# Naming Ionic Compounds

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook®**, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform®**.



Printed: November 25, 2013

flexbook
*next generation textbooks*

# CONCEPT 1 Naming Ionic Compounds

## Lesson Objectives

The student will:

- correctly name binary ionic compounds, compounds containing metals with variable oxidation numbers, and compounds containing polyatomic ions when given the formulas.
- provide chemical formulas for binary ionic compounds, compounds containing metals with variable oxidation numbers, and compounds containing polyatomic ions when given the names.

## Introduction

It is necessary for each symbol and each name in chemistry to be completely unique. Using an incorrect substance in a chemistry experiment could have disastrous results, so the names and symbols of elements and compounds must refer to exactly one substance. For beginning students, the system of naming chemicals can seem impossibly complex. This section presents the rules for naming various ionic compounds.

## Rules for Naming Ionic Compounds

When an atom gains or loses electrons to form an ion, its name sometimes changes. Main group metals retain their name when forming cations. For example, $K^+$ is a potassium ion, and $Mg^{2+}$ is a magnesium ion. However, when nonmetallic elements gain electrons to form anions, the ending of their names is changed to "-ide." For example, a fluorine atom gains one electron to become a fluoride ion ($F^-$), and sulfur gains two electrons to become a sulfide ion ($S^{2-}$). Polyatomic ions have names that you simply need to memorize. A list of common polyatomic ions was presented earlier in the chapter.

### Binary Ionic Compounds

Binary ionic compounds are compounds that contain only two kinds of ions, regardless of how many of each ion is present. To name such compounds, you simply write the name of the cation followed by the name of the anion. Unless you are dealing with a metal that can have multiple oxidation states, there is no need to indicate the relative number of cations and anions, since there is only one possible ratio that will give you a neutral compound.

**Examples:**

$MgCl_2$ ..... magnesium chloride

NaBr ..... sodium bromide

$AlF_3$ ..... aluminum fluoride

$K_2S$ ..... potassium sulfide

$CaI_2$ ..... calcium iodide

$Rb_2O$ ..... rubidium oxide

$H_3N$ ..... hydrogen nitride

## Polyatomic Ions

When naming a compound containing a polyatomic ion, the name of the polyatomic ion does not change regardless of whether it is written first or last in the formula. If the formula contains a positive polyatomic ion and a nonmetal, the ending of the nonmetal is replaced with "-ide." If the compound contains a metal and a polyatomic ion, both the metal and the polyatomic ion are written without any changes to their names.

**Examples:**

$NaC_2H_3O_2$ ..... sodium acetate

$Mg(NO_3)_2$ ..... magnesium nitrate

$(NH_4)_2CrO_4$ ..... ammonium chromate

$(NH_4)_2S$ ..... ammonium sulfide

$Ca(OH)_2$ ..... calcium hydroxide

$BaCr_2O_7$ ..... barium dichromate

$H_3PO_4$ ..... hydrogen phosphate

## Variable Oxidation Number Metals

Metals with variable oxidation numbers may form multiple different compounds with the same nonmetal. Iron, for example, may react with oxygen to form either FeO or $Fe_2O_3$. These are very different compounds with different properties. When we name these compounds, it is absolutely vital that we clearly distinguish between them. They are both iron oxides, but in FeO, iron has an oxidation number of $+2$, while in $Fe_2O_3$, it has an oxidation number of $+3$. The rule for naming these compounds is to write the oxidation number of the metal after the name. The oxidation number is written using Roman numerals and is placed in parentheses. For these two examples, the compounds would be named iron(II) oxide and iron(III) oxide. When you see that the compound involves a metal with multiple oxidation numbers, you must determine the oxidation number of the metal from the formula and indicate it using Roman numerals.

In general, main group metal ions have only one common oxidation state, whereas most of the transition metals have more than one. However, there are plenty of exceptions to this guideline. Main group metals that can have more than one oxidation state include tin ($Sn^{2+}$ or $Sn^{4+}$) and lead ($Pb^{2+}$ or $Pb^{4+}$). Transition metals with only one common oxidation state include silver ($Ag^{+}$), zinc ($Zn^{2+}$), and cadmium ($Cd^{2+}$). These should probably be memorized, but when in doubt, include the Roman numerals for transition metals. Do not do this for main group metals that do not have more than one oxidation state. Referring to AgCl as silver(I) chloride is redundant and may be considered wrong. However, copper chloride is definitely incorrect, because it could refer to either CuCl or $CuCl_2$.

Other than the use of Roman numerals to indicate oxidation state, naming these ionic compounds is no different than what we have already seen. For example, consider the formula $CuSO_4$. We know that the sulfate anion has a charge of -2. Therefore, for this to be a neutral compound, copper must have a charge of +2. The name of this compound is copper(II) sulfate.

How about $SnS_2$? Tin is a variable oxidation number metal. We need a Roman numeral in the name of this compound. The oxidation number of sulfur is $-2$. Two sulfide ions were necessary to combine with one tin ion. Therefore, the oxidation number of the tin must be $+4$, and the name of this compound is tin(IV) sulfide.

**Examples:**

PbO ..... lead(II) oxide

$FeI_2$ ..... iron(II) iodide

$Fe_2(SO_4)_3$ ..... iron(III) sulfate

$AuCl_3$ ..... gold(III) chloride

$CuO$ ..... copper(II) oxide

$PbS_2$ ..... lead(IV) sulfide

The most common error made by students in naming these compounds is to choose the Roman numeral based on the number of atoms of the metal. The Roman numeral in these names is the oxidation number of the metal. For example, in $PbS_2$, the oxidation state of lead (Pb) is $+4$, so the Roman numeral following the name lead is IV. Notice that there is no four in the formula. As in previous examples, the empirical formula is always the lowest whole number ratio of the ions involved. Think carefully when you encounter variable oxidation number metals. Make note that the Roman numeral does not appear in the formula but does appear in the name.

## Lesson Summary

- Cations have the same name as their parent atom.
- Monatomic anions are named by replacing the end of the parent atom's name with "-ide."
- The names of polyatomic ions do not change.
- Ionic compounds are named by writing the name of the cation followed by the name of the anion.
- When naming compounds that include a metal with more than one common oxidation state, the charge of the metal ion is indicated with Roman numerals in parentheses between the cation and anion.

## Review Questions

1. Name the following compounds.
    a. $CaF_2$
    b. $(NH_4)_2CrO_4$
    c. $K_2CO_3$
    d. $NaCl$
    e. $PbO$
    f. $CuSO_4$
    g. $Ca(NO_3)_2$
    h. $Mg(OH)_2$
    i. $SnO_2$
2. Write the formulas from the names of the following compounds.
    a. Sodium carbonate
    b. Calcium hydroxide
    c. Iron(III) nitrate
    d. Magnesium oxide
    e. Aluminum sulfide
    f. Copper(I) dichromate
    g. Ammonium sulfate
    h. Iron(II) phosphate
    i. Lead(IV) sulfate