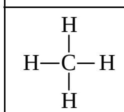
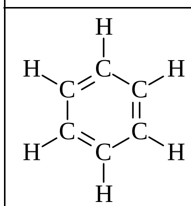
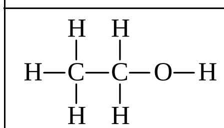
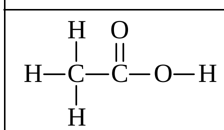
3.1 Molecular Compounds (p. 78)
A **molecule** is a group of two or more atoms held together in a definite spatial arrangement by forces called _______________ bonds.

For our studies we will define a molecule as a compound composed of only ___________________.

A **molecular formula** is a symbolic representation of the composition of a compound in terms of its constituent elements (e.g., B_2O_3, NH_3, H_2O, CH_4, C_6H_{14}, $HC_2H_3O_2$, $C_6H_{12}O_6$). The **molecular formula** is the actual number of atoms in a molecule represented by whole number ratio. The **empirical formula** is the simplest formula that can be written for a compound from the molecular formula. The molecular formula for glucose can be written as $C_6H_{12}O_6$. The empirical formula is ______________.

Sometimes the empirical formula and the empirical formula are the same, as in the case for water (H_2O) or for the hydrocarbon pentane (C_5H_{12}).

A **structural formula** is a chemical formula that shows how atoms are attached to one another.

Structural Formula	**Molecular Formula**	**Empirical Formula**
H—O—H		
H—O—O—H		
		
		
		
		

3.2 Naming Binary Molecular Compounds (p. 81)
A **binary molecule** is a compound of only two elements.

1. Element to the left in the period named first. HCl: hydrogen named first
2. The element in the period below named first. BrCl: bromine is named first.
3. The other element is named with -ide ending.

HCl _______________ _________________ **BrCl** _______________ ________________

4. When two nonmetals form more than one compound, prefixes are used.

Table 3.2, p. 81

Number	**one**	**two**	**three**	**four**	**five**	**six**	**seven**	**eight**	**nine**	**ten**
Prefix	**mono-**	**di-**	**tri-**	**tetra-**	**penta-**	**hexa-**	**hepta-**	**octa-**	**nona-**	**deca-**

Name or give formulas for the following binary covalent compounds.

NO	
N_2O	
NO_2	
N_2O_3	
N_2O_4	

Dintrogen pentoxide	
Phosphorus pentachloride	
Diphosphorus pentoxide	
Sulfur hexafluoride	
Dichlorine heptoxide	

~~3.3 Hydrocarbons~~
~~3.4 Alkanes and Their Isomers~~
We will skip the sections 3.3 and 3.4.

3.5 Ions and Ionic Compounds (p. 88)
An **ionic compound** is a compound composed of ions. Ionic compounds are also call **ionic solids** or in some cases **salts**.

For our studies we will define a salt (ionic compound) as a compound composed of a ___________ and a _________________.

An **ion** is an electrically charged particle obtained from an atom or chemically bonded group of atoms by adding or removing _________________.

There are two types of ions: ____________, which are positively charged, and ____________, which are negatively charged.

When metals react with nonmetals, the metal atoms typically ________ electrons and acquire a ___________ charge.

On the other hand the nonmetals typically ________ electrons and acquire a _____________ charge.

Ionic compounds are _____________________ neutral. That is to say, the total positive charge contributed by the cation is cancelled by the total negative charge contributed by the anion.

Cation charge = number of electrons lost. Group 1 metals ***always*** lose one electron. Na^{1+} Group 2 metals ***always*** lose two electrons. Ca^{2+} Aluminum ***always*** loses three electrons. Al^{3+}	**Anion charge** = number of electrons gained. In binary ionic compounds, Group 15 (5A) elements ***typically*** can gain 3 electrons. N^{3-} In binary ionic compounds, Group 16 (6A) elements ***typically*** can gain 2 electrons. O^{2-} In binary ionic compounds, Group 17 (7A) elements (halogens) ***typically*** can gain 1 electron. Cl^{1-}

NOTE: The nonmetals in Groups 5A, 6A, and 7A commonly form **monatomic** anions that have a negative charge usually equal to 8 minus the A group number.
Examples: Chlorine can form the chloride anion, Cl^{1-}. 7 – 8 = -1
Sulfur can form the sulfide anion, S^{2-}. 6 – 8 = -2
Phosphorus can form the phosphide anion, P^{3-}. 5 – 8 = -3

Polyatomic Ions (p. 90)
A **polyatomic ion** is an electrically charged collection of two or more atoms.

Polyatomic ions can be understood as charged molecules composed of covalently bonded atoms that can be considered as acting as a single unit in the makeup of the ionic compound.

Polyatomic Ions Table 3.7, p. 91

Cation (1+)			
NH_4^{1+}	Ammonium		
Anion (1-)			
OH^{1-}	Hydroxide	NO_2^{1-}	Nitrite
HSO_4^{1-}	Hydrogen sulfate (or bisulfate)	NO_3^{1-}	Nitrate
$C_2H_3O_2^{1-}$	Acetate	MnO_4^{1-}	Permanganate
ClO^{1-}	Hypochlorite	$H_2PO_4^{1-}$	Dihydrogen phosphate
ClO_2^{1-}	Chlorite	CN^{1-}	Cyanide
ClO_3^{1-}	Chlorate	HCO_3^{1-}	Hydrogen carbonate (or bicarbonate)
ClO_4^{1-}	Perchlorate		
Anion (2-)			
CO_3^{2-}	Carbonate	SO_3^{2-}	Sulfite
HPO_4^{2-}	Hydrogen phosphate	SO_4^{2-}	Sulfate
$Cr_2O_7^{2-}$	Dichromate	$C_2O_4^{2-}$	Oxalate
$S_2O_3^{2-}$	Thiosulfate		
Anion (3-)			
PO_4^{3-}	Phosphate		

NOTE: The textbook shows the acetate anion as CH_3COO^-. I will refer to the acetate anion as $C_2H_3O_2^-$. This is a condensed formula.	$H-\overset{H}{\underset{H}{C}}-\overset{O}{\overset{\|}{C}}-O^- = CH_3COO^- = C_2H_3O_2^-$

Writing Formulas for Ionic Compounds (p. 92)
Compounds are electrically neutral. Therefore, the total positive charge contributed by the cation will equal the total charge contributed by the anion.

Note: The chemical formula for an ionic solid is referred to as a **formula unit.** It is the group of atoms or ions explicitly symbolized in the formula. The chemical formula for an ionic compound will always be expressed in the form of an empirical formula.

Give the chemical formula of the compounds composed of the following ion pairs.

Combining Ions	Chemical Formula
Na^{1+} and O^{2-}	
Ca^{2+} and Cl^{1-}	
Al^{3+} and P^{3-}	

Combining Ions	Chemical Formula
Magnesium ion and nitrate ion	
Potassium ion and phosphate ion	
Barium ion and acetate ion	

3.6 Naming Ions and Ionic Compounds (p. 94)
Note: There are two common types of cations: **Type I and Type II.**
Type I cations exhibit only one type of charge.
Cations formed from Group 1A metals all adopt a charge of 1+ (e.g., Na^{1+}, K^{1+}).
Cations formed from Group 2A metals all adopt a charge of 2+ (e.g., Ca^{2+}, Ba^{2+}).
Aluminum always forms a cation with a 3+ charge (Al^{3+}).
Type II cations can adopt more than one type of charge (e.g., Fe^{2+} or Fe^{3+}; Cu^{1+} or Cu^{2+}).
Type II cations are most often formed from the transition metals. See Figure 3.2 p. 89.

Naming Ionic Compounds with Type I Cations

1. Cation named first and anion named last.
2. Metal takes its name from the element.
3. Anion is named by taking the first part of the elements name and adding "ide".

Name the following.

KF	MgS	LiH	Al_2O_3	Na_2SO_4

Give formulas for the following.

Barium oxalate	Ammonium nitrate	Cesium acetate	Sodium phosphate

Calcium perchlorate	Aluminum hydroxide	Strontium carbonate

Naming Ionic Compounds with Type II Cations

1. Cation named first and anion named last.

2. Metal takes its name from the element, but immediately following the metal a Roman numeral is used to indicate the charge. Parentheses are used to enclose the Roman numeral. There is no space between the metal and the opening parenthesis. There is a space between the closing parenthesis and the anion name.

3. Anion is named by taking the first part of the elements name and adding "ide".

NOTE: To determine the charge of a type II cation, set up an algebraic equation with the product of the metal cation's subscript and unknown charge (X) added to the product of the anion's subscript and charge, all being equal to zero. Solving for X will give the charge of the cation and hence the value for the Roman numeral in the name.

Example

What is the name of $Co_3(PO_4)_2$?	(3)(X) + (2)(-3) = 0 Solving for X gives a value of +2. The name of $Co_3(PO_4)_2$ is Cobalt(II) phosphate.

Name or give the formula for the following.

Formula	Name
$FeCl_2$	
$FeCl_3$	
CrO	
Cr_2O_3	
CrO_3	
	copper(II) sulfide
	niobium(V) oxide

3.7 Properties of Ionic Compounds (p. 97)
A **crystal lattice** is the ordered array of cations and anions that make up an ionic compound. This type of arrangement maximizes the attractions and minimized the repulsion. Each cation is surrounded by anions and each anion is surrounded by cations.

The crystal lattice gives rise to two characteristics properties of ionic solids.

1) ____ 2) ____

The formula of an ionic compound is given in the smallest whole-number ration of the number of cations to the number of anions. This type of formula is referred to as a **formula unit** is the group of atoms or ions explicitly symbolized in the formula. The formula unit is "hypothetical", because it does not exist as separate entity outside the crystal lattice.

Cleavage along definite lines results from layer shifting and bringing like charges in close proximity. The repulsion causes the crystal to split along definite lines. When ionic solids melt, then they can conduct electricity because the ions can then move freely.

Ionic Compounds in Aqueous Solution: Electrolytes (p. 99)
Electric current is the flow of charged particles. Metals conduct electricity. In solid and liquid metals, the charged particles that flow are **electrons.**

Molten (liquid) ionic compounds and **aqueous solutions of ionic compounds** are also good electrical conductors, but in these cases the charged particles that flow are **ions**. Ionic compounds that dissolve in water _________________, that is, the cations and anions separate.

Michael Faraday (1791-1867) did much of the early work on the conduction of electricity through aqueous solutions. He coined the following terms:
Electrode - electrical conductors (wires or plates) partially immersed in a solution and connected to a source of electricity.
Anode – the electrode connected to the ***positive*** pole of the source of electricity.
Cathode - the electrode connected to the ***negative*** pole of the source of electricity.
Ion - a carrier of electricity through a solution. *(Ion* is derived from Greek and means "wanderer.")
Anion - negatively charged ions (-) are attracted to the anode (+).
Cation - positively charged ions (+) are attracted to the cathode (-).

In 1884, Svante Arrhenius presented the concept of dissociation of ionic species in aqueous solution. His idea is now referred to as the **Theory of Electrolytic Dissociation**. An **electrolyte** is a substance that conducts electricity when dissolved in water. A **nonelectrolyte** is a substance that does not conduct an observable amount of electricity when dissolved in water.

3.8 Moles of Compounds (p. 100)
The **molar mass** of a compound is the sum of the atomic weights of the atoms in a molecule of the substance.
For molecules, the molar mass is referred to as **molecular weight**. For ionic compounds the molar mass is commonly referred to as the **formula weight.**

Calculate the molar mass of each of the following.

sodium nitrate [85.00]	dinitrogen tetroxide [92.02 g/mol]	$Fe(NH_4)_3(C_2O_4)_3$ [374.06 g/mol]

#1 What is the mass of 3.500 moles of sodium nitrate? [297.5 g]

#2 How many moles are in 50.00 g of dinitrogen tetroxide? [0.5434 mol]

#3 How many molecules are in 50.00 g of dinitrogen tetroxide? [3.272×10^{23}]

#4 How many atoms of oxygen are in 1.00 g of ferric ammonium oxalate, $Fe(NH_4)_3(C_2O_4)_3$? [1.93×10^{22}]

3.9 Percent Composition (p. 104)

The **mass percent composition** of a compound is the proportion of the constituent elements in a compound expressed as the number of grams of each element per 100 g of the compound. Note that percent composition is a number without units.

$$\text{Percent composition} = \frac{\text{mass of atom A}}{\text{total mass of sample}} \times 100$$

Percent Composition Problem #1
What is the percent composition of each element in sulfuric acid?

Percent Composition Problem #2
Which has a higher oxygen content, water or hydrogen peroxide?

Percent Composition Problem #3
How many grams of oxygen are there in 36.45 g of hydrogen peroxide? Hydrogen peroxide is 94.06% oxygen.

Percent Composition Problem #4
Rank the following by percent carbon by mass. CH_3Cl CH_2Cl_2 $CHCl_3$ CCl_4

3.10 Determining Empirical and Molecular Formulas (p. 106)

Empirical formula is the formula of a substance written with the smallest integer (whole number) subscripts. Empirical formula shows the simplest whole-number ratio of each element in a molecule. The chemical formula of ionic compounds is always written in the form of an empirical formula.

Converting % Composition to an Empirical Formula

Step 1 Convert the percent of each element to a mass.
Step 2 Convert the mass of each element to an amount in moles.
Step 3 Use the number of moles of the elements as subscripts in a tentative formula.
Step 4 Attempt to get integers as subscripts by dividing each of the subscripts by the smallest subscript.
Step 5 If any subscripts obtained after Step 4 are fractional quantities, multiply each of the subscripts by the smallest integer that will convert all the subscripts to integers. The result is an empirical formula.

Empirical Formula Problem #1
Benzene is a hydrocarbon composed of only carbon and hydrogen. Elemental analysis of a sample of benzene revealed that it is composed of 92.2% carbon by mass. What is the empirical formula of benzene?

Empirical Formula Problem #2
A compound contains only nitrogen and oxygen and is 30.4% N by mass. Calculate the empirical formula.

Empirical Formula Problem #3
What is the empirical formula of a hydrocarbon with 83.63% C and 16.38% H?

Empirical Formula Problem #4
An oxide of aluminum is 52.91% Al. Calculate the empirical formula.

NOTE: The molecular formula is a multiple of the empirical formula. The number of empirical formula units in the molecular formula can be determined by dividing the molar mass by the empirical formula mass.

$$\frac{\textbf{Molar Mass}}{\textbf{Empirical Formula Mass}} = \mathbf{n}$$

n = number of empirical formula units in the molecular formula

Molecular Formula Problem #1
What is the molecular formula of benzene if the molar mass is 78.12g/mol and the empirical formula is CH?

Molecular Formula Problem #2
Nicotine is 74.03% C, 8.70% H, and 17.27% N. If the molecular weight of nicotine is found to be 162.26, what is the molecular formula?