4.6.1: Naming Ionic Compounds

Learning Objectives

- To use the rules for naming ionic compounds.

After learning a few more details about the names of individual ions, you will be one step away from knowing how to name ionic compounds. This section begins the formal study of nomenclature, the systematic naming of chemical compounds.

Naming Ions

Monatomic cations can be separated into two categories.

Type I- Ions whose charge does not vary.

Ions like Na^+, Al^{3+}, Ca^{2+} only form ions of a single charge magnitude. So, it is unambiguous and simplest to refer to them by their name, simply adding the word "ion". So a sodium ion is Na^+, an aluminum ion is Al^{3+}, etc.

Type II- Ions whose charge does vary.

Some elements lose different numbers of electrons, producing ions of different charge magnitude (Figure 3.3). Iron, for example, can form two cations, each of which, when combined with the same anion, makes a different compound with unique physical and chemical properties. Thus, we need a different name for each iron ion to distinguish Fe^{2+} from Fe^{3+}. The same issue arises for other ions with more than one possible charge. The International Union of Pure and Applied Chemists (IUPAC) dictates that an ion's positive charge is indicated in parentheses after the element name, followed by the word *ion*. This can be done with either arabic numerals for charge (e.g. Iron (3+) ion) or roman numerals for oxidation state (e.g. Iron (III) ion). In this case, either would be correct, but many textbooks and instructors continue to use only roman numerals, so we will adopt the same convention for cations with variable charge for the sake of consistency.

Sodium forms only a 1+ ion, so there is no ambiguity about the name *sodium ion*.

*Refer to section IR-5.3.2-3 of the IUPAC Red Book for more on cation and anion naming conventions.

Table 4.6.1.1: The Modern and Common System of Cation Names

Element	Charge	Name
iron	2+	iron(II) ion
	3+	iron(III) ion
copper	1+	copper(I) ion
	2+	copper(II) ion
tin	2+	tin(II) ion
	4+	tin(IV) ion
lead	2+	lead(II) ion
	4+	lead(IV) ion
chromium	2+	chromium(II) ion
	3+	chromium(III) ion
gold	1+	gold(I) ion
	3+	gold(III) ion

Monatomic Anions

Like, type I cations, monatomic anions generally form ions of a single charge magnitude. To avoid confusion with cations, the ending of the element's name is changed to "-ide", before addition of the word anion. See the table below for examples.

Table 4.6.1.2: Some Monatomic Anions

Ion	Name
F^-	fluoride ion
Cl^-	chloride ion
Br^-	bromide ion
I^-	iodide ion
O^{2-}	oxide ion
S^{2-}	sulfide ion
P^{3-}	phosphide ion
N^{3-}	nitride ion

Example 4.6.1.1

Name each ion.

a. Ca^{2+}
b. S^{2-}
c. SO_3^{2-}
d. NH_4^+
e. Cu^+

Solution

a. the calcium ion
b. the sulfide ion
c. the sulfite ion
d. the ammonium ion
e. the copper(I) ion

Exercise 4.6.1.1

Name each ion.

a. Fe^{2+}
b. Fe^{3+}
c. SO_4^{2-}
d. Ba^{2+}
e. HCO_3^-

Answer a:

iron(II) ion

Answer b:

iron(III) ion

Answer c:

sulfate ion

Answer d:

barium ion

Answer e:

hydrogencarbonate ion or bicarbonate ion

Example 4.6.1.2

Write the formula for each ion.

a. the bromide ion
b. the phosphate ion
c. the copper(II) ion
d. the magnesium ion

Solution

a. Br^-
b. PO_4^{3-}
c. Cu^{2+}
d. Mg^{2+}

Exercise 4.6.1.2

Write the formula for each ion.

a. the fluoride ion
b. the carbonate ion
c. the tin(II) ion
d. the potassium ion

Answer a:

F^-

Answer b:

CO_3^{2-}

Answer c:

Sn^{2+}

Answer d:

K^+

Naming Binary Ionic Compounds with a Metal that Forms Only One Type of Cation

A **binary** ionic compound is a compound composed of a **monatomic** metal **cation** and a monatomic nonmetal **anion**. The metal cation is named first, followed by the nonmetal anion as illustrated in Figure 4.6.1.1 for the compound $BaCl_2$. The word *ion* is dropped from both parts.

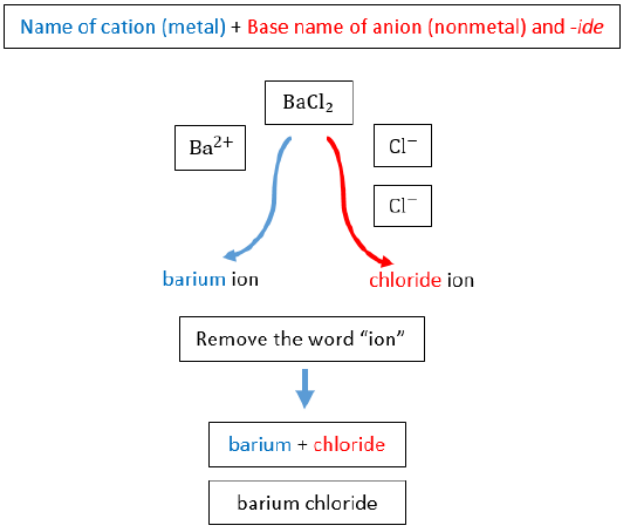


Figure 4.6.1.1: Naming $BaCl_2$
Naming formula: Name of metal cation + base
name of nonmetal anion + suffix -ide. BaCl2 is named as barium chloride.

Subscripts in the formula do not affect the name.

Example 4.6.1.3: Naming Ionic Compounds

Name each ionic compound.

a. $CaCl_2$
b. AlF_3
c. KCl

Solution

a. Using the names of the ions, this ionic compound is named calcium chloride.
b. The name of this ionic compound is aluminum fluoride.
c. The name of this ionic compound is potassium chloride

Exercise 4.6.1.3

Name each ionic compound.

a. AgI
b. MgO
c. Ca_3P_2

Answer a:

silver iodide

Answer b:

magnesium oxide

Answer c:

calcium phosphide

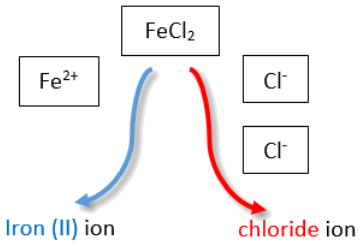
Naming Binary Ionic Compounds with a Metal That Forms More Than One Type of Cation

If you are given a formula for an ionic compound whose cation can have more than one possible charge, you must first determine the charge on the cation before identifying its correct name. For example, consider $FeCl_2$ and $FeCl_3$. In the first compound, the iron ion has a 2+ charge because there are two Cl^- ions in the formula (1− charge on each chloride ion). In the second compound, the

iron ion has a 3+ charge, as indicated by the three Cl^- ions in the formula. These are two different compounds that need two different names. By the Stock system, the names are iron(II) chloride and iron(III) chloride (Figure 4.6.1.2).

Table 4.6.1.3: Naming the $FeCl_2$ and $FeCl_3$ Compounds in the Modern/Stock System.

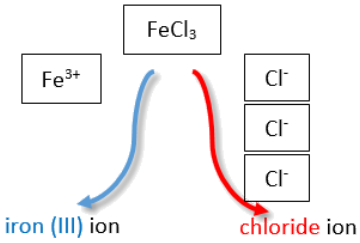
Name of cation (metal) + (Roman Numeral in parenthesis) + Base name of anion (nonmetal) and *-ide*



Remove the word "ion"

iron (II) + chloride

iron (II) chloride



Remove the word "ion"

iron (III) + chloride

iron (III) chloride

Example 4.6.1.4:

Name each ionic compound.

a. Co_2O_3
b. FeCl2

Solution

Solutions to Example 5.7.4

	Explanation	Answer
a	We know that cobalt can have more than one possible charge; we just need to determine what it is. • Oxide always has a 2− charge, so with three oxide ions, we have a total negative charge of 6−. • This means that the two cobalt ions have to contribute 6+, which for two cobalt ions means that each one is 3+. • Therefore, the proper name for this ionic compound is cobalt(III) oxide.	cobalt(III) oxide

	Explanation	Answer
b	Iron can also have more than one possible charge. • Chloride always has a 1− charge, so with two chloride ions, we have a total negative charge of 2−. • This means that the one iron ion must have a 2+ charge. • Therefore, the proper name for this ionic compound is iron(II) chloride.	iron(II) chloride

? Exercise 4.6.1.4

Name each ionic compound.

a. $AuCl_3$
b. PbO_2
c. CuO

Answer a:
gold(III) chloride

Answer b:
lead(IV) oxide

Answer c:
copper(II) oxide

Naming Ionic Compounds with Polyatomic Ions

The process of naming ionic compounds with polyatomic ions is the same as naming binary ionic compounds. The cation is named first, followed by the anion. One example is the ammonium sulfate compound in Figure 4.6.1.6

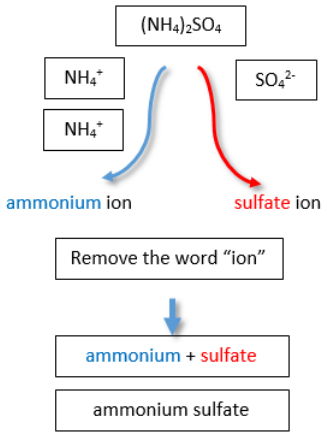


Figure 4.6.1.2: Naming Ionic Compounds with Polyatomic Ions

✓ Example 4.6.1.5: Naming Ionic Compounds

Write the proper name for each ionic compound.

a. $(NH_4)_2S$
b. $AlPO_4$,
c. $Fe_3(PO_4)_2$

Solution

Solutions to Example 5.7.5

Explanation	Answer
a. The ammonium ion has a 1+ charge and the sulfide ion has a 2− charge. Two ammonium ions need to balance the charge on a single sulfide ion. The compound's name is ammonium sulfide.	ammonium sulfide
b. The ions have the same magnitude of charge, one of each (ion) is needed to balance the charges. The name of the compound is aluminum phosphate.	aluminum phosphate
c. Neither charge is an exact multiple of the other, so we have to go to the least common multiple of 6. To get 6+, three iron(II) ions are needed, and to get 6−, two phosphate ions are needed . The compound's name is iron(II) phosphate.	iron(II) phosphate

? Exercise 4.6.1.5A

Write the proper name for each ionic compound.

a. $(NH_4)_3PO_4$
b. $Co(NO_2)_3$

Answer a:

ammonium phosphate

Answer b:

cobalt(III) nitrite

Figure 4.6.1.1is a synopsis of how to name simple ionic compounds.

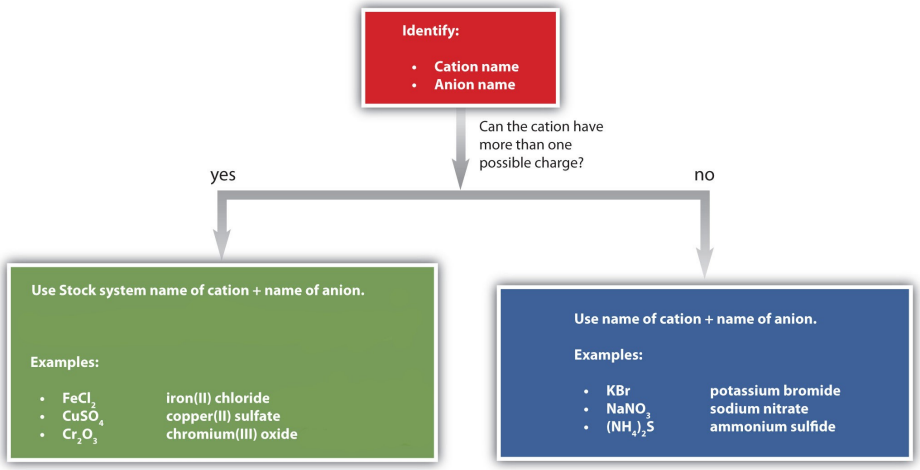


Figure 4.6.1.3: A Guide to Naming Simple Ionic Compounds.

? Exercise 4.6.1.5B

Name each ionic compound.

a. $ZnBr_2$
b. Al_2O_3

c. $(NH_4)_3PO_4$
d. AuF_3
e. AgF

Answer a:

zinc bromide

Answer b:

aluminum oxide

Answer c:

ammonium phosphate

Answer d:

gold(III) fluoride or auric fluoride

Answer e:

silver fluoride

Summary

- Ionic compounds are named by stating the cation first, followed by the anion.
- Positive and negative charges must balance.
- Some anions have multiple forms and are named accordingly with the use of roman numerals in parentheses.
- Ternary compounds are composed of three or more elements.
