9 Chemical Names and Formulas

INSIDE:

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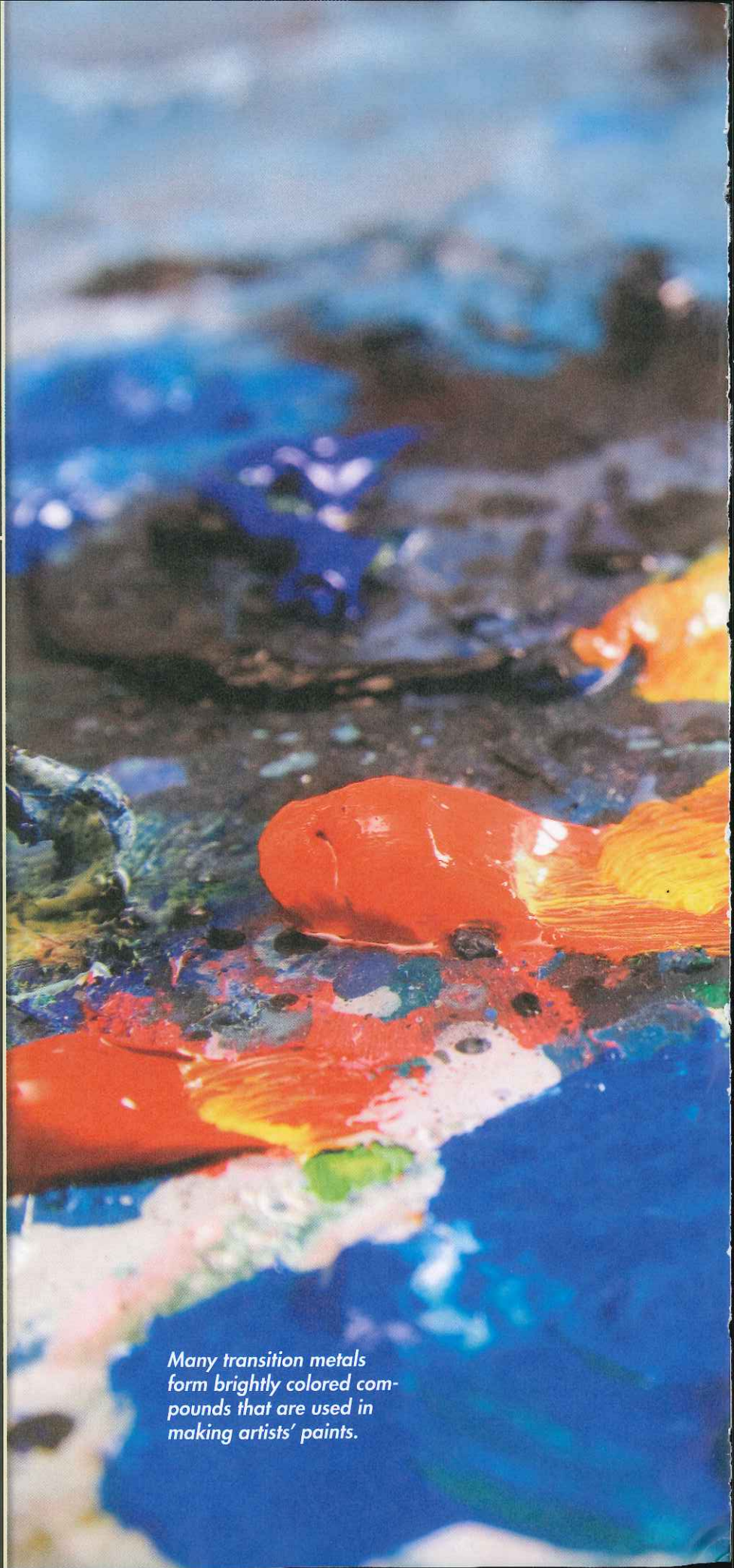


Many transition metals form brightly colored compounds that are used in making artists' paints.

BIG IDEAS

- **ELECTRONS AND THE STRUCTURE OF ATOMS**
- **BONDING AND INTERACTIONS**

Essential Questions:

1. *How does the periodic table help you determine the names and formulas of ions and compounds?*
2. *What is the difference between an ionic and a molecular compound?*

CHEMYSTERY

Cucumber Blunder

Tara's friend, Ellie, raves about the delicious lime pickles that Tara's grandma makes. As a surprise, Tara decided to make a batch for Ellie. She got the recipe from her grandma. It called for "1 cup of lime for every 3 pounds of cucumbers."

When the pickles were ready, Tara proudly presented the gift to Ellie. She watched Ellie's face as she bit into a pickle. After the first bite, Ellie made an awful face. "What's wrong?" Tara asked. After a short pause, Ellie replied, "They taste . . . funny." Tara tried one and agreed; they tasted nothing like her grandma's pickles. What did Tara do wrong?

▶ Connect to the BIG IDEA As you read about naming compounds, think about what might have caused Tara's cucumber blunder.

NATIONAL SCIENCE EDUCATION STANDARDS

A-1, A-2, B-2, E-2, F-4, G-1, G-2, G-3

9.1 Naming Ions

CHEMISTRY & YOU

Q: *Do you speak "Chemistry"?* Try looking at the ingredient label on a household product—a bottle of shampoo, a tube of toothpaste, a box of detergent. Do the names of the ingredients make sense? To truly understand chemistry, you must learn its language. Part of learning the language of chemistry involves understanding how to name ionic compounds. For this you need to know how to name ions.

Key Questions

- ***How can you determine the charges of monatomic ions?***
- ***How do polyatomic ions differ from monatomic ions? How are they similar?***

Vocabulary

- monatomic ion

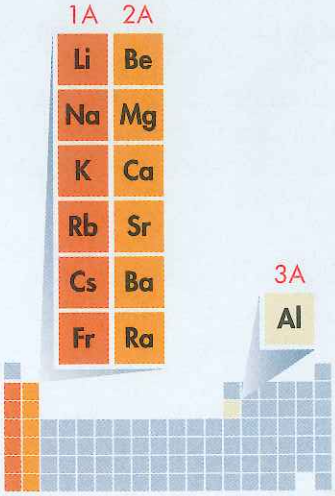


Figure 9.1
Elements That Form Cations
These representative elements form positive ions with charges equal to their group number.

Monatomic Ions

How can you determine the charges of monatomic ions?

Ionic compounds consist of a positive metal ion and a negative nonmetal ion combined in a proportion such that their charges add up to a net charge of zero. For example, the ionic compound sodium chloride (NaCl) consists of one sodium ion (Na^+) and one chloride ion (Cl^-). Probably you are already familiar with the name and formula of sodium chloride, which is common table salt. But it is important, in learning the language of chemistry, to be able to name and write the chemical formulas for all ionic compounds. The first step is to learn about the ions that form ionic compounds. Some ions, called **monatomic ions,** consist of a single atom with a positive or negative charge resulting from the loss or gain of one or more valence electrons, respectively.

Cations Recall that metallic elements tend to lose valence electrons. Lithium, sodium, and potassium in Group 1A lose one electron to form cations. All the Group 1A ions have a 1+ charge (Li^+, Na^+, K^+, Rb^+, Cs^+, and Fr^+). Magnesium and calcium are Group 2A metals. They tend to lose two electrons to form cations with a 2+ charge (Mg^{2+} and Ca^{2+}), as do all the other Group 2A metals. Aluminum is the only common Group 3A metal. As you might expect, aluminum tends to lose three electrons to form a 3+ cation (Al^{3+}). **When the metals in Groups 1A, 2A, and 3A lose electrons, they form cations with positive charges equal to their group number.** Figure 9.1 shows some of the elements whose ionic charges can be obtained from their positions in the periodic table.

The names of the cations of the Group 1A, Group 2A, and Group 3A metals are the same as the name of the metal, followed by the word *ion* or *cation*. Thus Na^+ is the sodium ion (or cation), Ca^{2+} is the calcium ion (or cation), and Al^{3+} is the aluminum ion (or cation).

Table 9.1

Ion Symbols for Some Group A Elements

1A	2A	3A	4A	5A	6A	7A	8A
Li^+	Be^{2+}			N^{3-}	O^{2-}	F^-	
Na^+	Mg^{2+}	Al^{3+}		P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}			As^{3-}	Se^{2-}	Br^-	
Rb^+	Sr^{2+}					I^-	
Cs^+	Ba^{2+}						

Anions Nonmetals tend to gain electrons to form anions, so the charge of a nonmetallic ion is negative. **The charge of any ion of a Group A nonmetal is determined by subtracting 8 from the group number.** The elements in Group 7A form anions with a 1− charge (7 − 8 = −1). The name of an anion is not the same as the element's name. Anion names start with the stem of the element name and end in *-ide*. For example, two elements in Group 7A are fluorine and chlorine. The anions for these nonmetals are the fluor*ide* ion (F^-) and chlor*ide* ion (Cl^-). Anions of nonmetals in Group 6A have a 2− charge (6 − 8 = −2). Group 6A elements, oxygen and sulfur, form the ox*ide* anion (O^{2-}) and the sulf*ide* anion (S^{2-}), respectively. The first three elements in Group 5A, nitrogen, phosphorus, and arsenic, can form anions with a 3− charge (5 − 8 = −3). These anions have the symbols N^{3-}, P^{3-}, and As^{3-} and are called, respectively, nitr*ide* ion, phosph*ide* ion, and arsen*ide* ion. Figure 9.2 shows some common Group A elements that form anions. Table 9.1 summarizes the ionic charges of representative elements that can be obtained from the periodic table. The majority of the elements in Groups 4A and 8A usually do not form ions.

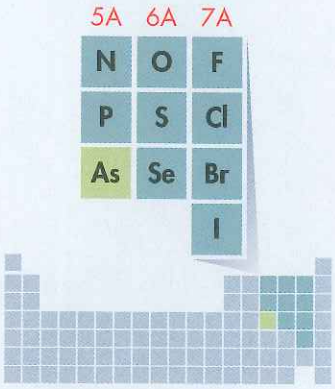


Figure 9.2 Elements That Form Anions
These representative elements form negative ions with charges equal to the group number of the element minus 8.

Metals That Form More Than One Ion The metals of Groups 1A, 2A, and 3A consistently form cations with charges of 1+, 2+, and 3+, respectively. Many of the transition metals (Groups 1B–8B) form more than one cation with different ionic charges. Some of these are shown in Figure 9.3. **The charges of the cations of many transition metal ions must be determined from the number of electrons lost.** For example, the transition metal iron forms two common cations, Fe^{2+} (two electrons lost) and Fe^{3+} (three electrons lost). Cations of tin and lead, the two metals in Group 4A, can also have more than one common ionic charge.

Two methods are used to name these ions. The preferred method is called the Stock system. In the Stock system, you place a Roman numeral in parentheses after the name of the element to indicate the numerical value of the charge. For example, the cation Fe^{2+} is named iron(II) ion. Note that no space is left between the element name and the Roman numeral in parentheses. The name for Fe^{2+} is read "iron two ion." The Fe^{3+} ion is named iron(III) ion and is read "iron three ion."

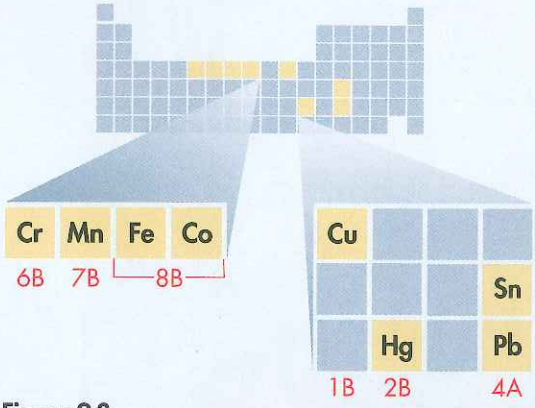


Figure 9.3
Elements That Form More Than One Ion
These metallic elements form more than one positive ion.
Identify ***Which of these elements are transition metals?***

CHEMISTRY & YOU

Q: *Suppose you were trying to teach someone how to name ions. Which rules about the "language of chemistry" would you emphasize?*

An older, less useful method for naming these cations uses a root word with different suffixes at the end of the word. The older, or classical, name of the element is used to form the root name for the element. For example, *ferrum* is Latin for iron, so *ferr-* is the root name for iron. The suffix *-ous* is used to name the cation with the lower of the two ionic charges. The suffix *-ic* is used with the higher of the two ionic charges. Using this system, Fe^{2+} is the ferrous ion, and Fe^{3+} is the ferric ion, as shown in Table 9.2. Notice that you can usually identify an element from what may be an unfamiliar classical name by looking for the element's symbol in the name. For example, *f*errous (Fe) is iron; *cu*prous (Cu) is copper; and *stan*nous (Sn) is tin. A major disadvantage of using classical names for ions is that they do not tell you the actual charge of the ion. A classical name tells you only that the cation has either the smaller (*-ous*) or the larger (*-ic*) charge of the pair of possible ions for that element.

A few transition metals have only one ionic charge. The names of these cations do not have a Roman numeral. These exceptions include silver, with cations that have a 1+ charge (Ag^+), as well as cadmium and zinc, with cations that have a 2+ charge (Cd^{2+} and Zn^{2+}). As Figure 9.4 shows, some transition metal ions form colorful solutions.

Figure 9.4
Transition Metal Ions
Compounds of transition metals are often strongly colored. Solutions that contain transition metal ions can also be colored.

Table 9.2

Symbols and Names of Common Metal Ions With More Than One Ionic Charge

Symbol	Stock name	Classical name
Cu^+	Copper(I) ion	Cuprous ion
Cu^{2+}	Copper(II) ion	Cupric ion
Fe^{2+}	Iron(II) ion	Ferrous ion
Fe^{3+}	Iron(III) ion	Ferric ion
*Hg_2^{2+}	Mercury(I) ion	Mercurous ion
Hg^{2+}	Mercury(II) ion	Mercuric ion
Pb^{2+}	Lead(II) ion	Plumbous ion
Pb^{4+}	Lead(IV) ion	Plumbic ion
Sn^{2+}	Tin(II) ion	Stannous ion
Sn^{4+}	Tin(IV) ion	Stannic ion
Cr^{2+}	Chromium(II) ion	Chromous ion
Cr^{3+}	Chromium(III) ion	Chromic ion
Mn^{2+}	Manganese(II) ion	Manganous ion
Mn^{3+}	Manganese(III) ion	Manganic ion
Co^{2+}	Cobalt(II) ion	Cobaltous ion
Co^{3+}	Cobalt(III) ion	Cobaltic ion

*A diatomic elemental ion

Sample Problem 9.1

Naming Cations and Anions

Name the ion formed by each of the following elements:

a. potassium **b.** lead, 4 electrons lost **c.** sulfur

1 Analyze **Identify the relevant concepts.** You can use the periodic table to determine the charge of most Group A elements. Ions with positive charges are cations; ions with negative charges are anions. The names of nonmetallic anions end in *-ide*. Metallic cations take the name of the metal. Some metals, including transition metals, can form more than one cation. Use a Roman numeral in the Stock name or use the classical name with a suffix to name these metals.

2 Solve **Apply the concepts to this problem.**

	a. K	**b.** Pb	**c.** S
Write the symbol for the element.			
Determine the charge of the ion formed by the element.	1+	4+	2−
Determine whether the ion is a cation or an anion.	K^+ is a cation.	Pb^{4+} is a cation.	S^{2-} is an anion.
Apply the appropriate rules for naming the ion. Use a Roman numeral if necessary.	Following the rules for naming metallic cations, K^+ is named potassium ion.	Following the rules for naming metals that can form more than one cation, Pb^{4+} is named lead(IV) or plumbic ion.	Following the rules for naming nonmetallic anions, S^{2-} is named sulfide ion.

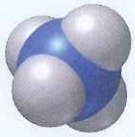
1. Name the ions formed by the following elements:

a. selenium
b. barium
c. phosphorus
d. iodine

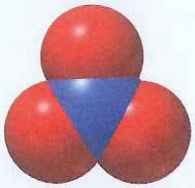
2. How many electrons were lost or gained to form these ions?

a. Fe^{3+} **c.** Cu^+
b. O^{2-} **d.** Sr^{2+}

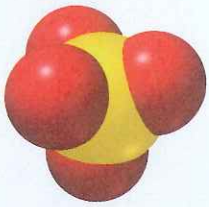
A negative charge means electrons gained; a positive charge means electrons lost.



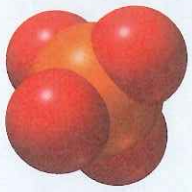
Ammonium ion
(NH_4^+)



Nitrate ion
(NO_3^-)



Sulfate ion
(SO_4^{2-})



Phosphate ion
(PO_4^{3-})

Figure 9.5 Polyatomic Ions
These molecular models show the arrangement of atoms in four common polyatomic ions.
Compare *How does the ammonium ion differ from the other three ions?*

Table 9.3

Common Polyatomic Ions

Charge	Formula	Name
1–	$H_2PO_4^-$	Dihydrogen phosphate
	$C_2H_3O_2^-$	Ethanoate
	HSO_3^-	Hydrogen sulfite
	HSO_4^-	Hydrogen sulfate
	HCO_3^-	Hydrogen carbonate
	NO_2^-	Nitrite
	NO_3^-	Nitrate
	CN^-	Cyanide
	OH^-	Hydroxide
	MnO_4^-	Permanganate
	ClO^-	Hypochlorite
	ClO_2^-	Chlorite
	ClO_3^-	Chlorate
	ClO_4^-	Perchlorate
2–	HPO_4^{2-}	Hydrogen phosphate
	$C_2O_4^{2-}$	Oxalate
	SO_3^{2-}	Sulfite
	SO_4^{2-}	Sulfate
	CO_3^{2-}	Carbonate
	CrO_4^{2-}	Chromate
	$Cr_2O_7^{2-}$	Dichromate
	SiO_3^{2-}	Silicate
3–	PO_3^{3-}	Phosphite
	PO_4^{3-}	Phosphate
1+	NH_4^+	Ammonium

Polyatomic Ions

How do polyatomic ions differ from monatomic ions? How are they similar?

Some ions, such as the sulfate ion, are called polyatomic ions. **Unlike a monatomic ion, a polyatomic ion is composed of more than one atom. But like a monatomic ion, a polyatomic ion behaves as a unit and carries a charge.** The sulfate anion consists of one sulfur atom and four oxygen atoms. These five atoms together comprise a single anion with an overall 2– charge. The formula is written SO_4^{2-}. You can see the structure of the sulfate ion along with three other common polyatomic ions in Figure 9.5.

The names and formulas of some common polyatomic ions are shown in Table 9.3, grouped according to their charges. Note that the names of most polyatomic anions end in *-ite* or *-ate*. For example, notice the endings of the names of the hypochlor*ite* ion (ClO^-) and the hydrogen carbon*ate* ion (HCO_3^-). Also notice that three important ions have different endings—the cyan*ide* anion (CN^-), the hydrox*ide* anion (OH^-), and the ammon*ium* cation (NH_4^+).

Sometimes the same two or three elements combine in different ratios to form different polyatomic ions. Several examples appear in Table 9.3. Look for pairs of ions for which there is both an *-ite* and an *-ate* ending, for example, sulfite and sulfate. Examine the charge on each ion in the pair. Note the number of oxygen atoms and the endings on each name. You should be able to discern a pattern in the naming convention.

-ite	*-ate*
SO_3^{2-}, sulfite	SO_4^{2-}, sulfate
NO_2^-, nitrite	NO_3^-, nitrate
ClO_2^-, chlorite	ClO_3^-, chlorate

The charge on each polyatomic ion in a given pair is the same. The *-ite* ending indicates one less oxygen atom than the *-ate* ending. However, the ending does not tell you the actual number of oxygen atoms in the ion. For example, the nitrite ion has two oxygen atoms, and the sulfite ion has three oxygen atoms. All anions with names ending in *-ite* or *-ate* contain oxygen.

When the formula for a polyatomic ion begins with H (hydrogen), you can think of the H as representing a hydrogen ion (H^+) combined with another polyatomic ion. For example, HCO_3^- is a combination of H^+ and CO_3^{2-}. Note that the charge on the new ion is the algebraic sum of the ionic charges of the two component ions.

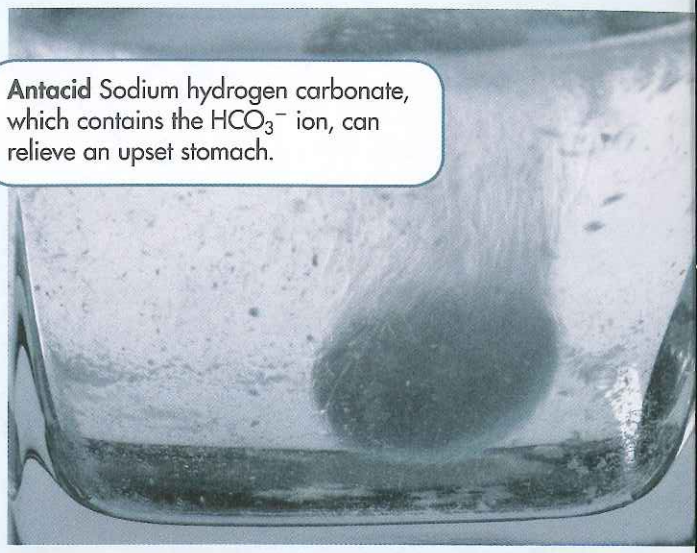
$$H^+ + CO_3^{2-} \longrightarrow HCO_3^-$$
carbonate → hydrogen carbonate

$$H^+ + PO_4^{3-} \longrightarrow HPO_4^{2-}$$
phosphate → hydrogen phosphate

$$H^+ + HPO_4^{2-} \longrightarrow H_2PO_4^-$$
hydrogen phosphate → dihydrogen phosphate

The hydrogen carbonate anion (HCO_3^-), the hydrogen phosphate anion (HPO_4^{2-}), and the dihydrogen phosphate anion ($H_2PO_4^-$) are essential components of living systems. In contrast, the cyanide ion (CN^-) is extremely poisonous to living systems because it blocks a cell's means of producing energy. Figure 9.6 shows two uses for compounds with hydrogen-containing polyatomic ions.

Figure 9.6 Hydrogen-Containing Polyatomic Ions Polyatomic ions that contain hydrogen are part of several compounds that affect your daily life.



Antacid Sodium hydrogen carbonate, which contains the HCO_3^- ion, can relieve an upset stomach.

Blood The presence of dissolved HCO_3^-, HPO_4^{2-}, and $H_2PO_4^-$ ions in your blood is critical for your health.

9.1 LessonCheck

3. Explain How can you determine the charges of metal cations? Of nonmetal anions? Of transition metal cations?

4. Review What are the similarities and differences between polyatomic ions and monatomic ions?

5. Identify What are the charges on ions of Group 1A, Group 3A (aluminum), and Group 5A?

6. Describe Write the symbol for the ion of each element. Classify the ion as an anion or a cation, and name the ion.

a. potassium
b. oxygen
c. bromine
d. tin (2 electrons lost)
e. beryllium
f. cobalt (3 electrons lost)

7. Describe Write the symbol or formula (including charge) for each of the following ions:

a. ammonium ion
b. chromium(II) ion
c. chromate ion
d. nitrate ion

8. Compare How do the differences in the polyatomic ions PO_3^{3-} and PO_4^{3-} help you determine whether each ends in *-ite* or *-ate*?

BIG IDEA
ELECTRONS AND THE STRUCTURE OF ATOMS

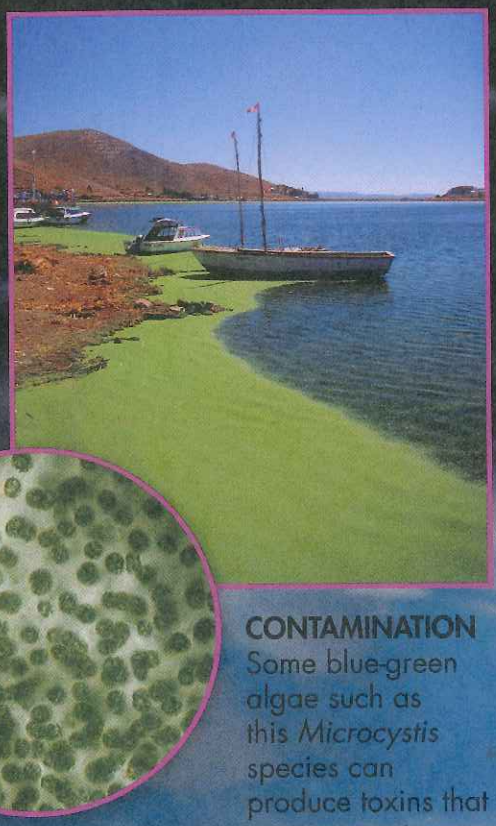
9. How does the electron configuration of an ion of a Group 1A or Group 7A element compare to that of the nearest noble gas?

Algal Blooms

Have you ever seen a lake or river covered with what looks like green or blue-green paint? This "paint" is actually high concentrations of algae that have reproduced rapidly. This event is called an algal bloom. Freshwater algal blooms often occur when there is an excess of phosphate compounds, commonly called phosphates, in the water. Phosphates are nutrients that algae need to survive. However, when phosphate levels are too high, algae grow and reproduce at unusually rapid rates.

Although most algal blooms are not harmful, some release toxins that are dangerous to humans and animals. Even nontoxic algal blooms may cause problems. For example, they may deplete the amount of oxygen in water and block sunlight, which underwater plants need to live. In addition, algal blooms may alter the taste and odor of the water.

Phosphates are found in fertilizers, detergents, and other cleaning products. These products can enter waterways by direct dumping and runoff. To help reduce the occurrence of algae blooms, government agencies and industries have collaborated to provide detergents, soaps, and cleaning agents that are more environmentally friendly. Next time you go to the store, notice that many detergents have a "Phosphate Free" label.



CONTAMINATION Some blue-green algae such as this *Microcystis* species can produce toxins that may contaminate drinking water.

Take It Further

1. Identify Sodium phosphate is one example of a phosphate compound. It was once widely used in detergents. Write the formula for this compound.

2. Infer How might an algal bloom affect aquatic grasses?

3. Research a Problem There are several other factors that can contribute to an algal bloom. Research this topic and identify at least two other factors that contribute to algal blooms.

SUFFOCATION Algal blooms can result in the death of fish by consuming too much dissolved oxygen in the water.

9.2 Naming and Writing Formulas for Ionic Compounds

CHEMISTRY & YOU

Q: *What's the name of the secret ingredient?* If this ingredient isn't included in the recipe, the fruit can turn an ugly brown. Think about when you slice an apple at home. The slices don't look that tasty if you let them sit for too long because they begin to change color. But with the recipe and the secret ingredient, your apple slices could keep their color. Chemistry also uses recipes or formulas, but without any secrets. Once you know the rules, you can apply them and name any chemical compound. In this lesson, you will learn how to name ionic compounds.

Key Questions

- ***How do you determine the formula and name of a binary ionic compound?***
- ***How do you determine the formula and name of a compound with a polyatomic ion?***

Vocabulary

- binary compound

Binary Ionic Compounds

How do you determine the formula and name of a binary ionic compound?

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 another example. The common name, *baking soda*, describes its use in baking to make baked goods rise. Figure 9.7 shows a compound with the common name of cinnabar. Can you tell what elements are in cinnabar just from looking at the name? Unfortunately, such names do not tell you anything about the chemical composition of the compound.

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.

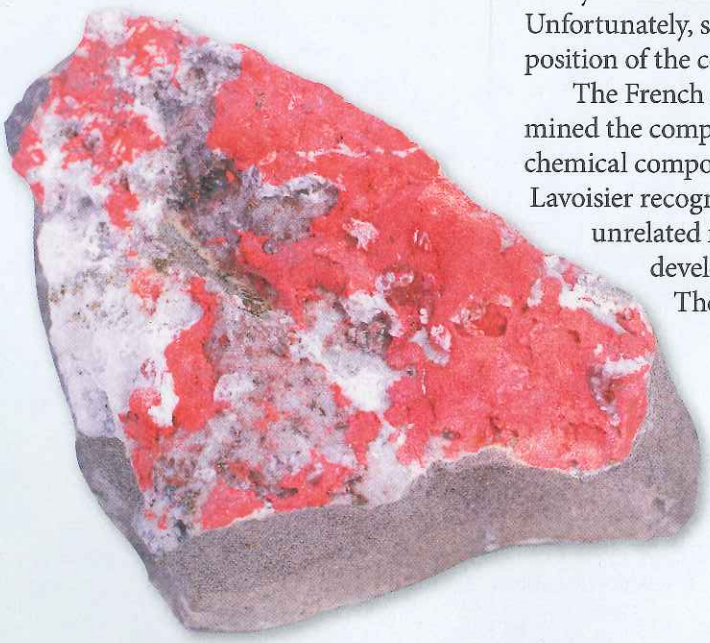


Figure 9.7 Cinnabar
The red substance that is deposited in this rock is commonly called cinnabar. Cinnabar (HgS) is comprised of mercury(II) ions and sulfide ions.

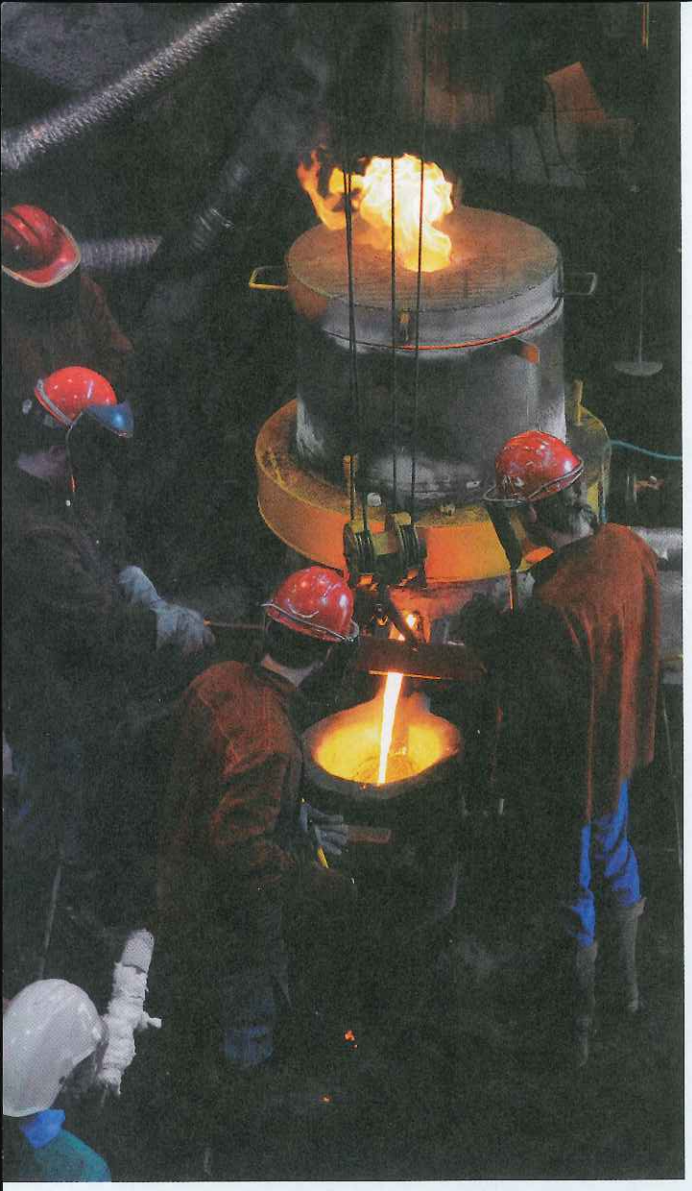


Figure 9.8 Steelworks
In the process for making steel, iron is extracted from hematite, an ore containing iron(III) oxide.
Apply Concepts ***What is the formula for iron(III) oxide?***

READING SUPPORT

Build Reading Skills: ***Compare and Contrast*** As you read about ionic and molecular compounds, compare the procedures for naming and writing formulas for each. ***How can you tell the difference between an ionic and a molecular compound?***

Writing Formulas for Binary Ionic Compounds

A **binary compound** is composed of two elements. Binary compounds can be ionic compounds or molecular compounds. If you know the name of a binary ionic compound, you can write the formula. **To write the formula of a binary ionic compound, first write the symbol of the cation and then the anion. Then add subscripts as 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 9.8 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.

$$Fe^{3+}\ O^{2-}$$

$$Fe_2O_3$$

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

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

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. However, the 2:2 ratio of calcium and sulfide ions is not the lowest whole-number ratio. The correct 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.

SampleProblem 9.2

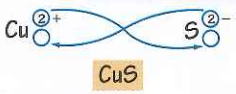
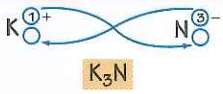
Writing Formulas for Binary Ionic Compounds

Write formulas for the following binary ionic compounds.

a. copper(II) sulfide **b.** potassium nitride

1 Analyze **Identify the relevant concepts.** Binary ionic compounds are composed of a monatomic cation and a monatomic anion. The symbol for the cation appears first in the formula for the compound. The ionic charges in an ionic compound must balance, and the ions must be combined in the lowest whole-number ratio.

2 Solve **Apply the concepts to this problem.**

	a. Cu^{2+} and S^{2-}	**b.** K^+ and N^{3-}
Write the symbol and charge for each ion in the compound—the cation first, then the anion.		
	The crisscross method is used in the following solutions.	
Balance the formula using appropriate subscripts. Make sure that the formula expresses the lowest whole-number ratio of ions.	 CuS	 K_3N
Check that the charges of the two ions add up to zero.	$1(2+) + 1(2-) = 0$	$3(1+) + 1(3-) = 0$

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 the following ionic compounds.

a. sodium iodide
b. stannous chloride
c. potassium sulfide
d. calcium iodide

Remember to add subscripts to make the compound neutral.

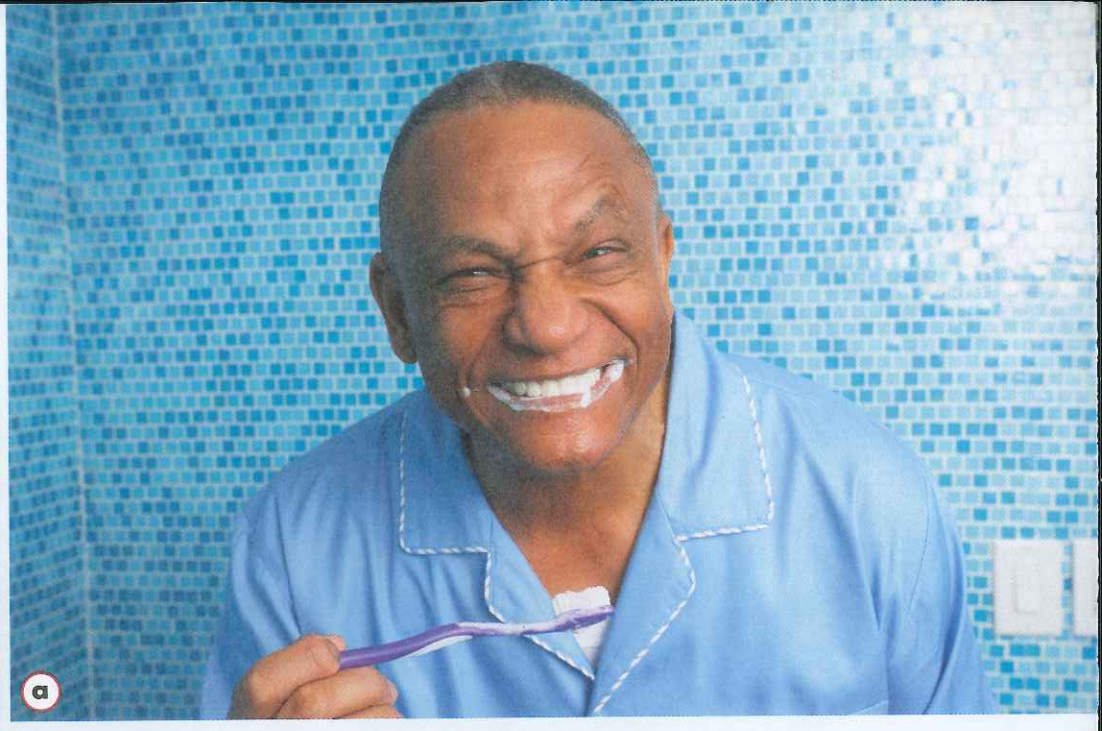


Figure 9.9 Tin Compounds
Tin(II) fluoride and tin(IV) oxide have different compositions and uses. **a.** Tin(II) fluoride is added to some toothpastes to prevent cavities. **b.** Tin(IV) oxide is used in glazes for pottery.
Identify *What are the charges of the tin ions in the two compounds?*

See some everyday chemical names online.

CHEMISTRY & YOU

Q: *Many companies use sodium sulfite (Na_2SO_3) to keep dried fruit looking delicious. Is Na_2SO_3 a binary compound? Explain.*

Naming Binary Ionic Compounds 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. **To name any binary ionic compound, place the cation name first, followed by the anion name.** For example, the compound Cs_2O is composed of the metal cesium and the nonmetal oxygen. Both cesium and oxygen are Group A elements that have only one charge. The name of Cs_2O, then, is cesium oxide. Similarly, 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. **If the metallic element in a binary ionic compound has more than one common ionic charge, a Roman numeral must be included in the cation name.**

Table 9.2 lists the symbols and names of the common metals that form more than one cation. Recall that the charges of monatomic anions can be determined from the periodic table. Using these two 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 cations to anions 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 SnO_2 is not tin(II) oxide. Oxygen 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 oxide anions. Thus, the name of SnO_2 is tin(IV) oxide or stannic oxide. Figure 9.9 shows examples of uses of stannous fluoride and stannic oxide.

SampleProblem 9.3

Naming Binary Ionic Compounds

Name the following binary ionic compounds:

a. CoI_2 **b.** Li_2Se

1 Analyze **Identify the relevant concepts.** Confirm that the compound is a binary ionic compound. To name the compound, name the ions in the order written in the formula—the cation name followed by the anion name. The name of a metal ion that has more than one common ionic charge must include a Roman numeral indicating the charge.

2 Solve **Apply the concepts to this problem.**

Interpret the chemical formula in terms of component elements. If you find two elements, the compound is binary.

a. CoI_2 contains cobalt cations and iodide anions.

b. Li_2Se contains lithium cations and selenide anions.

Determine whether the metal ion in the compound has more than one common ionic charge.

a. Cobalt forms two common cations: Co^{2+} and Co^{3+}.

b. Lithium forms one cation: Li^+.

If the metal ion has more than one ionic charge, use the nonmetal anion to determine which cation is indicated by the formula.

a. Iodide ion is I^-. The formula CoI_2 specifies two iodide ions, which give a charge of 2−. So the cobalt ion must be Co^{2+} to balance the charge.

b. This step is not needed for Li_2Se because the lithium ion has only one common charge.

Write the name of the cation, followed by the name of the anion. Include Roman numerals as needed.

a. cobalt(II) iodide

b. lithium selenide

12. Name the following binary ionic compounds:

a. ZnS **c.** BaO

b. KCl **d.** $CuBr_2$

13. Write the names for these binary ionic compounds.

a. CaO **c.** FeS

b. Cu_2Se **d.** AlF_3

Check each answer by writing the formula using the ions from the name.

Compounds With Polyatomic Ions

How do you determine the formula and name of a compound with a polyatomic ion?

The seashells shown in Figure 9.10 are 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. Calcium carbonate 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-}.

Figure 9.10
Compounds With Polyatomic Ions
Some examples of ionic compounds that contain polyatomic ions are shown.
Explain ***Why is there a Roman numeral in the name lead(II) sulfate?***

Car Battery Lead(II) sulfate ($PbSO_4$) is formed when an automobile battery discharges.

Writing Formulas for Compounds With Polyatomic Ions How would you write the formula for an ionic compound with a polyatomic ion? For starters, try following the same procedure you used for binary ionic compounds. **To write the formula for a compound with a polyatomic ion, first write the symbol (or formula) for the cation followed by the symbol (or formula) for the anion. Then, add subscripts as needed to 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 expressed 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. **Whenever more than one polyatomic ion is needed to balance the charges in an ionic compound, use parentheses to set off the polyatomic ion in the formula.**

Go online to make and name some ionic compounds. VIRTUAL LAB

Shells The shells of marine organisms are composed of calcium carbonate ($CaCO_3$).

Lithium carbonate is a compound that can be prescribed for patients who have mood disorders, such as manic-depressive disorder or bipolar disorder. The compound is composed of lithium cations (Li^+) and polyatomic carbonate anions (CO_3^{2-}). In the formula for 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.

Li_2CO_3

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

Strontium sulfate is another example of a compound in which only a single polyatomic ion (SO_4^{2-}) is needed to balance the cation (Sr^{2+}). So, no parentheses are needed when writing the formula: $SrSO_4$.

SampleProblem 9.4

Writing Formulas for Compounds With Polyatomic Ions

What are the formulas for these ionic compounds?

a. magnesium hydroxide **b.** potassium sulfate

1 Analyze **Identify the relevant concepts.** Write the symbol or formula for each ion in the order listed in the name. Use subscripts to balance the charges. The ions must be combined in the lowest whole-number ratio. If more than one polyatomic ion is needed to balance a formula, place the polyatomic ion formula in parentheses, followed by the appropriate subscript.

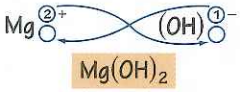
2 Solve **Apply the concepts to this problem.**

Write the symbol or formula for each ion in the compound—the cation first, then the anion. Include the charge for each ion.

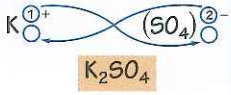
a. cation: Mg^{2+}
anion: OH^-

b. cation: K^+
anion: SO_4^{2-}

Balance the formula using appropriate subscripts. Make sure that the formula expresses the lowest whole-number ratio of ions.



$Mg(OH)_2$



K_2SO_4

Remember: Only use parentheses if there is more than one polyatomic ion in the balanced formula.

Check that the charges of the two ions add up to zero.

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

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

14. Write formulas for compounds formed from these pairs of ions.
a. NH_4^+, SO_3^{2-}
b. calcium ion, phosphate ion

15. Write formulas for the following compounds:
a. lithium hydrogen sulfate
b. chromium(III) nitrite

Figure 9.11 Sodium Hypochlorite The compound NaClO is often added to laundry water to bleach (brighten) white fabrics.

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, you must first identify any polyatomic ions in the formula for the compound. If the polyatomic ion is unfamiliar, find its name in Table 9.3. **To name a compound containing a polyatomic ion, state the cation name first and then the anion name. If the cation is a metallic element that has more than one common ionic charge, include a Roman numeral in the cation name.** Recall that the same rules apply when naming binary ionic compounds.

The compound NaClO is used as a disinfectant for swimming pools and as a bleach, as shown in Figure 9.11. The cation in this compound is sodium ion (Na^+). The other ion, ClO^-, is a polyatomic ion called hypochlorite ion. So, the name for NaClO is sodium hypochlorite.

SampleProblem 9.5

Naming Compounds With Polyatomic Ions

Name the following ionic compounds:

a. $(NH_4)_2C_2O_4$ **b.** $Fe(ClO_3)_3$

1 Analyze **Identify the relevant concepts.** Determine whether there is a polyatomic ion in the formula. To name the compound, list the names of the ions in the order written in the formula—the cation name followed by the anion name. The name of an ion that has more than one common ionic charge must include a Roman numeral indicating the charge.

2 Solve **Apply the concepts to this problem.**

	a.	**b.**
Identify any polyatomic ions.	NH_4^+ and $C_2O_4^{2-}$	ClO_3^-
Determine if any metal ions in the compound have more than one common ionic charge. If so, use the nonmetal anion to determine which cation is indicated by the formula.	This step is not needed because there is no metal ion in this compound.	Iron forms two common cations: Fe^{2+} and Fe^{3+}. Chlorate ion is ClO_3^-. Three chlorate ions give a charge of 3−. So the iron ion must be Fe^{3+} to balance the charge.
Write the name of the cation, then the name of the anion. Include Roman numerals as needed.	ammonium oxalate	iron(III) chlorate

16. Name the following ionic compounds:

a. CaC_2O_4 **c.** $KMnO_4$

b. KClO **d.** Li_2SO_3

17. Write the names for these ionic compounds.

a. $Al(OH)_3$ **c.** $Sn_3(PO_4)_2$

b. $NaClO_3$ **d.** Na_2CrO_4

Quick Lab

Purpose To mix solutions containing cations and anions to make ionic compounds

Materials

- 9 small test tubes
- test tube rack
- paper, pencil, ruler
- 6 droppers
- solution A (Fe^{3+} ion)
- solution B (Ag^{+} ion)
- solution C (Pb^{2+} ion)
- solution X (CO_3^{2-} ion)
- solution Y (OH^{-} ion)
- solution Z (PO_4^{3-} ion)

Making Ionic Compounds

Procedure

1. Label three test tubes A, three test tubes B, and three test tubes C.

2. Add 10 drops (approximately 0.5 mL) of solution A to the test tubes that are labeled A. Add 10 drops of solution B to the test tubes that are labeled B. Repeat this step with solution C.

3. Add 10 drops of solution X to one test tube of A, 10 drops to one test tube of B, and 10 drops to one test tube of C. Observe each test tube for the formation of a solid.

4. Make a 3-by-3 inch grid to record your observations. Label the rows A, B, and C. Label the columns X, Y, and Z. Describe any solid material you observe.

5. Repeat Step 3, adding 10 drops of solution Y to test tubes A, B, and C. Record your observations.

6. Repeat Step 3, adding 10 drops of solution Z to test tubes A, B, and C. Record your observations.

Analyze and Conclude

1. Infer Some ionic compounds are insoluble in water. What did you observe? How many of the compounds formed were insoluble?

2. Describe Write the formula for each ionic compound formed.

3. Describe Name each ionic compound formed.

4. Draw Conclusions Will mixing any cation with any anion always lead to the formation of an insoluble ionic compound? Explain your answer.

9.2 LessonCheck

18. Summarize Describe the procedures for writing the formulas and names of binary ionic compounds.

19. Review How do you write the formulas and the names of compounds with polyatomic ions?

20. Evaluate What are the advantages and disadvantages of common names?

21. Apply Concepts Write the formula for these binary ionic compounds.

a. beryllium chloride
b. cesium sulfide
c. sodium iodide
d. strontium oxide

22. Identify What condition must be met when writing a formula for an ionic compound?

23. Apply Concepts Write the formula for these compounds containing polyatomic ions.

a. chromium(III) nitrite
b. sodium perchlorate
c. magnesium hydrogen carbonate
d. calcium acetate

24. Explain When do you use parentheses in writing a chemical formula?

25. Describe Name the following ionic compounds:

a. LiF
b. SnS_2
c. $MnCO_3$
d. $Sr(H_2PO_4)_2$

26. Identify Which of the following formulas are incorrect? Explain your answer.

a. $Mg_2(SO_4)_3$
b. $AsRb_3$
c. $BeCl_3$
d. NaF

9.3 Naming and Writing Formulas for Molecular Compounds

CHEMISTRY & YOU

Q: *What numerical prefixes are used in chemistry?* You're already familiar with words containing numerical prefixes. For example, the word *triathlon* contains the prefix *tri-*, indicating the number 3. Athletes sometimes compete in multisport events—pentathlons, heptathlons, decathlons, and so on. The prefix of each tells you how may sports are in the event. Prefixes are used in chemistry, too. In this lesson, you will learn how prefixes in the name of a binary molecular compound tell you its composition.

Key Question

What guidelines are used to write the name and formula of a binary molecular compound?

Binary Molecular Compounds

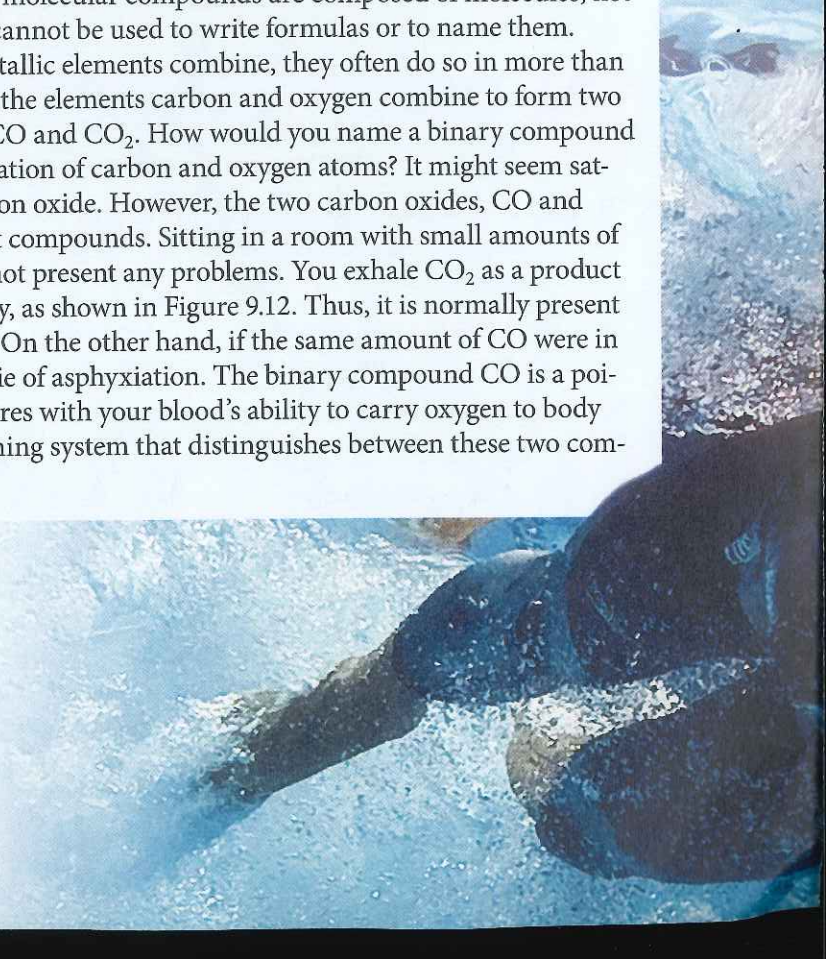
What guidelines are used to write the name and formula of a binary molecular compound?

Recall that binary ionic compounds are composed of the ions of two elements, a metal and a nonmetal. Binary molecular compounds are also composed of two elements, but both elements are nonmetals and are not ions. These differences affect the naming of these compounds and the writing of their formulas. Binary molecular compounds are composed of molecules, not ions, so ionic charges cannot be used to write formulas or to name them.

When two nonmetallic elements combine, they often do so in more than one way. For example, the elements carbon and oxygen combine to form two gaseous compounds, CO and CO_2. How would you name a binary compound formed by the combination of carbon and oxygen atoms? It might seem satisfactory to call it carbon oxide. However, the two carbon oxides, CO and CO_2, are very different compounds. Sitting in a room with small amounts of CO_2 in the air would not present any problems. You exhale CO_2 as a product of your body chemistry, as shown in Figure 9.12. Thus, it is normally present in the air you breathe. On the other hand, if the same amount of CO were in the room, you could die of asphyxiation. The binary compound CO is a poisonous gas that interferes with your blood's ability to carry oxygen to body cells. Obviously, a naming system that distinguishes between these two compounds is needed.

CHEMISTRY & YOU

Q: *How does a triathlon differ from a pentathlon? How does phosphorus trifluoride differ from phosphorus pentafluoride?*



Naming Binary Molecular Compounds Prefixes in the names of binary molecular compounds help distinguish compounds containing different numbers of atoms such as CO and CO_2. Table 9.4 lists the prefixes used to name binary molecular compounds. These prefixes tell how many atoms of an element are present in each molecule of the compound. According to the table, the prefix *mono-* would be used for the single oxygen atom in CO. The prefix *di-* would be used to indicate the presence of the two oxygen atoms in CO_2.

Use the prefixes listed in Table 9.4 along with the following guidelines to name a binary molecular compound. But before you apply these steps, you must confirm that the compound is a binary molecular compound. **To name a binary molecular compound, use the following guidelines:**

1. **Write the names of the elements in the order listed in the formula.**
2. **Use prefixes appropriately to indicate the number of each kind of atom.** If just one atom of the first element is in the formula, omit the prefix *mono-* for that element. Also, the vowel at the end of a prefix is sometimes dropped when the name of the element begins with a vowel.
3. **End the name of the second element with the suffix *-ide*.**

Following these guidelines, CO is named carbon *mon*oxide and CO_2 is named carbon *di*oxide. What about the compound Cl_2O_8? This binary molecular compound consists of two chlorine atoms and eight oxygen atoms. The name is therefore *di*chlorine *oct*oxide.

Table 9.4

Prefixes Used in Naming Binary Molecular Compounds

Prefix	Number
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

Figure 9.12 Carbon Dioxide When you exhale underwater, bubbles containing CO_2 rise to the surface of the water.

SampleProblem 9.6

Naming Binary Molecular Compounds

Name the following binary molecular compounds:

a. N_2O **b.** PCl_3

1 Analyze **Identify the relevant concepts.** Confirm that the compound is a binary molecular compound—a compound composed of two nonmetals. To name the compound, name the elements in the order written in the formula. Use prefixes as necessary to indicate the number of each kind of atom. Use the suffix *-ide* on the name of the second element.

2 Solve **Apply the concepts to this problem.**

Identify the elements in the compound and the number of atoms of each element in a molecule of the compound.

a. N_2O is composed of two nonmetals, nitrogen and oxygen.

Each molecule of N_2O has:
2 nitrogen atoms;
1 oxygen atom.

b. PCl_3 is composed of two nonmetals, phosphorus and chlorine.

Each molecule of PCl_3 has:
1 phosphorus atom;
3 chlorine atoms.

Write the names of the elements in the order they are written in the formula. Include prefixes to show how many atoms of each element. Use the suffix *-ide* with the name of the second element.

dinitrogen monoxide

phosphorus trichloride

The prefix *mono-* is not used with the first element indicated in the formula.

27. Name the following binary molecular compounds:

a. OF_2 **c.** SO_3

b. S_2F_{10} **d.** SF_6

Writing Formulas for Binary Molecular Compounds Suppose you know the name of a molecular compound and want to write the formula. **To write the formula of a binary molecular compound, first use the prefixes in the name to tell you the subscript of each element in the formula. Then, write the correct symbols for the two elements with the appropriate subscripts.** An interesting example is tetraphosphorus trisulfide, which is used in some matches. The name *tetraphosphorus trisulfide* has the prefixes *tetra-* and *tri-*, so the subscripts of phosphorus and sulfur must be 4 and 3, respectively. Thus, the formula for tetraphosphorus trisulfide is P_4S_3.

SampleProblem 9.7

Writing Formulas for Binary Molecular Compounds

Write formulas for the following binary molecular compounds:

a. nitrogen trifluoride **b.** disulfur dichloride

1 Analyze **Identify the relevant concepts.** The prefixes in the name indicate the subscript of each element in the formula. Write the symbols for the two elements with the appropriate subscripts.

2 Solve **Apply the concepts to this problem.**

Use the prefixes to determine how many atoms of each element are in the compound.

a. Each molecule of nitrogen trifluoride has:
1 nitrogen atom;
3 fluorine atoms.

b. Each molecule of disulfur dichloride has:
2 sulfur atoms;
2 chlorine atoms.

Construct the formula using the correct symbols and subscripts.

a. NF_3

b. S_2Cl_2

28. Write formulas for these binary molecular compounds.

a. dinitrogen tetroxide **c.** disulfur decafluoride
b. xenon tetrafluoride **d.** iodine heptafluoride

Note: The number 1 is never used as a subscript in a formula.

9.3 LessonCheck

29. Review Explain how to write the name and formula of a binary molecular compound.

30. Describe Write the names of these molecular compounds.

a. NCl_3 **c.** NI_3 **e.** N_2H_4
b. BCl_3 **d.** SO_3 **f.** N_2O_3

31. Apply Concepts Write the formulas for these binary molecular compounds.

a. phosphorus pentachloride
b. iodine heptafluoride
c. chlorine trifluoride
d. iodine dioxide

32. Describe Write the formulas or names for these molecular compounds.

a. CS_2 **c.** carbon tetrabromide
b. Cl_2O_7 **d.** diphosphorus trioxide

33. Evaluate The name a student gives for the molecular compound $SiCl_4$ is monosilicon trichloride. Is this name correct? Explain your answer.

34. Explain Are the bonds between silicon and chlorine in silicon tetrachloride single bonds? Justify your answer by drawing an electron dot structure of silicon tetrachloride.

35. Classify Determine whether each of the following compounds is a molecular compound or an ionic compound. How can you tell?

a. PBr_3 **c.** iron(III) oxide
b. KBr **d.** carbon tetraiodide

BIG IDEA BONDING AND INTERACTIONS

36. What is the difference between an ionic compound and a molecular compound?

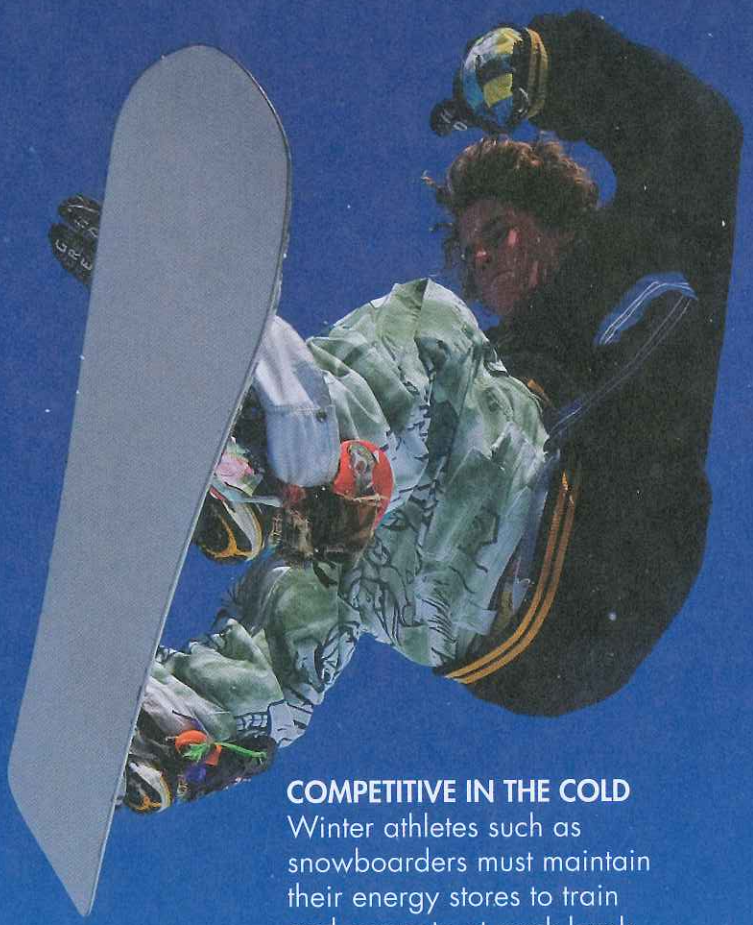
CHEMISTRY & YOU: CAREERS

Sports Nutrition Advisor

Athletes have different nutrition requirements than the average person. As a result, many professional athletes hire nutrition advisors that specialize in athlete nutrition.

Sports nutrition advisors create individualized nutritional programs that ensure optimal body compositions, performance levels, and recovery rates in athletes. The program might include such things as how to maintain energy balance throughout the day, how to avoid dehydration or overhydration, or which vitamins and minerals to take to maintain proper body chemistry.

It is important that the advisors understand the "language of chemistry" to be able to decipher the ingredient labels on products. Registered advisors have taken courses in chemistry, biochemistry, anatomy, physiology, and statistics, in addition to several nutrition classes.



COMPETITIVE IN THE COLD Winter athletes such as snowboarders must maintain their energy stores to train and compete at peak levels.

Take It Further

1. Infer How might understanding chemistry help a sports nutrition advisor develop a personalized meal plan for an athlete?

2. List Choose five nutritional consumer products—food or supplements—from your home. Read the ingredient labels on each product. Make a list of the compounds you understand and classify each as an ionic compound or a molecular compound.

9.4 Naming and Writing Formulas for Acids and Bases

CHEMISTRY & YOU

Q: *What's the name of the acid responsible for the crisp taste in this drink?*
There's a certain acid that gives many soft drinks their crisp, enjoyable taste. In this lesson, you will learn the names and formulas of some important acids, including one found in many soft drinks.

Key Questions

- ***How do you determine the name and formula of an acid?***
- ***How do you determine the name and formula of a base?***

Vocabulary

- acid
- base

Names and Formulas of Acids

How do you determine the name and formula of an acid?

Acids are a group of ionic compounds with unique properties. As you will see in Chapter 19, acids can be defined in several ways. For now, it is enough to know that an **acid** is a compound that contains one or more hydrogen atoms and produces hydrogen ions when dissolved in water. Acids have many uses. For example, sulfuric acid is often used to etch circuit boards like the one shown in Figure 9.13.

When naming an acid, you can consider the acid to consist of an anion combined with as many hydrogen ions as needed to make the molecule electrically neutral. Therefore, the chemical formulas of acids are in the general form H_nX, where X is a monatomic or polyatomic anion and n is a subscript indicating the number of hydrogen ions that are combined with the anion.

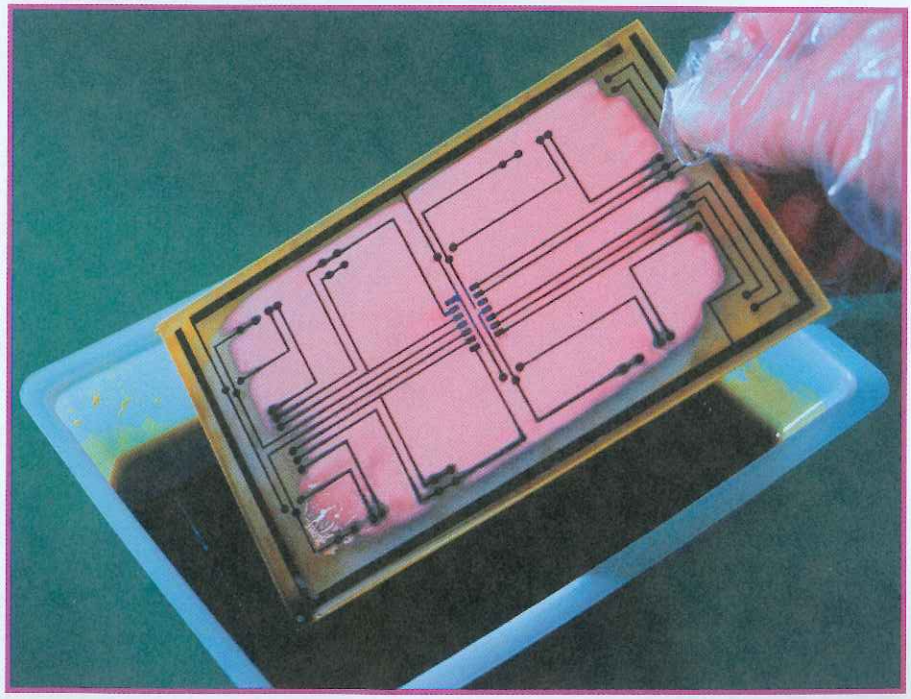


Figure 9.13 Sulfuric Acid
Circuit boards that are used in computers and other electronic devices have grooves (or circuits) that hold the wires for carrying signals. The circuits are often created using a mixture that contains sulfuric acid.

Table 9.5

Naming Common Acids

Anion ending	Example	Acid name	Example
-ide	chlor*ide*, Cl^-	*hydro-*(stem)*-ic acid*	*hydro*chlor*ic acid*
-ite	sulf*ite*, SO_3^-	(stem)*-ous acid*	sulfur*ous acid*
-ate	nitr*ate*, NO_3^-	(stem)*-ic acid*	nitr*ic acid*

Three rules can help you name an acid with the general formula H_nX dissolved in water. Read the rules and the examples carefully. Notice that the naming system depends on the name of the anion (X), in particular the suffix of the anion name. Each rule deals with an anion with a different suffix: *-ide*, *-ite*, and *-ate*.

1. **When the name of the anion ends in *-ide*, the acid name begins with the prefix *hydro-*. The stem of the anion has the suffix *-ic* and is followed by the word *acid*.** Therefore, HCl (X = chloride) is named *hydro*chlor*ic acid*.
2. **When the anion name ends in *-ite*, the acid name is the stem of the anion with the suffix *-ous*, followed by the word *acid*.** Thus, H_2SO_3 (X = sulfite) is named sulfur*ous acid*.
3. **When the anion name ends in *-ate*, the acid name is the stem of the anion with the suffix *-ic*, followed by the word *acid*.** Thus, HNO_3 (X = nitrate) is named nitr*ic acid*.

These three rules are summarized in Table 9.5. Use the table to help you write acid names until you become an expert.

CHEMISTRY & YOU

Q: *An acid that provides the crisp taste in many soft drinks has the formula H_3PO_4. What's the name of this acid?*

Table 9.6

Common Acids

Name	Formula
Hydrochloric acid	HCl
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Ethanoic acid	$HC_2H_3O_2$
Phosphoric acid	H_3PO_4
Carbonic acid	H_2CO_3

Writing Formulas of Acids If you know the name of an acid, you can write its formula. **To write the formula for an acid, use the rule for writing the name of the acid in reverse. Then balance the ionic charges just as you would for any ionic compound.** For example, consider hydrobromic acid. Following Rule 1, hydrobromic acid (*hydro-* prefix and *-ic* suffix) must be a combination of hydrogen ion (H^+) and bromide ion (Br^-). So the formula of hydrobromic acid is HBr. How do you write the formula for phosphorous acid? Using Rule 2, hydrogen ion and phosphite ion (PO_3^{3-}) must be the components of phosphorous acid. You need three hydrogen ions to balance the 3– charge of the phosphite anion. Thus, the formula for phosphorous acid is H_3PO_3. Finally, what is the formula for sulfuric acid? According to Rule 3, sulfuric acid (*-ic* ending) must be a combination of hydrogen ion and sulfate ion (SO_4^{2-}). The formula for sulfuric acid is H_2SO_4 because two hydrogen ions are needed to balance the 2– charge of the sulfate anion.

Many industrial processes, including steel and fertilizer manufacturing, use acids. You should become familiar with the names and formulas of common acids such as those listed in Table 9.6.

SampleProblem 9.8

Naming Acids

Name the following compounds as acids:

a. HClO **b.** HCN

1 Analyze **Identify the relevant concepts.** The anion of the acid determines the acid name. (1) If the name of the anion ends in *-ide*, name the acid using the stem of the anion with the prefix *hydro-* and the suffix *-ic*, followed by the word *acid*. (2) If the anion name ends in *-ite*, name the acid using the stem of the anion with the suffix *-ous*, followed by the word *acid*. (3) If the anion name ends in *-ate*, name the acid using the stem of the anion with the suffix *-ic*, followed by the word *acid*.

2 Solve **Apply the concepts to this problem.**

Identify the anion in the acid and the suffix of the anion name.

a. ClO^- (hypochlor*ite*)

b. CN^- (cyan*ide*)

Name the acid using the appropriate prefix (if any) and suffix. Finish with the word *acid*.

a. hypochlorous acid (Rule 2)

b. hydrocyanic acid (Rule 1)

37. Name the following compounds as acids:
- **a.** HF
- **b.** HNO_3
- **c.** H_2SO_3

38. Write formulas for the following acids:
- **a.** perchloric acid
- **b.** hydroiodic acid
- **c.** chlorous acid

Hint: For Problem 38, use the corresponding naming rule in reverse.

Names and Formulas of Bases

How do you determine the name and formula of a base?

A **base** is generally an ionic compound that produces hydroxide ions when dissolved in water. **Bases are named in the same way as other ionic compounds—the name of the cation is followed by the name of the anion.** The common base sodium hydroxide is used in making cleaners, soap, and paper as shown in Figure 9.14. Sodium hydroxide (NaOH) is composed of sodium cations (Na^+) and hydroxide anions (OH^-).

To write the formula for a base, first write the symbol for the metal cation followed by the formula for the hydroxide ion. Then, balance the ionic charges just as you would for any ionic compound. For example, aluminum hydroxide consists of the aluminum cation (Al^{3+}) and the hydroxide anion (OH^-). You need three hydroxide ions to balance the 3+ charge of the aluminum cation. Thus, the formula for aluminum hydroxide is $Al(OH)_3$.

Figure 9.14 Use of Sodium Hydroxide
In the first step of papermaking, manufacturers use NaOH to break down recycled paper and wood to make pulp.

SampleProblem 9.9

Naming Bases

Name the following bases:

a. KOH **b.** $Fe(OH)_2$

1 Analyze **Identify the relevant concepts.** Bases are named like other ionic compounds—the name of the cation is followed by the name of the anion.

2 Solve **Apply the concepts to this problem.**

First identify the cation and the anion in the compound.

a. cation: K^+
anion: OH^-

b. cation: Fe^{2+}
anion: OH^-

Now write the name of the cation, followed by the name of the anion.

potassium hydroxide

iron(II) hydroxide

Remember: You need to include a Roman numeral if the metal ion can have different ionic charges.

39. Name the following bases:
- **a.** $Ba(OH)_2$
- **b.** $Ca(OH)_2$
- **c.** RbOH

40. Write formulas for the following bases:
- **a.** cesium hydroxide
- **b.** beryllium hydroxide
- **c.** manganese(III) hydroxide

9.4 LessonCheck

41. Review Explain how to determine the name and formula of an acid.

42. Review How are the names and formulas determined for bases?

43. Identify Give the names of the following acids:
- **a.** HNO_2
- **b.** $HMnO_4$
- **c.** HBr
- **d.** H_2S

44. Identify Write the names of these bases.
- **a.** LiOH
- **b.** $Pb(OH)_2$
- **c.** $Mg(OH)_2$
- **d.** $Al(OH)_3$

45. Classify Identify each compound as an acid or a base. Then name each compound.
- **a.** NH_4OH
- **b.** $HClO_3$
- **c.** $Fe(OH)_3$
- **d.** KOH

46. Describe Write the formulas for these ionic compounds.
- **a.** carbonic acid
- **b.** sulfurous acid
- **c.** iron(III) hydroxide
- **d.** zinc hydroxide

47. Compare What element generally appears in the formula of an acid? What ion generally appears in the formula of a base?

9.5 The Laws Governing How Compounds Form

CHEMISTRY & YOU

Q: *Did you know that sand from a beach can be used to make glass?* Sand contains the compound silicon dioxide, which is used in glass making. One molecule of silicon dioxide consists of one silicon atom and two oxygen atoms. In this lesson, you will learn why the ratio of silicon to oxygen atoms in silicon dioxide is always the same.

Key Questions

How is the law of definite proportions consistent with Dalton's atomic theory?

What general guidelines can help you write the name and formula of a chemical compound?

Vocabulary

- law of definite proportions
- law of multiple proportions

The Laws of Definite and Multiple Proportions

How is the law of definite proportions consistent with Dalton's atomic theory?

Consider the compound calcium carbonate ($CaCO_3$), which is commonly found in rocks. Whether you find the compound in a rock in Thailand or New Zealand, it is still calcium carbonate. This statement is true because the three elements—calcium, carbon, and oxygen—are combined in the same proportions in every molecule of $CaCO_3$. Two laws—the law of definite proportions and the law of multiple proportions—describe the proportions in which elements combine to form compounds. The rules for naming and writing formulas for compounds are possible because compounds obey these two rules.

Law of Definite Proportions A chemical formula tells you, by means of subscripts, the ratio of atoms of each element in the compound. Ratios of atoms can also be expressed as ratios of masses. For example, magnesium sulfide (MgS) is composed of magnesium cations and sulfide anions. If you could take 100.00 g of magnesium sulfide and break it down into its elements, you would obtain 43.13 g of magnesium and 56.87 g of sulfur. The Mg:S ratio of these masses is 43.13/56.87 or 0.758:1. This mass ratio does not change regardless of how the magnesium sulfide is formed or the size of the sample. Magnesium sulfide obeys the **law of definite proportions,** which states that in samples of any chemical compound, the masses of the elements are always in the same proportions. This law is consistent with Dalton's atomic theory.

Dalton postulated that atoms combine in simple whole-number ratios. If the ratio of atoms of each element in a compound is fixed, then it follows that the ratio of their masses is also fixed.

Law of Multiple Proportions In the early 1800s, Dalton and others studied pairs of compounds that contain the same elements but have different physical and chemical properties. Using the results from these studies, Dalton stated the **law of multiple proportions:** Whenever the same two elements form more than one compound, the different masses of one element that combine with the same mass of the other element are in the ratio of small whole numbers. Figure 9.15 shows two compounds—CuCl and $CuCl_2$—that demonstrate the law of multiple proportions.

Figure 9.15 CuCl and $CuCl_2$
a. Copper(I) chloride (CuCl) contains the elements copper and chlorine. This compound is green. **b.** Copper(II) chloride ($CuCl_2$) contains the same two elements as copper(I) chloride—copper and chlorine. But, this compound is blue.

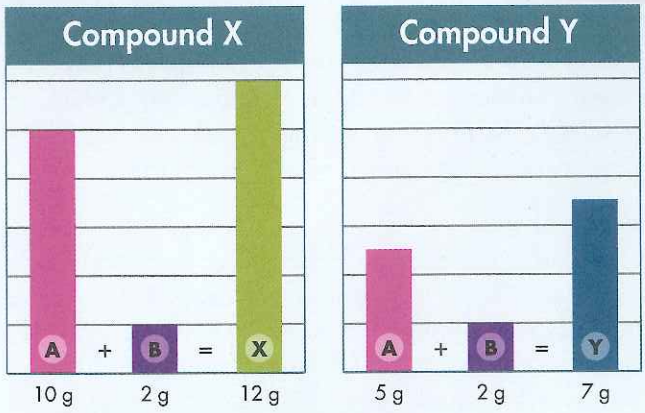


Figure 9.16 Law of Multiple Proportions
Two compounds, X and Y, contain equal masses of element B. The ratio of the masses of A in these compounds is 10:5 or 2:1 (a small whole-number ratio).
Compare ***Would the ratio be different if samples of X and Y contained 3 g of B? Explain.***

KINETIC ART *See the law of multiple proportions animated online.*

Two familiar compounds, water (H_2O) and hydrogen peroxide (H_2O_2), are formed by the same two elements. Although these compounds are formed by the elements hydrogen and oxygen, they have different physical and chemical properties. For example, water does not bleach fabric dyes, but hydrogen peroxide bleaches the dye in most fabrics. Each compound obeys the law of definite proportions. In every sample of hydrogen peroxide, 16.0 g of oxygen are present for each 1.0 g of hydrogen. The mass ratio of oxygen to hydrogen is always 16:1. In every sample of water, the mass ratio of oxygen to hydrogen is always 8:1. If a sample of hydrogen peroxide has the same mass of hydrogen as a sample of water, the ratio of the mass of oxygen in the two compounds is exactly 2:1.

$$\frac{16\text{ g O (in } H_2O_2\text{ sample that has 1 g H)}}{8\text{ g O (in } H_2O\text{ sample that has 1 g H)}} = \frac{16}{8} = \frac{2}{1} = 2{:}1$$

A simple example of the law of multiple proportions is shown in Figure 9.16.

Sample Problem 9.10

Calculating Mass Ratios

Carbon reacts with oxygen to form two compounds. Compound A contains 2.41 g of carbon for each 3.22 g of oxygen. Compound B contains 6.71 g of carbon for each 17.9 g of oxygen. What is the lowest whole-number mass ratio of carbon that combines with a given mass of oxygen?

1 Analyze **List the knowns and the unknown.**

Apply the law of multiple proportions to the two compounds. For each compound, find the grams of carbon that combine with 1.00 g of oxygen. Then find the ratio of the masses of carbon in the two compounds. Confirm that the ratio is the lowest whole-number ratio.

KNOWNS

Compound A = 2.41 g C and 3.22 g O
Compound B = 6.71 g C and 17.9 g O

UNKNOWN

Mass ratio of C per g O in the two compounds = ?

2 Calculate **Solve for the unknown.**

First, calculate grams of carbon per gram of oxygen in compound A.

$$\frac{2.41\ g\ C}{3.22\ g\ O} = \frac{0.748\ g\ C}{1.00\ g\ O}$$

Then, calculate grams of carbon per gram of oxygen in compound B.

$$\frac{6.71\ g\ C}{17.9\ g\ O} = \frac{0.375\ g\ C}{1.00\ g\ O}$$

To calculate the mass ratio, compare the masses of one element per one gram of the other element in each compound.

Calculate the mass ratio to compare the two compounds.

$$\frac{0.748\ g\ C}{0.375\ g\ C} = \frac{1.99}{1} \approx \frac{2}{1}$$

Express the mass ratio as the lowest whole-number ratio.

The mass ratio of carbon per gram of oxygen in the two compounds is 2:1.

3 Evaluate **Does this result make sense?** The ratio is a low whole-number ratio, as expected. For a given mass of oxygen, compound A contains twice the mass of carbon as compound B.

48. Lead forms two compounds with oxygen. One contains 2.98 g of lead and 0.461 g of oxygen. The other contains 9.89 g of lead and 0.763 g of oxygen. For a given mass of oxygen, what is the lowest whole-number mass ratio of lead in the two compounds?

49. In the compound iron(III) oxide, also known as rust, the mass ratio of iron to oxygen is 7:3. A 33-g sample of a compound composed of iron and oxygen contains 10 g of oxygen. Is the sample iron(III) oxide? Explain.

To answer Problem 49, first calculate the mass of iron in the sample.

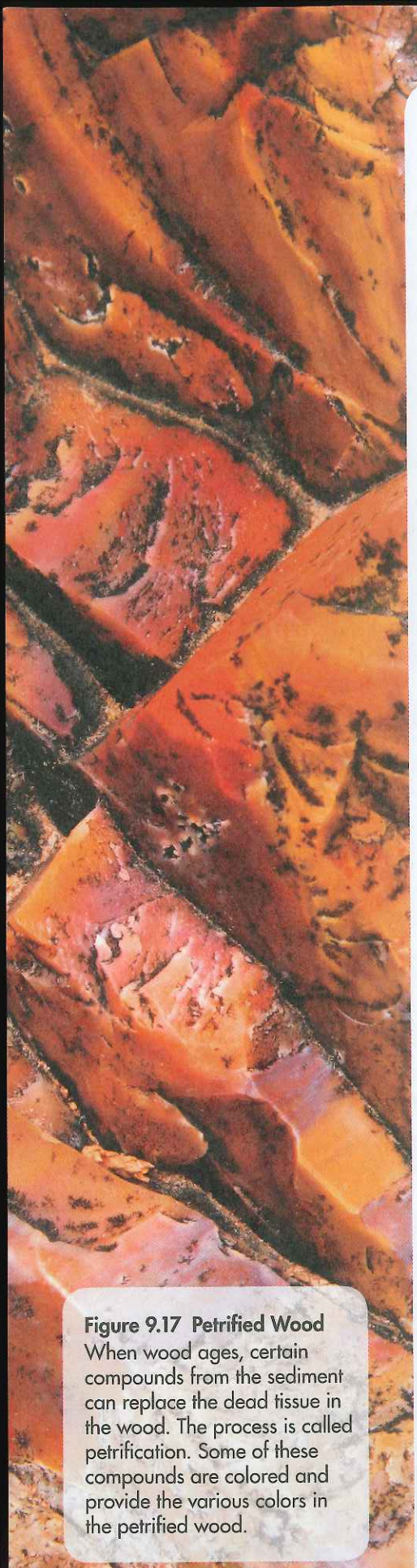


Figure 9.17 Petrified Wood When wood ages, certain compounds from the sediment can replace the dead tissue in the wood. The process is called petrification. Some of these compounds are colored and provide the various colors in the petrified wood.

Practicing Skills: Chemical Names and Formulas

What general guidelines can help you write the name and formula of a chemical compound?

In the average home, you can probably find hundreds of chemicals, including cleaning products, pharmaceuticals, and pesticides. You've probably noticed warning labels on products, which tell about their possible dangers. Most people would not know what to do if a child ingested one of these chemicals. A phone call to a poison control center can provide lifesaving information to victims of such poisonings. But a poison control center can be much more effective if the caller can supply some information about the name or formula of the substance.

Naming Chemical Compounds One of the skills you learned in this chapter is to name chemical compounds. If this is the first time you have tried to master this skill, you may feel a little overwhelmed. For example, you may find it difficult to know when you should or should not use prefixes and Roman numerals in a name. Or you may have trouble determining if a compound's name should end in *-ate, -ide,* or *-ite.*

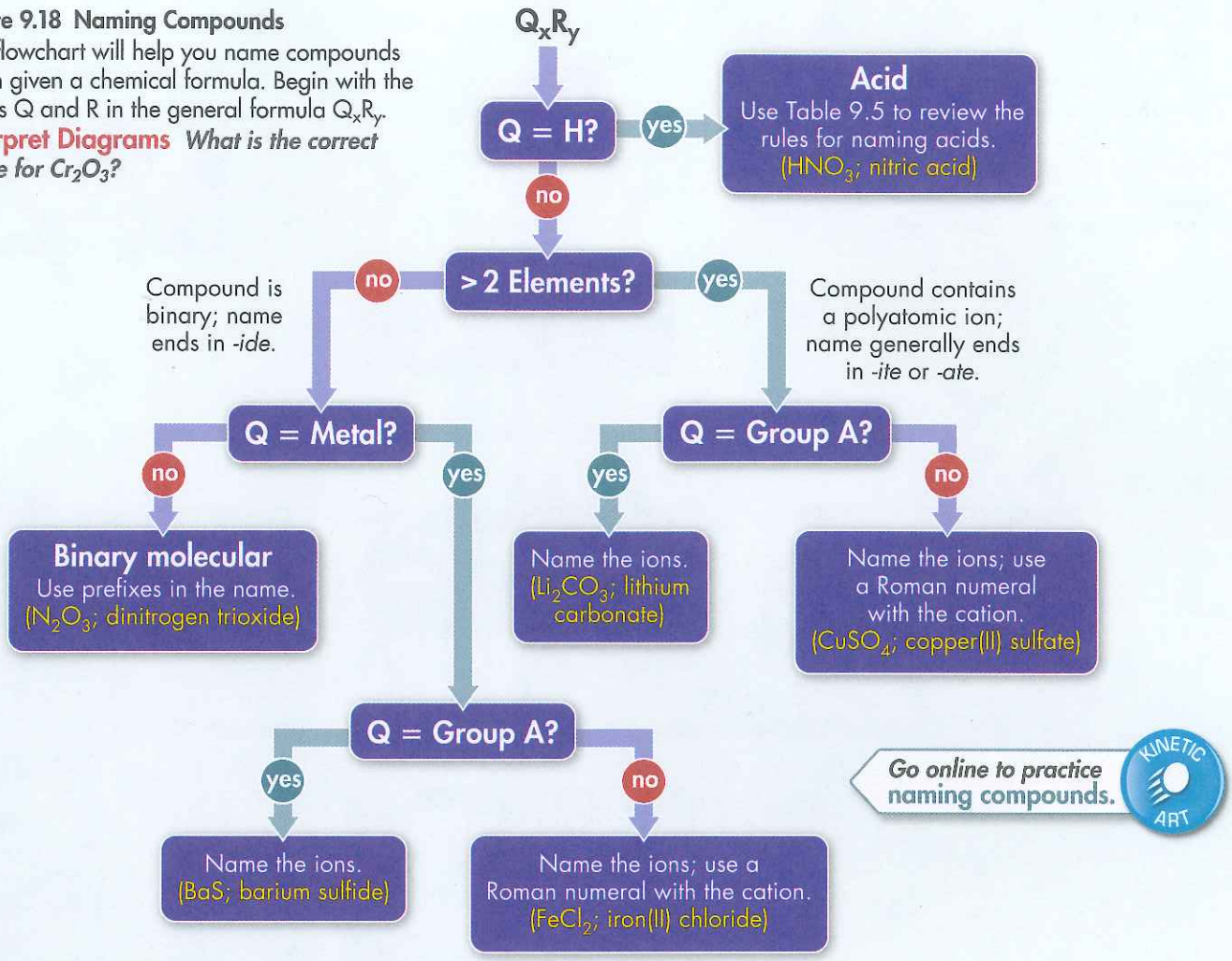
Here are some guidelines to help you in naming a chemical compound from the chemical formula.

1. **Follow the rules for naming acids when H is the first element in the formula.**
2. **If the compound is binary, generally the name ends with the suffix *-ide*. If the compound is a molecular binary compound, use prefixes to indicate the number of atoms.**
3. **When a polyatomic ion that includes oxygen is in the formula, the compound name generally ends in *-ite* or *-ate*.**
4. **If the compound contains a metallic cation that can have different ionic charges, use a Roman numeral to indicate the numerical value of the ionic charge in the compound.**

The flowchart in Figure 9.18 provides you with a sequence of questions for naming a compound when you know its formula. Follow the arrows and answer the questions on the flowchart to write the correct name for a compound. The sequence of questions in the flowchart can help you name compounds you may have in your home as well as the compounds that are responsible for the beautiful colors in the petrified wood shown in Figure 9.17. Apply the general formula Q_xR_y to each compound. Q and R can be atoms, monatomic ions, or polyatomic ions. For example, to name HNO_3, let H = Q and NO_3 = R. Follow the first arrow down to the question "Q = H?" The answer is yes, so the arrow to the right tells you that the compound is an acid. You can then follow the rules for naming acids. HNO_3 is nitric acid.

To name the compound N_2O_3, let N = Q and O = R. The answer to the question "Q = H?" is no, so you follow the arrow down. Does the compound have more than two elements? The answer is no, so you follow the arrow to the left. The compound is binary, and its name ends in *-ide.* Is Q a metal? The answer is no, so you must use prefixes in the name for N_2O_3, which is *di*nitrogen *tri*oxide. Practice naming other compounds using the flowchart. Soon you won't need the flowchart anymore.

Figure 9.18 Naming Compounds
This flowchart will help you name compounds when given a chemical formula. Begin with the letters Q and R in the general formula Q_xR_y.
Interpret Diagrams *What is the correct name for Cr_2O_3?*



Writing Chemical Formulas In writing a chemical formula from a chemical name, it is helpful to remember the following guidelines:

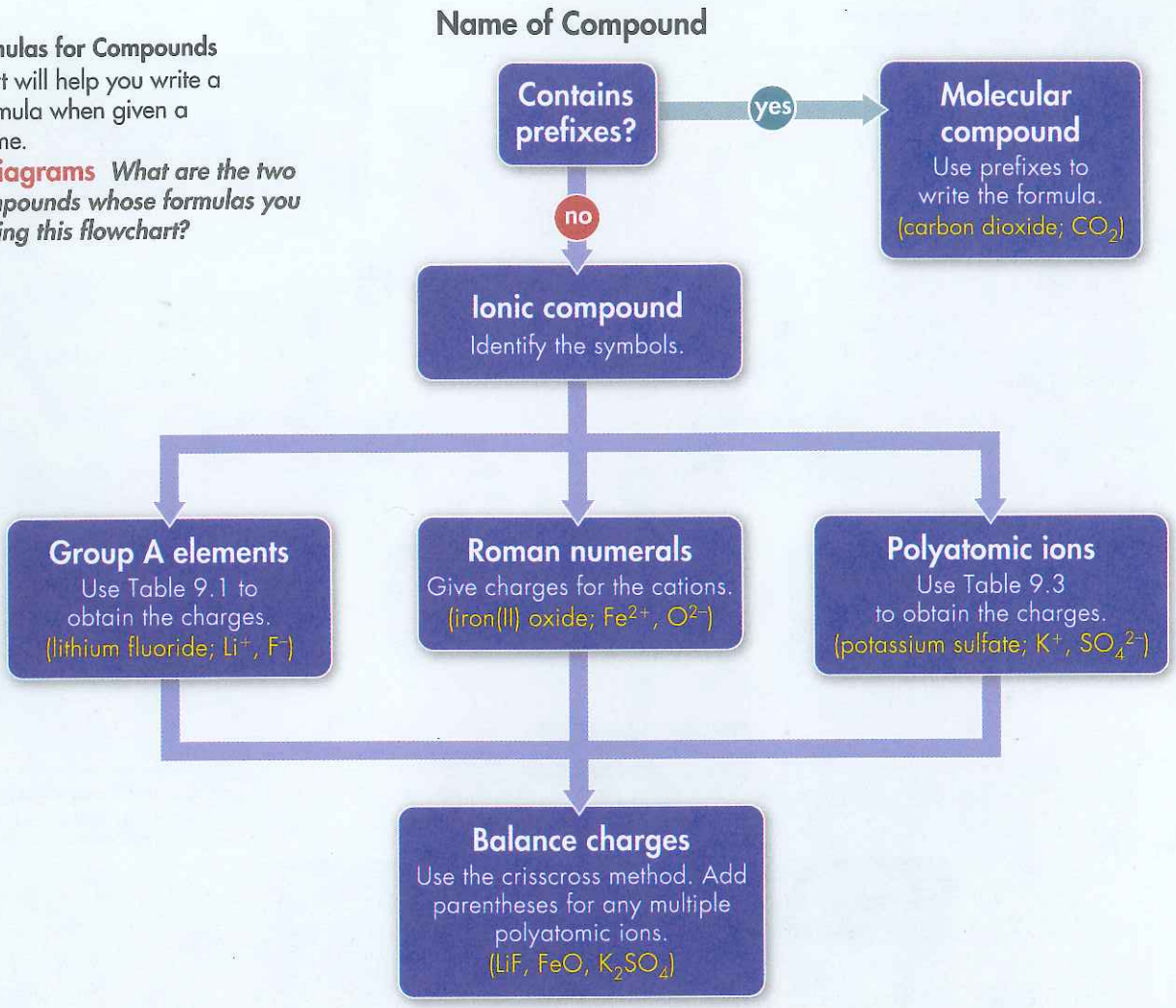
1. **An *-ide* ending generally indicates a binary compound.**
2. **An *-ite* or *-ate* ending means a polyatomic ion that includes oxygen is in the formula.**
3. **Prefixes in a name generally indicate that the compound is molecular.**
4. **A Roman numeral after the name of a cation shows the ionic charge of the cation.**

These guidelines and the questions in the flowchart in Figure 9.19 will help you write the formula for a compound when you know its name. For example, use the flowchart to write the formula for sodium chromate. The name does not contain prefixes, so the compound is ionic. The ions are sodium ion and chromate ion. Sodium is a Group A element, so use the periodic table or Table 9.1 to obtain its ionic charge (1+). Chromate ion is a polyatomic ion, so use Table 9.3 to obtain its charge (2−). Balance the charges to obtain the formula Na_2CrO_4. Use this flowchart to practice writing formulas until you don't need it anymore.

CHEMISTRY & YOU

Q: *Use the flowchart in Figure 9.19 to help you write the formula for silicon dioxide.*

Figure 9.19
Writing Formulas for Compounds
This flowchart will help you write a chemical formula when given a chemical name.
Interpret Diagrams ***What are the two types of compounds whose formulas you can write using this flowchart?***



ONLINE PROBLEMS

9.5 LessonCheck

50. **Review** How is the law of definite proportions consistent with Dalton's atomic theory?

51. **List** What general guidelines can help you write the name and formula of a compound?

52. **Compare** Two compounds that contain copper and chlorine have the following masses:

Compound A: 32.10 g Cu and 17.90 g Cl
Compound B: 23.64 g Cu and 26.37 g Cl

Are the compounds the same? If not, what is the lowest whole-number mass ratio of copper that combines with a given mass of chlorine?

53. **Identify** Name the following compounds:
a. $CaCO_3$ **b.** $PbCrO_4$ **c.** $SnCr_2O_7$

54. **Describe** Write the chemical formulas for each of the following compounds:
a. tin(II) hydroxide **c.** tetraiodide nonoxide
b. barium fluoride **b.** iron(III) oxalate

55. **Evaluate** Identify any incorrect names or formulas from the following choices. Explain your answer(s).
a. calcium(II) oxide **c.** $Na_2C_2O_4$
b. aluminum oxide **d.** $Mg(NH_4)_2$

BIG IDEA BONDING AND INTERACTIONS

56. Explain why the chemical composition of water (H_2O) is always the same.

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
- chemicals shown in Figure B

Procedure

On separate sheets of paper, draw two grids similar to Figure A. Make each square 2 cm on each side. Draw black X's 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 X's and add the chemicals as indicated in Figure A.

	$AgNO_3$ (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

Figure A

	$FeCl_3$ (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

Figure B

Analyze and Conclude

1. Observe 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. Describe Write the formulas and names of the chemical compounds produced in the mixings.

You're the Chemist

1. Analyze Data Repeat the experiment, using the chemicals in Figure B. Identify the precipitates, write their formulas, and name them.

2. Explain 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, the first reaction in Figure B would be written as follows:

$$2Fe^{3+} + 3CO_3^{2-} \longrightarrow Fe_2(CO_3)_3$$

9 Study Guide

BIG IDEAS THE STRUCTURE OF ATOMS; BONDING AND INTERACTIONS

An element's position in the periodic table supplies information on ion formation and bonding tendencies, which is used to write the names and formulas of ions and compounds. Ionic and molecular compounds differ in composition—ions form ionic compounds and molecules form molecular compounds.

9.1 Naming Ions

When metals in Groups 1A, 2A, and 3A lose electrons, they form cations with positive charges equal to their group number. The charge of any ion of a Group A nonmetal is determined by subtracting 8 from the group number. The charges of the cations of many transition metals must be determined from the number of electrons lost.

A polyatomic ion is composed of more than one atom that behaves as a unit and carries a charge.

- monatomic ion (264)

9.2 Naming and Writing Formulas for Ionic Compounds

To write the formula of a binary ionic compound, write the symbol of the cation and then the anion. Then balance the charges. The name of a binary ionic compound is the cation name followed by the anion name.

To write formulas for compounds with polyatomic ions, write the symbol for the cation followed by the symbol for the anion. Then balance the charges. To name a compound containing a polyatomic ion, state the cation name followed by the anion name.

- binary compound (272)

9.3 Naming and Writing Formulas for Molecular Compounds

To name a binary molecular compound, write the names of the elements in the order listed in the formula. Use prefixes to indicate the number of each atom. End the name of the second element with *-ide*.

To write the formula of a binary molecular compound, use the prefixes to determine the subscript of each element. Write the symbols for the elements with the subscripts.

9.4 Naming and Writing Formulas for Acids and Bases

If the anion name ends in *-ide*, the acid name begins with the prefix *hydro-*. The stem of the anion has the suffix *-ic* and is followed by the word *acid*. If the anion name ends in *-ite*, the acid name is the stem of the anion with the suffix *-ous*, followed by the word *acid*. If the anion name ends in *-ate*, the acid name is the stem of the anion with the suffix *-ic*, followed by the word *acid*. To write the formula for an acid, use the rule for writing the name of the acid in reverse.

Bases are named like other ionic compounds. To write the formula for a base, write the symbol for the metal cation followed by that of the hydroxide ion. Then, balance the ionic charges.

- acid (285)
- base (287)

9.5 The Laws Governing How Compounds Form

If the ratio of atoms of each element in a compound is fixed, then the ratio of their masses is also fixed.

Follow the rules for naming acids when H is the first element. If the compound is binary, generally the name ends with *-ide*. For a molecular binary compound, use prefixes to indicate the number of atoms. When a polyatomic ion with oxygen is in the formula, the compound name ends in *-ite* or *-ate*. If the compound contains a metallic cation that can have different ionic charges, use a Roman numeral to indicate the ionic charge.

An *-ide* ending usually indicates a binary compound. An *-ite* or *-ate* ending indicates a polyatomic ion with oxygen. Prefixes usually indicate a molecular compound. A Roman numeral after the name of a cation shows the ionic charge of the cation.

- law of definite proportions (289)
- law of multiple proportions (290)

Skills Tune-Up: Names and Formulas

Problem	❶ Analyze	❷ Solve
Write the name for the binary ionic compound CrI_2.	Name the ions in the order written in the formula. Use a Roman numeral if the metal cation in the compound can have more than one common ionic charge. Hint: Refer to Sample Problems 9.2–9.3 if you have trouble identifying binary ionic compounds.	CrI_2 contains chromium cations and iodide anions. Chromium forms two common cations: Cr^{2+} and Cr^{3+}. The compound CrI_2 is electrically neutral. Iodide ion is I^- and the formula CrI_2 specifies two iodide ions, which give a charge of 2−. So the chromium ion must be Cr^{2+}. The name of the compound is chromium(II) iodide.
Write the name for the binary molecular compound N_2O_5. Hint: Review Sample Problem 9.6 if you need help naming binary molecular compounds.	Name the elements in the order written in the formula. Use prefixes as necessary to indicate the number of each kind of atom. Use the suffix *-ide* on the name of the second element.	N_2O_5 is composed of two nitrogen atoms and five oxygen atoms. The name of the compound is dinitrogen pentoxide.
Write the formula for the ionic compound aluminum sulfate.	Write the symbol or formula for each ion in the order written in the name. Use subscripts to balance the charges. The ions must be combined in the lowest whole-number ratio. Use parentheses if more than one polyatomic ion is needed to balance a formula.	Aluminum sulfate contains Al^{3+} cations and SO_4^{2-} anions.  The formula for aluminum sulfate is $Al_2(SO_4)_3$. Remember: Use parentheses when there is more than one polyatomic ion in the balanced formula.
Write the formula for the binary molecular compound selenium dioxide. Remember: The number 1 is never used as a subscript in a formula.	The prefixes in the name indicate the subscript of each element in the formula. Write the symbols for the two elements with the appropriate subscripts.	Selenium dioxide is composed of one selenium atom and two oxygen atoms. The formula for selenium dioxide is written as SeO_2.

9 Assessment

* Solutions appear in Appendix E

Lesson by Lesson

9.1 Naming Ions

57. Give the expected charges on the ions of elements of these groups of the periodic table.

a. Group 6A
b. Group 1A
c. Group 7A
d. Group 3A

***58.** Give the expected charge of the cations of the following elements:

a. Sr **b.** Ca **c.** Al **d.** Cs

59. Name these ions, using Table 9.2, if necessary.

a. Ba^{2+} **b.** I^- **c.** Ag^+ **d.** Hg^{2+}

60. Write the names and formulas of the two polyatomic anions in Table 9.3 with names that do not end in *-ite* or *-ate*.

61. Name the following ions:

a. OH^- **b.** Pb^{4+} **c.** SO_4^{2-} **d.** O^{2-}

9.2 Naming and Writing Formulas for Ionic Compounds

62. What is the net charge of every ionic compound? Explain.

63. How are chemical formulas written for binary ionic compounds, given their names? How is the reverse done?

***64.** How do you determine the charge of a transition metal cation from the formula of an ionic compound containing that cation?

65. How are formulas written for ionic compounds with polyatomic ions, given their names? How is the reverse done?

66. Complete the table by writing correct formulas for the compounds formed by combining positive and negative ions. Then name each compound.

	NO_3^-	CO_3^{2-}	CN^-	PO_4^{3-}
NH_4^+	a.____	e.____	i.____	m.____
Sn^{4+}	b.____	f.____	j.____	n.____
Fe^{3+}	c.____	g.____	k.____	o.____
Mg^{2+}	d.____	h.____	l.____	p.____

67. Which of the following compounds are binary ionic compounds?

a. KBr
b. K_3PO_4
c. sodium nitride
d. calcium sulfate

68. When must parentheses be used in a formula for a compound?

9.3 Naming and Writing Formulas for Molecular Compounds

69. What are the components of a binary molecular compound?

***70.** What prefix indicates each of the following numbers of atoms in the formula of a binary molecular compound?

a. 3 **b.** 1 **c.** 2 **d.** 6 **e.** 5 **f.** 4

71. How are formulas for binary molecular compounds written, given their names? How is the reverse performed, given their formulas?

72. Write the formula or name for the following compounds:

a. P_2O_5
b. CCl_4
c. boron trichloride
d. dinitrogen tetrahydride

9.4 Naming and Writing Formulas for Acids and Bases

73. Give the name or the formula for these acids.

a. HCl
b. HNO_3
c. sulfuric acid
d. acetic acid

74. Is every compound that contains hydrogen an acid? Explain.

75. Write formulas for these compounds.

a. nitrous acid
b. aluminum hydroxide
c. hydroselenic acid
d. strontium hydroxide
e. phosphoric acid

***76.** Write names or formulas for these compounds.

a. $Pb(OH)_2$
b. $Co(OH)_2$
c. copper(II) hydroxide
d. iron(II) hydroxide

9.5 The Laws Governing How Compounds Form

77. What is the law of definite proportions?

78. Describe the law of multiple proportions.

***79.** Nitrous oxide, laughing gas, is used as an anesthetic in dentistry. The mass ratio of nitrogen to oxygen is 7:4. A 68-g sample of a compound composed of nitrogen and oxygen contains 42 g of nitrogen. Is the sample nitrous oxide?

Understand Concepts

80. Write formulas for these compounds.

a. potassium permanganate
b. calcium hydrogen carbonate
c. dichlorine heptoxide
d. trisilicon tetranitride
e. sodium dihydrogen phosphate
f. phosphorus pentabromide

81. Write formulas for these compounds.

a. magnesium sulfide
b. sodium phosphite
c. barium hydroxide
d. copper(II) nitrite
e. potassium sulfite
f. calcium carbonate
g. sodium bromide
h. ferric sulfate

***82.** Name these compounds.

a. $NaClO_3$
b. Hg_2Br_2
c. K_2CrO_4
d. $HClO_4$
e. SnO_2
f. $Fe(C_2H_3O_2)_3$
g. $KHSO_4$
h. $Ca(OH)_2$
i. BaS

83. Name each substance.

a. $LiClO_4$
b. Cl_2O
c. HgF_2
d. CaO
e. $Ba_3(PO_4)_2$
f. I_2
g. $SrSO_4$
h. $CuC_2H_3O_2$
i. $SiCl_4$

84. Name each compound.

a. $Mg(MnO_4)_2$
b. $Be(NO_3)_2$
c. K_2CO_3
d. N_2H_4
e. LiOH
f. BaF_2
g. PI_3
h. ZnO
i. H_3PO_3

85. Write formulas for these compounds.

a. calcium bromide
b. silver chloride
c. aluminum carbide
d. nitrogen dioxide
e. tin(IV) cyanide
f. lithium hydride
g. strontium acetate
h. sodium silicate

***86.** A compound of general formula Q_xR_y contains no hydrogen, and Q and R are both elements. Neither Q nor R is a metal. Is Q_xR_y an acid, a binary ionic compound, or a binary molecular compound?

87. A compound of general formula Q_xR_y contains no hydrogen, Q is the alkali metal of lowest atomic mass, and R contains the elements oxygen and carbon in a 3:1 ratio. Write the name and the formula of the compound.

***88.** Two compounds contain only tin and chlorine. The ratio of the masses of chlorine combined with 1.00 g of tin in the two compounds is 2:1. If one compound has the formula $SnCl_2$, what is the formula for the other compound?

89. Analysis of two compounds shows that they contain only lead and iodine in these amounts:

Compound I: 22.48 g Pb and 27.52 g I
Compound II: 5.80 g Pb and 14.20 g I

a. Determine the ratio of lead contained in the two compounds for every 1 g of iodine.
b. Use your ratio and your knowledge of ionic charges to write the formulas and the names of the two compounds.

90. The U.S. produces thousands of inorganic chemicals. Inorganic chemicals, for the most part, do not contain carbon. The table shows the amounts (in billions of kg) of the top ten inorganic chemicals produced in a recent year.

Chemical name	Amount produced (10^9 kg)
Sulfuric acid	39.4
Nitrogen	26.9
Oxygen	17.7
Ammonia	16.5
Lime	16.3
Phosphoric acid	11.2
Sodium hydroxide	11.0
Chlorine	10.3
Sodium carbonate	9.3
Nitric acid	6.8

a. What percentage of the total production of the top ten is lime (calcium oxide)?
b. Three diatomic gases are on the list. What are their names? What was the combined production of these gases in billions of kilograms?
c. The three acids make up what percentage of the total production of the top ten?
d. Write formulas for the top ten inorganic chemicals.

Think Critically

91. Compare and Contrast How does the information conveyed by a molecular formula differ from that given by a formula unit of a compound?

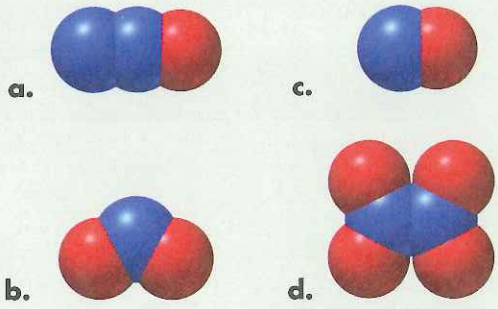
92. Make Generalizations Where on the periodic table will you find the two elements in a binary molecular compound?

93. Draw Conclusions Why is it important for chemists to have a system of writing chemical names and formulas?

94. Evaluate Criticize this statement: "The ionic charge of any metal can be determined from the position of the element in the periodic table."

95. Explain Summarize the rules that chemists use for naming ionic compounds. What is the purpose for each rule?

***96. Use Models** Nitrogen and oxygen form a number of stable chemical compounds. In the models below, nitrogen is blue; oxygen is red. Write the molecular formula and name of each.



97. Evaluate and Revise Examine the following names for ionic compounds. Show, by writing all possible formulas for the compounds, that the names are incomplete. Then, write each complete name.

a. copper sulfide
b. iron sulfate
c. lead oxide
d. manganese fluoride

***98. Evaluate and Revise** Explain what is wrong with each formula. Write the correct formula.

a. $CsCl_2$
b. LiNe
c. ZnO_2
d. Ba_2S_2

99. Infer Sodium aluminum sulfate is an active ingredient in baking powder. The molecular formula for this ionic compound contains two sulfate ions. Write the complete molecular formula for sodium aluminum sulfate.

***100. Classify** Separate the following compounds into five categories: binary ionic compounds, binary molecular compounds, compounds with polyatomic ions, acids, and bases. Some compounds may fit in more than one category.

a. CBr_4
b. HCN
c. NH_4OH
d. MgS
e. H_2SiO_3
f. ClBr
g. Al_2O_3
h. Na_2HPO_4
i. $KMnO_4$

***101. Calculate** A student heats 5.00 g of a white compound and obtains 3.60 g of a green compound and 1.40 g of a colorless gas. Another student heats a 9.00-g sample of the same compound and obtains 6.48 g of a green compound and 2.52 g of a colorless gas.

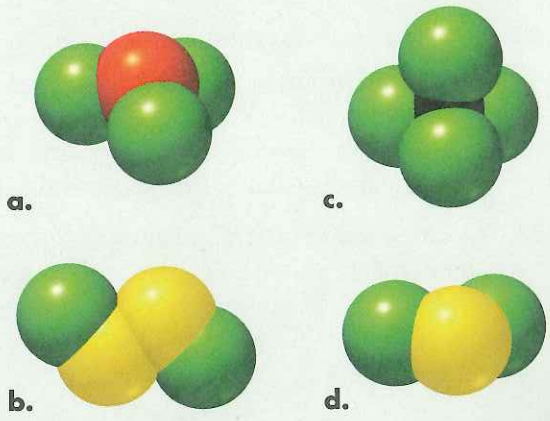
a. Show by calculation that the white compound obeys the law of definite proportions.
b. If a third student heats 14.0 g of the white compound, how many grams of colorless gas will be produced?

***102. Draw Conclusions** What other law is illustrated (twice) by the experiment described in the previous question?

103. Apply Concepts Ionic compounds are present in items commonly found in your home. Write formulas for the ionic compounds found in the following common household products:

a. antacid (calcium carbonate and magnesium hydroxide)
b. toothpaste for sensitive teeth (sodium fluoride and potassium nitrate)
c. sunscreen (titanium(IV) oxide and zinc oxide)
d. pasta (ferrous sulfate)

104. Use Models In the models below, chlorine is green; phosphorus is orange; carbon is black; and sulfur is yellow. Write the formula and the name for each compound. Are these compounds ionic or molecular compounds?



Enrichment

105. Organize Data *CRC Handbook of Chemistry and Physics* is a reference book that contains a wealth of information about elements and compounds. Two sections of this book that you might use are called "Physical Constants of Inorganic Compounds" and "Physical Constants of Organic Compounds." To familiarize yourself with this work, make a table with these headings: Name, Formula, Crystalline Form or Color, Density, Melting Point (°C), Boiling Point (°C), and Solubility in Water.

Name	Formula	Crystalline Form or Color	Density	MP (°C)	BP (°C)

Enter these substances in the body of the table: ammonium chloride, barium, barium sulfate, bromine, calcium carbonate, chlorine, copper(II) sulfate pentahydrate, iodine, iron(II) sulfate pentahydrate, mercury, potassium carbonate, and sulfur. Use the handbook to complete the table.

***106. Analyze Data** Use the table you prepared for Problem 105 to answer the following questions:

- **a.** You have two unlabeled bottles, each containing a white powder. One of the substances is calcium carbonate, and the other is potassium carbonate. How could you distinguish between these two compounds?
- **b.** How would you distinguish between samples of copper(II) sulfate pentahydrate and iron(II) sulfate pentahydrate?
- **c.** A bottle contains a mixture of ammonium chloride and barium sulfate. How could you separate these two compounds?
- **d.** List the elements in the table in order of increasing density. Identify the elements as metals or nonmetals.
- **e.** List the compounds in the table in order of decreasing density.
- **f.** Calculate the mass of 47.0 cm^3 of mercury.
- **g.** Calculate the volume of 16.6 g of sulfur.
- **h.** How would you distinguish among the Group 7A elements listed in the table?

Write About Science

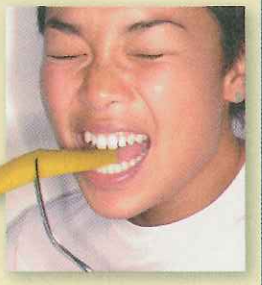
107. Research a Problem Sodium ions (Na^+) and potassium ions (K^+) are needed for the human body to function. Deficiencies in these ions can have adverse effects on your health. Research where these ions are most likely to be found in the body and the roles they play. Write a brief essay describing your findings.

108. Explain 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.

109. Connect to the BIGIDEA Choose five personal care products from your home. Read each ingredient label and identify all the compounds that you are able to decipher. Write a short paragraph in which you explain how learning to name chemical compounds has helped you decipher these ingredient labels.

CHEMYSTERY

Cucumber Blunder



Tara called her grandmother to find out what she did wrong. She started to describe what she had done. When Tara mentioned squeezing limes, her grandmother interrupted and explained: lime, in this case, meant pickling lime, not the citrus fruit. "Pickling lime? I've never heard of that!" Tara exclaimed.

Her grandmother fetched a package of pickling lime from the cupboard to look at the ingredient label. She read aloud "food-grade calcium hydroxide." Her grandmother elaborated, "That's what makes the pickles crunchy like you like 'em."

110. Compare Lime is the common name for calcium hydroxide. What are the advantages and disadvantages of each name?

***111. Connect to the BIGIDEA** Is calcium hydroxide an ionic or a molecular compound? Write the formula.

Cumulative Review

112. List five properties of the chair you are sitting on. Classify each as physical or chemical.

***113.** How many significant figures are in the following measurements?

a. 15.05 g
b. 0.31 cm
c. 890 mL
d. 300.0 cm^3
e. 3.0×10^5 kg
f. 0.001 mm

114. Determine the sum of the following measurements to the correct number of significant figures.

$$1.55 \text{ cm} + 0.235 \text{ cm} + 3.4 \text{ cm}$$

115. Make the following conversions:

a. 775 mL to microliters (μL)
b. 65°C to K
c. 8.32 mg Ag to centigrams of silver (cg Ag)

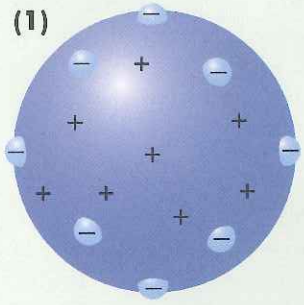
116. A student finds that 6.62 g of a substance occupies a volume of 12.3 cm^3. What is the density of the substance?

117. Compare neutrons and protons with respect to their charge, mass, and position in the atom.

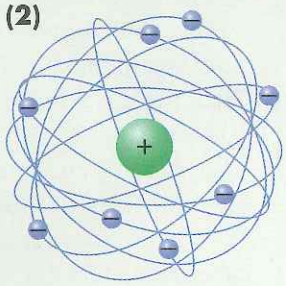
***118.** The diagrams show two models of the atom.

a. Which model is more accurate?
b. What do the positively charged particles represent?
c. What do the negatively charged particles represent?
d. What major subatomic particle is missing in both of these models?

(1)



(2)



***119.** What elements have these electron configurations?

a. $1s^2 2s^2 2p^6$
b. $1s^2 2s^2 2p^2$
c. $1s^2 2s^2 2p^1$
d. $1s^2$

120. Where are the metalloids found on the periodic table? Compare the properties of the metalloids to metals and nonmetals.

121. Arrange the following groups of elements in order of increasing ionization energy.

a. potassium, cesium, lithium, sodium
b. fluorine, boron, lithium, carbon, neon

122. From the positions of the elements in the periodic table, choose the element in each pair with the higher electronegativity.

a. Cs and Li
b. Sr and I
c. S and Mg
d. O and Se
e. Te and N
f. C and F

123. The ions of the elements of Groups 1A and 2A have smaller radii than their neutral atoms, whereas the ions of Group 7A have larger radii than their neutral atoms. Explain.

***124.** How many valence electrons do atoms of the following elements have?

a. lithium
b. sulfur
c. neon
d. calcium
e. bromine
f. phosphorus

125. Write the electron configuration for the element neon, then identify three ions that have the same electron configuration.

126. How many protons and electrons are in each ion?

a. magnesium ion
b. bromide ion
c. strontium ion
d. sulfide ion

***127.** Which of these compounds would you expect to contain covalent bonds? Why?

a. KCl
b. PBr_3
c. ClBr
d. NaI

128. Which of these substances would you expect to be polar?

a. Cl_2
b. CO
c. CO_2
d. NH_3
e. CCl_4
f. H_2O
g. CH_4

129. Draw electron dot structures for the substances in Question 128.

130. Explain what a hydrogen bond is and under what conditions a hydrogen bond will form.

131. Explain the difference between an ionic bond and a covalent bond. Use electron dot structures to illustrate your explanation.

If You Have Trouble With . . .

Question	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131
See Chapter	2	3	3	3	3	4	5	5	6	6	6	6	7	7	7	8	8	8	8	8

Standardized Test Prep

Select the choice that best answers each question or completes each statement.

1. Identify the pair in which the formula does not match the name.
   (A) sulfite, SO_3^{2-} (C) hydroxide, OH^-
   (B) nitrite, NO_3^- (D) dichromate, $Cr_2O_7^{2-}$
2. Which of these compounds are ionic?
   I. $CaSO_4$ II. N_2O_4 III. NH_4NO_3 IV. CaS
   (A) I and II only (C) III and IV only
   (B) II and III only (D) I, III, and IV only
3. What is the name of $AlCl_3$?
   (A) aluminum trichloride
   (B) aluminum(III) chloride
   (C) aluminum chlorite
   (D) aluminum chloride
4. The Roman numeral in manganese(IV) sulfide indicates the
   (A) group number on the periodic table.
   (B) positive charge on the manganese ion.
   (C) number of manganese ions in the formula.
   (D) number of sulfide ions needed in the formula.

Tips for Success

Eliminate Wrong Answers If you don't know which choice is correct, start by eliminating those you know are wrong. If you can rule out some choices, you'll increase your chances of choosing the correct answer.

5. Which of these statements does not describe every binary molecular compound?
   (A) Molecules of binary molecular compounds are composed of two atoms.
   (B) The names of binary molecular compounds contain prefixes.
   (C) The names of binary molecular compounds end in the suffix *-ide*.
   (D) Binary molecular compounds are composed of two nonmetals.
6. What is the formula of ammonium carbonate?
   (A) NH_4CO_3 (C) NH_3CO_4
   (B) $(NH_4)_2CO_3$ (D) NH_4CO_2

The lettered choices below refer to Questions 7–10.

(A) QR (B) QR_2 (C) Q_2R (D) Q_2R_3

Which formula shows the correct ratio of ions in the compound formed by each pair of elements?

	Element Q	Element R
7.	aluminum	sulfur
8.	potassium	oxygen
9.	lithium	chlorine
10.	strontium	bromine

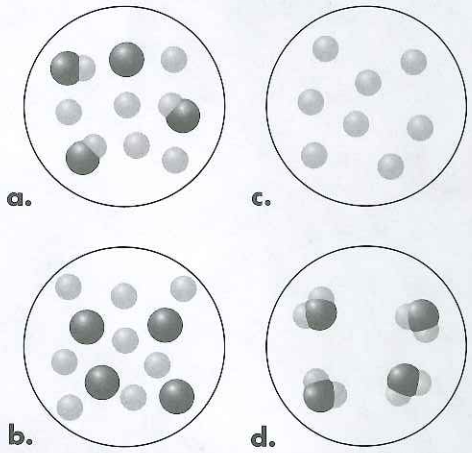
Use the data table to answer Questions 11–12. The table gives formulas for some of the ionic compounds formed when cations (M, N, P) combine with anions (A, B, C, D).

Cation	Anion			
	A	B	C	D
M	MA_2	(1)	(2)	MD
N	(3)	N_2B	(4)	(5)
P	PA_3	(6)	PC	$P_2(D)_3$

11. Use the given formulas to determine the ionic charge of each cation and anion.
12. Write formulas for compounds (1) through (6).

Use the atomic windows to answer Question 13.

13. Classify the contents as elements only, compounds only, or elements and compounds.



If You Have Trouble With . . .													
Question	1	2	3	4	5	6	7	8	9	10	11	12	13
See Lesson	9.1	9.2	9.2	9.2	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2