Home Quit

6.2 Names and Formulas of Common Compounds

Here is a summary of what you will learn in this section:

- Ionic and molecular compounds have many uses in our everyday lives.
- Compounds can be represented by chemical formulas or chemical names.
- You can use a chemical formula to write the name for a compound. You can also use the name of a compound to write its formula.

Figure 6.9 The shells of sea animals and land snails are made up of the compound calcium carbonate.

Common Names and Chemical Names

Have you ever drawn a picture with pastel chalks? Some classrooms use chalk for writing on a chalkboard. People sometimes use another product that contains chalk — antacids. Antacids are taken to relieve indigestion. The chalk in antacids is mixed with sweeteners and flavours so that it tastes better. However, do not eat drawing chalk for your upset stomach, because these types of chalk and the chalk in antacids are not the same chemical. Drawing chalk is mainly calcium sulphate, while the antacid chalk is calcium carbonate (Figure 6.10). Calcium carbonate is also the main compound in sea shells, snail shells, and eggshells (Figure 6.9).

The different meanings of the term “chalk” show how confusing it can be to inaccurately name compounds. This example also shows the importance of using names that provide information about the chemical composition of a substance. The term “chalk” gives no hint as to what elements are present in either compound.

Figure 6.10 Chalkboard chalk is composed of calcium sulphate. Antacids and some calcium supplements contain calcium carbonate.

Naming Salts

Another example of a common name that can cause confusion is the word “salt.” We use the word “salt” as a common term for table salt. In chemistry, salt does not refer to a particular pure substance. In fact, it refers to the type of ionic compound. Salts have similarities in how they are formed and in their properties.

However, the term "salt" does not indicate which specific elements are found within a compound.

In the language of chemistry, table salt is called sodium chloride. Sodium chloride is not the same as the salt used on our roads in winter to melt ice. Road salt contains calcium chloride. Calcium chloride is somewhat less harmful to plants than sodium chloride is. Figure 6.11 shows a variety of ionic compounds, all of which are salts.

Every compound has a chemical name and formula. The **chemical formula** identifies which elements, and how much of each, are in the compound. For example, sodium chloride's formula is NaCl. Baking soda's chemical name is sodium hydrogen carbonate, and its chemical formula is $NaHCO_3$.

Figure 6.11 Clockwise from the lower left, the salts shown here are sodium chloride, iron(II) sulphate, iron(III) sulphate, copper(II) sulphate, and copper(II) carbonate.

B24 *Quick Lab*

Naming Compounds

Modern naming systems try to reveal a lot about a compound. Work with a partner to uncover as much information as possible about each compound.

Purpose

To interpret chemical names for compounds

Procedure

1. Using the periodic table on page 191, work with a partner and try to figure out from each name what elements are present in the following compounds. Each compound contains two elements only.
   (a) sodium fluoride (prevents tooth decay)
   (b) zinc oxide (present in mineral supplements)
   (c) potassium chloride (sodium-free salt substitute)
   (d) lithium nitride (used in some batteries)
   (e) iron(III) oxide (present in common rust)
2. Examine each formula below, and determine what elements are present in each compound.
   (a) CuI (a mineral present in copper ore)
   (b) NaI (dietary supplement added to table salt)
   (c) $CaSO_4$ (drawing chalk)
   (d) $CaCO_3$ (main component in eggshells)
   (e) $Mg(OH)_2$ (milk of magnesia, an antacid)

Questions

3. Locate where each element named in step 1 occurs in the periodic table, and suggest answers to the following.
   (a) What two different kinds of elements are present in this type of compound?
   (b) What determines the order in which each element name occurs in the compound name?
   (c) Not all element names that appear in the compound names are exactly the same as they appear on the periodic table. What pattern(s) are there in how these names are changed?
4. In step 2, what patterns can you find in the way the chemical formulas of these compounds are written?
5. Chemists use both chemical names and chemical formulas. Suggest situations where one might be more useful than the other.
6. Your teacher will give you the ingredients list from a food product, medicine, or household product such as shampoo or toothpaste. Examine the list and discuss what kind of chemical information you are able to determine about the product from your analysis of the product label.

Ion Charges

Each of the elements that commonly form ionic compounds has an entry in the periodic table showing what ion charge it can have. Table 6.2 shows some examples of ions and their charges, which were taken from the periodic table.

- The ion notation contains the symbol for the element and a superscript number and + or – sign at the top right. For example, the lithium ion has a 1+ charge, which is shown as Li^{+}.
- Iron, copper, and lead can form an ion in more than one way. A Roman numeral is included in the ion's name to show the ion's charge. For example, the name of Fe^{2+} is iron(II), which is read "iron two". The "two" refers to the charge. Similarly, iron(III) is read "iron three" and names the Fe^{3+} ion. Table 6.2 shows the connection between the ion charge and the Roman numeral.
- The name of non-metal ions is formed by taking the element name and changing the ending so that it includes the suffix "– ide." For example, the element oxygen produces the ion O^{2-}, which is called oxide.

Table 6.2 Ion Charges

Element	Ion Charge	Ion Notation	Ion Name
hydrogen	1+	H^{+}	hydrogen
lithium	1+	Li^{+}	lithium
nitrogen	3–	N^{3-}	nitride
oxygen	2–	O^{2-}	oxide
magnesium	2+	Mg^{2+}	magnesium
aluminum	3+	Al^{3+}	aluminum
iron	2+ or 3+	Fe^{2+} or Fe^{3+}	iron(II) or iron(III)
copper	1+ or 2+	Cu^{+} or Cu^{2+}	copper(I) or copper(II)
lead	2+ or 4+	Pb^{2+} or Pb^{4+}	lead(II) or lead(IV)

Learning Checkpoint

1. What is a salt? Give an example.
2. Explain why using standard chemical names for compounds would be important when working in a laboratory.
3. Refer to the periodic table and write all possible ion charges, ion notations, and ion names for ions formed by the following elements.

   (a) calcium (b) chlorine (c) phosphorus (d) gold (e) tin

Naming Ionic Compounds

The following rules explain how to name ionic compounds based on a given chemical formula.

1. Name the metal ion first. The name of the metal ion is the same as the element name. For example, in NaCl, the name of the Na^+ ion is sodium. If the element can form an ion in more than one way, include a Roman numeral to indicate the charge.
2. Name the non-metal ion second. When a non-metal becomes a negative ion, the ending of its name changes to "ide." For example, a chlor**ine** atom (Cl) gains an electron to become a chlor**ide** ion (Cl^-).
3. The name for an ionic compound is a combination of the ion names of the elements. The name of NaCl is, therefore, sodium chloride.

Name of metal	Name of non-metal + ide
sodium	**chloride**

The formulas of ionic compounds often contain numbers, called subscripts, such as the "3" in $AuCl_3$. We will look at the meaning of subscripts on page 222. If the metal forms only one type of ion, the subscript can be ignored when determining the compound name. In the examples in Table 6.3, each formula is examined and the two ions present are identified.

Table 6.3 Naming Ionic Compounds

Formula	Positive Ion	Negative Ion	Name
MgO	Mg^{2+}	O^{2-}	magnesium oxide
BaF_2	Ba^{2+}	F^-	barium fluoride
K_3N	K^+	N^{3-}	potassium nitride

Example Problem 6.1

Write the name of the ionic compound Ag_2S.

1. Name the metal ion: Ag forms only one type of ion (Ag^+), so the name is silver.
2. Name the non-metal ion: The atom is sulphur, so the ion is sulphide.
3. Combine the names: silver sulphide

Practice Problems

Write the names of the following ionic compounds.

1. NaF
2. KI
3. $MgCl_2$
4. $AlCl_3$
5. Ca_3P_2

WORDS MATTER

Sodium chloride is essential in the diet, making it a very valuable compound. Armed troops once guarded the salt supplies of ancient Rome along the Via Salarium (Salt Road) and were paid in bags of salt. In time, their payment changed from salt to money and became known as salarium, the origin of the modern English word "salary."

Suggested Activity •
B25 Quick Lab on page 227

Multivalent Elements

Some metals can form more than one type of ion. For example, iron has two stable ions: Fe^{2+} and Fe^{3+}. Elements with more than one stable ion are called multivalent elements. Ionic compounds containing multivalent elements must have Roman numerals in their names to indicate which ion is forming that compound. The Roman numeral is written in brackets after the element to indicate the charge. For example, the compound name iron(III) oxide indicates that the Fe^{3+} ion forms that compound (Figure 6.12).

You can find the Roman numeral to use in the name of a multivalent ion by using the subscripts in the compound's formula. For example, in $FeBr_2$, the subscript 2 after the Br is a guide to the iron ion's charge. The positive and negative charges in an ionic compound must be equal. According to this rule, only an Fe^{2+} could pair up with two Br^- to give the 1:2 ratio in the formula. $FeBr_2$ is written out as iron(II) bromide. In $FeBr_3$, only an Fe^{3+} could pair up with three Br^- to give the 1:3 ratio in the formula. $FeBr_3$ is written out as iron(III) bromide.

Figure 6.12 Rust contains iron(III) oxide, or Fe_2O_3. Rust is produced when iron corrodes.

Practice Problems

Write the names of the following ionic compounds.

1. $FeCl_3$
2. PbO_2
3. Ni_2S_3
4. CuF_2
5. Cr_2S_3

Example Problem 6.2

Write the name of the ionic compound Cu_3N.

1. Identify the ions that form the compound: $Cu^?$ and N^{3-}
2. Use the charge of the non-metal ion and the rule that the total positive and negative charges in the formula must be equal. Three copper ions are present in the formula, so each must have a charge of 1+.
3. Name the metal ion: The ion has a 1+ charge, so the name is copper(I).
4. Name the non-metal ion: The name of the atom is nitrogen, so the ion is nitride.
5. Combine the names: copper(I) nitride

Polyatomic Ions

Sometimes, a group of atoms of different elements act as a single ion. This type of ion is called a polyatomic ion. Some examples of polyatomic ions are given in Table 6.4. For example, one atom of carbon and three atoms of oxygen form the polyatomic ion called carbonate, or CO_3^{2-}. This ion is present in your teeth as well as in eggshells. In both cases, it is present with calcium ions (Ca^{2+}) and forms the compound calcium carbonate ($CaCO_3$).

As with other ionic compounds, you can use the formula for an ionic compound with a polyatomic ion to write the compound's name. First, look at the formula and identify and name the positive ion, which will be a metal ion. For example, NaOH contains the metal ion Na^+, or sodium ion. The next step is to identify and name the polyatomic ion. In NaOH, the polyatomic ion is OH^-, or hydroxide. You do not need to change the ending of a polyatomic ion's name. The name of the compound NaOH is sodium hydroxide.

In some cases, the formula uses brackets to help identify the polyatomic ion. Table 6.5 gives some hints for writing the names of ionic compounds with polyatomic ions.

Table 6.4 Common Polyatomic Ions

Ion Symbol	Ion Name
OH^-	hydroxide
HCO_3^-	hydrogen carbonate
SO_4^{2-}	sulphate
CO_3^{2-}	carbonate
PO_4^{3-}	phosphate

WORDS MATTER

The prefix "poly" comes from the Greek term polys, meaning many.

Table 6.5 Naming Ionic Compounds with Polyatomic Ions

Formula	Positive Ion	Negative Ion	Name	Hint for writing name
$Mg(OH)_2$	Mg^{2+}	OH^-	magnesium hydroxide	• The polyatomic ion is often found in brackets.
$AlPO_4$	Al^{3+}	PO_4^{3-}	aluminum phosphate	• Brackets are not always used. • Everything after the metal ion is part of the polyatomic ion.

Example Problem 6.3

Write the name of the ionic compound $NaHCO_3$.

1. Name the metal ion: Na forms only one type of ion (Na^+), so the name is sodium.
2. Identify the polyatomic ion in each compound by examining the formula and cross-checking with the table of common polyatomic ions: The name for HCO_3^- is hydrogen carbonate.
3. Combine the names: sodium hydrogen carbonate

Practice Problems

Write the names of the following ionic compounds.

1. KOH
2. $ZnCO_3$
3. $Mg_3(PO_4)_2$
4. $CaSO_4$
5. $Al_2(CO_3)_3$

Suggested STSE Activity •····
B26 Decision-Making Analysis on page 228

Writing Formulas for Ionic Compounds

It is possible to write the chemical formula for an ionic compound when given the name (Figure 6.13). The steps in Table 6.6 will help you write the formulas for ionic compounds.

Table 6.6 Steps for Writing Formulas for Ionic Compounds

Steps	Examples		
1. Examine the compound's name. Identify the ions and their charges.	magnesium chloride Mg^{2+} Cl^{-}	calcium nitride Ca^{2+} N^{3-}	iron(II) oxide Fe^{2+} O^{2-}
2. Determine the number of each ion needed to balance the charges.	Mg^{2+} Cl^{-} Cl^{-}	Ca^{2+} Ca^{2+} Ca^{2+} N^{3-} N^{3-}	Fe^{2+} O^{2-}
3. Note the ratio of positive to negative ions, and write the formula.	$MgCl_2$	Ca_3N_2	FeO

Take It Further

A hydrate is a compound that has water molecules linked to it. Hydrates usually involve ionic compounds. Two examples of hydrates are magnesium sulphate heptahydrate (bath salt) and sodium carbonate decahydrate (washing soda). The formulas for these substances are $MgSO_4 \cdot 7H_2O$ and $Na_2CO_3 \cdot 10H_2O$. With a partner, research other hydrates and make a reference guide of their uses, properties, and formulas. Begin your search at *ScienceSource*.

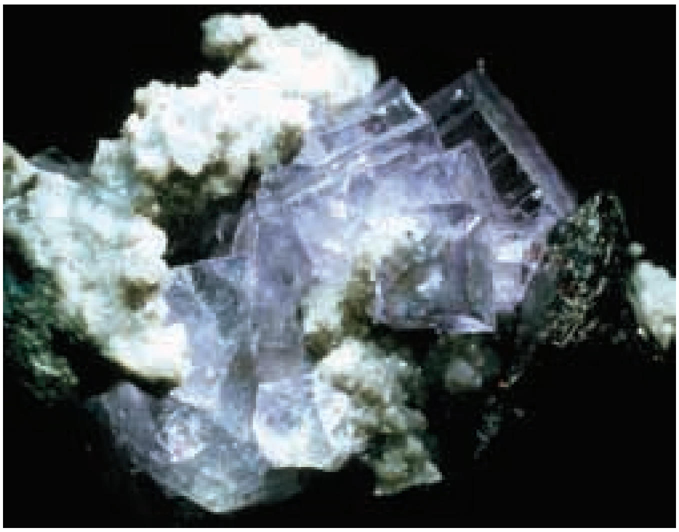


Figure 6.13 The chemical name for this pink-purple crystal is calcium fluoride. Its formula is CaF_2.

Practice Problems

Write the formulas for the following ionic compounds.

1. lithium bromide
2. magnesium fluoride
3. silver nitride
4. iron(III) chloride
5. chromium(III) sulphide

Example Problem 6.4

Write the formula for potassium sulphide.

1. Identify the ions and their charges: K^{+} S^{2-}
2. Determine the number of each ion needed to balance the charges: K^{+} K^{+} S^{2-}
3. Note the ratio of positive to negative ions, and write the formula: K_2S

Formulas for Compounds with Polyatomic Ions

The rules for writing formulas for compounds containing polyatomic ions are similar to the rules for other ionic compounds. One difference is that brackets may be used to show the ratio of ions. For example, in $Zn(OH)_2$ there is one Zn^{2+} for every two OH^-.

Table 6.7 shows how ions are identified so that the formulas for the compounds can be written. Notice that in sodium hydroxide, the 1+ charge on Na^+ balances the 1– charge on the polyatomic ion OH^-. Since there is one Na^+ for every OH^-, the formula for sodium hydroxide is NaOH and no brackets are used (Figure 6.14).

Figure 6.14 The common name for sodium hydroxide is lye, and its formula is NaOH. Sodium hydroxide is used in low concentrations in lye soap (a) and in high concentrations in drain cleaner (b).

Table 6.7 Examples of Polyatomic Ions in Formulas

Name	sodium hydroxide	zinc hydroxide	aluminum sulphate	sodium phosphate
Ions	Na^+ OH^-	Zn^{2+} OH^-	Al^{3+} SO_4^{2-}	Na^+ PO_4^{3-}
Ratio of ions	Na^+ OH^-	Zn^{2+} OH^- OH^-	Al^{3+} Al^{3+} SO_4^{2-} SO_4^{2-} SO_4^{2-}	Na^+ Na^+ Na^+ PO_4^{3-}
Formula	NaOH	$Zn(OH)_2$	$Al_2(SO_4)_3$	Na_3PO_4

Example Problem 6.5

Write the formula for magnesium phosphate.

1. Identify the ions and their charges: Mg^{2+} and PO_4^{3-}
2. Determine the numbers of each ion needed to balance the charges:
   Mg^{2+} Mg^{2+} Mg^{2+} PO_4^{3-} PO_4^{3-}
3. Note the ratio of positive to negative ions:
   three Mg^{2+} for every two PO_4^{3-}
4. Use the ratio to determine what subscripts to use. If a subscript is needed for the polyatomic ion, include brackets and place the subscript *outside* the brackets:
   A subscript of 3 is needed after Mg^{2+}.
   A subscript of 2 outside a bracket is needed for PO_4^{3-}.
5. Write the formula: $Mg_3(PO_4)_2$

Practice Problems

Write the formulas for the following ionic compounds.

1. aluminum hydroxide
2. calcium sulphate
3. sodium carbonate
4. iron(III) carbonate
5. copper(II) sulphate

Table 6.8 Prefixes Used for Naming Molecules

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Naming Molecular Compounds

For the names of molecular compounds of two elements, Greek prefixes are used to indicate how many atoms of each element are present in a compound. The prefixes are listed in Table 6.8. For example, N_2O_3 is a molecular compound present in car exhaust that contributes to smog. Its name is dinitrogen trioxide. The "di" means "2" and the "tri" means "3".

The rules in Table 6.9 will help you to name molecular compounds of two elements.

Table 6.9 Steps for Naming Molecular Compounds

Steps	Examples		
1. Examine the formula.	N_2O	PBr_3	CS_2
2. Name the first element. Note that the prefix "mono-" is not used when the first element is only one atom.	nitrogen	phosphorus	carbon
3. Name the second element, which ends with "–ide." When the prefix "mono-" is required before "oxide," the last "o" in the prefix is dropped. For example, it is "monoxide," not "monooxide."	oxide	bromide	sulphide
4. Add prefixes indicating the numbers of atoms.	dinitrogen monoxide	phosphorus tribromide	carbon disulphide

Molecular compounds containing hydrogen or more than two elements are often given special names, as in Table 6.10.

Table 6.10 Common Molecular Compounds that Contain Hydrogen

Common Name	Chemical Name	Formula	Use
Natural gas	methane	CH_4	fuel, plastics industry
Wood alcohol	methanol	CH_3OH	antifreeze
Table sugar	sucrose	$C_{12}H_{22}O_{11}$	sweetener
Rubbing alcohol	propanol	C_3H_8O	antiseptic

Practice Problems

Write the names of the following molecular compounds.

1. CO
2. CI_4
3. OF_2
4. N_2O_4
5. PCl_3

Example Problem 6.6

Write the name for P_2O_5.

1. Name the first element: phosphorus
2. Name the second element, which ends with "ide": oxide
3. Add prefixes indicating the numbers of atoms: diphosphorus pentaoxide

Writing Formulas for Molecular Compounds

You can also work backward to determine the formula of a binary molecular compound from its name. The prefixes indicate the number of atoms of each type of element (Table 6.8).

Example Problem 6.7

Write the formula for carbon tetrachloride.

1. Identify the first element, and give its symbol: carbon, C
2. Identify the second element, and give its symbol: chlorine, Cl
3. Add subscripts to indicate the numbers of atoms: Carbon does not have a prefix, so there is only one C. The prefix "tetra" is used with chloride, so a subscript of 4 is needed after Cl.
4. Write the formula: CCl_4

Practice Problems

Write the formulas for the following molecular compounds.

1. carbon dioxide
2. oxygen difluoride
3. nitrogen trifluoride
4. phosphorus pentafluoride
5. dinitrogen trioxide

B25 Quick Lab

Copper Compounds

Copper reacts with non-metals to form various colourful compounds. Copper reacts with oxygen to form red or black copper compounds. In moist air, copper reacts to produce a blue-green compound called copper(II) carbonate. Vinegar (acetic acid) and copper react to produce copper(II) acetate.

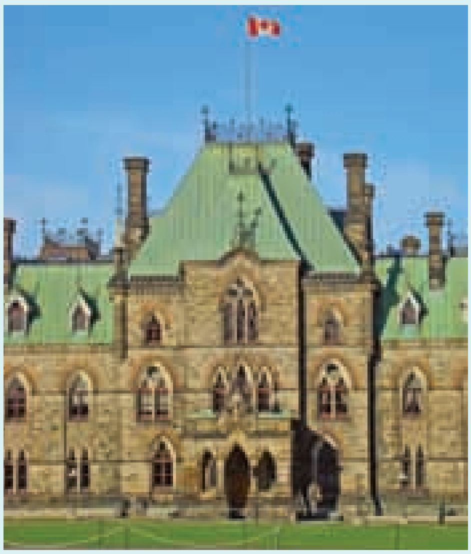


Figure 6.15 The copper rooftops of Canada's Parliament Buildings are coated with a blue-green copper compound.

Purpose

To produce a copper compound

Materials & Equipment

- 2 pennies
- 1 paper towel
- vinegar (acetic acid)

Procedure

1. Observe a penny, and note its properties.
2. Fold a paper towel in quarters. Moisten the paper towel with acetic acid.
3. Fold the wet paper towel around the penny. Set the paper and penny aside overnight or longer.
4. Unfold the paper towel, and observe the penny. Compare it to a penny not soaked in acetic acid.

Questions

5. Describe any evidence of a chemical reaction.
6. What colour is copper(II) acetate?

B26 **STSE** *Decision-Making Analysis* Skills References 4, 6

SKILLS YOU WILL USE
- identifying and locating research sources
- Thinking critically and logically

Salt or Sand?

Issue

Canadian winters are harsh. Keeping our roads safe in winter is a vital concern for Canadians. Safety can be enhanced by improving traction, or grip, on slippery roads. Many car owners use winter tires, while others add chains to their tires. Substances such as road salt, sand, or gravel are also used to reduce slippery conditions. However, road salt can harm the natural environment and damage stone structures and metal on cars. Some ingredients in road salt are also toxic.

Background Information

Calcium chloride ($CaCl_2$) and sodium chloride ($NaCl$) are the major components of road salt. Magnesium chloride ($MgCl_2$) and iron salts may also be used in small amounts. The substances are finely crushed and spread on icy roads and pavements (Figure 6.16). In the right conditions, road salt helps ice melt away. Salt lowers the freezing point of water. For example, a 20 percent salt solution freezes at about –16°C, whereas fresh water freezes at 0°C. However, much below –15°C, road salt is not effective.

Unfortunately, road salt can be harmful to plants and animals. Some types of plants die if the soil is too salty. Pets may step in the road salt and become ill when they lick their paws. Wildlife that wanders on to highways to lick the road salt may get hit by vehicles.

Road salt can also damage built structures. In Ottawa, a limestone wall along a popular route is covered by plywood boards every winter. Though unattractive, these boards protect the limestone from being "eaten away." Left uncovered, the limestone would react with the $CaCl_2$ in the road salt.

Figure 6.16 Some road salts contain colour to make it easier to see where they have been spread.

Analyze and Evaluate

Your task is to find information about the costs and benefits of using various road salts, sand, or alternative methods to treat icy roads. This information will help you to evaluate whether or not your school or community is making the best decision for your safety and the environment. You will present your findings in a table and your decision in a brief paragraph.

1. ***ScienceSource*** Begin your search for information. Use search engines. Try keywords such as "road salt," "calcium chloride," "winter driving," and "road safety." Be sure to keep a list of your online sources of information.
2. Look in print materials such as magazines, newspapers, and books for information on the effects of salt on cars and roads in Ontario. Keep a list of all information sources.
3. Examine the listed ingredients in different brands of road salt. Compare a "paw safe" brand to another. Find out about the properties of each ingredient and why it is used.
4. Create a table summarizing the pros and cons of using road salt. Give your table a title. Under "Options," list types of road salt, sand, or alternatives such as tire chains. For the other headings, use "Pros," "Best Conditions for Use," and "Cons."
5. Based on what you now know, would you use salt on the roads in your neighbourhood? If so, in what conditions would you use road salt? If not, what alternative would you use and why? Write a brief paragraph to answer these questions. Refer to the table you created to help you as you write.

6.2 CHECK and REFLECT

Key Concept Review

1. Identify each of the following as an atom, an ion, an ionic compound, or a molecular compound.

(a) C
(b) CO_2
(c) CO_3^{2-}
(d) Co
(e) CO
(f) NaCl
(g) NF_3

2. Using the periodic table on page 191, write the ion notation for all possible ions of each of the following elements.

(a) lithium
(b) strontium
(c) vanadium
(d) chlorine
(e) sulphur

3. Write the chemical names of the following ionic compounds.

(a) Li_2O
(b) CaF_2
(c) KF
(d) Na_3N
(e) $Mg(OH)_2$
(f) $FeCl_2$
(g) $Al_2(SO_4)_3$

4. Write the chemical formula for each ionic compound below.

(a) magnesium chloride
(b) sodium sulphide
(c) calcium phosphide
(d) potassium nitride
(e) calcium fluoride
(f) aluminum oxide

5. Write the formulas for the following molecular compounds.

(a) nitrogen triiodide
(b) carbon dioxide
(c) sulphur hexafluoride
(d) methane
(e) sucrose

6. Write the name of each of the following molecular compounds.

(a) CBr_4
(b) NO
(c) OF_2
(d) IBr_2
(e) PCl_3
(f) N_2O_3

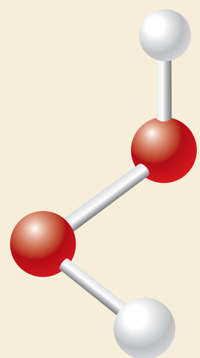
Connect Your Understanding

7. Consider the process in which an iron atom turns into an iron(III) ion. Explain whether the atom gains or loses electrons in this process and how many.

8. Explain why H_2S is a compound but HCO_3^- is not.

9. Use the following diagram to answer this question.

(a) What do the different-coloured balls in the diagram represent?
(b) What do the lines in the diagram represent?
(c) What compound is shown?


Question 9

10. Create a concept map about compounds. Include references to both ionic and molecular compounds, how to tell them apart based on their formulas, and some examples of specific compounds and their uses.

Reflection

11. List three chemical names for substances for which you knew only the common names when you began this section.

For more questions, go to ***ScienceSource***.