6 Nomenclature of Inorganic Compounds

Seashells are formed from calcium carbonate ($CaCO_3$) aka limestone. This compound is also used in many dietary supplements.

Foundations of College Chemistry, 14th Ed.
Morris Hein and Susan Arena

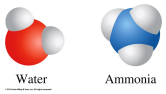
Chapter Outline

Common and Systematic Names

Chemical nomenclature is the systematic naming of chemical compounds.

Common names are historical names of compounds which are not based on systematic rules.

Example N_2O
Common name: nitrous oxide (laughing gas)
Systematic name: dinitrogen monoxide



Water Ammonia

Common names reveal nothing about the physical and chemical properties of a compound.

Common and Systematic Names

Common names are often used because systematic names are too long and technical for everyday use.

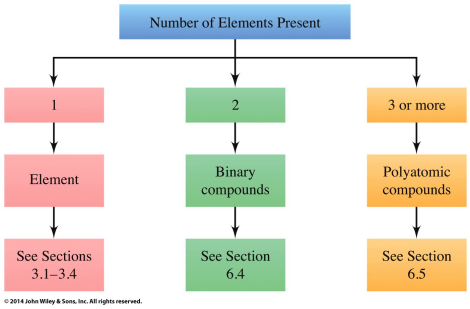
Example CaO
Common name: lime
Systematic name: calcium oxide

Chemists prefer systematic names that precisely identify the chemical composition of compounds.

The system for nomenclature was devised by the International Union of Pure and Applied Chemistry.

Naming Flowchart

We will focus on nomenclature of inorganic compounds.



Elements and Ions

The formula for most elements is the symbol of the element.

Example sodium (Na)

Exception: certain elements exist as polyatomic (multiatom) molecules under standard conditions

Example 7 elements exist as diatomic molecules (contain two atom units)

H_2, O_2, N_2, F_2, Cl_2, Br_2, and I_2

Gases Liquid Solid

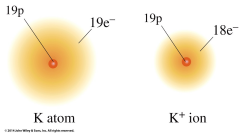
Two other elements exist in polyatomic arrangements

Sulfur - S_8 Phosphorus - P_4

Elements and Ions

A charged particle, called an ion, can be produced by adding or removing electrons from a neutral atom.

A neutral potassium atom contains 19 p^+ and 19 e^-.
A potassium ion can be formed by removing 1 e^-.
This gives an ion with 19 p^+ and 18 e^-, K^+.



$$K \longrightarrow K^+ + e^-$$

A positive ion is called a cation.

Elements and Ions

Any neutral atom that loses an electron forms a cation.

An atom may lose more than one electron.

$$Mg \longrightarrow Mg^{2+} + 2\ e^-$$

$$Al \longrightarrow Al^{3+} + 3\ e^-$$

Cations are named the same as their parent atoms.

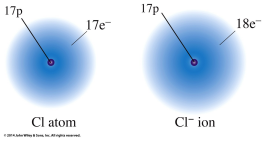
K	**potassium**	**K^+**	**potassium ion**
Mg	**magnesium**	**Mg^{2+}**	**magnesium ion**
Al	**aluminum**	**Al^{3+}**	**aluminum ion**

Elements and Ions

Any neutral atom that gains an electron forms an anion.

$$Cl + e^- \longrightarrow Cl^-$$

A neutral chlorine atom contains 17 p^+ and 17 e^-.
A chlorine ion can be formed by adding 1 e^-.
This gives an ion with 17 p^+ and 18 e^-, Cl^-.



An atom may also gain more than one electron.

$$O + 2\ e^- \longrightarrow O^{2-}$$

Elements and Ions

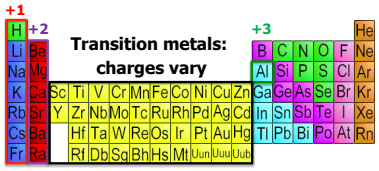
Naming Anions

Change the element ending to -*ide*

Atom	Name	Anion	Name
F	Fluorine	F^-	Fluor**ide** ion
Cl	Chlorine	Cl^-	Chlor**ide** ion
Br	Bromine	Br^-	Brom**ide** ion
I	Iodine	I^-	Iod**ide** ion
O	Oxygen	O^{2-}	Ox**ide** ion
N	Nitrogen	N^{3-}	Nitr**ide** ion

Elements and Ions

Predicting Ion Charge From the Periodic Table



Metals form cations

Charge = Group Number

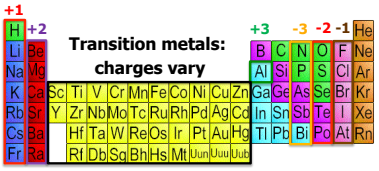
Group 1A and H: +1

Group 2A : +2

Group 3A (Al): +3

Elements and Ions

Predicting Ion Charge From the Periodic Table



Nonmetals form anions

Charge = 8 - Group Number

Group 5A: -3

Group 6A: -2

Group 7A: -1

Writing Formulas from Names of Ionic Compounds

Ionic compounds: contain both a cation and an anion.

Example NaCl (table salt)

Ionic compounds must have a net charge of 0.

The sum of the charges of the cations and anions in an ionic compound equal 0.

Compound	Ions	Least Common Multiple	Sum of Charges	Compound Formula
Sodium bromide	Na^+ Br^-	1	(1) + (-1) = 0	NaBr
Potassium sulfide	K^+ S^{2-}	2	2(1) + (-2) = 0	K_2S
Zinc sulfate	Zn^{2+} SO_4^{2-}	2	(2) + (-2) = 0	$ZnSO_4$
Ammonium phosphate	NH_4^+ PO_4^{3-}	3	3(1) + (-3) = 0	$(NH_4)_3PO_4$
Aluminum chromate	Al^{3+} CrO_4^{2-}	6	2(3) + 3(-2) = 0	$Al_2(CrO_4)_3$

Writing Formulas from Names of Ionic Compounds

Rules for Writing Formulas for Ionic Compounds

1. **Write the metal ion formula followed by the nonmetal ion formula.**
2. **Combine the smallest whole numbers of each ion to provide an overall charge equal to zero.**
3. **Write the compound formula for the metal and nonmetal, using subscripts determined from Step 2 for each ion.**

Writing Formulas from Names of Ionic Compounds

Example

Write the chemical formula for barium nitride.

Step 1: Write the formula for the metal and nonmetal ions.

Ba^{2+} N^{3-}

Step 2: Determine the number of each ion that will provide a net charge of 0.

$3(Ba^{2+}) + 2(N^{3-}) = 0$

$3(2+) + 2(3-) = 0$

Step 3: Write the correct formula.

Ba_3N_2

Writing Formulas from Names of Ionic Compounds

Write the chemical formula for magnesium oxide.

a. MgO

b. Mg_2O

c. MgO_2

d. Mg_2O_3

Step 1: Write the formula for the metal and nonmetal ions.

Mg^{2+} O^{2-}

Step 2: Determine the number of each ion that will provide a net charge of 0.

$(Mg^{2+}) + (N^{2-}) = 0$

$(2+) + (2-) = 0$

Step 3: Write the correct formula.

MgO

Naming Binary Compounds

Binary compounds contain only two different elements.

Binary compounds can be either ionic or molecular.

Ionic binary compounds can be further subdivided:

I) Binary compounds containing a metal which forms only one cation.

II) Binary compounds containing a metal which can form multiple cations.

Ionic Binary Compounds

Binary compounds containing a metal which forms only one cation.

By convention, the cation is written/named first followed by the anion.

Rules for Naming Binary Ionic Compounds

1. **Name the cation.**
2. **Write the anion root and add the *–ide* suffix.**

Symbol	Element	Root	Anion Name
Br	bromine	brom	bromide
F	fluorine	fluor	fluoride
H	hydrogen	hydr	hydride
N	nitrogen	nitr	nitride
O	oxygen	ox	oxide

Ionic Binary Compounds

Name the compound $MgBr_2$.

1. Name the cation: magnesium.
2. Name the anion : bromide.

The compound is magnesium bromide.

Provide a formula for sodium oxide.

1. Provide the symbol and charge for the cation: Na^+.
2. Provide the symbol and charge for the anion: O^{2-}.
3. Charge balance the cation and anion.

Na_2O

Writing Formulas for Ionic Compounds Practice

Name the compound Al_2O_3.

a. Aluminum(III) oxide
b. Dialuminum trioxide
c. Aluminum oxide
d. Aluminum(III) trioxide

Step 1: Name the cation: aluminum.
(Note Al can only have a +3 charge)

Step 2: Name the anion with an *-ide* ending.
oxide

Aluminum oxide

Writing Formulas for Ionic Compounds Practice

Write a chemical formula for calcium sulfide.

a. Ca_2S
b. CaS
c. CaS_2
d. Ca_2S_3

Step 1: Provide the symbol for the cation: Ca^{2+}.

Step 2: Provide the symbol for the anion: S^{2-}.

Step 3: Charge balance the compound using subscripts.

Naming Compounds Containing Metals with Multiple Charges

Transition metals can often form more than one type of cation.

Example Cu can exist as either Cu^+ or Cu^{2+}

To specify the cation charge in a compound, a Roman numeral is placed directly after the metal in the compound name.

Example iron(III) chloride $FeCl_3$ Fe^{3+}

When a metal forms only one cation (ie Na^+), there is no need to use Roman numerals.

Naming Compounds Containing Metals with Multiple Charges

Rules for Naming Compounds Involving Metals that Could Form Multiple Charges

1. Write the cation name.
2. Write the cation charge in Roman numerals in parentheses.
3. Write the root of the anion and use the *–ide* suffix.

Exception: for metals that only form two cations, a Latin root with either an *–ous* or *–ic* suffix can also be used.

Formula	Name	Classical Name	Formula	Name	Classical Name
Cu^+	Copper(I)	cuprous	Sn^{2+}	Tin(II)	stannous
Cu^{2+}	Copper(II)	cupric	Sn^{4+}	Tin(IV)	stannic
Fe^{2+}	Iron(II)	ferrous	Pb^{2+}	Lead(II)	plumbous
Fe^{3+}	Iron(III)	ferric	Pb^{4+}	Lead(IV)	plumbic

Naming Compounds Containing Metals with Multiple Charges

Name the compound FeS.

Step 1: Name the cation. Recognize Fe is a transition metal and can have more than one possible charge.

Step 2: Use the charge of the nonmetal (S^{2-}) to help choose the Roman numeral and name for Fe.

To charge balance, Fe must be iron(II)

Step 3: Name the anion sulfide

Name: iron(II) sulfide or ferrous sulfide

Naming Compounds Containing Metals with Multiple Charges

Name the compound $CrCl_3$.

a. Chromium chloride
b. Chromium(II) chloride
c. Chromium(III) chloride
d. Chromium trichloride

Step 1: Name the cation. Recognize Cr is a transition metal and can have more than one possible charge.

Step 2: Use the charge of the nonmetal (Cl^-) to help choose the Roman numeral and name for Cr.

To charge balance, Cr must be chromium(III)

Step 3: Name the anion chloride

Naming Compounds Containing Metals with Multiple Charges

Write a formula for the following compound.

Copper(I) oxide

Step 1: Choose the cation symbol. Recognize Cu is a transition metal and can have more than one possible charge.

Step 2: Use the charge of the nonmetal (O^{2-}) to help choose the number of Cu atoms.

$$x\,Cu(+1) + O(2-) = 0$$

2 Cu atoms are needed to balance the charge.

Name: Cu_2O

Naming Compounds Containing Metals with Multiple Charges

Write a formula for tin(IV) fluoride.

a. SnF
b. SnF_2
c. SnF_3
d. SnF_4

Step 1: Choose the cation symbol. Recognize Sn can have more than one possible charge.

Step 2: Use the charge of the nonmetal (F^-) to help choose the number of Sn atoms.

$$Sn(+4) + x\,F(-) = 0$$

4 F atoms are needed to balance the charge.

Name: SnF_4

Binary Compounds Containing Two Nonmetals

Molecular compounds contain two nonmetals.

Rules for Naming Molecular Compounds

1. **Write the name for the first element, including the appropriate prefix (*mono* is rarely used).**
2. **Write the name for the second element, including the appropriate prefix and *-ide* ending (*mono* is used for the 2nd element).**

Prefix	Number	Prefix	Number
mono	1	hexa	6
di	2	hepta	7
tri	3	octa	8
tetra	4	nona	9
penta	5	deca	10

Binary Compounds Containing Two Nonmetals

Name the following compound.

P_2O_5

1. *di*phosphorus indicates 2 P atoms.
2. *pent*oxide indicates 5 O atoms

Diphosphorus pentoxide

Note: the *-o* or *-a* in *mono* or *penta* is usually dropped if there are two vowels next to each other.

Name the following compound.

CCl_4

1. chlorine indicates 1 Cl atom (*mono* not needed).
2. *tetra*chloride indicates 4 Cl atoms

Carbon tetrachloride

Binary Compounds Containing Two Nonmetals

Name the following compound.

SO_2

a. Sulfur dioxide
b. Monosulfur dioxide
c. Sulfur oxide
d. Sulfur(IV) oxide

1. sulfur indicates 1 S atom.
2. *di*oxide indicates 2 O atoms.

Sulfur dioxide

Name the following compound.

N_2O_5

a. Nitrogen oxide
b. Dinitrogen oxide
c. Dinitrogen pentoxide
d. Nitrogen(V) oxide

1. *di*nitrogen indicates 2 N atoms.
2. *pent*oxide indicates 5 O atoms.

Dinitrogen pentoxide

Binary Acids

Certain binary compounds containing hydrogen behave as acids in water and have special names.

HCl(g) is hydrogen chloride
HCl(aq) is hydrochloric acid

Hydrogen is always written first in an acid formula.
(Indicates the compound is an acid versus NH_3 or CH_4)

Rules for Naming Binary Acids

1. Write the prefix *hydro* followed by the root of the second element and add an *-ic* suffix.
2. Add the word *acid*.

Binary Acids

Name the following compound.

H_2S

1. hydrosulfuric
2. acid

hydrosulfuric acid

Name the following compound.

HI

1. hydroiodic
2. acid

hydroiodic acid

Binary Acids Practice

Name the following compounds.

H_2Se

1. hydroselenic
2. acid

Hydroselenic acid

HF

1. hydrofluoric
2. acid

Hydrofluoric acid

Review of Binary Compound Naming

Binary Compounds Usually end in *-ide*

Molecular (2 Nonmetals)

Use prefixes to name both elements

Review of Binary Compound Naming

Binary Compounds Usually end in *-ide*

Ionic (Metal/Nonmetal)

Metal with one type of cation

1. Name metal
2. Root + *-ide* for nonmetal

Metal with varying cations (Determine cation charge)

1. Roman numerals (cation)
2. Root + *-ide* for nonmetal

1. Name metal *-ous* or *-ic* suffix
2. Root + *-ide* for nonmetal

Review of Binary Compound Naming

Binary Compounds Usually end in *-ide*

Hydrogen/Nonmetal

In H_2O

1. Prefix *hydro* suffix *-ic*
2. Add acid

Not in H_2O

1. Hydrogen
2. Root + *-ide* Suffix for nonmetal

Naming Practice

Name the following compound.

$CuCl_2$

a. Copper chloride
b. Copper(III) chloride
c. Copper(II) chloride
d. Cuprous chloride

1. Cu is a transition metal
2. Based on Cl charge (-1), Cu must be +2.

Name the following compound.

C_3N_2

a. Carbon nitride
b. Tricarbon nitride
c. Carbon dinitrogen
d. Tricarbon dinitride

1. *tri*carbon indicates 3 C atoms.
2. *di*nitride indicates 2 N atoms.

Naming Practice

Name the following compound.

ICl_3

a. Iodine trichloride
b. Iodochloride
c. Iodine(III) chloride
d. Monoiodine trichloride

1. iodine indicates 1 I atom.
2. *tri*chloride indicates 3 Cl atoms.

Name the following compound.

HCl (aq)

a. Hydrogen chloride
b. Hydrochloride
c. Hydrochloric acid
d. Hydrochlorous acid

1. Use the prefix *hydro* and root chlor and *–ic* suffix.
2. Add acid.

Naming Polyatomic Ions

Polyatomic ion: an ion that contains two or more elements.

Example cyanide anion CN^-

Naming compounds containing polyatomic ions is similar to that for binary compounds.
The cation is named followed by the anion.

The names, formulas, and charges of common polyatomic ions should be learned.

Rules for Naming Compounds Containing Polyatomic Ions

1. Name the cation.
2. Name the anion.

Common Polyatomic Ions

Name	Formula	Charge	Name	Formula	Charge
Acetate	$C_2H_3O_2^-$	-1	Cyanide	CN^-	-1
Ammonium	NH_4^+	+1	Dichromate	$Cr_2O_7^{2-}$	-2
Hydrogen Carbonate	HCO_3^-	-1	Hydroxide	OH^-	-1
Hydrogen Sulfate	HSO_4^-	-1	Nitrate	NO_3^-	-1
Bromate	BrO_3^-	-1	Nitrite	NO_2^-	-1
Carbonate	CO_3^{2-}	-2	Permanganate	MnO_4^-	-1
Chlorate	ClO_3^-	-1	Phosphate	PO_4^{3-}	-3
Chromate	CrO_4^{2-}	-2	Sulfate	SO_4^{2-}	-2
			Sulfite	SO_3^{2-}	-2

Oxyanions

Oxyanions: polyatomic ions that contain oxygen

Often end in the suffix *-ate* or *-ite*.

***-ate* compound(s) contains more O atoms than *-ite* compound(s).**

For elements that form multiple ions with oxygen, prefixes are also needed.

***per*: add one oxygen to the *-ate* root**
***hypo*: subtract one oxygen from the *-ite* root**

Oxyanions

Oxyanions and Oxyacids of Chlorine

Anion Formula	Anion Name	Anion Formula	Anion Name
ClO^-	*hypo*chlor*ite*	HClO	*hypo*chlor*ous* acid
ClO_2^-	chlor*ite*	$HClO_2$	chlor*ous* acid
ClO_3^-	chlor*ate*	$HClO_3$	chlor*ic* acid
ClO_4^-	*per*chlor*ate*	$HClO_4$	*per*chlor*ic* acid

Naming Polyatomic Ions Practice

Name the following compound.

$NaNO_3$

a. Sodium nitrogen trioxide
b. Sodium nitrite
c. Sodium nitrate
d. Sodium pernitrate

Name the following compound.

KCN

a. Potassium monocarbon monoxide
b. Potassium(I) cyanide
c. Potassium monocyanide
d. Potassium cyanide

Naming Polyatomic Ions Practice

Name the following compound.

$LiClO_2$

a. Lithium chlorite
b. Lithium perchlorate
c. Lithium hypochlorite
d. Lithium chlorate

Name the following compound.

NH_4I

a. Ammonia iodide
b. Ammonium iodide
c. Ammonium(I) iodide
d. Ammonium monoiodide

More Complicated Polyatomics

Inorganic ions can be formed from more than 3 elements.

The same method is used as before:
identify the ions and name in order -- cations then anions.

Compound	Ions	Name
$NaHCO_3$	Na^+; HCO_3^-	Sodium hydrogen carbonate
NaHS	Na^+; HS^-	Sodium hydrogen sulfide
$MgNH_4PO_4$	Mg^{2+}; NH_4^+; PO_4^{3-}	Magnesium ammonium phosphate
$NaKSO_4$	Na^+; K^+; SO_4^{2-}	Sodium potassium sulfate

Complicated Polyatomic Ions Practice

Name the following compound.

$KAl(SO_4)_2$

a. Potassium aluminum sulfate
b. Potassium aluminum sulfite
c. Potassium aluminum(III) sulfate
d. Potassium aluminum disulfate

Name the following compound.

$Ca(HSO_3)_2$

a. Calcium hydrogen sulfate
b. Calcium hydrogen sulfite
c. Calcium hydrogen persulfate
d. Calcium hydrogen hyposulfite

Naming Acids

Acids often begin with hydrogen.

To recognize oxyacids, make sure:
1. H is the first element in the formula.
2. The compound contains a polyatomic ion with oxygen.

The following modifications are made to the name of an acid:

***–ate* ions are changed to *–ic* acids**
***–ite* ions are changed to *–ous* acids**
***–ic* acids contain one more oxygen than *–ous* acids**

Naming Acids Practice

Name the following acid.

H_2SO_4

a. Dihydrogen sulfate
b. Sulfurous acid
c. Sulfuric acid
d. Persulfuric acid

Derived from sulfate anion.
Change to *–ic* ending.
Acid added to show the presence of H.

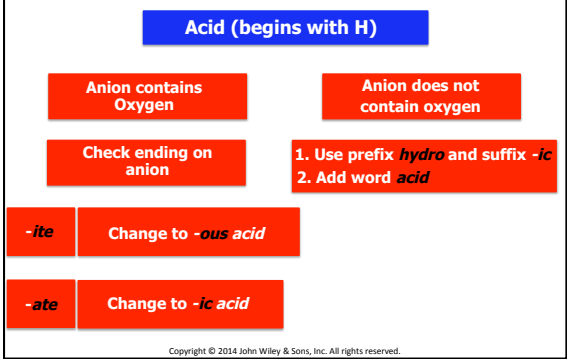
Name the following acid.

HNO_2

a. Nitrous acid
b. Nitric acid
c. Hydrogen nitrite
d. Hydrogen nitrate

Derived from the nitrite anion.
Change to *–ous* ending.
Acid added to show the presence of H.

Naming Acids Flowchart



Learning Objectives

6.1 Common and Systematic Names

Distinguish between the common and systematic names of chemical substances.

6.2 Elements and Ions

Discuss the formation, charge, and naming of simple ions.

6.3 Writing Formulas from Names of Ionic Compounds

Write the chemical formula for an ionic compound from the name of the compound.

Learning Objectives

6.4 Naming Binary Compounds

Name binary ionic and molecular compounds.

6.5 Acids

Use the rules to name an acid from its formula and to write the formula of an acid from its name.