# 7.4: Covalent Compounds - Names and Formulas

**Learning Objectives**

- Derive names for common types of inorganic compounds using a systematic approach

The bonding characteristics of inorganic molecular compounds are different from ionic compounds, and they are named using a different system as well. The charges of cations and anions dictate their ratios in ionic compounds, so specifying the names of the ions provides sufficient information to determine chemical formulas. However, because covalent bonding allows for significant variation in the combination ratios of the atoms in a molecule, the names for molecular compounds must explicitly identify these ratios.

## Compounds Composed of Two Elements

When two nonmetallic elements form a molecular compound, several combination ratios are often possible. For example, carbon and oxygen can form the compounds CO and $CO_2$. Since these are different substances with different properties, they cannot both have the same name (they cannot both be called carbon oxide). To deal with this situation, we use a naming method that is somewhat similar to that used for ionic compounds, but with added prefixes to specify the numbers of atoms of each element. The name of the more metallic element (the one farther to the left and/or bottom of the periodic table) is first, followed by the name of the more nonmetallic element (the one farther to the right and/or top) with its ending changed to the suffix *–ide*. The numbers of atoms of each element are designated by the Greek prefixes shown in Table 7.4.3.

Table 7.4.3: Nomenclature Prefixes

| Number | Prefix | Number | Prefix |
|---|---|---|---|
| 1 (sometimes omitted) | mono- | 6 | hexa- |
| 2 | di- | 7 | hepta- |

| Number | Prefix | Number | Prefix |
|---|---|---|---|
| 3 | tri- | 8 | octa- |
| 4 | tetra- | 9 | nona- |
| 5 | penta- | 10 | deca- |

When only one atom of the first element is present, the prefix *mono-* is usually deleted from that part. Thus, CO is named carbon monoxide, and $CO_2$ is called carbon dioxide. When two vowels are adjacent, the *a* in the Greek prefix is usually dropped. Some other examples are shown in Table 7.4.4.

Table 7.4.4: Names of Some Molecular Compounds Composed of Two Elements

| Compound | Name | Compound | Name |
|---|---|---|---|
| $SO_2$ | sulfur dioxide | $BCl_3$ | boron trichloride |

| Compound | Name | Compound | Name |
|---|---|---|---|
| $SO_3$ | sulfur trioxide | $SF_6$ | sulfur hexafluoride |
| $NO_2$ | nitrogen dioxide | $PF_5$ | phosphorus pentafluoride |

| Compound | Name | | Compound | Name |
|---|---|---|---|---|
| $N_2O_4$ | dinitrogen tetroxide | | $P_4O_{10}$ | tetraphosphorus decaoxide |
| $N_2O_5$ | dinitrogen pentoxide | | $IF_7$ | iodine heptafluoride |

There are a few common names that you will encounter as you continue your study of chemistry. For example, although NO is often called nitric oxide, its proper name is nitrogen monoxide. Similarly, $N_2O$ is known as nitrous oxide even though our rules would specify the name dinitrogen monoxide. (And $H_2O$ is usually called water, not dihydrogen monoxide.) You should commit to memory the common names of compounds as you encounter them.

### Naming Covalent Compounds

Name the following covalent compounds:

a. $SF_6$
b. $N_2O_3$
c. $Cl_2O_7$
d. $P_4O_6$

**Solution**

Because these compounds consist solely of nonmetals, we use prefixes to designate the number of atoms of each element:

a. sulfur hexafluoride
b. dinitrogen trioxide
c. dichlorine heptoxide
d. tetraphosphorus hexoxide

### Exercise 7.4.2

Write the formulas for the following compounds:

a. phosphorus pentachloride
b. dinitrogen monoxide
c. iodine heptafluoride
d. carbon tetrachloride

*Answer:*

*(a) $PCl_5$; (b) $N_2O$; (c) $IF_7$; (d) $CCl_4$*

## Binary Acids

Some compounds containing hydrogen are members of an important class of substances known as acids. The chemistry of these compounds is explored in more detail in later chapters of this text, but for now, it will suffice to note that many acids release hydrogen ions, $H^+$, when dissolved in water. To denote this distinct chemical property, a mixture of water with an acid is given a name derived from the compound's name. If the compound is a binary acid (comprised of hydrogen and one other nonmetallic element):

1. The word "hydrogen" is changed to the prefix *hydro-*
2. The other nonmetallic element name is modified by adding the suffix *-ic*
3. The word "acid" is added as a second word

For example, when the gas HCl (hydrogen chloride) is dissolved in water, the solution is called *hydrochloric acid*. Several other examples of this nomenclature are shown in Table 7.4.5.

Table 7.4.5: Names of Some Simple Acids

| Name of Gas | Name of Acid |
|---|---|
| HF(*g*), hydrogen fluoride | HF(*aq*), hydrofluoric acid |
| HCl(*g*), hydrogen chloride | HCl(*aq*), hydrochloric acid |
| HBr(*g*), hydrogen bromide | HBr(*aq*), hydrobromic acid |
| HI(*g*), hydrogen iodide | HI(*aq*), hydroiodic acid |
| $H_2S$(*g*), hydrogen sulfide | $H_2S$(*aq*), hydrosulfuric acid |

## Oxyacids

Many compounds containing three or more elements (such as organic compounds or coordination compounds) are subject to specialized nomenclature rules that you will learn later. However, we will briefly discuss the important compounds known as

oxyacids, compounds that contain hydrogen, oxygen, and at least one other element, and are bonded in such a way as to impart acidic properties to the compound (you will learn the details of this in a later chapter). Typical oxyacids consist of hydrogen combined with a polyatomic, oxygen-containing ion. To name oxyacids:

1. Omit “hydrogen”
2. Start with the root name of the anion
3. Replace *–ate* with *–ic*, or *–ite* with *–ous*
4. Add “acid”

For example, consider $H_2CO_3$ (which you might be tempted to call “hydrogen carbonate”). To name this correctly, “hydrogen” is omitted; the *–ate* of carbonate is replace with *–ic*; and acid is added—so its name is carbonic acid. Other examples are given in Table 7.4.6. There are some exceptions to the general naming method (e.g., $H_2SO_4$ is called sulfuric acid, not sulfic acid, and $H_2SO_3$ is sulfurous, not sulfous, acid).

Table 7.4.6: Names of Common Oxyacids

| Formula | Anion Name | Acid Name |
|---|---|---|
| $HC_2H_3O_2$ | acetate | acetic acid |
| $HNO_3$ | nitrate | nitric acid |
| $HNO_2$ | nitrite | nitrous acid |
| $HClO_4$ | perchlorate | perchloric acid |
| $H_2CO_3$ | carbonate | carbonic acid |
| $H_2SO_4$ | sulfate | sulfuric acid |
| $H_2SO_3$ | sulfite | sulfurous acid |
| $H_3PO_4$ | phosphate | phosphoric acid |

## Summary

Chemists use nomenclature rules to clearly name compounds. Ionic and molecular compounds are named using somewhat-different methods. Binary ionic compounds typically consist of a metal and a nonmetal. The name of the metal is written first, followed by the name of the nonmetal with its ending changed to *–ide*. For example, $K_2O$ is called potassium oxide. If the metal can form ions with different charges, a Roman numeral in parentheses follows the name of the metal to specify its charge. Thus, $FeCl_2$ is iron(II) chloride and $FeCl_3$ is iron(III) chloride. Some compounds contain polyatomic ions; the names of common polyatomic ions should be memorized. Molecular compounds can form compounds with different ratios of their elements, so prefixes are used to specify the numbers of atoms of each element in a molecule of the compound. Examples include $SF_6$, sulfur hexafluoride, and $N_2O_4$, dinitrogen tetroxide. Acids are an important class of compounds containing hydrogen and having special nomenclature rules. Binary acids are named using the prefix *hydro-*, changing the *–ide* suffix to *–ic*, and adding “acid;” HCl is hydrochloric acid. Oxyacids are named by changing the ending of the anion to *–ic*, and adding “acid;” $H_2CO_3$ is carbonic acid.

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