AMSAT CHEM 1H TOPIC#4
ATOM NOTES

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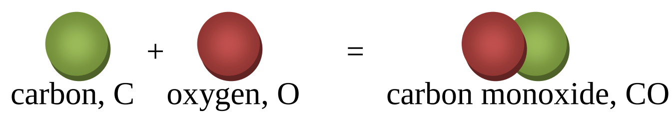
HISTORY OF ATOMIC THEORY SECTION #1

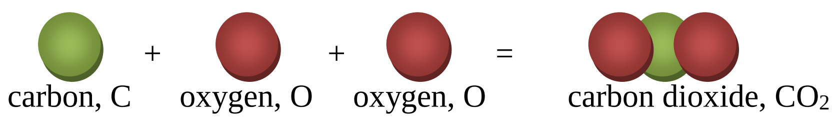
- Foundations of Atomic Theory
    - Particle theory of matter
        - First support as early as 400 B.C.
            - Democritus
            - Called nature's basic particle an atom
                - Based on "*atomos*"
                    - Meaning indivisible
        - Aristotle
            - Generation succeeded Democritus
                - Did not believe in atoms
                - All matter was continuous
                - Thought lasted nearly 2000yrs
        - By 1700's
            - Modern definition of element was accepted
                - A substance that cannot be broken down by ordinary chemical means
            - Controversy as to whether atoms always combined in the same ratio when forming a compound
                - Chemical reactions (chem rxns)
                    - Transformation of a substance or substances into one or more new substances
        - Law of Conservation of Matter (Antoine Lavoisier)
            - A chemical reaction neither creates nor destroys matter, but matter is conserved.
                - Carefully measured the mass of substances before and after a reaction.
                    - Found masses were equal.
        - Law of Constant Composition (Joseph Proust)
            - A given compound always contains the same elements in the same proportion by mass.
                - H_2O is 11%H and 89% O (always)
                    - Regardless of sample size or production
        - Law of Multiple Proportions

- If two or more different compounds are composed of the same elements, then the ratio of the masses of the second element combined w/ a certain mass of the first element is always a ratio of small whole numbers
    - Consider CO_2 and CO
        - 1g of C in CO_2 combines with 2.66g of O
        - 1g of C in CO combines with 1.33g of O
            - Ratio of the mass of O is 2.66:1.33 or 2:1

- Dalton's Atomic Theory (John Dalton)
    - Proposed an explanation for the three laws

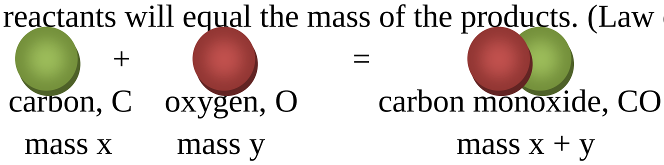
1. All matter is composed of atoms. Each element is composed of extremely small particles called atoms.
2. Atoms of a given element are the same in size, mass, and other properties; atoms of different elements differ in size, mass, and properties. In other words, identical atoms differ from other atoms.
3. Atoms cannot be divided, created, or destroyed.
4. Atoms combine in simple whole number ratios to form chemical compounds. A given compound always has the same relative numbers of and kinds of atoms. (Law of Definite Proportions, Law of Multiple Proportions)

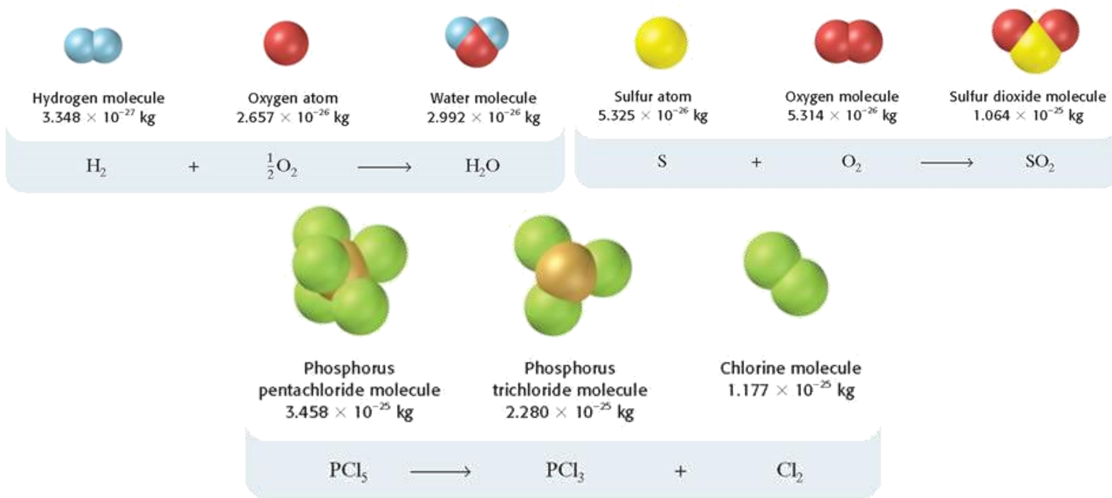




Name of compound	Description	As shown in figures	Formula	Mass O (g)	Mass N (g)	$\frac{\text{Mass O (g)}}{\text{Mass N (g)}}$
Nitrogen monoxide	colorless gas that reacts readily with oxygen		NO	16.00	14.01	$\frac{16.00\text{ g O}}{14.01\text{ g N}} = \frac{1.14\text{ g O}}{1\text{ g N}}$
Nitrogen dioxide	poisonous brown gas in smog		NO_2	32.00	14.01	$\frac{32.00\text{ g O}}{14.01\text{ g N}} = \frac{2.28\text{ g O}}{1\text{ g N}}$

5. Chemical reactions involve the combination, separation, or rearrangement of atoms. The mass of reactants will equal the mass of the products. (Law of Conservation of Mass)

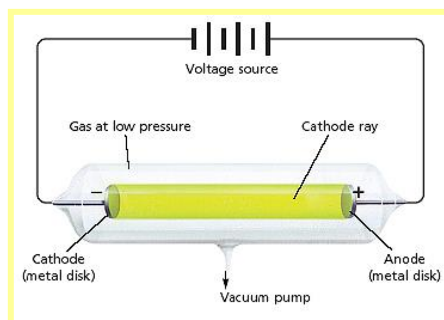




- Modern Atomic Theory
  - By turning Democritus' idea into a scientific theory, Dalton opened up the testing of the theory by experimentation.
      - What parts of Dalton's Atomic theory have been proven incorrect?
      - What parts remain the same?

STRUCTURE OF THE ATOM SECTION #2

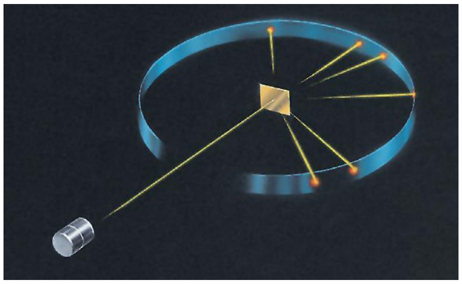
- Atom
  - Smallest part of an element that retains the properties of the element
  - Daltons model of the atom
    - BB Model
      - A hard, indestructible sphere
        - Smallest part of matter
- Discovery of Electron
  - 1st subatomic particle to be discovered
  - J.J Thomson
    - Cathode ray tube
      - A glass tube with very low pressure of a gas
        - Electric current flowed from one end to the other
          - Glowing occurred called a cathode ray
        - A very small paddle wheel was place in between the ends of the tube
          - When an electric current was applied the paddle wheel moved from one end to the other
            - Demonstrated ray had enough mass to move wheel.
        - Ray was deflected by a magnet same as a wire carrying a current.
        - Ray was deflected away from a negatively charged object
    - Experiments by JJ Thomson
      - Found the ratio of the ray's charge to mass was the same for all metals used in the cathode ray tube.



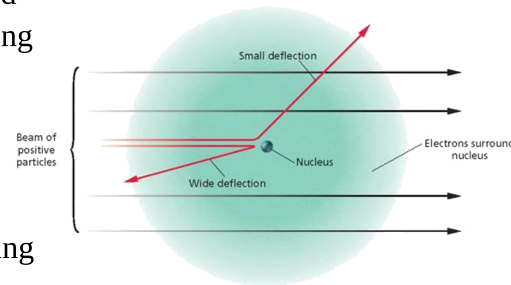
- Concluded all rays are composed of identical negatively charged particles (later named electrons)
- Plum Pudding Model of the atom (chocolate chip cookie model)
  - Large ambiguous positive charge w/ electrons interspersed through positive charge

- Robert Millikan
  - Oil drop experiment
    - Ionized oil drops by using x-rays
    - Found the mass of an electron was about 2 thousandths the mass of the simplest H atom
      - Since
        - Mass of e^- = 9.109×10^{-31}kg, 1/1837 the mass of H atom
    - Confirmed e^- carried a negative charge
    - Concluded e^- present in all atoms
  - Two inferences made of atomic structure from electron experiments
    1. Atoms are electrically neutral, positive and negative charge balance
    2. Since electrons have so little mass, most of the mass of an atom must come from some other particle(s).

- Discovery of the Atomic Nucleus
  - Ernest Rutherford (with Hans Geiger and Ernest Marsden)
    - Gold Foil Experiment
      - Bombarded thin gold foil (pounded to a few atoms thick, gold is the most malleable metal) with fast moving alpha particles
        - Alpha particles
          - Helium nuclei ($^{4}_{2}He^{2+}$)
      - Expected charge and mass to be uniformly distributed
        - Expected alpha particles to pass through w/ a slight deflection
        - Set up experiment to check for wide angle deflection
          - Why?
      - Found most did go through but 1 in 8000 redirected back at the source
        - Wide angle deflection
    - Rutherford theorized the reflecting force must be small in size and be positively charged
      - Small volume
        - Due to small number of deflections
      - Positive charge
        - Due to the 1 in 8000 direct deflections
      - Called this small, positive mass the nucleus
        - Volume of nucleus a very small part of the overall volume of the atom



                - Size of a marble, then the size of the atom would be about the size of a football field
            - Called the individual particles comprising nucleus protons
                - Same charge value as electron but opposite (+)
        - Orbital theory (Planetary Model)
            - Electrons orbited the nucleus like orbiting planet



Rutherford reasoned that each atom in the gold foil contained a small, dense, positively charged nucleus surrounded by electrons. A small number of the alpha particles directed toward the foil were deflected by the tiny nucleus (red arrows). Most of the particles passed through undisturbed (black arrows).

    - Robert Moseley
        - Worked with Rutherford
        - Identified atomic number
            - Number of protons in an element's atomic nucleus
                - Whole number from 1 to 104
            - Each element has a unique atomic number
    - James Chadwick
        - Worked for the University of Cambridge
        - Discovered neutrons
            - Used scattering data to calculate the mass of this neutral particle
            - Roughly the same mass as a proton but no charge
                - Actually equal to the mass of a proton and an electron
        - Last particle of an atom to be discovered
- Composition of the Atomic Nucleus
    - Composed of protons (atomic number) and neutrons
        - Protons and neutrons make up all of the nucleus' mass
            - Except the hydrogen atom
                - Only has a proton in the nucleus
        - Mass of a proton
            - $1.673x10^{-27}$kg
        - Mass of a neutron
            - $1.675x10^{-27}$kg
    - Overall charge of an atom
        - Neutral
            - No charge
        - Positive protons in nucleus is balanced by an equal number of negative electrons outside the nucleus
    - Nuclei of different elements
        - Differ in number of protons and neutrons
    - Forces holding the atom together
        - Nucleus
            - Nuclear forces
                - Strong force
                    - Works at only "very" small distances

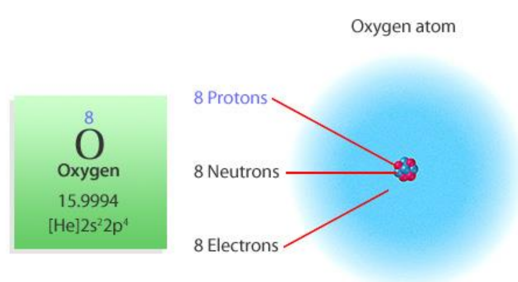
        - 1000^{th} millionth millionth of a meter
        - Attraction between protons
        - Attraction between neutrons
        - Attraction between protons and neutrons
      - Much stronger than the repulsive force between protons
  - Atom
    - Electrostatic force
      - Attraction between unlike charged particles
        - Protons in nucleus attract electrons outside of nucleus

- Sizes of Atoms
  - Radius of an atom is the distance from the center of the nucleus and the outer portion of the electron cloud
  - Very small
    - Use the picometer (pm) to measure
      - $1\text{x}10^{-12}$ of a meter
      - Atomic Radii range
        - 40 – 270 pm
          - Nuclei of atom
            - About 0.001 pm
            - Density of nuclei
              - About $2\text{x}10^{8}$ metric tons/cm^{3}

Properties of Subatomic Particles					
Particle	**Symbols**	**Relative electric charge**	**Mass number**	**Relative mass (amu*)**	**Actual mass (kg)**
electron	e^{-}, ${}_{-1}^{0}e$	-1	0	0.000 5486	9.109×10^{-31}
proton	p^{+}, ${}_{+1}^{1}p$ or ${}_{1}^{1}\text{H}$	+1	1	1.007 276	1.673×10^{-27}
neutron	n^{0}, ${}_{0}^{1}n$	0	1	1.008 665	1.675×10^{-27}
*1 amu (atomic mass unit) = $1.660\ 540 \times 10^{-27}$ kg					

COUNTING ATOMS SECTION #3

- Atomic Number (*Z*)
  - Number of protons in nucleus
    - Hydrogen, H
      - *Z* = 1
    - Silver, Ag
      - *Z* = 47



- Isotopes
  - Same element
    - Same atomic number
    - Different number of neutrons in nucleus

- 3 isotopes of hydrogen
    - Hydrogen-1 →1 p^+ and 0 n^0
        - protium
    - Hydrogen-2 →1 p^+ and 1 n^0
        - deuterium
    - Hydrogen-3 →1 p^+ and 2 n^0
        - tritium
- Nuclide
    - General term for any isotope of any element

- Mass Number
    - Proton + neutrons = mass of nucleus
        - $p^+ + n^0$ = mass #

Mass Numbers of Hydrogen Isotopes			
	Atomic #	Neutrons	Mass number
protium	$1p^+$	$0n^0$	$1p^+ + 0n^0 = 1$
deuterium	$1p^+$	$1n^0$	$1p^+ + 1n^0 = 2$
tritium	$1p^+$	$2n^0$	$1p^+ + 2n^0 = 3$

- Designating Isotopes
    - Hyphen notation
        - Element "-" mass number
            - Tritium
                - hydrogen – 3
            - uranium with a mass number of 235
                - uranium – 235
    - Nuclear symbol (atomic symbol)
        - $^{A}_{Z}X$
            - X – element symbol
            - ^{A} – mass number
            - $_{Z}$ – atomic number
            - Uranium – 235
                - $^{235}_{92}U$
        - Number of neutrons
            - $n^0 = A - Z$
                - $n^0 = 235 - 92 = 143$ (for uranium – 235)

Isotopes of Hydrogen and Helium				
Isotope	**Atomic Symbol**	**Protons**	**Electrons**	**Neutrons**
hydrogen – 1	$^{1}_{1}H$	1	1	0
hydrogen – 2	$^{2}_{1}H$	1	1	1
hydrogen – 3	$^{3}_{1}H$	1	1	2
helium – 3	$^{3}_{2}He$	2	2	1
helium – 4	$^{4}_{2}He$	2	2	2

- Complete Chemical Structure (symbol)
  - Same as atomic symbol
    - Includes mass number (^{A}), atomic number($_{Z}$), atomic symbol (X) AND the charge of the ion
      - 8 protons, 10 electrons, and 10 neutrons
        - $^{18}_{8}O^{2-}$
    - Chemical symbol
      - Only has the element symbol AND charge
        - O^{2-}
- **<u>Sample Problems 3.1</u>** – Particles and Atomic Symbols
  How many protons, electrons, and neutrons are in chlorine – 37? Write the atomic symbol for chlorine – 37.
  - **<u>Practice</u>**
    (1) How many protons, electrons, and neutrons are in bromine – 80? Write the atomic symbol for bromine – 80.
    (2) How many protons, electrons, and neutrons are in carbon – 13? Write the atomic symbol for carbon – 13.
    (3) Write the hyphen notation and the atomic symbol for the atom with 15 electrons and 15 neutrons.
    (4) Write the complete chemical symbol for an ion with 8 protons, 10 electrons, and 8 neutrons.
    (5) Write the complete chemical symbol for an ion with 84 protons, 80 electrons, and 125 neutrons.
    (6) Write the complete chemical symbol for an ion with 51 protons, 54 electrons, and 70 neutrons.

- Relative atomic mass
  - Atomic mass
    - Use the atomic mass unit (*amu*)
      - 1*amu* = 1/12 of a carbon-12 atom
    - The mass of one atom of an element in *amu*
    - Isotopes of an element
      - Have different atomic masses
        - Different number of neutrons will decrease/increase atomic mass
        - Does not affect chemical/physical properties of the element
  - Artificial isotopes
    - Isotopes of an element created by man
- Average Atomic Masses of Elements
  - The weighted average of the atomic masses of the naturally occurring isotopes of an element
    - Atomic mass listed on periodic table
      - H has an average atomic mass of 1.00797*amu*
  - Weighted average
    - Atomic mass of isotope multiplied by its percentage abundance in nature

- Purified 100g sample of an element
- Copper is made up primarily of two main isotopes, copper-63 and copper-65
  - 100g sample
    - 69.17% copper-63
      - Atomic mass of 62.929 599*amu*
    - 30.83% copper-65
      - Atomic mass of 64.927 793*amu*
  - Calculate Average Atomic mass (AAM) of copper
    - AAM = isotope$_1$ (%(decimal form) x mass#) + isotope$_2$(%(decimal form) x mass#) + etc.
    - AAM_{Cu} = 0.6917(62.929 599*amu*) + 0.3083(64.927 793*amu*) = 63.55amu (rounded to 100th)
    - In the event you do not have the mass in *amu*, calculate using the mass number for the element.

- **Sample Problem 3.2** – Average Atomic Mass
  What is the average atomic mass (AAM) of a 100g sample of pure uranium? Percentage of natural abundance is 0.005% for uranium - 234, 0.720% uranium - 235 and 99.275% uranium - 238.

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