4.2 Names and Formulas of Compounds

Compounds can be represented with both a name and a chemical formula. In an ionic compound, the first part of the name indicates the positive ion and the second part indicates the negative ion. In the formula of an ionic compound, the subscripts indicate the ratio in which the positive ions and negative ions are present together in the compound. In a binary covalent compound, both the name and the formula indicate the number of each type of atom present in the compound.

Words to Know

binary covalent compound
ionic compounds
polyatomic
subscript

Figure 4.18 A single crystal of salt (sodium chloride) embedded in a rock formation

If you were asked to take a chisel and carve a cube out of a large crystal of table salt, would you be able to make one as perfect as the one shown in Figure 4.18? Or would you need to be a master carver? In fact, the crystal shown here formed naturally in this shape. How can this happen?

Table salt (sodium chloride) is an ionic compound, meaning that it is made of positive and negative ions that are held together by ionic bonds. Instead of being shaped from the outside, as a sculptor would do, the crystal is highly organized and formed piece by piece (ion by ion) from the inside out.

This crystal of salt formed from a solution that contained sodium and chloride ions. Slowly, the solution dried up, leaving this cube embedded in other rocks. The regular shape reveals the order of the ions at the atomic level.

Did You Know?

Before chemical names were standardized, a single compound might have more than one name. For example, sulfur dioxide (SO_2) was known as both vitriolic acid air and sulfurous gas.

The ions in the sodium chloride crystal line up this way because of the forces acting between the ions. The oppositely charged ions are attracted to each other, and the similarly charged ions repulse each other. The combination of charges forms the arrangement of ions shown in Figure 4.19.

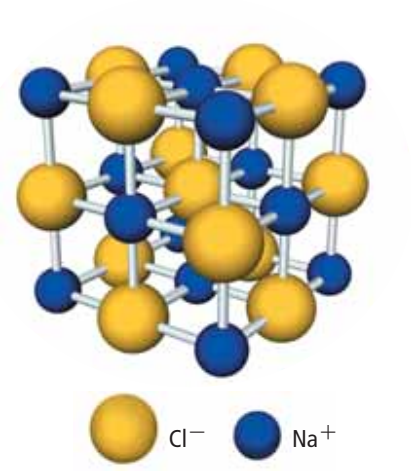


Figure 4.19 The arrangement of ions in sodium chloride

4-2A Chemical Names — Think About It

In this activity, you will work with a partner to discover what information can be collected from the names of ionic compounds and covalent compounds.

What to Do

1. With a partner, use the periodic table in Figure 4.3 on page 172 to determine the elements in the ionic compounds listed below. Notice where each element in the compound is located on the periodic table. List three patterns that you can find in how these names are written.
   (a) sodium bromide
   (b) magnesium sulfide
   (c) iron(III) oxide
   (d) lead(IV) nitride
   (e) aluminum fluoride
2. Review the covalent compounds listed below. Notice where each element in the compound is located on the periodic table. List three patterns that you can find in how these names are written.
   (a) dinitrogen trioxide
   (b) nitrogen trichloride
   (c) carbon disulfide
   (d) tetraphosphorus decaoxide
   (e) phosphorus pentabromide
3. Write the chemical formula for each covalent compound listed in step 2. Use the following hint to suggest how the formulas are written from the name.
   Hint: disulfur decachloride is S_2Cl_{10}.
4. Share your findings with the class.

What Did You Find Out?

1. Which parts of the periodic table do elements come from when they combine to form ionic compounds?
2. Which part of the periodic table do elements come from when they combine to form covalent compounds?
3. What are two ways to distinguish ionic compounds from covalent compounds by looking only at a compound's name?
4. What information is included in the name of a covalent compound that is not included in the name of an ionic compound?

The Chemical Name of an Ionic Compound

Ionic compounds are compounds that are composed of positive ions and negative ions. You can describe ionic compounds using a name or a formula. A chemical formula indicates the elements present in the compound.

The International Union of Pure and Applied Chemistry (IUPAC) is the organization that represents chemists around the world and develops the rules for naming compounds. One rule is that the chemical name of an ionic compound always has two parts, one for each type of ion in it. An example of a compound made of only two elements is potassium iodide, which is a component of sea salt (Figure 4.20).

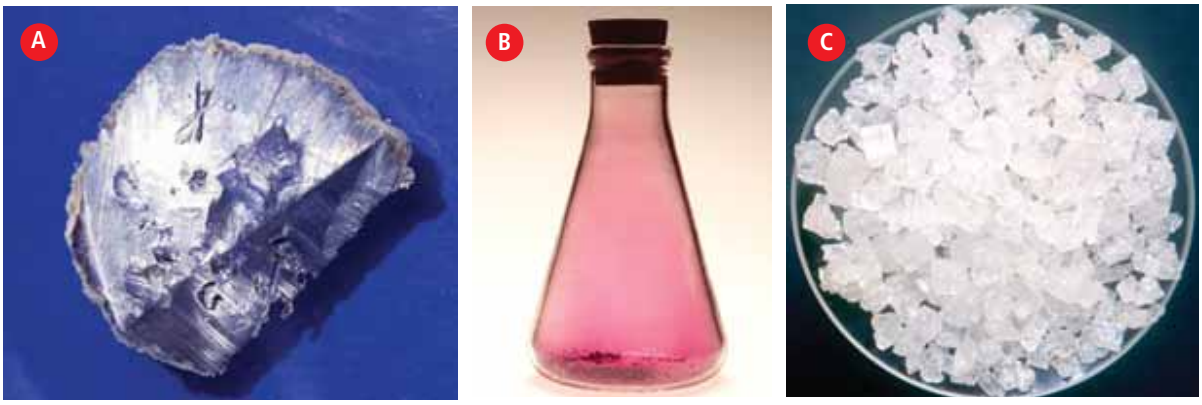


Figure 4.20 Potassium metal (A) and iodine gas (B) can combine to form potassium iodide crystals (C).

- The first part of "potassium iodide" names the positive ion, potassium. The positive ion is *always* a metal in a compound containing two elements. The positive, metal ion is *always* written first.
- The second part of "potassium iodide" names the negative ion, iodide, an ion of iodine. The negative ion is *always* a non-metal in a compound containing two elements. The negative, non-metal ion is *always* written second.
- The non-metal's name always ends with the suffix "-ide." In this example, "iodine" changed to "iodide."

The names and symbols of the non-metal ions are shown in Table 4.3. You may recall from earlier in this chapter that the charge of each ion refers to the electrons present (for metals) or missing (for non-metals) in the valence shell. Some examples of ionic compounds are listed in Table 4.4.

Table 4.3 Examples of Names and Symbols of Non-Metal Ions

Name	Symbol
fluoride	F^-
chloride	Cl^-
bromide	Br^-
iodide	I^-
oxide	O^{2-}
sulfide	S^{2-}
selenide	Se^{2-}
nitride	N^{3-}
phosphide	P^{3-}

Table 4.4 Examples of Names of Ionic Compounds

Elements Forming the Ionic Compound	Name of the Ionic Compound
magnesium and phosphorus	magnesium phosphide
calcium and bromine	calcium bromide
aluminum and oxygen	aluminum oxide
lithium and nitrogen	lithium nitride
zinc and sulfur	zinc sulfide

The Chemical Formula of an Ionic Compound

The chemical formula of an ionic compound contains a symbol to identify each ion. The formula also shows the number of ions of each element in the compound. The small number written to the right of the symbol of an element, such as the 3 in Na_3P, is called a **subscript**. A subscript gives the ratio of each type of ion in the compound. If no subscript is shown after an element, such as after the P in Na_3P, you can assume the number to be 1. In Na_3P, there are three sodium ions for every one phosphorus ion. Figure 4.21 shows three examples of chemical formulas of ionic compounds.

Naming Ionic Compounds

You can determine the name of an ionic compound containing two elements by analyzing its formula (Table 4.5).

Table 4.5 Naming Ionic Compounds Containing Two Elements

Steps	Examples	
	CaI_2	Na_3P
1. Name the metal ion.	• The metal ion is Ca^{2+}. • The ion's name is given in the periodic table as calcium.	• The metal ion is Na^+. • The ion's name is given in the periodic table as sodium.
2. Name the non-metal ion by ending the element name with the suffix "ide."	• The non-metal ion is I^-. The element's name is iodine. • Changing the name to end with the suffix "-ide" gives iodide.	• The non-metal ion is P^{3-}. The element's name is phosphorus. • Changing the name to end with the suffix "-ide" gives phosphide.
3. Write the name of the compound.	calcium iodide	sodium phosphide

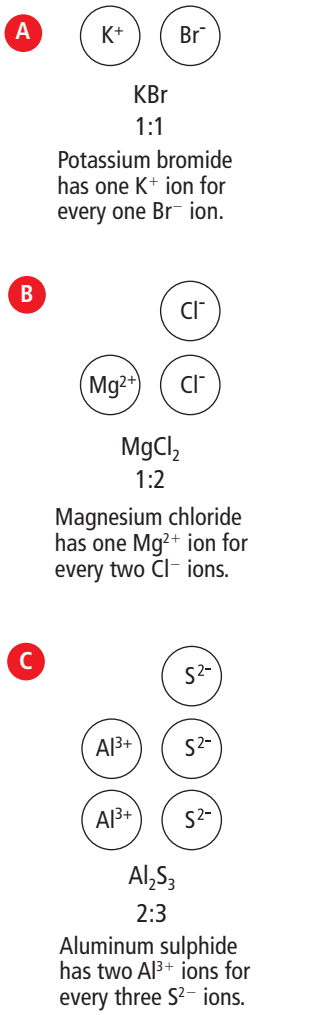


Figure 4.21 Chemical formulas for three ionic compounds

Practice Problems

Write the names of the following ionic compounds.

1. (a) Li_3N (b) $MgBr_2$ (c) Ag_2O (d) RbF (e) AgI (f) $AlBr_3$ (g) CaI_2 (h) GaI_3 (i) Ag_3N (j) MgSe (k) Ca_3P_2 (l) Na_2O (m) CdS (n) Sr_3P_2 (o) CsF

Answers provided on page 591

Writing the Formulas of Ionic Compounds

In an ionic compound, the positive charges balance the negative charges. You can use this balance to find the ratio of positive ions to negative ions. Then you can use the ratio to write subscripts in the formula. Table 4.6 shows the steps for writing the formula of an ionic compound if you know the names of the elements it contains.

Notice that the final formula represents the smallest whole number ratio. For example, Pb^{4+} combining with S^{2-} is written as PbS_2, and not as Pb_2S_4.

Table 4.6 Writing Formulas of Ionic Compounds Containing Two Elements

Steps	Examples	
	aluminum fluoride	**magnesium nitride**
1. Identify each ion and its charge.	aluminum: Al^{3+} fluoride: F^-	magnesium: Mg^{2+} nitride: N^{3-}
2. Determine the total charges needed to balance positive with negative.	Al^{3+}: $= +3$ F^-: $-1\ -1\ -1 = -3$	Mg^{2+}: $+\ 2\ +\ 2\ +\ 2 = +6$ N^{3-}: $-3\ -3 \quad = -6$
3. Note the ratio of positive ions to negative ions.	1 Al^{3+} ion for every 3 F^- ions	3 Mg^{2+} ions for every 2 N^{3-} ions
4. Use subscripts to write the formula. A "1" is not shown in the subscripts.	AlF_3	Mg_3N_2

Practice Problems

1. Write the formulas of the compounds containing the following ions.

(a) Na^+ with Br^-
(b) Zn^{2+} with I^-
(c) K^+ with S^{2-}
(d) Al^{3+} with S^{2-}
(e) Ca^{2+} with O^{2-}
(f) Al^{3+} with P^{3-}

2. Write the formulas of the following ionic compounds.

(a) strontium nitride
(b) lithium oxide
(c) silver sulfide
(d) barium phosphide
(e) sodium nitride
(f) potassium selenide
(g) cesium sulfide
(h) aluminum nitride
(i) zinc oxide
(j) aluminum iodide
(k) lithium fluoride
(l) sodium sulfide
(m) zinc phosphide
(n) magnesium chloride
(o) rubidium bromide

Answers provided on page 591

Compounds Containing a Multivalent Metal

You may recall from section 4.1 that some metals are multivalent, which means they can form ions in more than one way, depending on the situation. Multivalent metals can form two or more different positive ions with different ion charges. For example, find nickel (Ni) in the periodic table. The periodic table lists two ion charges, 2+ and 3+. This means that nickel is multivalent. In some compounds, the nickel ion is Ni^{2+}; in other compounds, the nickel ion is Ni^{3+}. The periodic table always lists the most common ion charge first. So for nickel, Ni^{2+} is more common than Ni^{3+}. An example of an ionic compound containing nickel is $NiCl_2$, used in some kinds of batteries (Figure 4.22).

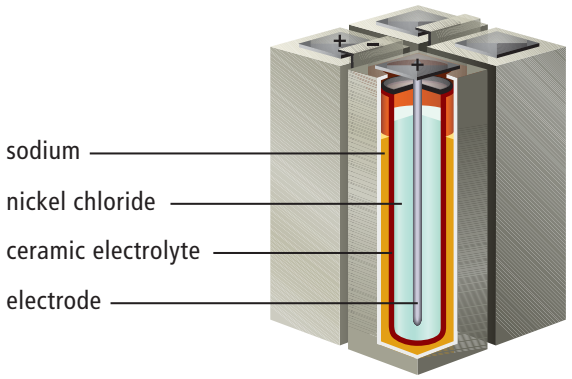


Figure 4.22 A Na-$NiCl_2$ battery, also called a zebra battery, operates at temperatures above 250°C and can be used to power vehicles.

To distinguish between two ions formed from multivalent metals, you need to name each ion. The name must contain the ion's charge. To indicate the charge, you use the Roman numerals from I to VII that correspond to ion charges from 1+ to 7+, as shown in Table 4.7. Examples of how to show the charge on ions include the following.

- Ni^{2+} or nickel(II) is called "nickel two" and shows the nickel ion has an ion charge of 2+.
- Ni^{3+} or nickel(III) is called "nickel three" and shows the nickel ion has an ion charge of 3+.
- V^{4+} or vanadium(IV) is called "vanadium four" and shows the vanadium ion has an ion charge of 4+. (The other valence for vanadium is 5+.)
- Au^{+} or gold(I) is called "gold one" and shows the gold ion has an ion charge of 1+. (The other valence for gold is 3+.)

What does a Roman numeral reveal about an ion of a metal? First, it tells you that there is more than one type of ion for that metal—the metal is multivalent. Second, it tells you the charge of the metal ion. Table 4.8 gives examples of names and formulas for some compounds containing a multivalent ion. Remember that the positive and negative charges on the ions must balance so that the overall charge on the compound is zero.

Table 4.7
Roman Numerals

Metal Ion Charge	Roman Numeral
1+	I
2+	II
3+	III
4+	IV
5+	V
6+	VI
7+	VII

Table 4.8
Some Compounds with Multivalent Metal Ions

Name	Formula
nickel(II) chloride	$NiCl_2$
nickel(III) chloride	$NiCl_3$
titanium(IV) oxide	TiO_2
lead(IV) sulfide	PbS_2
chromium(II) fluoride	CrF_2
chromium(III) fluoride	CrF_3
copper(I) nitride	Cu_3N
copper(I) phosphide	Cu_3P

Formulas of Compounds Containing a Multivalent Metal

Table 4.9 shows how to write the formula when you are given the name of a compound containing a multivalent metal. Figure 4.23 shows two examples of compounds containing a multivalent metal.

Figure 4.23 Although they are both made of copper and chlorine, copper(I) chloride has a greenish colour, whereas copper(II) chloride has a bluish colour.

Table 4.9 Writing Formulas of Compounds Containing a Multivalent Metal

Steps	Examples	
	manganese(IV) sulfide	**cobalt(III) oxide**
1. Identify each ion and its charge.	manganese(IV): Mn^{4+} sulfide: S^{2-}	cobalt(III): Co^{3+} oxide: O^{2-}
2. Determine the total charges needed to balance positive with negative.	Mn^{4+}: $= +4$ S^{2-} : $-2 \; -2 = -4$	Co^{3+}: $+ \; 3 \; + \; 3 \; = +6$ O^{2-}: $-2 \; -2 \; -2 = -6$
3. Note the ratio of positive ions to negative ions.	1 Mn^{4+} ion for every 3 S^{2-} ions	2 Co^{3+} ions for every 3 O^{2-} ions
4. Use subscripts to write the formula. A "1" is not shown in the subscripts.	MnS_2	Co_2O_3

Did You Know?

Roman numerals are numerals used by the ancient Romans for trade and commerce. The Romans did not have a numeral to represent zero.

Practice Problems

1. Write the formulas of the following compounds containing multivalent metals.
   (a) copper(I) nitride
   (b) iron(II) phosphide
   (c) manganese(II) oxide
   (d) manganese(IV) oxide
   (e) chromium(II) bromide
   (f) chromium(III) bromide
   (g) lead(IV) chloride
   (h) iron(III) phosphide
   (i) tin(II) sulfide
   (j) tin(II) nitride
   (k) tin(IV) nitride
   (l) mercury(II) fluoride
   (m) copper(I) iodide
   (n) copper(II) iodide
   (o) copper(II) selenide

Answers provided on page 591

Naming Compounds that Contain a Multivalent Metal

When you are writing the name of an ionic compound containing a multivalent metal, you need a Roman numeral to indicate the ion charge. Table 4.10 shows how to determine the correct Roman numeral.

Table 4.10 Naming Ionic Compounds Containing a Multivalent Metal

Steps	Examples	
	Au_3N	PdS_2
1. Identify the metal.	gold (Au)	palladium (Pd)
2. Verify that it can form more than one kind of ion by checking the periodic table.	Au^+ and Au^{3+}	Pd^{2+} and Pd^{4+}
3. Determine the ratio of the ions in the formula.	Au_3N means 3 gold ions for every 1 nitride ion.	PdS_2 means 1 palladium ion for every 2 sulfide ions.
4. Note the charge of the negative ion from the periodic table.	The charge on the N^{3-} ion is 3−.	The charge on the S^{2-} ion is 2−.
5. The positive and negative charges must balance out. Determine what the charge needs to be on the metal ion to balance the negative ion.	Each of the 3 gold ions must have a charge of 1+ to balance the 1 nitride ion with a charge of 3−. Therefore the name of the gold ion is gold(I).	The 1 palladium ion must have a charge of 4+ to balance the 2 sulfide ions that each have a charge of 2−. Therefore, the name of the palladium ion is palladium(IV).
6. Write the name of the compound.	gold(I) nitride	palladium(IV) sulfide

Practice Problems

Each of these compounds contains a multivalent metal ion. That means that the name of the metal ion will contain a Roman numeral, which you will need to determine. Write the names of the following compounds.

1. (a) Fe_2O_3
(b) PbF_4
(c) FeI_2
(d) HgI_2
(e) Hg_3N_2
(f) Sn_3P_4
(g) MnS
(h) MnS_2
(i) VCl_5
(j) Ni_2S_3
(k) NiS
(l) Mo_2O_3
(m) UCl_6
(n) ReF_7
(o) TiS_2

Answers provided on page 591

Did You Know?

Iron(III) oxide forms nanoparticles that change colour depending on the magnetic field they are exposed to. Research is being conducted to see whether this form of iron(III) oxide could be used in computer displays. Iron(III) oxide is cheap, abundant, and non-toxic.

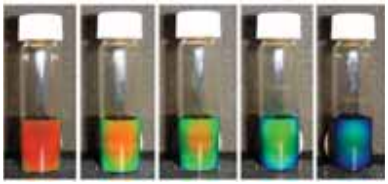


Figure 4.24 Shellfish, such as clams, use carbonate ions to make their shells.

Polyatomic Ions

A **polyatomic** ion is an ion composed of more than one type of atom joined by covalent bonds. Because polyatomic ions carry an electric charge, they cannot exist on their own. An example of a polyatomic ion is carbonate, CO_3^{2-} (Figure 4.24).

Table 4.11 lists some common polyatomic ions. The names of these ions were assigned by the IUPAC. You do not have to memorize them. Simply refer to the ion table to find a name and formula. Table 4.12 explains the steps for writing the formula of a compound with polyatomic ions.

Table 4.11 Names, Formulas, and Charges of Some Polyatomic Ions

Positive Ions	Negative Ions		
NH_4^+ ammonium	CH_3COO^- acetate	HCO_3^- hydrogen carbonate, bicarbonate	NO_2^- nitrite
	CO_3^{2-} carbonate	HSO_4^- hydrogen sulfate, bisulfate	ClO_4^- perchlorate
	ClO_3^- chlorate	HS^- hydrogen sulfide, bisulfide	MnO_4^- permanganate
	ClO_2^- chlorite	HSO_3^- hydrogen sulfite, bisulfite	PO_4^{3-} phosphate
	CrO_4^{2-} chromate	OH^- hydroxide	PO_3^{3-} phosphite
	CN^- cyanide	ClO^- hypochlorite	SO_4^{2-} sulfate
	$Cr_2O_7^{2-}$ dichromate	NO_3^- nitrate	SO_3^{2-} sulfite

Word Connect

"Poly-" means many. Per-, hypo-, -ate, and -ite are prefixes and suffixes that help indicate the number of oxygen atoms present in some polyatomic ions.

Table 4.12 Writing the Formula of a Compound with Polyatomic Ions

Steps	Examples	
	manganese(III) chlorate	**ammonium sulfate**
1. Identify each ion and its charge.	manganese(III): Mn^{3+} chlorate: ClO_3^-	ammonium: NH_4^+ sulfate: SO_4^{2-}
2. Determine the total charges needed to balance positive with negative.	Mn^{3+}: $= +3$ ClO_3^-: $-1\ -1\ -1 = -3$	NH_4^+: $+1\ +1 = +2$ SO_4^{2-}: $= -2$
3. Note the ratio of positive ions to negative ions.	1 Mn^{3+} ion for every 3 ClO_3^- ions	2 NH_4^+ ions for every 1 SO_4^{2-} ion
4. Use brackets around ions to correctly show the ratio of ions.	$(Mn)(ClO_3)_3$	$(NH_4)_2(SO_4)$
5. Use subscripts and brackets to write the formula. Omit brackets if only one ion is needed.	$Mn(ClO_3)_3$	$(NH_4)_2SO_4$

Notice the use of brackets in the formula to allow the ratio of ions to be shown correctly. Brackets are dropped if the ion is not polyatomic or if the ratio number outside the brackets is 1. However, when you read the formula, you should always remember that the ratio numbers and brackets are implied. For example, you would read Na_2CO_3 as sodium carbonate with two Na^+ ions for every one CO_3^{2-} ion.

Practice Problems

Refer to Table 4.11, Names, Formulas, and Charges of Some Polyatomic Ions, as you do these problems.

1. Write the names of the following compounds with polyatomic ions.

(a) KCH_3COO
(b) $Ca(CH_3COO)_2$
(c) $(NH_4)_3P$
(d) $(NH_4)_3PO_4$
(e) $Al(OH)_3$
(f) $Fe(OH)_3$
(g) K_2CrO_4
(h) $K_2Cr_2O_7$
(i) $Ca(HCO_3)_2$
(j) $Mg_3(PO_4)_2$

2. Write the formulas of the following compounds with polyatomic ions.

(a) potassium permanganate
(b) sodium chromate
(c) ammonium nitrate
(d) lithium hydroxide
(e) aluminum hydroxide
(f) lead(II) perchlorate
(g) iron(III) hydrogen sulfide
(h) vanadium(V) nitrate
(i) magnesium acetate
(j) tin(II) cyanide

Answers provided on page 591

Names and Formulas of Covalent Compounds

In a covalent compound, the precise number of atoms of each element in the molecule is shown by the chemical formula. For example, H_2O_2 is a covalent compound that may be familiar to you as a disinfectant. Its name is hydrogen peroxide. Each molecule of hydrogen peroxide has two hydrogen atoms and two oxygen atoms, for a total of four atoms in each molecule (Figure 4.25). Notice that the formula is not reduced to HO, as would be the case for an ionic compound. This is because the subscripts in a covalent compound have a different meaning than those in an ionic compound. In an ionic compound, subscripts are used to show the smallest whole-number ratio of the ions. In a covalent compound, the subscripts show the actual number of atoms of each element in the molecule.

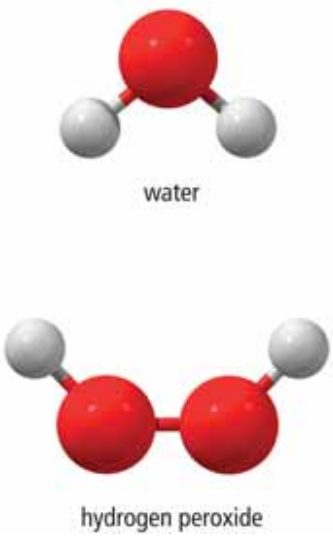


Figure 4.25 Water and hydrogen peroxide are both molecules.

Word Connect

"Binary" means involving two. For example, binary digits in computer technology are 0 and 1. Binary fission in biology involves reproduction by splitting into two parts.

Naming Binary Covalent Compounds

A **binary covalent compound** contains two non-metal elements joined together by one or more covalent bonds. Atoms in covalent compounds do not connect by forming ions. Instead, they combine chemically by sharing electrons in a covalent bond. A binary covalent compound can have many atoms, such as in $C_{25}H_{52}$, a main component of candle wax, or it can be diatomic (having only two atoms) as in ClF.

Prefixes indicate the numbers of atoms of each element that appear in the formula of binary covalent compounds. These prefixes are used for naming only covalent compounds. See Table 4.13 for a list of prefixes. Table 4.14 shows how to use these prefixes for naming binary covalent compounds that do *not* contain hydrogen.

Table 4.13 Prefixes Used in Naming Binary Covalent Compounds

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

Table 4.14 Writing the Names of Binary Covalent Compounds

Steps	Examples	
	CO	N_2O_3
1. Name the left most element in the formula first.	• The first element is C (carbon).	• The first element is N (nitrogen).
2. Name the second element, making sure the element name ends with the suffix "ide."	• The second element is O (oxygen). • It becomes oxide.	• The second element is O (oxygen). • It becomes oxide.
3. Add a prefix to each element's name to indicate the number of atoms of each element in the compound. Exceptions to rule 3: • If the first element has only one atom, do *not* add a prefix. • The prefix "mono-" is shortened to "mon-" if it is placed before "oxide."	• Do not use a prefix when there is only one atom of the first element. • The compound's name is carbon monoxide.	• There are two (di-) nitrogen atoms and three (tri-) oxygen atoms. • The compound's name is dinitrogen trioxide.

Steps for naming most compounds containing hydrogen are given in Chapter 5; however, three common binary compounds of hydrogen are listed in Table 4.15. These compounds were known before any standard naming system came into use.

Table 4.16 give some examples of hints you can use when you write the names of covalent compounds from their formulas. Remember, you do not use a subscript when there is only one atom.

Table 4.15 Common Binary Compounds of Hydrogen

Formula	Name
CH_4	methane
NH_3	ammonia
H_2O	water

Table 4.16 Hints for Writing Names of Binary Covalent Compounds

Formula	Name	Hints for Writing Names
CS_2	carbon disulfide	Do not use a prefix when there is only one atom of the first element.
CCl_4	carbon tetrachloride	Do not use a prefix when there is only one atom of the first element.
P_4O_{10}	tetraphosphorus decaoxide	Do not reduce the name to diphosphorus pentoxide.

Figure 4.26 Sulfur, shown here in Vancouver harbour, forms many useful industrial compounds. For example, carbon disulfide is produced commercially for use in making viscose material, cellophane film, insecticide, and rubber products.

Practice Problems

1. Write the names of the following compounds.
   (a) N_2O
   (b) CO_2
   (c) PI_3
   (d) PCl_5
   (e) SO_2
   (f) N_2O_4
   (g) P_4S_{10}
   (h) S_2F_{10}
   (i) NI_3
   (j) NO
2. Write the formulas of the following compounds.
   (a) nitrogen tribromide
   (b) sulfur hexafluoride
   (c) dinitrogen tetrasulfide
   (d) oxygen difluoride
   (e) carbon tetraiodide
   (f) sulfur trioxide
   (g) phosphorus pentabromide
   (h) diiodine hexachloride
   (i) dichlorine monoxide
   (j) xenon hexafluoride

Answers provided on page 591

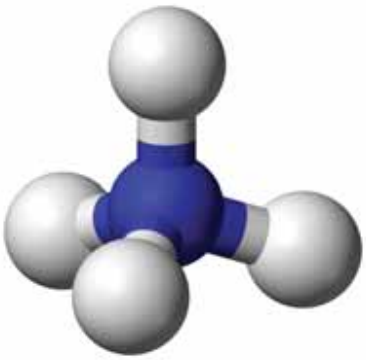


Figure 4.27 The positively charged ammonium ion forms four covalent bonds connecting the nitrogen to each hydrogen.

Comparing Ionic and Covalent Compounds

The formulas of ionic compounds and covalent compounds can look very similar. This makes naming them difficult if you are not sure which naming rules to use. The following tips are helpful for naming compounds.

1. **Examine the formula**
   - Ionic compounds begin with a metal or the ammonium ion (NH_4^+) as shown in Figure 4.27.
   - If the formula starts with a non-metal, it is likely that it is a covalent compound. There are special rules for compounds with hydrogen.
2. **If the compound is covalent**
   - If the covalent compound is binary (and does not begin with hydrogen), then use the prefix naming system. For example, P_2F_4 is binary because it has only two elements, and it is covalent because it begins with a non-metal. Using the prefix naming system, its name is diphosphorus tetrafluoride.
3. **If the compound is ionic**
   - If the positive ion is a metal, the periodic table will show whether it has one or more than one ion charge.
     - For a metal with only one form of ion, the ion simply takes the name of the element. For example, the name of Ba^{2+} is the barium ion.
     - For a metal with more than one form of ion (multivalent), a Roman numeral is added to the name of the first element (the metal). The Roman numeral indicates the ion's charge. For example, nickel has two common ion charges, so the name of Ni^{2+} is nickel(II), and the name of Ni^{3+} is nickel(III).
   - If the negative ion comes from a single non-metal atom (such as P^{3-}) then the name of the ion ends with the suffix "-ide." For example, K_3P is called potassium phosphide, and Fe_2O_3 is called iron(III) oxide.
   - If the negative ion is a polyatomic ion, look up the formula in Table 4.11, Names, Formulas, and Charges of Some Polyatomic Ions, on page 192. Use that name in the compound's name. Pay close attention to the endings (suffixes). Some examples include the following.
     $(NH_4)_2S$ is ammonium sulf**ide**
     $(NH_4)_2SO_4$ is ammonium sulf**ate**
     Na_2SO_4 is sodium sulf**ate**
     Na_2SO_3 is sodium sulf**ite**

Sodium sulfate and sodium sulfite are shown in Figure 4.28 on the next page.

Figure 4.28 Sodium sulfite (Na_2SO_3) is used to reduce chlorine levels in swimming pools and to prevent dried fruit from discolouring (A). Sodium sulfate (Na_2SO_4) shown in (B) as crystals, is used as a filler in laundry detergents, to remove air bubbles from molten glass, and to reduce negative charges on fabrics so dyes can penetrate evenly.

Practice Problems

1. Identify each of the following compounds as either ionic or covalent.
   (a) $(NH_4)_2S$
   (b) OCl_2
   (c) $SnCl_2$
   (d) $NaNO_3$
   (e) N_2O_3
   (f) SCl_2
   (g) NBr_3
   (h) FeF_2

2. The compounds in each group below have similar–looking formulas. However, they may have very different names. Some in each group are ionic, while others are covalent. Classify and name each compound.
   (a) VO_2, NO_2
   (b) $CrBr_2$, $CdBr_2$, SBr_2
   (c) $Na_2Cr_2O_7$, Na_2CrO_4, Cr_2O_3, N_2O_3
   (d) SO_3, Li_2SO_3, Li_2SO_4, SO_2
   (e) OCl_2, BeF_2, FeF_2
   (f) CO_2, $NaHCO_3$, $PbCO_3$

Answers provided on page 591

Suggested Activity

Conduct an Investigation 4-2B on page 198

Explore More

Most of the compounds you have been writing names and formulas for have some practical use. Discover the uses for $FeCl_3$, $CuSO_4$, and ZnO. Find out more at **www.bcscience10.ca**.

4-2B Combining Solutions of Ionic Compounds

SkillCheck

- Observing
- Predicting
- Communicating
- Working co-operatively

Safety

- Wear safety goggles and protective clothing.
- Handle chemicals safely.
- Follow your teacher's directions regarding using open flames.
- Avoid touching the chemical solutions and solids.
- Wash your hands and equipment thoroughly after completing this activity.
- Do not remove any materials from the science room.

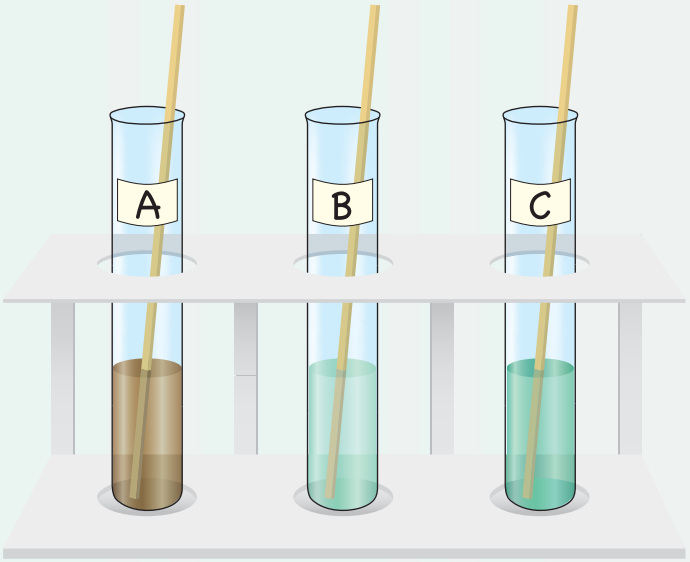
Materials

- masking tape
- marker
- 6 medium test tubes
- test tube rack
- iron(III) chloride solution ($FeCl_3$)
- nickel(II) chloride solution ($NiCl_2$)
- copper(II) chloride solution ($CaCl_2$)
- 4 long wooden splints
- sodium hydroxide solution (NaOH)
- glass stirring rod
- paper towel
- Bunsen burner
- ceramic pad
- brass test tube holder

You have been studying chemical names and formulas. Soon, you will study chemical equations, which show how elements and compounds combine to form new compounds. In this activity, you will combine solutions of ionic compounds and observe the results.

Question

What are some of the chemical and physical properties of some common ionic compounds?



Allow the wooden splints to soak for about 5 min.

Procedure

1. Create a table for your observations. Give your table a title.
2. Label three test tubes A, B, and C, and place in test tube rack. In test tube A, place iron(III) chloride solution to a depth of about 2 cm. In test tube B, place nickel(II) chloride solution to a depth of about 2 cm. In test tube C, place copper(II) chloride solution to a depth of about 2 cm.
3. Place a wooden splint into each of the three test tubes containing the solutions you have just poured. Allow them to soak for about 5 min. Label your wooden splints using the metal ion name. Set the wooden splints aside.
4. In each of three new test tubes, pour sodium hydroxide to a depth of about 2 cm. Place a wooden splint into one of these three new test tubes. Label the wooden splint as Na^+, and let it soak for about 5 min. Set the wooden splints aside.

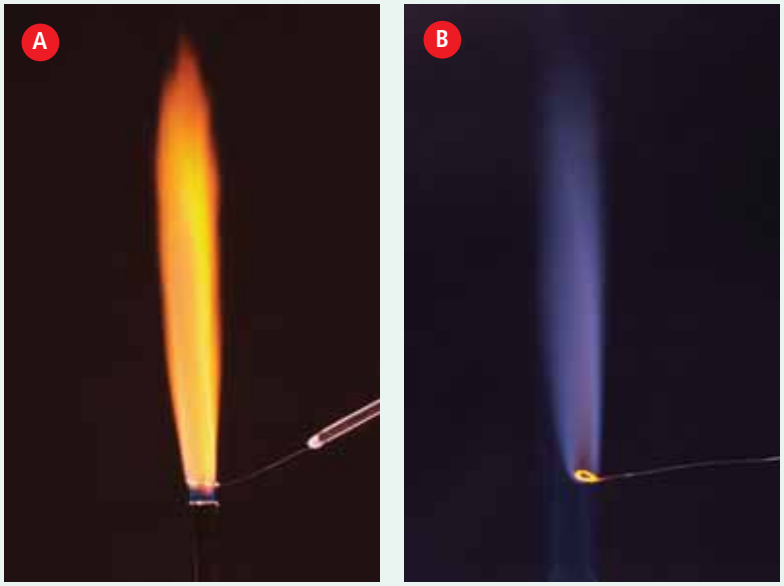
5. Take the three test tubes containing sodium hydroxide and pour their contents into each of the other three test tubes containing the chloride solutions and observe. Record your observations.
6. Mix each solution using a glass stirring rod, and allow to settle for several minutes. Then decant (pour off) the liquid into the designated waste container.
7. Using the glass stirring rod, scrape some of the solid from each test tube out onto a piece of paper towel. Examine the solid. Record your observations.
8. Set up a Bunsen burner. Place the soaked tip of each wooden splint into the flame of the Bunsen burner briefly until the flame takes on a colour due to the solution it soaked in. Note the colour in each case. Then make sure the wooden splints have stopped burning. Place the burned splints onto the ceramic pad.
9. Using the brass test tube holder, test each of the solids in the flame as well. Note the colour.
10. Clean up and put away the equipment you have used. Follow your teacher's instructions for disposal of wastes.

Analyze

1. Refer to your table of observations to help you describe the appearance of the solids when they first formed. Include the texture and colour in your answer.
2. How did the flame colours of the solutions compare with the flame colours of the solids?

Conclude and Apply

1. Each ionic compound name comes in two parts, the positive ion name and the negative ion name. When the solutions were combined, the ions involved in the two compounds also combined. Try predicting the names of the newly produced pure substances by recombining the names of the starting materials. List the possible names of the new compounds.
2. The flame test is a method that can identify the presence of certain ions, particularly metal ions. Using the results from the flame test, try to predict the name and formula of the solid in each of the three test tubes.

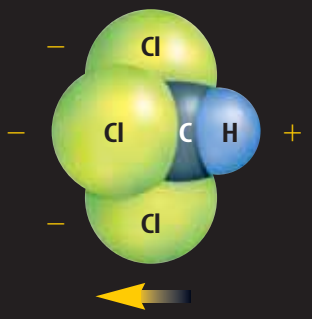


The colour of the flame is different for different elements and can be used to identify unknown substances. Calcium burns with an orange flame (A). Potassium has a lilac flame (B).

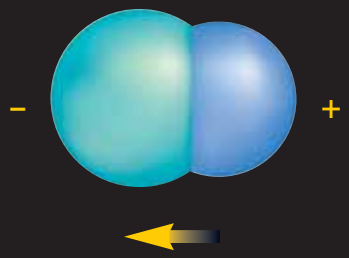
NATIONAL GEOGRAPHIC

Visualizing Polar Molecules

When playing tug-of-war, if there are more—or stronger—team members on one end of the rope than the other, there is an unequal balance of power. The stronger team can pull harder on the rope and has the advantage. A similar situation exists in polar molecules, in which electrons are attracted more strongly by one type of atom in the molecule than another. Because of this unequal sharing of electrons, polar molecules have a slightly negative end and a slightly positive end, as shown below.



In a molecule of chloroform ($CHCl_3$), or trichloromethane (tri klor oh ME thayn), the three chlorine atoms attract electrons more strongly than the hydrogen atom does. This creates a partial negative charge on the chlorine end of the molecule and a partial positive charge on the hydrogen end. Chloroform is a clear, sweet-smelling liquid once widely used as an anesthetic in human and veterinary surgery.



Hydrogen and fluorine react to form hydrogen fluoride (HF). In an HF molecule, the two atoms are bound together by a pair of electrons, one contributed by each atom. The electrons are not shared equally because the fluorine atom attracts them more strongly than the hydrogen atom does. The result is a polar molecule with a slightly positive charge near the hydrogen end and a slightly negative charge near the fluorine end.

Checking Concepts

1. List the information about a compound given by the name of:
   (a) an ionic compound
   (b) a covalent compound
2. Explain the following terms related to chemical naming.
   (a) multivalent
   (b) polyatomic
   (c) ratio of ions
3. List the prefixes used in covalent naming that represent the numbers 1 through 10.
4. Name each of the ions in the list below.
   (a) Na^+ (d) CN^-
   (b) SO_4^{2-} (e) NH_4^+
   (c) V^{4+} (f) O^{2-}
5. List which of the following words describes each ion in question 4: polyatomic ion, multivalent metal, negative ion, positive ion.
6. Copy and complete the following chart about polyatomic ions in your notebook.

	Formula	Name	Number of Each Kind of Atom	Total Number of Atoms	Electric Charge on the Ion
(a)	CH_3COO^-				
(b)	HSO_3^-				
(c)	PO_4^{3-}				
(d)	CrO_4^{2-}				
(e)	$Cr_2O_7^{2-}$				
(f)	MnO_4^-				

Understanding Key Ideas

7. Write the formula of each of the following ionic compounds.
   (a) sodium bromide
   (b) calcium fluoride
   (c) iron(III) bromide
   (d) gold(I) iodide
   (e) vanadium(V) oxide
   (f) molybdenum(III) nitride
   (g) ammonium phosphate
   (h) potassium nitrate
   (i) manganese(II) perchlorate
8. Write the name of each of the following ionic compounds.
   (a) LiF (e) Au_3N
   (b) MgI_2 (f) $Pt(SO_4)_2$
   (c) Fe_2O_3 (g) $(NH_4)_2CO_3$
   (d) Ag_3N (h) $CsNO_3$
9. Write the formula of each of the following covalent compounds.
   (a) sulfur dioxide
   (b) chlorine monofluoride
   (c) nitrogen triiodide
   (d) dinitrogen monoxide
   (e) dinitrogen tetraoxide
   (f) selenium difluoride
10. Write the name of each of the following covalent compounds.
    (a) PF_5 (e) XeO_3
    (b) P_4O_{10} (f) NO_2
    (c) CO (g) OF_2
    (d) SF_6
11. Copy and complete the following chart in your notebook.

	Formula	Ionic or Covalent?	Name of Compound
(a)	Cl_2O		
(b)	CO_2		
(c)	CoO		
(d)	CO		
(e)	PbO_2		
(f)	$MgCl_2$		
(g)	$PtCl_2$		
(h)	SCl_2		
(i)	$NaCH_3COO$		
(j)	NH_4CH_3COO		

Pause and Reflect

Reflect on the similarities and differences between ionic compounds and covalent compounds. Draw a mind map that shows both types of compounds and the steps for writing their chemical formulas. Include examples of compounds in your mind map.