5.3: A Closer Look at Elements and Compounds

Learning Objectives

- Classify substances as atomic elements, molecular elements, molecular compounds, or ionic compounds.

Atomic Elements

Most elements exist with **individual atoms** as their basic unit. It is assumed that there is only one atom in a formula if there is no numerical subscript to the right of a chemical symbol.

Molecular Elements

There are many substances that exist as two or more atoms connected together so strongly that they behave as a single particle. These multi-atom combinations are called **molecules**. A molecule is the smallest part of a substance that retains the physical and chemical properties of that substance. In some respects, a molecule is similar to an atom. A molecule, however, is comprised of two or more atoms.

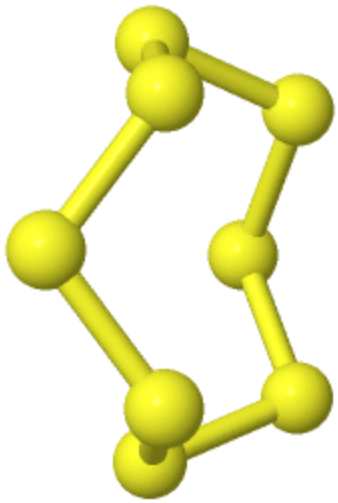
Some elements exist naturally as molecules. For example, hydrogen and oxygen exist as two-atom molecules, called **diatomic molecules**. A complete list of elements that exist naturally as diatomic molecules are shown Table 5.3.1. As with any molecule, these elements are labeled with a **molecular formula**, a formal listing of what and how many atoms are in a single molecule.

Table 5.3.1: Elements That Exist as Diatomic Molecules

Hydrogen	Oxygen	Nitrogen	Chlorine	Bromine	Iodine	Fluorine
H_2	O_2	N_2	Cl_2	Br_2	I_2	F_2

It would be helpful to memorize the elements that exist naturally as diatomic molecules. One way to do this is to use a mnemonic. The elements in Table 5.3.1 were purposefully arranged to provide such a mnemonic. When arranged in this order, the elements H, O, N, Cl, Br, I, F may be pronounced phonetically as HONK-uhl-briff.

Other elements exist as polyatomic molecules. For example, sulfur naturally exists as an eight-atom molecule, S_8, while phosphorus exists as a four-atom molecule, P_4 , as shown in Figure 5.3.1 below.



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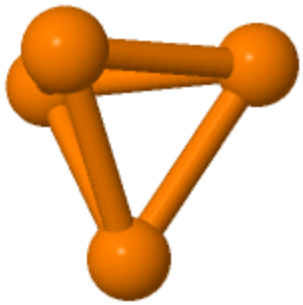

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Figure 5.3.1: Molecular models of S_8 and P_4. (from the PubChem database).

Ionic Compounds

The elements in the periodic table are divided into specific groupings: the metals, the nonmetals, the metalloids, and so on. These groupings are largely based on physical properties and on the tendency of the various elements to bond with other elements by forming either an ionic or a covalent bond. As a general rule of thumb, compounds that involve a metal bonding with either a nonmetal or a metalloid will display ionic bonding.

Figure 5.3.2 shows an atomic level view of sodium chloride. This compound would be expected to be ionic since a metal, Na, is bonded to a nonmetal, Cl. Since the ratio of sodium ions to chloride ions is 1:1, the formula for sodium chloride is NaCl. The basic unit of an ionic compound that retains the identity of the compound is called a **formula unit**. It is incorrect to refer to the basic unit of an ionic compound as a molecule (refer to the section on Molecular Compounds below). One formula unit of NaCl contains one sodium ion and one chloride ion.

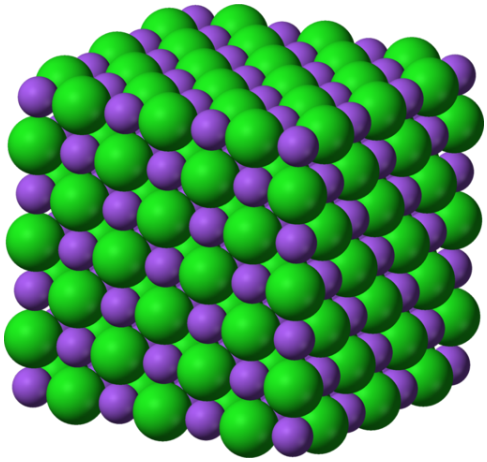

Figure 5.3.2: Atomic level view of sodium chloride, NaCl. (Benjah-bmm27 , Public domain, via Wikimedia Commons)

Molecular Compounds

Compounds that are composed of only nonmetals and/or metalloids with non-metals will display covalent bonding and will be classified as molecular compounds. Examples of molecular compounds include nitrogen monoxide (NO), consisting of two nonmetals covalently bonded together, and silicon dioxide (SiO_2), consisting of a metalloid covalently bonded to a nonmetal. The basic unit of molecular compounds is the **molecule**.

✅ Example 5.3.1

Provide the classification (i.e. atomic element, molecular element, molecular compound, or ionic compound) of each substance.

A. Fe
B. PCl_3
C. LiBr
D. P_4
E. oxygen gas

Solution

A. Fe (iron) is an element that is represented with no subscript, so it is an **atomic element**.
B. PCl_3 is made up of two nonmetals, so it is a **molecular compound**.
C. LiBr is made up of lithium, a metal, and bromine, a nonmetal, so it is an **ionic compound**.
D. P_4 is a substance that is made up of four atoms of the same element, so it is a **molecular element**.
E. The formula for oxygen gas is O_2 so it is a **molecular element**.

Exercise 5.3.1

Provide the classification (i.e. atomic element, molecular element, molecular compound, or ionic compound) of each substance.

A. I_2
B. He
C. H_2O
D. Al
E. CuCl

Answer A

molecular element

Answer B

atomic element

Answer C

molecular compound

Answer D

atomic element

Answer E

ionic compound

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