Chem 1045 **Chemistry & Chemical Reactivity**
Lecture Notes **Kotz/Treichel/Townsend, 8th Ed**

These Notes are to SUPPLEMENT the Text, They do NOT Replace reading the Text Material. Additional material that is in the Text will be on your tests! To get the most information, READ THE CHAPTER prior to the Lecture, bring in these lecture notes and make comments on these notes. These notes alone are NOT enough to pass any test! The author is not responsible for typos in these notes.

Chapter 2, Atoms Molecules and Ions

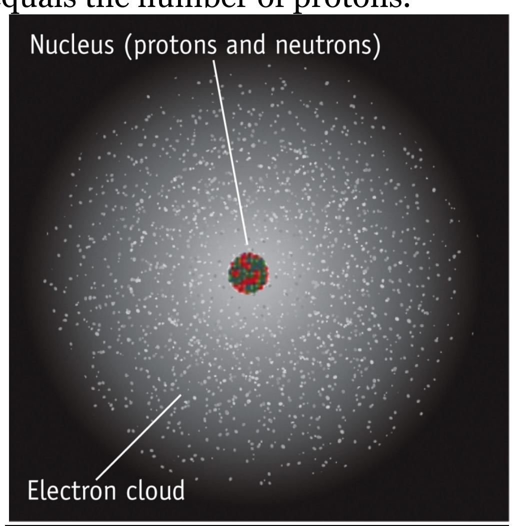
Memorize: Table 2.4 Polyatomic Naming

Periodic Table: Dmitri Mendeleev set up the 1st periodic table in 1870 based on the periodicity of the chemistry of the elements. Elements were placed in the table based on their atomic weight. He noted elements in rows had similar properties. He left empty spaces for elements that he did not know about, but calculated would occupy a spot based on atomic weight.

2.1 Atomic Structure

Rutherford's (1871-19370 model of the atom basis of modern atomic theory:

- Atoms are made of subatomic particles – Protons, Neutrons, Electrons.
- The larger Protons and Neutrons are in the center of a very small nucleus, the smaller electron surrounds the nucleus.
- The center of the atom is positively charged, the outside negatively.
- The number of electrons equals the number of protons.



2.2 Atomic Number & Mass John Dalton, beginning of 19th century, suggested the elements involve atoms and proposed a relative scale based on atom mass – The Periodic Table, Hydrogen = 1
The current standard is Carbon 12. 6.023×10^{23} atoms of ^{12}C weight 12.00 g

All atoms of a given element have the same number of protons in the nucleus

Atomic Mass Unit	=	**u**	= 1/12 the mass of ^{12}C 1 amu = 1.661×10^{-24} g
Mass Number	=	**A**	= number of protons and neutrons in the nucleus
Atomic Number	=	**Z**	= number of protons in the nucleus
Atomic Weight	=		= the average mass of a representative sample

Mass number → $^{A}_{Z}X$ ← Element symbol
Atomic number →

Do Some Examples (see the periodic table): H, He, Na 11 protons, 12 neutrons, U 238 = 92 protons, 146 neutrons, Iron with 30 neutrons, Ni with 32 neutrons.
Discuss ^{64}Zn. What has 12 neutrons and A = 23?

Table 2.1 Properties of Subatomic Particles*

Particle	Mass: *Grams*	Mass: *Atomic Mass Units*	Charge	Symbol
Electron	9.109383×10^{-28}	0.0005485799	1−	$_{-1}^{0}e$ or e^-
Proton	1.672622×10^{-24}	1.007276	1+	$_{1}^{1}p$ or p^+
Neutron	1.674927×10^{-24}	1.008665	0	$_{0}^{1}n$ or n

*These values and others in the book are taken from the National Institute of Standards and Technology website at http://physics.nist.gov/cuu/Constants/index.html

Example 2.1 Atomic Composition.
What is the composition of an atom of phosphorus with 16 neutrons?
What Is its mass number?
What is the symbol for such an atom?
What is the mass of this phosphorous atom related to the mass of a carbon atom with a mass number of 12?

2.3 Isotopes are atoms with the same atomic number and different mass numbers. They differ by the number of neutrons. ^{10}B = 5 protons, 5 neutrons, 5 electrons
^{11}B = 5 protons, 6 neutrons, 5 electrons

U 238 vs U 235. $^{1}_{1}$H = Hydrogen, $^{2}_{1}$H = Deuterium (D) or heavy water, $^{3}_{1}$H = Tritium (T)

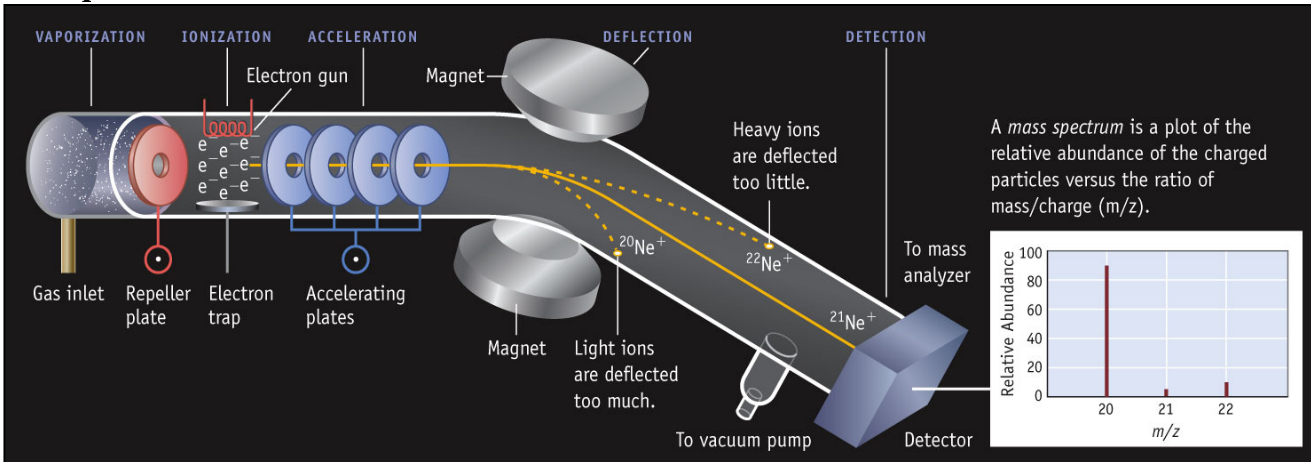
What are the p,n,e- count for ^{12}C and ^{14}C (Radioactive carbon)

Isotope Abundance: Water or H2O has 99.985% $^{1}_{1}$H and 0.015% $^{2}_{1}$H

% Abundance = 100% * # atoms of a given isotope / total number of atoms of all isotopes

Boron has ^{10}B 19.91% and ^{11}B of 80.09% or out of 10,000 B atoms, 1991 are ^{10}B and 8009 are ^{11}B

Mass of isotopes via **Mass Spec**. A Mass Spec separates ions of different mass can charge in a gaseous sample of ions.



1. A sample is introduced as a vapor into the ionization chamber.

There it is bombarded with high-energy electrons that strip electrons from the atoms or molecules of the sample.

2. The resulting positive particles are accelerated by a series of negatively charged accelerator plates into an analyzing chamber.

3. This chamber is in a magnetic field, which is perpendicular to the direction of the beam of charged particles.

The magnetic field causes the beam to curve. The radius of curvature depends on the mass and charge of the particles (as well as the accelerating voltage and strength of the magnetic field).

4. Here, particles of $^{21}Ne^{+}$ are focused on the detector, whereas beams of ions of $^{20}Ne^{+}$ and $^{22}Ne^{+}$ (of lighter or heavier mass) experience greater and lesser curvature, respectively, and so fail to be detected.

By changing the magnetic field, charged particles of different masses can be focused on the detector to generate the observed spectrum.

Atomic Weight of an element is the average mass of a representative sample.

$$\text{Atomic mass} = \left(\frac{\%\text{ abundance of isotope 1}}{100}\right) \text{ ? mass of isotope 1} + \left(\frac{\%\text{ abundance of isotope 2}}{100}\right) \text{ ? mass of isotope 2} + \ldots$$

Boron has 2 isotopes: ^{10}B at 19.91% and ^{11}B at 80.09%

Atomic Weight of B = (19.91 / 100) * 10.0129 + (80.09 / 100) * 11.0093 = 10.81 [grams/mole]

Table 2.2 Isotope Abundance and Atomic Weight

Element	Symbol	Atomic Weight	Mass Number	Isotopic Mass	Natural Abundance (%)
Hydrogen	H	1.00794	1	1.0078	99.985
	D*		2	2.0141	0.015
	T†		3	3.0161	0
Boron	B	10.811	10	10.0129	19.91
			11	11.0093	80.09
Neon	Ne	20.1797	20	19.9924	90.48
			21	20.9938	0.27
			22	21.9914	9.25
Magnesium	Mg	24.3050	24	23.9850	78.99
			25	24.9858	10.00
			26	25.9826	11.01

*D = deuterium; †T = tritium, radioactive.

Example 2.2 Bromine 1st mass = 78.91838 u at 50.69%, 2nd mass = 80.916291 at 49.31 %. What is the Atomic Weight?

Chlorine: ^{35}Cl is 34.96885 u at 75.77% and ^{37}Cl is 36.96590 at 24.23%. What is its Atomic Wt?

Example 2.3 Antimony, Sb has 2 stable isotopes: ^{121}Sb = 120.904 u and ^{123}SB = 122.904 u What are the relative abundances of the isotopes? Its Atomic Wt is 121.760 u

2.5 Peroidic Table

Mendeleev (1824 – 1907) If the elements were arranged by *increasing atomic mass*, elements with similar properties appear in a regular pattern. Elements with similar properties are in vertical columns.

Periodicity is the periodic repetition of the properties of the elements (rows).

Left empty space where he believed an element should be (Si, Sn, Ge)

Law of Chemical Periodicity: properties of elements are periodic functions of atomic number.

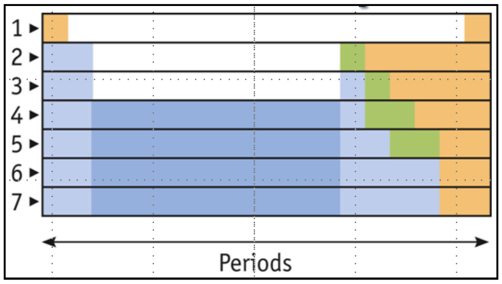
Features of the Periodic Table **SEE ELECTRON CONFIGURATION AT END**

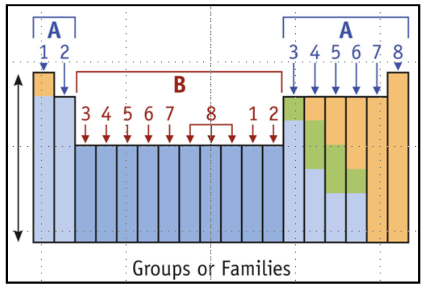
Groups or Families: Vertical columns, they have similar physical and chemical properties and are numbered 1 -> 8, each with an A or B.

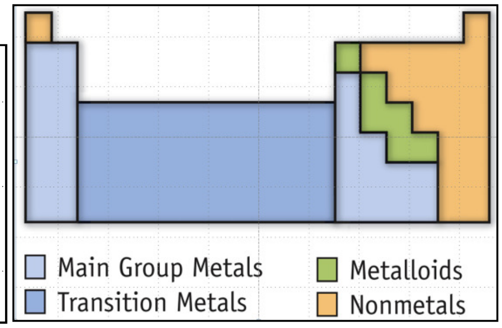
A Main Group elements

B Transition Elements

Periods Horizontal rows and are numbered beginning with 1.







Metals found on the left side of the table. At STP are solids, conduct electricity, and are ductile and malleable, can form alloys (mixtures of more than one metal).

Nonmetals on the right side of a diagonal line (B to Te). They have a wide variety of properties, solids, liquid (Bromine) and gases, do not conduct electricity

Semimetals or **Metalloids**, elements on the B to Te diagonal line has both metal and non-metal characteristics.

Alkali Metals Group 1A. solids at RT and are reactive, found combined as a compound not as the pure element

Alkaline Earth metals Group 2A, also found only as a compound, not as the pure element. Except for Be, all elements react with water. Mg = 7th and Ca = 5th are the most abundant element in the earth crust. Ca is in our teeth and bones, as limestone ($CaCO_2$), in corals, shells, marble, and Chalk. Radium (Ra) is radioactive and used to treat cancers.

Group 3A important elements are Aluminum 8.2% of the earth crust – most abundant metal on earth, Boron a metalloid found in Borax (20 mule team borax).

Group 4A starts the nonmetals: Carbon, metalloid Silicon and Germanium and the metals Tin and Lead. Carbon is an **Allotrope** – can exist in different distinct forms (graphite, diamond, buckyballs)

Group 5A has the diatomic gas N_2 which is important in "nitrogen fixation" and in the lab as amine compounds such as ammonia NH_3. Phosphorus is important in life in bones and DNA. Phosphoric Acid is used in food products and soft drinks and used to make fertilizers. N and P are nonmetals, As and Sb metalloids and B is a metal.

Group 6A has Oxygen with is 20% of the earth's atmosphere and forms important oxides such as DiHydrogen Oxide (H_2O), Sand (SiO_2) and many other metal oxides. Sulfuric Acid (H_2SO_4) is manufactured in larger amounts than any other compound in the world. Oxygen, sulfur and selenium are nonmetals, tellurium is a metalloid, and polonium is a radioactive metal. Oxygen **allotropes are** O_2 and O_3.

Groups 7A contains all nonmetals and are called halides. They exist as diatomic molecules: F_2. They are reactive and readily form salts.

Group 8A are the least reactive, the noble gases or inert gases and are not very abundant on earth. Helium is the 2nd most abundant element in the universe and hydrogen is the 1st. We are running out of He!! **(DISCUSS)**

Transition elements fit between Groups 2A and 3A, in th 4th through 7th period, all are metals, most occur naturally as compounds except Cu, Ag, Au and Pt are found as the pure elements.

Lanthanides and Actinides are 2 rows that fit between elements 57 -72 and 89 – 104.

Polyatomic Elements: Hydrogen (H2), Nitrogen (N2), Oxygen (O2) and all the halides.

Table 2.3 The 10 Most Abundant Elements in the Earth's Crust

Rank	Element	Abundance (ppm)*
1	Oxygen	474,000
2	Silicon	277,000
3	Aluminum	82,000
4	Iron	41,000
5	Calcium	41,000
6	Sodium	23,000
7	Magnesium	23,000
8	Potassium	21,000
9	Titanium	5,600
10	Hydrogen	1,520

*ppm = parts per million = g per 1000 kg.

Oxygen O 49.2% Silicon Si 25.7% Aluminum Al 7.50% Iron Fe 4.71%

Calcium Ca 3.39% Sodium Na 2.63% Potassium K 2.40% Magnesium Mg 1.93%

Hydrogen H 0.87%

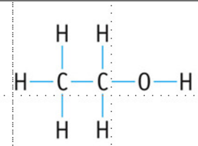
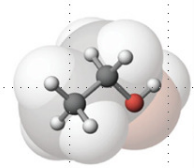
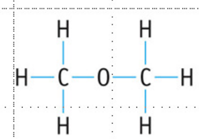
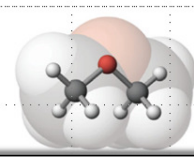
2.6 Formulas

Molecule is the smallest identifiable units into which some pure substances can be divided and still retain the composition and chemical properties of the substance.

Molecular formula describes the composition of the molecule: CO2, H2O

Condensed formula indicates how certain atoms are grouped together: CH3-CH2-CH2OH

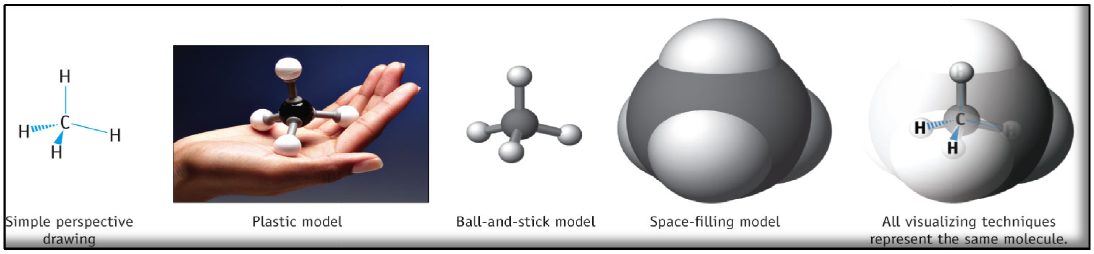
Structural formulae gives the detail of how al the atoms are attached within a molecule

NAME	MOLECULAR FORMULA	CONDENSED FORMULA	STRUCTURAL FORMULA	MOLECULAR MODEL
Ethanol	C_2H_6O	CH_3CH_2OH		
Dimethyl ether	C_2H_6O	CH_3OCH_3		

Molecular Models

Ball and Stick are different colored spheres which represent atoms and sticks to represent bonds

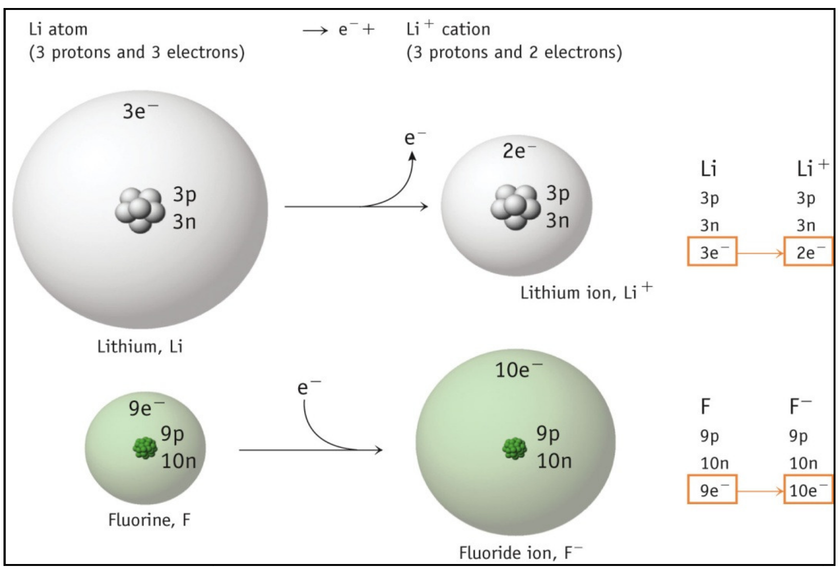
Molecular Model / Space filling models show the connection of elements and the area of the electron cloud.



Water's unique properties of ice is less dense the liquid water is important because ice will float on large bodies of water instead of sinking. Why is this important? Water vapour, clouds, helps cool inland areas. How?

2.7 Ionic Compounds consist of ions, atoms or groups of atoms that bear a positive or negative electric charge. These differ from Molecular Compounds that do not have charges: CH_4 Methane

Ions are elements that have gained or lost electrons, thus possess an electric charge



Cations are atoms that have lost an electron thus have a positive charge. Metals (Left side and the middle of the Periodic Table) loose electrons to form Cations.

$Li \rightarrow Li^{+} + 1\ e^{-}$ $Ca \rightarrow Ca^{2+} + 2\ e^{-}$ $Al \rightarrow Al^{3+} + 3\ e^{-}$

| 3 Protons, 2 e-

3 Protons, 3 e-

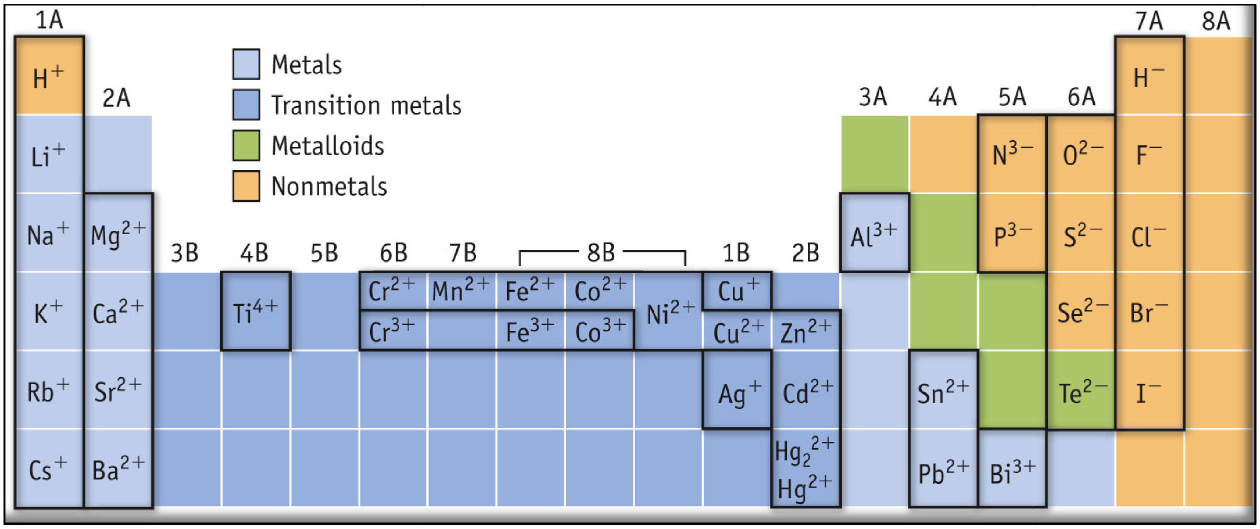
Anions are atoms that have gained an electron, thus have a negative charge. Nonmetals (Right side of the Periodic Table) gain electrons to form Anions.

$O + 2\ e^{-} \rightarrow O^{2-}$ $Cl + 1\ e^{-} \rightarrow Cl^{1-}$ or Cl^{-}

| 8 Protons, 10 e-

8 Protons, 8 e-

Monatomic Ions are single atoms that have lost or gained electrons. Metals lose electrons to form Cations; nonmetals gain electrons to form Anions. The Cations and Anions examples above are Monoatomic Ions – consisting on one atom or element. (See Polyatomic below)



Group	**Metal Atom**	**Electron Change**	**Resulting Metal Cation**
1A	Na (11 prot, 11 e-)	-1	→ Na^{+} (11 prot, 10 e-)
2A	Ca (20 prot, 20 e-)	-2	→ Ca^{2+} (20 prot, 18 e-)
3A	Al (13 prot, 13 e-)	-3	→ Al^{3+} (13 prot, 10 e-)

Ion charges and the Periodic Table

Elements on the **left side of the periodic table** will loose e^- in order to form the noble gas configuration.

Groups **1A** will lose 1 e-,
2A will lose 2 e-,
3A will lose 3 e-. This allows the remaining ion to have the same number of electrons in the outer shell as the noble gas in the previous row.

Mg^{2+} has 10 e-, Neon; the noble gas also has 10. The noble gas outer electron shell provides for a very stable configuration (the p orbital is filled with 6 electrons).

Elements on the **right side of the periodic table** will gain e- in order to form the noble gas electron configuration. Chlorine, Cl has 7 electrons in the outer shell. By gaining one electron, it has the 8 electron configuration which is very stable, Cl^-. Oxygen will gain 2 e- to form O^{2-}.

Transition metals (B-group) form Cations, they will lose e^-. It is not easy to predict which action it will form. They also may form several different Cations by losing various numbers of e-. Examples from a different text book:

Cr^{2+}	Chromium (II)	Cr^{3+}	Chromium (III)
Mn^{2+}	Mantanese (II)	Mn^{3+}	Manganese (III)
Fe^{2+}	Iron (II) or Ferrous	Fe^{3+}	Ione (III) or Ferric
Co^{2+}	Cobalt (II)	Co^{3+}	Cobalt (III)
Ni^{2+}	Nickel (II)		
Cu^{+}	Copper (I) or Cuprous	Cu^{2+}	Copper (II) or Cupric
Hg^{2+}	Mercury (II) or Mercuric		

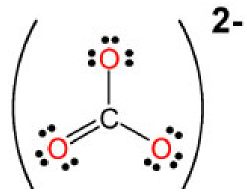
Nonmetals form negatively charged ions by gaining a number of e- equal to the group number - 8

Group	**Atom**	**e- change**	**Resulting non-metal**
5A	N (7 prot, 7 e-)	8 – 5 = 3e- →	N^{3+}
6A	S (16 prot, 16 e-)	8 – 6 = 2e- →	S^{2+}
7A	Br (35 prot, 35 e-)	8 – 7 = 1e- →	Br^{-}

Hydrogen can lose an e^-: H - e^- = H^+ or gain one H + e- = H^- (hydride)

Noble gases rarely react at all!

<u>**Polyatomic ions**</u> are made up of 2 or more atoms and this collection of atoms as a whole has the charge. Carbonate, CO_3^{2-} contains 1 carbon and 3 oxygen atoms



Polyatomic Ions TABLE 2.4 – Memorize it, This is important!

Table 2.4 Formulas and Names of Some Common Polyatomic Ions

Formula	Name	Formula	Name
Cation: Positive Ion			
NH_4^+	Ammonium ion		
Anions: Negative Ions			
Based on a Group 4A element		**Based on a Group 7A element**	
CN^-	Cyanide ion	ClO^-	Hypochlorite ion
$CH_3CO_2^-$	Acetate ion	ClO_2^-	Chlorite ion
CO_3^{2-}	Carbonate ion	ClO_3^-	Chlorate ion
HCO_3^-	Hydrogen carbonate ion (or bicarbonate ion)	ClO_4^-	Perchlorate ion
$C_2O_4^{2-}$	Oxalate ion		
Based on a Group 5A element		**Based on a transition metal**	
NO_2^-	Nitrite ion	CrO_4^{2-}	Chromate ion
NO_3^-	Nitrate ion	$Cr_2O_7^{2-}$	Dichromate ion
PO_4^{3-}	Phosphate ion	MnO_4^-	Permanganate ion
HPO_4^{2-}	Hydrogen phosphate ion		
$H_2PO_4^-$	Dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	Hydroxide ion		
SO_3^{2-}	Sulfite ion		
SO_4^{2-}	Sulfate ion		
HSO_4^-	Hydrogen sulfate ion (or bisulfate ion)		

Formulas of Ionic Compounds

Compounds are electrically neutral so Ionic Compounds must have:

# of Cations * Cation Charge = # of Anions * Anion Charge

In naming the formula, the Cation is first the Anion is last

NaCl is made up of Na^{+} and Cl^{-} That's one positive charge and one negative charge

Aluminum Oxide had Al^{3+} and O^{2-}. So we need 2 Al^{3+} and 3 O^{2-} there is a total of 6+ and 6-.
DEMONSTRATE NUMBER SWAP METHOD.

Compound	**Ion Combination**		
CaCl2	Ca^{2+}	2 Cl^{-}	
CaCO3	Ca^{2+}	CO_3^{2-}	
$Ca_3(PO_4)_2$	3 Ca^{2+}	3 PO_4^{3-}	**DISCUSS PARAENTHESIS!!**

Example 2.4 **Discuss** Lithium Carbonate and Iron II (Ferrous) Sulfate

Discuss Sodium Fluoride, Copper II (Cuprous) Nitrate, Sodium Acetate

Discuss Aluminum Fluoride, Sulfide, Nitrate

<u>Names of Ionic Compounds</u> (See alternative method at end of these notes)

Naming of Positive Ions (Cations)

1. For monatomic, the name is that of the metal plus the work "cation". Al^{3+} = aluminum cation.

2. Some cases, in the transition series, a metal can have more than 1 charge – see list above. Name the metal, followed by the Roman Numeral for the charge in parentheses followed by "cation". Co^{2+} = Cobalt (II) cation Co^{3+} = Cobalt (III) cation

3. NH_4^{+} is Ammonium cation, NH_3 is Ammonia compound

Naming the Negative Ions (Anions)

1. For monatomic, change the ine to ide. Chlorine → Chloride
2. For Polyatomic memorize the common name from table 2.4. Below are the **Oxoanions**

NO_3^{-}	Nitrate	SO_4^{2-}	Sulfate	ate = larger number of oxygen
NO_2^{-}	Nitrite	SO_3^{2-}	Sulfite	ite = smaller number of oxygen

ClO_4^{-}	**Per** chlor**ate** ion
ClO_3^{-}	Chlor**ate** ion
ClO_2^{-}	Chlor**ite** ion
ClO_1^{-}	**Hypo** chlor**ite** ion

Oxianions with Hydrogen:

HPO_4^{2-}	Hydrogen Phosphate ion
$H_2PO_4^{-}$	Dihydrogen Phosphate ion
HCO_3^{-}	Hydrogen Carbonate ion (also called bicarbonate)
CO_3^{-}	Carbonate ion
HSO_4^{-}	Hydrogen Sulfate ion
HSO_3^{-}	Hydrogen Sulfite ion

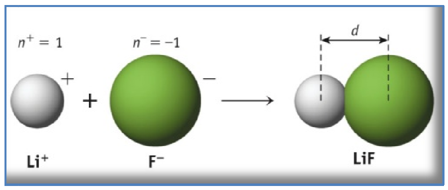
Naming of Ionic Compounds

The name of an ionic compound is the name of the Cation followed by the name of the Anion.

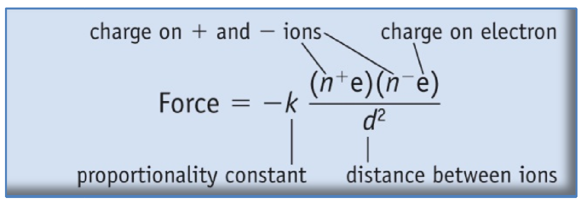
$CaBr_2$	Ca^{2+}	2 Br^-	Calcium Bromide	
$NaHSO_4$	Na^+	HSO_4^-	Sodium Hydrogen Sulfate	
$(NH_4)_2CO_3$	2 NH_4^+	CO_3^{2-}	Ammonium Carbonate	
$Mg(OH)_2$	Mg^{2+}	2 OH^-	Magnesium Hydroxide	
$TiCl_2$	Ti^{2+}	2 Cl^-	Titanium (II) Chloride	Transition Metals
Co_2O_3	2 Co^{3+}	3 O^{2-}	Cobalt (III) Oxide	Transition Metals
$PbSO_4$	Pb^{2+}	SO_4^{2-}	Lead (II) Sulfate	Transition Metals
$Pb(SO_4)_2$	Pb^{2+}	2 SO_4^{2-}	Lead (IV) Sulfate	Transition Metals
$Fe(NO_3)_3$	Fe^{3+}	3 NO_3^-	Iron (III) Nitrate	Transition Metals
$FE(NO_2)_2$	Fe^{2+}	2 NO_2^-	Iron (II) Nitrate	Transition Metals

Properties of Ionic Compounds

A positively charged particle is attracted to a negatively charged particle



Two positively or two negatively charged particles repel each other.
This electrostatic force is described by Coulomb's Law:



Ionic compound Properties: Hard solids,
Consist of many ions arranged in a 3D **crystal lattice** network
Have high melting points Al_2O_3 MP = 2072 ^oC

What is the difference between Na and Na^+ ?

Is a Compound ionic: Metal containing compounds are ionic
If there is no metal, it is not ionic
One exception is for compounds with polyatomic cations like NH_4^+
(What is the difference between NH_4^+ and NH_3)

2.8 Molecular Compound Properties:

- They are not ionic (separate + and – charges), they are molecular (no charges) – all atoms are joined together as one compound and they do not separate, even in solutions.
  Example Ethyl Alcohol $H_3C\text{-}CH_2OH$
- Can be solid, liquid or gas (higher mw tend to be solids)
- Can have complicated formulae
- Are formed from Non-Metals (usually from Groups 4A -> 7A, with or without Hydrogen)

Two nonmetals join to form a **Binary Compound** (Binary = 2) HBr

Naming Binary Compounds: put elements in order of increasing group number. Use the following prefixes:

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

You do not include Mono for a single cation:
NF_3 is Nitrogen trifluoride not MonoNitrogen trifluoride

HF	Hydrogen Fluoride (Hydrofluoric Acid)	HCl	Hydrogen Chloride (Hydrochloric Acid)
H_2S	Hydrogen Sulfide (DiHydrogen Sulfide)		

NF_3	Nitrogen Trifluoride	PCl_3	Phosphorus Trichloride
NO	Nitrogen Monoxide not Monooxide	PCl_5	Phosphorus Pentachloride
NO_2	Nitrogen Dioxide	SF_6	Sulfur Hexafluoride
N_2O	Dinitrogen Monoxide	S_2F_{10}	Disulfur Decafluoride
N_2O_4	Dinitrogen Tetraoxide		

Common Names

CH_4	Methane	N_2H_6	Hydrazine
C_2H_6	Ethane	PH_3	Phosphine
C_3H_8	Propane	NO	Nitric Oxide
C_4H_{10}	Butane	N_2O	Nitrous Oxide
NH_3	Ammonia (not Ammonium NH_4^+)	H_2O	Water

<u>2.9 The Mole</u> The Mole is the # of atoms in exactly 12.00… g of Carbon 12, ^{12}C

1 mole = 6.0221415×10^{23} Particles = Avogadro's Number

Molar Mass, M in g/mol

The Molar Mass is the weight in grams of 6.0221415×10^{23} Particles of an element. See Periodic Table

Number of Moles = wt in g / Mw of the compound

DISCUSS WHY WE NEED MOLES $C + 4H \rightarrow CH_4$ (atoms, moles, g)

Also shows the amount of Hydrogen that will react with an amount of Carbon

The molar mass of Sodium (Na) M = 22.99 g/mole = 6.0221415×10^{23} Particles of Sodium

The molar mass of Lead (Pb) is M = 207.2 g/mole = 6.0221415×10^{23} Particles of Lead

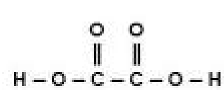
Mass to moles # moles = Mass (weight in grams) / molar mass (see Periodic Table)

moles in 5.0 g of Sodium (Na) # moles = 5.0 g / 22.99 g/mole = 0.21748 = 0.22 mole

of g in 1.2 moles of Na #g = 1.2 moles * 22.99 g/mole = 27.588 = 28. g of Na

NOTE SIG FIG, derive the formulae as needed

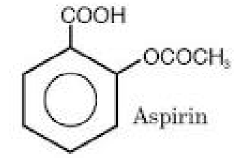
How many moles are in 16.5 g of oxalic acid? $H_2C_2O_6$



One mole of unpopped popcorn would cover the USA 9 miles deep

Example 2.6 What mass of lead, in grams, is equivalent to 2.50 mol of Pb?

What amount of tin is represented by 36.6 g of Sn?



Determine the Molar Mass of Water? Of Aspirin $C_9H_8O_4$

Determine the Molar Mass of Copper (II) Chloride dihydrate

2.10 Formulas

<u>Percent Composition</u>, Shows the % of each element in the compound (CHN Analysis)

1.000 mol of Ammonia	1-N		14.007	g/mole
	3-H	3 * 1.008	3.0237	g/mole
		NH3	17.0307	g/mole = 17.031 g/mole **(SD)**

NH3 weighs 17.031 g and contains 1.000 mole or 14.007 g of N and 3.000 mole or 3.0237 g of H. The Mass % of each element is:

Mass % of N in NH3 = 100 % * 14.007 g N / 17.031 g NH3 = 82.244 % N

or 82.244 g of N for each 100 g of NH3

Mass % of H in NH3 = 100 % * 3.0237 g H / 17.031 g NH3 = 17.755 % H

Or 17.755 g of H for each 100 g of NH3

Example 2.8 What is the mass % of each element in propane – C_3H_8 - $H_3C\text{-}CH_2\text{-}CH_3$

% Composition is used in Organic Chemistry to help verify the synthesis of the correct compound **DISCUSS**

<u>Empirical Formulae</u> from % Composition

Reverse the above procedure:

1. Convert Mass Percent to mass (% -> g)
2. Convert mass to moles
3. Fine the mole ratio of each element
4. Determine the empirical formulae

SEE ADDITIONAL PROBLEMS AT END

Hydrazine shows the following CHN analysis: 87.42% N, 12.58% H. What is its empirical formulae?

1. 87.42 % N = 87.42 g N 12.58% H = 12.58 g H
2. 87.42 g N / 14.007 g/mol N = 6.241 mol N 12.58 g H/1.0079 g/mol H = 12.48 mol H **(SD)**
3. Divide by the smallest 6.241 mol N / 6.241 mol N = 1 N

   12.48 mol H / 6.241 mol N = 2.00 H for every N

Empirical Formulae = N_1H_2

Empirical Formulae is the simplest whole number ratio of atoms in a formulae

But, the molar mass of Hydrazine is 32.0 g/mole. The molar mass of N_1H_2 is 16.0 g/mol

So the **Molecular Formulae** of Hydrazine is 32.0 g/mole / 16.0 g/mol or 2 times Empirical Formula or N_2H_4

DISCUSS THE 1.5 AND 1.3 RULE

IE 2.10 1.250 g Bromine reacts with Ozone (O_3) to form 1.876 g Br_xO_y. What are the values for x and y.

Example 2.11 $Sn + I_2 \rightarrow Sn_xI_y$

Start with 1.056 g Sn. After the reaction is complete, there is an of excess Sn of 0.601 g
The starting amount of I_2 is 1.947 g. It's all used up. What is the empirical formula of the product?

Mass Spec

DISCUSS HOW IT WORKS – see picture above.

Mass Spec can give the exact mw of the parent molecule minus 1 e- .

$$R \rightarrow R^+$$

This exact mw can be used along with a CHN analysis to determine the Molecular Formulae of a molecule – see examples in book

2.11 Hydrated Compounds are compounds in which water molecules are associated with the ions of the compound. The water is not chemically (ionic or covalent) bonded.

Copper sulfate are blue crystals: $CuSO_4 \cdot 5 H_2O$, Copper (II) Sulfate Pentahydrate. Heating blue copper sulfate crystals gives the anhydrous $CuSO_4$.

$CuCl_2 \cdot 2 H_2O$ is Copper (II) Chloride dihydrate

Wallboard is $CaSO_4 \cdot 2 H_2O$
Heating it gives Plaster of Paris $CaSO_4 \cdot \frac{1}{2} H_2O$

Cobalt (II) Chloride, $CoCl_2 \cdot 6 H_2O$ is a red solid, heating it gives the anhydrous blue $CoCl_2$. These crystals are commonly placed in a small plastic bag as an indicator for moisture.

Periodic Table of Elements

Alkaline earth metals → 2A; Halogens → 7A; Noble gases → 8A; Transition metals (3rd–12th columns); Alkali metals (1A, periods 2–7)

	1A	2A											3A	4A	5A	6A	7A	8A
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226	89 **Ac**** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)	112 **Uub**	113 **Uut**	114 **Uuq**	115 **Uup**			

metals ← → nonmetals

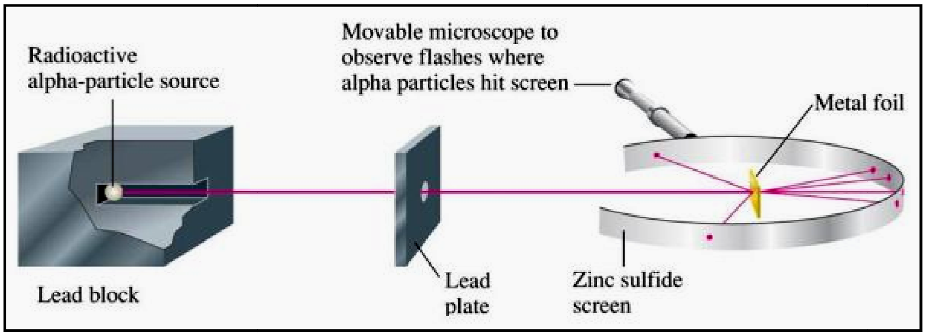
EXTRA NOTES

Nuclear Model of the Atom

Rutherford Alpha Particle Source → Lead Plate with a hole → hits a gold foil → -> Circular Zinc Sulfide Screen

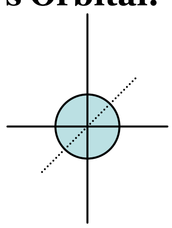
Found 99.95% of the mass of the atom is the positively charged center

Or **If a golf ball** represented the nucleus, the electron shell would be 3 miles in diameter

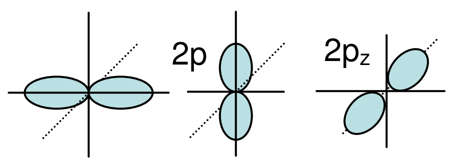


ELECTRON CONFIGURATION (This is not in your book)

s Orbital:



p Orbital



	S	Px	Py	Pz	D1	D2	D3	D4	D5
3	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓
2	↑↓	↑↓	↑↓	↑↓	Noble Bas Configuration				
1	↑↓								

How to etermine the charges on the Cation and Anion, you need to memorize these

Cation	Group 1A	Alkali Metals	**+1**	**Li, Na, K, Rb, Cs**
	Group IIA	Alkaline Earth Metals	**+2**	**Be, Mg, Ca, Sr, Ba**
	Group IIIA	Some Transition Metals	**+3**	**Al, Ga, In, Tl**
Anion	Group 8A	Noble Gases do not form ionic compounds		
	Group 7A	Halogens	**-1**	**F, Cl, Br, I**

From EBBING's book the list of transitions metals

The are 3 rules for naming

Type 1 Group 1 and 2 Metals [Metal has only one charge]

1. Cation named first, then the Anion 2nd
2. Simple Cation [single atom] takes the name from the element Na^{+} = Sodium
3. Simple Anion named taking the 1st part of the element name, **remove the -ine** and add **–ide if it's a halogen.**

e.g. NaCl = Sodium Chloride

Type II Transitions Metals [Metal can have more than one charge]

1. Cation is always named 1st, then the Anion
2. Cation can assume more than one charge – specify the charge with Roman Numerals

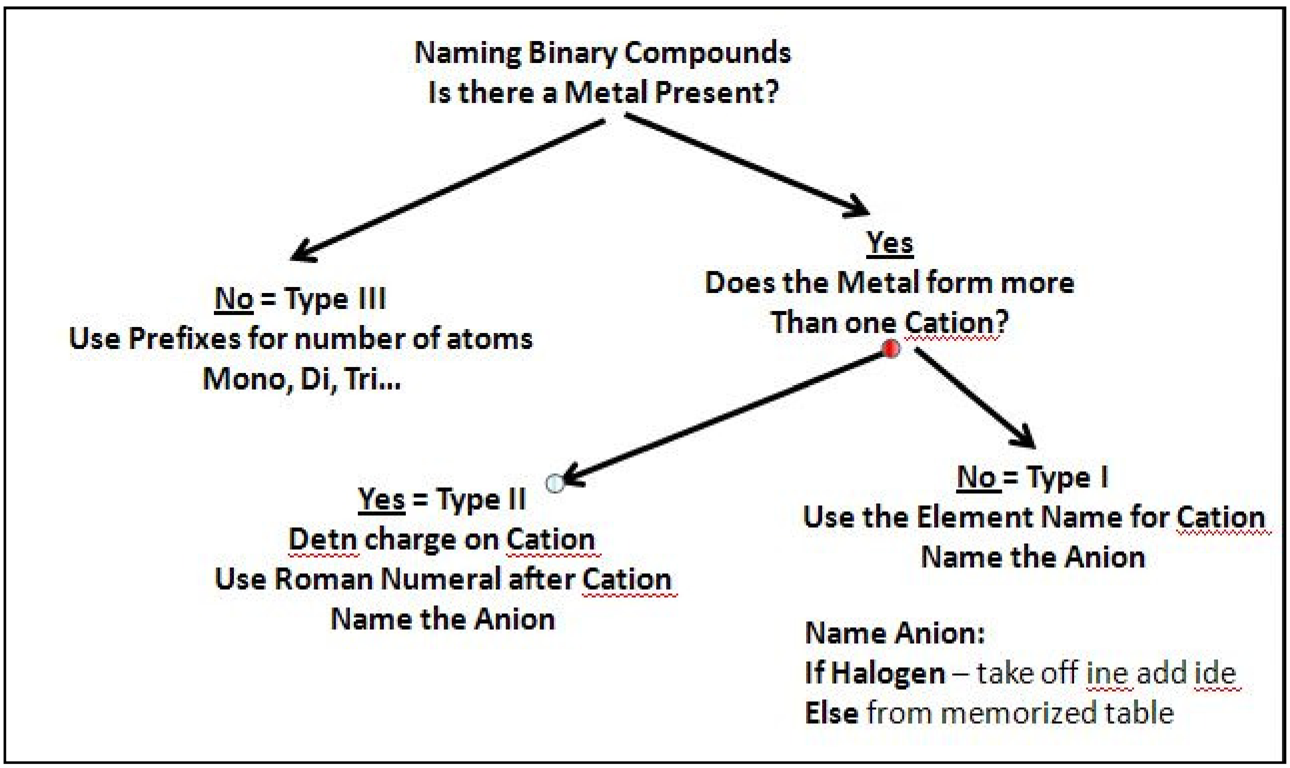
Cu^{+1} and Cu^{+2} = Copper (I) and Copper (II)

$FeCl_3$ = Iron (III) Chloride $FeCl_2$ = Iron (II) Chloride

Type III Binary Compounds containing NonMetals [No Metals]

1. The 1st element is named first and the full name is used
2. The 2nd element is named as if it were an ANION [ide]
3. Prefixes donate the number of atoms present
4. Prefix MONO is NEVER used for the 1st element **[See Table 2.7 p 68]**

1. Mono	3. Tri	5. Penta	7. Hepta
2. Di	4. Tetra	6. Hexa	8. Octa



To help with the PolyAtomics, try grouping them:

Hypochlorite	ClO^-	Hypo comes first	Note order is by increasing number of Oxygen from 1 → 4
Chlorite	ClO_2^-	**ite comes before ate**	
Chlorate	ClO_3^-	ate comes after ite	
Perchlorate	ClO_4^-	Per is last	

CHN Calculations Procedure:

1. If the values are given in grams or milligrams, change the units to %.
2. Add up all of the percentages. If it does not equal 100%, then the remaining is assumed to be Oxygen. Put Oxygen into your calculations.
3. Divide each of the percentages by the elemental weight for that element
4. Divide all of those numbers by the smallest number
5. These numbers represent the relative ratio of each of the elements.

If at least one number ends in 0.9, 0.0 or 0.1 go with those numbers

If at least one number ends in 0.2, 0.3 or 0.7 or 0.8 then multiply all of the numbers by 3

If at least one number ends in 0.4, 0.5 or 0.6, then multiply all of the numbers by 2

Empirical Formulae – simplest formula. Shows the simplest ratios of numbers of the atoms
Molecular Formulae from Empirical Formulae Need molecular weight

P 120, 3.95 MothBalls – para-dichlorobenzene has the composition: C 49.1%, H 2.7%, Cl 48.2% and a molecular weight of 147. What is its molecular formulae?

SPECIAL PROBLEM An organic compound was found to have the following composition: C 92.15 %, H 7.84 %. Two separate determinations of the molecular weight found it to be approximately 25 g/mole and a second trail gave 79 g/mole. What Molecular Formula would support these two molecular weights?

Table 3.1
Acetylene has an empirical formula of CH and a molecular formula of C_2H_2.

Benzene has an empirical formula of CH and a molecular formula of C_6H_6.

1. Calculate the % of C and H in each?
2. If you were given this %C and %H, how would you differentiate between acetylene and benzene?

Exercise 3.11 A sample of Benzoic Acid gave the following analysis: C 68.8% and H 5.0%. What is the empirical formula?

The % add up to 68.8 + 5.0 = 73.8. Therefore it is assumed that O is 100% - 73.8% = 26.2%.

C	68.8 / 12.01	= 5.73	5.73 / 1.64 = 3.49	3.49 * 2 = 6.98 or @ 7
H	5.0 / 1.008	= 4.96	4.96 / 1.64 = 3.02	3.02 * 2 = 6.04 or @ 6
O	26.2 / 16.00	= 1.64	1.64 / 1.64 = 1	1 * 2 = 2

Therefore the empirical formula is $C_7H_6O_2$

Example 3.12 An acetic acid sample has C 39.9%, H 6.7% and a molecular weight of approximately 60.0 g/mol. What is the molecular formula?

Again, the % add up to 39.9 + 6.7 = 46.6. Therefore it is assumed that O is 100% - 46.6% = 54.5%

C	39.9 / 12.01	= 3.32	3.32 / 3.32 = 1	Empirical Formulae = C_1H_2O
H	6.7 / 1.008	= 6.65	6.65 / 3.32 = 2.00	
O	54.5 / 16.00	= 3.41	3.41 / 3.32 = 1.03	

Empirical Formula Weight =	C	1 * 12.01	12.01
	H	2 * 1.008	2.016
	O	1 * 16.00	16.00
			30.026 = 30.03 g/ mole

The molecular weight is 60.00, the empirical formula weight is 30.03, so
60.00 / 30.03 = 2. Multiply the empirical formula by 2 to get the **molecular formula = $C_2H_4O_2$**