Focus Questions — Sections 4.1–4.3

1. Why is a system for naming compounds necessary?
2. How can you tell if a substance is a binary compound?
3. How are the anions in all types of binary compounds similar?
4. How are the cations different in each type of binary compound?
5. Use Figure 4.1 to name the following compounds:

a. KBr	d. CuBr
b. SnF_2	e. MgI_2
c. CO	f. PCl_3

4.4 Naming Compounds That Contain Polyatomic Ions

Objective: *To learn the names of common polyatomic ions and how to use them in naming compounds.*

CHEMISTRY
Ionic compounds containing polyatomic ions are not binary compounds, because they contain more than two elements.

A type of ionic compound that we have not yet considered is exemplified by ammonium nitrate, NH_4NO_3, which contains the **polyatomic ions** NH_4^+ and NO_3^-. As their name suggests, polyatomic ions are charged entities composed of several atoms bound together. Polyatomic ions are assigned special names that you *must memorize* to name the compounds containing them. The most important polyatomic ions and their names are listed in **Table 4.4.**

Note in Table 4.4 that several series of polyatomic anions exist that contain an atom of a given element and different numbers of oxygen atoms. These anions are called **oxyanions.** When there are two members in such a series, the name of the one with the smaller number of oxygen atoms ends

CHEMISTRY
The names and charges of polyatomic ions must be memorized. They are an important part of the vocabulary of chemistry.

TABLE 4.4
Names of Common Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	CO_3^{2-}	carbonate
NO_2^-	nitrite	HCO_3^-	hydrogen carbonate (bicarbonate is a widely used common name)
NO_3^-	nitrate		
SO_3^{2-}	sulfite		
SO_4^{2-}	sulfate	ClO^-	hypochlorite
HSO_4^-	hydrogen sulfate (bisulfate is a widely used common name)	ClO_2^-	chlorite
		ClO_3^-	chlorate
		ClO_4^-	perchlorate
OH^-	hydroxide	$C_2H_3O_2^-$	acetate
CN^-	cyanide	MnO_4^-	permanganate
PO_4^{3-}	phosphate	$Cr_2O_7^{2-}$	dichromate
HPO_4^{2-}	hydrogen phosphate	CrO_4^{2-}	chromate
$H_2PO_4^-$	dihydrogen phosphate	O_2^{2-}	peroxide

in *-ite*, and the name of the one with the larger number ends in *-ate*. For example, SO_3^{2-} is sulfite and SO_4^{2-} is sulfate. When more than two oxyanions make up a series, *hypo-* (less than) and *per-* (more than) are used as prefixes to name the members of the series with the fewest and the most oxygen atoms, respectively. The best example involves the oxyanions containing chlorine:

CHEMISTRY
Note that the SO_3^{2-} anion has very different properties from SO_3 (sulfur trioxide), a pungent, toxic gas.

ClO^-	*hypo*chlor*ite*
ClO_2^-	chlor*ite*
ClO_3^-	chlor*ate*
ClO_4^-	*per*chlor*ate*

Naming ionic compounds that contain polyatomic ions is very similar to naming binary ionic compounds. For example, the compound NaOH is called sodium hydroxide, because it contains the Na^+ (sodium) cation and the OH^- (hydroxide) anion. To name these compounds, *you must learn to recognize the common polyatomic ions*. That is, you must learn the *composition* and *charge* of each of the ions in Table 4.4. Then when you see the formula $NH_4C_2H_3O_2$, you should immediately recognize its two "parts":

CHEMISTRY
Except for hydroxide, peroxide, and cyanide, the names of polyatomic ions do not have an *-ide* ending.

$$\boxed{NH_4 \backslash C_2H_3O_2}$$
$$\uparrow \qquad \uparrow$$
$$NH_4^+ \qquad C_2H_3O_2^-$$

The correct name is ammonium acetate.

When a metal is present that forms more than one cation, a Roman numeral is required to specify the cation charge, just as in naming Type II binary ionic compounds. For example, the compound $FeSO_4$ is called iron(II) sulfate, because it contains Fe^{2+} (to balance the 2^- charge on SO_4^{2-}). Note that to determine the charge on the iron cation, you must know that sulfate has a 2^- charge.

CHEMISTRY
Certain transition metals form only one ion. Common examples are zinc (forms only Zn^{2+}) and silver (forms only Ag^+). For these cases the Roman numeral is omitted from the name.

Example 4.7

Naming Compounds That Contain Polyatomic Ions

Give the systematic name of each of the following compounds.

a. Na_2SO_4 **c.** $Fe(NO_3)_3$ **e.** Na_2SO_3
b. KH_2PO_4 **d.** $Mn(OH)_2$

Solution

Compound	*Ions Present*	*Ion Names*	*Compound Name*
a. Na_2SO_4	two Na^+ SO_4^{2-}	sodium sulfate	sodium sulfate
b. KH_2PO_4	K^+ $H_2PO_4^-$	potassium dihydrogen phosphate	potassium dihydrogen phosphate
c. $Fe(NO_3)_3$	Fe^{3+} three NO_3^-	iron(III) nitrate	iron(III) nitrate

(continued)

(continued)

d. $Mn(OH)_2$	Mn^{2+} two OH^-	manganese(II) hydroxide	manganese(II) hydroxide
e. Na_2SO_3	two Na^+ SO_3^{2-}	sodium sulfite	sodium sulfite

Self-Check Exercise 4.6

Name each of the following compounds.

a. $Ca(OH)_2$
b. Na_3PO_4
c. $KMnO_4$
d. $(NH_4)_2Cr_2O_7$
e. $Co(ClO_4)_2$
f. $KClO_3$
g. $Cu(NO_2)_2$

Example 4.7 illustrates that when more than one polyatomic ion appears in a chemical formula, parentheses are used to enclose the ion and a subscript is written after the closing parenthesis. Other examples are $(NH_4)_2SO_4$ and $Fe_3(PO_4)_2$.

In naming chemical compounds, use the strategy summarized in **Figure 4.2.** If the compound being considered is binary, use the procedure summarized in Figure 4.1. If the compound has more than two elements, ask yourself whether it has any polyatomic ions. Use Table 4.4 to help you recognize these ions until you have committed them to memory. If a polyatomic ion is present, name the compound using procedures very similar to those for naming binary ionic compounds.

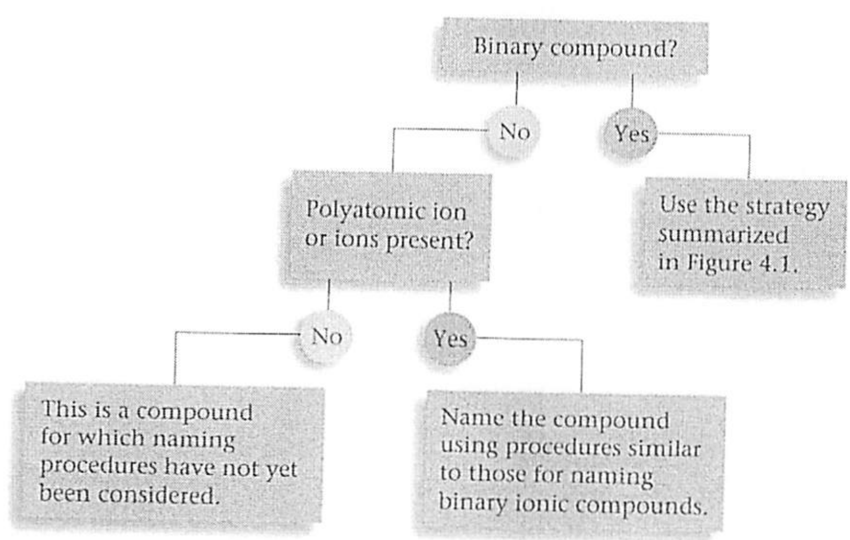


Figure 4.2
Overall strategy for naming chemical compounds.

Example 4.8

Summary of Naming Binary Compounds and Compounds That Contain Polyatomic Ions

Name the following compounds.

a. Na_2CO_3	**d.** PCl_3	**e.** $CuSO_4$
b. $FeBr_3$	**c.** $CsClO_4$	

Solution

Compound	*Name*	*Comments*
a. Na_2CO_3	sodium carbonate	Contains $2Na^+$ and CO_3^{2-}.
b. $FeBr_3$	iron(III) bromide	Contains Fe^{3+} and $3Br^-$.
c. $CsClO_4$	cesium perchlorate	Contains Cs^+ and ClO_4^-.
d. PCl_3	phosphorus trichloride	Type III binary compound (both P and Cl are nonmetals).
e. $CuSO_4$	copper(II) sulfate	Contains Cu^{2+} and SO_4^{2-}.

Self-Check Exercise 4.7

Name the following compounds.

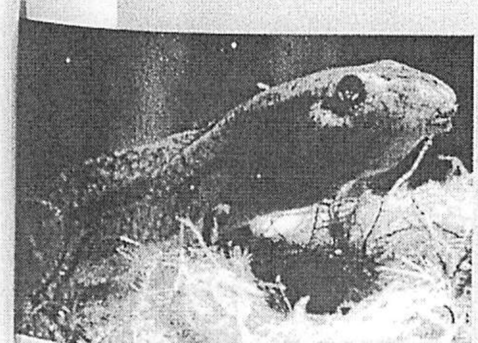
a. $NaHCO_3$	**c.** $CsClO_4$	**e.** NaBr	**g.** $Zn_3(PO_4)_2$
b. $BaSO_4$	**d.** BrF_5	**f.** KOCl	

CHEMICAL IMPACT

Connection to Biology

Talking Tadpoles

It is well known that animals communicate by releasing chemicals that others of the same species receive and "understand." For example, ants use chemicals to signal news about food supplies and danger from predators, and honeybees "recognize" other bees from the same hive by their chemical signals. Now scientists at Yale University have shown that tadpoles send chemical signals to one another.



A California red-legged frog tadpole.

The experiment involved two groups of tadpoles of red-legged frogs. They were placed in an aquarium partitioned by a screen that allowed water to flow but blocked communications by sight and sound. When a wooden heron (a bird that preys on tadpoles) threatened the tadpoles in the one compartment, those on the other side moved away from the partition and ducked under a shelter. The researchers concluded that the frightened tadpoles signaled their fear to the tadpoles in other compartment by releasing a chemical signal that flowed to the other side in the water.

Other water-dwelling animals such as crayfish, hermit crabs, and a fish called the Iowa darter also have been observed to send chemical danger signals when they are threatened. Scientists think that the chemical used to send the signal is the ammonium ion, NH_4^+. Researchers are now trying to find out whether all aquatic species have a common chemical "language" to signal one another, just as ants and bees do.