

NAMING INORGANIC COMPOUNDS

Introduction

A primary control in chemical experiments is knowing the identity of the initial substances. This knowledge can be communicated by the name of the substances and labels on reagent containers. The following sections describe systematic names for simple inorganic compounds. These systematic names can be assigned from the chemical formula, and then the name communicates the chemical formula.

Binary Covalent Compounds

Covalent compounds can be operationally defined as compounds that do not conduct electricity when pure and in the liquid state. These compounds, with few exceptions, are composed of nonmetal elements only. Binary covalent compounds are composed of two nonmetal elements, and the name for the compound is constructed from the chemical formula in the following manner:

Prefix + name of 1st element Prefix + stem of 2nd element + ide

The stem of an element is formed by dropping the last syllable of the element's name. Prefixes are assigned by the number of atoms of each element in the formula, and the prefix corresponding to a given number of atoms can be found Table 1. The prefix "mon" is dropped with the exception of carbon monoxide, and the suffix "ide" is used with all two element compounds. Carbon dioxide is a familiar example of a systematic name. The name tells us what elements compose carbon dioxide, the number of atoms of each element, and hence the chemical formula of carbon dioxide. Note, a compound that appeared on the Internet was dihydrogen oxide, what is the formula of this compound? The following examples may help you answer this question.

Example 1--What is the formula of sulfur hexafluoride?

The elements composing the compound are S and F. Also the prefix hex says there are 6 F atoms so the formula is SF₆.

Example 2--Please name the compound N₂O₄?

The name is dinitrogen tetroxide.

Table 1--Prefixes for number of atoms

Number of atoms	Prefix
1	mon
2	di
3	tri
4	tetra or tetr*
5	penta or pent*
6	hexa or hex*

*The first spelling is used if the stem of the element begins with a consonant and the second spelling if the stem of the element begins with a vowel.

Binary Ionic Compounds

Ionic compounds are operationally defined as compounds that conduct electricity when pure and in the liquid state. All ionic compounds are solids at room temperature and with a few exceptions composed of a metal and nonmetal elements. When the metal is a group IA element, group II A element, or aluminum, the name is assigned using the form:

metal stem of nonmetal element + ide

This system does not use prefixes and assumes a knowledge of the law of electrical neutrality, the octet rule, and ionic theory. Ionic theory states that ionic compounds are composed of positive and negative ions formed by the transfer of valence electrons between atoms or molecules. The attraction between the oppositely charged ions bonds the ions together in the solid state. In the liquid state the electrical attraction is much weaker, and the ions are mobile. This explains why ionic compounds conduct electricity only in the liquid state. Electrical neutrality requires the total positive and negative charge on the ions be equal and that no valence electrons are lost or gained by the transfer of electrons between atoms and molecules. The octet rule is used to assign charges on the ions composing a compound, and states that group IA and IIA elements and aluminum lose their valence electron while nonmetals gain electrons until the total number of valence electron is eight. The following examples illustrate the naming system and the chemical principles.

Example 1- The mineral fluorite has the chemical formula CaF_2 . What is fluorite's systematic name?

The names of the elements composing fluorite are calcium and fluorine.

The last syllable of fluorine is changed to ide and the name is calcium fluoride.

Example 2- What is the chemical formula of cesium sulfide?

The compound is composed of cesium and sulfur. From the Periodic Table and the Octet Rule, we have

Cs has 1 valence e^- loses 1 e^-

S has 6 valence e^- gains 2 e^- .

To make electrons lost equal electrons gained, two cesium atoms lose electrons so we have

2 Cs have 2 valence e^- lose 2 e^-

S has 6 valence e^- gains 2 e^-

and the formula of cesium sulfide is Cs_2S . Note the ions composing cesium sulfide are Cs^+ and S^{2-} .

There are many other examples of metal elements, and these metals are called transition metals (elements in columns headed with a B), inner transition metals (metals in block separated from Periodic Table), or post-transition metals (all Group IIIA--VIA metals except aluminum). A property common to all of these metals is the formation of stable ions with different charges depending on the conditions under which the ion is formed. For ionic compounds with these metals, the systematic name is:

metal(Roman numeral) stem of nonmetal + ide.

The Roman numeral equals the charge on the metal ion. The following examples show

how the names in these compounds are assigned and used to determine the chemical formula from the name.

Example 1--The color of ruby and sapphire is due to a small quantity of Cr_2O_3 in these gem stones. What is the systematic name of Cr_2O_3 ?

The charge on the "B" metal is determined from the nonmetal. From the periodic table and the octet rule

O has 6 valence e^- gains 2

and for the compound

3 O have 18 valence e^- and gained 6.

Since electrons lost equals electrons gained, the chemical formula says

2 Cr have lost 6 e^-

and then

Cr has lost 3 e^- .

The name of the compound is Chromium(III) oxide.

Example 2--The compound Lead(IV) oxide is used in car batteries. What is the chemical formula of Lead(IV) oxide?

Pb has lost 4 e^- (from Lead(IV))

O has 6 valence e^- gains 2 e^- (from Periodic Tale and Octet rule)

To make electrons lost equal electrons gained, multiply O by two

Pb has lost 4 e^-

2 O have 12 valence e^- gain 4 e^- .

The chemical formula is PbO_2 .

Ionic compounds with Polyatomic or Complex ions

Polyatomic or Complex ions are examples of molecules that have lost or gained valence electrons. The names of ionic compounds with negative complex ions end in "ite" or "ate" with a few exceptions. The most common exceptions are compounds which contain the following complex ions:

OH^- hydroxide ion

CN^- cyanide ion

O_2^{2-} peroxide ion.

The names of compounds with these ions consist of the metal and the anion. For example, the poison NaCN has the name sodium cyanide.

Many complex ions have the general formula NMO_m^{n-} , and the names of ionic compounds containing these ions are constructed in the manner:

metal stem of nonmetal + ate or ite.

The "ate" ion always has one more O atom than the "ite" ion. For example SO_4^{2-} is sulfate ion and SO_3^{2-} is sulfite ion. For a specific nonmetal, knowing the charge and number of oxygen atoms in the "ate" ion is sufficient to remember the formula and charge in the "ite" ion. Table 2 lists six "ate" ions and these are best memorized. The formulas of other ions can be derived from these ions and periodic law. In writing formulas with complex ions, multiple complex ions are enclosed in parenthesis but single complex ions are not enclosed in parenthesis. Some examples illustrating the names of compounds with complex ions follow.

Example 1--Phosphate rock has the chemical formula $\text{Ca}_3(\text{PO}_4)_2$. What is the systematic name of phosphate rock?

The names of the component elements excluding oxygen are

calcium phosphorous
and since PO_4 is the formula of phosphate ion the name is calcium phosphate.

Example 2--A preservative has the name sodium nitrite. What is the chemical formula of the preservative?

Nitrite ion refers to the ion NO_2^- which has gained $1 e^-$

Na has 1 valence e^- loses $1 e^-$.

Since electrons lost equals electrons gained, the chemical formula is NaNO_2 .

Example 3--What is the charge on the complex ion in the compound $\text{Na}_2\text{C}_2\text{O}_4$?

The charge is determined from the "A" metal

Na has 1 valence e^- loses $1 e^-$

and since the formula has 2 Na ions, the number of electrons lost is

2 Na have 2 valence e^- lose $2 e^-$.

and electrical neutrality requires that

$\text{C}_2\text{O}_4^{n-}$ gains $2 e^-$.

The charge is -2 ($\text{C}_2\text{O}_4^{2-}$).

Table 2--Names and formulas of common oxyanions

Ion	Name
CO_3^{2-}	carbonate ion
NO_3^-	nitrate ion
SiO_4^{4-}	silicate ion
PO_4^{3-}	phosphate ion
SO_4^{2-}	sulfate ion
ClO_3^-	chlorate ion

Acids

Acids are operationally defined as compounds that form sour tasting solutions, turn blue litmus paper pink, have a pH less than 7, and chemically react with bases to neutralize acid and base properties. Theoretically acids donate hydrogen ions (H^+) and produce hydronium ion (H_3O^+) in water. The formulas of these compounds are written with acid hydrogen first. For example, H_2SO_4 is the chemical formula of sulfuric acid and indicates two acidic H. The systematic name of a binary acid, H_nX where X is a nonmetal element, is assigned using the format

Hydro + stem of nonmetal element + ic acid.

The chemical formula of a binary acid can be determined from the name by determining the charge predicted by the octet rule for the nonmetal element and then balancing this charge with the appropriate number of hydrogen ions. Examples 1 and 2 below illustrate the application of these rules.

Oxyacids are another common group of acids, and the chemical formulas for these compounds have the form H_nNMO_m . The name of an oxyacid has the form stem of nonmetal + ous or ic acid.

For a specific nonmetal, the ous acid always has one less oxygen than the ic acid. The correct ending can be selected by treating the acid as an ionic compound composed of

hydrogen ions (H^+) and a complex ion, applying electrical neutrality to assign the charge on the complex ion, naming the complex ion, and then changing the ionic ending to ous acid or the ate ending to ic acid. The procedure is reversed to determine the chemical formula from the systematic name. Also, the system can be extended to less or more oxygens by adding the prefix hypo to the ous acid for one less oxygen and the prefix hyper to the ic acid for one more oxygen. Examples 3 and 4 illustrate the systematic naming of oxyacids.

Example 1-- H_2S is a foul smelling gas that forms an acidic solution when dissolved in water. What is the acid name of H_2S ?

The compound is a binary acid and the name is hydrosulfuric acid.

Example 2--Hydrofluoric acid is used to etch glass. What is the chemical formula of hydrofluoric acid?

The nonmetal is fluorine and the octet rule predicts

F has 7 valence e^- - gains 1 e^- ; F^-

H has lost 1 e^- ; H^+

The chemical formula is HF.

Example 3--One of the acids found in acid rain has the chemical formula H_2SO_3 . What is the name of this acid?

The acid has two acidic H hence

2 H have lost 2 e^- ; 2 H^+

SO_3 has gained 2 e^- ; SO_3^{2-} .

The name of the complex ion is sulfite ion, and the name of the acid is sulfurous acid.

Example 4--Carbonic acid is present in all carbonated beverages. What is the chemical formula of carbonic acid?

The ic ending says the acid may be treated as composed of carbonate ion and hydrogen ion. The corresponding chemical formulas are

CO_3^{2-} has gained 2 e^-

H^+ has lost 1 e^- ,

and electrical neutrality says

CO_3^{2-} has gained 2 e^-

2 H^+ have lost 2 e^- .

The chemical formula of carbonic acid is H_2CO_3 .

Chemistry 1000 exercise on Inorganic Nomenclature

1. The correct scientific name for the mineral hematite, Fe_2O_3 , is

a) iron oxide

b) iron(III) oxide

c) diiron trioxide

2. Please name the following

a) AsF_3

b) Al_2S_3

c) TiO_2

d) CoCl_2

e) $\text{Cr}(\text{OH})_3$

3. Please write the formula for

a) Manganese(III) phosphite

b) Strontium fluoride

c) Sodium nitrate

d) Dinitrogen pentoxide

e) Potassium carbonate

4. Please write the chemical formula and charge for

a) sulfide ion

b) sulfate ion