4.1 Representing Ionic Compounds

Think about all the paper products you encounter in your daily life. Paper is used for countless purposes throughout our society. Even with current recycling initiatives, however, paper is often wasted and taken for granted.

Paper is made with fibres that can come from wood, plants, or recycled paper. Historically, paper manufacturing required a large supply of trees and energy, and produced large amounts of pollutants, as shown in **Figure 4.1**. Paper manufacturing is estimated to be the source of 50 percent of the waste that is dumped in Canada's waterways. Many **ionic compounds** are used to produce paper. More recently, stronger regulations and more effective recycling and treatment of waste materials have helped to reduce the environmental impact of paper manufacturing. The goal is to build zero-emission pulp and paper mills, in which all wastes are recovered. For example, ionic compounds such as sodium carbonate (Na_2CO_3) and calcium oxide (CaO) are used in the recovery of chemicals from the pulping process.

Key Terms

- ionic compound
- ion
- cation
- anion
- valence electron
- binary ionic compound
- polyatomic ion
- ternary compound

ionic compound a compound composed of oppositely charged ions

Suggested Investigation

Inquiry Investigation 4-A, Monitoring Paper Recycling, on page 169

Figure 4.1 This pulp and paper mill in Thunder Bay, Ontario, produces useful products. It also produces solid, liquid, and gas wastes.

Forming Ionic Compounds

ion a charged particle formed from the loss or gain of one or more electrons

cation a positively charged ion

anion a negatively charged ion

Elements can combine to make ionic compounds when their atoms lose or gain electrons, becoming charged particles called **ions**. When atoms lose electrons, they form positively charged ions called **cations**. When atoms gain electrons, they form negatively charged ions called **anions**.

When an ionic compound forms, one or more electrons from one atom are transferred to another atom. An ionic bond forms between oppositely charged ions, creating a neutral compound. The loss and gain of electrons allows each atom to form a full outer energy level of electrons and, therefore, become more stable. Scientists often refer to this arrangement as a *stable octet*. This is because all noble gases, except helium, have eight electrons in their outer energy level. Recall that noble gases are the least reactive (most stable) elements.

The Periodic Table and Ion Formation

Ionic compounds are usually composed of the ions of a metal and one or more non-metals. As shown in **Figure 4.2**, metals are found on the left-hand side of the periodic table. They tend to lose electrons to form cations. Non-metals, except for hydrogen, are found on the right-hand side of the periodic table and tend to gain electrons to form anions.

valence electron an electron in the outermost occupied energy level

Recall from your previous studies that there are patterns related to the arrangement of electrons in atoms in the periodic table. One important pattern involves the number of **valence electrons**—electrons in the outer energy level. **Figure 4.3** shows how elements in the same group have the same number of valence electrons. For example, all the elements in Group 1 have one valence electron, while all the elements in Group 17 have seven valence electrons. Valence electrons are involved in the chemical bonding between elements. Therefore, knowing the number of valence electrons helps you predict the formation of compounds, name the compounds that are formed, and write the chemical formulas for the compounds.

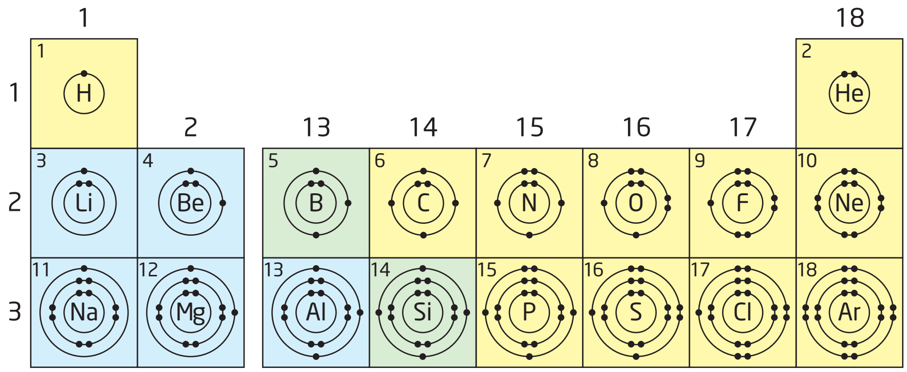
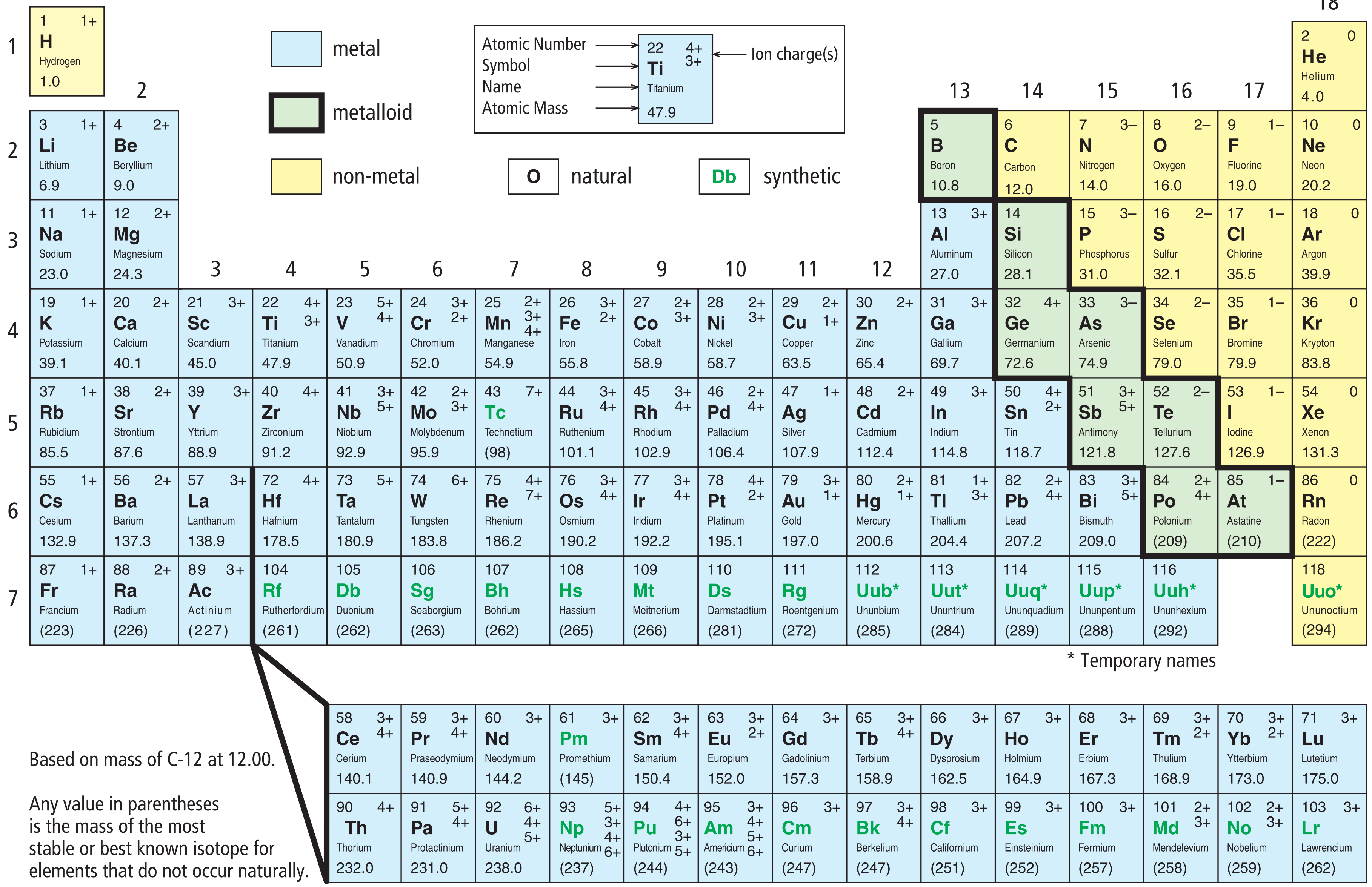


Figure 4.3 The atoms of the elements in each group share a common property: they all have the same number of valence electrons.

Periodic Table of the Elements



🟦 metal

▨ metalloid

🟨 non-metal

O natural

Db synthetic

Atomic Number → 22
Symbol → Ti
Name → Titanium
Atomic Mass → 47.9
4+ 3+ ← Ion charge(s)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1+ **H** Hydrogen 1.0																	2 0 **He** Helium 4.0
2	3 1+ **Li** Lithium 6.9	4 2+ **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 3– **N** Nitrogen 14.0	8 2– **O** Oxygen 16.0	9 1– **F** Fluorine 19.0	10 0 **Ne** Neon 20.2
3	11 1+ **Na** Sodium 23.0	12 2+ **Mg** Magnesium 24.3											13 3+ **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 3– **P** Phosphorus 31.0	16 2– **S** Sulfur 32.1	17 1– **Cl** Chlorine 35.5	18 0 **Ar** Argon 39.9
4	19 1+ **K** Potassium 39.1	20 2+ **Ca** Calcium 40.1	21 3+ **Sc** Scandium 45.0	22 4+ 3+ **Ti** Titanium 47.9	23 5+ 4+ **V** Vanadium 50.9	24 3+ 2+ **Cr** Chromium 52.0	25 2+ 3+ 4+ **Mn** Manganese 54.9	26 3+ 2+ **Fe** Iron 55.8	27 2+ 3+ **Co** Cobalt 58.9	28 2+ 3+ **Ni** Nickel 58.7	29 2+ 1+ **Cu** Copper 63.5	30 2+ **Zn** Zinc 65.4	31 3+ **Ga** Gallium 69.7	32 4+ **Ge** Germanium 72.6	33 3– **As** Arsenic 74.9	34 2– **Se** Selenium 79.0	35 1– **Br** Bromine 79.9	36 0 **Kr** Krypton 83.8
5	37 1+ **Rb** Rubidium 85.5	38 2+ **Sr** Strontium 87.6	39 3+ **Y** Yttrium 88.9	40 4+ **Zr** Zirconium 91.2	41 3+ 5+ **Nb** Niobium 92.9	42 2+ 3+ **Mo** Molybdenum 95.9	43 7+ **Tc** Technetium (98)	44 3+ 4+ **Ru** Ruthenium 101.1	45 3+ 4+ **Rh** Rhodium 102.9	46 2+ 4+ **Pd** Palladium 106.4	47 1+ **Ag** Silver 107.9	48 2+ **Cd** Cadmium 112.4	49 3+ **In** Indium 114.8	50 4+ 2+ **Sn** Tin 118.7	51 3+ 5+ **Sb** Antimony 121.8	52 2– **Te** Tellurium 127.6	53 1– **I** Iodine 126.9	54 0 **Xe** Xenon 131.3
6	55 1+ **Cs** Cesium 132.9	56 2+ **Ba** Barium 137.3	57 3+ **La** Lanthanum 138.9	72 4+ **Hf** Hafnium 178.5	73 5+ **Ta** Tantalum 180.9	74 6+ **W** Tungsten 183.8	75 4+ 7+ **Re** Rhenium 186.2	76 3+ 4+ **Os** Osmium 190.2	77 3+ 4+ **Ir** Iridium 192.2	78 4+ 2+ **Pt** Platinum 195.1	79 3+ 1+ **Au** Gold 197.0	80 2+ 1+ **Hg** Mercury 200.6	81 1+ 3+ **Tl** Thallium 204.4	82 2+ 4+ **Pb** Lead 207.2	83 3+ 5+ **Bi** Bismuth 209.0	84 2+ 4+ **Po** Polonium (209)	85 1– **At** Astatine (210)	86 0 **Rn** Radon (222)
7	87 1+ **Fr** Francium (223)	88 2+ **Ra** Radium (226)	89 3+ **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 **Ds** Darmstadium (281)	111 **Rg** Roentgenium (272)	112 **Uub*** Ununbium (285)	113 **Uut*** Ununtrium (284)	114 **Uuq*** Ununquadium (289)	115 **Uup*** Unupentium (288)	116 **Uuh*** Ununhexium (292)		118 **Uuo*** Ununoctium (294)
					58 3+ 4+ **Ce** Cerium 140.1	59 3+ 4+ **Pr** Praseodymium 140.9	60 3+ **Nd** Neodymium 144.2	61 3+ **Pm** Promethium (145)	62 3+ 4+ **Sm** Samarium 150.4	63 3+ 2+ **Eu** Europium 152.0	64 3+ **Gd** Gadolinium 157.3	65 3+ 4+ **Tb** Terbium 158.9	66 3+ **Dy** Dysprosium 162.5	67 3+ **Ho** Holmium 164.9	68 3+ **Er** Erbium 167.3	69 3+ 2+ **Tm** Thulium 168.9	70 3+ 2+ **Yb** Ytterbium 173.0	71 3+ **Lu** Lutetium 175.0
					90 4+ **Th** Thorium 232.0	91 5+ 4+ **Pa** Protactinium 231.0	92 6+ 4+ 5+ **U** Uranium 238.0	93 5+ 3+ 4+ 6+ **Np** Neptunium (237)	94 4+ 6+ 3+ 5+ **Pu** Plutonium (244)	95 3+ 4+ 5+ 6+ **Am** Americium (243)	96 3+ **Cm** Curium (247)	97 3+ 4+ **Bk** Berkelium (247)	98 3+ **Cf** Californium (251)	99 3+ **Es** Einsteinium (252)	100 3+ **Fm** Fermium (257)	101 2+ 3+ **Md** Mendelevium (258)	102 2+ 3+ **No** Nobelium (259)	103 3+ **Lr** Lawrencium (262)

* Temporary names

Based on mass of C-12 at 12.00.

Any value in parentheses
is the mass of the most
stable or best known isotope for
elements that do not occur naturally.

Figure 4.2 The periodic table includes information about the ion(s) that each element forms.

Naming Binary Ionic Compounds

binary ionic compound a compound composed of a metal cation and a non-metal anion

There are two ways to identify a compound: by its chemical name and by its chemical formula. An organization called the International Union of Pure and Applied Chemistry (IUPAC) develops rules for naming compounds so that scientists throughout the world can use the same names for the same compounds. The chemical names of all ionic compounds have two parts—one part for each type of ion. The following rules are used to name **binary ionic compounds**, which are composed of only two different elements:

Rules for Naming Binary Ionic Compounds

1. The first part of the name *always* identifies the positive ion, which is the metal cation. Thus, this part of the name is the name of the metal.
2. The second part of the name *always* identifies the negative ion, which is the non-metal anion. The name of the non-metal ion always ends with the suffix *-ide*. Some examples are provided in **Table 4.1**.

Table 4.1 Examples of Names of Non-Metal Ions

Name	Symbol
fluoride	F^-
chloride	Cl^-
oxide	O^{2-}
sulfide	S^{2-}
nitride	N^{3-}
phosphide	P^{3-}

A few names of simple ionic compounds, as well as the elements that form them, are given in **Table 4.2**. Notice the name of an ionic compound that you are very familiar with—sodium chloride, or table salt, shown in **Figure 4.4**.

Table 4.2 Examples of Names of Ionic Compounds

Elements in Ionic Compound	Name of Ionic Compound
magnesium and phosphorus	magnesium phosphide
sodium and chlorine	sodium chloride (table salt)
calcium and bromine	calcium bromide
aluminum and oxygen	aluminum oxide

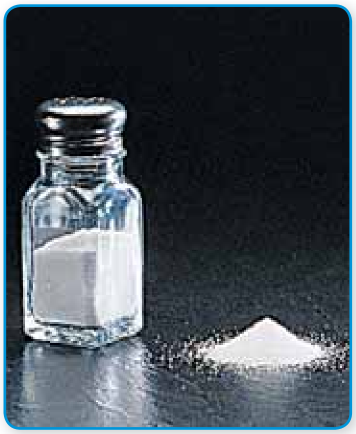


Figure 4.4 Table salt is an ionic compound composed of sodium cations and chloride anions.

Learning Check

1. Why is knowing the number of valence electrons important in chemical bonding?
2. When naming a binary ionic compound, what suffix is used in the part of the name that represents the anion?
3. Write the names of the following binary ionic compounds.
   - **a.** $MgBr_2$
   - **b.** CaI_2
   - **c.** Al_2O_3
   - **d.** KCl
4. Why is it important to provide rules for naming compounds? Provide an example from your own life that illustrates your reason.

Determining the Chemical Formula for an Ionic Compound

A binary ionic compound forms when electrons are transferred from a metal to a non-metal. The number of electrons that are given up by the metal must equal the number of electrons that are gained by the non-metal.

For example, one electron is transferred from one sodium atom to one chlorine atom to form sodium chloride. Many binary ionic compounds, however, do not form in a 1:1 ratio of ions to achieve a stable octet of valence electrons. Examine the Bohr-Rutherford models in **Figure 4.5** to see the transfer of electrons between aluminum and chlorine atoms. The aluminum atom can give away its electrons only when there is just the right number of atoms to receive them. In this example, one atom of aluminum forms an ionic compound with three atoms of chlorine.

In the following activity, you will model the transfer of electrons between metal atoms and non-metal atoms and relate this to the chemical formulas for ionic compounds.

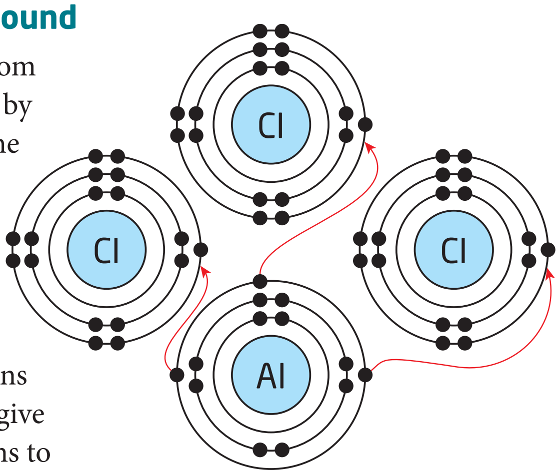


Figure 4.5 The three valence electrons of an aluminum atom can transfer over to three chlorine atoms, forming aluminum chloride.

Activity 4-2

Take My Electron–Please!

In this activity, you will use circular objects to represent electrons and to model the formation of ionic compounds. Based on what you know about ionic compounds, what must happen to the electrons?

Materials

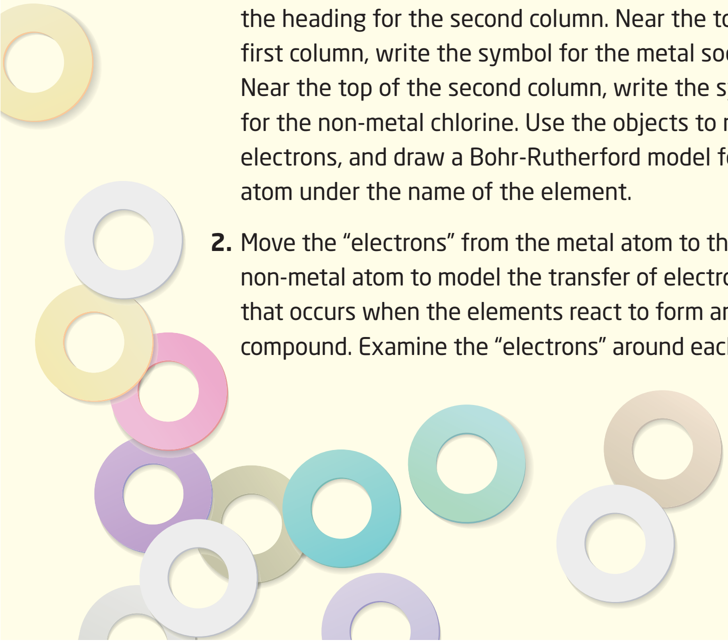
- bag that contains small circular objects (such as washers or coloured paper reinforcements) to mimic valence electrons

Procedure

1. Make two columns on a sheet of paper. Write "Metal" as the heading for the first column and "Non-metal" as the heading for the second column. Near the top of the first column, write the symbol for the metal sodium. Near the top of the second column, write the symbol for the non-metal chlorine. Use the objects to represent electrons, and draw a Bohr-Rutherford model for each atom under the name of the element.
2. Move the "electrons" from the metal atom to the non-metal atom to model the transfer of electrons that occurs when the elements react to form an ionic compound. Examine the "electrons" around each symbol.
   - If the metal has no "electrons" remaining in its original outer level and the non-metal now has eight "electrons" in its outer level, then the transfer is complete. If your model does not represent this, continue modelling electron transfer until it does.
3. Record the names of the elements and the ratio of the ions needed to complete the transfer of electrons. For sodium and chlorine, the ratio is 1:1.
4. Write the chemical formula for the binary ionic compound formed by writing the symbol for the metal followed by the symbol for the non-metal and using the numbers of ions in the ratio as subscripts. The chemical formula for the compound formed by sodium and chlorine is NaCl.
5. Repeat steps 1 to 4 for each of the following pairs of elements: (a) magnesium and fluorine, (b) lithium and nitrogen, and (c) aluminum and sulfur.

Questions

1. For each pair of elements, compare the total number of electrons lost by the metal atoms to the total number of electrons gained by the non-metal atoms. Describe the pattern, and explain why it must be so.
2. "An ion has a charge, but an ionic compound has no charge." Based on your models, what evidence supports this statement?



Determining Chemical Formulas for Binary Ionic Compounds

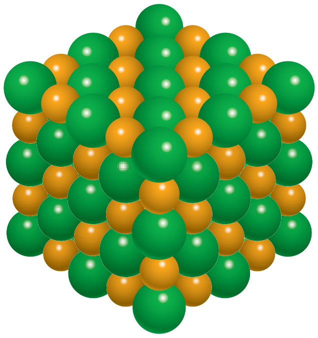


Figure 4.6 The crystal of an ionic solid, as shown in this model, is made up of many ions that are arranged in a repeating pattern in three dimensions.

Recall that ionic compounds tend to be solid at room temperature and exist as *crystal lattices*. The ions in a crystal lattice are organized in a large repeating array, as shown in the model of sodium chloride in **Figure 4.6**. There are no individual particles of sodium chloride in the crystal. Therefore, to write the chemical formula for an ionic compound, you use the ratio of the ions that make up the crystal.

Figure 4.7 shows one way that you can determine the chemical formula for an ionic compound based on the name of the compound, knowledge of the valence electrons for each atom, and the ion charge that each atom forms. Since ionic compounds are neutral, the sum of the positive and negative charges from the ions must be zero. Therefore, the correct ratio of ions must be determined so that the net charge of the compound is zero.

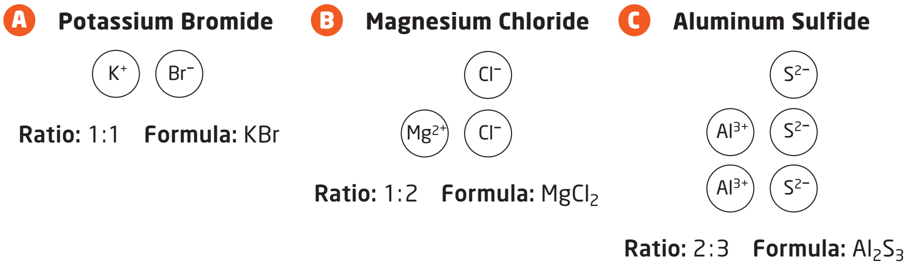


Figure 4.7 By using models of the ions, as shown, the number of each ion needed for the compound to have a total charge of zero can be determined.

The symbols and charges of several non-metal ions are shown in **Table 4.3**. Remember that the charge of each anion represents the number of electrons that the atom gains, which is related to the element's group in the periodic table. According to the same principles, the charge of each cation represents the number of electrons that the atom loses, which is related to the element's group in the periodic table. Therefore, it is important to understand the relationship between loss and gain of electrons and position of the element in the periodic table.

Once you have determined the ratio of ions, you can write the chemical formula by writing the symbol for the cation with a subscript to show how many cations are needed, followed by the symbol for the anion with a subscript to show how many anions are needed. If only one ion is needed, do not write a subscript—the subscript is understood to be the number 1.

Table 4.3 Charges and Symbols of Some Non-metal Ions

Symbol	Group	Electrons Gained
F^-	17	1
Cl^-	17	1
Br^-	17	1
O^{2-}	16	2
S^{2-}	16	2
N^{3-}	15	3
P^{3-}	15	3

Writing Chemical Formulas for Binary Ionic Compounds

The steps to follow when writing the chemical formula for a binary ionic compound from its name are summarized in **Table 4.4**. As you read through the steps, look at how each one applies to the examples in the table.

Table 4.4 How to Write the Chemical Formula for a Binary Ionic Compound

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 positive charge and the total negative charge needed to equal zero.	Al^{3+}:3+ = 3+ F^{-}:3(1–) = 3– (3+) + (3–) = 0	Mg^{2+}:3(2+) = 6+ N^{3-}:2(3–) = 6– (6+) + (6–) = 0
3. Note the ratio of cations to anions.	$1Al^{3+}:3F^{-}$	$3Mg^{2+}:2N^{3-}$
4. Use subscripts to show the ratio of ions.	AlF_3	Mg_3N_2

Using the Cross-Over Method

Another way to determine the chemical formula for an ionic compound, which is also useful to check that a formula you have written has balanced charges, is to use the *cross-over method*.

- Write the ions beside each other.
- Take the amount of charge (ignoring the sign) from the cation and make this number the subscript for the anion in your formula.
- Take the amount of charge (again, ignoring the sign) from the anion and make this number the subscript for the cation in your formula.

The following example shows how to use the cross-over method to write the chemical formulas for two ionic compounds.

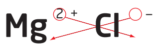
Study Toolkit

Skim, Scan, or Study

To help you determine how carefully you should read the material, identify the purpose of **Table 4.4**. Then describe a suitable reading approach, based on the options listed on page 138.

Writing the Chemical Formula for Magnesium Chloride

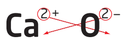
Determine the subscripts by "crossing over" the amount of charge from each ion. Remember that you do not write the number 1.



$MgCl_2$

Writing the Chemical Formula for Calcium Oxide

Cross over the amount of charge from each ion.



Ca_2O_2

Express the ratio in simplest form. In this case, that is 1:1.

CaO

Learning Check

5. Describe what happens to aluminum's valence electrons in **Figure 4.5**.

6. Draw Bohr-Rutherford diagrams to show why $MgCl_2$ is the correct chemical formula for the ionic compound formed in a reaction between magnesium and chlorine.

7. Show how the total charge of the following compounds is zero.
   - **a.** sodium oxide
   - **b.** lithium nitride
   - **c.** aluminum iodide
   - **d.** barium phosphide

8. Write the chemical formula for each binary ionic compound.
   - **a.** potassium sulfide
   - **b.** lithium selenide
   - **c.** zinc oxide
   - **d.** rubidium bromide
   - **e.** cesium sulfide
   - **f.** strontium nitride

Multivalent Metals

You may have noticed that some metals have more than one ion charge listed in the periodic table. These elements, called *multivalent metals*, can form different ions, depending on the chemical reaction they undergo. For example, copper can form ions with a 1+ or 2+ charge, as shown in **Figure 4.8**. To distinguish between the ions, a Roman numeral is written after the name of the metal. For example, Cu^{+} is written as copper(I), called "copper one." Cu^{2+} is written as copper(II), called "copper two." The charge of the most common ion that a multivalent metal forms is listed at the top of the element's box in the periodic table.

Figure 4.8 Although both of these compounds contain copper and oxygen, copper(II) oxide is black, while copper(I) oxide is red. This colour difference is evidence that they are different compounds with different chemical and physical properties.

Writing Chemical Formulas and Naming Ionic Compounds with a Multivalent Metal

To write the chemical formula for a compound that contains a multivalent ion, based on the name of the compound, the same steps that were used for binary ionic compounds apply (see **Table 4.4** on page 145).

When naming a compound that contains a multivalent ion, you must include a Roman numeral to show which charge the ion has. **Table 4.5** contains the symbols for Roman numerals that apply to multivalent ions. To determine this charge, you must work back from the charge of the anion, as shown in **Table 4.6**.

Table 4.5 Roman Numerals

Number	Roman Numeral
1	I
2	II
3	III
4	IV
5	V
6	VI
7	VII

Table 4.6 Naming an Ionic Compound That Contains a Multivalent Metal

	Examples	
Steps	Cu_3N	SnS_2
1. Identify the metal.	copper (Cu)	tin (Sn)
2. Verify that the metal can form more than one kind of ion by checking the periodic table.	Cu^+ and Cu^{2+}	Sn^{2+} and Sn^{4+}
3. Determine the ratio of the ions in the chemical formula.	3 copper:1 nitride	1 tin:2 sulfide
4. Note the charge of the anion.	3–	2–
5. The positive and negative charges must balance out so that the net charge is zero.	Total negative charge: 3– Total positive charge: 3+	Total negative charge: 4– Total positive charge: 4+
6. Determine what charge the metal ion must have to balance the anion.	$3(Cu^?) = 3+$ Therefore, the charge on the copper must be 1+.	$1(Sn^?) = 4+$ Therefore, the charge on the tin must be 4+.
7. Write the name of the metal ion.	The name of the metal ion is copper(I).	The name of the metal ion is tin(IV).
8. Write the name of the compound.	copper(I) nitride	tin(IV) sulfide

Using the Reverse of the Cross-Over Method

You can also use the reverse of the cross-over method to determine the charge of a multivalent metal ion. Be aware, however, that this method may result in an error unless you check that the charge of the anion is correct.

Determining the Name of FeO

Add the charge signs for each ion.

The charge of the oxide ion is not correct, which means that the subscripts were reduced.

Fe^{+} O^{-}

The oxide ion should be O^{2-}. Therefore, double the charge of each ion. The iron ion is Fe^{2+}, so the name of FeO is iron(II) oxide.

Fe^{2+} O^{2-}

Ionic Compounds with Polyatomic Ions

polyatomic ion an ion that is composed of more than one atom

ternary compound a compound composed of three different elements

The beautiful shells in **Figure 4.9** are made from the ionic compound calcium carbonate. Notice that the name of this compound ends in *-ate*. The carbonate ion is composed of carbon and oxygen. An ion, such as carbonate, that is composed of more than one atom is a **polyatomic ion**. Because calcium carbonate contains the carbonate ion, it is composed of more than two elements: calcium, carbon, and oxygen. Therefore, calcium carbonate is *not* a binary compound. It is an example of a **ternary compound**. Like a binary compound, however, it is named by writing the name of the cation followed by the name of the anion.

Some common polyatomic ions that you will use in this course are listed in **Table 4.7**. Notice that the names of most of these ions end in *-ate* or *-ite*. There are three exceptions: ammonium, hydroxide, and peroxide. The ammonium ion is a cation. Therefore, when naming a compound that contains this ion, write its name first. The names *hydroxide* and *peroxide* end in *-ide*, like the names of the non-metal ions in **Table 4.1**. The name *hydroxide* tells you that there are two elements in the ion: hydrogen and oxygen. The name *peroxide* tells you that there are two oxygen atoms in the ion.

Table 4.7 Common Polyatomic Ions

1+ Charge	3– Charge	2– Charge	1– Charge
• ammonium, NH_4^+	• phosphate, PO_4^{3-} • phosphite, PO_3^{3-}	• carbonate, CO_3^{2-} • sulfate, SO_4^{2-} • sulfite, SO_3^{2-} • peroxide, O_2^{2-}	• hydrogen carbonate (bicarbonate), HCO_3^- • hydroxide, OH^- • nitrate, NO_3^- • nitrite, NO_2^- • chlorate, ClO_3^-

Figure 4.9 These shells are made from calcium carbonate–an ionic compound that is composed of a calcium ion and a carbonate ion. The carbonate ion is a polyatomic ion.

Writing Chemical Formulas for Compounds with a Polyatomic Ion

Calcium hydroxide is an ionic compound that is used in many products and processes. For example, it is an ingredient in making mortar and plaster for construction. **Figure 4.10** shows how to write the chemical formula for calcium hydroxide. The brackets are an important part of the formula. The hydroxide ion is composed of one hydrogen atom and one oxygen atom. The ratio of the ions in calcium hydroxide calls for two hydroxide ions, which would be a total of two hydrogen atoms and two oxygen atoms. If you write the formula *incorrectly* as $CaOH_2$, the subscript applies only to the hydrogen atom. You must use brackets to show that two whole hydroxide ions are in the formula. **Table 4.8** outlines the steps to follow when writing the chemical formula for a compound that contains polyatomic ions.

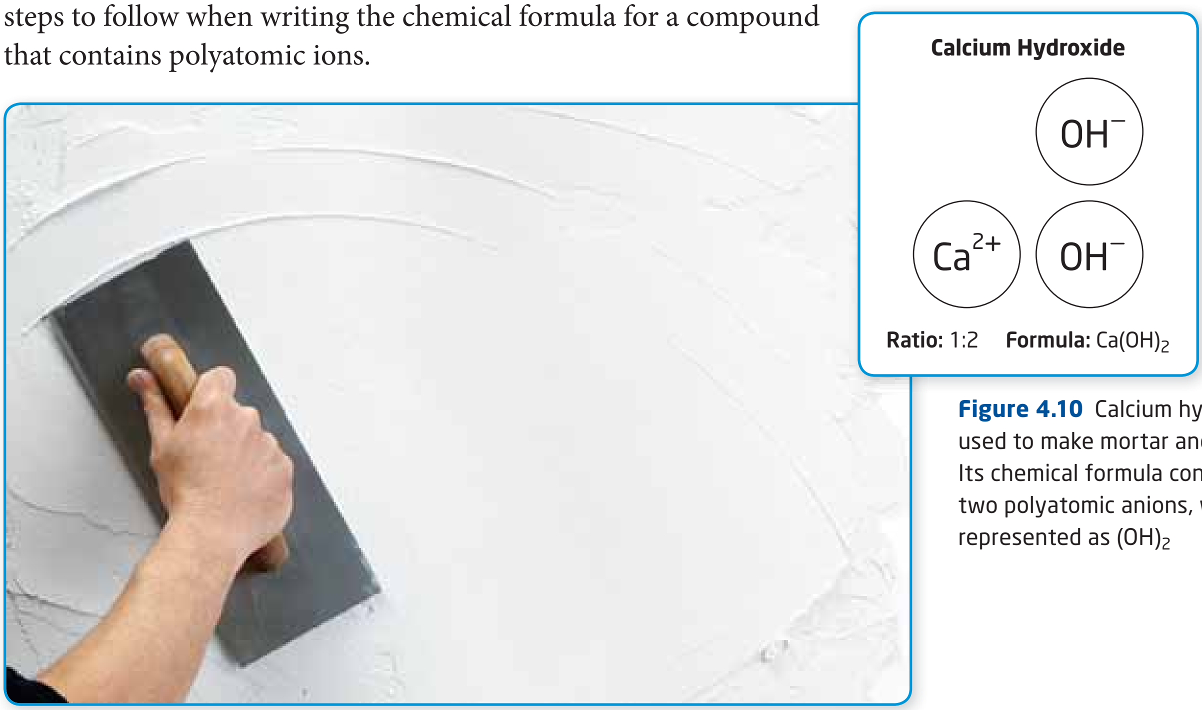


Figure 4.10 Calcium hydroxide is used to make mortar and plaster. Its chemical formula contains two polyatomic anions, which is represented as $(OH)_2$

Table 4.8 How to Write the Chemical Formula for a Compound with a Polyatomic Ion

Steps	Examples	
	Aluminum Carbonate (used as an antacid)	Ammonium Sulfate (used as a fertilizer)
1. Using the periodic table and a table of common polyatomic ions, identify each ion and its charge.	aluminum: Al^{3+} carbonate: CO_3^{2-}	ammonium: NH_4^+ sulfate: SO_4^{2-}
2. Determine the total positive charge and the total negative charge needed to equal zero.	Al^{3+}: 2(3+) = 6+ CO_3^{2-}: 3(2–) = 6– (6+) + (6–) = 0	NH_4^+: 2(1+) = 2+ SO_4^{2-}: 2– = 2– (2+) + (2–) = 0
3. Note the ratio of cations to anions.	2:3	2:1
4. Use subscripts to show the ratio of ions. Place the polyatomic ion in brackets if it needs a subscript.	$Al_2(CO_3)_3$	$(NH_4)_2SO_4$

Learning Check

9. Identify each of the following compounds as binary or ternary. Then write the chemical formula for each ionic compound.

- **a.** nickel(III) oxide
- **b.** copper(II) iodide
- **c.** tin(IV) nitride
- **d.** chromium (II) bromide
- **e.** iron(III) phosphide
- **f.** lithium hydroxide
- **g.** potassium sulfate
- **h.** ammonium phosphide
- **i.** barium nitrate
- **j.** cobalt(II) phosphate

10. Write the name of each ionic compound. Check for multivalent and polyatomic ions when naming.

- **a.** $AuCl_3$
- **b.** Sn_3P_4
- **c.** Cr_2O_3
- **d.** Ni_2S_3
- **e.** $(NH_4)_2S$
- **f.** CaF_2
- **g.** $Fe_2(SO_3)_3$
- **h.** $Mg_3(PO_3)_2$

Ionic Compounds at Home

Many ionic compounds can be found in most households. Some of these compounds are ones you have already learned about. For example, table salt (sodium chloride) and baking soda (sodium bicarbonate) are ionic compounds. In addition, there are numerous products that contain ionic compounds. Antacids contain magnesium hydroxide and calcium carbonate. Toothpaste contains the compound sodium fluoride, which helps to prevent tooth decay. A common ingredient in sunblocks, shown in **Figure 4.11**, is zinc oxide.

Suggested Investigation

Inquiry Investigation 4-B, Keep That Toothy Grin, on page 170

Figure 4.11 Ionic compounds are in numerous products, including many that you use. For example, a common ingredient in sunblocks and sunscreens is the ionic compound zinc oxide.

Section 4.1 Review

Section Summary

- Ionic compounds are composed of oppositely charged ions, called cations and anions.
- Solid ionic compounds are made up of repeating patterns of ions that occur in specific ratios. The chemical formula for an ionic compound shows the ratio of ions.
- Subscripts are used in the chemical formula for an ionic compound to show the ratio of ions needed to make the total charge zero.
- The name of an ionic compound contains the name of the cation followed by the name of the anion. For binary ionic compounds, the part that represents the anion always ends with the suffix *-ide*.
- When naming compounds with multivalent metals, a Roman numeral is used to indicate the ion form of the metal.
- Ternary ionic compounds contain polyatomic ions, which are composed of more than one atom. Polyatomic ions have specific names that are based on the group of atoms present.

Review Questions

K/U **1.** Write the name of each ion.

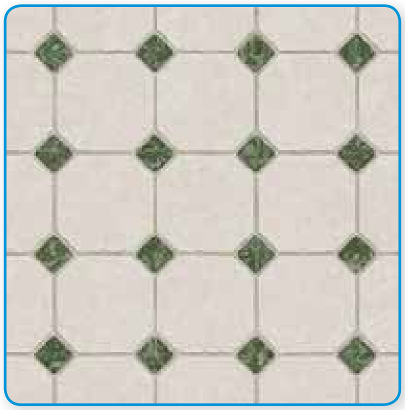
a. Cl^{-}
b. SO_4^{2-}
c. Mg^{2+}
d. Cu^{2+}

K/U **2.** Write the symbol of each ion.

a. hydroxide ion
b. sulfide ion
c. aluminum ion
d. chromium(III) ion

C **3.** Draw a Bohr-Rutherford model to show how atoms of potassium and sulfur form a binary ionic compound. Clearly show the ratio of ions in the compound.

A **4.** Examine the photograph of the tiles. How can these tiles be considered a model of an ionic solid? How could you change the tiles so that they represent the compound sodium chloride?



K/U **5.** Name each ionic compound.

a. Li_2CO_3
b. NH_4NO_2
c. CuO

K/U **6.** Write the chemical formula for each ionic compound.

a. magnesium nitride
b. aluminum hydroxide
c. tin(II) bromide
d. nickel(II) sulfate

T/I **7.** Describe the error in each chemical formula, and write the correct chemical formula for the compound.

a. sodium phosphate, Na_3P
b. calcium nitrate, $CaNO_{32}$
c. potassium sulfite, KSO_3

K/U **8.** Using the periodic table in **Figure 4.2**, identify the possible ion charges for iron.