

McGraw-Hill Ryerson

BC Science

CONNECTIONS



BC Science Connections 9

Unit 2: The electron arrangement of atoms impacts their
chemical nature

Topic 2.5: How do we name and write formulas for compounds?

- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.



Concept 1: The chemical name of an ionic compound communicates its composition.

Binary ionic compound:

- Made up of ions of one metal element and ions of one non-metal element; joined by ionic bonds
- *Binary* in chemistry means “composed of two elements

Figure 2.36: Potassium iodide is a binary ionic compound that is added to table salt to prevent iodine deficiency. Seaweed contains compounds that include iodide ion. Iodine deficiency leads to swellings called goitres.



Names of Binary Ionic Compounds

The name of a binary ionic compound comes from the name of its elements.

Example: potassium iodide

- The first part names the positive ion, potassium (K^+)
 - In a binary ionic compound, the positive ion is always a metal and its name is the same as the name of its element
- The second part names the negative ion, iodide (I^-)
 - In a binary ionic compound, the negative ion is always a non-metal and has the suffix *-ide*
 - The negative ion of iodine is iodide

Names of Binary Ionic Compounds (continued)

Table 2.5 Ions of Non-Metals

Element	Ion	Symbol	Group
fluorine	fluoride	F ⁻	17
chlorine	chloride	Cl ⁻	17
bromine	bromide	Br ⁻	17
iodine	iodide	I ⁻	17
oxygen	oxide	O ²⁻	16
sulfur	sulfide	S ²⁻	16
selenium	selenide	Se ²⁻	16
nitrogen	nitride	N ³⁻	15
phosphorus	phosphide	P ³⁻	15

Discussion Questions

1. Each of the following pairs of elements react to form a binary ionic compound. What is the name of the compound in each case?
 - a) lithium and oxygen
 - b) calcium and fluorine
 - c) magnesium and sulfur
 - d) rubidium and bromine.

Discussion Questions (continued)

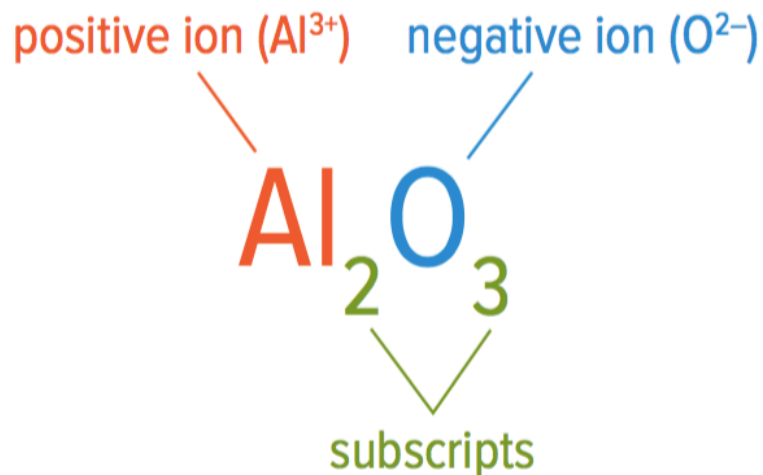
2. What is the difference between the name of a non-metal element and the name of the negative ion it forms?

Concept 2: You can determine the formula of an ionic compound from its name.

Formulas for binary ionic compounds:

- Positive ion (metal) first, negative ion (non-metal) second
- Subscripts indicate the ratio of each type of ion in the compound (no subscript: assume the number is 1)
- Chemical formula represents the smallest repeating part of the crystal lattice (*formula unit*)

Figure 2.37: Formulas for ionic compounds are always written with the positive ion first and the negative ion second. In binary ionic compounds, the positive ion is a metal ion and the negative ion is a non-metal ion.



Examples of Chemical Formulas of Binary Ionic Compounds

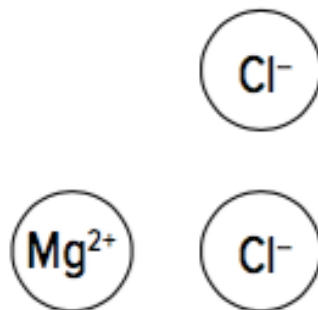
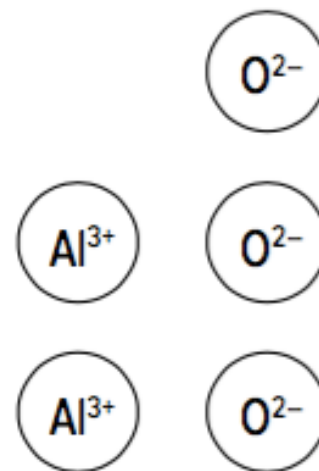
KI1 K⁺ ion : 1 I⁻ ion**MgCl₂**1 Mg²⁺ ion : 2 Cl⁻ ions**Al₂O₃**2 Al³⁺ ions : 3 O²⁻ ions

Figure 2.38: The subscripts in chemical formulas of ionic compounds tell you the ratio of the ions in the compound.

Writing Formulas of Ionic Compounds

Although an ionic compound is made up of ions, the compound's overall charge is 0 (it is electrically neutral)

- Positive charges on the metal ions must balance the negative charges on the non-metal ions
- Example: Aluminum oxide has two aluminum ions, Al^{3+} , and three oxide ions, O^{2-} . What is the total charge?

Charge from Al^{3+} ions	Charge from Cl^{-} ions
There are 2 aluminum ions in the formula, each with a charge of 3+. $2 \times (3+) = 6+$	There are 3 oxide ions in the formula, each with a charge of 2-. $3 \times (2-) = 6-$
Total charge: $(6+) + (6-) = 0$	

Writing Formulas of Ionic Compounds (continued)

When writing the formula of a binary ionic compound, you first need to determine the charges on the ion.

- For non-metals: Look at the periodic table or refer to Table 2.5
- For metals: Look at the periodic table. Some metals can form more than one ion (each ion has a different charge).

Group 1 metals all form ions with a charge of 1+.

Group 2 metals all form ions with a charge of 2+.

Notice that some metals can form more than one ion.

2	3 Li Lithium 6.9	1+	4 Be Beryllium 9.0	2+										
3	11 Na Sodium 23.0	1+	12 Mg Magnesium 24.3	2+	3	4	5	6	7					
4	19 K Potassium 39.1	1+	20 Ca Calcium 40.1	2+	21 Sc Scandium 45.0	3+	22 Ti Titanium 47.9	4+	23 V Vanadium 50.9	5+ 4+	24 Cr Chromium 52.0	3+ 2+	25 Mn Manganese 54.9	2+ 3+ 4+
5	37 Rb Rubidium 85.5	1+	38 Sr Strontium 87.6	2+	39 Y Yttrium 88.9	3+	40 Zr Zirconium 91.2	4+	41 Nb Niobium 92.9	3+ 5+	42 Mo Molybdenum 95.9	2+ 3+	43 Tc Technetium (98)	7+

Figure 2.39: The periodic table lists the charges of ions commonly formed by the various elements.

Sample Problem: Writing the Formulas of Ionic Compounds (Step 1)

Problem:

What is the chemical formula for calcium chloride?

Step 1: Identify each ion and its charge

- Look at the periodic table to find the ion charge
- Calcium is a Group 2 metal, so its ion charge is 2+: **Ca²⁺**
- Chlorine is a Group 17 metal, so its ion charge is 1-: **Cl⁻**

Sample Problem: Writing the Formulas of Ionic Compounds (Step 2)

Problem:

What is the chemical formula for calcium chloride?

Step 2: Determine the number of ions needed to balance positive charges with negative charges.

- A calcium ion (Ca^{2+}) has a charge of 2+
- A chloride ion (Cl^-) has a charge of 1-
- Therefore, two chloride ions are needed to balance the positive charge of one calcium ion

Charge from Ca^{2+}	Charge from Cl^-
A calcium ion has a charge of 2+. $1 \times (2+) = 2+$	A chloride ion has a charge of 1-. Therefore, two chloride ions are needed to balance the charge of one calcium ion. $2 \times (1-) = 2-$

Sample Problem: Writing the Formulas of Ionic Compounds (Step 3)

Problem:

What is the chemical formula for calcium chloride?

Step 3: Use subscripts to write the formula (do not include a subscript if the subscript would be “1”). Remember to write the metal ion first.

- Recall: Two chloride ions are needed to balance the positive charge of one calcium ion
- Therefore, the formula for calcium chloride is **CaCl₂**.

Discussion Questions

1. What is a formula unit and how does it relate to the formula for an ionic compound?
2. Even though ionic compounds are made up of charged particles, they are electrically neutral. Why is this?

Concept 3: Multivalent metals form more than one ion.

Multivalent metal: a metal element that can form two or more types of ions with different charges

Example: Copper can form ions with a 1+ or 2+ charge

- A Roman numeral is written after the name of the metal to distinguish between the ions
- Cu^+ : copper(I)
- Cu^{2+} : copper(II)



Figure 2.41: Although both of these compounds contain copper and oxygen, copper(II) oxide, CuO , is black and copper(I) oxide, Cu_2O , is red.

Writing Formulas for Ionic Compounds Containing Multivalent Metals

To write the chemical formula of a compound with a multivalent metal, follow the same process as for binary ionic compounds.

- Difference: You cannot tell the charge on the metal ion by looking at the periodic table, since there will be multiple charges listed
- Look at the Roman numeral in the name, which will tell you the charge
- Example: chromium(III) chloride tells you that the chromium ion is Cr^{3+}

Writing Formulas for Ionic Compounds Containing Multivalent Metals (continued)

Table 2.6 Roman Numerals

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

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 1)

Problem:

What is the chemical formula for chromium(III) chloride?

Step 1: Identify each ion and its charge.

- Look at the periodic table to find the ion charge
- Chromium is a multivalent metal (ion charge can be 3+ or 2+). Its ion charge is 3+ since its name contains the Roman numeral "III": **Cr³⁺**
- Chlorine is a Group 17 metal, so its ion charge is 1-: **Cl⁻**

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 2)

Problem:

What is the chemical formula for chromium(III) chloride?

Step 2: Determine the number of ions needed to balance positive charges with negative charges.

- A chromium ion (Cr^{3+}) has a charge of 3+
- A chloride ion (Cl^-) has a charge of 1-
- Therefore, three chloride ions are needed to balance the positive charge of one chromium ion

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 3)

Problem:

What is the chemical formula for chromium(III) chloride?

Step 3: Use subscripts to write the formula (do not include a subscript if the subscript would be “1”). Remember to write the metal ion first.

- Recall: Three chloride ions are needed to balance the positive charge of one chromium ion
- Therefore, the formula for chromium(III) chloride is **CrCl₃**.

Sample Problem: Naming an Ionic Compound with a Multivalent Metal (Step 1)

Problem:

What is the name of Fe_2O_3 ?

Step 1: Identify each ion and its charge

- Look at the periodic table to find the ion charge
- Iron is a multivalent metal (ion charge can be 2+ or 3+):
 Fe^{2+} or **Fe^{3+}**
- Oxygen's ion charge is 2-: **O^{2-}**

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 2)

Problem:

What is the name of Fe_2O_3 ?

Step 2: Determine the ratio of ions in the compound.

- According to the formula, the compound has 2 iron (Fe) ions for every 3 oxide (O) ions

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 3)

Problem:

What is the name of Fe_2O_3 ?

Step 3: The negative charges and the positive charges must be equal in magnitude for the compound to be electrically neutral. Which of the two possible iron ions achieves this balance?

• Recall:

- Iron is a multivalent metal (ion charge can be 2+ or 3+): **Fe^{2+}** or **Fe^{3+}**
- Oxygen's ion charge is 2-: **O^{2-}**
- Since there are 3 oxide ions, there is an overall negative charge of 6- [calculation: $3 \times (2-) = 6-$]
- Since there are 2 iron ions, they must each have a charge of 3+ to give an overall positive charge of 6+ [calculation: $2 \times (3+) = 6+$]
- Therefore the iron ion in this compound is **Fe^{3+}**

Sample Problem: Writing Formulas for Ionic Compounds Containing Multivalent Metals (Step 4)

Problem:

What is the name of Fe_2O_3 ?

Step 4: Write the name of the compound using a Roman numeral to indicate the charge of the metal ion.

- Recall: The iron ion in this compound is Fe^{3+}
- Therefore, the name of Fe_2O_3 is iron(III) oxide

Discussion Questions

1. Explain why copper is able to form two different compounds with oxygen.
2. Why are Roman numerals included in the names of multivalent metal ions?

Concept 4: Polyatomic ions are made up of more than one atom.

Polyatomic ion: an ion made up of two or more covalently bonded atoms

- Example: carbonate ion (CO_3^{2-})
 - 1 carbon atom
 - 2 oxygen atoms
- There are a limited number of polyatomic ions that regularly occur in compounds

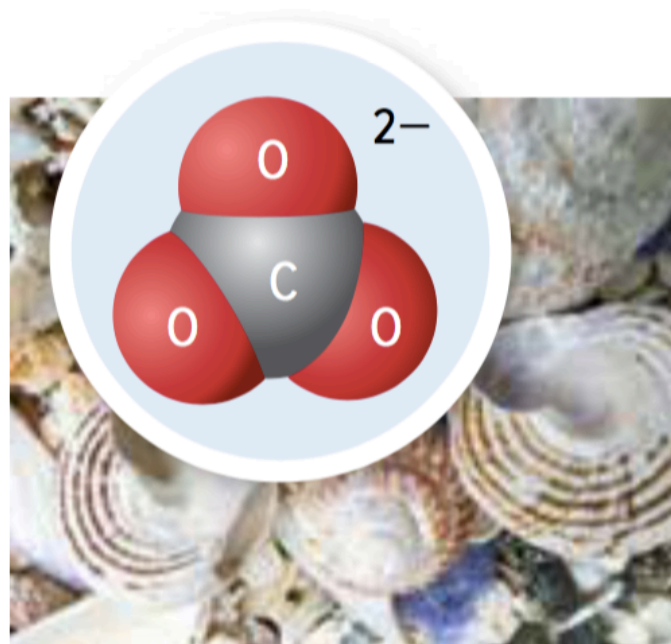


Figure 2.43: Shellfish use calcium carbonate to make their shells. The carbonate ion is shown here.

Common Polyatomic Ions

Table 2.7 Names, formulas, and charges of some common polyatomic ions

1+ Charge	1- Charge	2- Charge	3- Charge
ammonium, NH_4^+	acetate, CH_3COO^- chlorate, ClO_3^- chlorite, ClO_2^- hydrogen carbonate, HCO_3^- hydroxide, OH^- nitrate, NO_3^- nitrite, NO_2^- permanganate, MnO_4^-	carbonate, CO_3^{2-} chromate, CrO_4^{2-} dichromate, $\text{Cr}_2\text{O}_7^{2-}$ peroxide, O_2^{2-} sulfate, SO_4^{2-} sulfite, SO_3^{2-}	phosphate, PO_4^{3-} phosphite, PO_3^{3-}

Sample Problem: Writing Chemical Formulas of a Compound with a Polyatomic Ion (Step 1)

Problem:

What is the chemical formula for calcium nitrate?

Step 1: Identify each ion and its charge. Use Table 2.7 to find the formula of the polyatomic ion.

- Look at the periodic table to find the ion charge of calcium. Use Table 2.7 to find the formula and charge of nitrate.
- Calcium is a Group 2 metal, so its ion charge is 2+: **Ca²⁺**
- Nitrate: **NO₃⁻**

Sample Problem: Writing Chemical Formulas of a Compound with a Polyatomic Ion (Step 2)

Problem:

What is the chemical formula for calcium nitrate?

Step 2: Determine the number of ions needed to balance positive charges with negative charges.

- A calcium ion (Ca^{2+}) has a charge of 2+
- A nitrate ion (NO_3^-) has a charge of 1-
- Therefore, two nitrate ions are needed to balance the positive charge of one calcium ion

Charge from Ca^{2+}	Charge from NO_3^-
A calcium ion has a charge of 2+.	A nitrate ion has a charge of 1-. Therefore, 2 nitrate ions are needed to balance the charge of one calcium ion.
$1 \times (2+) = 2+$	$2 \times (1-) = 2-$

Sample Problem: Writing Chemical Formulas of a Compound with a Polyatomic Ion (Step 3)

Problem:

What is the chemical formula for calcium nitrate?

Step 3: Use subscripts to write the formula (do not include a subscript if the subscript would be “1”).

If the polyatomic ion is going to take a subscript, use parentheses to enclose the polyatomic ion before adding the subscript.

- Recall: Two nitrate ions are needed to balance the positive charge of one calcium ion
- Therefore, the formula for calcium nitrate is **Ca(NO₃)₂**.

Discussion Questions

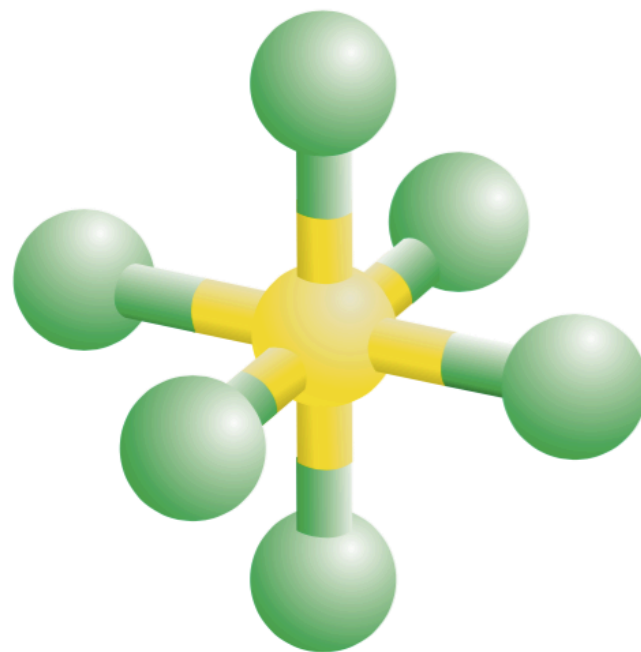
1. What is a polyatomic ion?
2. How are parentheses used in writing formulas containing polyatomic ions?
3. Give the names and chemical formulas of two different polyatomic ions that contain nitrogen and oxygen.

Concept 5: Names and formulas of covalent compounds reflect their molecular structure.

Binary covalent compound: a compound made up of the atoms of two elements joined by covalent bonds

- Example: sulfur hexafluoride (SF_6)

Figure 2.44: Sulfur hexafluoride (SF_6) is a gas that does not conduct thermal energy well. It is used to insulate double-glazed windows.



Writing Names of Binary Covalent Compounds

The names of binary covalent compounds have prefixes (Table 2.8) to indicate how many atoms of are present in one molecule of the compound.

- *Mono-* is used only for the second element in the name
- No prefix: *mono-* is implied (example: carbon monoxide)
- When *mono-* comes before *-oxide*, an “o” is dropped (*monoxide*, not *monoxide*)

Table 2.8 Prefixes Used to Name Binary Covalent compounds

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

Sample Problem: Naming a Binary Covalent Compound (Step 1)

Problem:

What is the name of NO_2 ?

Step 1: Name the leftmost element in the formula first.

- The first element is N (nitrogen).

Sample Problem: Naming a Binary Covalent Compound (Step 2)

Problem:

What is the name of NO_2 ?

Step 2: Name the second element, making sure the name ends with the suffix *-ide*.

- The second element is O (oxygen), which becomes oxide.

Sample Problem: Naming a Binary Covalent Compound (Step 3)

Problem:

What is the name of NO_2 ?

Step 3: Add a prefix to each element's name to indicate the number of atoms of each element in a molecule of a compound. If the first element would get the prefix *mono*, do not include that prefix.

- The first element is nitrogen. There is 1 nitrogen atom.
- The second element is oxygen, which becomes oxide. There are 2 oxygen atoms. Add the prefix *di-* to oxide.
- Therefore, the name of NO_2 is nitrogen dioxide.

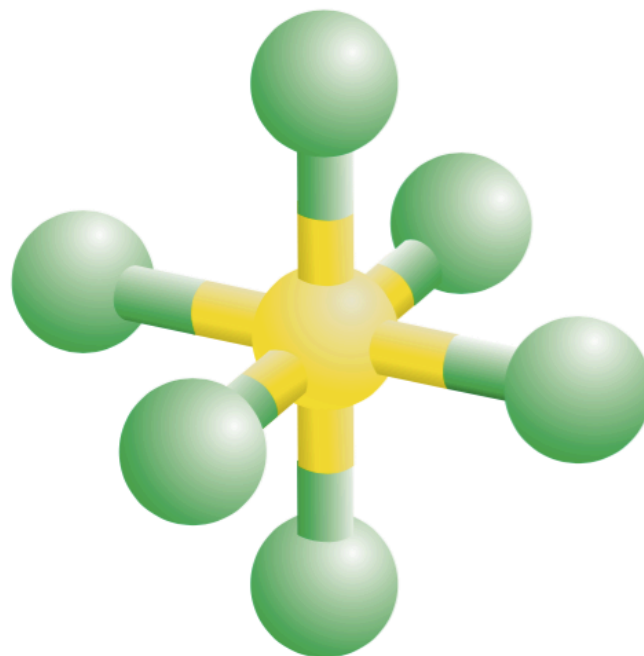
Writing Formulas of Binary Covalent Compounds

Chemical formulas of binary covalent compounds indicate how many atoms of each element are present in a single molecule of a compound

Example: SF₆ (sulfur hexafluoride)

1.1 sulfur atom

2.6 fluoride atoms



Sample Problem: Writing Formulas for Binary Covalent Compounds (Step 1)

Problem:

What is the chemical formula for dinitrogen tetroxide?

Step 1: Write the element symbols in the order that they appear in the name.

- Look at the periodic table to find the element symbols.
- The first element is nitrogen, N.
- The second element is oxygen (oxide), O.

Sample Problem: Sample Problem: Writing Formulas for Binary Covalent Compounds (Step 2)

Problem:

What is the chemical formula for dinitrogen tetroxide?

Step 2: Add subscripts based on the prefixes used in the name.

- The prefix *di* from dinitrogen tells you that there are 2 nitrogen atoms
- The prefix *tetr-* from tetroxide tells you that there are 4 oxygen atoms.
- Therefore, the formula of dinitrogen tetroxide is N_2O_4 .

Discussion Questions

1. What does the formula for a covalent compound tell you about the compound?
2. Identify two problems with the name mononitrogen monoxide for the compound NO and correct them.

Discussion Questions (continued)

3. Sketch a model of a molecule of carbon dioxide, CO_2 , and carbon monoxide, CO .

How do the names and formulas communicate the difference between these compounds?

Topic 2.5 Summary: How do we name and write formulas for compounds?

- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.

