Practice Packet

Chapter 7: Formulas & Chemical Equations
Naming Ionic Compounds

What are the structural units that make up ionic compounds and how are they named?

Why?

When working in chemistry, it is often convenient to write a chemical in symbols. For example, we might write down the substance table salt as NaCl. In talking about chemistry, however, it is a bit tacky to say “en-ay see-ell” when we want to refer to a substance. Also, in formal writing, we should use the name of the compound rather than its symbols. Therefore, we need to learn how to say the proper names of ionic substances.

Model 1 – Ion Charges for Selected Elements

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>H&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Be&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Li&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Mg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Na&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Li&lt;sup&gt;+&lt;/sup&gt;</td>
</tr>
<tr>
<td>Li&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Be&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Fe&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Fe&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>Fe&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Fe&lt;sup&gt;3+&lt;/sup&gt;</td>
</tr>
<tr>
<td>Na&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Mg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Ni&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Ni&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>Cu&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Cu&lt;sup&gt;2+&lt;/sup&gt;</td>
</tr>
<tr>
<td>K&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Ca&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Cu&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Zn&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Sn&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Sn&lt;sup&gt;4+&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rb&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Sr&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Ag&lt;sup&gt;+&lt;/sup&gt;</td>
<td>Sn&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>I&lt;sup&gt;-&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Ba&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Hg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Hg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Pb&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>Pb&lt;sup&gt;4+&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

1. Based on the information in Model 1:
   a. Identify three elements that form only one cation.
   b. Identify three elements that form only one anion.
   c. Identify three elements that form more than one cation.
   d. In what region of the periodic table are these “multiple ion” elements usually located?

2. Consider the ions of potassium (K) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of potassium (K) and sulfur (S). Keep in mind that the sum of the charges in an ionic compound must equal zero.

3. Consider the ions of iron (Fe) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of iron (Fe) and sulfur (S). Keep in mind that the sum of the charges in an ionic compound must equal zero.
Model 2 – Ionic Compound Names (Metals that form one ion)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Compound</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Sodium chloride</td>
<td>Zn₃P₂</td>
<td>Zinc phosphide</td>
</tr>
<tr>
<td>CaS</td>
<td>Calcium sulfide</td>
<td>Al₂O₃</td>
<td>Aluminum oxide</td>
</tr>
<tr>
<td>Ag₂S</td>
<td>Silver sulfide</td>
<td>SrCl₃</td>
<td>Strontium chloride</td>
</tr>
</tbody>
</table>

4. Circle the symbol for the metal in each of the compounds in Model 2.

5. Which element comes first in the name and formula of the compounds in Model 2—the metal or the nonmetal?

6. Use the table of ions in Model 1 to answer the following questions:
   a. In the compound zinc phosphide, what is the charge on the zinc ion?
   b. In the compound zinc phosphide, what is the charge on the phosphide ion?

7. Explain why a 3 to 2 ratio of ions is necessary for the compound zinc phosphide.

8. The compound carbon dioxide has a name that gives you a hint as to how many oxygen atoms are in the compound. Is there anything in the name “zinc phosphide” that indicates there are three zinc and two phosphorus ions in the formula unit?

9. Is there any other ratio of zinc and phosphorus ions that could exist? For instance, could you have Zn₂P or ZnP₂? Explain your answer.

10. Explain why you don't need to specify the number of ions in the compound when you are naming ionic substances like those in Model 2.

11. Model 2 is labeled “Metals that form one ion.” What other metals that also form only one ion could be included in the Model 2 list? Model 1 may be helpful in this regard.

12. Describe how the names of the nonmetal elements in Model 2 are changed when they are in their anion forms.

13. Name the following ionic compounds using what you learned from Model 2.
    Li₂O           MgF₂           Al₂S₃           K₃N
14. Provide the chemical formula for each of the following ionic compounds.
   Barium chloride
   Magnesium oxide

15. Consider the two chemical formulas you wrote in Question 3 for compounds of iron and sulfur. Would the name "iron sulfide" be sufficient to uniquely identify either of those compounds? Explain.

Read This!
When the metal in an ionic compound always forms an ion with the same charge, you need not indicate that charge as part of the compound name. However, some atoms have the ability to form more than one type of ion. This can make naming confusing. You can't simply refer to a compound of copper and oxygen as "copper oxide." People won't know which compound you are referring to—CuO or Cu₂O.

Model 3 – Ionic Compound Names (Metals that form multiple ions)

<table>
<thead>
<tr>
<th>Chemical Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu₂O</td>
<td>Copper(I) oxide</td>
</tr>
<tr>
<td>CuO</td>
<td>Copper(II) oxide</td>
</tr>
<tr>
<td>PbO</td>
<td>Lead(II) oxide</td>
</tr>
<tr>
<td>PbO₂</td>
<td>Lead(IV) oxide</td>
</tr>
<tr>
<td>SnF₂</td>
<td>Tin(II) fluoride</td>
</tr>
<tr>
<td>SnF₄</td>
<td>Tin(IV) fluoride</td>
</tr>
<tr>
<td>FeCl₂</td>
<td>Iron(II) chloride</td>
</tr>
<tr>
<td>FeCl₃</td>
<td>Iron(III) chloride</td>
</tr>
</tbody>
</table>

16. Model 3 is labeled "Metals that form multiple ions." What other metals that form multiple ions could be included in Model 3? Model 1 may be helpful in this regard.

17. Describe the most obvious difference between the names in Model 3 and those in Model 2.

18. Do the Roman numerals in the names in Model 3 relate to the number of cations or number of anions in the formula unit? Support your answer by citing two specific examples.

19. Keeping in mind that the sum of the charges in an ionic compound must equal zero, use the chemical formulas in Model 3 to answer the following questions:
   a. Identify the charge on the copper cations in copper(I) oxide and copper(II) oxide, respectively.
   b. Identify the charge on the iron cations in iron(II) chloride and iron(III) chloride, respectively.

20. What do the Roman numerals in the compounds described in Question 19 indicate?
21. Fill in the table below using what you’ve learned from Model 3.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Charge on Cation</th>
<th>Name of the Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>PbCl₄</td>
<td>Pb⁴⁺</td>
<td>Lead(IV) chloride</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SnO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CuBr₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22. For each of the compounds in the table below, determine the type of metal in the compound and then name the compound using the correct naming method.

<table>
<thead>
<tr>
<th></th>
<th>Metal forms only one ion</th>
<th>Metal forms multiple ions</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaBr₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag₃N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SnCl₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CuF₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₃P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn₃N₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HgO</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Polyatomic Ions

Can a group of atoms have a charge?

Why?
Do you know you eat a lot of “-ates”? Next time you look at a food label, read the ingredients and you will likely find a number of ingredients that end with “-ate,” such as sodium phosphate or calcium carbonate. Did you ever wonder what the chemical formulas of these ingredients look like? In this activity we will explore polyatomic ions, which are groups of atoms that carry a charge. These ions are found in our food ingredients, natural waterways, and many other chemical compounds you encounter every day.

Model 1 – Types of Ions

<table>
<thead>
<tr>
<th>Monatomic Ions</th>
<th>Nitride</th>
<th>Sulfide</th>
<th>Chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Ion</td>
<td>Nitrate</td>
<td>Sulfate</td>
<td>Ammonium</td>
</tr>
<tr>
<td>Charge on Ion</td>
<td>-1</td>
<td>-2</td>
<td>1+</td>
</tr>
<tr>
<td>Type and Number of Atoms</td>
<td>1 sulfur 4 oxygen</td>
<td>2 sulfur 3 oxygen</td>
<td>1 hydrogen 4 nitrogen</td>
</tr>
<tr>
<td>Chemical Formula</td>
<td></td>
<td>SO₃⁻²</td>
<td>H₃N⁺</td>
</tr>
</tbody>
</table>

1. Use Model 1 to complete the table below.

<table>
<thead>
<tr>
<th>Name of Ion</th>
<th>Nitride</th>
<th>Nitrate</th>
<th>Sulfate</th>
<th>Sulfite</th>
<th>Ammonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge on Ion</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type and Number of Atoms</td>
<td></td>
<td>1 sulfur 4 oxygen</td>
<td>2 sulfur 3 oxygen</td>
<td>1 hydrogen 4 nitrogen</td>
<td>1+</td>
</tr>
<tr>
<td>Chemical Formula</td>
<td></td>
<td></td>
<td>SO₃⁻²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Consider the terms “monatomic” and “polyatomic” as they are used in Model 1. Write a definition for each of these terms. It may be helpful to break the words apart (i.e., poly – atomic). Make sure your group comes to consensus.

   Monatomic—
   Polyatomic—

3. What types of elements (metals or nonmetals) are shown in the polyatomic ions in Model 1?

4. The net charge on a sulfide ion ($S^{2–}$) is –2. Explain how this ion obtains its charge. Your answer should include a discussion of subatomic particles.

5. The dotted line around each polyatomic ion in Model 1 shows that the group of atoms has a charge. The charge is not on any one atom, but rather on the group of atoms as a whole. Based on your knowledge of monatomic ions, propose an explanation for the net charge on a polyatomic ion. Your answer should include a discussion of subatomic particles.

6. What are the similarities and differences between the nitrate and nitrite ions in Model 1?

7. What are the similarities and differences between the sulfate and sulfite ions in Model 1?

8. The “chlorate” polyatomic ion has a charge of –1 and is composed of one chlorine atom (the central atom) and three oxygen atoms.
   a. Draw a model of a chlorate ion.
b. Write the chemical formula for the chlorate ion, including its charge.

9. In your group discuss what “chlorite” would look like.
   a. Draw a model of a chlorite ion.

b. Write the chemical formula for the chlorite ion, including its charge.

Model 2 – Common Polyatomic Ions

<table>
<thead>
<tr>
<th>1+</th>
<th>1–</th>
<th>2–</th>
<th>3–</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonium NH₄⁺</td>
<td>acetate CH₃COO⁻</td>
<td>sulfate SO₄²⁻</td>
<td>phosphate PO₄³⁻</td>
</tr>
<tr>
<td>hydroxide</td>
<td>nitrate NO₃⁻</td>
<td>sulfite SO₃²⁻</td>
<td></td>
</tr>
<tr>
<td>nitrite</td>
<td>NO₂⁻</td>
<td>carbonate CO₃²⁻</td>
<td></td>
</tr>
<tr>
<td>bicarbonate</td>
<td>HCO₃⁻</td>
<td>chromate CrO₄²⁻</td>
<td></td>
</tr>
<tr>
<td>permanganate</td>
<td>MnO₄⁻</td>
<td>dichromate Cr₂O₇²⁻</td>
<td></td>
</tr>
<tr>
<td>perchlorate</td>
<td>ClO₄⁻</td>
<td></td>
<td></td>
</tr>
<tr>
<td>chlorate</td>
<td>ClO₃⁻</td>
<td></td>
<td></td>
</tr>
<tr>
<td>chlorite</td>
<td>ClO₂⁻</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hypochlorite</td>
<td>ClO⁻</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. What is the only polyatomic ion that is a cation?

11. How are bicarbonate and carbonate related?

12. Predict the chemical formula and charge for the bisulfate ion.

13. How are chromate and dichromate related?
14. Bromine forms polyatomic ions with structures similar to those of chlorine. Using the chlorine family of polyatomic ions as a model, predict the name of the BrO$_4^{1–}$ ion.

15. Identify the polyatomic ion in each of these ionic compounds. Write out the name and formula of the ions including their charges.

   a. CaCO$_3$
   b. Mg(OH)$_2$
   c. NH$_4$Cl

Model 3 – Ternary Ionic Compounds

<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Ion Symbols and Charges</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium phosphate</td>
<td>NH$_4^{1+}$ PO$_4^{3–}$</td>
<td>(NH$_4$)$_3$PO$_4$</td>
</tr>
<tr>
<td>Barium nitrite</td>
<td>Ba$^{2+}$ NO$_2^{1–}$</td>
<td>Ba(NO$_2$)$_2$</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>NH$_4^{1+}$ SO$_4^{2–}$</td>
<td>(NH$_4$)$_2$SO$_4$</td>
</tr>
<tr>
<td>Aluminum carbonate</td>
<td>Al$^{3+}$ CO$_3^{2–}$</td>
<td>Al$_2$(CO$_3$)$_3$</td>
</tr>
<tr>
<td>Iron(III) hydroxide</td>
<td>Fe$^{3+}$ OH$^{1–}$</td>
<td>Fe(OH)$_3$</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>K$^{1+}$ NO$_3^{1–}$</td>
<td>KNO$_3$</td>
</tr>
</tbody>
</table>

16. How are ternary ionic compounds in Model 3 different from binary ionic compounds (NaCl, MgO, CaBr$_2$, etc.) that you’ve seen previously? *Hint:* Consider the meaning of the word “binary.”

17. Consider the compound iron(III) hydroxide in Model 3.

   a. How many hydroxide ions (OH$^{1–}$) are combined with an iron(III) ion (Fe$^{3+}$)?

   b. Is your answer to part a the only combination of iron(III) and hydroxide that should exist in nature? Explain.

18. Consider the compound barium nitrite in Model 3.

   a. What does the subscripted “2” inside the parentheses of the chemical formula tell you about the compound?

   \[ \text{Ba(NO}_2\text{)}_2 \]
b. What does the subscripted “2” outside the parentheses of the chemical formula tell you about the compound?

\[ \text{Ba(NO}_2\text{)}_2 \]

19. How many atoms of each element are in one formula unit of ammonium phosphate, \((\text{NH}_4\text{)}_3\text{PO}_4\)?

- nitrogen
- hydrogen
- phosphorus
- oxygen

20. A student writes the chemical formula for the ionic compound calcium hydroxide as \(\text{CaOH}_2\).

a. Write the chemical formula for each ion in the compound.

- Calcium:
- Hydroxide:

b. Why is the student’s chemical formula for the compound calcium hydroxide wrong?

21. Many of the chemical formulas in Model 3 include parentheses. Which one of the following rules summarizes the appropriate use of parentheses in ternary ionic compounds? For the three rules that do not apply in all cases, show at least one counter example from the chemical formulas in Model 3.

*Parentheses are used around any ion that is used more than once in a formula unit.

*Parentheses are used around any polyatomic ion.

*Parentheses are used around any polyatomic ion used more than once in a formula unit.

*Parentheses are only used around polyatomic anions used more than once in a formula unit.

22. Write chemical formulas for the following ternary ionic compounds.

a. Calcium sulfate  

b. Copper(II) nitrate  

c. Lithium phosphate  

d. Potassium permanganate  

e. Aluminum sulfite  

f. Magnesium bicarbonate
23. Name the following ternary ionic compounds.

   a. \( \text{BaSO}_4 \)  
   b. \( \text{NH}_4\text{NO}_3 \)  
   c. \( \text{K}_2\text{Cr}_2\text{O}_7 \)  

   d. \( \text{Fe(NO}_3)_3 \)  
   e. \( \text{Mg(CH}_3\text{COO)}_2 \)  
   f. \( \text{Al}_2\text{(CO}_3)_3 \)
Naming Molecular Compounds

How are the chemical formula and name of a molecular compound related?

Why?

When you began chemistry class this year, you probably already knew that the chemical formula for carbon dioxide was CO₂. Today you will find out why CO₂ is named that way. Naming chemical compounds correctly is of paramount importance. The slight difference between the names carbon monoxide (CO, a poisonous, deadly gas) and carbon dioxide (CO₂, a greenhouse gas that we exhale when we breathe out) can be the difference between life and death! In this activity you will learn the naming system for molecular compounds.

Model 1 – Molecular Compounds

<table>
<thead>
<tr>
<th>Molecular Formula</th>
<th>Number of Atoms of First Element</th>
<th>Number of Atoms of Second Element</th>
<th>Name of Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClF</td>
<td></td>
<td></td>
<td>Chlorine monofluoride</td>
</tr>
<tr>
<td>ClF₅</td>
<td>1</td>
<td>5</td>
<td>Chlorine pentafluoride</td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td></td>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>Cl₂O</td>
<td></td>
<td></td>
<td>Dichlorine monoxide</td>
</tr>
<tr>
<td>PCl₅</td>
<td></td>
<td></td>
<td>Phosphorus pentachloride</td>
</tr>
<tr>
<td>N₂O₅</td>
<td></td>
<td></td>
<td>Dinitrogen pentoxide</td>
</tr>
</tbody>
</table>

1. Fill in the table to indicate the number of atoms of each type in the molecular formula.

2. Examine the molecular formulas given in Model 1 for various molecular compounds.
   a. How many different elements are present in each compound shown?

   b. Do the compounds combine metals with metals, metals with nonmetals, or nonmetals with nonmetals?

3. Find all of the compounds in Model 1 that have chlorine and fluorine in them. Explain why the name “chlorine fluoride” is not sufficient to identify a specific compound.

4. Assuming that the name of the compound gives a clue to its molecular formula, predict how many atoms each of these prefixes indicates, and provide two examples.

   mono-
   di-
   penta-

Naming Molecular Compounds
5. Examine the prefixes in Model 2. Fill in the numerical value that corresponds to each prefix.

6. What suffix (ending) do all the compound names in Model 2 have in common?

7. Carefully examine the names of the compounds in Model 2. When is a prefix NOT used in front of the name of an element?

8. Consider the compound NO.

   a. Which element, nitrogen or oxygen, would require a prefix in the molecule name? Explain your answer.

   b. Name the molecule NO.

9. Find two compounds in Model 2 that contain a subscript of “4” in their molecular formula.

   a. List the formulas and names for the two compounds.

   b. What is different about the spelling of the prefix meaning “four” in these two names?
10. Find two compounds in Model 2 that contain the prefix “mono-” in their names.  
   a. List the formulas and names for the two compounds.  
   b. What is different about the spelling of the prefix meaning “one” in these two names?  

11. Identify any remaining names of compounds in Model 2 where the prefixes do not exactly match the spelling shown in the prefix table.  

12. Use your answers to Questions 9–11 to write a guideline for how and when to modify a prefix name for a molecular compound. Come to a consensus within your group.  

13. Would the guideline you wrote for Question 12 give you the correct name for NI₃ as it is given in Model 2? If not, modify your guideline to include this example.  

14. All of the compounds listed in Model 2 are binary molecular compounds. Compounds such as CH₃OH or PF₂Cl₃ are not binary, and compounds such as NaCl or CaCl₂ are not molecular. Propose a definition for “binary molecular compounds.”  

15. Collaborate with your group members to write a list of rules for recognizing and naming binary molecular compounds from their chemical formulas.
16. For each of the following compounds, indicate whether or not your naming rules from Question 15 will apply. If not, explain why the naming rules do not apply.

FeI$_3$  ICl$_5$  HBrO$_4$

17. Using the rules your group developed in Question 15, name each of the following molecular compounds.

<table>
<thead>
<tr>
<th>Molecular Formula</th>
<th>Molecule Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBr$_3$</td>
<td></td>
</tr>
<tr>
<td>SCl$_4$</td>
<td></td>
</tr>
<tr>
<td>N$_2$F$_2$</td>
<td></td>
</tr>
<tr>
<td>SO$_3$</td>
<td></td>
</tr>
<tr>
<td>BrF</td>
<td></td>
</tr>
</tbody>
</table>

18. Write molecular formulas for the following compounds.

<table>
<thead>
<tr>
<th>Molecular Formula</th>
<th>Molecule Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disulfur decafluoride</td>
</tr>
<tr>
<td></td>
<td>Carbon tetrachloride</td>
</tr>
<tr>
<td></td>
<td>Oxygen difluoride</td>
</tr>
<tr>
<td></td>
<td>Dinitrogen trioxide</td>
</tr>
<tr>
<td></td>
<td>Tetraphosphorus heptasulfide</td>
</tr>
</tbody>
</table>
The compounds below are of several different types. Use the flow chart to determine the naming system to use and name each compound shown below.

<table>
<thead>
<tr>
<th>Formula</th>
<th>IUPAC Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fe(NO₂)₃</td>
<td></td>
</tr>
<tr>
<td>2. Na₂S₂O₃</td>
<td></td>
</tr>
<tr>
<td>3. P₂O₅</td>
<td></td>
</tr>
<tr>
<td>4. BaBr₂</td>
<td></td>
</tr>
<tr>
<td>5. Mn₂(Cr₂O₇)₇</td>
<td></td>
</tr>
<tr>
<td>6. CaCl₂</td>
<td></td>
</tr>
<tr>
<td>7. (NH₄)₂S</td>
<td></td>
</tr>
<tr>
<td>8. CuF</td>
<td></td>
</tr>
<tr>
<td>9. Br₂O</td>
<td></td>
</tr>
<tr>
<td>10. HgSO₄</td>
<td></td>
</tr>
<tr>
<td>11. Al₂O₃</td>
<td></td>
</tr>
<tr>
<td>12. SCl₆</td>
<td></td>
</tr>
<tr>
<td>13. IF₇</td>
<td></td>
</tr>
<tr>
<td>14. Cr(CO₃)₃</td>
<td></td>
</tr>
<tr>
<td>15. KNO₂</td>
<td></td>
</tr>
</tbody>
</table>
Write the correct name for the chemical formulas below. Use the flow chart to help!

<table>
<thead>
<tr>
<th>IUPAC Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. antimony tribromide</td>
<td></td>
</tr>
<tr>
<td>2. chlorine dioxide</td>
<td></td>
</tr>
<tr>
<td>3. sodium sulfate</td>
<td></td>
</tr>
<tr>
<td>4. iron (II) oxide</td>
<td></td>
</tr>
<tr>
<td>5. calcium chloride</td>
<td></td>
</tr>
<tr>
<td>6. ammonia</td>
<td></td>
</tr>
<tr>
<td>7. zinc hydroxide</td>
<td></td>
</tr>
<tr>
<td>8. diphosphorus pentoxide</td>
<td></td>
</tr>
<tr>
<td>9. zinc nitrate</td>
<td></td>
</tr>
<tr>
<td>10. iron (III) oxide</td>
<td></td>
</tr>
<tr>
<td>11. potassium nitride</td>
<td></td>
</tr>
<tr>
<td>12. tin (IV) oxide</td>
<td></td>
</tr>
<tr>
<td>13. ammonium phosphate</td>
<td></td>
</tr>
<tr>
<td>14. magnesium hydroxide</td>
<td></td>
</tr>
<tr>
<td>15. carbon monoxide</td>
<td></td>
</tr>
</tbody>
</table>
### Formula Writing & Naming Review

1. In the formula $X_2(SO_4)_3$, the $X$ represents a metal. This metal could be located on the Periodic Table in
   - 1) Group 1  
   - 2) Group 2  
   - 3) Group 13
   - 4) Group 14

2. Every water molecule has two hydrogen atoms bonded to one oxygen atom. This fact supports the concept that elements in a compound are
   - 1) chemically combined in a fixed proportion
   - 2) chemically combined in proportions that vary
   - 3) physically mixed in a fixed proportion
   - 4) physically mixed in proportions that vary

3. Which element forms a compound with chlorine with the general formula $MCl$?
   - 1) Rb  
   - 2) Ra  
   - 3) Re  
   - 4) Rn

4. Which formula represents strontium phosphate?
   - 1) SrPO$_4$  
   - 2) Sr$_3$PO$_8$  
   - 3) Sr$_2$(PO$_4$)$_3$  
   - 4) Sr$_3$(PO$_4$)$_2$

5. The compound $XCl$ is classified as ionic if $X$ represents the element
   - 1) H  
   - 2) I  
   - 3) Rb  
   - 4) Br

6. What is the chemical formula for iron(III) oxide?
   - 1) FeO  
   - 2) Fe$_2$O$_3$  
   - 3) Fe$_3$O  
   - 4) Fe$_3$O$_2$

7. In which compound is the ratio of metal ions to nonmetal ions 1 to 2?
   - 1) calcium bromide  
   - 2) calcium oxide  
   - 3) calcium phosphide  
   - 4) calcium sulfide

8. Element $X$ reacts with iron to form two different compounds with the formulas Fe$X$ and Fe$_2X_3$. To which group on the Periodic Table does element $X$ belong?
   - 1) Group 8  
   - 2) Group 2  
   - 3) Group 13  
   - 4) Group 16

9. What is the chemical formula for sodium sulfate?
   - 1) Na$_2$SO$_3$  
   - 2) Na$_2$SO$_4$  
   - 3) NaSO$_3$  
   - 4) NaSO$_4$

10. What is the IUPAC name for the compound ZnO?
    - 1) zinc oxide  
    - 2) zinc peroxide  
    - 3) zinc oxalate  
    - 4) zinc hydroxide

11. What is the chemical formula of iron(III) sulfide?
    - 1) FeS  
    - 2) Fe$_2$S$_3$  
    - 3) Fe$_3$(SO$_3$)$_3$  
    - 4) Fe$_4$(SO$_3$)$_3$

12. Which formula represents copper(I) oxide?
    - 1) CuO  
    - 2) Cu$_2$O  
    - 3) Cu$_3$O  
    - 4) Cu$_2$O$_2$

13. Which formula represents lead(II) chromate?
    - 1) PbCrO$_4$  
    - 2) Pb$_2$(CrO$_4$)$_2$  
    - 3) Pb$_2$CrO$_4$  
    - 4) Pb$_2$(CrO$_4$)$_3$

14. A compound is made up of iron and oxygen, only. The ratio of iron ions to oxide ions is 2:3 in this compound. The IUPAC name for this compound is
    - 1) triiron dioxide  
    - 2) iron(II) oxide  
    - 3) iron(III) oxide  
    - 4) iron trioxide

15. What is the IUPAC name for the compound FeS?
    - 1) iron(II) sulfate  
    - 2) iron(III) sulfate  
    - 3) iron(II) sulfide  
    - 4) iron(III) sulfide

16. What is the formula of titanium(II) oxide?
    - 1) TiO  
    - 2) TiO$_2$  
    - 3) Ti$_2$O  
    - 4) Ti$_2$O$_3$

17. Which is a binary compound?
    - 1) CaCl$_2$  
    - 2) KOH  
    - 3) NaNO$_3$  
    - 4) MgSO$_4$

18. What is the correct formula for ammonium carbonate?
    - 1) NH$_4$(CO$_3$)$_2$  
    - 2) NH$_4$CO$_3$  
    - 3) (NH$_4$)$_2$(CO$_3$)$_2$  
    - 4) (NH$_4$)$_2$CO$_3$
**Chemical Equations**

**THE ANATOMY OF A CHEMICAL EQUATION**

**Part A:** Label the chemical equation using **PRODUCT, REACTANTS, SUBSCRIPT, COEFFICIENT** and **YIELDS**.

\[4\text{Al (s)} + 3\text{O}_2 (g) \rightarrow 2\text{Al}_2\text{O}_3 (s)\]

**Part B: Parts & Pieces:**
1. Circle each subscript.
2. Draw a square around each coefficient.
3. Answer the questions related to each chemical formula.

- **O\textsubscript{2}**
  - What element does the O represent?
  - How many atoms of each element are shown?
  - C = _____  O = _____

- **CO\textsubscript{2}**
  - How many atoms of each element are shown in the formula?
  - C = _____  O = _____

- **5H\textsubscript{2}**
  - How many atoms of Hydrogen are in this formula as shown?
  - C = _____  O = _____

- **2C\textsubscript{2}H\textsubscript{6}**
  - How many atoms of each element are shown in the formula?
  - C = _____  H = _____

- **2Na\textsubscript{2}SO\textsubscript{4}**
  - How many atoms of each element are shown in the formula?
  - Na = _____  S = _____  O = _____
### Number of Atoms in a Formula

Determine the number of atoms in the following chemical formulas.

<table>
<thead>
<tr>
<th></th>
<th>Formula</th>
<th></th>
<th>Formula</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \text{NaCl} )</td>
<td></td>
<td>11</td>
<td>( \text{Cu(NO}_3\text{)}_2 )</td>
</tr>
<tr>
<td>2</td>
<td>( \text{H}_2\text{SO}_4 )</td>
<td></td>
<td>12</td>
<td>( \text{KMnO}_4 )</td>
</tr>
<tr>
<td>3</td>
<td>( \text{KNO}_3 )</td>
<td></td>
<td>13</td>
<td>( \text{H}_2\text{O}_2 )</td>
</tr>
<tr>
<td>4</td>
<td>( \text{CaCl}_2 )</td>
<td></td>
<td>14</td>
<td>( \text{H}_3\text{PO}_4 )</td>
</tr>
<tr>
<td>5</td>
<td>( \text{C}_2\text{H}_6 )</td>
<td></td>
<td>15</td>
<td>( \text{(NH}_4\text{)}_3\text{PO}_4 )</td>
</tr>
<tr>
<td>6</td>
<td>( \text{Ba(OH)}_2 )</td>
<td></td>
<td>16</td>
<td>( \text{Fe}_2\text{O}_3 )</td>
</tr>
<tr>
<td>7</td>
<td>( \text{NH}_4\text{Br} )</td>
<td></td>
<td>17</td>
<td>( \text{NaC}_2\text{H}_3\text{O}_2 )</td>
</tr>
<tr>
<td>8</td>
<td>( \text{Ca}_3(\text{PO}_4)_2 )</td>
<td></td>
<td>18</td>
<td>( \text{Mg(C}_2\text{H}_3\text{O}_2)_2 )</td>
</tr>
<tr>
<td>9</td>
<td>( \text{Al}_2(\text{SO}_4)_3 )</td>
<td></td>
<td>19</td>
<td>( \text{Hg}_2\text{Cl}_2 )</td>
</tr>
<tr>
<td>10</td>
<td>( \text{Mg(NO}_3\text{)}_2 )</td>
<td></td>
<td>20</td>
<td>( \text{K}_2\text{SO}_3 )</td>
</tr>
</tbody>
</table>
Balancing Chemical Equations

We balance chemical equations to confirm the law of conservation of mass. The law of conservation of mass states that the mass of substances produced by a chemical reaction is always equal to the mass of the reactants. Matter is neither created nor destroyed.

RULES FOR BALANCING CHEMICAL EQUATIONS:
1. All formulas for molecules and compounds must be correct (No cheating!)
2. Add coefficients to balance atoms.
3. ONLY change coefficients, NOT formulas or subscripts
4. Balance the atoms in the largest compound first
5. Balance monatomic and diatomic elements last
6. Check to be sure that the number of atoms are the same on both sides of the equation
7. Reduce all coefficients to the lowest whole number ratio

Balance the following chemical equations.

1. _____ Ca + _____ O₂ → _____ CaO

2. _____ Mg + _____ HCl → _____ H₂ + _____ MgCl₂

3. _____ AgNO₃ + _____ Na₂S → _____ Ag₂S + _____ NaNO₃

4. _____ HCl + _____ Fe₂O₃ → _____ H₂O + _____ FeCl₃

5. _____ AlBr₃ + _____ K₂SO₄ → _____ KBr + _____ Al₂(SO₄)₃
6. \[ _____ S + _____ O_2 \rightarrow _____ SO_3 \]

7. \[ _____ Zn + _____ HCl \rightarrow _____ ZnCl_2 + _____H_2 \]

8. \[ _____ Na + _____ Cl_2 \rightarrow _____ NaCl \]

9. \[ _____ Al_2O_3 \rightarrow _____ Al + _____O_2 \]

10. \[ _____ LiBr + _____ F_2 \rightarrow _____ Br_2 + _____ LiF \]
Types of Chemical Reactions

Do atoms rearrange in predictable patterns during chemical reactions?

Why?
Recognizing patterns allows us to predict future behavior. Weather experts use patterns to predict dangerous storms so people can get their families to safety. Political analysts use patterns to predict election outcomes. Similarly, chemists classify chemical equations according to their patterns to help predict products of unknown but similar chemical reactions.

Model 1 – Types of Reactions

Set A

4Fe(s) + 3O\(_2\)(g) \rightarrow 2Fe\(_2\)O\(_3\)(s)
N\(_2\)(g) + 3H\(_2\)(g) \rightarrow 2NH\(_3\)(g)
2SO\(_2\)(g) + O\(_2\)(g) \rightarrow 2SO\(_3\)(g)
MgO(s) + H\(_2\)O(l) \rightarrow Mg(OH)\(_2\)(aq)
P\(_2\)O\(_5\)(g) + 3H\(_2\)O(l) \rightarrow 2H\(_3\)PO\(_4\)(aq)
SO\(_4\)(g) + H\(_2\)O(l) \rightarrow H\(_2\)SO\(_4\)(aq)

Set B

MgCO\(_3\)(s) \rightarrow MgO(s) + CO\(_2\)(g)
8Li\(_2\)S(s) \rightarrow 16Li(s) + S\(_6\)(s)
2H\(_2\)O(l) \rightarrow 2H\(_2\)(g) + O\(_2\)(g)
2KClO\(_3\)(s) \rightarrow 2KCl(s) + 3O\(_2\)(g)
2Na\(_2\)O\(_2\)(s) \rightarrow 2Na\(_2\O\(_2\)(s) + O\(_2\)(g)
(NH\(_4\))\(_2\)CO\(_3\)(s) \rightarrow 2NH\(_3\)(g) + H\(_2\)O(l) + CO\(_2\)(g)

Set C

2FeCl\(_3\)(aq) + 3Zn(s) \rightarrow 2Fe(s) + 3ZnCl\(_2\)(aq)
2Al(NO\(_3\))\(_3\)(aq) + 3Ca(s) \rightarrow 3Ca(NO\(_3\))\(_2\)(aq) + 2Al(s)
Mg(s) + CuSO\(_4\)(aq) \rightarrow MgSO\(_4\)(aq) + Cu(s)
2Al(s) + 6HCl(aq) \rightarrow 2AlCl\(_3\)(aq) + 3H\(_2\)(g)
Cl\(_2\)(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br\(_2\)(l)
ZnBr\(_2\)(aq) + F\(_2\)(g) \rightarrow ZnF\(_2\)(aq) + Br\(_2\)(l)

Set D

AgNO\(_3\)(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO\(_3\)(aq)
2HNO\(_3\)(aq) + Mg(OH)\(_2\)(aq) \rightarrow Mg(NO\(_3\))\(_2\)(aq) + 2H\(_2\)O(l)
Na\(_2\)CO\(_3\)(aq) + CaCl\(_2\)(aq) \rightarrow CaCO\(_3\)(s) + 2NaCl(aq)
FeS(s) + 2HCl(aq) \rightarrow H\(_2\)S(g) + FeCl\(_2\)(aq)
HCl(aq) + NaOH(aq) \rightarrow H\(_2\)O(l) + NaCl(aq)
FeBr\(_3\)(aq) + K\(_3\)PO\(_4\)(aq) \rightarrow FePO\(_4\)(s) + 3KBr(aq)

1. The chemical equations in Model 1 contain the phase notations (s), (l), (g), and (aq). Match each symbol with its meaning.
   - dissolved in water
   - liquid
   - solid
   - gas

2. Based on the examples provided, which set(s) of reactions in Model 1 typically involve ions in solution (A, B, C or D)?

3. Based on the examples provided, which set(s) of reactions in Model 1 typically involve gases and/or solids?
4. Match each description below to one of the reactions sets (A, B, C or D) from Model 1.
__________________ Ionic compounds dissolved in water switch partners.
__________________ One compound breaks into elements or smaller compounds.
__________________ Two or more elements or compounds combine to form one product.
__________________ Part of an ionic compound is removed and replaced by a new element.

5. Define the following terms as they are commonly used in the English language.
Synthesis—
Decomposition—
Replacement—

6. The four sets of chemical reactions shown in Model 1 have the following general names. Discuss within your group which name belongs to which set of chemical reactions. Write the name in the appropriate place in Model 1.

   Single Replacement Reaction  Synthesis Reaction
   Double Replacement Reaction  Decomposition Reaction

7. Can two elements be used as reactants for a synthesis reaction? If yes, give at least one example from Model 1 to support your answer.

8. Can two compounds be used as reactants for a synthesis reaction? If yes, give at least one example from Model 1 to support your answer.

9. What types of substances (elements or compounds) are seen in the products of decomposition reactions? Use examples from Model 1 to support your answer.

10. In single replacement reactions, do any of the atoms change their charge? If yes, use an example from Model 1 to describe the changes that take place.

11. In double replacement reactions, do any of the atoms change their charge? If yes, use an example from Model 1 to describe the changes that take place.
12. Choose one example from the set of synthesis reactions in Model 1.
   
   a. Write the chemical reaction in reverse.
   
   b. Label the reaction written in part a with one of the reaction types in Model 1.

13. Identify each of the reactions below as synthesis (S), decomposition (D), single replacement (SR) or double replacement (DR).

   ____  K$_2$O(s) + H$_2$O(l) → 2KOH(aq)
   ____  2MgCl$_2$(aq) + Na$_2$CO$_3$(aq) → 2NaCl(aq) + MgCO$_3$(s)
   ____  2Al$_2$O$_3$(s) → 4Al(s) + 3O$_2$(g)
   ____  Cu(NO$_3$)$_2$(aq) + Zn(s) → Cu(s) + Zn(NO$_3$)$_2$(aq)
   ____  H$_2$SO$_4$(aq) + 2NaOH(aq) → Na$_2$SO$_4$(aq) + 2H$_2$O(l)
   ____  2K(s) + 2H$_2$O(l) → 2KOH(aq) + H$_2$(g)
   ____  2O$_2$(g) + N$_2$(g) → N$_2$O$_4$(g)
   ____  2NaF(s) → 2Na(s) + F$_2$(g)

14. A student writes the following incorrect chemical equation for the synthesis of magnesium oxide.

   Mg + O$_2$ → MgO$_2$

   Another student writes the following incorrect synthesis reaction.

   Mg + O → MgO

   a. What is the correct formula for magnesium oxide? Hint: Magnesium oxide is an ionic compound.

   b. What is the correct formula for elemental oxygen?

   c. Describe the error made by the first student.

   d. Describe the error made by the second student.

   e. Write the correct balanced chemical equation for the synthesis of magnesium oxide.
15. A student writes the following incorrect chemical equation for a single replacement reaction between lithium bromide and fluorine.

\[ 2\text{LiBr}(aq) + \text{F}_2(g) \rightarrow 2\text{Li}(s) + 2\text{FBr}(g) \]

\textit{a.} In a single replacement reaction, part of an ionic compound is removed and replaced by a new element. What element will fluorine replace in lithium bromide? \textit{Hint:} What is the most common ionic form of fluorine?

\textit{b.} What is wrong with the student’s prediction of the products in the above reaction?

\textit{c.} Predict the products and write the correct balanced equation for the single replacement reaction between lithium bromide and fluorine.

16. A student writes the following incorrect chemical equation for a double replacement reaction between iron(III) bromide and sodium hydroxide solutions.

\[ \text{FeBr}_3(aq) + \text{NaOH}(aq) \rightarrow \text{FeOH}(s) + \text{NaBr}_3(aq) \]

\textit{a.} What is wrong with the chemical formula(s) of the product(s) predicted by this student?

\textit{b.} Write the correct equation for the double replacement reaction between iron(III) bromide and sodium hydroxide.

17. Consider the following chemical reaction written as a word equation.

\textit{diphosphorus pentoxide} + \textit{water} \rightarrow \textit{phosphoric acid}

\textit{a.} Identify the type of chemical reaction from Model 1 that would describe this reaction.

\textit{b.} Write chemical formulas under the names of the substances in the word equation.

\textit{c.} Balance the chemical equation.
Read This!

Chemists use their knowledge of synthesis, decomposition, single replacement, and double replacement to predict what will happen in chemical reactions. When predicting the products for a reaction it is important to remember that atoms or ions will only combine in ways that make them stable, otherwise the reaction will not happen under normal conditions. This means that it is important to pay attention to ion charges, the natural state of elements, and the formulas of common molecular substances like carbon dioxide and water. It is only after predicting the products and writing the correct formulas that a chemist would then apply the law of conservation of mass and balance the chemical equation using coefficients as needed.

18. Use your understanding of common chemical reactions to predict the products for the following reactions. Writing a word equation may be helpful. Balance the chemical equations after you have written the correct chemical formulas for all of the reactants and products.

   a. Al(s) + N₂(g) →

   b. dinitrogen oxide(g) →

   c. SrCl₂(aq) + 2AgNO₃(aq) →

   d. chromium(III) nitrate(aq) + zinc chloride(aq) →

   e. 2Na(s) + Cl₂(g) →

   f. Zn(s) + 2HCl(aq) →