

CHAPTER 6 The Structure of Matter

SECTION

3

Compound Names and Formulas

KEY IDEAS

As you read this section, keep these questions in mind:

- What are the rules for naming ionic compounds?
- What are the rules for naming covalent compounds?
- How can you determine an empirical formula?

Why Do We Name Compounds?

Compounds have names that distinguish them from other compounds. In general, the name of a compound comes from the elements that form it.

How Are Ionic Compounds Named?

Ionic compounds are formed by the strong attraction between two oppositely charged ions: cations (positive ions) and anions (negative ions). The name of an ionic compound identifies the cation first and the anion second.

CATION NAMES

In many cases, a cation name is the same as the element name. For example, when an atom of the element sodium loses an electron, the sodium ion, Na^+ , forms. ✓

Recall that you can use the periodic table to help you determine which ions are formed by different elements. For example, Group 1 elements form cations with 1+ charges.

Some Common Cations

| Ion name and symbol | Ion charge |
|---------------------------------|------------|
| Lithium ion, Li^+ | 1+ |
| Potassium ion, K^+ | |
| Sodium ion, Na^+ | |
| Calcium ion, Ca^{2+} | 2+ |
| Magnesium ion, Mg^{2+} | |
| Aluminum ion, Al^{3+} | 3+ |

ANION NAMES

The name of an anion typically ends in *-ide*. Like most cations, anions of elements in the same group of the periodic table have the same charge. ✓

READING TOOLBOX

Summarize As you read this section, make a T-chart that lists the rules for naming ionic compounds and covalent compounds.

**READING CHECK**

1. Explain In general, how is the name of a cation related to the name of the element?

**READING CHECK**

2. Describe How is the name of an anion different from the name of the element?

SECTION 3 Compound Names and Formulas *continued***LOOKING CLOSER**

3. Identify What is the charge of a chloride ion?

| Some Common Anions | | |
|--------------------|-------------------------------|------------|
| Element | Ion | Ion charge |
| Fluorine, F | fluoride ion, F ⁻ | 1- |
| Chlorine, Cl | chloride ion, Cl ⁻ | |
| Bromine, Br | bromide ion, Br ⁻ | |
| Iodine, I | iodide ion, I ⁻ | |
| Oxygen, O | oxide ion, O ²⁻ | 2- |
| Sulfur, S | sulfide ion, S ²⁻ | |
| Nitrogen, N | nitride ion, N ³⁻ | 3- |

TOTAL CHARGE OF IONIC COMPOUNDS

The sum of the charges of all of the ions in a compound must add up to zero. Therefore, if an ionic compound has two ions with different charges, the ratio of ions will not be 1:1. For example, calcium fluoride contains calcium ions, Ca²⁺, and fluoride ions, F⁻. For the compound to have a total charge of zero, there must be two fluoride ions for every calcium ion. Thus, the formula for calcium fluoride is CaF₂. ✓

 **READING CHECK**

4. Identify What is the total charge on an ionic compound?

CHARGES OF TRANSITION METALS

Many transition metals can form several cations—each with a different charge. The table below lists some common cations. For example, the compounds FeO and Fe₂O₃ both have iron cations, but the charges of the iron cations are different. If you used the naming rules described so far, you would name both of these iron oxide. However, they are different compounds, so they need different names.

To show the difference between FeO and Fe₂O₃, the charge of the iron cation is included in the name. Roman numerals in parentheses after the cation name show the charge on the cation. The cation in FeO is Fe²⁺, so it is named iron (II) oxide. The cation in Fe₂O₃ is Fe³⁺, so it is named iron (III) oxide. ✓

 **READING CHECK**

5. Explain What do the roman numerals after the cation name of a transition metal represent?

| Some Transition Metal Cations | | | |
|-------------------------------|------------------|-------------------|------------------|
| Ion name | Ion symbol | Ion name | Ion symbol |
| Copper(I) ion | Cu ⁺ | Chromium(II) ion | Cr ²⁺ |
| Copper(II) ion | Cu ²⁺ | Chromium(III) ion | Cr ³⁺ |
| Iron(II) ion | Fe ²⁺ | Cadmium(II) ion | Cd ²⁺ |
| Iron(III) ion | Fe ³⁺ | Titanium(II) ion | Ti ²⁺ |
| Nickel(II) ion | Ni ²⁺ | Titanium(III) ion | Ti ³⁺ |
| Nickel(III) ion | Ni ³⁺ | Titanium(IV) ion | Ti ⁴⁺ |

SECTION 3 Compound Names and Formulas *continued***DETERMINING TRANSITION METAL CHARGES**

How can you tell that the iron ion in Fe_2O_3 has a $3+$ charge? Examine the total charge on the oxide ion. An oxide ion has a $2-$ charge. Thus, three oxide ions have a total charge of $6-$. If the total anion charge is $6-$, the total cation charge must be $6+$. Because there are two Fe ions in Fe_2O_3 , each Fe ion must have a $3+$ charge.

DETERMINING FORMULAS OF IONIC COMPOUNDS

You can find the charge of each ion in a compound if you know the compound's formula. You can find the formula for a compound if you know the compound's name.

What is the chemical formula for aluminum fluoride?

| | | |
|--|---|-------------------------------------|
| Step 1: List the known and unknown values. | Known: aluminum ion: Al^{3+} fluoride ion: F^- | Unknown: chemical formula |
| Step 2: Write the symbols for the ions with the cation first. | $\text{Al}^{3+}, \text{F}^-$ | |
| Step 3: Find the least common multiple of the ions' charges. Write the chemical formula. Use subscripts to show the number of each ion needed to make a neutral compound. | The least common multiple of 3 and 1 is 3. Three positive charges and three negative charges are needed. $(1 \times 3+) = 3+$ Only one Al^{3+} ion is needed. $(3 \times 1-) = 3-$ Three F^- ions are needed. | |

So, the chemical formula for aluminum fluoride is AlF_3 .

How Are Covalent Compounds Named?

The rules for naming covalent compounds are different from those used to name ionic compounds. The names of covalent compounds have prefixes to indicate how many atoms of each element are in the molecule. The table below shows some prefixes used to name covalent compounds. ✓

| Prefixes Used to Name Covalent Compounds | | | |
|---|---------------|------------------------|---------------|
| Number of atoms | Prefix | Number of atoms | Prefix |
| 1 | mono- | 6 | hexa- |
| 2 | di- | 7 | hepta- |
| 3 | tri- | 8 | octa- |
| 4 | tetra- | 9 | nona- |
| 5 | penta- | 10 | deca- |

Critical Thinking

6. Apply Concepts What is the charge on the titanium ion in the compound TiO_2 ?

LOOKING CLOSER

7. Apply Concepts What is the chemical formula for beryllium chloride? Use the steps described in the table to help you.

**READING CHECK**

8. Identify What do the prefixes in the names of covalent compounds tell you?

SECTION 3 Compound Names and Formulas *continued***USING NUMERICAL PREFIXES TO NAME COMPOUNDS**

The element farthest to the left in the periodic table is named first in a compound. If there is only one atom of the first element, its name does not get a prefix. The element farthest to the right in the periodic table is named second. Its name ends in *-ide*. ✓

READING CHECK

9. Identify Which element in a compound is named first?

For example, N_2O_4 has two nitrogen atoms and four oxygen atoms. Nitrogen is farther to the left in the periodic table than oxygen, so it is named first. The name of this compound is dinitrogen tetroxide. The *a* in tetra is dropped to make the name easier to say.

What Are Empirical Formulas?

An **empirical formula** gives the smallest whole-number ratio of atoms in a compound. For example, the empirical formula for water is H_2O . This tells you that the ratio of hydrogen atoms to oxygen atoms is 2:1. For most ionic compounds, the empirical formula is the same as the chemical formula. However, for many covalent compounds, the empirical and chemical formulas are different.

One mole of a compound contains 62 g of phosphorus and 80 g of oxygen. What is the empirical formula of this compound?

Math Skills

10. Calculate A sample of a compound contains 160 g of oxygen and 20.2 g of hydrogen. What is the compound's empirical formula?

| | | |
|---|---|--------------------------------------|
| Step 1: List the given and unknown values. | Given: Mass, <i>m</i> of phosphorus: 62 g Mass, <i>m</i> of oxygen: 80 g | Unknown: empirical formula |
| Step 2: Write the atomic masses. | phosphorus: 30.97 g/mol oxygen: 16.00 g/mol | |
| Step 3: Write the molar ratio of the elements. The molar ratio of elements in the compound will be the compound's empirical formula. | $\frac{62 \text{ g P} \times 1 \text{ mol P}}{30.97 \text{ g P}} = 2.0 \text{ mol P}$ $\frac{80 \text{ g O} \times 1 \text{ mol O}}{16.00 \text{ g O}} = 5.0 \text{ mol O}$ | |

So, the empirical formula of the compound is P_2O_5 .

SECTION 3 Compound Names and Formulas *continued***THE SAME EMPIRICAL FORMULA**

Empirical formulas only show the ratio of atoms in a compound. They do not show the actual number of atoms of each element that is in the compound. So, it is possible for two different compounds to have the same empirical formula. ✓

For example, formaldehyde, acetic acid, and glucose all have the empirical formula CH_2O . That is, the ratio of the atoms in each of the compounds is 1:2:1. However, these three compounds are very different from one another. Formaldehyde is used to preserve dead organisms. Acetic acid gives vinegar its sour taste. Glucose is a sugar that your body uses for energy.

MOLECULAR FORMULAS

A **molecular formula** tells you how many atoms are in one molecule of the compound. You can use the empirical formula of a compound and its molar mass to find its molecular formula.

| Compound | Empirical formula | Molar mass (g/mol) | Molecular formula | Structure |
|--------------|-----------------------|--------------------|---|-----------|
| Formaldehyde | CH_2O | 30.03 | CH_2O | |
| Acetic acid | CH_2O | 60.06 | $2 \times \text{CH}_2\text{O}$ $= \text{C}_2\text{H}_4\text{O}_2$ | |
| Glucose | CH_2O | 180.2 | $6 \times \text{CH}_2\text{O}$ $= \text{C}_6\text{H}_{12}\text{O}_6$ | |

READING CHECK

11. Explain Why is it possible for different compounds to have the same empirical formulas?

Critical Thinking

12. Predict A particular compound has the empirical formula CH_2O . Its molar mass is 240.0 g/mol. Predict the molecular formula for this compound.

Section 3 Review

SECTION VOCABULARY

empirical formula a chemical formula that shows the composition of a compound in terms of the relative numbers and kinds of atoms in the simplest ratio

molecular formula a chemical formula that shows the number and kinds of atoms in a molecule, but not the arrangement of the atoms

1. Identify Complete the table below to identify and name several ionic compounds.

| Chemical Formula | Chemical Name | Cation | Anion |
|------------------|---------------------|------------------|-----------------|
| CaBr_2 | | | |
| | Nickel(II) oxide | | |
| | Cadmium(II) nitride | Cd^{2+} | N^{3-} |

2. Identify Complete the table below to identify and name several covalent compounds.

| Chemical Formula | Chemical Name |
|---------------------------|---------------------|
| SiI_4 | |
| | Dinitrogen monoxide |
| P_4O_{10} | |

3. Explain What is the charge of the cadmium ion in cadmium bromide, CdBr_2 ? Explain your answer.

4. Calculate One mole of an unknown sample contains 120 g of carbon and 30.3 g of hydrogen. What is the empirical formula of the compound? Show your work.

5. Compare How does a molecular formula differ from an empirical formula?
