ADVANCED PLACEMENT CHEMISTRY
CHAPTER 2
ATOMS, MOLECULES, AND IONS

History

Greeks 400 BC

Aristotle

4 elements: earth(*s*), air(*g*), fire(energy), and water(*l*)

Democritus

-matter was composed of small indivisible particles called "atomos"

-tom = to divide   atom = can't be divided

Alchemists -next 2000 years

-tried to turn cheap materials into gold

-some elements and compounds were discovered (HNO_3, H_2SO_4, HCl, aqua regia(HNO_3 and HCl)) and some procedures were developed

Robert Boyle -1600's

-First person to perform quantitative experiments

-wrote a book called "The Skeptical Chemist"

-his research destroyed the notion of only 4 elements

Phlogiston theory- (John Becher & George Stahl)

-phlogiston flowed out of burning material

Joseph Priestly -1700's

-credited with discovery of oxygen (called it dephlogisticated air)

Antoine Lavoisier -

-named oxygen

-He determined the nature of combustion with careful quantitative procedures.

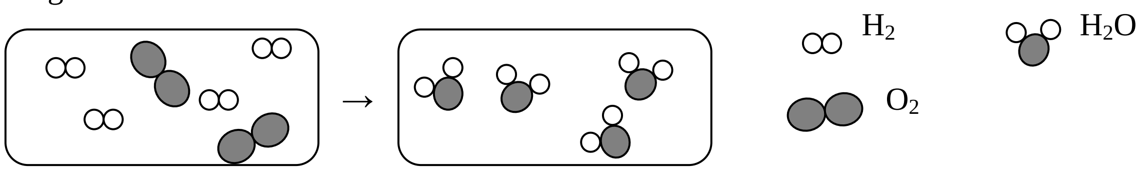
-He developed the law of conservation of mass (mass is neither created nor destroyed)

-disproved the phlogiston theory

-wrote first chemistry textbook

-executed by guillotine during French Revolution

Law of Conservation of Mass- Mass is neither created nor destroyed in a chemical reaction. The same number and types of atoms will be found in the products as in the reactants. They are simply rearranged.



Law of definite proportion - A given compound always contains exactly the same proportion of elements by mass. For example, all samples of pure water are approx. 89% oxygen and 11% hydrogen by mass. This is because water always contains 2 atoms of hydrogen and 1 atom of oxygen.

Law of multiple proportion - When two elements form a series of compounds, the ratios of the masses of the second element that combine with 1 gram of the first element can always be reduced to small whole numbers.

Data for compounds of nitrogen and oxygen:

Compound	Percent N	Percent O	Grams of N reacting with 1.00 g of O
I	30.4	69.6	0.437
II	46.7	53.3	0.876
III	63.6	36.4	1.747

0.437 : 0.876 : 1.747 = 1 : 2 : 4
This shows that each element consists of a certain type of atom and that compounds were formed from specific combinations of atoms.

Dalton's Atomic Theory -1808

1. Each element is made of tiny particles called atoms.
2. The atoms in a given element are identical; atoms in different elements are different in some fundamental way or ways.
3. Chemical compounds are formed when atoms of different elements combine with each other. A given compound always has the same relative numbers and types of atoms.
4. Chemical reactions involve the reorganization of atoms--changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.

Dalton determined the first table of atomic masses. Many were wrong because of incorrect formulas. Ex. OH for water with O having a mass of 8 and H having a mass of 1

Gay -Lussac and Avogadro studied the volumes of combining gases. This allowed them to determine correct formulas for these gases.

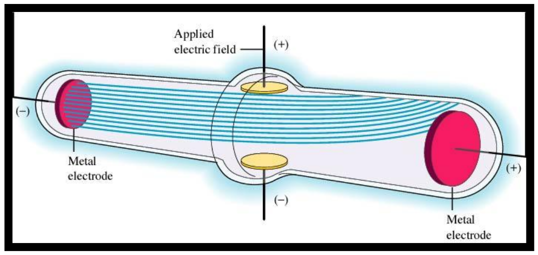
Avogadro's Hypothesis- At the same temperature and pressure, equal volumes of different gases contain the same number of particles. The identity of the gas does not matter.

Gay-Lussac's Law- When gases are involved in chemical reactions, they always react or appear in small whole-number ratios by volume as long as the temperature and pressure remain the same.

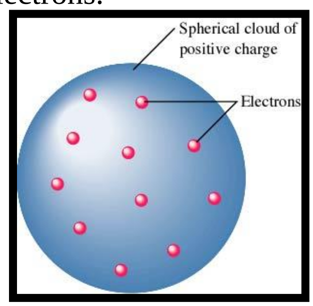
When we write equations involving gases, the coefficients give the ratio by volume as well as the ratio by mole.

Early Experiments to Determine Atomic Structure

JJ Thomson 1903



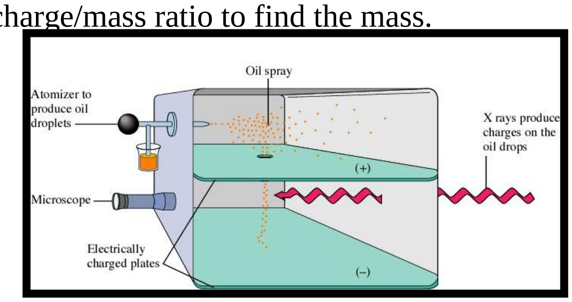
- -He used a cathode ray tube.
- -A ray was produced at the negative electrode and was repelled by a negative field.
- -He assumed that the ray was a stream of negative particles which he called electrons.
- -He measured the amount of deflection of the beam by a magnetic field and **determined the charge-to-mass ratio of an electron.**
- -Electrodes made from any metal produced cathode rays, so all atoms contain electrons.
- -The atom was neutral, so the rest must be positive
- -Plum Pudding Model



Robert Millican -1909

-determined the mass of an electron through the use of charged oil droplets.

He found the charge of an electron and used this, along with the charge/mass ratio to find the mass.



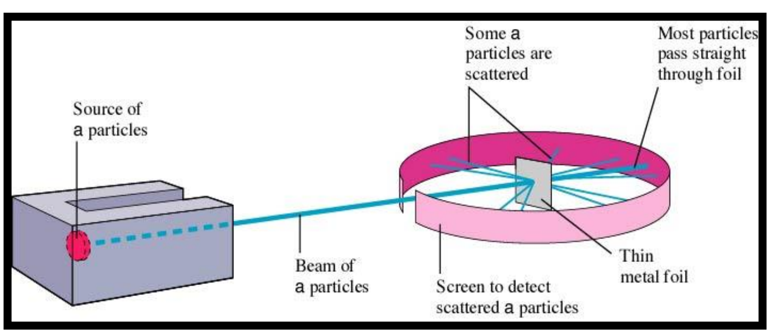
Becquerel -1896

- -discovered radioactivity
- -studies found 3 types of emissions:
  - gamma γ -high energy light (no charge)
  - beta β - high speed electron (1− charge)
  - alpha α -helium nucleus (2+ charge)

Rutherford's Gold Foil Experiment -1911

He shot alpha particles through gold foil. Most went straight through, a few were deflected.

This showed that the atom was mostly empty space with a dense, positively charged center, the nucleus.



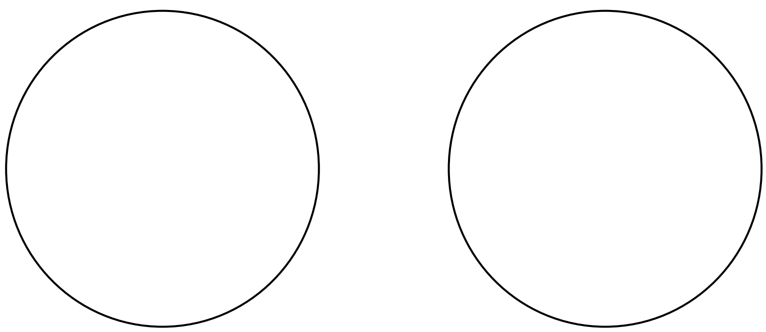
MODERN VIEW OF ATOMIC STRUCTURE

Nucleus (contains the protons and neutrons) -very tiny
Electrons -determine chemical behavior
Isotope - atom with the same number of protons but different number of neutrons

$$\begin{matrix} \text{mass \#} \rightarrow \\ \text{atomic\#} \rightarrow \end{matrix} {}^{A}_{Z}E \leftarrow \text{symbol of element}$$

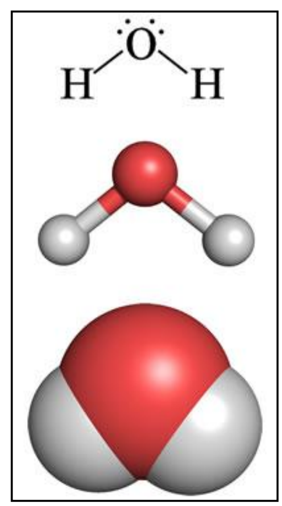
Atomic number = number of protons
Mass number = number of protons + number of neutrons
When a number follows the name of an element, the number refers to the mass number of the isotope. For example, carbon-14 is the isotope of carbon with mass number 14.
Number of protons = Number of electrons in a neutral atom

Using squares to represent protons, triangles to represent neutrons, and circles to represent electrons, draw representations of a carbon-12 nucleus and a carbon-14 nucleus.
Proton = □ Neutron = △ Electron= ○

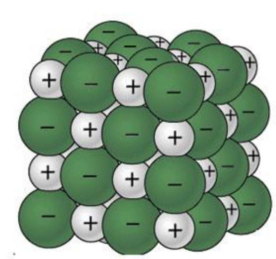


carbon-12 carbon-14

Covalent bonds are formed when atoms **share** electrons to form **molecules.** The chemical formulas of molecules can be shown in several different ways. The formula for water can be written as H_2O, or it can be shown by a structural formula, a ball-and-stick model or as a space-filling model as seen here.



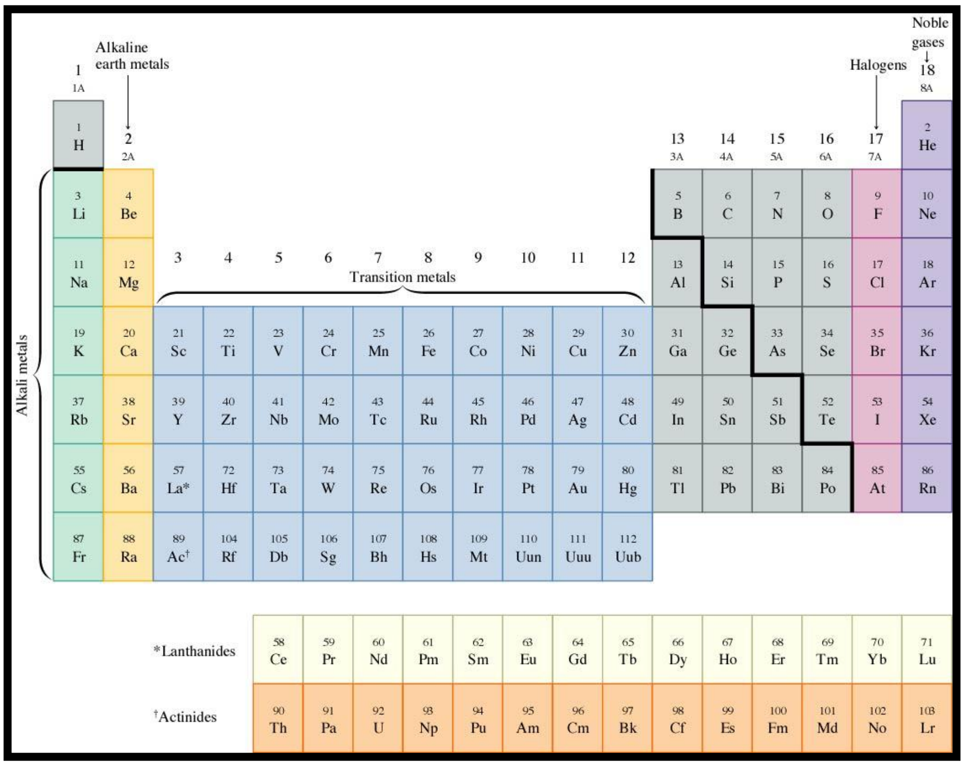
Ions are formed when **electrons are lost or gained** by an atom or group of atoms.
Cations are positive ions and result when an atom or group of atoms **loses** one or more electrons (#protons>#electrons).
$Na \rightarrow Na^{+} + e^{-}$ Na has 11 electrons, Na^{+} has 10
Anions are negative ions and result when an atom or group of atoms **gains** one or more electrons (#electrons>#protons).
$Cl + e^{-} \rightarrow Cl^{-}$ Cl has 17 electrons, Cl^{-} has 18.
Electrostatic (or Coulombic) attraction between oppositely charged ions forms **ionic bonds**. **Ionic compounds** contain ions. Coulombic attraction is greatest with ions that are small and highly charged.



Assume that two elements, A and B, form a molecular compound with the formula A_2B and two other elements, C and D, form an ionic compound with the formula CD. Draw a molecular view of each compound, using the following symbols. Draw at least two molecules of each.

A= ◇ B = □ C = ○ D= △

Compound A_2B Compound CD



Periodic Table

The metals are found to the left side of the stair-step line (and below). The nonmetals are found on the right side of the stair-step line. Those elements lying on the stair-step line (other than aluminum) are metalloids and have properties of both metals and nonmetals. Vertical columns are called groups. Elements in the same group have similar chemical properties. Horizontal rows are called periods. You should know where to find the elements in the labeled sections of this periodic table. Review using the periodic table to find charges of monatomic ions.

NAMING COMPOUNDS

It is extremely important that you have memorized the names and symbols of common ions. You are expected to know them by the end of this chapter and to be able to use them to write formulas and name compounds. The tables of ions found in your textbook are usually a good list to learn. Flashcards are helpful.

Binary Molecular Compounds consist of two different nonmetals.
1. Name the first element using a prefix to tell the number of atoms if there are more than one.
2. Name the second element, always using a prefix to give the number of atoms, and change the ending to -ide. A list of prefixes is found in your text.
CO is carbon monoxide. N_2O_5 is dinitrogen pentoxide.

Ionic Compounds consist of a metal and a nonmetal (or polyatomic ion).
1. Name the cation, followed by the anion (Anion name ends in -ide, unless it is a polyatomic ion)
2. When writing formulas for ionic compounds, the positive and negative charges must be equal. 3. When naming ionic compounds containing a transition metal, don't forget to include the Roman numeral for the charge.
NaCl is sodium chloride, not sodium chlorine. $AlPO_4$ is aluminum phosphate, not aluminum phosphorus oxide.
Iron(II) chloride is $FeCl_2$, because two chloride ions are needed to balance the 2+ charge of iron.

Acids ionize in water to produce hydrogen ions. To name an acid, look at the ending of the anion (H is the cation). Using the chart below, add a prefix if necessary and the proper suffix followed by "acid".

Anion ending	acid prefix	acid suffix	
-ide	hydro-	-ic	acid
-ate		-ic	acid
-ite		-ous	acid

HNO_3 is nitric acid, HCl is hydrochloric acid.
$HC_2H_3O_2$ is acetic acid. This is often written as CH_3COOH and can be called ethanoic acid.

Practice with Naming and Formula Writing:

CuI

$NaHCO_3$

$HClO_2$

P_2O_5

selenium tetrabromide

hypochlorous acid

potassium oxalate

Also know classic names for metallic ions:
Fe^{2+} ferrous
Fe^{3+} ferric
Cu^{+} cuprous
Cu^{2+} cupric
Co^{2+} cobaltous
Co^{3+} cobaltic
Sn^{2+} stannous
Sn^{4+} stannic
Pb^{2+} plumbous
Pb^{4+} plumbic
Hg_2^{2+} mercurous
Hg^{2+} mercuric

Simple Organic Chemistry

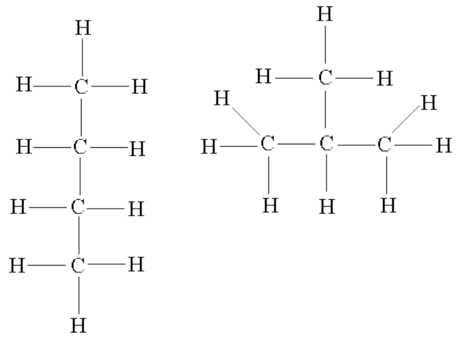
Hydrocarbons are compounds containing only hydrogen and carbon.
Ex. CH_4 C_2H_6
Hydrocarbon derivatives- compounds with some hydrogen atoms replaced by other elements (O, N, F, Cl, Br, I)
ex. CH_3Br
Alkanes- hydrocarbons with only single bonds
General formula: C_nH_{2n+2}
Names of alkanes end in -ane

IUPAC Names

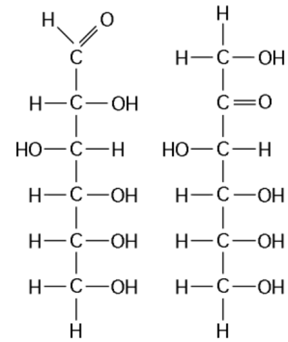
Name	**# carbons**	**Structural Formula**
Methane	1	**CH_4**
Ethane	**2**	**CH_3CH_3**
Propane	**3**	**$CH_3CH_2CH_3$**
Butane	**4**	**$CH_3CH_2CH_2CH_3$**
Pentane	**5**	**$CH_3CH_2CH_2CH_2CH_3$**
Hexane	**6**	**$CH_3CH_2CH_2CH_2CH_2CH_3$**
Heptane	**7**	**$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$**
Octane	**8**	**$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$**
Nonane	**9**	**$CH_3\ CH_2\ CH_2CH_2CH_2CH_2CH_2CH_2CH_3$**
Decane	**10**	**$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$**

Alkenes- contain at least one double bond
Alkene name ends in –ene.
general formula: C_nH_{2n}
Alkynes- contain at least one triple bond
name ends in -yne
general formula: C_nH_{2n-2}

Isomers- Have the same molecular formula but different structural formula
Structural Isomers- compounds with the same chemical formula but differ in the sequence in which the atoms are put together

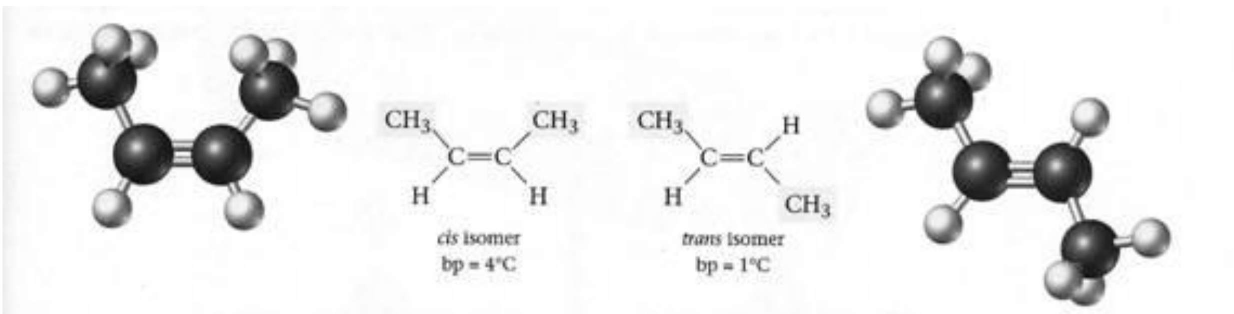


n-Butane Isobutane



glucose fructose

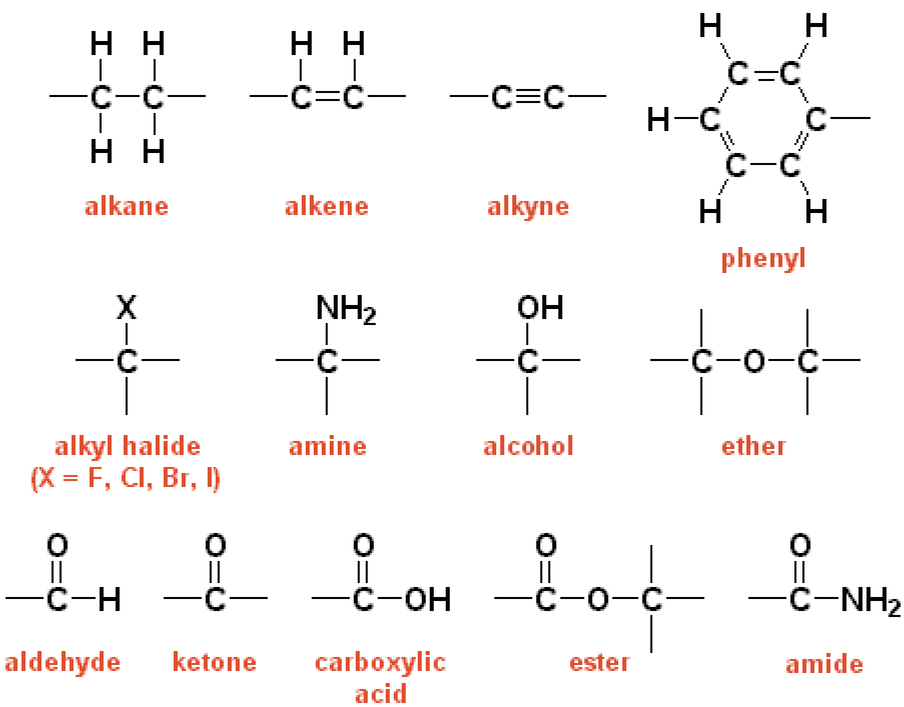
Geometric Isomers- occur when atoms are restricted from rotating around a bond. Double bonds do not allow rotation while single bonds allow free rotation.



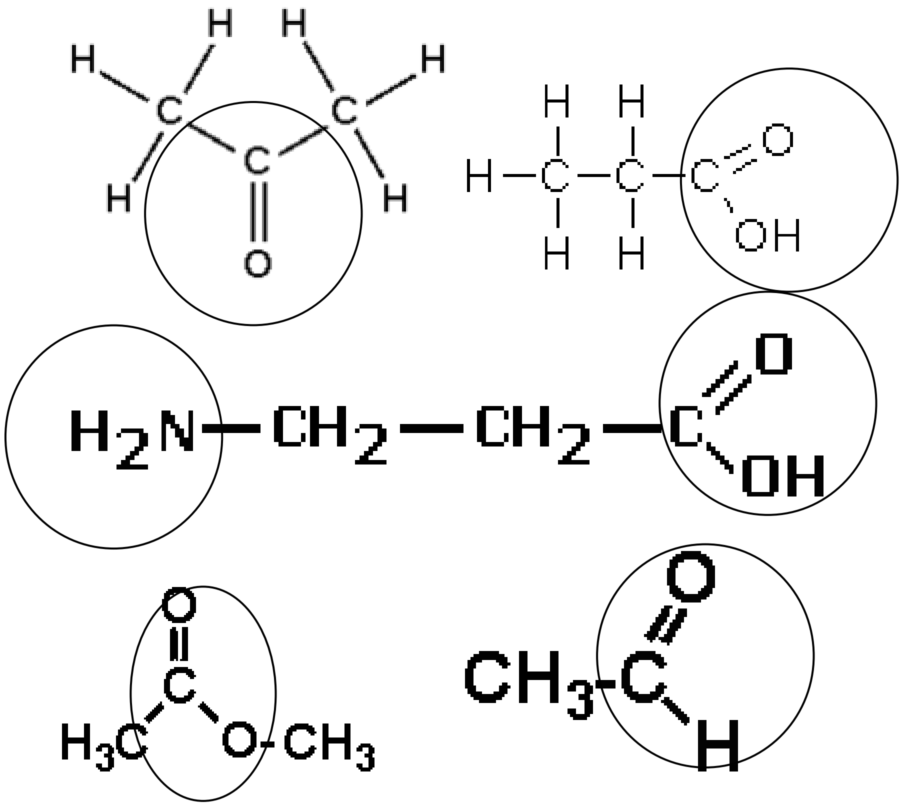
Functional Group -Chemically reactive part of an organic molecule

R means the rest of the molecule (usually hydrocarbon)

The Common Functional Groups



Identify the circled functional group (compound type) in the following compounds:



Polymers -a large molecule formed by the covalent bonding of repeating smaller molecules (called monomers). Polymers range from synthetic plastics such as polystyrene and polyethylene to natural biopolymers such as DNA and proteins that are fundamental to biological structure and function. Polymers, both natural and synthetic, are created via polymerization of many monomers.