9.2

1 FOCUS

Objectives

9.2.1 **Apply the rules** for naming and writing formulas for binary ionic compounds.

9.2.2 **Apply the rules** for naming and writing formulas for compounds with polyatomic ions.

Guide for Reading

Build Vocabulary L2

Word Parts The word *compound* comes from the Latin *componere,* which means "to put." Parts are put together to make a whole. A compound always contains at least two parts. A compound with two parts is called a binary compound.

Reading Strategy L2

Anticipation Guide Have students page through the section and note the two major headings in red. Ask, **What are the two types of compounds you will be reading about?** *(binary ionic compounds and compounds with polyatomic ions)* Building on the vocabulary discussion above, ask, **What do you think is the difference between a binary compound and a compound with a polyatomic ion?** *(A binary compound contains only two elements. A compound with a polyatomic ion can contain three or more elements because a polyatomic ion can have two or more elements.)*

2 INSTRUCT

Connecting to Your World

Ask students to draw an analogy between a recipe that calls for 4 cups of tomato sauce and 1 teaspoon of salt and the formula for a chemical compound such as $CaCl_2$. *(Calcium and chlorine correspond to the ingredients tomato sauce and salt; the subscripts correspond to the quantities of the ingredients.)*

9.2 Naming and Writing Formulas for Ionic Compounds

Connecting to Your World

At festivals throughout the summer, contestants compete for blue ribbons for the best barbecue. Some cooks say the recipe for their barbecue sauce is the key to winning and they may hint at a secret ingredient. The recipe is the formula for the sauce—a complete list of ingredients and their proportions. With the recipe, anyone could reproduce a sauce, so a cook is likely to keep a prize-winning recipe a closely guarded secret. Chemistry also uses formulas, but without any secrets. Once you know the rules, you can write the formula for any chemical compound. In this section, you will learn how to write the formulas for ionic compounds.

Guide for Reading

Key Concepts

- How are the names of binary ionic compounds determined?
- How do you write the formulas for binary ionic compounds?
- How do you write the formulas and names of compounds containing polyatomic ions?

Vocabulary

binary compound

Reading Strategy

Predicting Before you read, preview the section by reading the Key Concepts, the headings, and the boldfaced sentences. Predict how you would write the formulas for binary ionic compounds. After you have read the section, check the accuracy of your prediction.

Binary Ionic Compounds

In the days before the science of chemistry developed, the person who discovered a new compound often named it anything he or she wished. It was not uncommon for the name to describe some property of the substance or its source. For example, a common name for potassium carbonate (K_2CO_3) is *potash.* The name evolved because the compound was obtained by boiling wood ashes in iron pots. Baking soda ($NaHCO_3$) is added to batter to make cakes rise. Plaster of paris ($CaSO_4 \cdot \frac{1}{2}H_2O$) is the name for a substance used to make face masks like those shown in Figure 9.7. When plaster of Paris sets, it forms gypsum ($CaSO_4 \cdot 2H_2O$). Unfortunately, such names do not tell you anything about the chemical composition of a compound or give you any indication about how it is related to other compounds.

The French chemist Antoine-Laurent Lavoisier (1743–1794) determined the composition of many compounds in his experiments to show how chemical compounds form. As more and more compounds were identified, Lavoisier recognized that it was becoming impossible to memorize all the unrelated names of the compounds. He worked with other chemists to develop a systematic method for naming chemical compounds. Their work is the basis for naming compounds today.

Figure 9.7 These masks are made of an ionic compound with the common name gypsum ($CaSO_4 \cdot 2H_2O$). Gypsum is also used in wallboard.

Section Resources

Print

- **Small-Scale Chemistry Laboratory Manual,** Lab 12
- **Guided Reading and Study Workbook,** Section 9.2
- **Core Teaching Resources,** Section 9.2 Review
- **Transparencies,** T96–T97

Technology

- **Interactive Textbook with ChemASAP,** Simulation 9; Problem-Solving 9.11, 9.12; Assessment 9.2
- **Go Online,** Section 9.2

Naming Binary Ionic Compounds A **binary compound** is composed of two elements and can be either ionic or molecular. If you know the formula for a binary ionic compound, you can write its name. First you must verify that the compound is composed of a monatomic metallic cation and a monatomic nonmetallic anion. The compound Cs_2O is composed of the metal cesium and the nonmetal oxygen. Both cesium and oxygen are Group A elements, so each ion has only one charge. **To name any binary ionic compound, place the cation name first, followed by the anion name.** The name of Cs_2O, then, is cesium oxide. The name of NaBr is sodium bromide and the name of SrF_2 is strontium fluoride. But suppose you want to name the binary ionic compound CuO. Following the rule above, you would name this compound copper oxide. However, the name *copper oxide* is incomplete. Recall that copper commonly forms two cations: Cu^+ and Cu^{2+}. The names of these ions are copper(I) ion and copper(II) ion, respectively. How can you tell which of these cations forms the compound CuO? Working backward will help. The formula indicates that the copper cation and the oxide anion combine in a 1:1 ratio. You know that the oxide anion always has a 2− charge. Therefore, the charge of the copper cation must be 2+ in order to balance the 2− charge. The compound CuO must be copper(II) oxide. The formula for copper(I) oxide is Cu_2O.

Table 9.2 lists the symbols and names of the common metal ions that form more than one ion. Recall that the charges of monatomic anions can be determined from the periodic table; those of polyatomic anions are shown in Table 9.3. Using these sources, you can write the names of SnF_2 and SnS_2. Tin (Sn) forms cations with 2+ and 4+ charges. Fluorine is a Group 7A element, so the charge of the fluoride ion is 1−. In SnF_2, the ratio of cation to anion is 1:2. Therefore, the charge of the tin cation must be 2+ to balance the combined 2− charge of two fluoride ions. The name of SnF_2 is tin(II) fluoride or stannous fluoride. However, the name of SnS_2 is not tin(II) sulfide. Sulfur is a Group 6A element, so its charge is 2−. The charge of the tin cation must be 4+ to balance the combined charges of two sulfur anions. Thus the name of SnS_2 is tin(IV) sulfide or stannic sulfide. Figure 9.8 shows examples of uses of stannous fluoride and stannic sulfide.

Checkpoint ***What are the charges of the two ions of copper?***

Word *Origins*

Binary comes from the Latin word *bini* meaning "two by two" or "twofold." Binary compounds consist of two elements. **Predict what a binary star might be and then check your prediction in the dictionary.**

Figure 9.8 Tin(II) fluoride and tin(IV) sulfide have different compositions and uses. **a** Tin(II) fluoride is added to toothpastes to prevent cavities. **b** Tin(IV) sulfide is used in glazes for porcelain fixtures and dishes. **Inferring** ***What are the charges on the tin ions in the two compounds?***

Differentiated Instruction

Less Proficient Readers L1

Cut index cards to obtain pieces that are one-third and two- thirds of a card. Keep some cards whole. On some whole cards, mark three large positive signs; on others mark three large negative signs. Mark some of the one-third pieces with single positive signs; others with single negative signs. Mark the two-thirds pieces with two positive signs or two negative signs. On the opposite side of each card, write the formula for an ion having the appropriate charge. Have students match single positive and negative signs. Have them match double positive signs with double negative signs and with two single positive signs. Continue with all possible combinations. Then have students turn the cards over to see the formulas of the ionic compounds they produced.

Binary Ionic Compounds

Word *Origins* L2

A binary star is a system of two stars that revolve around each other.

Relate L1

Ask, **Do you or someone you know have a nickname? Does the nickname tell something about the person?** *(Students will have a variety of responses.)* Guide students to recognize that nicknames are somewhat like the common names used to describe compounds. Use sodium carbonate (Na_2CO_3) as an example. Its common name is soda or soda ash. Ask, **Which tells you more about the compound, soda or sodium carbonate?** *(sodium carbonate)*.

CLASS Activity

Naming Ionic Binary Compounds L2

Purpose Students practice naming binary compounds.

Materials chalkboard, chalk

Procedure Divide the class into teams. Have each team write the names of ionic compounds on a sheet of paper as you write formulas on the board. Use chlorides, bromides, phosphides, and oxides of the elements of Groups 1A, 2A, and aluminum in 3A. Mix in sulfides, oxides, chlorides, and bromides of lead, tin, iron, cobalt, copper, and zinc. Have the teams compare their lists of names. When a discrepancy occurs, have them discuss it and come to agreement on the correct name. Save the lists of names for the activity on page 263.

Answers to...

Figure 9.8 2+ and 4+

Checkpoint 1+ and 2+

TEACHER Demo

Making and Naming an Ionic Compound L2

Purpose Students see a reaction in which an ionic compound is formed and then name the compound and write its formula.

Materials 1 g powdered zinc, 4 g iodine (I_2), watch glass, eyedropper, 8 mL water

Safety Wear goggles and perform the demo in a fume hood. Place the zinc iodide in a plastic or cardboard container and dispose of it in an approved landfill site.

Procedure Wear safety goggles and use a fume hood. Mix 1 g of powdered zinc (Zn) and 4 g of iodine (I_2) on a watch glass. With an eyedropper, carefully add 8 mL of water, one drop at a time. After the reaction is complete, show students the zinc iodide that was formed. Write the formula unit for zinc iodide (ZnI_2) along with its name on the chalkboard. Ask, **What happened to elemental Zn and I_2 during the reaction?** *(Zinc and iodine reacted to form an ionic compound composed of Zn^{2+} and I^- ions.)* Use the criss-cross method to show how the formula unit for zinc iodide was derived. **Why is ZnI_2 named zinc iodide and not zinc(II) iodide?** *(Zinc forms only one ion.)*

Expected Outcome The masses of Zn and I_2 are the stoichiometic amounts. The reactants should be used up and white, crystalline ZnI_2 formed.

Go Online NSTA SCILINKS

Download a worksheet on **Ionic Compounds** to complete, and find additional teacher support from NSTA SciLinks.

Figure 9.9 In the process for making steel, iron is extracted from hematite, an ore containing iron(III) oxide. **Applying Concepts** ***What is the formula for iron(III) oxide?***

Go Online NSTA SCILINKS

For: Links on Ionic Compounds
Visit: www.SciLinks.org
Web Code: cdn-1092

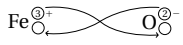
Writing Formulas for Binary Ionic Compounds

If you know the name of a binary ionic compound, you can write its formula. **Write the symbol of the cation and then the anion. Add whatever subscripts are needed to balance the charges.** The positive charge of the cation must balance the negative charge of the anion so that the net ionic charge of the formula is zero. The ionic compound potassium chloride is composed of potassium cations (K^+) and chloride anions (Cl^-), so potassium chloride is a binary ionic compound. The charge of each K^+ cation is balanced by the charge of each Cl^- anion, so in potassium chloride, the potassium and chloride ions combine in a 1:1 ratio. Thus the formula for potassium chloride is KCl. The net ionic charge of the formula unit is zero.

The binary ionic compound calcium bromide is composed of calcium cations (Ca^{2+}) and bromide anions (Br^-). The two ions do not have equal numerical charges. Thus each calcium ion with its 2+ charge must combine with (or be balanced by) two bromide ions, each with a 1− charge. That means that the ions must combine in a 1:2 ratio, so the formula for calcium bromide is $CaBr_2$. The net ionic charge of the formula unit is zero.

Figure 9.9 shows one step in the process of making steel from iron ore. Hematite, a common ore of iron, contains iron(III) oxide. What is the formula for this compound? Recall that a Roman numeral in the name of an ion shows the charge of the metal ion. Thus iron(III) oxide contains Fe^{3+} cations combined with oxide anions (O^{2-}). How can you balance a 3+ charge and a 2− charge? You must find the least common multiple of the charges, which is 6. Iron's three charges taken two times equals six ($3 \times 2 = 6$). Oxygen's two charges taken three times also equals six. Thus two Fe^{3+} cations (a 6+ charge) will balance three O^{2-} anions (a 6− charge). The balanced formula, then, is Fe_2O_3.

Another approach to writing a balanced formula for a compound is to use the crisscross method. In this method, the numerical value of the charge of each ion is crossed over and becomes the subscript for the other ion. Notice that the signs of the charges are dropped.



Fe_2O_3

$2(3+) + 3(2-) = 0$

The formula is correct because the overall charge of the formula is zero and the subscripts are in the lowest whole number ratio.

Interactive Textbook

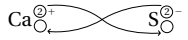
Simulation 9 Simulate combining ions and deriving the chemical formulas for several ionic compounds.
with ChemASAP

Facts and Figures

Lattice Energy in Ionic Bonding

Ionic compounds tend to be stable—energy in the form of heat or electricity is needed to decompose them. Thus, energy must be released when ionic bonds form. But the released energy is not primarily from the transfer of electrons. Forming a cation is an endothermic process. In addition, both the metal and the nonmetal must be vaporized—another endothermic process—before electron transfer can take place. Some energy (electron affinity) is released when the nonmetal gains one or more electrons, but this is not enough to make the entire process exothermic. It is lattice energy that makes the difference. Lattice energy is the energy released when gaseous cations and anions settle into the orderly crystal structure characteristic of a solid ionic compound.

If you use the crisscross method to write the formula for some compounds such as calcium sulfide (Ca^{2+} and S^{2-}), you will obtain the result Ca_2S_2. The 2:2 ratio of calcium and sulfide ions is not the lowest whole number ratio. The formula for calcium sulfide is CaS.



Ca_2S_2 reduces to CaS

$1(2+) + 1(2-) = 0$

Of course, if the magnitudes of the charges of the cation and anion are the same, as they are in this case, the ions combine in a 1:1 ratio and the charges are balanced.

Checkpoint ***Explain why the formula CaS is correct.***

CONCEPTUAL PROBLEM 9.2

Writing Formulas for Binary Ionic Compounds

Write formulas for these binary ionic compounds.

a. copper(II) sulfide, shown in the photo

b. potassium nitride

1 Analyze ***Identify the relevant concepts.***

Binary ionic compounds are composed of a monatomic cation and a monatomic anion. The ionic charges in an ionic compound must balance (add up to zero), and the ions must be in the lowest whole number ratio. The symbol for the cation appears first in the formula for the compound.

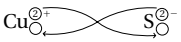
2 Solve ***Apply concepts to this situation.***

Write the symbol and charge for each ion in each compound.

a. Cu^{2+} and S^{2-} **b.** K^+ and N^{3-}

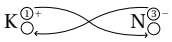
Balance the formula using appropriate subscripts.

a.



CuS

b.



K_3N

The ions are in the lowest whole number ratio, and the net ionic charge is zero: $1(2+) + 1(2-) = 0$ and $3(1+) + 1(3-) = 0$.

Practice Problems

10. Write formulas for compounds formed from these pairs of ions.

a. Ba^{2+}, S^{2-} **b.** Li^+, O^{2-}

c. Ca^{2+}, N^{3-} **d.** Cu^{2+}, I^-

11. Write formulas for these compounds.

a. sodium iodide **b.** stannous chloride

c. potassium sulfide **d.** calcium iodide

Interactive Textbook

Problem-Solving 9.11 Solve Problem 11 with the help of an interactive guided tutorial.

with ChemASAP

CLASS Activity

Formulas for Binary Ionic Compounds

L2

Purpose Students become more proficient in writing formulas.

Materials The lists of names of ionic compounds generated in the activity on p. 261.

Procedure Have teams of students write the formulas for the names on the lists. When the formulas on two or more lists do not agree, have the teams resolve the discrepancy by using the criss-cross method to write the formula on the board.

CONCEPTUAL PROBLEM 9.2

Answers

10. a. BaS **b.** Li_2O **c.** Ca_3N_2 **d.** CuI_2

11. a. NaI **b.** $SnCl_2$ **c.** K_2S **d.** CaI_2

Practice Problems Plus

L2

Write formulas for these compounds.

a. lithium fluoride *(LiF)*

b. aluminum chloride *($AlCl_3$)*

c. sodium nitride *(Na_3N)*

d. ferric oxide *(Fe_2O_3)*

Answers to...

Figure 9.9 Fe_2O_3

Checkpoint The charges are balanced and the subscripts are in the lowest whole number ratio.

Compounds with Polyatomic Ions

TEACHER Demo

Making and Naming Lead Carbonate L2

Purpose Students watch the formation of an ionic precipitate and postulate possible formulas.

Materials 50 mL 0.1*M* lead(II) nitrate, 50 mL 0.1*M* sodium carbonate, 100-mL beaker.

Procedure Wear goggles and gloves. Slowly mix the two solutions. Make sure students see the precipitate of lead carbonate that forms. Write on the board the symbols or formulas for the four ions that are in the two solutions: Pb^{2+}, NO_3^-, Na^+, CO_3^{2-}. Tell students that the two solutions contained these four ions and that the precipitate is an ionic compound formed by the combination of two of them. Ask students to list all possible formula units for the solid and to name each possibility. Identify the solid as lead(II) carbonate ($PbCO_3$).

Safety Wear goggles and gloves because lead(II) nitrate is toxic. For disposal, combine the reaction mixture with 10 g of solid NaCl in a beaker. Stir and allow to settle. Filter or decant to isolate the precipitate. Place the dry precipitate in a plastic or cardboard container and dispose of it in an approved landfill. Flush the filtrate down the drain with excess water.

Use Visuals L1

Figure 9.10 Tell students that the compounds mentioned in this caption are only a small fraction of the compounds with polyatomic ions that they may encounter daily. Ask, **What are the formulas for calcium carbonate, lead(II) sulfate, ammonium sulfate, and ammonium phosphate?** *($CaCO_3$, $PbSO_4$, $(NH_4)_2SO_4$, $(NH_4)_3PO_4$)*

Compounds with Polyatomic Ions

The pearl and the oyster shell shown in Figure 9.10 are both made of calcium carbonate ($CaCO_3$). Calcium carbonate is obviously not a binary compound because it contains more than two elements. Remember that an *-ate* or *-ite* ending on the name of a compound indicates that the compound contains a polyatomic anion that includes oxygen. This compound contains one monatomic ion (Ca^{2+}) and one polyatomic ion (CO_3^{2-}). Figure 9.10 also shows a typical automobile battery called a lead storage battery. The energy-producing reaction inside the battery uses the ionic compound lead(II) sulfate ($PbSO_4$), which consists of the monatomic ion Pb^{2+} and the polyatomic ion SO_4^{2-}. The fertilizer mixture also shown in the illustration could have been produced from such compounds as potassium hydrogen phosphate (K_2HPO_4), potassium sulfate (K_2SO_4), or sodium nitrate ($NaNO_3$). Each contains a polyatomic anion. How would you write the formula for an ionic compound with a polyatomic ion? You would do what you did for binary ionic compounds. **Write the symbol for the cation followed by the formula for the polyatomic ion and balance the charges.** For example, calcium nitrate is composed of a calcium cation (Ca^{2+}) and a polyatomic nitrate anion (NO_3^-). In calcium nitrate, two nitrate anions, each with a 1− charge, are needed to balance the 2+ charge of each calcium cation.

$$Ca^{2+} \quad (NO_3)^{-}$$

$$Ca(NO_3)_2$$

$$1(2+) + 2(1-) = 0$$

The charge is balanced and the ions are in the lowest whole number ratio, so the formula is correct. Parentheses are used around the nitrate ion in the formula because more than one nitrate anion is needed. The subscript 2 that follows the parentheses shows that the compound contains two nitrate anions. Use parentheses to set off the polyatomic ion in a formula only when the compound contains more than one polyatomic ion. The formula for strontium sulfate, $SrSO_4$, has no parentheses because one polyatomic sulfate anion balances the charge of the strontium cation.

Checkpoint ***When are parentheses used in a formula containing a polyatomic ion?***

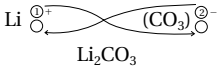
Figure 9.10 Some examples of ionic compounds containing polyatomic ions are shown. a Oysters produce calcium carbonate to form their shells and sometimes pearls. b Lead(II) sulfate is an important component of an automobile battery. c Compounds such as ammonium sulfate or ammonium phosphate are common fertilizers.

Differentiated Instruction

Gifted and Talented L3

Have interested students research the possible mechanisms for the alleviation of symptoms of bipolar disorder by lithium ions. Challenge students to explain why other Group 1A ions, such as sodium and potassium, which are normally present in substantial concentrations in the body, do not have the same effects as lithium ions even though they have the same charge.

Lithium carbonate is a compound composed of lithium cations (Li^+) and polyatomic carbonate anions (CO_3^{2-}).



In lithium carbonate, two lithium cations, each with a 1+ charge, are needed to balance the 2− charge of one carbonate anion. Parentheses are not needed to set off the polyatomic carbonate anion. Lithium carbonate can be prescribed for patients who have mood disorders, such as manic-depressive or bipolar disorder. A person with bipolar disorder experiences distressing mood swings, from elation to depression and back again. The exact mechanism is not known, but lithium ions may exert a mood-stabilizing effect on neurotransmission. Neurotransmission is the process by which "messages" are sent and received between nerve cells, including those in the brain.

CONCEPTUAL PROBLEM 9.3

Writing Formulas for Compounds with Polyatomic Ions

What are the formulas for these ionic compounds?

a. magnesium hydroxide, shown in the photo as milk of magnesia

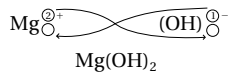
b. potassium sulfate

1 Analyze ***Identify the relevant concepts.***

Write the formula for each ion in the order listed in the name. Use subscripts to balance the charges. If more than one polyatomic ion is needed to balance a formula, place the polyatomic ion formula in parentheses, followed by a subscript showing the number needed.

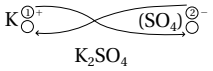
2 Solve ***Apply concepts to this situation.***

a.



Two hydroxide anions with 1− charges are needed to balance the 2+ charge on one magnesium cation. The formula for magnesium hydroxide must make use of parentheses.

b.



Two potassium cations with 1+ charges are needed to balance the 2− charge on one sulfate anion. The formula for potassium sulfate is K_2SO_4.

Practice Problems

12. Write formulas for compounds formed from these pairs of ions.

a. NH_4^+, SO_3^{2-}

b. calcium ion, phosphate ion

13. Write formulas for these compounds.

a. lithium hydrogen sulfate

b. chromium(III) nitrite

Interactive Textbook

Problem-Solving 9.12 Solve Problem 12 with the help of an interactive guided tutorial.

with ChemASAP

Facts and Figures

Lithium Carbonate as Medication

When John Cade, a doctor in the Victoria Department of Mental Health in Victoria, Australia, injected guinea pigs with a lithium salt of uric acid in 1949, he found that the usually hyperactive animals became calm and lethargic for a period of time. After further experimentation, Cade injected a severely disturbed patient with lithium carbonate. The results were so astonishingly positive for this patient, and for many others who followed, that within 10 years the treatment had spread throughout Europe and into the United States. Patients who had been confined to mental institutions for virtually their entire lives were able to return to normal living.

CLASS Activity

Naming and Writing Formulas L2

Purpose Students gain experience in naming and writing formulas for compounds with polyatomic ions.

Procedure Divide the class into groups of two to four students. Have one student in each group randomly choose ions from Tables 9.2 and 9.3. The other member or members of the group must write the formula and name the compound. Rotate the position of "ion chooser" through the group. All students in the group should agree on the names and formulas.

Relate L1

Milk of magnesia, shown in the Conceptual Problem photo, is a suspension of magnesium hydroxide ($Mg(OH)_2$) in water and is useful as an antacid and laxative. In the stomach, the hydroxide ion reacts with excess acid that causes the discomfort of indigestion. In larger amounts, magnesium hydroxide also acts as a muscle relaxant and relieves constipation.

CONCEPTUAL PROBLEM 9.3

Answers

12. a. $(NH_4)_2SO_3$ **b.** $Ca_3(PO_4)_2$

13. a. $LiHSO_4$ **b.** $Cr(NO_2)_3$

Practice Problems Plus L2

Write formulas of compounds formed from these pairs of ions:

a. Pb^{2+}, NO_3^- ($Pb(NO_3)_2$)

b. iron(III) ion and sulfate ion ($Fe_2(SO_4)_3$)

c. Cr^{3+}, OH^- ($Cr(OH)_3$)

d. sodium ion and hydrogen phosphate ion (Na_2HPO_4)

Answers to...

Checkpoint Parentheses are used in a formula when the formula contains more than one unit of the same polyatomic ion.

3 ASSESS

Evaluate Understanding L2

Write the following cations on one side of the board: NH_4^+, Mg^{2+}, Pb^{4+}. Write the following anions on the other side of the board: Br^-, S^{2-}, PO_4^{3-}. Ask students to write formula units for all the possible ionic compounds that these ions could form and name them. Ask them to explain how they arrived at their answers.

Reteach L1

Point out that three things must be considered when naming an ionic compound: (1) the identity of the ions, (2) the order of the names, and (3) the possibility that an element may form cations with more than one charge. (1) For binary compounds, ions can be identified from their symbols. The suffix *-ide* is used when naming the nonmetal ion. For compounds with polyatomic ions, the polyatomic ion can be obtained from Table 9.3 (2) The name of the cation always precedes the name of the anion. (3) For elements that form more than one cation, the correct charge is shown by a Roman numeral in parentheses directly after the cation name. Ask students to use the three-step naming procedure to name FeN and $Mg(NO_3)_2$. (*iron(III) nitride and magnesium nitrate*)

Writing Activity

Answers should mention that lithium carbonate is used because it is effective in regulating the patient's mental state.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 9.2.

with ChemASAP

Figure 9.11 Sodium hypochlorite (NaClO) is often added to the water in swimming pools to prevent bacteria from exceeding safe levels.

Naming Compounds with Polyatomic Ions You have learned to write formulas for compounds containing polyatomic ions when you were given their names. Now, if you were given the formulas for these compounds, could you name them? When naming compounds containing polyatomic ions, follow these guidelines. First, recognize that the compound contains a polyatomic ion. If the ion is unfamiliar, find its name in Table 9.3. How would you name the compound LiCN? You could easily think that this compound is composed of individual atoms of lithium, carbon, and nitrogen. But you know that lithium is a Group 1A element and that this group forms 1+ ions. In addition, carbon is a Group 4A element that does not form a monatomic ion. From this you might suspect that the carbon and nitrogen atoms are part of a polyatomic ion with a 1− charge. Table 9.3 confirms your conclusion and tells you that the ion's name is cyanide ion. **To name a compound containing a polyatomic ion, state the cation first and then the anion just as you did in naming binary ionic compounds.** The name of LiCN is lithium cyanide.

The compound NaClO is used as a bleach and a disinfectant for swimming pools, as shown in Figure 9.11. The metallic cation in this compound is sodium (Na^+), a Group IA element that forms 1+ cations. The polyatomic ion must be ClO^-. This ion is called hypochlorite ion, so the name for NaClO is sodium hypochlorite.

Some ionic compounds containing polyatomic ions do not include a metal cation. Instead, the cation may be the polyatomic ammonium ion (NH_4^+). What is the name of $(NH_4)_2C_2O_4$? The ammonium cation has a charge of 1+. The anion must have a charge of 2− to balance the combined 2+ charge of two ammonium ions. Table 9.3 shows that the name of the anion $C_2O_4^{2-}$ is oxalate ion, so $(NH_4)_2C_2O_4$ is named ammonium oxalate.

9.2 Section Assessment

14. **Key Concept** Describe how to determine the names of binary ionic compounds.
15. **Key Concept** Describe how to write the formulas for binary ionic compounds.
16. **Key Concept** How do you write the formulas and the names of compounds with polyatomic ions?
17. Write the formula for these binary compounds.
    a. beryllium chloride
    b. cesium sulfide
    c. sodium iodide
    d. strontium oxide
18. Write the formula for these compounds containing polyatomic ions.
    a. chromium(III) nitrite
    b. sodium perchlorate
    c. magnesium hydrogen carbonate
    d. calcium acetate
19. Identify any incorrect formulas. Explain your answer.
    a. $Mg_2(SO_4)_3$ **b.** Rb_3As
    c. $BeCl_3$ **d.** NaF

Writing Activity

Report Investigate the role of lithium carbonate in the successful treatment of bipolar disorder. Write a brief report that includes information on bipolar disorder and why lithium carbonate is used to treat it.

Interactive Textbook

Assessment 9.2 Test yourself on the concepts in Section 9.2.

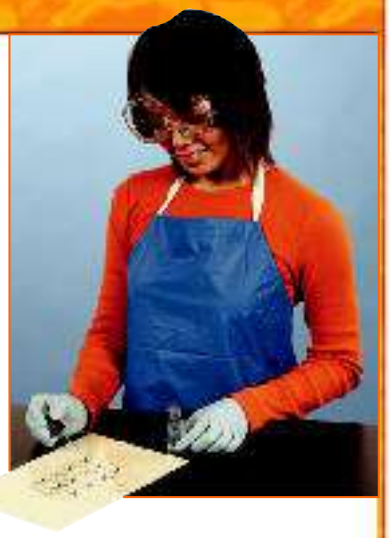
with ChemASAP

Section 9.2 Assessment

14. Write the name of the cation followed by the name of the anion.
15. Write the symbol of the cation followed by the symbol of the anion, then use subscripts to balance the charges.
16. Write the symbol for the metal ion followed by the formula of the polyatomic ion and balance the charges. Name the cation first followed by the anion.
17. **a.** $BeCl_2$ **b.** Cs_2S **c.** NaI **d.** SrO
18. **a.** $Cr(NO_2)_3$ **b.** $NaClO_4$ **c.** $Mg(HCO_3)_2$ **d.** $Ca(C_2H_3O_2)_2$
19. **a.** incorrect; charges are not balanced, $MgSO_4$ **c.** incorrect; charges are not balanced, $BeCl_2$

Small-Scale LAB

Names and Formulas for Ionic Compounds



Purpose

To observe the formation of compounds, and to write their names and formulas.

Materials

- pencil
- paper
- ruler
- reaction surface
- chemicals shown in Figure A

Procedure

On separate sheets of paper, draw two grids similar to Figure A. Make each square 2 cm on each side. Draw black Xs on one of the grids. Use the other grid as a data table to record your observations. Place a reaction surface over the grid with black Xs and add the chemicals as shown in Figure A.

Analyze

Using your experimental data, record the answers to the following questions below your data table.

1. Describe each precipitate (solid product) that forms. Use terms such as milky, grainy, cloudy, or gelatinous. Which mixture(s) did not form a precipitate?
2. Write the formulas and names of the chemical compounds produced in the mixings.

	$AgNO_3$ (Ag^+)	$Pb(NO_3)_2$ (Pb^{2+})	$CaCl_2$ (Ca^{2+})
Na_2CO_3 (CO_3^{2-})	a	e	i
Na_3PO_4 (PO_4^{3-})	b	f	j
NaOH (OH^-)	c	g	k
Na_2SO_4 (SO_4^{2-})	d	h	l

FOR REFERENCE ONLY

Figure A

You're The Chemist

The following small-scale activities allow you to develop your own procedures and analyze the results.

1. **Analyze It!** Repeat the experiment, using the chemicals in Figure B. Identify the precipitates, write their formulas, and name them.
2. **Explain It!** In ionic equations, the precipitate is written to the right of an arrow, and the ions that produced it are written to the left. Write ionic equations for the precipitates formed from the reactions related to Figure B. For example:

$$2Ag^+ + CO_3^{2-} \longrightarrow Ag_2CO_3$$

	$FeCl_3$ (Fe^{3+})	$MgSO_4$ (Mg^{2+})	$CuSO_4$ (Cu^{2+})
Na_2CO_3 (CO_3^{2-})	a	e	i
Na_3PO_4 (PO_4^{3-})	b	f	j
NaOH (OH^-)	c	g	k
Na_2SO_4 (SO_4^{2-})	d	h	l

FOR REFERENCE ONLY

Figure B

You're The Chemist

1. **a.** $Fe_2(CO_3)_3$ iron(III) carbonate
   b. $FePO_4$, iron(III) phosphate
   c. $Fe(OH)_3$, iron(III) hydroxide
   e. $MgCO_3$, magnesium carbonate
   f. $Mg_3(PO_4)_2$, magnesium phosphate
   g. $Mg(OH)_2$, magnesium hydroxide
   i. $CuCO_3$, copper(II) carbonate
   j. $Cu_3(PO_4)_2$, copper(II) phosphate
   k. $Cu(OH)_2$, copper(II) hydroxide
2. **a.** $2Fe^{3+} + 3CO_3^{2-} \rightarrow Fe_2(CO_3)_3(s)$
   b. $Fe^{3+} + PO_4^{3-} \rightarrow FePO_4(s)$
   c. $Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3(s)$
   e. $Mg^{2+} + CO_3^{2-} \rightarrow MgCO_3(s)$
   f. $3Mg^{2+} + 2PO_4^{3-} \rightarrow Mg_3(PO_4)_2(s)$
   g. $Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2(s)$
   i. $Cu^{2+} + CO_3^{2-} \rightarrow CuCO_3(s)$
   j. $3Cu^{2+} + 2PO_4^{3-} \rightarrow Cu_3(PO_4)_2(s)$
   k. $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2(s)$

For Enrichment L3

Have students design an experiment to make a measureable amount of a precipitate, separate it, dry it, and determine its mass.

Small-Scale LAB

Names and Formulas for Ionic Compounds L2

Objective After completing this activity, students will be able to:

- recognize and describe precipitates.
- write the names and formulas for the precipitates.

Prep Time 1 hour

Solution	Preparation
0.05*M* $AgNO_3$	2.1 g in 250 mL
0.2*M* $Pb(NO_3)_2$	16.6 g in 250 mL
0.5*M* $CaCl_2$	13.9 g in 250 mL
1.0*M* Na_2CO_3	26.5 g in 250 mL
0.1*M* Na_3PO_4	9.5 g $Na_3PO_4 \cdot 12H_2O$ in 250 mL
0.5*M* NaOH	20.0 g in 1.0 L
0.2*M* Na_2SO_4	7.1 in 250 mL
0.2*M* $CuSO_4$	12.5 g $CuSO_4 \cdot 5H_2O$ in 250 mL
0.2*M* $MgSO_4$	6.0 g in 250 mL
0.1*M* $FeCl_3$	6.8 g $FeCl_3 \cdot 6H_2O$ in 25 mL of 1.0*M* NaCl (for stability); dilute to 250 mL

Class Time 30 minutes

Expected Outcome In Figure A, a, f, g, h, and j: milky white; b and k: cloudy white; e: cloudy tan; i and l: grainy white; c: muddy brown; d: no visible reaction. In Figure B, a, b, and c: orange; e, f, and g: white; i, j, and k: blue; d, h, and l: no visible reaction.

Analyze and Conclude

1. $AgNO_3$ and Na_2SO_4 did not form a precipitate.
2. **a.** Ag_2CO_3, silver carbonate **b.** Ag_3PO_4, silver phosphate **c.** AgOH, silver hydroxide (Note: The product is actually Ag_2O, silver oxide.)
   e. $PbCO_3$, lead(II) carbonate
   f. $Pb_3(PO_4)_2$, lead(II) phosphate
   g. $Pb(OH)_2$, lead(II) hydroxide
   h. $PbSO_4$, lead(II) sulfate
   i. $CaCO_3$, calcium carbonate
   j. $Ca_3(PO_4)_2$, calcium phosphate
   k. $Ca(OH)_2$, calcium hydroxide
   l. $CaSO_4$, calcium sulfate