teach Key Concepts

L2

Comparing and Contrasting Ionic Compounds

Focus Have students compare and contrast ionic compounds to infer their shared properties.

Teach Name several familiar examples of ionic compounds, such as table salt (NaCl), baking soda ($NaHCO_3$), rust (Fe_2O_3). Ask: **What is different about the compounds?** *(Accept all reasonable observations. Sample answer: They have different colors.)* **What is similar about the compounds?** *(Sample answer: They are solids.)*

Apply Ask: **What do you think is a property of ionic compounds in general?** *(Sample answer: They are solids at room temperature.)* **learning modality: verbal**

Lab zone Teacher Demo

L1

High Melting Point of an Ionic Compound

Materials heavy pot, stove or hot plate, wooden spoon, 100 mL salt

Time 15 minutes

Focus Demonstrate how an ionic compound fails to melt at a relatively high temperature.

Teach Before doing the demonstration, explain to students that sugar, which is not an ionic compound, can be melted in a few minutes in a pot on a stove or hot plate. Then, place the salt in the pot and heat the pot on high heat, stirring occasionally. After about 5 minutes, invite students to observe whether the salt has melted. Explain that salt must be heated to more than 800°C before it will melt, which is several times hotter than the temperature of a stove or hot plate.

Apply Ask: **Why do you think salt has such a high melting point?** *(Sample answer: Its ionic bonds require a lot of energy to break for melting to occur.)* **learning modality: visual**

Lab zone 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 19 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 Na^+ and 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°C before the crystal melts.

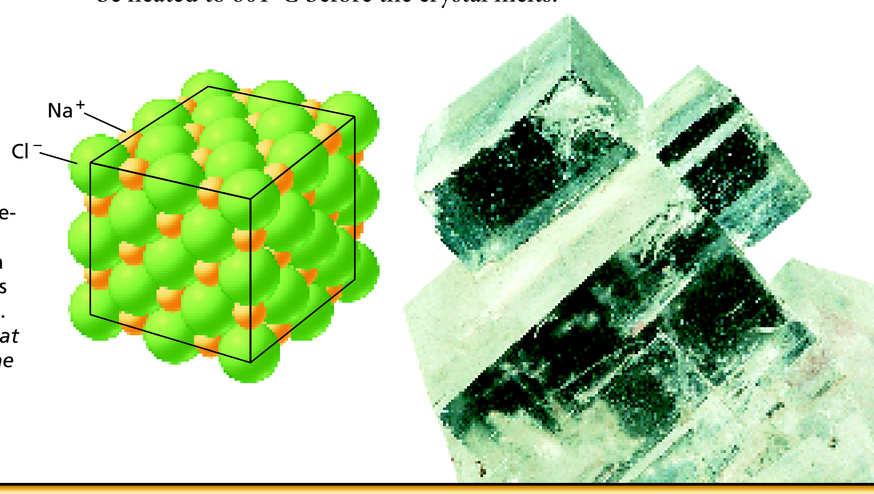


FIGURE 19
Ionic Crystals
The ions in ionic compounds are arranged in specific three-dimensional shapes called crystals. Some crystals have a cube shape like these crystals of halite, or sodium chloride.
Making Generalizations *What holds the ions together in the crystal?*

Lab zone Try This Activity

Skills Focus Observing

L2

Materials 15 cm thread, coarse salt such as kosher salt or sea salt, jar or cup, pencil, hot tap water, stirring rod or spoon

Time 15 minutes for setup, 3 minutes a day for 3 days for observation

Tip The hotter the water, the more salt that will dissolve.

Expected Outcome The crystal will increase in size as sodium and chloride ions in the solution wick up the thread and join the crystal.

Extend Allow students to examine salt crystals under a microscope and compare the shape of the crystals to the large crystal produced in this activity. **learning modality: visual**

FIGURE 20
Ions in Solution
A solution of sodium chloride conducts electricity across the gap between the two black rods of a conductivity tester. As a result, the bulb lights up.

Electrical Conductivity When ionic compounds dissolve in water, the solution conducts electricity. The flow of electricity is the flow of charged particles, and ions are charged particles. However, crystals of ionic compounds do not conduct electricity well. The ions in the crystal are tightly bound to each other. If charged particles cannot move, no electricity can flow. When ionic crystals dissolve in water, however, the bonds between ions are broken. So, the ions are free to move, and the solution conducts electricity. Likewise, after an ionic compound melts, the ions are able to move freely, and the liquid conducts electricity.

Reading Checkpoint **What is a crystal?**

Go Online SCI LINKS NSTA
For: Links on ionic compounds
Visit: www.SciLinks.com
Web Code: scn-1213

Section 3 Assessment

Target Reading Skill **Previewing Visuals** Compare your questions and answers about Figure 17 with those of a partner.

Reviewing Key Concepts

1. 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.

2. a. Identifying What information is given by the formula of an ionic compound?
b. Explaining The formula for sodium sulfide is Na_2S. Explain what this formula means.
c. Applying Concepts Write the formula for calcium chloride. Explain how you determined this formula.

3. 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.

Go Online SCI LINKS NSTA
For: Links on ionic compounds
Visit: www.SciLinks.org
Web Code: scn-1213

Download a worksheet that will guide students' review of Internet sources on ionic compounds.

Monitor Progress L2

Answers
Figure 19 Ionic bonds

Reading Checkpoint An orderly, three-dimensional arrangement of ions

Assess

Reviewing Key Concepts

1. a. Atoms can lose or gain electrons. **b.** A sodium ion (Na^+) forms when a sodium atom loses one electron and becomes positively charged. A chloride ion (Cl^-) forms when a chlorine atom gains one electron and becomes negatively charged. **c.** An ionic bond holds the ions together. The sodium ion has a charge of 1+, and the chloride ion has a charge of 1−.
2. a. The ratio of positive ions to negative ions **b.** Sodium sulfide consists of two sodium ions and one sulfide ion. **c.** The formula is $CaCl_2$, because two chloride ions (Cl^{1-}) are needed to balance one calcium ion (Ca^{2+}).
3. a. Ionic compounds are hard, brittle crystals that have high melting points and can conduct electricity when melted or in solution. **b.** Ionic bonds are strong due to the attraction between oppositely charged ions. This makes crystals of ionic compounds hard and brittle and causes the compounds to have high melting points. Because the ions are charged, they can conduct electricity when the compound is melted or dissolved.

Reteach L1

Call on students to describe the properties of ionic compounds.

Performance Assessment L2

Drawing Have students draw an electron dot diagram of potassium iodide.

All in One **Teaching Resources**
- Section Summary: *Ionic Bonds*
- Review and Reinforcement: *Ionic Bonds*
- Enrich: *Ionic Bonds*

Lab zone **Chapter Project**

Keep Students on Track At this point, students can use their model atoms to make models of ionic crystals.

Writing in Science

Writing Mode Firsthand account
Scoring Rubric
4 Exceeds criteria; includes a detailed eyewitness account that correctly describes the reaction of potassium and fluorine
3 Meets criteria
2 Includes a firsthand description but is too brief and/or contains some errors
1 Includes only a general description and/or contains serious errors

Lab zone Skills Lab L2

Shedding Light on Ions

Prepare for Inquiry

Key Concept
Solutions containing ions can conduct electricity. Students will determine whether solutions conduct electricity and decide on the nature of their bonds.

Skills Objective
After this lab, students will be able to
- control variables to test which solutions conduct electricity
- interpret data from the tests to determine which solutions conduct electricity
- infer the nature of the bonds in each solution tested

Prep Time 30 minutes
Class Time 40 minutes

Advance Planning
- Gather additional materials students can test, such as vegetable oil, hydrogen peroxide, orange juice, vinegar, sugar, baking soda, Epsom salts, and/or powdered skim milk.
- Obtain 16- or 18-gauge wire. The resistance of wire with a higher gauge is too great. Cut the wire into lengths of about 25–30 cm. With wire strippers, remove about 2 cm of insulation from the ends of the wires.
- Use fresh batteries and 2.2-V bulbs.
- If necessary, you can use 6-V dry cells instead of 1.5-V dry cells. However, some eletrolysis may occur using the higher voltage.

Alternative Materials
Instead of having students make their own conductivity testers, as described in the procedure, you may provide students with conductivity probes.

Safety
Caution students to handle the light bulbs carefully. Tell them ends of the wires are sharp. Review the safety guidelines in Appendix A.

All in One Teaching Resources
- Lab Worksheet: *Shedding Light on Ions*

Lab zone Skills Lab

Shedding Light on Ions

Problem
What kinds of compounds produce ions in solution?

Skills Focus
controlling variables, interpreting data, inferring

Materials
- 2 dry cells, 1.5 V
- small light bulb and socket
- 4 lengths of wire with alligator clips on both ends
- 2 copper strips

(or conductivity probe)
- distilled water
- small beaker
- small plastic spoon
- sodium chloride
- graduated cylinder, 100-mL
- sucrose
- additional materials supplied by your teacher

Procedure
1. Make a conductivity tester as described below or, if you are using a conductivity probe, see your teacher for instructions. Then make a data table in your notebook similar to the one above.

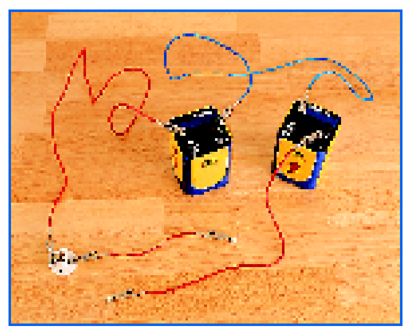
Data Table

Sample	Observations
Tap water	
Distilled water	
Sodium chloride	
Sodium chloride in water	

2. Pour about 50 mL of tap water into a small beaker. Place the copper strips in the beaker. Be sure the strips are not touching each other. Attach the alligator clip of the free end of one wire to a copper strip. Do the same with the other wire and the other copper strip. Record your observations.
3. Disconnect the wires from the copper strips. Take the strips out of the beaker, and pour out the tap water. Dry the inside of the beaker and the copper strips with a paper towel.
4. Pour 50 mL of distilled water into the beaker. Reconnect the conductivity tester and test the water as in Step 2. Keep the copper strips about the same distance apart as in Step 2. Record your observations.
5. Use 3 spoonfuls of sodium chloride to make a small pile on a clean piece of paper. Dry off the copper strips of the conductivity tester and use it to test the conductivity of the sodium chloride. Record your observations.

Making a Conductivity Tester

A. Use wire with alligator clips to connect the positive terminal of a dry cell to a lamp socket. **CAUTION:** *The bulb is fragile and can break.*
B. Similarly connect another wire between the negative terminal of the cell and the positive terminal of the second cell.
C. Connect one end of a third wire to the negative terminal of the second dry cell.
D. Connect one end of a fourth wire to the other terminal of the lamp socket.



Guide Inquiry

Invitation
Place the leads of a conductivity tester into a beaker of distilled water to show students that the bulb does not light up. Then, add salt to the distilled water until the light starts to glow. Ask: **Why did the salt allow the distilled water to carry electricity?** *(Ions of the dissolved salt carried the charge.)*

Introduce the Procedure
Tell students that they will construct and/or use a conductivity tester to determine whether different solutions conduct electricity. From the data, they will decide whether or not the solutions are ionic.

6. Add 1 spoonful of sodium chloride to the distilled water in the beaker. Stir with the spoon until the salt dissolves. Repeat the conductivity test and record your observations.
7. Disconnect the conductivity tester and rinse the beaker, spoon, and copper strips with distilled water. Dry the beaker as in Step 3.
8. Test sucrose (table sugar) in the same ways that you tested sodium chloride in Steps 4 through 7. Test additional materials supplied by your teacher.
   - If the material is a solid, mix 1 spoonful of it with about 50 mL of distilled water and stir until the material dissolves. Test the resulting mixture.
   - If the substance is a liquid, simply pour about 50 mL into the beaker. Test it as you did the other mixtures.

Analyze and Conclude

1. **Controlling Variables** Why did you test both tap water and distilled water before testing the sodium chloride solution?
2. **Interpreting Data** Could you have used tap water in your tests instead of distilled water? Explain.
3. **Drawing Conclusions** Based on your observations, add a column to your data table indicating whether each substance produced ions in solution.
4. **Inferring** Sodium chloride is an ionic compound. How can you account for any observed differences in conductivity between dry and dissolved sodium chloride?
5. **Communicating** Based on your observations, decide whether or not you think sucrose (table sugar) is made up of ions. Explain how you reached your answer, using evidence from the experiment.

Design an Experiment

Design an experiment to test the effects of varying the spacing between the copper strips of the conductivity tester. *Obtain your teacher's permission before carrying out your investigation.*

Troubleshooting the Experiment

- Before students assemble their conductivity testers, have them test the bulbs using wires and a battery.
- Students should use solutions of the same concentration to make valid comparisons among substances.

Data Table

Sample	Observations
Tap water	Conducts current
Distilled water	Does not conduct current
Sodium chloride	Does not conduct current
Sodium chloride in water	Conducts current

Expected Outcome

Most substances containing ionic bonds will be good conductors when dissolved in water. Molecular compounds will not conduct electricity as well. (*Note:* Students will not yet be able to use the term *molecular compounds*, which they will learn about in the following chapter.).

Analyze and Conclude

1. Both tap water and distilled water were used as controls. Testing tap water showed that the circuit was functioning, because tap water contains ions and conducts electricity. Testing distilled water showed that water without dissolved ions does not conduct electricity.

2. No; tap water is a conductor and would not allow you to determine whether the dissolved substances were also conductors.

3. Substances that students identify as conductors or nonconductors will depend on the substances tested. Tap water, salt water, and any other solutions of ionic compounds are likely to be good conductors, whereas vegetable oil, sucrose solution, and other solutions of molecular compounds are unlikely to be good conductors.

4. The ions in dry sodium chloride are bound together in a rigid crystal structure. When sodium chloride dissolves, the ionic bonds break, allowing the ions to move freely through the solution and carry a charge.

5. Students are expected to observe that a sucrose solution does not carry a charge and to decide that it is not made up of ions.

Extend Inquiry

Design an Experiment Students can test the same ionic solution twice, changing only the spacing of the copper strips from one test to the next. When the strips are farther apart, a weaker conductor may not be able to carry the charge far enough. The opposite may be true when the strips are closer together.