Memorize Tables: 3.2 - 3.4

Chapter Goals

- ✓ *Know different types of formulas*
- ✓ *Differentiate between ionic and molecular compounds.*
- ✓ *Give formulas and names of common polyatomic ions, ionic compounds, binary molecular compounds, common acids and some organic compounds.*
- ✓ *Calculate the molar mass of a molecule from its chemical formula and a table of atomic masses and how to convert the mass of a molecular substance to moles, number of particles,*
- ✓ *Determine the percent composition and empirical formula of a compound.*
- ✓ *Use elemental and combustion analysis data to obtain the empirical formula and the molecular formula of a compound.*
- ✓ *Write and balance chemical equations for simple chemical reactions.*

❖ **When two or more elements combine to form a compound, an entirely new substance results (e.g water)**

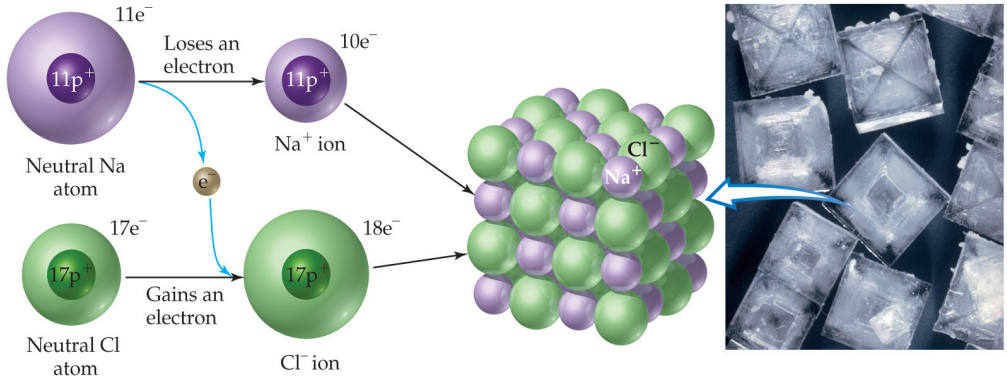
- ➢ In a mixture, elements can mix in any proportions whatsoever (hydrogen, H_2, and oxygen, O_2). A hydrogen–oxygen mixture can have any proportions of hydrogen and oxygen gas.
- ➢ In a compound, elements combine in fixed, **definite proportions** for example
  Water is composed of water molecules that always contain two hydrogen atoms to every one oxygen atom.
- Water has a definite proportion of hydrogen to oxygen.

Compounds are composed of atoms held together by Chemical Bonds

- Chemical bonds are classified into two types:
  - Ionic = Cation (+ve) + Anions (-ve) (**electron transfer**)
  - Covalent = nonmetal + nonmetal (**electrons sharing**)

Ionic compounds (such as NaCl) are ***generally formed*** between metal (Na) and nonmetal (Cl)

- **involve the *transfer* of electrons from one atom to another.**



- ✓ Ionic compounds form **formula unit (neutral)**
- ✓ **Total charge on cation + total anion charge = 0.**

- **To be able to name chemical compounds you have to memorize the following tables (3.2-3.4)**

TABLE 3.2 Some Common Monoatomic 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
Phosphorus	P^{3-}	phosph	Phosphide

TABLE 3.3 Some Metals That Form Cations with Different Charges

Metal	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. Additionally, the suffix *-ous* indicates the ion with the lesser charge, and *-ic* indicates the ion with the greater charge. We will *not* use the older system in this text.

*Polyatomic ions : are composed of a group of **covalently bonded** atoms with an overall charge.

TABLE 3.4 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^-
Nitrite	NO_2^-	Permanganate	MnO_4^-
Nitrate	NO_3^-	Sulfite	SO_3^{2-}
Chromate	CrO_4^{2-}	Hydrogen sulfite (or bisulfite)	HSO_3^-
Dichromate	$Cr_2O_7^{2-}$	Sulfate	SO_4^{2-}
Phosphate	PO_4^{3-}	Hydrogen sulfate (or bisulfate)	HSO_4^-
Hydrogen phosphate	HPO_4^{2-}	Cyanide	CN^-
Dihydrogen phosphate	$H_2PO_4^-$	Peroxide	O_2^{2-}
Ammonium	NH_4^+		

Writing Ionic Compound Formulas

- ✓ Ionic compounds are made of positive and negative ions. There are **six** different combinations:

Positive ions **Negative ions**

I. Main group metal cation Main group anion (nonmetals)

- *Binary Ionic Compounds*

Calcium chloride

Magnesium nitride

Aluminum sulfide

II. Main group metal cation Polyatomic ion* (e.g. CO_3^{2-}, PO_4^{3-})

Magnesium carbonate

Aluminum phosphate

III. Polyatomic cation (H_3O^+, NH_4^+) Main group anion

Ammonium chloride

IV. Polyatomic cation(NH_4^+) Polyatomic ion(e.g. CO_3^{2-}, PO_4^{3-})

Ammonium phosphate

V. Transition metal cation Main group anion (nonmetals)

Tin(II)chloride

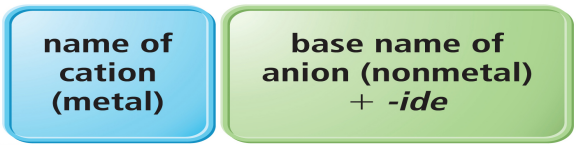
Lead (IV) bromide

VI. Transition metal cation Polyatomic ion (CO_3^{2-}, PO_4^{3-})

Iron (II) nitrite

Copper(I) Sulfate

Naming Binary Ionic Compounds with main group metals



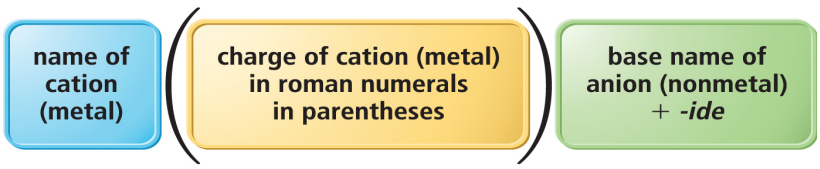
NaBr Sodium Bromide

Ca_3N_2 Calcium nitride

Naming Ionic Compounds Containing Polyatomic Ions
$NaNO_3$ Sodium Nitrate
$Mg(NO_2)_2$ Magnesium Nitrite

- ✓ **Naming Ionic Compounds with transition metal:**

The charge of the metal cation can be determined by inference from the sum of the charges of the nonmetal



Old system

$CrBr_3$ Chromium(III) Bromide

Fe_2S_3 Iron(III) Sulfide

- ✓ **Patterns in Oxyanion Nomenclature**

- 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^- *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*

- Polyatomic anions containing oxygen with additional hydrogens are named by adding
- ✓ **hydrogen or bi- (one H), ,** to the name as follows:
  - CO_3^{2-} Carbonate HCO^- Bicarbonate OR Hydrogen carbon
  - PO_4^{3-} Phosphate HPO_4^{2-} Biphosphate OR hydrogen phosphate

- ✓ **dihydrogen (two H)**

❖ **Hydrates** are ionic compounds containing a specific number of water molecules associated with each formula unit.

$MgSO_4 \cdot 7H_2O$ Magnesium sulfate hepta hydrate

$CoCl_2 \cdot 6H_2O$ Cobalt (II) chloride hexa hydrate

✓ ***Covalent bonds*** occur between two or more nonmetals. Or a a metalloid and a nonmetal. The two atoms ***share*** **electrons between them**, composing a ***molecule.***

Covalently bonded compounds are also called **molecular compounds**.

- Generally, write the name of the element with the smallest group number first (closer to the metals
- If the two elements lie in the same group, then write the element with the greatest row number first.
- The prefixes given to each element indicate the number of atoms present.
- These prefixes are the same as those used in naming hydrates:

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

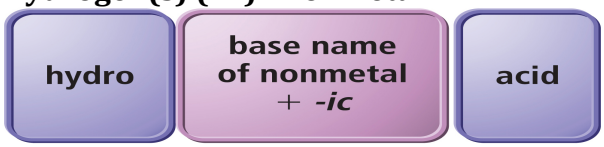
- If there is only one atom of the *first element* in the formula, the prefix *mono-* is normally omitted.

NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
N_2O_3	Dinitrogen trioxide
N_2O_4	Dinitrogen tetroxide

- The basic units of molecular compounds are **molecules** composed of the constituent atoms.

➢ Acids are **molecular compounds** that release hydrogen ions (H^+) when dissolved in water.
➢ Acids are composed of hydrogen, usually written first in their formulas, and one or more nonmetals, written second.

Naming Binary Acids
Hydrogen(s) (H^+)+ nonmetal



HCl(aq) Hydrochloric acid
HF Hydrofluoric acid

Naming Oxyacids

oxyanions ending with *–ate*

H_2SO_4

HNO_3

oxyanions ending with *-ite*

HNO_2

Acid Rain:

- Certain pollutants, such as NO, NO_2, SO_2, and SO_3, form acids when mixed with water, resulting in acidic rainwater.
- Acid rain can fall or flow into lakes and streams, making these bodies of water more acidic.

Modern Organic Compounds:

- The key element of organic chemistry is **carbon**.
- Organic compounds are mainly made of C and H, sometimes with O, N, P, S, and trace amounts of other elements.
- **Hydrocarbons** are organic compounds that contain only carbon and hydrogen.

- Hydrocarbons containing only single bonds are called **alkanes**.
- Hydrocarbons containing double Bonds are **alkenes**
- Hydrocarbons containing triple bonds are **alkynes**
- Hydrocarbons consist of a base name and a suffix.
  - alkane (*-ane*)
  - alkene (*-ene*)
  - alkyne (*-yne*)
- The base names for a number of hydrocarbons are listed here:

1 meth-	6 hex-
2 eth-	7 hept-
3 prop-	8 oct-
4 but-	9 non-
5 pent-	10 dec-

Organic Acids:

Acetic Acid CH_3CO_2H

Oxalic Acid $C_2O_4H_2$

Organic polyatomic ions:

Acetate : $CH_3CO_2^{-1}$

Oxalate: $C_2O_4^{-2}$

Inorganic Nomenclature Flow Chart

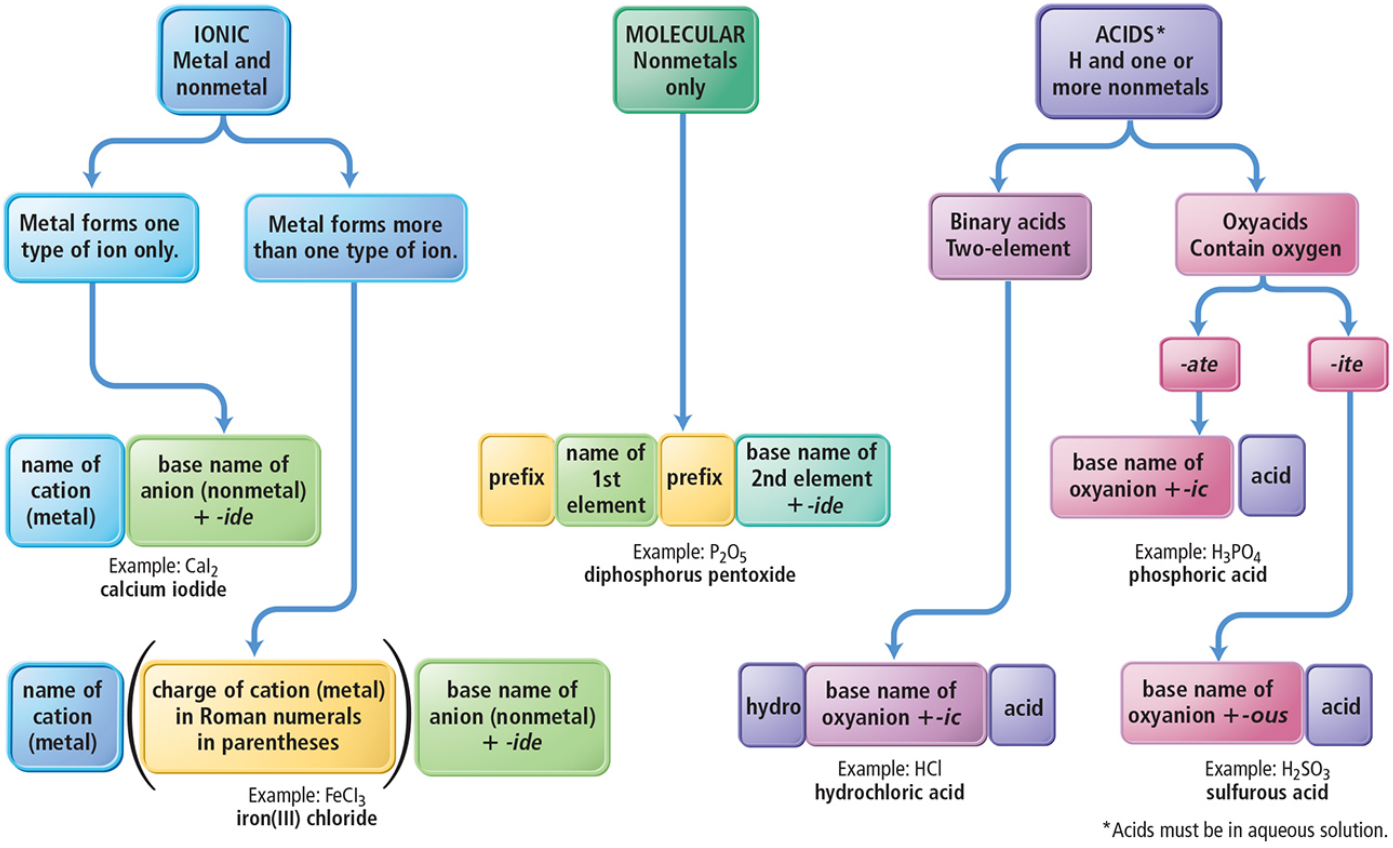
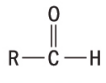
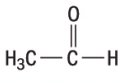
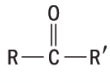
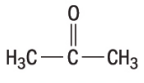
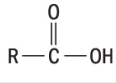
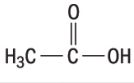
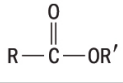
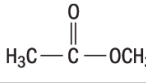
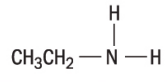


TABLE 3.8 Families of Organic Compounds

Family	Name Ending	General Formula	Example	Name	Occurrence/Use
Alcohols	-ol	R—OH	CH_3CH_2—OH	Ethanol (ethyl alcohol)	Alcohol in fermented beverages
Ethers	ether	R—O—R′	CH_3CH_2—O—CH_2CH_3	Diethyl ether	Anesthetic; laboratory solvent
Aldehydes	-al			Ethanal (acetaldehyde)	Perfumes; flavors
Ketones	-one			Propanone (acetone)	Fingernail polish remover
Carboxylic acids	acid			Acetic acid	Vinegar
Esters	-ate			Methyl acetate	Laboratory solvent
Amines	amine	RNH_2		Ethyl amine	Smell of rotten fish

- **Chemical formula indicates the elements present in the compound and the relative number of atoms or ions of each.**

Types of Formulas:

- **Molecular formula**: gives the *actual* number of atoms of each element in the molecule of a compound.

- **Empirical formula**: gives the lowest whole number ratio of atoms in a compound.

✓ **Molecular Formula is a whole-number multiple of the empirical formula.**

- **Molecular formula = (empirical formula)*n*,**
- ***where n is a positive integer.***

$$n = \frac{\textit{Molar mass of the compound}}{\textbf{Molar mass of the Empirical formula}}$$

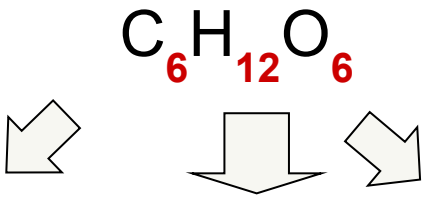
Molecular Formula: H_2O H_2O_2 $C_6H_{12}O_6$ $C_{12}H_{22}O_{11}$

Empirical Formula:

- **Structural formula** uses lines to represent covalent bonds and shows how atoms in a molecule are connected or bonded to each other.
- It can also show the molecule's geometry
  **Molecular Models: will be used in chapter 9*

The **subscripts in a formula** show

- the relationship of atoms in the formula.
- the moles of each element in 1 mole of compound.



6 atoms C 12 atoms H 6 atoms O
6 mole C **12 mole H** **6 mole O**

- Formula for glycine is $C_2H_5NO_2$
  In one molecule there are
  - 2 C atoms or 2 moles C
  - 5 H atoms or 5 moles H
  - 1 N atom or 1 mole N
  - 2 O atoms or 2moles O

✓ A mole of a covalent compound has Avogadro's number of molecules.

1 mole CO_2 = 6.02 x 10^{23} CO_2 molecules
1 mole H_2O = 6.02 x 10^{23} H_2O molecules

✓ A mole of an ionic compound contains Avogadro's number of formula units.

1 mole NaCl = 6.02 x 10^{23} NaCl formula units

1 mole K_2SO_4 = 6.02 x 10^{23} K_2SO_4 formula units

How many potassium ions are in 2.50 moles K_2SO_4

Formula Mass:

- The mass of an individual molecule or formula unit

Formula mass= molecular mass =molecular weight

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

formula mass of 1 molecule of H_2O =

2(1.01 **amu** H) + 16.00 **amu** O = 18.02 **amu**

Molar Mass of Compounds:

- *The molar mass of a compound*—the mass, in **grams**, of **1 mol** of its molecules or formula units—is numerically equivalent to its formula mass with units of **g/mol.**

Molar mass = 1 mole H_2O

= 2mol(1.01 g/1 mol H) + 1mol(16.00 g/1 mol O)

= 18.02 g/1 mol H_2O

- Molar mass = formula mass (in g/mole)

Using Molar Mass to Count Molecules by Weighing: use Avogadro's #

If the odor of $C_6H_{10}S$ can be detected from 2 x 10^{-13} g in one liter of air, how many molecules of $C_6H_{10}S$ are present?

How many H_2O molecules are in 24.0 g H_2O?

Composition of Compounds:

- Percentage by mass of each element in a compound. Can be determined from
  1. the formula of the compound and
  2. the experimental **mass analysis** of the compound.

The percentages may not always total to 100% due to rounding

Formula of the compound

$$\%\ \text{element} = \frac{\left[\begin{array}{c}\text{number of atoms}\\ \text{of element}\end{array}\right]\left[\begin{array}{c}\text{atomic mass}\\ \text{of element}\end{array}\right]}{(\text{Molar mass of the compound})} \times 100$$

Calculate the percentage composition of Sodium carbonate, Na_2CO_3?
Molar mass=

%Na

%C

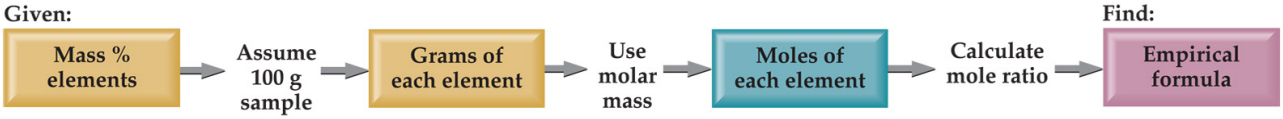
%O

What is the percentage of carbon in ethane $\mathbf{C_2H_6}$

Determining a Chemical Formula from Experimental Data:

A. From elemental analysis, Percent composition

- **Empirical Formula**: Simplest, whole-number ratio of the atoms or moles of elements in a compound, ***not a ratio of masses***



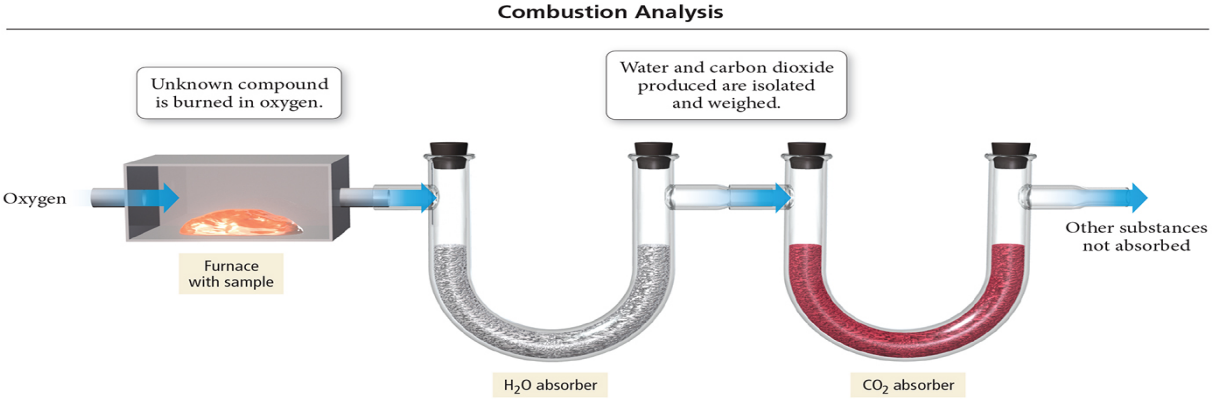
The compound *para*-aminobenzoic acid (you may have seen it listed as PABA on your bottle of sunscreen) is composed of carbon (61.31%), hydrogen (5.14%), nitrogen (10.21%), and oxygen (23.33%). Find the empirical formula of PABA.

Adipic acid contains 49.32% C, 43.84% O, and 6.85% H by mass.

A. What is the empirical formula of adipic acid?

B. What is the Molecular formula of adipic acid if the molar mass is 146.14 g/mol

B. Combustion Analysis:



- By knowing the mass of the products and composition of constituent element in the product, the original amount of constituent element can be determined.

– **All the original C forms CO_2, the original H forms H_2O, and the original mass of O is found by subtraction**.

Caproic acid is a foul-smelling acid that is composed of **C, H and O** atoms. Combustion of a 3. 375 g sample of this compound produces 7.680 g CO_2 and 3.135 g H_2O.

Determine the empirical formula of this compound.

Burn 0.115 g of a hydrocarbon, C_xH_y, and produce 0.379 g of CO_2 and 0.1035 g of H_2O.

C_xH_y + some oxygen **CO_2 + H_2O**. What is the empirical formula of C_xH_y?

Chemical Equations

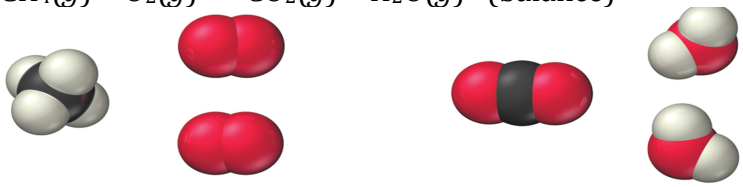
A chemical equation gives the chemical formulas of the reactants on the left of the arrow and the products on the right.

Table 8.3 Some Symbols Used in Writing Equations

Symbol	Meaning
+	Separates two or more formulas
⟶	Reacts to form products
Δ	The reactants are heated
(*s*)	Solid
(*l*)	Liquid
(*g*)	Gas
(*aq*)	Aqueous

Combustion of Methane:

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$ (balance)



Write a **balanced** Chemical for the reaction of solid aluminum and oxygen gas to form solid aluminum oxide.

Write a **balanced** Chemical for the reaction between aqueous strontium chloride and aqueous lithium phosphate to form solid strontium phosphate and aqueous lithium chloride.

What coefficients are needed to complete the balancing of the following equation:

$$Pb(NO_3)_{2\,(aq)} + Na_3PO_{4\,aq} \rightarrow Pb_3(PO_4)_{2\,(s)} + NaNO_{3\,(aq)}.$$

HOMEWORK

Determine the empirical and molecular formula of each of the following:

1. Ethylene glycol, the substance used as antifreeze has 38.70 % C, 9.70 % H and 51.60 % O , mm= 62.10 g/mol

Empirical formula CH_3O Molecular formula $C_2H_6O_2$

2. Caffeine, a stimulant in coffee has the following percent composition:

49.50 % C, 5.15% H, 28.90 % N and 16.50 % O , molar mass= 195.00g/mol

Empirical formula $C_4H_5N_2O$ Molecular formula $C_8H_{10}N_4O_2$