**Information**: Naming Ions

To write an ion, you write the symbol of the atom and put the charge in the upper right corner. Consider the following examples: $\text{Al}^{3+}$, $\text{O}^{2-}$, $\text{Mg}^{2+}$. You should verify that each of the charges is correct.

Positive and negative ions are named differently. Positive ions retain the same name as the parent atom. For example, $\text{Al}^{3+}$ is called the “aluminum ion” and $\text{Mg}^{2+}$ is called the “magnesium ion.” Negative ions are named a little differently. For negative ions, you change the ending of the name to “-ide”. Therefore, $\text{O}^{2-}$ is named oxide and $\text{P}^{3-}$ is named phosphide.

**Critical Thinking Questions**

1. Write the symbol (including the charge) and name for each of the ions for each of the following:
   a) $\text{Ca}$
   b) $\text{Cl}$
   c) $\text{N}$
   d) $\text{K}$
   e) $\text{S}$
   f) $\text{B}$
   g) $\text{P}$

**Information**: Ionic Bonding and Formulas

There are two ways in which atoms can “bond” to each other and form a compound. The means of bonding that we will consider now is called ionic bonding, which occurs between a metal and a nonmetal. As you know, opposite charges attract. Ionic bonding is when two ions of opposite charge attract and bond to each other forming an ionic compound. Consider the following examples of formulas for ionic compounds:

- One $\text{Na}^+$ (sodium ion) and one $\text{Cl}^-$ (chloride ion) bond to make $\text{NaCl}$, “sodium chloride.”
- One $\text{Mg}^{2+}$ (magnesium ion) and two $\text{F}^-$ (fluoride ion) bond to make $\text{MgF}_2$, “magnesium fluoride.”
- Three $\text{Ca}^{2+}$ (calcium ion) and two $\text{N}^{3-}$ (nitride ion) bond to make $\text{Ca}_3\text{N}_2$, “calcium nitride.”
- One $\text{Al}^{3+}$ (aluminum ion) and one $\text{N}^{3-}$ (nitride ion) bond to make $\text{AlN}$, “aluminum nitride.”

The small numbers at the bottom right of each symbol in a formula are called “subscripts.” Subscripts tell us how many of each type of atom are present. For example in the formula $\text{Mg}_3\text{N}_2$ there are three magnesium ions and two nitride ions.

**Critical Thinking Questions**

2. Consider the formula $\text{NaCl}$ in the above example. It tells us that one $\text{Na}^+$ ion is bonded to one $\text{Cl}^-$ ion. What is the overall charge for $\text{NaCl}$? Is it positive, negative, or neutral?
3. Consider MgF₂. This formula tells us that one Mg²⁺ ion bonds with two F⁻ ions. What is the overall charge on MgF₂?

4. What is the overall charge on any ionic compound?

5. Why is calcium nitride written like Ca₃N₂ and not something like CaN₂ or Ca₂N₃? In other words why do exactly three calcium ions bond with exactly two nitride ions?

6. The formula Ca₃N₂ can never be written as N₂Ca₃. To find out why, take note of each of the four example formulas given above.
   a) In terms of charge, what do the first ions named all have in common?
   b) In terms of charge, what do the second ions named all have in common?
   c) Now, why can’t Ca₃N₂ ever be written like N₂Ca₃?

7. There are two rules to follow when writing formulas for ionic compounds. One has to do with charges (see questions 4 and 5) and the other has to do with which atom to write first and which one to write second (see question 6). What are these two rules?

8. What is wrong with the following formulas?
   a) Al₂S            b) PNa₃            c) Mg₂S₂

9. Write the formula and name for the compound that forms when the following atoms form ionic compounds. The first is done for you.
   a) nitrogen and sodium        b) barium and sulfur          c) magnesium and iodine
   Na₃N
   sodium nitride
   d) oxygen and aluminum        e) calcium and phosphorus      f) sodium and sulfur

10. Given the following compounds, determine the charge on the unknown ion “X”.
    a) X₂S            b) MgX            c) X₃P₂
**Information**: Polyatomic Ions

The word, "polyatomic" means "many atoms". A polyatomic ion, therefore, is an ion that is made of more than one atom. An example of a polyatomic ion is the sulfate ion, $\text{SO}_4^{2-}$. Sulfate is composed of one sulfur atom and four oxygen atoms and overall sulfate has a negative two charge. Some polyatomic ions:

- Sulfate: $\text{SO}_4^{2-}$
- Cyanide: $\text{CN}^-$
- Acetate: $\text{C}_2\text{H}_3\text{O}_2^-$
- Phosphate: $\text{PO}_4^{3-}$
- Ammonium: $\text{NH}_4^+$
- Hydroxide: $\text{OH}^-$
- Nitrate: $\text{NO}_3^-$
- Chlorate: $\text{ClO}_3^-$
- Carbonate: $\text{CO}_3^{2-}$

**Critical Thinking Questions**

1. What do all of the polyatomic ions that have the suffix "-ate" have in common?

2. Which two atoms do you think compose the polyatomic ion called "silicate"?

3. What is the difference between calcium nitride and calcium nitrate?

**Information**: Writing Formulas With Polyatomic Ions

First of all, you must remember that you can never change the formula for a polyatomic ion. Sulfate is always $\text{SO}_4^{2-}$ and never $\text{S}_2\text{O}_5^{4+}$ or something else. Following are some examples of chemical formulas that contain polyatomic ions.

Ammonium chloride is formed from one ammonium ion ($\text{NH}_4^+$) and one chloride ion (Cl$^-$) to give the formula: $\text{NH}_4\text{Cl}$. Sodium sulfate requires two sodium ions (Na$^+$) because sulfate ($\text{SO}_4^{2-}$) has a negative two charge; the formula is: $\text{Na}_2\text{SO}_4$.

Consider calcium hydroxide. Calcium has a positive two charge ($\text{Ca}^{2+}$) and hydroxide has a negative one charge (OH$^-$_). We need two hydroxide ions to combine with one calcium ion so that the overall charge ends up being zero. We write calcium hydroxide like $\text{Ca(OH)}_2$.

Following are some more examples:

- Potassium acetate: $\text{KC}_2\text{H}_3\text{O}_2$
- Barium phosphate: $\text{Ba}_3(\text{PO}_4)_2$
- Magnesium nitrate: $\text{Mg(NO}_3)_2$
- Calcium carbonate: $\text{CaCO}_3$

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Critical Thinking Questions

4. As mentioned above, calcium hydroxide is written like Ca(OH)$_2$. Why can’t it be written like CaOH$_2$?

5. As mentioned above, barium phosphate is written as Ba$_3$(PO$_4$)$_2$. Why can’t it be written like Ba$_3$PO$_{42}$?

6. Name the following compounds. Each includes at least one polyatomic ion.
   a) Na$_3$PO$_4$  
   b) (NH$_4$)$_2$SO$_4$  
   c) Mg(C$_2$H$_3$O$_2$)$_2$
   
   d) (NH$_4$)$_2$S  
   e) CaCO$_3$  
   f) Ba(NO$_3$)$_2$

7. Write formulas for the following ionic compounds. Note that each includes a polyatomic ion.
   a) lithium phosphate  
   b) ammonium oxide  
   c) barium hydroxide
   
   d) calcium cyanide  
   e) sodium chlorate  
   f) potassium sulfate

8. In question 3, you were asked the difference between calcium nitride and calcium nitrate. Write the formula for each of them.

   calcium nitride:  
   calcium nitrate:

Information: Formulas for Acids

Acids are compounds that contain positive hydrogen ions (H$^+$) bonded to a negative ion. For example, carbonic acid is formed when the carbonate ion (CO$_3^{2-}$) bonds with two hydrogen ions (H$^+$) to give H$_2$CO$_3$. Other common acids are listed below:

- Hydrochloric acid: HCl
- Sulfuric acid: H$_2$SO$_4$
- Nitric Acid: HNO$_3$
- Acetic Acid: HC$_2$H$_3$O$_2$

Critical Thinking Questions

9. Why do carbonic and sulfuric acid require two H$^+$ ions to bond, but HCl and HNO$_3$ only have one H$^+$?

10. Phosphoric acid is made from the phosphate ion and H$^+$ ions. Write the formula for phosphoric acid.
Information: Charges of Some Transition Elements

So far you have learned that you can predict the charge that an ion will have based on its location on the periodic table. However, the transition elements are not easy to predict. A few common transition elements are listed below. You should memorize their charges.

Silver: Ag⁺  Zinc: Zn²⁺  Cadmium: Cd²⁺

Critical Thinking Questions

1. Write the formulas for the following compounds:
   a) silver nitrate
   b) zinc phosphate
   c) cadmium chloride

Information: More Than One Possible Charge

Many transition elements can have more than one charge when they become an ion. Copper ions, for example, can be Cu⁺ or Cu²⁺. As another example, iron ions are sometimes Fe²⁺ and sometimes Fe³⁺.

Critical Thinking Questions

2. Copper and iron are in the “d block” and so you need to calculate their charge by comparing what bonds to them. Find the charge on copper and iron in each of the following compounds.
   a) CuCl₂  b) CuCl  c) FeSO₄  d) Fe₃(SO₄)₂

3. Give your best attempt at naming the compounds from question 2. (They are rewritten below.)
   a) CuCl₂  b) CuCl  c) FeSO₄  d) Fe₃(SO₄)₂

* Cations from the p-block can also have more than one charge. Exceptions are boron, aluminum, gallium, and indium that will always have a +3 charge.

   e) SnCl₂  f) PbS₂  g) AlBr₃
**Information: Formulas Containing Roman Numerals**

You probably put the same name for the compounds in question 3a and 3b. You may also have put the same name for the compounds in 3c and 3d. BUT these are not the same compound! You cannot have the same name for two different compounds. Here are the correct names for the compounds in questions 2 and 3:

- a) CuCl₂ copper(II) chloride
- b) CuCl copper(I) chloride
- c) FeSO₄ iron(II) sulfate
- d) Fe₂(SO₄)₃ iron(III) sulfate

**Critical Thinking Questions**

4. Compare your answers for questions 2 & 3 with the names of the compounds given in the information section. What do the Roman numerals stand for?

5. Why is MnO₂ called manganese(IV) oxide?

6. Name the following compounds. *Note: assume that anytime you have a transition element (d block element) you must use a Roman numeral unless the element is silver, zinc, or cadmium.* (The first one is done for you.)

- a) NiNO₃
- b) Cr₂(CO₃)₃
- c) FeNO₃
- d) CoCl₂
  *nickel(I) nitrate*

- e) Cu₃(PO₄)₂
- f) MnS
- g) ZnCl₂
- h) AgNO₃

7. Write the formulas for the following compounds. (The first one is done for you.)

- a) mercury(II) acetate
- b) chromium(III) sulfate
- c) iron(I) carbonate
  
  \( \text{Hg}(C₂H₃O₂)₂ \)

- d) potassium carbonate
- e) strontium nitride
- f) manganese(IV) chlorate


Information: Terminology

Recall that an ionic bond results from the combination of a metal and a nonmetal. A covalent bond is the type of bond between two nonmetals. Covalent bonds are formed by neutral atoms that share electrons rather than by charged ions. When a compound is formed by sharing electrons, the compound is called a molecule or molecular compound. It is important to note that ionic compounds are not called molecules. The largest class of molecules are called organic molecules. Carbon is the distinguishing mark of organic compounds.

Critical Thinking Questions

1. Circle any of the following compounds that would properly be called a “molecule”.

   a) H₂O        b) CO₂       c) NaCl       d) Mg₃P₂       e) N₂O₅

Information: Naming Covalent Compounds

There are several prefixes used to name molecules. The name “carbon oxide” is not sufficient because carbon and oxygen sometimes form CO₂ and sometimes CO. Prefixes are necessary to distinguish between them.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂O₄</td>
<td>dinitrogen tetraoxide</td>
</tr>
<tr>
<td>SF₆</td>
<td>sulfur hexafluoride</td>
</tr>
<tr>
<td>XeCl₅</td>
<td>xenon pentachloride</td>
</tr>
<tr>
<td>SO₃</td>
<td>sulfur trioxide</td>
</tr>
<tr>
<td>CO</td>
<td>carbon monoxide</td>
</tr>
</tbody>
</table>

Critical Thinking Questions

2. Fill in the table to indicate which prefix is used to represent the numbers. The first one is done for you.

<table>
<thead>
<tr>
<th>Number</th>
<th>Prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mono</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
3. Name each of the following molecules using the appropriate prefixes.
   a) $\text{N}_2\text{O}_5$        b) $\text{CF}_4$        c) $\text{SCl}_3$        d) $\text{SO}_2$

4. Which of the above compounds would be classified as “organic”?

**Information: Empirical Formulas**

Molecules can be represented by using either a molecular formula or an empirical formula. The molecular formula tells you exactly how many atoms of each element are in the compound. For example, in the table below, compound #2 has exactly 4 carbons and 8 hydrogens in each molecule. Observe the table below that shows four organic molecules along with a molecular and empirical formula for each one:

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Molecular Formula</th>
<th>Empirical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>$\text{C}_2\text{H}_4$</td>
<td>$\text{CH}_2$</td>
</tr>
<tr>
<td>#2</td>
<td>$\text{C}_4\text{H}_8$</td>
<td>$\text{CH}_2$</td>
</tr>
<tr>
<td>#3</td>
<td>$\text{C}_3\text{H}_8$</td>
<td>$\text{C}_3\text{H}_6$</td>
</tr>
<tr>
<td>#4</td>
<td>$\text{C}<em>8\text{H}</em>{18}$</td>
<td>$\text{C}_4\text{H}_9$</td>
</tr>
</tbody>
</table>

**Critical Thinking Questions**

5. What is an empirical formula?

6. How can molecules #1 and #2 have the same empirical formula even though they are different molecules?

7. Given the empirical formula for a compound is it possible to determine the molecular formula? If so, explain how.

8. Given the molecular formula for a compound is it possible to determine its empirical formula? If so, explain how.

9. Give the empirical formula for each of the molecules below:
   a) $\text{N}_2\text{O}_6$        b) $\text{C}_2\text{H}_4\text{O}_2$        c) $\text{C}_4\text{H}_{14}$        d) $\text{C}_3\text{H}_5$