

4.5.2: Writing Formulas for Ionic Compounds

Learning Objectives

- Write the correct formula for an ionic compound.
- Recognize polyatomic ions in chemical formulas.

Ionic compounds do not exist as molecules. In the solid state, ionic compounds are in crystal lattice containing many ions each of the cation and anion. An ionic formula, like NaCl , is an empirical formula. This formula merely indicates that sodium chloride is made of an equal number of sodium and chloride ions. Sodium sulfide, another ionic compound, has the formula Na_2S . This formula indicates that this compound is made up of twice as many sodium ions as sulfide ions. This section will teach you how to find the correct ratio of ions, so that you can write a correct formula.

If you know the name of a binary ionic compound, you can write its **chemical formula**. Start by writing the metal ion with its charge, followed by the nonmetal ion with its charge. Because the overall compound must be electrically neutral, decide how many of each ion is needed in order for the positive and negative charges to cancel each other out.

✓ Example 4.5.2.1: Aluminum Nitride and Lithium Oxide

Write the formulas for aluminum nitride and lithium oxide.

Solution


	Write the formula for aluminum nitride	Write the formula for lithium oxide
1. Write the symbol and charge of the cation (metal) first and the anion (nonmetal) second.	$\text{Al}^{3+} \quad \text{N}^{3-}$	$\text{Li}^{+} \quad \text{O}^{2-}$
2. Use a multiplier to make the total charge of the cations and anions equal to each other.	total charge of cations = total charge of anions $1(3+) = 1(3-)$ $+3 = -3$	total charge of cations = total charge of anions $2(1+) = 1(2-)$ $+2 = -2$
3. Use the multipliers as subscript for each ion.	Al_1N_1	Li_2O_1
4. Write the final formula. Leave out all charges and all subscripts that are 1.	AlN	Li_2O

An alternative way to writing a correct formula for an ionic compound is to use the **crisscross method**. In this method, the numerical value of each of the ion charges is crossed over to become the subscript of the other ion. Signs of the charges are dropped.

✓ Example 4.5.2.2: The Crisscross Method for Lead (IV) Oxide

Write the formula for lead (IV) oxide.

Solution

Crisscross Method	Write the formula for lead (IV) oxide
1. Write the symbol and charge of the cation (metal) first and the anion (nonmetal) second.	$\text{Pb}^{4+} \quad \text{O}^{2-}$
2. Transpose only the number of the positive charge to become the subscript of the anion and the number only of the negative charge to become the subscript of the cation.	
3. Reduce to the lowest ratio.	Pb_2O_4

Crisscross Method

Write the formula for lead (IV) oxide

4. Write the final formula. Leave out all subscripts that are 1.



? Exercise 4.5.2.2

Write the chemical formula for an ionic compound composed of each pair of ions.

- the calcium ion and the oxygen ion
- the 2+ copper ion and the sulfur ion
- the 1+ copper ion and the sulfur ion

Answer a:



Answer b:



Answer c:




Be aware that ionic compounds are empirical formulas and so must be written as the lowest ratio of the ions.

✓ Example 4.5.2.3: Sulfur Compound

Write the formula for sodium combined with sulfur.

Solution

Crisscross Method	Write the formula for sodium combined with sulfur
1. Write the symbol and charge of the cation (metal) first and the anion (nonmetal) second.	$\text{Na}^+ \text{S}^{2-}$
2. Transpose only the number of the positive charge to become the subscript of the anion and the number only of the negative charge to become the subscript of the cation.	
3. Reduce to the lowest ratio.	This step is not necessary.
4. Write the final formula. Leave out all subscripts that are 1.	Na_2S

? Exercise 4.5.2.3

Write the formula for each ionic compound.

- sodium bromide
- lithium chloride
- magnesium oxide

Answer a:



Answer b:



Answer c:



Writing Formulas for Ionic Compounds Containing Polyatomic Ions

Polyatomic ions were introduced in a previous subsection. It is important to understand the relationship between the name, formula, and charge of polyatomic ions before beginning to use them within ionic compounds.


The rule for constructing formulas for ionic compounds containing polyatomic ions is the same as for formulas containing monatomic (single-atom) ions: the positive and negative charges must balance. If more than one of a particular polyatomic ion is needed to balance the charge, the *entire formula* for the polyatomic ion must be enclosed in parentheses, and the numerical subscript is placed *outside* the parentheses. This is to show that the subscript applies to the entire polyatomic ion. An example is $\text{Ba}(\text{NO}_3)_2$.

Writing a formula for ionic compounds containing polyatomic ions also involves the same steps as for a binary ionic compound. Write the symbol and charge of the cation followed by the symbol and charge of the anion.

✓ Example 4.5.2.4: Calcium Nitrate

Write the formula for calcium nitrate.

Solution

Crisscross Method	Write the formula for calcium nitrate
1. Write the symbol and charge of the cation (metal) first and the anion (nonmetal) second.	$\text{Ca}^{2+} \quad \text{NO}_3^-$
2. Transpose only the number of the positive charge to become the subscript of the anion and the number only of the negative charge to become the subscript of the cation.	
3. Reduce to the lowest ratio.	$\text{Ca}_1(\text{NO}_3)_2$
4. Write the final formula. Leave out all subscripts that are 1. If there is only 1 of the polyatomic ion, leave off parentheses.	$\text{Ca}(\text{NO}_3)_2$

✓ Example 4.5.2.5

Write the chemical formula for an ionic compound composed of the potassium ion and the sulfate ion.

Solution

Explanation	Answer
Potassium ions have a charge of $1+$, while sulfate ions have a charge of $2-$. We will need two potassium ions to balance the charge on the sulfate ion, so the proper chemical formula is K_2SO_4 .	K_2SO_4

? Exercise 4.5.2.5

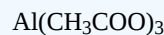
Write the chemical formula for an ionic compound composed of each pair of ions.

- the magnesium ion and the carbonate ion
- the aluminum ion and the acetate ion

Answer a:



Answer b:



Recognizing Ionic Compounds

There are two ways to recognize ionic compounds. First, compounds between metal and nonmetal elements are usually ionic. For example, CaBr_2 contains a metallic element (calcium, a [group 2 \[or 2A\]](#) metal) and a nonmetallic element (bromine, a [group 17 \[or 7A\]](#) nonmetal). Therefore, it is most likely an ionic compound. (In fact, it is ionic.) In contrast, the compound NO_2 contains two elements that are both nonmetals (nitrogen, from [group 15 \[or 5A\]](#), and oxygen, from [group 16 \[or 6A\]](#)). It is not an ionic compound; it belongs to the category of covalent compounds discussed elsewhere. Also note that this combination of nitrogen and oxygen has no electric charge specified, so it is *not* the nitrite ion.

Second, if you recognize the formula of a polyatomic ion in a compound, the compound is ionic. For example, if you see the formula $\text{Ba}(\text{NO}_3)_2$, you may recognize the “ NO_3 ” part as the nitrate ion, NO_3^- . (Remember that the convention for writing formulas for ionic compounds is not to include the ionic charge.) This is a clue that the other part of the formula, Ba, is actually the Ba^{2+} ion, with the 2+ charge balancing the overall 2- charge from the two nitrate ions. Thus, this compound is also ionic.

✓ Example 4.5.2.6

Identify each compound as ionic or not ionic.

- Na_2O
- PCl_3
- NH_4Cl
- OF_2

Solution

Explanation	Answer
a. Sodium is a metal, and oxygen is a nonmetal. Therefore, Na_2O is expected to be ionic.	Na_2O , ionic
b. Both phosphorus and chlorine are nonmetals. Therefore, PCl_3 is not ionic.	PCl_3 , not ionic
c. The NH_4 in the formula represents the ammonium ion, NH_4^+ , which indicates that this compound is ionic.	NH_4Cl , ionic
d. Both oxygen and fluorine are nonmetals. Therefore, OF_2 is not ionic.	OF_2 , not ionic

? Exercise 4.5.2.6

Identify each compound as ionic or not ionic.

- N_2O
- FeCl_3
- $(\text{NH}_4)_3\text{PO}_4$
- SOCl_2

Answer a:

not ionic

Answer b:

ionic

Answer c:

ionic

Answer d:

not ionic

Summary

Formulas for ionic compounds contain the symbols and number of each atom present in a compound in the lowest whole number ratio.

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