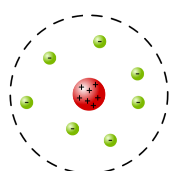
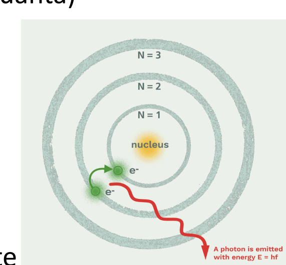
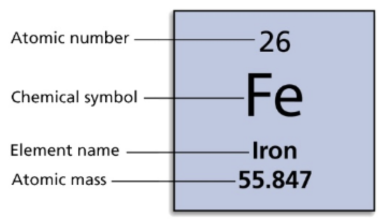
Unit 2 Atomic Structure SG

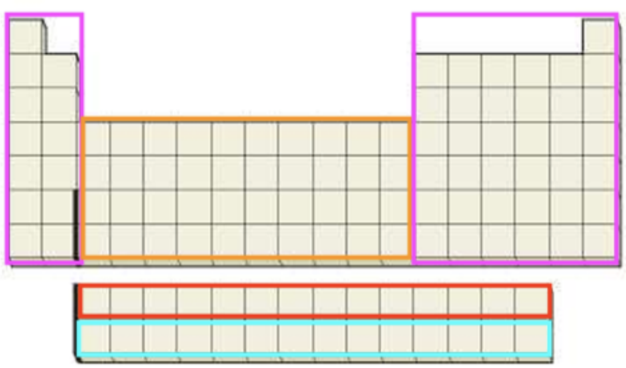
Atomic Models Scientists

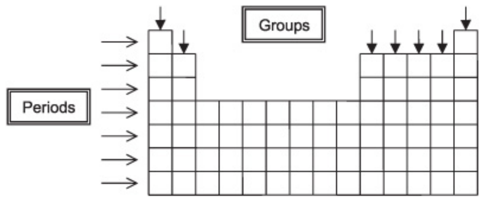
- Dalton
    - Based atomic theory on law of definite & multiple proportions (same proportions of mass)
        - E.g. H2O always consists of hydrogen & oxygen in 1:8 ratio
    - Five points of his atomic theory
        - All matter is composed of atoms
            - Dalton said that atoms are also indivisible and indestructible
            - FALSE. Can be divided into proton, neutron, electron in nuclear reaction
        - Atoms of a given element are identical
            - FALSE, as isotopes exist
        - Atoms of different elements are different
        - Atoms combine in simple whole-number ratios to form compounds
        - Atoms are rearranged in chemical reactions, not created/destroyed
- Thomson
    - He discovered the **<u>electron</u>** in the plum pudding model
    - Plum pudding model: atoms made up of + charged "soup" with embedded electrons like "plums."
- Rutherford
    - Gold foil experiment, found that atoms had small dense + charged nucleus
        - Atom mostly empty space except **<u>nucleus</u>**, almost all mass in the nucleus and all the (+) charges are in it
    - Do not draw multiple protons/neutrons in the center though. Do not draw orbits either.

      Those were not found at his time. 
- Bohr
    - Bohr model: proposed that electrons orbit the nucleus in **<u>specific energy levels</u>** or shells at set distances. Electrons can jump between these levels by absorbing or emitting energy in discrete amounts (quanta)
    - Close to nucleus = ground state 

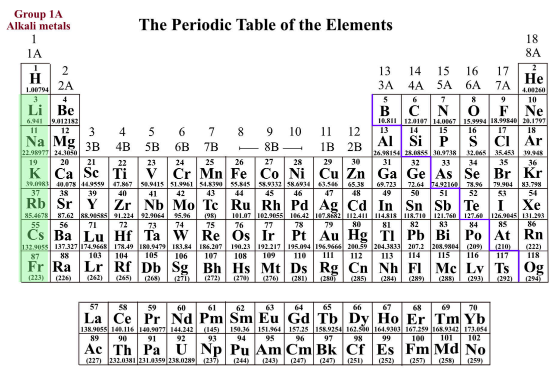
Periodic Table Basics Notes

- Mendeleyev's Periodic Table of the Elements
    - Organized elements by mass and properties
    - Things that he did that others did not:
        - Left space blank for elements whose properties did not match in between two known elements
        - estimated the atomic masses and properties of the unknown elements based on the trends observed in neighboring elements
            - made accurate predictions of previously unknown elements
- Element Symbols
    - Atomic #: # of protons
    - Chemical symbol: 1-2 letter code for name
        - First letter = uppercase, second (if exists) = lowercase
        - 

    - Atomic mass: average mass of one atom
- Parts of the Periodic Table: Sections
    - 
        - Main group elements
        - Transition metals
        - Lanthanides & Actinides (inner transition metals)
    - Elements in the same **group/family** (column!) have the same *PROPERTIES*
    - Elements in the same **period** (row!) have similar *ELECTRON STRUCTURES*

            - 

    - Elements are ordered in the current periodic table according to the **total # of protons** / increasing atomic number, rather than by mass
    - The atomic number of an atom determines which element it is
        - Atoms are made up for protons, electron, and neutrons
        - Elements are a pure substance that only have one type of atom
            - Types of atoms that have the same atomic # / number of protons
- Periodic table numbering



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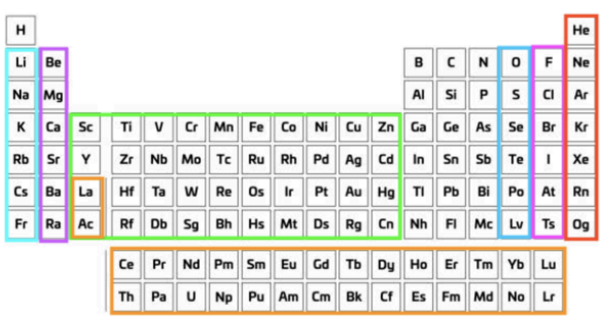
Dr. Anne O'Connor
    - Groups numbered 1, 2, … 18. Can also be done 1A, 2A, 3A, …, 8A
    - Periods numbered 1-7.
- Periodic Table families



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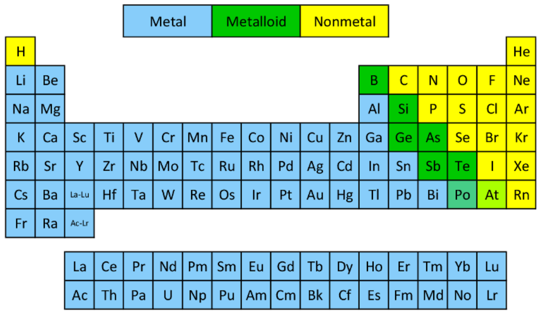
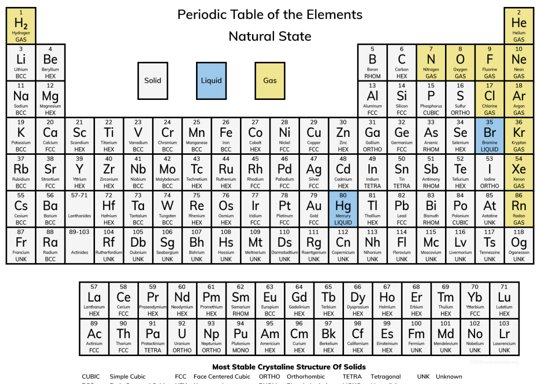
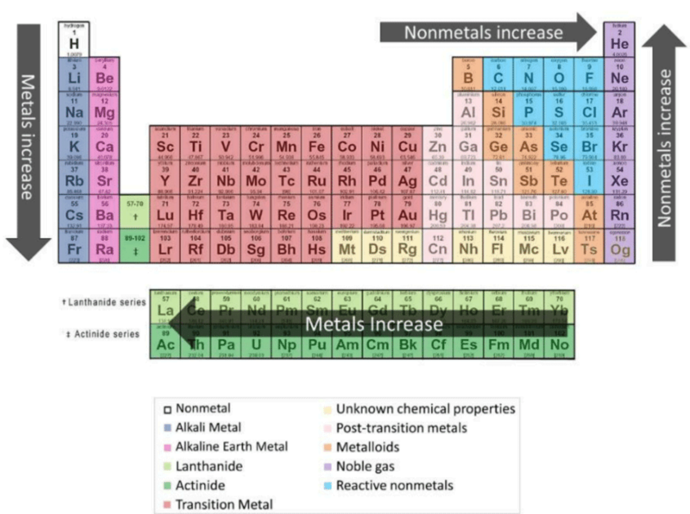
    - Alkali metals, alkaline earth metals, transition metals, chalcogens, halogens, noble gasses, lanthanides & actinides

- Metals, Nonmetals, and Metalloids
    - 

    - Most elements exist as <u>metals</u>
- Properties on the Periodic Table
    - 

    - @ room temp (25 deg C), most elements are solids, some elements are gasses, and a few elements are liquids
- Reactivity
    - 

    - Francium = most reactive on left side, fluorine most reactive on right side
    - Noble gasses are very unreactive

Subatomic Particles Notes

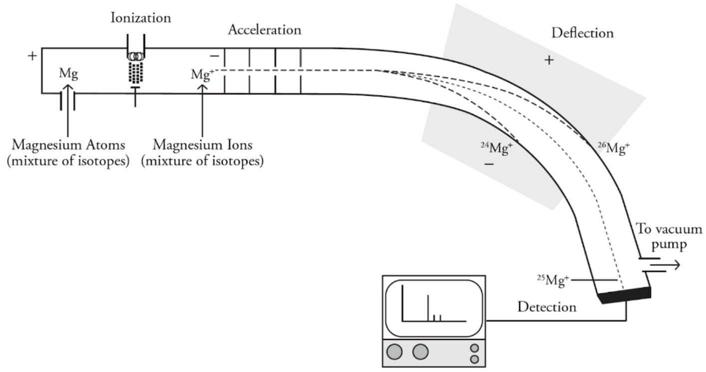
- Definitions
  - Atom = smallest unit of an element that retains the chemical properties of that element
  - Isotope = atoms of same element, but different masses (same # of protons, but different # of neutrons)
  - Ion = atoms of the same element with an overall net charge (same # of protons, different # of electrons)
    - Cations - positively charged ion, anion = negatively charged ion
    - Atoms are neutral by definition, but ions have charge
  - Molecule = a group of atoms covalently bonded together
    - An example = sugar
    - Salts = ionically bonded, so it is **NOT** a molecule
- The Subatomic Particles
  -

particle	symbol	location	charge	relative mass (amu)
proton	p^+	nucleus	+1	1 amu (1.67*10^-24 g)
neutron	n^0	nucleus	0	1 amu (1.67*10^-24 g)
electron	e^-	Electron cloud	-1	0 amu (9.11*10^-28 g)

    - Electrons have ***negligible mass*** compared to the mass of the nucleus
  - Atomic number - # of protons, sets the identity of the element
  - Mass number - # of protons + # of neutrons (always a whole #)
    - NOT the same as atomic mass
    - NOT on the periodic table
  - Atomic/Nuclide symbol
    - $^{a}_{z}X^{b}$
    - X = element symbol (identified by the # of protons)
    - Z = atomic number (# of protons)
    - a = mass number (# of protons + # of neutrons)
    - b = charge (# protons - # electrons)
  - Isotope name: [element name]-[mass number] + (ion, if necessary)
    - E.g. magnesium-24 ion, carbon-14, etc.
- Example: $^{23}_{11}Na^{1+}$
  - Atomic # / proton # = 11, mass # = 23, hence # of neutrons = 23 - 11 = 12. The charge is 1+ so there are a total of 11-1=10 electrons. Name = sodium-23 ion.

Mass Spectroscopy (not on the test)

Model 1 – Sorting by Mass



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    - Ionization: electrons knocked off sample particles to form +1 ions.
    - Acceleration: Ions move through a series of charged plates to form a narrow beam of high speed particles with equal KE
    - Deflection: Ions attracted to the negative side of an EM field causing separation of the mixture based on mass and charge.
    - Detection: ions collide with a metal plate and electrons transfer from metal to ion
- When injecting a sample into mass spectrometer the atoms/molecules turn into + ions
    - + ions because they are deflected by the + side in deflection, and in ionization they are attracted to the (-) plate
- mixture becomes deflected because mixture is separated based on mass and charge
    - Lighter ions are deflected more

Average Atomic Mass

$$(0.7899)(23.9850\text{ amu}) + (0.1000)(24.9858\text{ amu}) + (0.1101)(25.9826\text{ amu}) = \_\_\_\_\_\_\_\_\_\_$$

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- Use a weighted average
    - for example, if there is 78.99% abundance of 23.9850 amu isotope, you do 0.7899*23.9850.
    - Final answer = 4 s.f., because 0.7899 = least # of sig figs (4)
    - If multiplication AND addition (e.g. 0.04*1.000+0.05*1.200 = round final ans to 2 sig figs because 0.04 has the least # of sig figs (2)).
    - If you round using s.f. every step you will still get full credit. ***Review sig figs!!!***
- An isotope with a higher weighting towards it (e.g. 80% vs 20% for the other isotope), will be the more abundant naturally occurring isotope on Earth

Nuclear Reactions and Decay

- Forces Inside the Nucleus
  - Force pushing nucleus apart = proton-proton electrostatic repulsion
  - Force holding nucleus together = strong nuclear force (attracts all protons and neutrons / nucleons together)
  - Neutrons: the glue that holds the nucleus together
    - Experience no repulsions but experience the strong nuclear force
  - In a large neutron, the strong nuclear force works across neighbors. EM repulsion can work across any distance, even large ones, but strong nuclear force cannot. Hence, we cannot have a nucleus that is too big.
- What is a nuclear reaction
  - Involves changes in the # of protons and neutrons inside an atom's nucleus
    - Change in # of proton -> new element, change in # of neutron -> new isotope
  - Large amounts of energy released, often in the form of heat
- Nuclear vs chemical reactions
  - Chemical reactions generally only involve the electrons, not the nucleus
- What happens when an isotope is unstable
  - You have radioactive decay that is **spontaneous**, meaning occurring by itself
    - It is also constant/always happening
  - Isotope is unstable when it has the wrong ratio of protons:neutrons, or if it is just too big
  - Radioisotopes try to get a more stable state through radioactive decay.
  - All elements past bismuth (atomic number 83) are radioactive. No stable isotopes exist
- Types of Radioactive Decay
  - Alpha Particle/Decay
    - $^{4}_{2}\mathrm{He}$ or $^{4}_{2}\alpha$
      - Combination of 2 protons, 2 neutrons
        - A helium ion
      - Only very large nuclei undergo alpha decay
    - It changes the nucleus by decreasing mass # by 4, atomic # by 2, thereby changing the identity of the element
    - Alpha particles have LOW penetrating power (can be stopped by clothing/paper)
  - Beta Particle/Decay
    - $^{0}_{-1}\mathrm{B}$ or 0, -1 e
      - Beta particle ejected from nucleus when the nucleus had too many neutrons relative to protons
      - Neutrons turn into a proton (adds one proton to the nucleus) and an electron (ejected @ a high speed, called a beta particle)

        - Causes the atomic # to go up by 1 (as you add one proton), and the mass # does not change as neutron -> proton + electron, as lessened by 1 neutron is countered by the addition of 1 proton
            - electron has negligible mass and neutron and proton have almost the same mass, hence atomic mass also does not change that much
        - MODERATE penetrating power
    - Gamma Particle/Decay
        - $^{0}_{0}\gamma$
            - Occurs AFTER a nucleus undergoes alpha/beta decay
            - Nucleus with excess energy decays into atom with lesser energy
                - emits the excess energy in the form of gamma rays
                - Gamma rays are high energy photons
                    - Pure energy, no charge, no mass
                    - Particles of EM radiation
        - Does not change the atomic #, mass #, or the identity of the element
        - Has a HIGH penetrating power
- In a nuclear reaction…
    - Sum of **<u>mass</u>** number of ALL reactants = Sum of **<u>mass</u>** number of ALL products
    - Sum of **<u>atomic</u>** number of ALL reactants = Sum of **<u>atomic</u>** number of ALL products
- Nuclear Reactions
    - Fission
        - Starts when an unstable nucleus is hit by a neutron at high speed, and then the large, unstable nucleus splits into smaller, lighter nuclei and releases a lot of energy, often in the form of heat
            - Neutron, high speed + Large atom -> smaller atoms + electrons + energy
            - Triggers a chain reaction, as released neutrons from one fission event can go on to hit other nuclei which causes them to also undergo fission
        - Used for controlled chain reaction such as in nuclear power plants
        - Also used for uncontrolled chain reactions, such as the nuclear bomb, which releases as much energy as quickly as possible
    - Fusion
        - Combines small nuclei to form a larger nuclei
        - Releases massive amounts of energy, but also requires very high temp/pressure
            - 2 smaller atoms -> larger atom + energy
        - Fusion occurs in stars like the sun, in hydrogen bombs, and theorized for future nuclear power plants to be more efficient than fission

Half-Life

- Half-life = the amount of time it takes for half of the radioactive nuclei in a given sample of an isotope to decay into its products