1.4: Chemical Elements and Symbols

Learning Objectives

- Identify names and symbols of common chemical elements.
- Represent a chemical compound with a chemical formula.

As described in the previous section, an element is a pure substance that cannot be broken down into simpler chemical substances. There are about 90 naturally occurring elements known on Earth. Using technology, scientists have been able to create nearly 30 additional elements that do not occur in nature. Today, chemistry recognizes 118 elements—some of which were created an atom at a time. Figure 1.4.1 shows some of the chemical elements.

Figure 1.4.1: Samples of Elements. Gold is a yellowish solid, iron is a silvery solid, while mercury is a silvery liquid at room temperature. © Thinkstock

Elemental Names and Symbols

Each element has a name. Some of these names date from antiquity, while others are quite new. Today, the names for new elements are proposed by their discoverers but must be approved by the International Union of Pure and Applied Chemistry, an international organization that makes recommendations concerning all kinds of chemical terminology.

> *Today, new elements are usually named after famous scientists.*

The names of the elements can be cumbersome to write in full, especially when combined to form the names of compounds. Therefore, each element name is abbreviated as a one- or two-letter chemical symbol. By convention, the first letter of a chemical symbol is a capital letter, while the second letter (if there is one) is a lowercase letter. The first letter of the symbol is usually the first letter of the element's name, while the second letter is some other letter from the name. Some elements have symbols that derive from earlier, mostly Latin names, so the symbols may not contain any letters from the English name. Table 1.4.1 lists the names and symbols of some of the most familiar elements.

Table 1.4.1: Element Names and Symbols

Element Name	Element Symbol	Element Name	Element Symbol
aluminum	Al	magnesium	Mg
argon	Ar	manganese	Mn
arsenic	As	mercury	Hg*
barium	Ba	neon	Ne
bismuth	Bi	nickel	Ni
boron	B	nitrogen	N
bromine	Br	oxygen	O
calcium	Ca	phosphorus	P
carbon	C	platinum	Pt
chlorine	Cl	potassium	K*

Element Name	Element Symbol	Element Name	Element Symbol
chromium	Cr	silicon	Si
copper	Cu*	silver	Ag*
fluorine	F	sodium	Na*
gold	Au*	strontium	Sr
helium	He	sulfur	S
hydrogen	H	tin	Sn*
iron	Fe	tungsten	W†
iodine	I	uranium	U
lead	Pb*	zinc	Zn
lithium	Li	zirconium	Zr
*The symbol comes from the Latin name of element. †The symbol for tungsten comes from its German name—*wolfram*.			

Element names in languages other than English are often close to their Latin names. For example, gold is *oro* in Spanish and *or* in French (close to the Latin *aurum*), tin is *estaño* in Spanish (compare to *stannum*), lead is *plomo* in Spanish and *plomb* in French (compare to *plumbum*), silver is *argent* in French (compare to *argentum*), and iron is *fer* in French and *hierro* in Spanish (compare to *ferrum*). The closeness is even more apparent in pronunciation than in spelling.

Elements in Nature and the Human Body

The elements vary widely in abundance. In the universe as a whole, the most common element is hydrogen (about 90% of atoms), followed by helium (most of the remaining 10%). All other elements are present in relatively minuscule amounts, as far as we can detect. On the planet Earth, however, the situation is rather different (Table $1.4.2$). Oxygen makes up 46.1% of the mass of Earth's crust (the relatively thin layer of rock forming Earth's surface), mostly in combination with other elements, while silicon makes up 28.2%. Hydrogen, the most abundant element in the universe, makes up only 0.14% of Earth's crust.

Table $1.4.2$: Elemental Composition of Earth and the Human Body

Earth's Crust		**Human Body**	
Element	**Percentage**	**Element**	**Percentage**
oxygen	46.1	oxygen	61
silicon	28.2	carbon	23
aluminum	8.23	hydrogen	10
iron	5.53	nitrogen	2.6
calcium	4.15	calcium	1.4
sodium	2.36	phosphorus	1.1
magnesium	2.33	sulfur	0.20
potassium	2.09	potassium	0.20
titanium	0.565	sodium	0.14
hydrogen	0.14	chlorine	0.12
phosphorus	0.105	magnesium	0.027

Earth's Crust		Human Body	
Element	**Percentage**	**Element**	**Percentage**
all others	0.174	silicon	0.026

Source: D. R. Lide, ed. *CRC Handbook of Chemistry and Physics*, 89th ed. (Boca Raton, FL: CRC Press, 2008–9), 14–17.

Table 1.4.2 also lists the relative abundances of elements in the human body. If you compare both compositions, you will find disparities between the percentage of each element in the human body and on Earth. Oxygen has the highest percentage in both cases, but carbon, the element with the second highest percentage in the body, is relatively rare on Earth and does not even appear as a separate entry; carbon is part of the 0.174% representing "other" elements.

How does the human body concentrate so many apparently rare elements? The relative amounts of elements in the body have less to do with their abundances on Earth than with their availability in a form we can assimilate. We obtain oxygen from the air we breathe and the water we drink. We also obtain hydrogen from water. On the other hand, although carbon is present in the atmosphere as carbon dioxide, and about 80% of the atmosphere is nitrogen, we obtain those two elements from the food we eat, not the air we breathe.

Looking Closer: The Phosphorous Bottleneck

There is an element that we need more of in our bodies than is proportionately present in Earth's crust, and *this* element is not easily accessible. Phosphorus makes up 1.1% of the human body but only 0.105% of Earth's crust. We need phosphorus for our bones and teeth, and it is a crucial component of all living cells. Unlike carbon, which can be obtained from carbon dioxide, there is no phosphorus compound present in our surroundings that can serve as a convenient source. Phosphorus, then, is nature's bottleneck. Its availability limits the amount of life our planet can sustain.

Higher forms of life, such as humans, can obtain phosphorus by selecting a proper diet (plenty of protein); but lower forms of life, such as algae, must absorb it from the environment. When phosphorus-containing detergents were introduced in the 1950s, wastewater from normal household activities greatly increased the amount of phosphorus available to algae and other plant life. Lakes receiving this wastewater experienced sudden increases in growth of algae. When the algae died, concentrations of bacteria that ate the dead algae increased. Because of the large bacterial concentrations, the oxygen content of the water dropped, causing fish to die in large numbers. This process, called *eutrophication*, is considered a negative environmental impact.

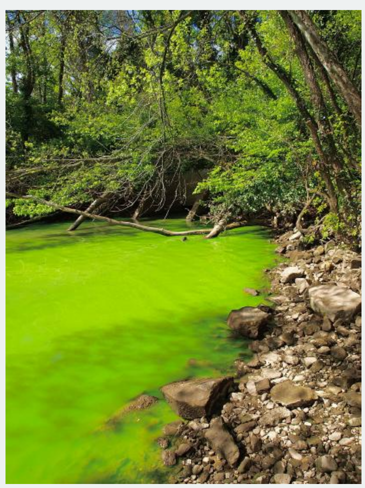

Figure 1.4.2: The eutrophication of the Potomac River is evident from the bright green water, caused by a dense bloom of cyanobacteria. (CC BY-SA 3.0; Alexandr Trubetskoy via Wikipedia)

Today, many detergents are made without phosphorus so the detrimental effects of eutrophication are minimized. You may even see statements to that effect on detergent boxes. It can be sobering to realize how much impact a single element can have on life—or the ease with which human activity can affect the environment.

Example 1.4.1

Write the chemical symbol for each element without consulting the above tables.

a. bromine
b. boron
c. carbon
d. calcium
e. gold

Strategy: The symbol for some of the more common elements is the first one or two letters of the element name. Test yourself to see if you know the symbol, then check your answer in the above tables. You will learn the element symbols as you practice.

Solution

a. Br
b. B
c. C
d. Ca
e. Au

Exercise 1.4.1

Write the chemical symbol for each element without consulting the above tables.

a. manganese
b. magnesium
c. neon
d. nitrogen
e. silver

Answer a

Mn

Answer b

Mg

Answer c

Ne

Answer d

N

Answer e

Ag

Example 1.4.2

What element is represented by each chemical symbol?

a. Na
b. Hg
c. P
d. K
e. I

a. sodium
b.
c. mercury

d.
e. phosphorus
f.
g. potassium
h. iodine
i.

Exercise 1.4.2

What element is represented by each chemical symbol?

a. Pb
b. Sn
c. U
d. O
e. F

Answer a

lead

Answer b

tin

Answer c

uranium

Answer d

oxygen

Answer e

fluorine

Chemical Formulas

A **chemical formula** is an expression that shows each of the elements in a compound and the relative proportions of those elements. Water is composed of hydrogen and oxygen in a 2:1 ratio and its chemical formula is H_2O. Sulfuric acid is one of the most widely produced chemicals in the United States and is composed of the elements hydrogen, sulfur, and oxygen; the chemical formula for sulfuric acid is H_2SO_4. Sucrose (table sugar) consists of carbon, hydrogen, and oxygen in a 12:22:11 ratio. The chemical formula of these are:

$$\underbrace{H_2O}_{\substack{\text{2 H atoms}\\ \text{1 O atom}}} \qquad \underbrace{H_2SO_4}_{\substack{\text{2 H atoms}\\ \text{1 S atom}\\ \text{4 O atoms}}} \qquad \underbrace{C_{12}H_{22}O_{11}}_{\substack{\text{12 H atoms}\\ \text{22 C atoms}\\ \text{11 O atoms}}}$$

Notice that the oxygen and sulfur in water and sulfuric acid, respectively, do not have a "1" subscripts - this is assumed.

Sometimes certain groups of atoms are bonded together within the chemical and act as a single unit. Polyatomic ions will be discussed later and are enclosed in parenthesis followed by a subscript if more than one of the same ion exist in a chemical formula. For example, the formula $Ca_3(PO_4)_2$ represents a compound with:

- 3 Ca atoms and
- 2 PO_4^{3-} polyatomic ions

To count the total number of atoms for formulas with polyatomic ions enclosed in parenthesis, use the subscript as a multiplier for each atom or number of atoms.

$$Ca_3(PO_4)_2$$

and decomposing this to elements gives

- 3 Ca atoms
- 2×1 P atoms
- 2×4 O atoms

That is, 3 Ca atoms, 2 P atoms, and 8 O atoms

Chemical formula can be used in chemical equations. For example, the reaction of hydrogen gas (H_2) burning with oxygen gas (O_2) to form water (H_2O) is written as:

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

Exercise 1.4.3

Identify the elements in each of the following chemical formulas and what is the ratio of different elements in the chemical formulas:

a. NaOH
b. NaCl
c. $\mathrm{CaCl_2}$
d. $\mathrm{CH_3COOH}$

Answer a

Sodium Na, oxygen O, and hydrogen H are present. This is sodium hydroxide and is also known as lye or caustic soda.

This is a 1:1:1 ratio of sodium, oxygen, and hydrogen, respectively.

Answer b

Sodium Na and chlorine O are present. This is sodium chloride and is also known as table salt.

This is a 1:1 ratio of sodium and chlorine, respectively.

Answer c

Calcium Ca and Chlorine Cl are present. This is calcium chloride and is a different type of salt than sodium chloride.

This is a 1:2 ratio of calcium and chlorine, respectively.

Answer d

Carbon C, Oxygen O, and Hydrogen H are present. This is acetic acid and is also known as vinegar.

This is a 2:2:4 (or 1:1:2) ratio of carbon, oxygen, and hydrogen, respectively.

Key Takeaways

- All matter is composed of elements, which are represented by one- or two-letter symbols.
- Chemical compounds are represented by formulas using element symbols and numerical subscripts to represent the ratio of each element in the compound.

Contributors and Attributions

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