5.8: Binary Molecular Compounds

Learning Objectives

- Determine the name of a simple molecular compound from its chemical formula.

Molecular Compounds

Molecular compounds are inorganic compounds that take the form of discrete **molecules**. Examples include such familiar substances as water (H_2O) and carbon dioxide (CO_2). These compounds are very different from ionic compounds like sodium chloride (NaCl). Ionic compounds are formed when metal atoms lose one or more of their electrons to nonmetal atoms. The resulting cations and anions are electrostatically attracted to each other.

So what holds the atoms of a molecule together? Rather than forming ions, the atoms of a molecule **share** their electrons in such a way that a **bond** forms between a pair of atoms. In a carbon dioxide molecule, there are two of these bonds, each occurring between the carbon atom and one of the two oxygen atoms.

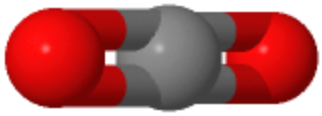

Figure 5.8.1: Carbon dioxide molecules consist of a central carbon atom bonded to 2 oxygen atoms.

Larger molecules can have many, many bonds that serve to hold the molecule together. In a large sample of a given molecular compound, all of the individual molecules are identical.

Naming Binary Molecular Compounds

Recall that a molecular formula shows the number of atoms of each element that a molecule contains. A molecule of water contains two hydrogen atoms and one oxygen atom, so its formula is H_2O. A molecule of octane, which is a component of gasoline, contains 8 atoms of carbon and 18 atoms of hydrogen. The molecular formula of octane is C_8H_{18}.

Figure 5.8.2: Nitrogen dioxide (NO_2) is a reddish-brown toxic gas and a prominent air pollutant produced by internal combustion engines.

Naming binary molecular compounds is similar to naming binary ionic compounds. The convention for naming binary molecular compounds:

- The first element in the formula retains its name.
- The second element retains its root name followed by a suffix of *-ide*.
- Greek prefixes (see Table 5.8.1) are added to each name* to indicate the number of atoms of each element present in the formula.

Table 5.8.1: Greek Prefixes for Naming Binary Molecular Compounds

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

*The prefix *mono-* is not used for the first element's name.

Note

- Generally, the element that is above and/or to the left in the Periodic Table is written first in the formula, though there are a few exceptions. The order of common nonmetals in formulas of binary molecular compounds:
  - C, P, N, H, S, I, Br, Cl, O, F
- An *a* or *o* at the end of a prefix is dropped when it precedes oxide. Examples:
  - carbon monoxide (rather than carbon monooxide)
  - dinitrogen pentoxide (rather than dinitrogen pentaoxide)
- The prefix is *mono-* is usually not added to the first element's name even if there is only one atom of the first element in a formula.

Some examples of molecular compounds are listed in Table 5.8.2.

Table 5.8.2: Examples of Molecular Compounds

Formula	Name
NO	nitrogen monoxide
N_2O	dinitrogen monoxide
S_2Cl_2	disulfur dichloride
Cl_2O_7	dichlorine heptoxide

Notice that the *mono-* prefix is not used with the nitrogen in the first compound, but is used with the oxygen in both of the first two examples. The formula S_2Cl_2 emphasizes that formulas for molecular compounds are not reduced to their lowest ratios. The *o* of the *mono-* and the *a* of *hepta-* are dropped from the name when paired with oxide.

✅ Example 5.8.1: Writing Chemical Names

Write the name for each compound.

A. ClF_3
B. P_2F_4
C. $BaBr_2$

Solution

A. Cl = chlorine. F = fluorine. The root name of fluorine is *fluor-*. The second element has a suffix of *-ide*. Cl does not need a prefix, since the formula shows one atom. The prefix that means "3" is *tri-*. ClF_3 is chlorine trifluoride.

B. P = phosphorus. F = fluorine. The root name of fluorine is *fluor-*. The second element has a suffix of *-ide*. The prefix that means 2 is *di-*. The prefix that means "4" is *tetra-*. P_2F_4 is diphosphorus tetrafluoride.

C. Be careful. $BaBr_2$ is a binary *ionic* compound. Rules for naming binary ionic compound were discussed in Section 5.5. Greek prefixes are *not* used for binary ionic compounds. Ba = barium. Br = bromine. The root name of bromine is *brom-*. The nonmetal has a suffix of *-ide*. $BaBr_2$ is barium bromide.

✅ Example 5.8.2: Writing Chemical Formulas

Write the chemical formula for each compound.

A. sulfur hexafluoride
B. dinitrogen pentoxide
C. aluminum oxide

Solution

Writing formulas for binary molecular compounds is simple. The prefixes tell exactly how many atoms of each element are present in one molecule. There is no need to look up charges based on the position in the periodic table. Nonmetals bond to each other with covalent bonds, where electrons are shared rather than transferred.

A. S = sulfur. F = fluorine. S has no prefix, so there is only one atom. The prefix *hexa-* means "6". Sulfur hexafluoride is SF_6.

B. N = nitrogen. O = oxygen. The prefix *di-* means "2". The prefix *pent-* means "5" (*a* is left off when paired with oxide). Dinitrogen pentoxide is N_2O_5.

C. Be careful. Aluminum oxide is a binary *ionic* compound. Rules for writing formulas for binary ionic compound were discussed in Section 5.5. Greek prefixes are *not* used for binary ionic compounds. The charge on an aluminum ion is 3+,

Al^{3+}. The charge on an oxide ion is 2–, O^{2-}. Charge is balanced with two Al^{3+} and three O^{2-}. Aluminum oxide is Al_2O_3.

Exercise 5.8.1

If the chemical formula is provided, write the name. If the name is provided, write the formula.

A. CF_4
B. diarsenic pentaiodide
C. SO_3

Answer A

carbon tetrafluoride

Answer B

As_2I_5

Answer C

sulfur trioxide

Simple Molecular Compounds with Common Names

For some simple covalent compounds, we use common names rather than systematic names. We have already encountered these compounds, but we list them here explicitly:

- H_2O: water
- NH_3: ammonia
- CH_4: methane
- H_2O_2: hydrogen peroxide

Methane is the simplest organic compound. Organic compounds are compounds with carbon atoms and are named by a separate nomenclature system.

Some Compounds Have Both Covalent and Ionic Bonds

If you recall the introduction of polyatomic ions, you will remember that the bonds that hold the polyatomic ions together are covalent bonds. Once the polyatomic ion is constructed with covalent bonds, it reacts with other substances as an ion. The bond between a polyatomic ion and another ion will be ionic. An example of this type of situation is in the compound sodium nitrate. Sodium nitrate is composed of a sodium ion and a nitrate ion. The nitrogen atom and oxygen atoms in a nitrate ion are held together by covalent bonds and the nitrate ion is attached to the sodium ion by an ionic bond.

Summary

- A molecular compound is usually composed of two or more nonmetal elements.
- Molecular compounds are named with the first element first and then the second element by using the stem of the element name plus the suffix -ide. Numerical prefixes are used to specify the number of atoms in a molecule.

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