THE PERIODIC TABLE & PERIODIC LAW

Chapter 6

I. History

A. Antoine Lavoisier (1790's): compiled a list of the elements known at the time; contained 23 elements

B. Johann Dobereiner (German physicist, 1817): noted a relationship between the properties of certain elements and their atomic masses

1. Arranged elements in groups of three by similar properties
2. Found patterns when averaging atomic masses of elements in groups
3. These groups of three are known as Dobereiner's triads

Triade 1	Triade 2	Triade 3	Triade 4	Triade 5
Li	Ca	S	Cl	Mn
Na	Sr	Se	Br	Cr
K	Ba	Te	I	Fe

C. John Newlands (English chemist, 1863): noted that there appeared to be a repetition of similar properties every eighth element.

1. He then arranged the elements known at that time into seven groups of seven each
2. Newlands referred to this arrangement as the <u>law of octaves</u>
3. Still, many elements did not fit this pattern…

Newland's Arranged Elements in Octrave

H	F	Cl	Cl / Ni	Br	Pd	I	Pt / Ir
Li	Na	K	Cu	Rb	Ag	Cs	Ti
G	Mg	Ca	Zn	Sr	Cd	Ba / V	Pb
Bo	Al	Cr	Y	Ce / La	U	Ta	Th
C	Si	Ti	In	Zn	Sn	W	Hg
N	P	Mn	As	Ds / Mo	Sb	Nb	Bi
O	S	Fe	Se	Ro /Ru	Te	Au	Os

D. Dmitri Mendeleev (Russian chemist, 1869): 6 years after Newlands' proposal, Mendeleev suggested the elements properties did repeat periodically, but that the periods were of varying lengths based on atomic masses

1. He developed a "periodic table" based on increasing atomic mass across periods and repeating properties in groups or families
2. Mendeleev left empty spaces in the table if no known element would fit the properties and atomic mass needed.
3. There were certain irregularities in Mendeleev's table due to the fact that he ordered the elements by atomic mass (ex: tellurium, iodine)

Ws 1a Introduction to the Naming of Elements

Name SAMPLE Date _____ Bell ___

Most elements have a two-letter symbol. The first letter is always CAPITAL and the second is always LOWERCASE.

Elements known for centuries were given one-letter symbols. Find all of the one letter symbols on the periodic table and list all 14 here: HYDROGEN (H), BORON (B), CARBON (C), NITROGEN (N), OXYGEN (O), FLUORINE (F), PHOSPHORUS (P), SULFUR (S), POTASSIUM (K), VANADIUM (V), YTTRIUM (Y), IODINE (I), TUNGSTEN (W), URANIUM (U)

Each element has an ***atomic name*** which is a descriptive title named after a person, place, or property. Use your periodic tables and deductive reasoning to complete the chart below.

Symbol	Atomic #	Element Name	Origin
Sc	21	SCANDIUM	SCANDANAVIA
Ge	32	GERMANIUM	GERMANY
Fr	87	FRANCIUM	FRANCE
U	92	URANIUM	URANUS
Np	93	NEPTUNIUM	NEPTUNE
Hg	80	MERCURY	MERCURY
Pu	94	PLUTONIUM	PLUTO
Cf	98	CALIFORNIUM	CALIFORNIA
Ar	18	ARGON	
Bk	97	BERKELIUM	BERKELEY
Symbol	**Atomic #**	**Element Name**	**Origin**
Cm	96	CURIUM	MARIE + PIERRE CURIE
Md	101	MENDELEVIUM	DMITRI MENDELEEV
Es	99	EINSTEINIUM	ALBERT EINSTEIN
No	102	NOBELIUM	ALFRED NOBEL
Symbol	**Atomic #**	**Element Name**	**Origin**
Rb	37	RUBIDIUM	RUBY LINES IN EMISSION SPECTRA
In	49	INDIUM	INDIGO LINE IN EMISSION SPECTRA
Ra	88	RADIUM	RADIOACTIVE / EMITS RAYS

Worksheet 1B

Many elements were discovered in the Renaissance and were given Latin names. Use your periodic tables to complete the chart below.

Symbol	Atomic #	Latin Names	English Names
Na	11	natrium	SODIUM
K	19	kalium	POTASSIUM
Fe	26	ferrum	IRON
Cu	29	cuprum	COPPER
Ag	47	argentum	SILVER
Sn	50	stannum	TIN
Sb	51	stibnum	ANTIMONY
W	74	wolfram	TUNGSTEN
Au	79	aurum	GOLD
Hg	80	hydrargentum	MERCURY
Pb	82	plumbum	LEAD

Fill in the missing information using your periodic tables.

Nb	41	NIOBIUM	5
Mg	12	magnesium	3
P	15	PHOSPHORUS	5
Ni	28	NICKEL	4
Mn	25	manganese	4
Pd	46	PALLADIUM	5
Na	11	SODIUM	3
Mo	42	molybdenum	5
Ro	84	ROENTGIUM	6
Np	93	NEPTUNIUM	7
Md	101	mendeleyium	7
Pt	78	PLATINUM	6

What pattern do you notice in the table above? MOST END IN "IUM", LARGER ATOMIC #'S ARE IN LOWER ROWS

Element Names have some similar endings.

Most ***metal*** names end in the letter I U M

Nonmetal names follow these patterns:

H, O, N end in O E N

F, Cl, Br, I, At end in I N E

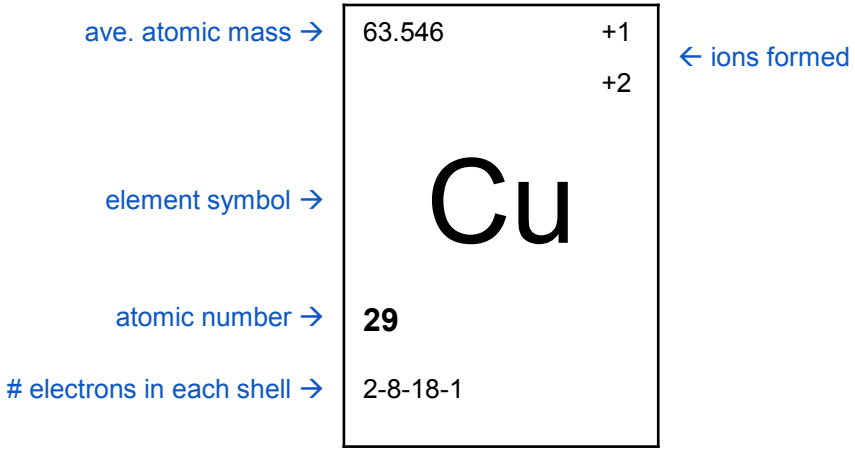
Ne, S, C, Si, Ar, Kr, Xe, Rn end in O N

E. Modern Periodic Table

1. Modern Periodic Law: similar properties of the elements occur periodically when arranged by their atomic **numbers** (not masses)
2. The arrangement of the periodic table is now based on how electrons fill various energy levels
3. Organization:
   a. Period: horizontal row of elements by increasing atomic number; seven periods exist at this time (example: Period 1 is hydrogen to helium, Period 2 is lithium to neon)

b. Group: vertical column of elements with similar properties; range from 1 - 18 and include the lanthanides (cerium – luthetium) & actinides (thorium – lawrencium)
   i. International System: numbered 1-18
   ii. American System (used in textbook): assigned a number (1-8) and a letter (A, B, C)
      - "A" group (1, 2, 13-18): usually called representative elements, possess wide range of chemical & physical properties
      - "B" group (3-12): called transition elements/metals
      - "C" groups: called inner transition elements/metals (lanthanides & actinides)

4. Element Notation
   a. First letter capitalized, second lowercase
   b. Always printed, never cursive
   c. If an element has not been officially confirmed, it is represented with a temporary name & the symbol is three letters (example: Uut, Uup)
   d. Example of element notation on your periodic table:



- Look at PT on p. 156-57
  - Copy Group #s (1A, 2A, 3B, etc…) onto your PT
  - In notes, copy entire PT from book; look at yours for info on #s 111-118
    - Color according to book PT (metals, metalloid, nonmetal, recently discovered)
    - #s 113-118 are recently discovered
    - Leave room at top to add family names next week

5. Classification of Elements
    a. Metals: generally hard & shiny, solid at room temperature, good conductors, malleable & ductile (Groups 1-12, lanthanides, actinides)
        i. Metals tend to lose electrons
        ii. 1/1A: alkali metals (+1) -- highly reactive
        iii. 2/2A: alkaline earth metals (+2) -- reactive
        iv. Lanthanides (+3) cerium to lutetium -- typical metal properties; most very rare in nature
        v. Actinides (+3,+4) thorium to lawrencium -- typical metal properties, but are radioactive; rare/nonexistent in nature, as all >92 are man-made
        vi. 3-12/B group: transition elements (variable charges) -- hard, brittle metals

b. Nonmetals: generally gases or brittle solids, transparent or have dull surfaces, poor conductors
   i. Nonmetals tend to gain electrons
   ii. 13/3A: boron group (+3)
   iii. 14/4A: carbon group (+2,+4)
   iv. 15/5A: nitrogen group (-3)
   v. 16/6A: oxygen group/chalcogens (-2)
   vi. 17/7A: halogens (-1) -- highly reactive
   vii. 18/8A: noble gases (0) -- nonreactive
   viii. **NOTE: not all members of groups 13-17 are nonmetals; some are metalloids

c. Metalloids are elements which sometimes act as metals and under different conditions act as nonmetals.
    i. “Stairstep line” under boron separates the metals from the nonmetals; elements that border this line are metalloids (except aluminum)
d. General rule:
    i. Elements with three or less electrons in the outer level are metals
    ii. Elements with five or more electrons in the outer level are nonmetals
    iii. Metals lose electrons and nonmetals gain electrons

6. Notable Elements
    a. All elements beyond uranium except plutonium are not found in nature, we have made them.
    b. Francium is the most reactive metal and fluorine is the most reactive nonmetal.
7. The s-, p-, d-, and f-block Elements
    a. The organization of the periodic table also reflects the electron configuration of the elements -- more on that next unit

- p. 158: 1-6

- Next week, I will give you an unknown metal sample and ask you to determine the identity
  - The metal will be either: one of the ones we worked with in lab (Mg, Ca, Al, Fe, Zn ,Cu), a member of Group 2, or a member of period 3 and 4
- Design a procedure that you could use to determine the identity of this unknown element – due Monday
  - You can use HCl, water, phenolphthalein, and flame tests
- Include step-by-step instructions, mLs of liquid being used, what various results of a test would indicate, etc. Basically go through a process of elimination. Example:
  - Step 1: identify color and luster of sample.
  - Step 2: Place the sample in 5 mL of HCl and observe the reaction. Gray bubbling and heat would indicate aluminum; a green solution and odor similar to that of tar indicates iron; _____ indicates _____.
  - Step 3: Place the metal in 5 mL of distilled water and phenolphthalein. If it turns pink, a reaction is occurring, which indicates a member of Group 2. If the reaction is less than that of calcium, it is most likely strontium or barium."

- Create an outline of a group of elements (assigned right): include background, isotopes, ions, properties representative elements, how they can be found in nature, and uses (pretty much anything in the book)
- Also include 3 multiple choice questions & one short answer/extended response question
- Write on a piece of paper & give to me by end of period – I'll put it all in a PowerPoint over the weekend, add anything I think is super important that you missed, & you'll "guest lecture" with me about your group next week!

Lab Group #	Group
1	1/1A (p. 181-2)
2	2/2A (p. 183-5)
3	13/3A (p. 186-7)
4	14/4A (p. 187-9)
5	15/5A (p. 189-91)
6	16/6A (p. 192-4)
7	17/7A (p. 194-5)
8	18/8A (p. 196)

II. Properties of Groups

A. Hydrogen: considered a group by itself
   1. Isotopes: protium* (1 p^+, 0 n^0), deuterium (1 p^+, 1 n^0), tritium (1 p^+, 2 n^0)
   2. Has one outer electron, which accounts for its unique properties
   3. Can react in four ways:
      a. Like a metal: lose an electron and become a positive hydrogen ion, H^+
      b. Share its single electron to form compounds (HCl, H_2O)
      c. Gain an electron to form a hydride ion, H^-
      d. Form a bridge between two atoms
   4. Most abundant & lightest element in the known universe
   5. Usually occurs as a colorless odorless flammable gas (H_2)
   6. Uses: nuclear fusion (stars), fuel (furnaces, cars, stoves, buses, welding, etc.)

B. Alkali Metals: Group 1/1A

1. Characteristics:
   a. +1 oxidation number & charge
   b. Highly reactive, especially with water
   c. Soft and silvery except cesium (yellow)
2. Representatives:
   a. Lithium (Li): found in water, soil, and rocks; least reactive; used in batteries & dehumidifiers, as well as to treat bipolar disorder
   b. Sodium (Na): with K, most abundant alkali metals; used in vapor lamps & nuclear reactors; necessary for life; ions are common in fluid surrounding cells; most common compound is NaCl (table salt, used for flavor & preserving food)
   c. Potassium (K): with Na, most abundant alkali metals; more reactive & less used industrially; necessary for life; ions are common in cells; used in fertilizers; KCl is salt substitute; KNO_3 is used in fireworks

C. Alkaline Earth Metals: Group 2/2A

1. Characteristics:
   a. +2 oxidation numbers & charges
   b. Soft and silvery except strontium (yellow)
   c. First three stable, last three form radioactive isotopes
2. Representatives:
   a. Beryllium (Be): used in nuclear reactors & making non-sparking tools
   b. Calcium (Ca): found widely in nature ($CaCO_3$); limestone, chalk, marble; antacid tablets, abrasives in toothpaste
   c. Magnesium (Mg): malleable; contained in chlorophyll; ions contribute to human muscle function & metabolism; hard water; used in lightweight corrosion resistant alloys

D. Boron Group: 13/3A

1. Characteristics:
   a. +3 oxidation numbers & charges
   b. All soft metals except boron (yellow-brown powder)
   c. All conduct electricity except boron
2. Representatives:
   a. Boron (B): doesn't have much in common with group; used in producing borosilicate glass such as Pyrex and Kimax (heat and impact resistant)
   b. Aluminum (Al): excellent conductor; extremely ductile and malleable; most abundant metal in the Earth's crust; used in corrosion resistant alloys, wiring, antiperspirants, & many ceramic materials; difficult to extract from ore, so recycle it!
   c. Gallium (Ga): melts in your hand; used in thermometers; Ga-containing compounds used in semiconductor chips & lasers

E. Carbon Group: 14/4A

1. Characteristics:
   a. +2 or +4 oxidation number; carbon and silicon can have -4 as well
   b. First three elements form brittle solids; last two are soft and metallic
   c. Forms allotropes: different forms of an element with different structures & properties in the same state of matter
2. Representatives:
   a. Carbon (C): all living things are carbon based; millions of carbon compounds exist (study of them is called organic chemistry); minerals & ores containing carbonates, cyanides, etc. are part of inorganic chem; graphite is used in pencils and lubricants & diamonds used in jewelry and cutting/grinding tools
   b. Silicon (Si): second most plentiful element in the Earth's crust after oxygen; found in quartz, sand, and other silicates (a silicon atom bonded to four oxygen atoms); used in glass, transistors, computer chips, & synthetic motor oils
   c. Lead (Pb): used to be commonly used until people realized it was toxic; now used in storage batteries for cars

F. Nitrogen Group: 15/5A

1. Characteristics

a. Oxidation numbers range from -3 to +5, -3 being the most common

b. All are brittle solids except nitrogen (gas)

c. Compounds range from stable to highly unstable

2. Representatives:

a. Nitrogen (N): nitrogen gas, N_2, is extremely stable; other nitrogen compounds are highly unstable, such as trinitrotoluene (TNT) and dynamite; ammonia (NH_3) is a fertilizer & cleaning compound; nitric acid (HNO_3) is used in production of fertilizer & explosives

b. Phosphorus (P): DNA, RNA, ATP, ADP are biologically important compounds which contain phosphate groups; used in fertilizer & converted to phosphoric acid, H_3PO_4, for industrial purposes; phosphate runoff is environmentally harmful

G. Chalcogens: Group 16/6A

1. Characteristics

a. All have -2 oxidation number except polonium (+2, +4)

b. Oxygen is a gas; sulfur, selenium, & tellurium are brittle solids; polonium is radioactive

c. The first three have allotropic forms, the last two form metallic compounds

2. Representatives:

a. Oxygen (O): most abundant element in the Earth's crust; very reactive; two basic forms: oxygen gas (O_2) which is necessary for combustion & respiration, and ozone (O_3), a highly reactive compound which absorbs UV radiation

b. Sulfur (S): sulfuric acid (H_2SO_4) is the most highly used substance in the USA & is produced in large quantities; used in fertilizer production, steel production, petroleum refining, and in production of paints & pigments; found in hydrothermal vents

c. Selenium (Se): found in vitamins & foods to help prevent cell damage; converts light into electricity & is used in solar panels, semiconductors, & photocopiers

H. Halogens: Group 17/7A

1. Characteristics
   a. -1 oxidation number & charge
   b. Most reactive nonmetals
   c. Can form compounds among themselves as well as with most other elements
   d. Pose a threat to living organisms when in the pure form
   e. Fluorine and chlorine are gases, bromine is a liquid, iodine is a solid, & astatine is radioactive
2. Representatives:
   a. Fluorine (F): most reactive; compounds are used to help prevent tooth enamel from decay, & create nonstick coatings for cookware
   b. Chlorine (Cl): chlorides of many elements exist; used in manufacturing & food processing; common acid is HCl (found in your stomach); NaOCl is household bleach; chlorine gas (Cl_2) is deadly & often accidentally produced by mixing bleach and cleansers.
   c. Iodine (I_2): used as a disinfectant; necessary in diet (iodized salt) to prevent thyroid condition called goiter

I. Noble Gases: Group 18/8A

1. Characteristics
   a. Oxidation number is zero, do not tend to form compounds
   b. All gases, radon is radioactive
   c. Stable electron configurations
2. Representatives:
   a. Helium (He): used in balloons, blimps, & airships, and to fill tubes in brightly colored signs along with neon, krypton, & xenon
   b. Neon (Ne): used in light displays with other noble gases
   c. Argon (Ar): used to fill light bulbs. Protects active metals during welding

J. Transition Metals: Groups 3-12 (3B-8B, 1B, 2B)

1. Characteristics
   a. Variable oxidation numbers ranging from +1 to +8
   b. Hard and brittle metals
   c. High melting points
   d. Principal structural metals (alone & as alloys)
   e. Some exhibit ferromagnetism: strong attraction of a substance to a magnetic field
2. Metallurgy: branch of applied science that studies and designs methods for extracting metals and their compounds from ores
3. Representatives:
   1. Silver (Ag): tableware, jewelry, dental fillings (silver-mercury amalgam), mirrors
   2. Chromium (Cr): highly resistant to corrosion; used to make stainless steel
   3. Ions of the transition metals are often responsible for the vivid colors found in liquids and solids (gemstones)
   4. All period 4 metal (except Sc & Ti) are necessary for living things

K. Lanthanides (part of Inner Transition Metals)

1. Characteristics
   a. +3 oxidation numbers
   b. Members have nearly identical properties
   c. Most are very rare in nature
2. Representatives:
   a. Neodymium (Nd): used in some alloys; neodymium oxide is used in glass filters & lasers
   b. Lanthanide compounds are used in movie projectors, high-intensity searchlights, lasers, & tin ted sunglasses

L. Actinides (part of Inner Transition Metals)

1. Characteristics
   a. Most have +3 or +4 oxidation numbers
   b. Members have nearly identical properties
   c. All are radioactive isotopes
   d. Rare or nonexistent in nature, after atomic number 92 are man-made
2. Representatives:
   a. Curium (Cm): made by bombarding plutonium with neutrons; highly reactive, toxic, deadly; used as an energy source in nuclear generators in spacecraft
   b. Uranium (U): found in small amounts in nature; refined for use in nuclear reactors & atomic weapons
   c. Plutonium is used as fuel in nuclear power plants; Americium can be used in smoke detectors

III. Periodic Trends (Section 6-3)

A. Certain characteristics of elements appear at regular intervals as atomic number increases; properties of elements are a result of the electron configuration
B. Diagonal Relationships: when elements in one group are more closely related in properties to elements of another group in a diagonal pattern; most common in second and third periods (ex: Li-Mg, Be-Al, B-Si)

C. Atomic radii

1. Background: electrons are contained in specific energy levels
2. As you go down a group in the periodic table, there are more energy levels; therefore, the electron cloud is bigger, and the radii of the atoms are bigger
3. As you go across a period the energy level remains the same, but protons are added; protons increase the attraction between (+) and (-) particles, so in general, this pulls the electrons closer – decreasing atomic radii.
4. **RULE:** atomic radii increases top to bottom and decreases left to right (see p. 163)

D. Radii of Ions

1. The radii of ions may be greater than or less than the radii of stable atoms
2. The ionic radii of nonmetals tend to be larger since they gain electrons and less for metals which lose electrons (see p. 166)
3. All atoms try to achieve noble gas configurations
   a. Example:
      i. $Na \rightarrow Na^{+}$ (Ne)
      ii. $Cl \rightarrow Cl^{-}$ (Ar)
      iii. Example: bonding - NaCl
      $Na \rightarrow e^{-} \rightarrow Cl$
      Sodium loses an electron to get to Ne's configuration; Cl gains that same electron to get to Ar's configuration
4. **RULE:** Ionic radii decrease left to right and then suddenly increase, and then decrease again

E. Ionization energy: energy necessary to completely remove an electron from an atom of the element being bombarded, leaving a positive ion (kJ/mol)

1. First ionization energy: energy needed to remove the most loosely held electron in an atom.
2. **RULE:** Ionization energies increase across rows and decrease down columns (see p. 167)
3. Exceptions:
   a. Be → B decrease
   b. N → O decrease

4. Multiple ionization energies: second, third, fourth and other higher ionization energies exist, which measure the energy needed to remove additional electrons
5. This energy increases dramatically with each additional electron removed (see p. 168)

F. Electronegativity: relative tendency of an atom to attract shared electrons to itself when bound with another atom

1. The most active metals (lower left) have the lowest electronegativities, the most active nonmetals (upper right) have the highest electronegativities (see p. 169)
2. Generally decreases as you move down a group & increases as you move across a period