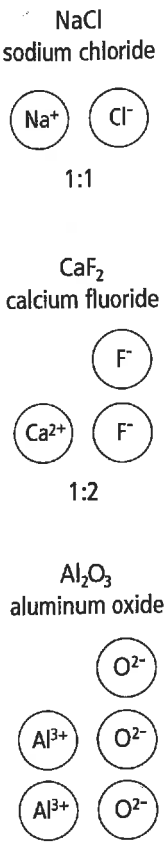

Figure 3.11 The formula and the diagram show the ratio of ions. Calcium fluoride has one Ca^{2+} ion for every two F^- ions. Aluminum oxide has two Al^{3+} and three O^{2-} ions.

The chemical formula

The **chemical formula** of an ionic compound contains symbols to identify each ion. It also shows the relative numbers of ions in the compound. These numbers are shown by a subscript set to the right of the element symbol. Figure 3.11 shows three examples.

- The metal ions in these examples are Na^+, Ca^{2+}, and Al^{3+}. Remember that these are ions, not atoms, when present in a compound. You can find their charges on the periodic table.
- The non-metal ions in these examples are Cl^-, F^-, and O^{2-}. You can also find their charges on the periodic table.

Rules for Writing the Names of Ionic Compounds

The rules for writing the name of an ionic compound from its formula are shown in Table 3.3, including two examples.

Table 3.3 Rules for Naming Ionic Compounds Containing Two Elements

Steps for Writing the Name	Examples	
	$MgBr_2$	Li_3N
1. Name the metal ion.	• The metal ion is Mg^{2+}. • The ion's name is given in the periodic table as magnesium.	• The metal ion is Li^+. • The ion's name is given in the periodic table as lithium.
2. Name the non-metal ion by ending the element name with the suffix "ide."	• The non-metal ion is Br^-. The element's name is bromine. • Changing the name to end with the suffix "-ide" gives bromide.	• The non-metal ion is N^{3-}. The element's name is nitrogen. • Changing the name to end with the suffix "-ide" gives nitride.
3. Write the name of the compound.	magnesium bromide	lithium nitride

Practice Problems

Write the names of the following compounds.

1. (a) AlI_3 (b) Na_2O (c) Mg_3P_2 (d) AgI (e) CaSe (f) K_2S (g) RbF (h) Ag_3N (i) KBr (j) Sr_3P_2 (k) CdS (l) Ag_2O (m) Cs_2S (n) CaI_2 (o) NaF

Answers provided on page 509

Rules for 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 use the ratio to write subscripts in the formula. Table 3.4 gives the rules and two examples.

Notice that the final formula must represent the smallest whole number ratio. For example, Sn^{4+} combining with O^{2-} is written SnO_2 and not Sn_2O_4.

Word Connect

The word "subscript" comes from the prefix "sub-," which means below, and "script," meaning to write. Subscripts are used in the formulas of ionic compounds to show the relative amounts of each ion.

Table 3.4 Rules for Writing Formulas of Ionic Compounds Containing Two Elements

Steps for Writing the Formula	Examples	
	zinc nitride	aluminum chloride
1. Identify each ion and its charge.	zinc: Zn^{2+} nitride: N^{3-}	aluminum: Al^{3+} chloride: Cl^-
2. Determine the total charges needed to balance positive with negative.	Zn^{2+}: $+2$ $+2$ $+2$ $= +6$ N^{3-}: -3 -3 $= -6$	Al^{3+} : $= +3$ Cl^-: -1 -1 -1 $= -3$
3. Note the ratio of positive ions to negative ions.	3 Zn^{2+} ions for every 2 N^{3-} ions	1 Al^{3+} ion for every 3 Cl^- ions
4. Use subscripts to write the formula. A "1" is not shown in the subscripts.	Zn_3N_2	$AlCl_3$

Practice Problems

1. Write the formulas of the compounds containing the following ions.
   - (a) Li^+ with Cl^-
   - (b) Ca^{2+} with F^-
   - (c) Na^+ with S^{2-}
   - (d) Ca^{2+} with S^{2-}
   - (e) Al^{3+} with O^{2-}
   - (f) Al^{3+} with N^{3-}
2. Write the formulas of the following compounds.
   - (a) lithium fluoride
   - (b) silver sulphide
   - (c) magnesium chloride
   - (d) zinc oxide
   - (e) lithium oxide
   - (f) aluminum iodide
   - (g) barium phosphide
   - (h) aluminum phosphide
   - (i) rubidium selenide
   - (j) strontium nitride
   - (k) cesium sulphide
   - (l) sodium nitride
   - (m) zinc phosphide
   - (n) calcium oxide

Answers provided on page 509

Suggested Activity

Think About It 3-2B on page 93

Writing the Formula

Table 3.7 shows how to write the formula when you are given the name of a compound containing a multivalent metal.

Table 3.7 Rules for Writing Formulas of Compounds Containing a Multivalent Metal

Steps for Writing the Formula	Examples	
	iron(III) sulphide	**lead(IV) oxide**
1. Identify each ion and its charge.	iron(III): Fe^{3+} sulphide: S^{2-}	lead(IV): Pb^{4+} oxide: O^{2-}
2. Determine the total charges needed to balance positive with negative.	Fe^{3+}: +3 +3 = +6 S^{2-} : −2 −2 −2 = −6	Pb^{4+}: = +4 O^{2-}: −2 −2 = −4
3. Note the ratio of positive ions to negative ions.	2 Fe^{3+} ions for every 3 S^{2-} ions	1 Pb^{4+} ion for every 2 O^{2-} ions
4. Use subscripts to write the formula. A "1" is not shown in the subscripts.	Fe_2S_3	PbO_2

Practice Problems

1. Write the formulas of the following compounds.

(a) chromium(II) chloride
(b) chromium(III) chloride
(c) copper(I) sulphide
(d) copper(I) iodide
(e) iron(II) phosphide
(f) iron(III) phosphide
(g) manganese(II) oxide
(h) manganese(IV) oxide
(i) mercury(II) bromide
(j) tin(II) sulphide
(k) tin(II) nitride
(l) tin(IV) nitride
(m) copper(I) nitride
(n) lead(IV) chloride

Answers provided on page 509

Writing the Name

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 3.8 shows how to determine the correct Roman numeral.

Table 3.8 Naming Ionic Compounds Containing a Multivalent Metal

Steps for Writing the Name	Examples	
	Cu_3P	MnO_2
1. Identify the metal.	copper (Cu)	manganese (Mn)
2. Verify that it can form more than one kind of ion by checking the periodic table.	Cu^{2+} and Cu^{+}	Mn^{2+}, Mn^{3+}, and Mn^{4+}
3. Determine the ratio of the ions in the formula.	Cu_3P means 3 copper ions for every 1 phosphide ion.	MnO_2 means 1 manganese ion for every 2 oxide ions.
4. Note the charge of the negative ion from the periodic table.	The charge on the phosphide P^{3-} is 3−.	The charge on the oxide O^{2-} 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 copper ions must have a charge of 1+ to balance the 1 phosphide ion with a charge of 3−. Therefore the name of the copper ion is copper(I).	The 1 manganese ion must have a charge of 4+ to balance the 2 oxide ions that each have a charge of 2−. Therefore, the name of the manganese ion is manganese(IV).
6. Write the name of the compound.	copper(I) phosphide	manganese(IV) oxide

Practice Problems

1. 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.

(a) $CrBr_2$
(b) $CrBr_3$
(c) FeI_2
(d) FeI_3
(e) PbF_2
(f) PbF_4
(g) MnO
(h) PbS
(i) Fe_2O_3
(j) Hg_3P_2
(k) Hg_3N_2
(l) HgI_2
(m) MnS
(n) MnS_2
(o) Sn_3P_4

Answers provided on page 509.

Polyatomic Ions

You learned in section 3.1 that some molecules gain or lose one or more electrons and become polyatomic ions. Because a polyatomic ion carries an electric charge, it cannot exist on its own. It is always paired up with ions that carry an opposite charge. Table 3.9 shows you how to write the formulas for compounds with polyatomic ions.

Table 3.9 Steps for Writing the Formula of a Compound with Polyatomic Ions

Steps for Writing the Formula	Examples	
	iron(III) hydroxide	ammonium carbonate
1. Identify each ion and its charge.	iron(III): Fe^{3+} hydroxide: OH^-	ammonium: NH_4^+ carbonate: CO_3^{2-}
2. Determine the total charges needed to balance positive with negative.	Fe^{3+}: $= 3+$ OH^{-1}: $-1\ -1\ -1 = 3-$	NH_4^+: $+1\ +1 = 2+$ CO_3^{2-}: $= 2-$
3. Note the ratio of positive ions to negative ions.	1 Fe^{3+} ion for every 3 OH^- ions	2 NH_4^+ ions for every 1 CO_3^{2-} ion
4. Use subscripts and brackets to write the formula. Omit brackets if only one ion is needed.	$Fe(OH)_3$	$(NH_4)_2CO_3$

Practice Problems

Refer to Table 3.10 on page 92 as you do these problems.

1. Write the names of the following compounds.

(a) $NaCH_3COO$
(b) $Ca(CH_3COO)_2$
(c) $Cr(CH_3COO)_3$
(d) $Al(OH)_3$
(e) $Cr(OH)_3$
(f) $(NH_4)_3P$
(g) $(NH_4)_3PO_4$
(h) $CaSO_4$
(i) $Mg_3(PO_4)_2$
(j) $Ba_3(PO_3)_2$

2. Write the formulas of the following compounds.

(a) sodium chromate
(b) potassium permanganate
(c) lithium dichromate
(d) sodium hydroxide
(e) magnesium hydroxide
(f) ammonium nitrate
(g) tin(II) hydroxide
(h) lead(II) hydroxide
(i) aluminum nitrate
(j) manganese(IV) sulphate

Answers provided on page 509

Did You Know?

All medicines come with a list of ingredients like the one shown below. The list includes the chemical name of the medicine. The chemical name allows you to compare products that have different brand names but contain the same active (medicinal) ingredient. Non-medicinal ingredients may improve the taste, act as filler to make the dose large enough to handle, or increase shelf life.

Common Polyatomic Ions

There are many polyatomic ions. Table 3.10 lists some common ones. The names of these ions were assigned by the IUPAC. You do not have to memorize them. Simply refer to this table to find a name and formula.

Table 3.10 Common Polyatomic Ions

Name	Formula
acetate	CH_3COO^-
ammonium	NH_4^+
carbonate	CO_3^{2-}
chlorate	ClO_3^-
chlorite	ClO_2^-
chromate	CrO_4^{2-}
cyanide	CN^-
dichromate	$Cr_2O_7^{2-}$
hydrogen carbonate	HCO_3^-
hydrogen sulphate	HSO_4^-
hydrogen sulphide	HS^-
hydrogen sulphite	HSO_3^-
hydroxide	OH^-
hypochlorite	ClO^-
nitrate	NO_3^-
nitrite	NO_2^-
perchlorate	ClO_4^-
permanganate	MnO_4^-
phosphate	PO_4^{3-}
phosphite	PO_3^{3-}
sulphate	SO_4^{2-}
sulphite	SO_3^{2-}

Ammonium (NH_4^+) and nitrate (NO_3^-) are present in fertilizers. They are both produced from ammonia (NH_3), which you may be familiar with as window cleaner. Find out about the Haber process for the production of ammonia. Begin your research at **www.bcscience9.ca**.

Reading Check

1. In Table 3.10, find the following:
   (a) the formula of an ion with a positive charge
   (b) the formulas of all four ions made of only two atoms
   (c) the name of the ion that contains nine atoms
   (d) the formula of the ion containing three elements and six atoms
   (e) the formula of the ion containing three elements and having a charge of 2−
   (f) the names and formulas of two ions containing nitrogen and oxygen
   (g) the charge on the ion containing four hydrogen atoms
2. Find all four ions in Table 3.10 that contain a chlorine atom, and write their formulas in descending order according to the number of oxygen atoms in each one.