Introductory Chemistry

Fourth Edition

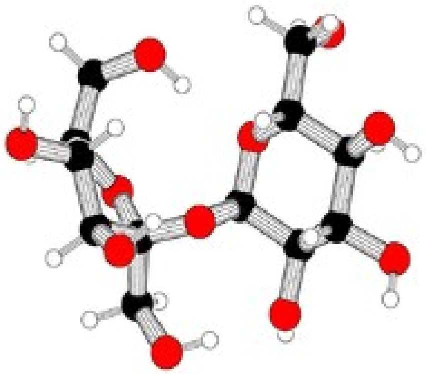
Nivaldo J. Tro

Chapter 5

Molecules and Compounds

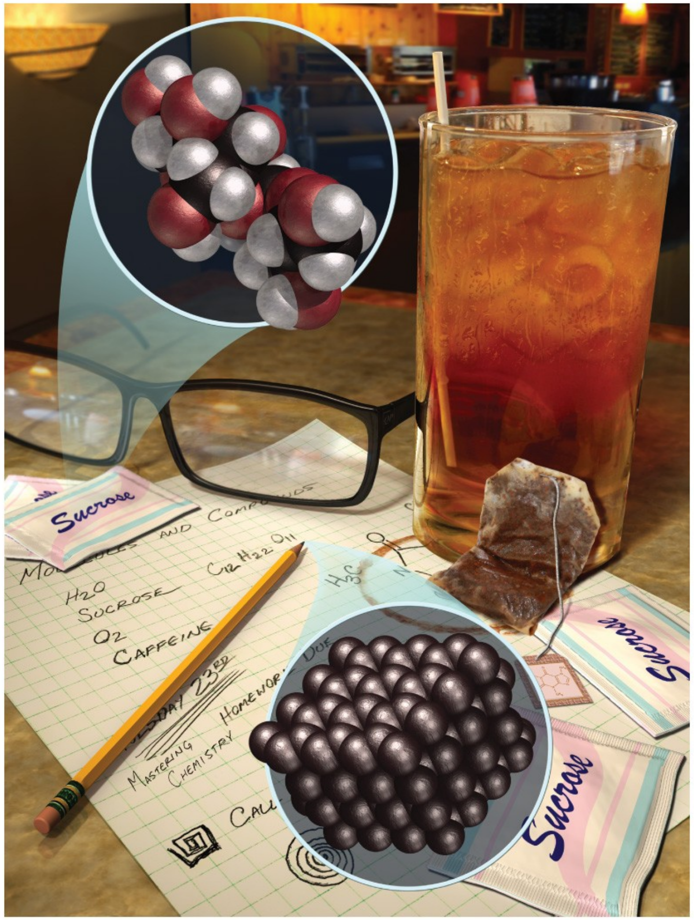
Dr. Sylvia Esjornson
Southwestern Oklahoma State University
Weatherford, OK

Updated by Dr. Bytautas (Galveston College),
September 4, 2025



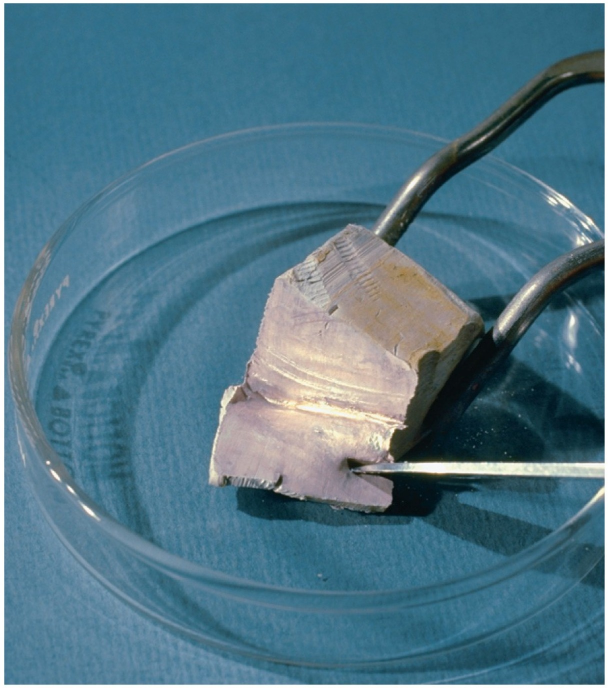
5.1 Sugar and Salt

- 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.



5.1 Sugar and Salt

- **FIGURE 5.1 Elemental sodium** Sodium is an extremely reactive metal that dulls almost instantly upon exposure to air.



- **FIGURE 5.2 Elemental chlorine** Chlorine is a yellow gas with a pungent odor. It is highly reactive and poisonous.

5.1 Sugar and Salt

© 2012 Pearson Education, Inc.

- **FIGURE 5.3 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.

5.2 Compounds Display Constant Composition

- 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.

5.2 Compounds Display Constant Composition

FIGURE 5.4 [**A mixture**]() **This balloon is filled with a mixture of hydrogen and oxygen gas. The relative amounts of hydrogen and oxygen are variable.**

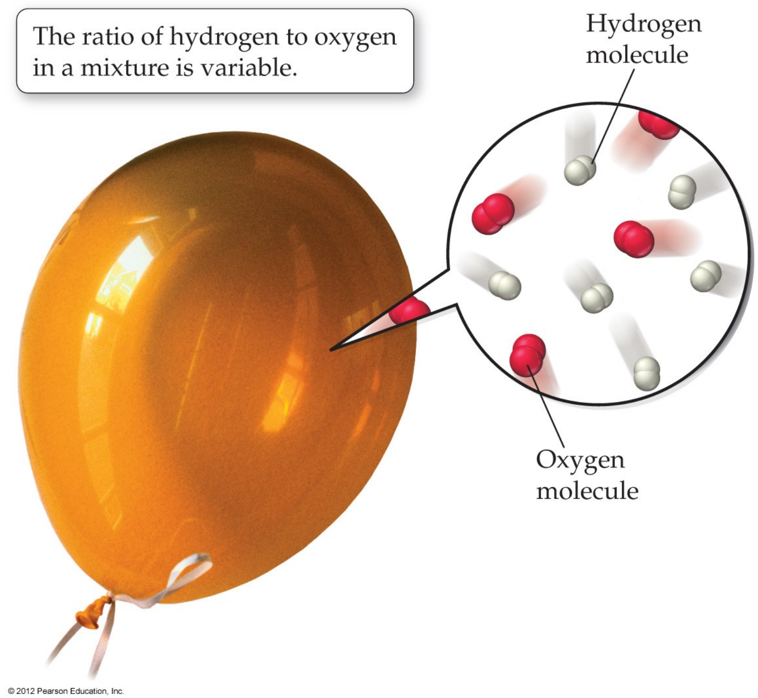
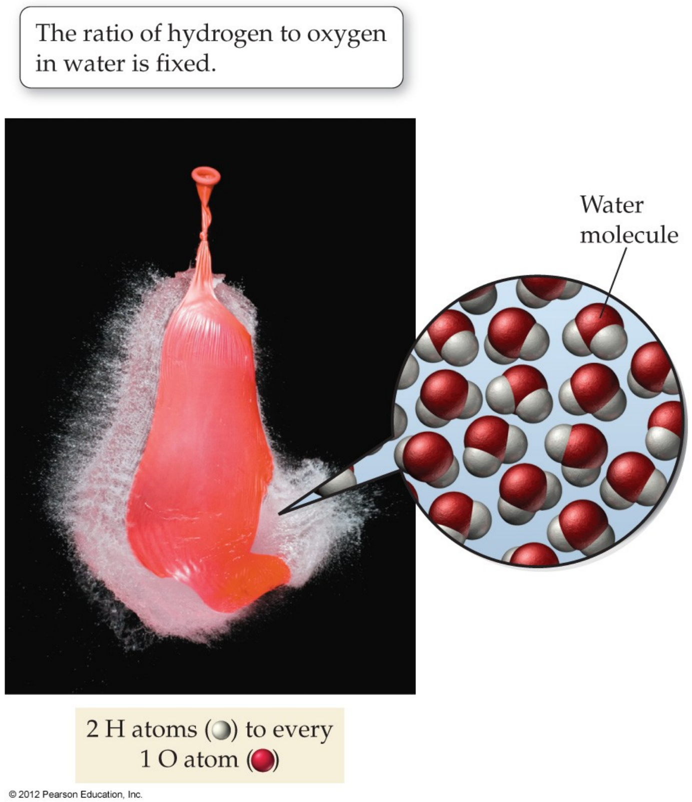


FIGURE 5.5 **A chemical compound** **This balloon is filled with water, composed of molecules that have a fixed ratio of hydrogen to oxygen. (*Source:* JoLynn E. Funk.)**



5.2 Compounds Display 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.

5.2 Constant Composition: Mass Ratio

- **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 <u>any sample of pure water,</u> no matter what its origin.

5.2 Constant Composition: Mass Ratio

- 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.

5.3 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.

5.3 Chemical Formulas: How to Represent Compounds

Common chemical formulas include:

- 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.

5.3 Chemical Formulas: How to Represent Compounds CO and CO_2

- 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.
  - When inhaled, carbon monoxide interferes with the blood's ability to carry oxygen, which can be fatal.
  - CO is the primary substance responsible for deaths of people who inhale too much automobile exhaust.
- 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.

5.3 Chemical Formulas: 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.

5.3 Chemical Formulas: How to List the Elements in Order 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 most metallic element is named first, such as the hydroxide ion, which is written as $\mathbf{OH^-}$.

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.

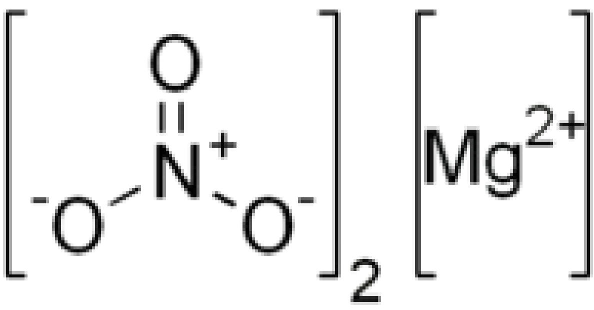
5.3 Chemical Formulas: How to Represent Compounds with Polyatomic Ions

- 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.

Total Number of Each Type of Atom in a Chemical Formula

- **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.**

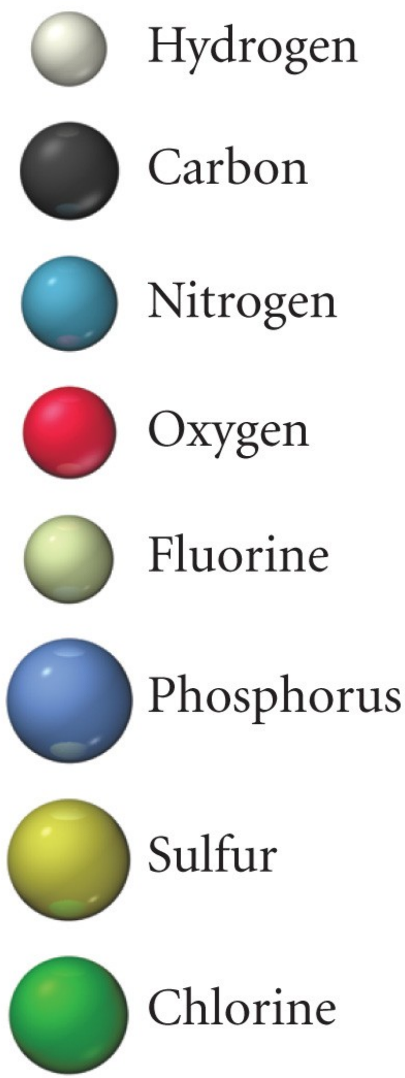
Mg:	**1**	**= 1 Mg**
N:	**1 × 2**	**= 2 N**
O:	**3 × 2**	**= 6 O**



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.

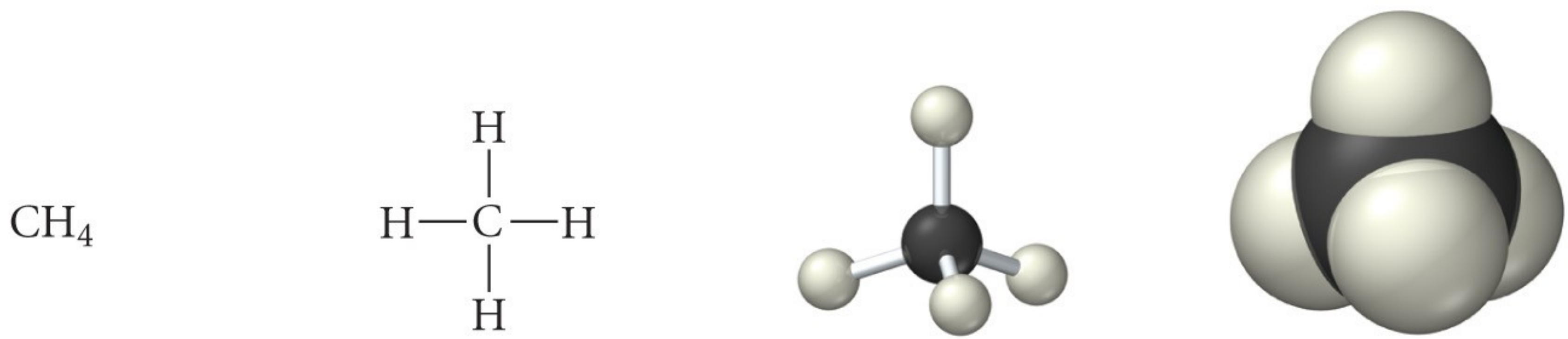
Types of Chemical Formulas



- **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.

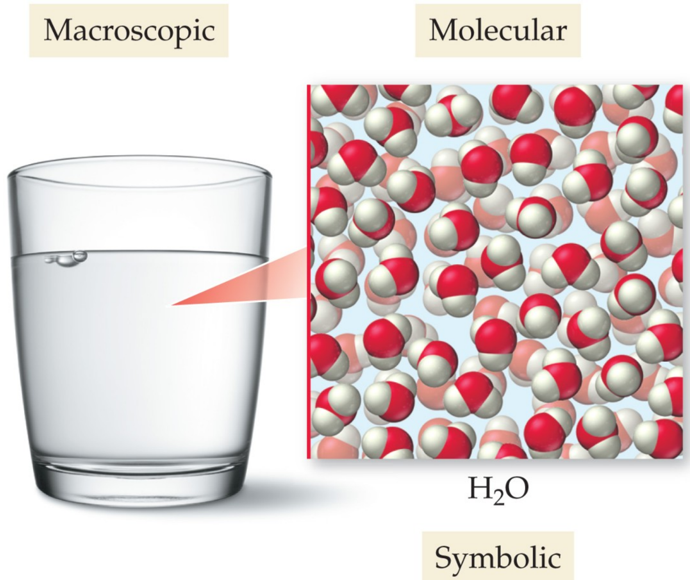
Comparison of Formulas and Models for Methane, CH_4

- The **molecular formula** of methane indicates that methane has 1 carbon atom and 4 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.



Molecular formula | Structural formula | Ball-and-stick model | Space-filling model

*Images make **[the connection]** between the world around us and the world of atoms and molecules.*

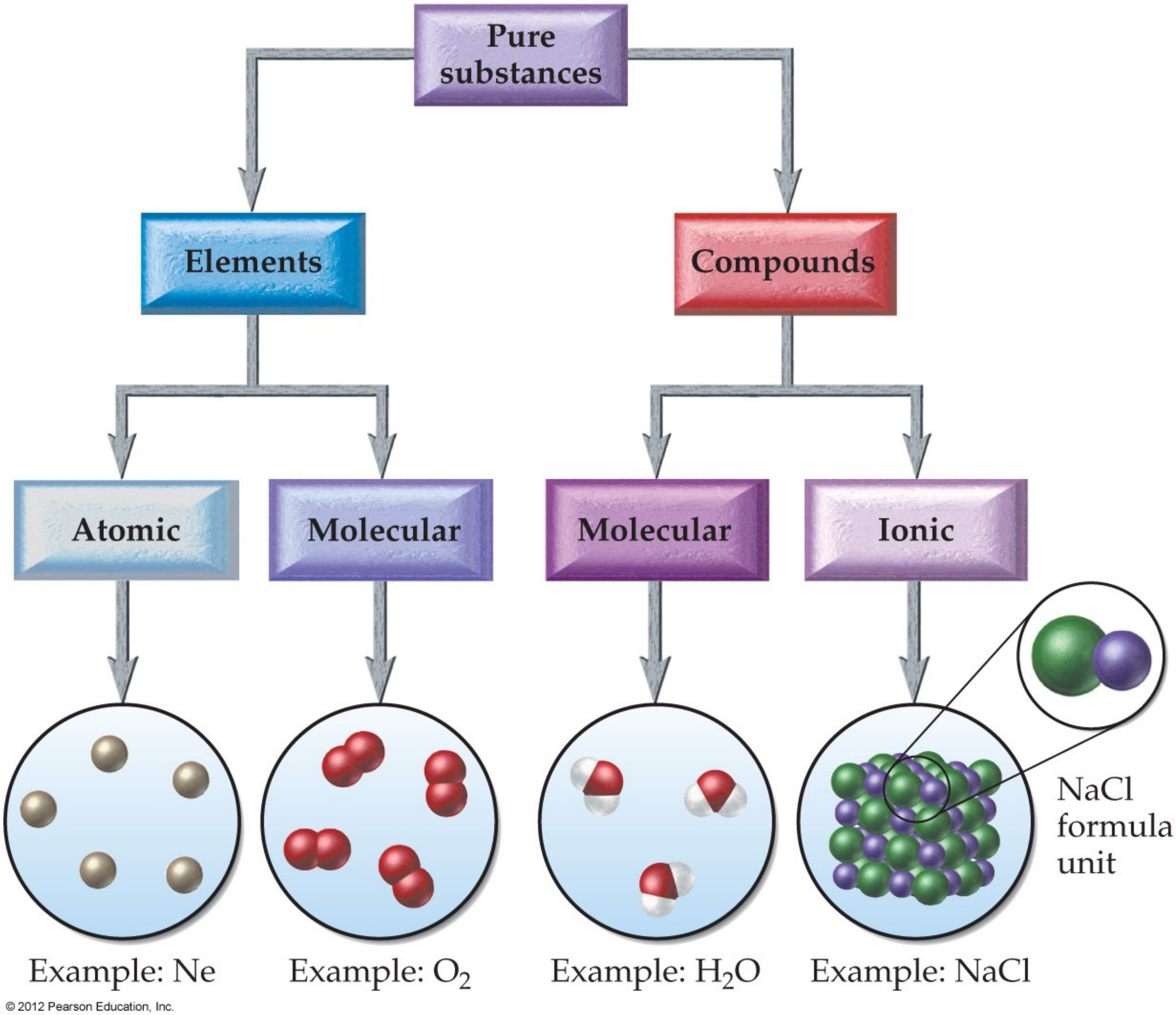


- The ***macroscopic world*** (what we see)
- The ***atomic and molecular world*** (the particles that compose matter)
- The *symbolic way* that chemists represent the atomic and molecular world.
- Here is an **image of water** using this kind of representation.

5.4 A Molecular View of Elements and Compounds

- Pure substances may be either **elements** or **compounds.**

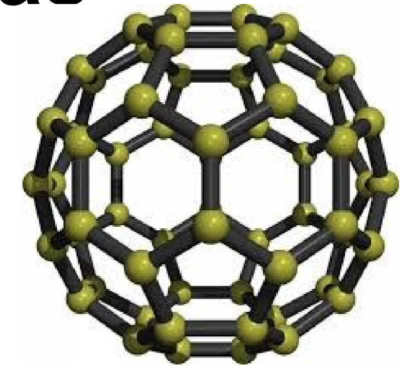
- **Elements** may be either **atomic** or **molecular.**
- **Compounds** may be either **molecular** or **ionic.**


Pure substances
Elements
Compounds
Atomic
Molecular
Molecular
Ionic
NaCl formula unit
Example: Ne
Example: O_2
Example: H_2O
Example: NaCl
© 2012 Pearson Education, Inc.

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 *diatomic molecules*—two atoms of that element bonded together—as their basic units.

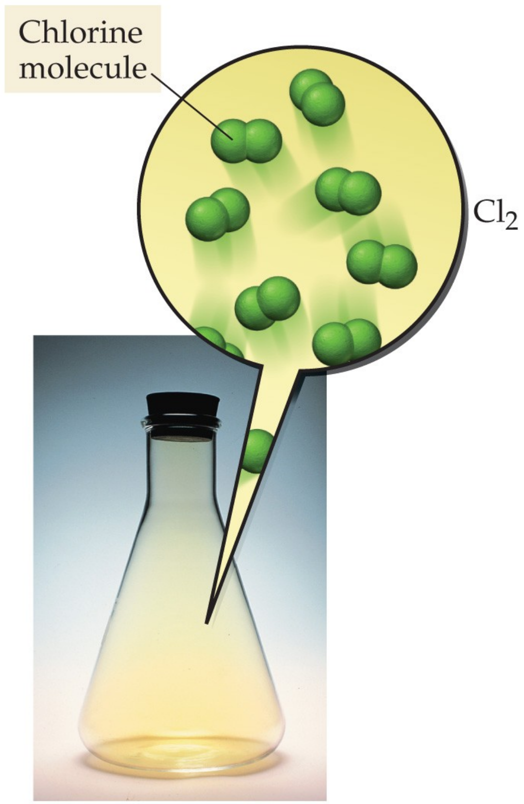
Could be larger (e.g. C_{60}).



Elements may be atomic or molecular.

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

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** are shown in Table 5.2.

TABLE 5.2 Elements That Occur 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 molecular or ionic.

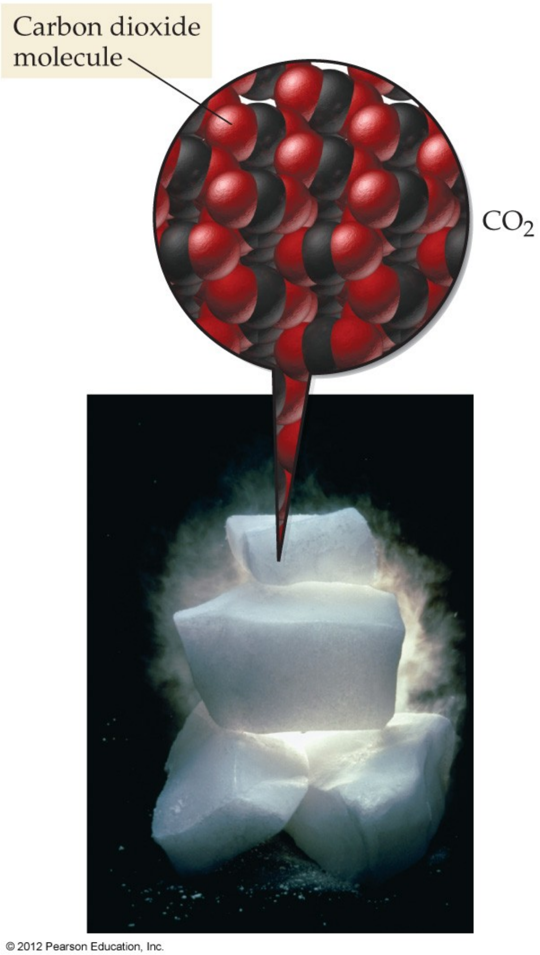
- Molecular compounds are compounds formed from two or more nonmetals. The basic units of molecular compounds are molecules composed of the constituent atoms.

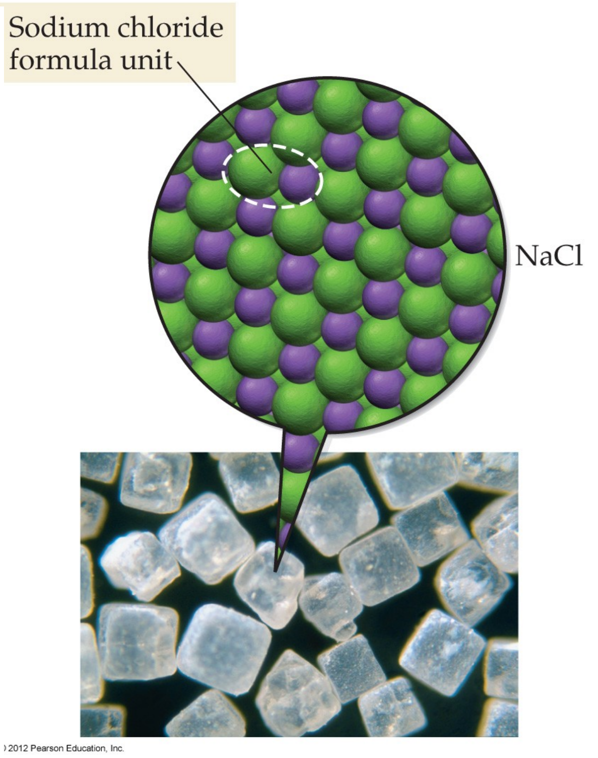
- Ionic compounds contain one or more cations paired with one or more anions.

Compounds may be molecular 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.**

Recommended videos:

- **KHAN ACADEMY:**
- https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties/introduction-to-compounds/v/introduction-to-ions
- https://www.khanacademy.org/science/chemistry/atomic-structure-and-properties/introduction-to-compounds/v/naming-ions-and-ionic-compounds
- **NAMING IONIC COMPOUNDS (Tyler De Witt)**
- https://www.youtube.com/watch?v=Rq0A-AHdB74
- **WRITING IONIC FORMULAS:**
- https://www.youtube.com/watch?v=URc75hoKGLY
- **WRITING IONIC FORMULAS with polyatomic ions:**
- https://www.youtube.com/watch?v=p9iQ5Qn42DM

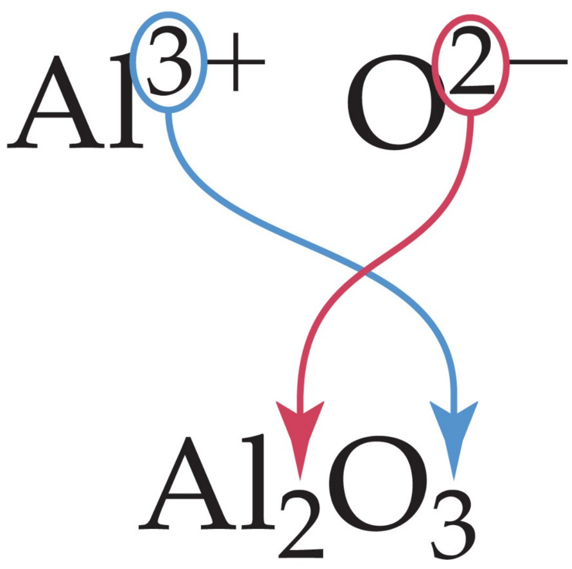
5.5 Writing Formulas for Ionic Compounds

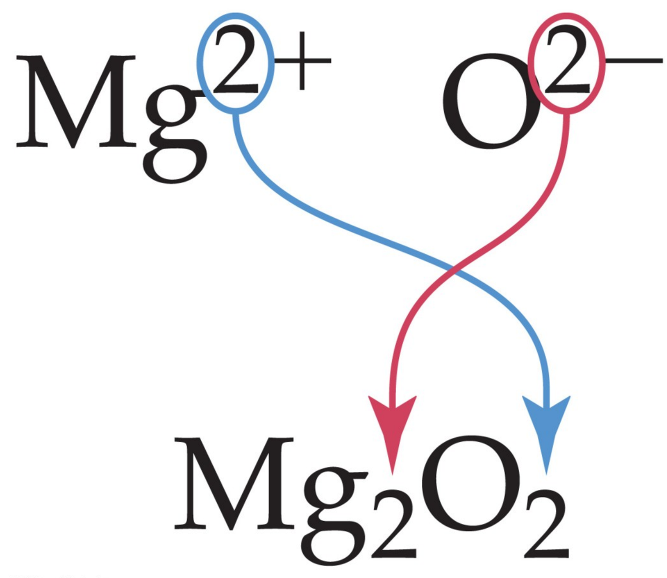
- Review the elements that form ions with a predictable charge.
- **Ionic compounds always contain positive and negative ions.**
- In the chemical formula, the sum of the charges of the positive ions (cations) must always equal the sum of the charges of the negative ions (anions).

5.5 Writing Formulas for Ionic Compounds

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.

Write a formula for **the ionic compound** that forms from **magnesium and oxygen.**





Algebraic method:

$\overset{3+}{Al}_x \overset{2-}{O}_y$

determine $x, y = ?$ (smallest integers)

charge neutrality condition:

$$x \cdot (+3) + y \cdot (-2) = 0$$

$$3x - 2y = 0 \Rightarrow 3x = 2y \quad \Big| \times \left(\frac{1}{3 \cdot y}\right)$$

$$\frac{\cancel{3}}{\cancel{3}} \cdot \frac{x}{y} = \frac{2}{3} \frac{\cancel{y}}{\cancel{y}}$$

$$\Rightarrow \frac{x}{y} = \frac{2}{3} \Rightarrow \overset{3+}{Al}_2 \overset{2-}{O}_3$$

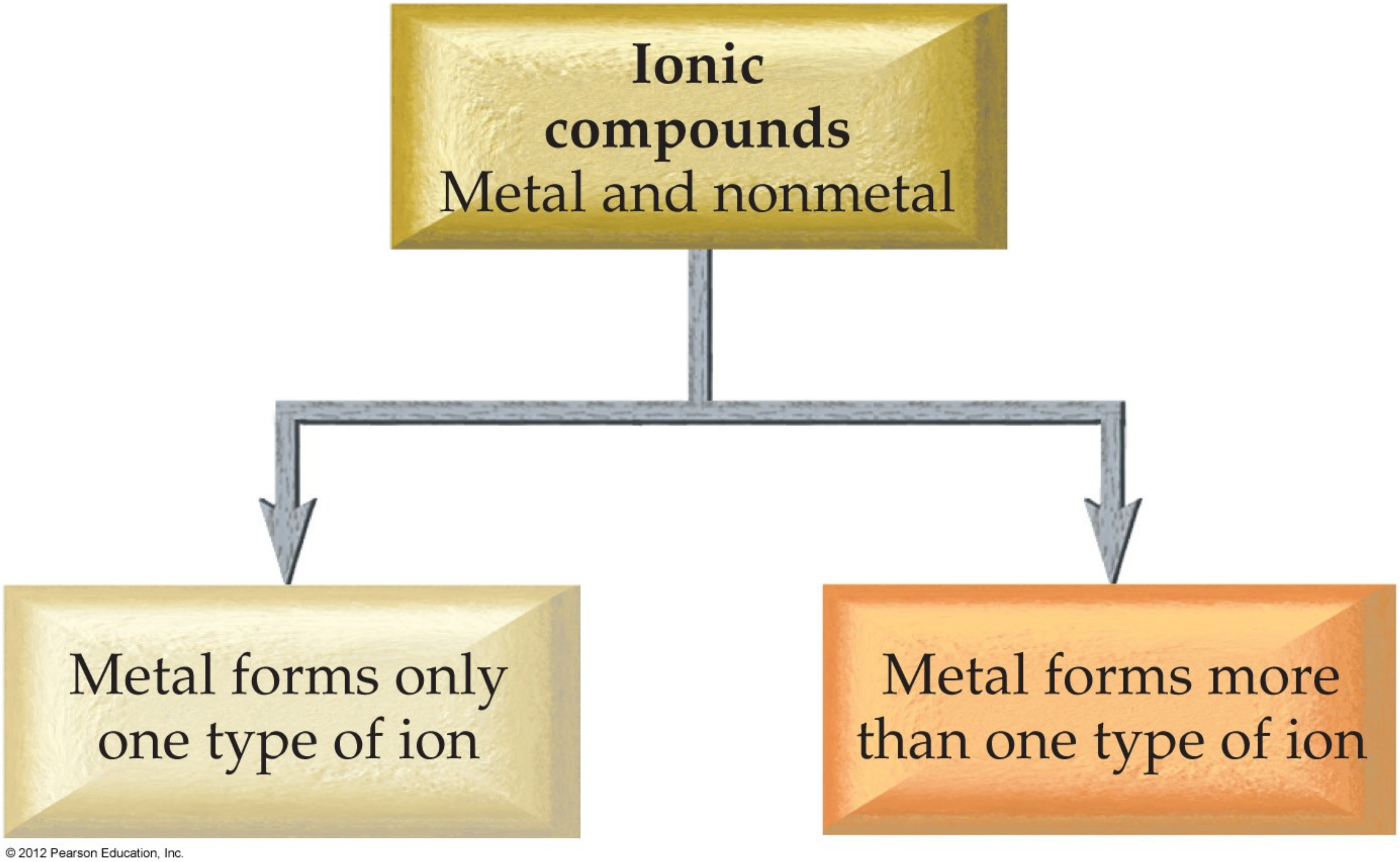
5.6 Nomenclature: Naming Compounds

- 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 *dihydrogen monoxide*.
- Since water is such a familiar compound, everyone uses its common name and *not* its systematic name.
- Common names can be learned only through familiarity; there is no system.

5.7 Naming Ionic Compounds

- The first step in naming an ionic compound is identifying it as one.
- Remember, any time you have a metal and one or more nonmetals together in a chemical formula, you can assume the compound is ionic.

Ionic compounds can be categorized into **two types**, depending **on the metal** in the compound.



Ionic compounds can be categorized into two types, depending on the metal in the compound.

- **The first type** (**called Type I)** contains **a metal** with an **invariant charge — one** that **does not vary from one compound to another**.
- **The second type** of **ionic compound** (**called Type II)** contains a metal with a charge **that can differ in different compounds**.
- Such metals **are usually (but not always)** found in the **transition metals** section of the periodic table.
- **Some transition metals**, such as **Zn and Ag**, form **cations** with **the same charge in all of their compounds.**
- **Some main group metals**, such as **Pb** and **Sn**, form **more than one type of cation**.

Metals Whose Charge Is Invariant from One Compound to Another

TABLE 5.3 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 with Their Common Charges

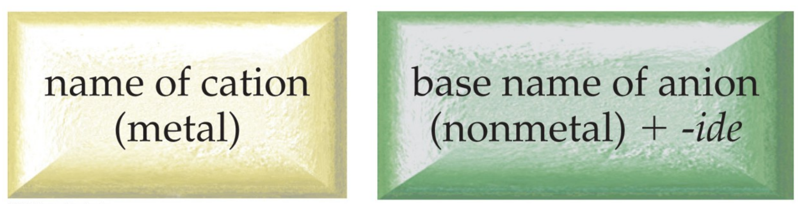
TABLE 5.4 Some Metals That Form More Than One Type of Ion and Their Common Charges

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.

Naming Binary Ionic Compounds Containing a Metal That Forms Only One Type of Cation

- **Binary compounds** are those that contain **only two different elements**. The names for binary ionic compounds containing a metal that forms **only one type** of ion have the form:



- Since **the charge** of the **metal is always the same** for these types of compounds, it need not be specified in the compound's name.

Naming Binary Ionic Compounds Containing a Metal That Forms Only One Type of Cation

- For example,

the name for NaCl consists of the name of the cation, ***sodium***,

followed by the base name of the anion, ***chlor***, with the ending ***-ide***.

- The full name is ***sodium chloride.***

NaCl **sodium chloride**

The base names for various nonmetals and their most common charges in ionic compounds

TABLE 5.5 **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

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

- **Since the charge of the metal cation** in these types of compounds **is not always the same**, the **charge must be specified in the metal's name**.

- We specify the charge with **a Roman numeral (in parentheses)** following the name of the metal.

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

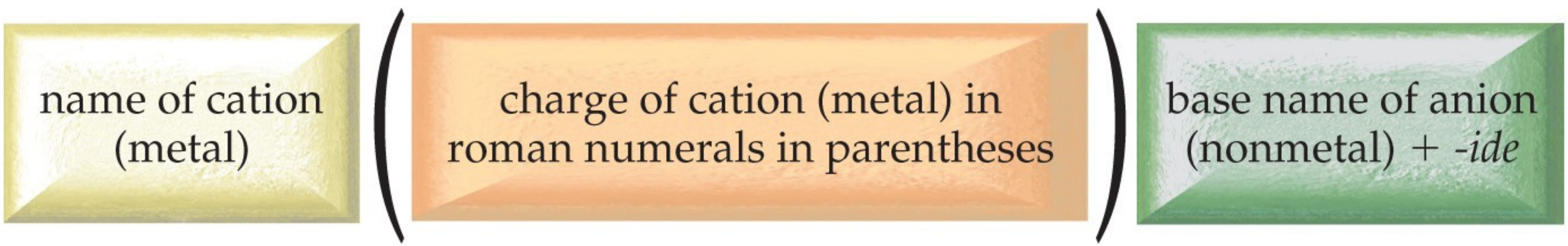
- For example,

we distinguish between **Cu^{+} and Cu^{2+}** by writing a **(I)** to indicate the **1+ ion** or a **(II)** to indicate the **2+ ion**:

- **Cu^{+} Copper(I)**
- **Cu^{2+} Copper(II)**

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

- **The full name for these type of compound has the form:**



Determine a charge from the formula of a specific compound.

- 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^+** in order for the compound to be **charge neutral** with the **three Cl^- anions**.

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

The name for the compound $FeCl_3$ is the name of the cation, *iron*,

followed by the charge of the cation in parentheses *(III)*,

followed by the base name of the anion, *chlor*, with the ending *-ide*.

- The full name is *iron(III) chloride*.

$FeCl_3$ iron(III) chloride

Naming **Ionic Compounds** Containing a **Polyatomic Ion**

- **Some ionic compounds contain polyatomic ions** (ions that are **themselves composed of a group of atoms with an overall charge**).

- **Ionic compounds containing polyatomic ions** are named using the same procedure we apply to other ionic compounds, except **that we use the name of the polyatomic ion** whenever it occurs.

The most common ***polyatomic ions*** are listed in Table 5.6.

TABLE 5.6 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^-

Naming Ionic Compounds Containing a Polyatomic Ion: Oxyanions

- **Many polyatomic ions are oxyanions, anions containing oxygen.**
- **When a series of oxyanions contain different numbers of oxygen atoms, they are named systematically according to the number of oxygen atoms in the ion.**
- **If there are two ions in the series**, the one with **more oxygen atoms** is given the ending
- ***-ate*** **and the one with fewer is given the ending *-ite*.**

NO_3^-	nitrate	SO_4^{2-}	sulfate
NO_2^-	nitrite	SO_3^{2-}	sulfite

Naming Ionic Compounds Containing a Polyatomic Ion

- If there are more than two ions in the series, then the prefixes *hypo-*, meaning "less than," and *per-*, meaning "more than," are used.

ClO^-	hypochlorite	BrO^-	hypobromite	IO^-	hypoiodite
ClO_2^-	chlorite	BrO_2^-	bromite	IO_2^-	iodite
ClO_3^-	chlorate	BrO_3^-	bromate	IO_3^-	iodate
ClO_4^-	perchlorate	BrO_4^-	perbromate	IO_4^-	periodate

When naming these ions in the homework, be sure to include the word ion in your answer, as in "perchlorate ion."

Everyday Chemistry: **Polyatomic Ions**

- 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.

5.8 Naming Molecular Compounds

- **The first step in naming a <u>molecular compound</u> is identifying it as one.**
- **Remember, nearly all molecular compounds form from two or more <u>nonmetals</u>.**
- **We learn how to name binary (two-element) <u>molecular compounds</u>.** Their names have the form:

5.8 Naming Molecular Compounds

When writing the name of a molecular compound, as when writing the formula, the first element is the more metal-like one (see Table 5.1).

The prefixes given to each element indicate the number of atoms present.

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

5.8 Naming Molecular Compounds

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

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

The full name is <u>*carbon dioxide*.</u>

The compound N_2O also called laughing gas,

is named according to the first element, *nitrogen*, with the prefix *di-*, followed by the base name of the second element, *ox*, prefixed by *mono-*, and the suffix *-ide*.

Since *mono-* ends with a vowel and *oxide* begins with a vowel, an *o* is dropped and the two are combined as *monoxide*. The entire name is <u>*dinitrogen monoxide*.</u>

When the prefix ends with a vowel and the base name starts with a vowel, the first vowel is sometimes dropped, as in monoxide, but not in triiodide.

Recommended videos:

- NAMING COVALENT MOLECULAR COMPOUNDS (Tyler DeWitt)
- https://www.youtube.com/watch?v=DejkvR4pvRw
- (NOTE: Iron(II) oxide formula is: FeO.)

- WHAT'S POLYATOMIC ION:
- https://www.youtube.com/watch?v=MJZeZvDxcx8

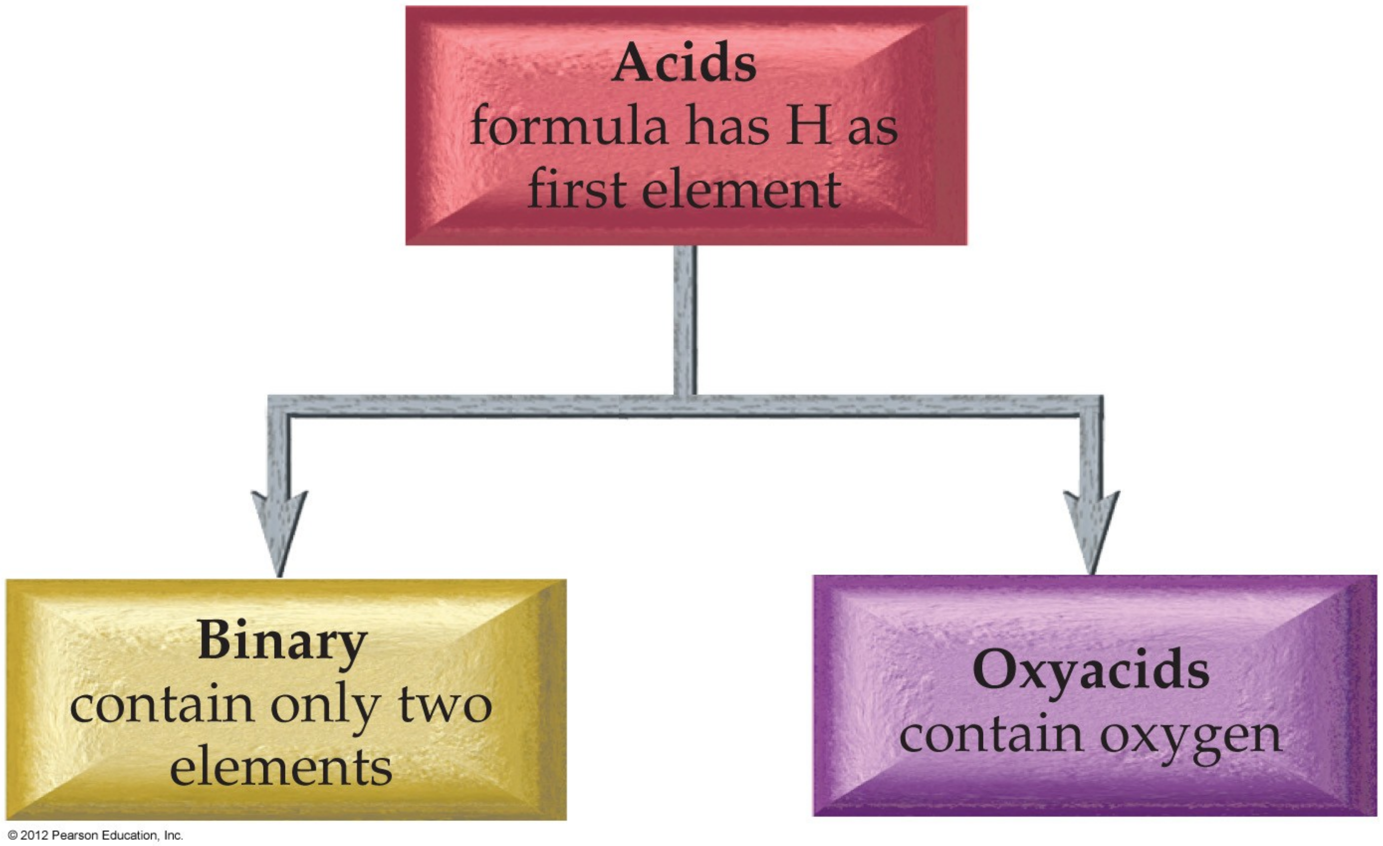
- NAMING ACIDS INTRODUCTION (Tyler DeWitt):
- https://www.youtube.com/watch?v=5Jb2u9ihfm4

- PRACTICE:
- https://www.youtube.com/watch?v=VyjnMk-Ta10

5.9 Naming Acids

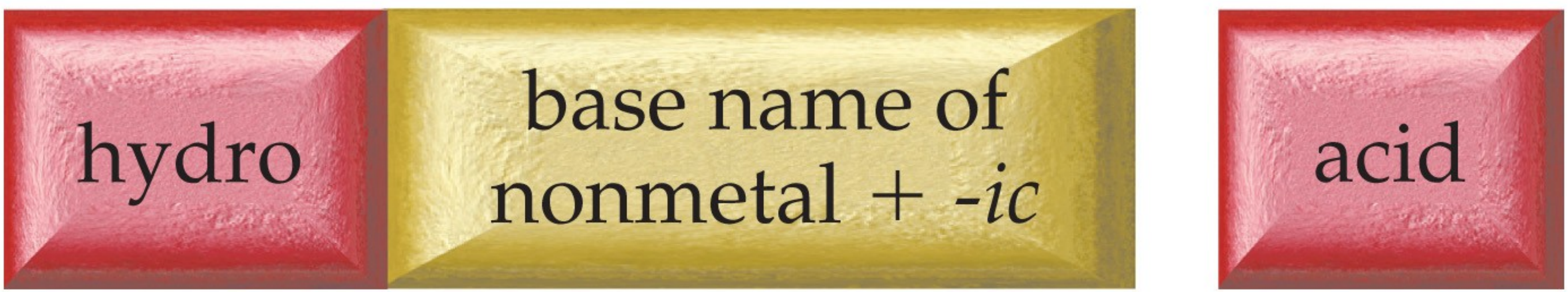
- Acids are molecular compounds that form H+ ions when dissolved in water.
- They are composed of hydrogen, usually written first in their formula, and one or more nonmetals, written second.
- We can categorize acids into two groups: binary acids, those containing only hydrogen and a nonmetal, and oxyacids, those containing hydrogen, a nonmetal, and oxygen.

FIGURE 5.14 Classification of acids



Naming **Binary Acids**

- Binary acids are composed of **hydrogen** and a **nonmetal.** The names for binary acids have the following form:



Naming Binary Acids

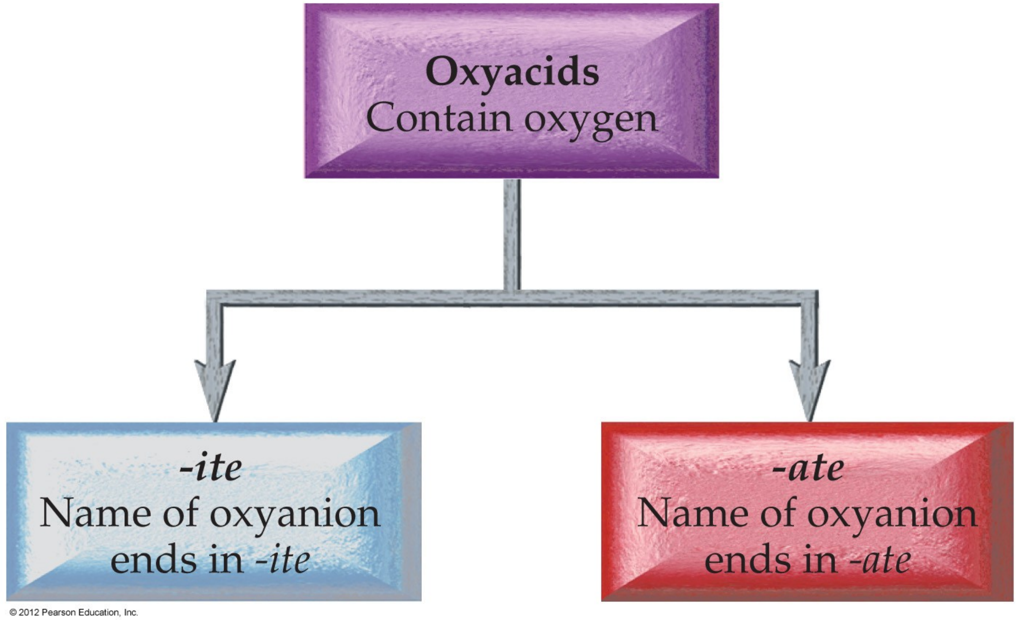
- **HCl(*aq*) is hydro*chlor*ic acid.**
- **HBr(*aq*) is hydro*brom*ic acid.**
- **HCl(*g*)** refers to **hydrogen chloride molecules** in the **gas phase**, **and not to the acid.**
- **H_2S(*g*) is covalent compound = hydrogen sulfide.**
- **However H_2S(*aq*) is an acid:**
- The base name of **S** is ***sulfur***, so the name is ***hydrosulfuric acid.***

Naming Oxyacids

- <u>Oxyacids</u> are acids that contain oxyanions—found in the table of polyatomic ions.

- $HNO_3(aq)$ contains the nitrate NO_3^- ion.
- $H_2SO_3\ (aq)$ contains the sulfite SO_3^{2-} ion.
- $H_2SO_4\ (aq)$ contains the sulfate SO_4^{2-} ion.

- These acids are a combination of one or more H^+ ions with an <u>oxyanion</u>.
- The number of H^+ ions depends on the charge of the oxyanion, so that the formula is always <u>charge-neutral</u>.



The names of acids containing **oxyanions** ending with *-ite* take this form:

Insert art page 145 “base name of oxyanion + *ous*

The names of acids containing **oxyanions** ending with *-ate* take this form:

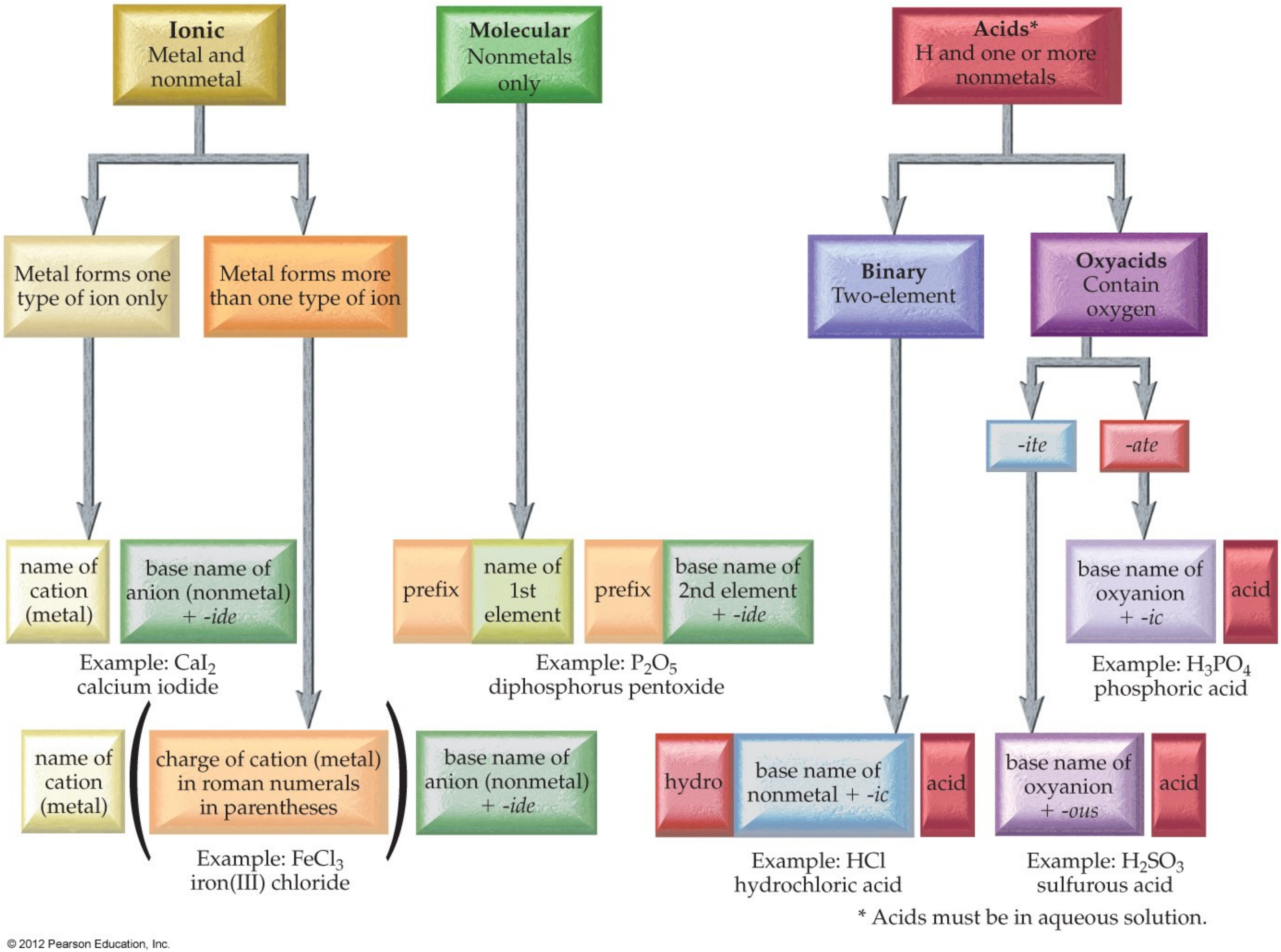
Insert art page 145 “ base name of oxyanion + *ic*

Table 5.7 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^-
H_2SO_4	sulfuric acid	sulfate	SO_4^{2-}
$HClO_2$	chlorous acid	chorite	ClO_2^-
$HClO_3$	chloric acid	chlorate	ClO_3^-
$H_2C_2H_3O_2$	acetic acid	acetate	$C_2H_3O_2^-$
H_2CO_3	carbonic acid	carbonate	CO_3^{2-}

© 2012 Pearson Education, Inc.



Ionic
Metal and nonmetal
Molecular
Nonmetals only
Acids*
H and one or more nonmetals
Metal forms one type of ion only
Metal forms more than one type of ion
Binary
Two-element
Oxyacids
Contain oxygen
-ite
-ate
name of cation (metal)
base name of anion (nonmetal) + -ide
Example: CaI_2
calcium iodide
prefix
name of 1st element
prefix
base name of 2nd element + -ide
Example: P_2O_5
diphosphorus pentoxide
base name of oxyanion + -ic
acid
Example: H_3PO_4
phosphoric acid
name of cation (metal)
charge of cation (metal) in roman numerals in parentheses
base name of anion (nonmetal) + -ide
Example: $FeCl_3$
iron(III) chloride
hydro
base name of nonmetal + -ic
acid
Example: HCl
hydrochloric acid
base name of oxyanion + -ous
acid
Example: H_2SO_3
sulfurous acid
* Acids must be in aqueous solution.
© 2012 Pearson Education, Inc.

EXAMPLE 5.14 Nomenclature Using the Flowchart

Formula	Flowchart Path	Name
CO	molecular	carbon monoxide
CaF_2	ionic ⟶ one type of ion ⟶	calcium fluoride
$HF(aq)$	acid ⟶ binary ⟶	hydrofluoric acid
$Fe(NO_3)_3$	ionic ⟶ more than one type of ion ⟶	iron(III) nitrate
$HClO_4\ (aq)$	acid ⟶ oxyacid ⟶ *-ate* ⟶	perchloric acid
$H_2SO_3\ (aq)$	acid ⟶ oxyacid ⟶ *-ite* ⟶	sulfurous acid

Chemistry in the Environment: **Acid Rain**

- **Acid rain occurs when rainwater mixes with air pollutants —such as NO, NO_2, and SO_2—that form acids.**

- **NO and NO_2, primarily from vehicular emission, combine with water to form $HNO_3(aq)$.**
- **SO_2, primarily from coal-powered electricity generation, combines with water and oxygen in air to form $H_2SO_4(aq)$.**

- **$HNO_3(aq)$ and $H_2SO_4(aq)$ both cause rainwater to become acidic.**

- **When acid rain flows into lakes and streams, some species of aquatic animals cannot tolerate the increased acidity and die.**
- **Acid rain weakens trees by dissolving nutrients in the soil and by damaging their leaves.**
- **Acid rain also damages building materials.**

5.11 Formula Mass:
The Mass of a Molecule or Formula Unit

- For any compound, the **formula mass** is the **sum of the atomic masses** of all the atoms in its chemical formula:

$$\text{Formula mass} = \left(\text{\# atoms of 1st element in chemical formula} \times \text{Atomic mass of 1st element}\right) + \left(\text{\# atoms of 2nd element in chemical formula} \times \text{Atomic mass of 2nd element}\right) + \ldots$$

© 2012 Pearson Education, Inc.

Chapter 5 in Review

Chemical principles:

- **Compounds** display constant composition. The elements that compose a particular compound are in fixed, definite proportions in all samples of the compound.
- **Chemical formulas** indicate the elements present in the compound and the relative number of atoms of each. These formulas represent the basic units that compose a compound.
- **Chemical nomenclature:** The names of simple ionic compounds, molecular compounds, and acids can all be written by examining their chemical formula.
- **Formula mass** of a compound is the sum of the atomic masses of all the atoms in the chemical formula for the compound.

Chemical Skills

- Verifying constant composition of compounds with calculations
- Writing chemical formulas
- Finding total number of each type of atom in a chemical formula
- Classifying elements as atomic or molecular
- Classifying compounds as ionic or molecular
- Writing formulas for ionic compounds
- Naming binary ionic compounds containing a metal that forms only one type of ion
- Naming binary ionic compounds containing a metal that forms more than one type of ion
- Naming compounds containing a polyatomic ion
- Naming molecular compounds
- Naming binary acids
- Naming oxyacids with an oxyanion ending in *–ate*
- Naming oxyacids with an oxyanion ending in *–ite*
- Calculating formula mass