Chapter 5

Molecules and Compounds

Based on slides provided with Introductory Chemistry, Fifth Edition
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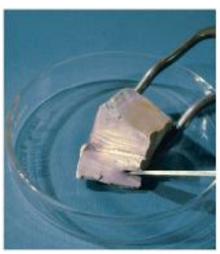
Sugar's Properties Differ from Those of the Elements C, H, and O in Sugar

- Ordinary table sugar is a compound called sucrose.
- A sucrose molecule, such as the one shown here, contains carbon, hydrogen, and oxygen atoms.
- The properties of sucrose are very different from those of carbon, shown here in the form of graphite, and hydrogen and oxygen.

Salt's Properties Differ from Those of the Elements Na and Cl in Salt

Elemental sodium Sodium is an extremely reactive metal that dulls almost instantly upon exposure to air.



Elemental chlorine Chlorine is a yellow gas with a pungent odor. It is highly reactive and poisonous.

Salt's Properties Differ from Those of the Elements Na and Cl in Salt

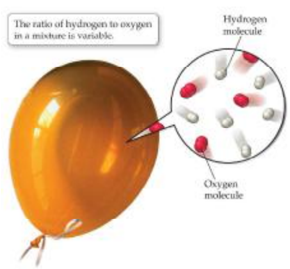
- **Sodium chloride** The compound formed by sodium and chlorine is table salt.
- The properties of a compound are, in general, different from the properties of the elements that compose it.

Many Natural Substances Are Compounds

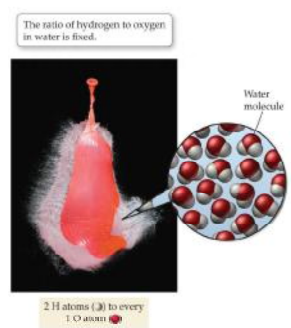
- Some of the substances we encounter in everyday life are elements.
- Most are not elements—they are compounds.
- Free atoms are rare in nature.
- A compound is different from a mixture of elements.
- In a compound, the elements combine in fixed, definite proportions.
- In a mixture, they can have any proportions whatsoever.

Compounds Display Constant Composition

A mixture This balloon is filled with a mixture of hydrogen and oxygen gas. The relative amounts of hydrogen and oxygen are variable.



A chemical compound This balloon is filled with water, composed of molecules that have a fixed ratio of hydrogen to oxygen. (*Source:* JoLynn E. Funk.)



Proust's Statement of Law of Constant Composition

- Joseph Proust (1754–1826) formally stated the idea that elements combine in fixed proportions to form compounds.
- **The law of constant composition** states:

  All samples of a given compound have the same proportions of their constituent elements.

Mass Ratio of Elements in Water Is Constant

- For example, if we decompose an 18.0-g sample of water, we would get 16.0 g of oxygen and 2.0 g of hydrogen, or an oxygen-to-hydrogen mass ratio of

$$\text{Mass ratio} = \frac{16.0\ \text{g O}}{2.0\ \text{g H}} = 8.0 \quad \text{or} \quad 8.0{:}1$$

- This is true of any sample of pure water, no matter what its origin.

Mass Ratio of Elements in Ammonia Is Constant

- If we decompose a 17.0-g sample of ammonia, a compound composed of nitrogen and hydrogen, we would get 14.0 g of nitrogen and 3.0 g of hydrogen, or a nitrogen-to-hydrogen mass ratio of

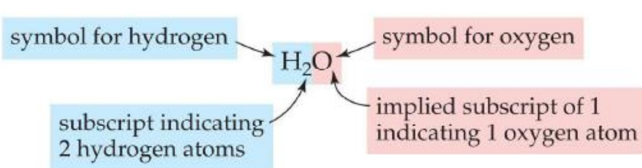
$$\text{Mass ratio} = \frac{14.0\ \text{g N}}{3.0\ \text{g H}} = 4.7 \quad \text{or} \quad 4.7{:}1$$

- Even though atoms combine in whole-number ratios, their mass ratios are not necessarily whole numbers.

Chemical Formulas: How to Represent Compounds

- Compounds have constant composition with respect to mass because they are composed of atoms in fixed ratios.
- A **chemical formula** indicates the elements present in a compound and the relative number of atoms of each.
- For example, H_2O is the chemical formula for water; it indicates that water consists of hydrogen and oxygen atoms in a 2:1 ratio.
- The formula contains the symbol for each element, accompanied by a subscript indicating the number of atoms of that element. By convention, a subscript of 1 is omitted.

By Convention, a Subscript of 1 is Omitted

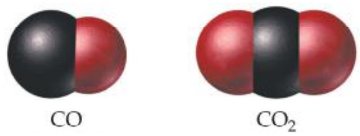


Chemical Formulas: How to Represent Compounds

Common chemical formulas include the following:

- NaCl for table salt, indicating sodium and chlorine atoms in a 1:1 ratio.
- CO_2 for carbon dioxide, indicating carbon and oxygen atoms in a 1:2 ratio.
- $C_{12}H_{22}O_{11}$ for table sugar (sucrose), indicating carbon, hydrogen, and oxygen atoms in a 12:22:11 ratio.
- The subscripts in a chemical formula represent the relative numbers of each type of atom in a chemical compound; they never change for a given compound.

Changing a Subscript Makes a Totally Different Compound



- The subscripts in a chemical formula are part of the compound's definition—if they change, the formula no longer specifies the same compound.
- CO is the chemical formula for ***carbon monoxide,*** an air pollutant with adverse health effects on humans.
- If you change the subscript of the O in CO from 1 to 2, you get the formula for a totally different compound.
- CO_2 is the chemical formula for ***carbon dioxide,*** the relatively harmless product of combustion and human respiration. We breathe small amounts of it all the time with no harmful effects.

How to List the Elements in Order in Compounds

- Chemical formulas list the most metallic elements first. The formula for table salt is NaCl, not ClNa.
- In compounds that do not include a metal, the more metal-like element is listed first.
- Metals are found on the left side of the periodic table and nonmetals on the upper right side.
- Among nonmetals, those to the left in the periodic table are more metal-like than those to the right and are normally listed first. We write NO_2 and NO, not O_2N and ON.
- Within a single column in the periodic table, elements toward the bottom are more metal-like than elements toward the top. We write SO_2, not O_2S.

Order to List the Nonmetal Elements in Compounds

- The specific order for listing nonmetal elements in a chemical formula is shown in Table 5.1.
- There are a few historical exceptions in which the less metallic element is named first, such as the hydroxide ion, which is written as **OH^-.**

TABLE 5.1 Order of Listing Nonmetal Elements in a Chemical Formula

C	P	N	H	S	I	Br	Cl	O	F

Elements on the left are generally listed before elements on the right.

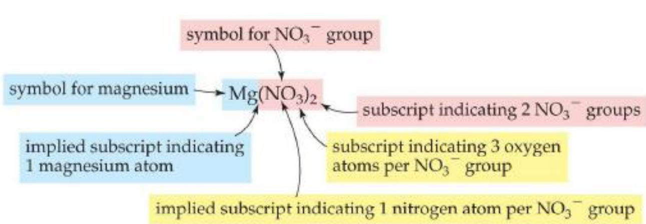
How to Represent Compounds with Polyatomic Ions

- Some chemical formulas contain groups of atoms that act as a unit.
- When several groups of the same kind are present, their formula is set off in parentheses with a subscript to indicate the number of that group.
- Many of these groups of atoms have a charge associated with them and are called **polyatomic ions.**
- To determine the total number of each type of atom in a compound containing a group within parentheses, multiply the subscript outside the parentheses by the subscript for each atom inside the parentheses.

Determine the Number of Each Type of Atom in $Mg(NO_3)_2$

$Mg(NO_3)_2$ indicates a compound containing one magnesium atom (present as the Mg^{2+} ion) and two **NO_3^-** groups.

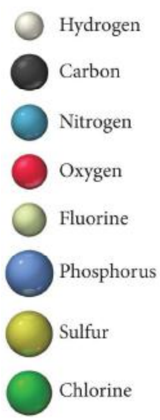
Mg:	1	= 1 Mg
N:	1 × 2	= 2 N
O:	3 × 2	= 6 O



Types of Chemical Formulas

- An **empirical formula** gives the *relative* number of atoms of each element in a compound.
- A **molecular formula** gives the *actual* number of atoms of each element in a molecule of the compound.
- For example, the molecular formula for hydrogen peroxide is H_2O_2, and its empirical formula is HO.
- The molecular formula is always a whole-number multiple of the empirical formula.
- For many compounds, such as H_2O, the molecular formula is the same as the empirical formula.
- A **structural formula** uses lines to represent chemical bonds and shows how the atoms in a molecule are connected to each other.

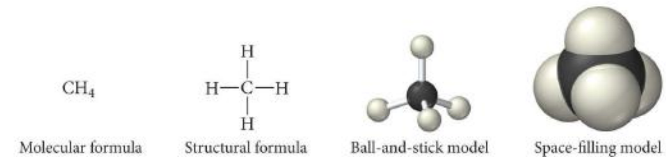
Types of Chemical Formulas



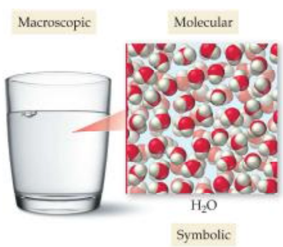
- **Molecular models**—three-dimensional representations of molecules—are used to represent compounds.
- We use two types of molecular models: ball-and-stick and space-filling.
- In **ball-and-stick models,** we represent atoms as balls and chemical bonds as sticks.
- The balls and sticks are connected to represent the molecule's shape. The balls are color coded, and each element is assigned a color as shown in the margin.
- In **space-filing models,** atoms fill the space between each other to more closely represent our best idea for how a molecule might appear if we could scale it to a visible size.

Comparison of Formulas and Models for Methane, CH_4

- The **molecular formula** of methane indicates that methane has one carbon atom and four hydrogen atoms.
- The **structural formula** shows how the atoms are connected: Each hydrogen atom is bonded to the central carbon atom.
- The **ball-and-stick model** and the **space-filling model** illustrate the *geometry* of the molecule: how the atoms are arranged in three dimensions.



Images Make the Connection Between the World Around Us and the World of Atoms and Molecules



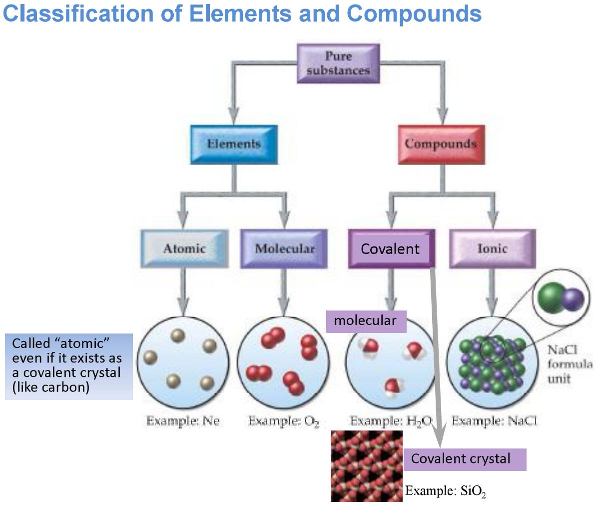
- The *macroscopic world* (what we see)
- The *atomic and molecular world* (the particles that compose matter)
- The *symbolic way* that chemists represent the atomic and molecular world
- Here is an image of water using this kind of representation.

A Molecular View of Elements and Compounds

- Pure substances may be elements or compounds.
- Elements may atomic or molecular.
  -- in their normal, natural state
- Compounds may be molecular or ionic.
  -- "Molecular" should be re-phrased to "covalent"
  -- Covalent compounds don't have ionic bonds
    -- not made of ions
  -- Covalent compounds are generally molecular
  -- But they might exist as an interconnected crystal instead of separate molecules

We will cite some examples of each case in class

Classification of Elements and Compounds

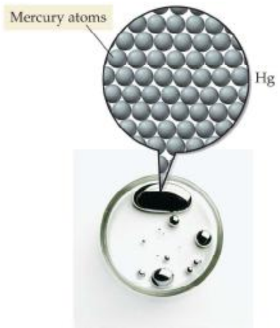


Elements May Be Atomic or Molecular

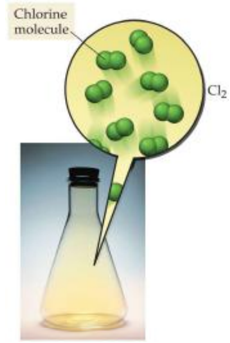
- **Atomic elements** are those that exist in nature with single atoms as their basic units. Most elements fall into this category.
- **Molecular elements** do not normally exist in nature with single atoms as their basic units. Instead, these elements exist as molecules, in most cases *diatomic molecules*—two atoms of that element bonded together—as their basic units.

Elements May Be Atomic or Molecular

An atomic element The basic units that compose mercury, an atomic element and a metal, are single mercury atoms.



A molecular element The basic units that compose chlorine, a molecular element, are diatomic chlorine molecules, each composed of two chlorine atoms.



Elements that Exist as Diatomic Molecules

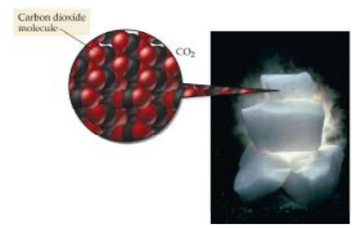
Name of Element	Formula of Basic Unit
hydrogen	H_2
nitrogen	N_2
oxygen	O_2
fluorine	F_2
chlorine	Cl_2
bromine	Br_2
iodine	I_2

Compounds May Be Covalent or Ionic

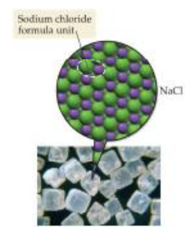
- **Covalent compounds** are compounds formed from two or more nonmetals.
  - Most often, the basic unit of a covalent compound is a molecule composed of the constituent atoms. Then it's a molecular compound
    Molecular compounds are covalent
  - Some covalent compounds exist as crystals where covalent bonds hold together the entire lattice. No individual molecules in that case
- **Ionic compounds** contain one or more cations paired with one or more anions.

Compounds May Be Covalent or Ionic

The basic units that compose dry ice, a molecular compound, are CO_2 **molecules.**



The basic units that compose table salt, an ionic compound, are NaCl **formula units.**



Ionic Compounds

- When a **metal,** which has a tendency to lose electrons, combines with a **nonmetal,** which has a tendency to gain electrons, one or more electrons transfer from the metal to the nonmetal, creating positive and negative ions that are attracted to each other.
- A compound composed of a metal and a nonmetal is considered **ionic.**
- The basic unit of ionic compounds is the **formula unit.**
- Unlike molecular compounds, ionic compounds do not contain individual molecules but rather cations and anions in an alternating three-dimensional array (crystal).

Writing Formulas for Ionic Compounds

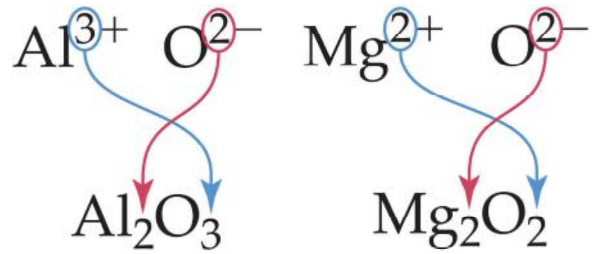
- Ionic compounds always contain positive and negative ions.
- In the chemical formula of a compound, the sum of the charges of the positive ions (cations) must always equal the sum of the charges of the negative ions (anions).
  -- Compounds are neutral

Writing Formulas for Ionic Compounds (cont.)

1. Write the symbol for the metal and its charge followed by the symbol of the nonmetal and its charge.
2. Make the magnitude of the charge on each ion (without the sign) become the subscript for the other ion.
3. If possible, reduce the subscripts to give a ratio with the smallest whole numbers.
4. Check to make sure that the sum of the charges of the cations exactly cancels the sum of the charges of the anions.

Use the Charge on One Ion as the Subscript on the Other Ion

Write formulas for ionic compounds that form from aluminum and oxygen and magnesium and oxygen.



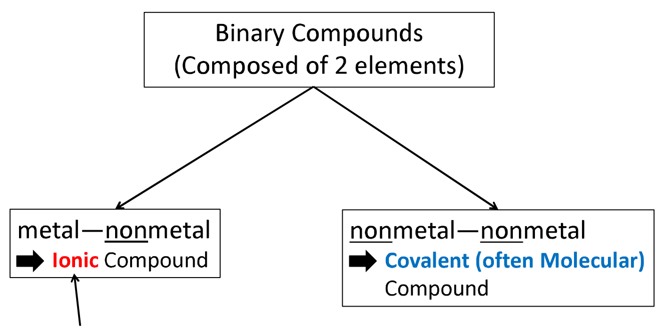
Then simplify

Don't leave the charges in the formula

Nomenclature: Naming Compounds

- Chemists have developed systematic ways to name compounds.
- If you learn the naming rules, you can examine a compound's formula and determine its name, and vice versa.
- Many compounds also have a common name.
- H_2O has the common name *water* and the systematic name *hydrogen monoxide*.
- Since water is such a familiar compound, everyone uses its common name, **water,** and ***not*** its systematic name.
- Common names can be learned only through familiarity; there is no system.

Naming Binary Compounds



Assumed ionic, and named accordingly.
Sometimes it's not really ionic, but even then it is named as if it were ionic.

Naming Binary Ionic Compounds

- The first step in naming an ionic compound is identifying it as one.
- Remember, when a **metal** is the first element in the formula with one (or more) **nonmetals** in a chemical formula, you can name the compound as an ionic compound (some metal-nonmetal compounds aren't really ionic, but it doesn't matter, we name them as if they were)

Naming Binary Ionic Compounds (cont.)

The cation is always a metal.

Simple case: the metal can form only one kind of cation

(i.e. a cation of a certain charge, and no other)

- Cation name first, anion name second.

  {cation name} {anion name}
- A monatomic cation takes its name from the name of the parent element (i.e. same name)
- A monatomic anion is named by taking the root of the element name and adding *–ide*

Examples:

KCl	Potassium chloride
$MgBr_2$	Magnesium bromide
CaO	Calcium oxide

Naming Binary Ionic Compounds (continued)

What if the metal can form more than one type of cation (cations with different charges)?

- Similar to the simple, "fixed charge" case, except:
  - Charge on the metal ion must be specified with a Roman numeral in parentheses
  - Most transition metal cations require a Roman numeral.
    -- exceptions include Zn^{2+}, Ag^{+} (they make only one kind of cation)
  - Some main group metals, such as Pb and Sn, form more than one type of cation.
  - Metals that form only one cation do not need to be identified by a roman numeral (simple case)

Examples:

CuBr	Copper(I) bromide
FeS	Iron(II) sulfide
PbO_2	Lead(IV) oxide

Naming Binary Ionic Compounds (continued)

Determine the Charge of a Metal from the Formula

- We can determine the charge of the metal from the chemical formula of the compound.
- The sum of all the charges must be zero.
- The charge of iron in $FeCl_3$ must be 3+ for the compound to be charge-neutral with the three Cl^- anions.

-- But that means we know the charge of the anion. Actually it's not hard.

TABLE 5.6 Some Common Anions

Nonmetal	Symbol for Ion	Base Name	Anion Name
fluorine	F^-	fluor-	fluoride
chlorine	Cl^-	chlor-	chloride
bromine	Br^-	brom-	bromide
iodine	I^-	iod-	iodide
oxygen	O^{2-}	ox-	oxide
sulfur	S^{2-}	sulf-	sulfide
nitrogen	N^{3-}	nitr-	nitride

Find which group the nonmetal is in the periodic table. If its group is:

1 position away from Noble gases:	anion charge = **-1**
2 positions away from Noble gases:	anion charge = **-2**
3 positions away from Noble gases:	anion charge = **-3**

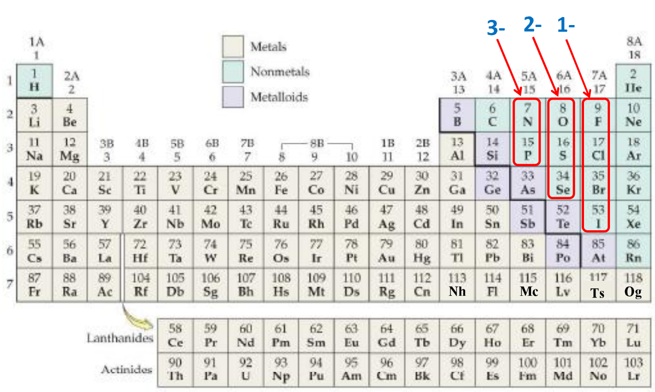
No need to memorize

Metals Whose Charge Is Invariant

TABLE 5.4 Metals Whose Charge Is Invariant from One Compound to Another

Metal	Ion	Name	Group Number
Li	Li^+	lithium	1A
Na	Na^+	sodium	1A
K	K^+	potassium	1A
Rb	Rb^+	rubidium	1A
Cs	Cs^+	cesium	1A
Mg	Mg^{2+}	magnesium	2A
Ca	Ca^{2+}	calcium	2A
Sr	Sr^{2+}	strontium	2A
Ba	Ba^{2+}	barium	2A
Al	Al^{3+}	aluminum	3A
Zn	Zn^{2+}	zinc	*
Ag	Ag^+	silver	*

*The charge of these metals cannot be inferred from their group number.



Some Metals that Form More than One Type of Ion

TABLE 5.5 Some Metals That Form More Than One Type of Ion and Their Common Charges

Metal	Symbol Ion	Name	Older Name*
chromium	Cr^{2+}	chromium(II)	chromous
	Cr^{3+}	chromium(III)	chromic
iron	Fe^{2+}	iron(II)	ferrous
	Fe^{3+}	iron(III)	ferric
cobalt	Co^{2+}	cobalt(II)	cobaltous
	Co^{3+}	cobalt(III)	cobaltic
copper	Cu^{+}	copper(I)	cuprous
	Cu^{2+}	copper(II)	cupric
tin	Sn^{2+}	tin(II)	stannous
	Sn^{4+}	tin(IV)	stannic
mercury	Hg_2^{2+}	mercury(I)	mercurous
	Hg^{2+}	mercury(II)	mercuric
lead	Pb^{2+}	lead(II)	plumbous
	Pb^{4+}	lead(IV)	plumbic

* An older naming system substitutes the names found in this column for the name of the metal and its charge. Under this system, chromium(II) oxide is named chromous oxide. We do *not* use this older system in this text.

Polyatomic Ions

- Polyatomic ions are like molecules, except that they carry a charge.
- A polyatomic ion has a definite, characteristic charge.
- Almost all polyatomic ions we will deal with are anions, except NH_4^+ and Hg_2^{2+}
- Naming ionic compounds of polyatomic ions are just like binary ionic compounds.
  -- The polyatomic anion name follows the cation name (which may itself be polyatomic)
- Polyatomic ion names must be memorized
  -- But there are some rules that help deriving some of them

TABLE 5.3 Some Common Polyatomic Ions

Name	Formula	Name	Formula
acetate	$C_2H_3O_2^-$	hypochlorite	ClO^-
carbonate	CO_3^{2-}	chlorite	ClO_2^-
hydrogen carbonate (or bicarbonate)	HCO_3^-	chlorate	ClO_3^-
hydroxide	OH^-	perchlorate	ClO_4^-
nitrate	NO_3^-	permanganate	MnO_4^-
nitrite	NO_2^-	sulfate	SO_4^{2-}
chromate	CrO_4^{2-}	sulfite	SO_3^{2-}
dichromate	$Cr_2O_7^{2-}$	hydrogen sulfite (or bisulfite)	HSO_3^-
phosphate	PO_4^{3-}	hydrogen sulfate (or bisulfate)	HSO_4^-
hydrogen phosphate	HPO_4^{2-}	peroxide	O_2^{2-}
ammonium	NH_4^+	cyanide	CN^-

- There are no rules about the formulas of the ions, such as how many oxygens there should be. They just are.

Polyatomic Ions in Everyday Chemistry

- The active ingredient in household bleach is ***sodium hypochlorite,*** which acts to destroy color-causing molecules and kill bacteria.
- Baking soda contains ***sodium bicarbonate*** (sodium hydrogen carbonate), which acts as a source of carbon dioxide gas in baking.
- ***Calcium carbonate*** is the active ingredient in antacids such as Tums™ and Alka-Mints™. It neutralizes stomach acids.
- ***Sodium nitrite*** is a food additive used to preserve packaged meats such as ham, hot dogs, and bologna. Sodium nitrite inhibits the growth of bacteria, especially those that cause botulism.

Naming oxyanions

What is an oxyanion?

anion containing oxygen atom(s) and another element

-- oxygen is written last in the formula

{root}**-ite** ⇨ Low oxygen content

{root}**-ate** ⇨ High oxygen content

NO_2^-	Nitrite	Low oxygen content
NO_3^-	Nitrate	High oxygen content
SO_3^{2-}	Sulfite	Low oxygen content
SO_4^{2-}	Sulfate	High oxygen content

Naming oxyanions of halogens (cont.)

hypo {root} ite ⇨ **Even lower** oxygen content

{root} ite ⇨ Low oxygen content

{root} ate ⇨ High oxygen content

per {root} ate ⇨ **Even higher** oxygen content

ClO^- or OCl^-	Hypochlorite	Lowest oxygen content
ClO_2^-	Chlorite	Low oxygen content
ClO_3^-	Chlorate	High oxygen content
ClO_4^-	Perchlorate	Highest oxygen content

Chlorine, Bromine, and Iodine form analogous oxyanions:

BrO_3^-	Bromate
IO_4^-	Periodate
IO^-	Hypoiodite
BrO_2^-	Bromite

Some of the analogous oxyanions of bromine and iodine might not actually be stable, but we'll ignore that

But we do need to know this:

FO^- Hypofluorite The only oxyanion of fluorine!

ClO^-	**hypo**chlor**ite**	BrO^-	**hypo**brom**ite**
ClO_2^-	chlor**ite**	BrO_2^-	brom**ite**
ClO_3^-	chlor**ate**	BrO_3^-	brom**ate**
ClO_4^-	**per**chlor**ate**	BrO_4^-	**per**brom**ate**

IO^-	**hypo**iod**ite**
IO_2^-	iod**ite**
IO_3^-	iod**ate**
IO_4^-	**per**iod**ate**

No need to memorize!

All ionic compounds, not just binary ionic compounds are named in this way:

{cation name} {anion name}

It's just a matter of knowing the cation name and anion name, and listing them in that order.

Examples of ionic compounds with polyatomic ions:

NaOH	Sodium hydroxide
$Mg(NO_3)_2$	Magnesium nitrate
$(NH_4)_2SO_4$	Ammonium sulfate

If multiple polyatomic ions are needed in the formula, they are enclosed in parentheses before putting their count as subscript

Practice:
Check your solution on next page

Which is *not* the correct chemical formula for the compound named?

a) potassium phosphate, K_3PO_4
b) iron(II) oxide, FeO
c) calcium carbonate, $CaCO_3$
d) sodium sulfide, NaS
e) lithium nitrate, $LiNO_3$

Practice:

Which is *not* the correct chemical formula for the compound named?

a) potassium phosphate, K_3PO_4
b) iron(II) oxide, FeO
c) calcium carbonate, $CaCO_3$
d) sodium sulfide, NaS ⟸
e) lithium nitrate, $LiNO_3$

Naming Binary **Covalent** Compounds

Formed between two nonmetals.

1. The first element in the formula is named first, using the full element name.
2. The second element is named as if it were an anion.

up to this point, same as for ionic compounds, but …

3. Prefixes are used to denote the numbers of atoms present.
   - The prefix *mono-* is never used for naming the first element.

Prefixes Used to Indicate Number in Chemical Names

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

The prefix *mono-* is never used for naming the first element.

Naming Binary **Molecular** (Covalent) Compounds

- The first step in naming a molecular compound is identifying it as one.
  -- If first element in formula is a metal (or NH_4^+): not molecular
  -- If two nonmetals in binary compound: molecular
- Starting point is to pretend that we are naming an ionic compound:
  First element is treated like a metal cation (just its name)
  Second element is treated like an anion: {root} ide
- But of course it is not ionic, and we cannot use charges as guide
  Instead, we use prefixes to indicate the number of atoms

Extra details to Note when Naming Molecular Compounds

If there is only one atom of the *first element,* the prefix *mono-* is normally omitted.

CO_2 ~~mono~~ carbon di- ox -ide

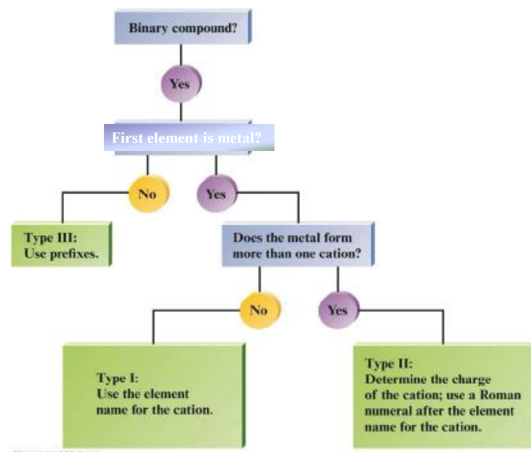
The full name is *carbon dioxide.*

If the prefix ends with –o or –a and the second element name starts with o, the vowel (– o or –a) at the end of the prefix is dropped.

N_2O : *dinitrogen monoxide*

P_4O_{10} : *tetraphosphorus decoxide* *(some may prefer decaoxide)*

Simplified Flowchart for Naming Binary Compounds



Binary Covalent Compounds Examples:

CO_2	Carbon dioxide
SF_6	Sulfur hexafluoride
N_2O_4	Dinitrogen tetroxide

Practice:
Check your solution on next page
Name the following

NO_2

PCl_5

I_2F_7

Practice :

NO_2 nitrogen dioxide

PCl_5 phosphorus pentachloride

I_2F_7 diiodine heptafluoride

Practice:
Check your solution on next page

Write Formulas for the Following

dinitrogen tetroxide

sulfur hexafluoride

diarsenic trisulfide

Practice:

Write Formulas for the Following

dinitrogen tetroxide N_2O_4

sulfur hexafluoride SF_6

diarsenic trisulfide As_2S_3

Practice:
Check your solution on next page
Which of the following is named incorrectly?

a. Li_2O, lithium oxide
b. $FePO_4$, iron(III) phosphate
c. HF, hydrogen fluoride
d. $BaCl_2$, barium dichloride
e. Mg_3N_2, magnesium nitride

Practice:

Which of the following is named incorrectly?

a. Li_2O, lithium oxide
b. $FePO_4$, iron(III) phosphate
c. HF, hydrogen fluoride
d. $BaCl_2$, barium dichloride ⬅
e. Mg_3N_2, magnesium nitride

Practice:
Check your solution on next page
Which is the correct formula for copper(I) sulfide?

a) Cu_2S
b) CuS
c) CuS_2
d) Cu_2S_2
e) None of these

Practice:

Which is the correct formula for copper(I) sulfide?

a) Cu_2S
b) CuS
c) CuS_2
d) Cu_2S_2
e) None of these

Practice:
Check your solution on next page
Which of the following is the correct chemical formula for iron(III) oxide?

a) FeO
b) Fe_3O
c) FeO_3
d) Fe_2O_3
e) Fe_3O_2

Practice:

Which of the following is the correct chemical formula for iron(III) oxide?

a) FeO
b) Fe_3O
c) FeO_3
d) Fe_2O_3 ⟵
e) Fe_3O_2

Practice:
Check your solution on next page

What is the correct name for the compound with the formula $Mg_3(PO_4)_2$?

a) Trimagnesium diphosphate
b) Magnesium(II) phosphate
c) Magnesium phosphate
d) Magnesium(II) diphosphate
e) Magnesium(III) diphosphate

Practice:

What is the correct name for the compound with the formula $Mg_3(PO_4)_2$?

a) Trimagnesium diphosphate
b) Magnesium(II) phosphate
c) Magnesium phosphate ⟵
d) Magnesium(II) diphosphate
e) Magnesium(III) diphosphate

Binary covalent compounds of hydrogen are special cases. They are either:

- acidic compounds, which have their own naming scheme, or
- named according to other conventions
  - We just need to know a few here:
    - **H_2O (water)**
    - **NH_3 (ammonia)**
    - **CH_4 (methane)**

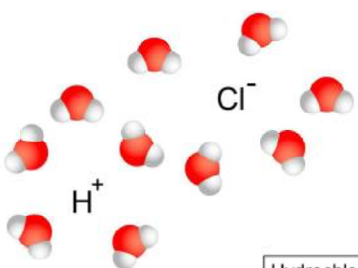
Metal hydrides are ionic compounds and are named accordingly: sodium hydride, calcium hydride, etc.

Acids

- Acids can be recognized by:
  the **hydrogen that appears <u>first</u>** in the formula.
  For example, HCl
- Molecule with one or more ionizable H atoms
- When the molecule acts as an acid, the acidic, ionizable H becomes an H^+, leaving behind an anion.
  - The acid **molecule** is producing ions, but it is not an ionic compound; it is a **molecular** compound.

Hydrogen Chloride (g)

Molecular
H-Cl *bond is covalent*
not ionic



Molecular
H-Cl *bond is covalent*
not ionic

Hydrochloric acid (aq)

HCl *in water:*
in the form of ions H^+ *and* Cl^-
No chemical bond between H^+ *and* Cl^-

Naming Acids

- **Just look at the ending of the anion it produces**

If the anion name ends with **–ide**, the acid is named with the prefix ***hydro–*** and the suffix ***–ic***.

{Hydro} {root} {ic} acid

{root}: root name of the ion that the acid forms

For acids whose anions end with –ide **<u>only:</u>**
Named as acid <u>only if they are in aqueous solution</u>, shown by (aq)

HCl(aq)	Hydro<u>chlor</u>ic acid	<u>chlor</u>ide (Cl^-)
HCN(aq)	Hydro<u>cyan</u>ic acid	<u>cyan</u>ide (CN^-)
H_2S(aq)	Hydro<u>sulfur</u>ic acid	<u>sulf</u>ide (S^{2-})

The <u>pure compound is named as a binary covalent compound</u>, or *as if it were* (even if the anion has more than one atom)

HCl(g)	Hydrogen chloride
HCN(g)	Hydrogen cyanide

Naming Acids *(continued)*

If the anion name ends in ***–ate***

The suffix ***–ic*** is added to the root name

{root}{ic} {acid}

Examples:

HNO_3	<u>Nitr</u>ic acid	<u>Nitr</u>ate (NO_3^-)
$HC_2H_3O_2$	<u>Acet</u>ic acid	<u>Acet</u>ate ($C_2H_3O_2^-$)
H_2SO_4	<u>Sulf*ur*</u>ic acid	<u>Sulf</u>ate (SO_4^{2-})

Always named as an acid, aqueous solution or not.
No "hydrogen nitrate" or "hydrogen acetate"!

Naming Acids *(continued)*

If the anion name ends in ***–ite***

The suffix ***–ous*** is added to the root name

{root}{ous} {acid}

Examples:

HNO_2	<u>Nitr</u>ous acid	<u>Nitr</u>ite (NO_2^-)
$HClO_2$	<u>Chlor</u>ous acid	<u>Chlor</u>ite (ClO_2^-)
H_2SO_3	<u>Sulf*ur*</u>ous acid	<u>Sulf</u>ite (SO_3^{2-})

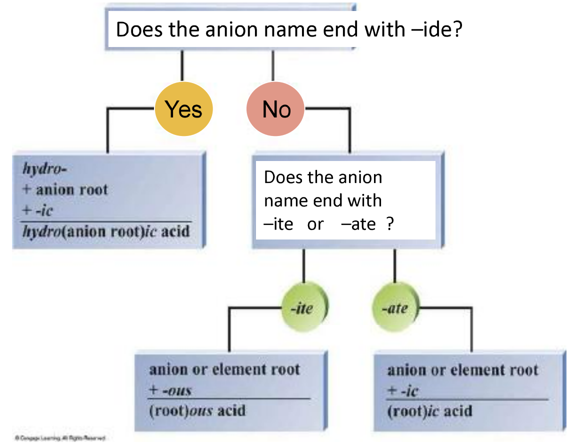
Always named as an acid, aqueous solution or not.
No "hydrogen nitrite" or "hydrogen chlorite"!

Names of Some Common Oxyacids and Their Oxyanions

TABLE 5.7 Names of Some Common Oxyacids and Their Oxyanions

Acid Formula	Acid Name	Oxyanion Name	Oxyanion Formula
HNO_2	nitrous acid	nitrite	NO_2^-
HNO_3	nitric acid	nitrate	NO_3^-
H_2SO_3	sulfurous acid	sulfite	SO_3^{2-}
H_2SO_4	sulfuric acid	sulfate	SO_4^{2-}
$HClO_2$	chlorous acid	chlorite	ClO_2^-
$HClO_3$	chloric acid	chlorate	ClO_3^-
$HC_2H_3O_2$	acetic acid	acetate	$C_2H_3O_2^-$
H_2CO_3	carbonic acid	carbonate	CO_3^{2-}

Flowchart for Naming Acids *(It's not about oxygen, really)*



Practice: Name the Following
Check your answer on the following page

H_2S (aq)

$HClO_3$

HNO_2

In subsequent courses, you will probably be asked to write acid formulas always as aqueous solutions, always putting (*aq*) after the formula.

As explained earlier, that is only necessary for acids with anion names that end with "-ide", when named as acids. Or, of course, if we are told that the acid **is** indeed in aqueous solution).

Be aware of the expected (*aq*) in future courses and follow it in order not to get penalized for knowing better.

Practice: Name the Following

H_2S hydrosulfuric acid

$HClO_3$ chloric acid

HNO_2 nitrous acid

Practice:
Check your solution on next page

What are the formulas for the following acids?

chlorous acid

phosphoric acid

hydrobromic acid

Practice:
Check your solution on next page

What are the formulas for the following acids?

chlorous acid	H^+ with ClO_2^-	$HClO_2$
phosphoric acid	H^+ with PO_4^{3-}	H_3PO_4
hydrobromic acid	H^+ with Br^-	HBr

Practice:
Check your solution on next page

What is the correct name for the acid with the formula HFO?

a) Fluoric Acid
b) Hydrofluoric Acid
c) Hydrofluorous Acid
d) Hypofluorous Acid
e) Perfluoric Acid

Practice:

What is the correct name for the acid with the formula HFO?

a) Fluoric Acid
b) Hydrofluoric Acid
c) Hydrofluorous Acid
d) Hypofluorous Acid ⟵
e) Perfluoric Acid

Practice:
Check your solution on next page

Which of the following compounds is named incorrectly?

a) KNO_3	potassium nitrate
b) TiO_2	titanium(II) oxide
c) $Sn(OH)_4$	tin(IV) hydroxide
d) PBr_5	phosphorus pentabromide
e) $CaCrO_4$	calcium chromate

Practice:
Check your solution on next page

Which of the following compounds is named incorrectly?

a) KNO_3	potassium nitrate
b) TiO_2	**titanium(II) oxide** ⟵
c) $Sn(OH)_4$	tin(IV) hydroxide
d) PBr_5	phosphorus pentabromide
e) $CaCrO_4$	calcium chromate

Practice:
Check your solution on next page

What are the formulas for compounds made from the following ions?

- Potassium ion with a nitride ion
- Calcium ion with a bromide ion
- Aluminum ion with a sulfide ion

Practice:

What are the formulas for compounds made from the following ions?

- Potassium ion with a nitride ion K_3N
- Calcium ion with a bromide ion $CaBr_2$
- Aluminum ion with a sulfide ion Al_2S_3

Practice:
Check your solution on next page

Name the following compounds

KCl

$MgBr_2$

Al_2S_3

Practice:
Check your solution on next page

Name the following compounds

KCl	potassium chloride
$MgBr_2$	magnesium bromide
Al_2S_3	aluminum sulfide

Practice:

Name the following compouds:

$TiCl_4$

CrO_3

Fe_3N_2

Practice:

$TiCl_4$	4 Cl = 4(-1) = 4− ⇒ Ti = 4+ Titanium(IV) chloride
CrO_3	3 O = 6− ⇒ Cr = 6+ Chromium(VI) chloride
Fe_3N_2	2 N = 6− ⇒ 3 Fe = 6+, Fe = 2+ Iron(II) nitride

Practice:
Check your solution on next page

Name the following compounds

$PbBr_2$

Fe_2S_3

Practice:

Name the following compounds

$PbBr_2$ lead(II) bromide

Fe_2S_3 iron(III) sulfide

Practice:
Check your solution on next page

What are the formulas for compounds made from the following ions?

copper(II) ion with a nitride ion

iron(III) ion with a bromide ion

Practice:

What are the formulas for compounds made from the following ions?

copper(II) ion with a nitride ion

Cu^{2+} with N^{3-} Cu_3N_2

iron(III) ion with a bromide ion

Fe^{3+} with Br^- $FeBr_3$

Practice:
Check your solution on next page

Name the Following Compounds

NH_4Cl

$Ca(C_2H_3O_2)_2$

$Cu(NO_3)_2$

Practice:

Name the Following Compounds

NH_4Cl ammonium chloride

$Ca(C_2H_3O_2)_2$ calcium acetate

$Cu(NO_3)_2$ copper(II) nitrate

Practice:
Check your solution on next page

What are the formulas for compounds made from the following ions?

aluminum ion with a sulfate ion

chromium(II) with hydrogen carbonate

Practice:

What are the formulas for compounds made from the following ions?

aluminum ion with a sulfate ion

Al^{3+} with SO_4^{2-} $Al_2(SO_4)_3$

chromium(II) with hydrogen carbonate

Cr^{2+} with HCO_3^- $Cr(HCO_3)_2$