8.1 Writing Chemical Formulas

As scientists came to recognize that many materials previously thought to be mixtures were actually compounds, they discovered that the ratio of the elements in a compound is always made up of small whole numbers. This meant that the identification of a compound not only required symbols for each element, but also ways to show the ratio of the elements in the compound. Recall that Berzelius created the standardized system of symbols for the elements. More importantly, he stated that every compound can be identified by a **chemical formula**, which shows the elements and their ratio.

A chemical formula for a compound such as water, which has two parts hydrogen and one part oxygen, is created using the symbols for the elements, and numbers for the relative proportions of the elements—H_2O. The number of particles of each element is shown using a subscript, which is a number following and slightly below the element symbol it describes. If there is no subscript after an element symbol (for example after the O in H_2O), it is understood to be 1. Table 1 shows a few other compounds and their formulas. 8A *Investigation*

8A *Investigation*

Separating the Elements from a Compound

To perform this investigation, turn to page 258.

In this investigation, you will separate the elements that form water and verify their proportions in the compound.

LEARNING TIP

Check your understanding. Use Table 1 to explain to a partner what a chemical formula is and how it is used.

Table 1 Some Simple Compounds, Their Formulas, and Their Proportions

Formula	Elements	Proportions	Particles
CuS	copper and sulfur	1 to 1	1 copper ion to 1 sulfur ion
Ag_2S	silver and sulfur	2 to 1	2 silver ions to 1 sulfur ion
CO_2	carbon and oxygen	1 to 2	1 carbon atom to 2 oxygen atoms
Al_2O_3	aluminum and oxygen	2 to 3	2 aluminum ions to 3 oxygen ions

The order of the elements in a chemical formula is important. By convention, when a compound is composed of a metal and a non-metal, the metal is shown in the formula ahead of the non-metal. For example, the formula CuS shows that copper is the metal and sulfur is the non-metal. The formula for the compound formed from silver and sulfur is written Ag_2S.

Polyatomic Ions

Some groups of atoms, called polyatomic groups, can occur together in a compound. When polyatomic groups are formed, they often have an imbalance between the total number of electrons and the total number of protons—in other words, they have a charge like an ion. Therefore, they are referred to as **polyatomic ions**. Most of the polyatomic ions are negative, and these ions behave as non-metals in a compound. Two common negative polyatomic ions

are CO_3^{2-} (the carbonate ion) and OH^- (the hydroxide ion). A common positive polyatomic ion is NH_4 (ammonium), which has an ion charge of 1+. Ammonium behaves as a metal in a compound.

Polyatomic ions are treated as if they were a single element's ions. If one ion is present, it is written without a subscript. If there is more than one of the ion present, the ion is enclosed in brackets and a subscript is used to show the number present. For example, $CaCO_3$ shows there is one ion of calcium and one carbonate ion in the compound (Figure 1). $Al_2(CO_3)_3$ contains 2 aluminum ions for every 3 carbonate ions. The subscript refers to everything in the brackets, so in $(CO_3)_3$ there are 3 carbonate ions, but there are 3 carbon atoms and 9 oxygen atoms in total.

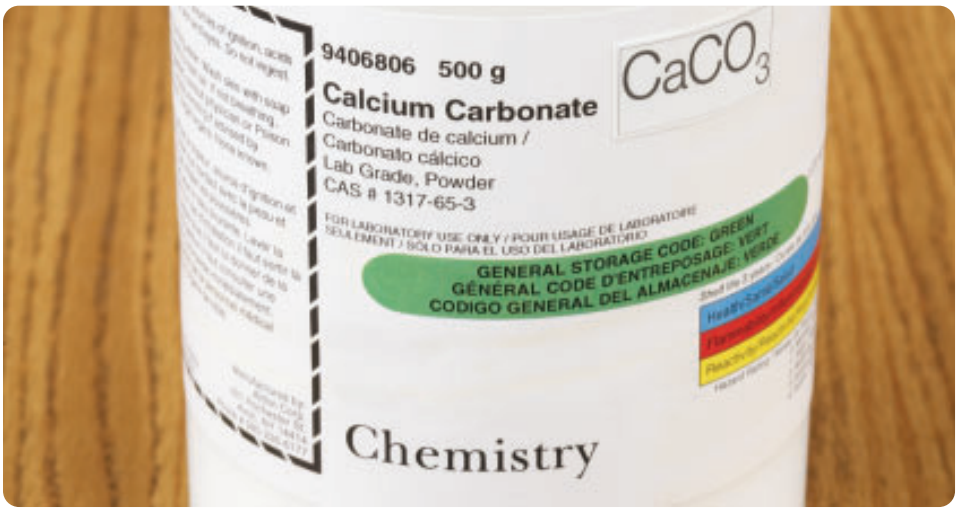


Figure 1 Chemical supply bottles always show the chemical name and the formula.

Table 2 provides the names, symbols, and ion charges for some polyatomic groups.

If you would like to learn about other polyatomic icons, go to **www.science.nelson.com**

Table 2 Common Polyatomic Ions and Their Names, Symbols, and Ion Charges

Name	Symbol	Ion charge	Name	Symbol	Ion charge
ammonium	NH_4	1+	hydrogen carbonate (also known as bicarbonate)	HCO_3	1−
carbonate	CO_3	2−	chlorate	ClO_3	1−
hydroxide	OH	1−	nitrate	NO_3	1−
phosphate	PO_4	3−	sulfate	SO_4	2−

Below are some examples of compounds that contain polyatomic ions. Notice how brackets are sometimes used. How many of each ion are in each formula?

- sodium phosphate, Na_3PO_4
- strontium nitrate, $Sr(NO_3)_2$
- aluminum hydroxide, $Al(OH)_3$
- calcium hydrogen carbonate, $Ca(HCO_3)_2$

TRY THIS: Writing and Decoding Chemical Formulas

Skills Focus: interpreting data

A chemical formula is a code. It gives you information about the composition of a compound. On the other hand, you can write the formula of a compound if you know the composition.

1. Complete Table 3. The first row has been done for you.

A. Which description of a chemical—the common name or the formula—provides clearer and more concise information about the compound? Explain.

B. Which description would be better to use when talking to a person who speaks a different language? Explain.

Table 3

Common name	Proportion of metal ion	Proportion of non-metal ion	Formula
baking soda	1 sodium	1 bicarbonate	$NaHCO_3$
caustic soda (oven cleaner)	1 sodium	1 hydroxide	
cinnabar (red stone used in jewellery)	1 mercury	1 sulfur	
cubic zirconia			ZrO_2
dentist's fluoride			SnF_2
epsom salt	1 magnesium		$MgSO_4$
Glauber's salts (a laxative)	2 sodium	1 sulfate	
gypsum (drywall)	1 calcium	1 sulfate	
lime			CaO
milk of magnesia	1 magnesium	2 hydroxide	
washing soda	2 sodium	1 carbonate	

LEARNING TIP

As you study Figure 2, ask yourself, "How many atoms, and what kind, are found in each article? How do colour, shape, and size help you "see" the chemical formula for each compound?"

Visual Representations of Compounds

Sometimes it is convenient to visualize a compound and its formula using a visual representation. Look at the representations of chemical formulas in Figure 2. Look at the number and kinds of atoms in each compound.

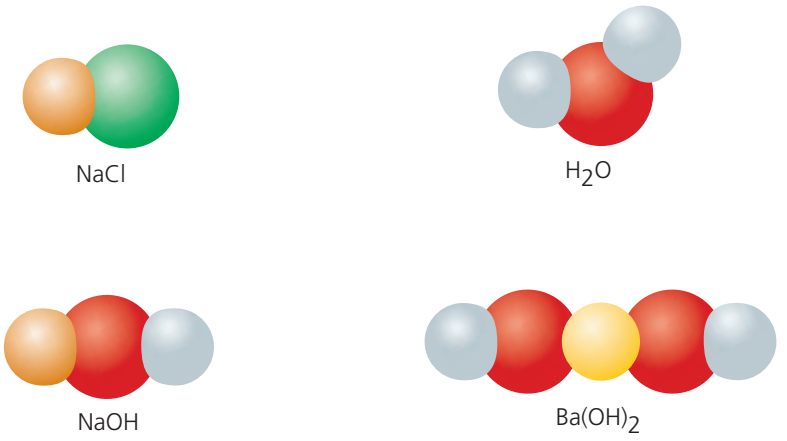


Figure 2 The formulas for compounds can be represented visually.

8.1 CHECK YOUR Understanding

1. Copy Table 4 into your notebook, and complete it.

Table 4

Formula	Elements	Proportions	Particles
PbO_2			
Al_2O_3			
N_2O_3			
$SnCl_4$			
Na_2S			
H_2S			
MnO_2			
WF_6			

2. Identify the elements, the polyatomic groups, and their proportions in the following compounds.
   (a) NH_4Cl
   (b) Na_2CO_3
   (c) $KClO_3$
   (d) $BaSO_4$
   (e) NH_4OH

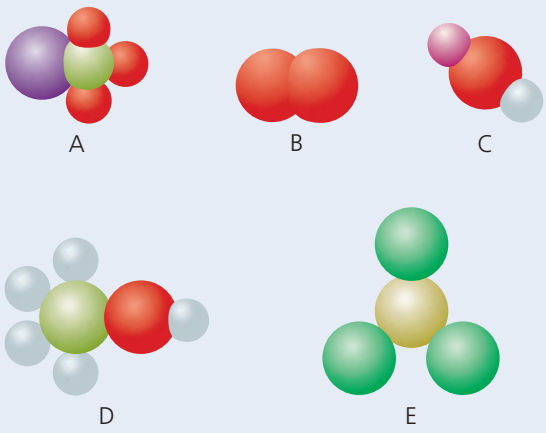
3. Write the chemical formula for each ionic compound.
   (a) 2 ammonium with 1 carbonate
   (b) 1 iron with 2 fluorine
   (c) 1 calcium with 2 nitrate
   (d) 2 aluminum with 3 oxygen
   (e) l nickel with 2 chlorine
   (f) 3 magnesium with 2 phosphorous
   (g) 1 potassium with 1 bicarbonate
   (h) 1 lead with 2 hydroxide

4. Consider sodium hydroxide, NaOH.
   (a) How many atoms of sodium are indicated in the formula?
   (b) How many atoms of hydrogen are indicated?
   (c) How many atoms of oxygen are indicated?
   (d) How many hydroxide ions are indicated?

5. Consider aluminum sulfate, $Al_2(SO_4)_3$.
   (a) How many atoms of aluminum are indicated in the formula?
   (b) How many atoms of sulfur are indicated?
   (c) How many atoms of oxygen are indicated?
   (d) How many sulfate ions are indicated?

6. How many atoms of oxygen are there in a particle of aluminum nitrate, $Al(NO_3)_3$?

7. Match each chemical formula with a possible visual representation.
   (a) $CrCl_3$
   (b) O_2
   (c) KNO_3
   (d) NH_4OH
   (e) LiOH



8. Draw a visual representation of each compound.
   (a) $CaCO_3$
   (b) $Pb(NO_3)_2$
   (c) HCl
   (d) Li_2SO_4
   (e) $CrPO_4$
   (f) $Mg(HCO_3)_2$
   (g) $(NH_4)_2S$
   (h) Li_3PO_4