Ch. 5 Notes – THE PERIODIC TABLE AND PERIODIC LAW

NOTE: Vocabulary terms are in **<u>boldface and underlined</u>**. Supporting details are in *italics.*

I. Development of the Periodic Table

A. Antoine *Lavoisier* (1743-1794)
1) compiled a list of the known elements (33 at the time)
2) "metals, nonmetals, earths, and gases"

B. Johann *Dobereiner*, German chemist (1780-1849) and his triads
1) In 1817, he formed *triads (groups of threes) of similar elements* such as Ca, Sr, Ba
2) the middle element of the triad was an average of the other two atomic masses

C. John *Newlands*, English chemist (1837-1898) and the Law of Octaves
1) In 1863, he arranged elements according to increasing atomic masses
2) *Law of Octaves—properties of elements seemed to change every eighth element* (noble gases were not known yet)

D. Dmitri *Mendeleev—the father of the modern periodic table* (1834-1907)
Lothar Meyer (1830-1895) also did this research but Mendeleev published first
1) *similar properties of elements were grouped in columns*
2) *he predicted properties of "missing" elements*
3) he arranged the elements by increasing atomic masses, not atomic numbers

E. Henry *Moseley*, British chemist (1887-1915)
1) In 1913, he found atomic numbers ("nuclear charges") of the elements by measuring the wavelength of x-rays given off by specific metals
2) he *ordered the elements by increasing atomic numbers*
3) **<u>Periodic Law</u>**— *there is a periodic (repeating) pattern in chemical and physical properties of the elements when they are arranged by increasing atomic numbers*
4) he was killed in World War I, which was a great loss to science

II. The Modern Periodic Table

A. element arrangements

<u>GROUP NUMBER</u>	**<u>SPECIAL NAME</u>**	**<u>CHARGE OF IONS</u>**
Group IA (1)	**<u>alkali metals</u>**	**1+**
Group IIA (2)	**<u>alkaline earth metals</u>**	**2+**
Group IIIA (13)	**-----**	**some 3+**
Group IVA (14)	**-----**	**varies; metals 2+, 4+**
Group VA (15)	**-----**	**3-**
Group VIA (16)	**<u>chalcogens</u>**	**2-**
Group VIIA (17)	**<u>halogens</u>**	**1-**
Group VIIIA/0 (18)	**<u>Noble Gases</u> (inert)**	**0 (none)**
Group III B-XII B (3-12)	**<u>Transition Metals</u>**	**varies**
<u>Inner Transition Metals</u>; Lanthanide and Actinide Series ; Rare Earth Metals		**varies**

1) **<u>representative elements</u>**— A groups (IA – VIIIA), or Groups 1, 2, 13, 14, 15, 16, 17, 18
2) **<u>transition metals</u>**— B groups (IIIB-XIIB), or Groups 3-12
3) **<u>inner transition metals</u>**— Lanthanide series and Actinide series (bottom two rows)
3) **<u>groups</u>** = *vertical* columns
4) **<u>periods</u>** = *horizontal* lines

B. **<u>Periodic Law</u>** (see Moseley)— *there is a periodic (repeating) pattern in chemical and physical properties of the elements when they are arranged by increasing atomic numbers* This is **<u>Periodicity</u>**.

1) elements are arranged by increasing atomic numbers
2) *atomic masses are in amu (atomic mass units)*

C. electron "shell" (energy level) capacities:

Shell #	**maximum number of electrons**
n = 1	**2**
n = 2	**8**
n = 3	**18**
n = 4	**32**
n = 5	**32**
n = 6	**18**
n = 7	**8**

(NOTE for p. 166-170.: We will cover electron configurations and their relationship to the periodic table in chapter 4. We do chapter 5 first.)

III. Electrons

A. **<u>valence electrons</u>**—electrons in the outermost "shell" or level

B. atomic structure of elements within a period: *as you move from left to right, the number of valence e- increases*

C. atomic Structure of elements within a group: *valence number = group number*

1) Electron dot diagrams (**<u>Lewis structures</u>**)—diagrams of valence electrons as *dots around the symbol of the element*
    a) *only the valence electrons* are shown
    b) used to see numbers of shared and unshared electron pairs around an atom
    c) number of unpaired electrons can show how many bonds can form
    d) procedure
        i) write the symbol of the element
        ii) place dots around symbol according to the number of valence electrons

**** There are a few different methods of placing the dots, but we will use this way…*

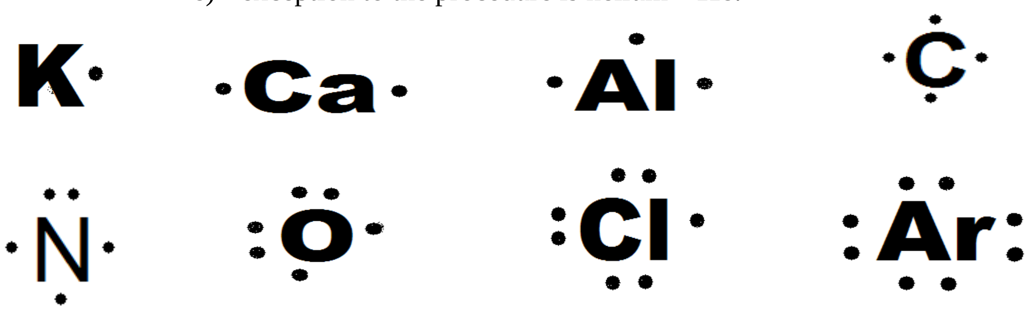
"right, left, up, down, top all the way around (counterclockwise)"

3 5

2 **SYMBOL** **1**
6 **8**

4 7

e) exception to the procedure is helium **He:**



GROUP NUMBER	# VALENCE (OUTER) ELECTRONS	# ELECTRON DOTS	STATUS
Group IA (1)	**1**	**1**	**(has 1 out of 8, missing 7 to be full)**
Group IIA (2)	**2**	**2**	**(has 2 out of 8, missing 6 to be full)**
Group IIIA (13)	**3**	**3**	**(has 3 out of 8, missing 5 to be full)**
Group IVA (14)	**4**	**4**	**(has 4 out of 8, exactly half-full)**
Group VA (15)	**5**	**5**	**(has 5 out of 8, needs 3 to be full)**
Group VIA (16)	**6**	**6**	**(has 6 out of 8, needs 2 to be full)**
Group VIIA (17)	**7**	**7**	**(has 7 out of 8, needs 1 to be full)**
Group VIIIA (18)	**8**	**8**	**(has 8 out of 8, completely full)**

IV. Physical States and Classes of the Elements

A. physical states of the elements

1) *most elements are solids* at room temperature
2) *Br, Hg, Cn are liquids at room temperature*
3) *gases at room temp.:* H_2, N_2, O_2, F_2, Cl_2, *He, Ne, Ar, Kr, Xe, Rn*

B. occurrence

1) most elements are naturally occurring
2) synthetic: Tc #43, Pm #61, all elements #93 and higher

C. classification

1) **metals**—*ductile, malleable, shiny, lustrous, conductors*
2) **nonmetals**—*brittle solids, nonconductors*

*** *C,H,N,O,P,S, - important nonmetallic elements for living organisms* ***

3) **metalloids**—*semimetals or semiconductors; on the periodic table "staircase"*
   - B, Si, Ge, As, Sb, Te, Po, At; probably Ts (NO Aluminum)

V. The Modern Periodic Table

A. **alkali metals—Group IA; Group 1**: **Li, Na, K, Rb, Cs, Fr**

1) *characteristics: good conductors, soft, silver-white, not found in elemental form naturally, react violently with water to form bases (alkali)*
2) uses of sodium: Na in NaCl;, NaOH used in paper-making and soap-making; NaOH in "lye" in oven and drain cleaners; Na^+ ion is important to our bodies
3) uses of potassium: K in KOH (hydroxide cleaners); in fertilizer; K^+ ion is important to our bodies

B. **alkaline earth metals—Group IIA; Group 2**: **Be, Mg, Ca, Sr, Ba, Ra**

1) *obtained from mining mineral ores*; *not found in elemental form naturally*
2) *some react with water, but less violently than the alkali metals*
3) uses of calcium ion and magnesium ion: important to our bodies
4) uses of strontium: pyrotechnics

C. **Group IIIA; Group 13 (aluminum group)**: **B, Al, Ga, In, Tl**

1) Al is the most useful member of the group; does not react with water
2) uses of aluminum: water purification; fabric dyeing; aluminum cans, siding, and foil; paper manufacture; in deodorants; $Al(OH)_3$ in antacids
3) uses of boron: in $Na_2B_4O_7 * 10H_2O$ borax (water softener and cleaner) and H_3BO_3 boric acid (contact lens cleaner and roach insecticide)
4) uses of gallium: GaAs (gallium arsenide) used in some semiconductors

D. **<u>Group IVA; Group 14 (carbon group)</u>: C, Si, Ge, Sn, Pb**

1) uses of carbon: graphite, diamond, organic compounds
2) uses of silicon: (in many minerals); SiO_2 in sand; semiconductors; microchips; glass photocells
3) uses of germanium: photocells
4) uses of tin and lead: alloys (solder Pb + Sn; bronze = Cu + Sn)
5) uses of tin: foil, metal can coating

E. **<u>Group VA; Group 15 (nitrogen group)</u>: N, P, As, Sb, Bi**

1) uses of nitrogen: needed by plants; nucleic acids (DNA and RNA); liquid N_2 for low temps; TNT; ammonia (NH_3)
2) uses of phosphorus: phosphate $(PO_4)^{3-}$;ATP; nucleic acids; fertilizer; red P used in matches
3) uses of arsenic: GaAs (gallium arsenide) used in some semiconductors
4) uses of antimony: alloys with Pb and other metals

F. **<u>chalcogens—Group VIA; Group 16 (oxygen group)</u>**: **O, S, Se, Te, Po**

1) uses of oxygen: atmospheric gas O_2; in water (H_2O); product of photosynthesis; ozone O_3; hydrogen peroxide (H_2O_2); in bleach – sodium hypochlorite (NaClO); in sulfuric acid (H_2SO_4)
2) sulfur: S_8, SO_2, SO_3; H_2SO_3, H_2SO_4…

G. **<u>halogens</u>—Group VIIA; Group 17** : **F, Cl, Br, I, At**

1) F is the most reactive
2) found as **<u>diatomic molecules</u>**: F_2, Cl_2, Br_2, I_2
3) commonly found as ions in a salt
4) hydrogen has characteristics of Group IA and VIIA
5) uses of fluorine: NaF or SnF_2 "fluoride"
6) uses of chlorine—$CaC1_2$ ("Damp Rid"), NaCl , Cl^- (chloride) ion in the body; water purification
7) uses of iodine: I^- (iodide) ion in the body; ion put into table salt; antibacterial cleaner

H. **<u>Noble Gases</u>—Group VIIIA / 0; Group 18: He, Ne, Ar, Kr, Xe, Rn**

1) inert; inactive; valence is full
2) they do not form compounds unless chemically "forced" (XeO_3)
3) uses: Ne/Kr/Xe signs, He balloons, welding atmosphere Ar and He

TRENDS: **ALL TRENDS INCREASE TOWARD FLUORINE, EXCEPT FOR RADIUS**

There are exceptions to periodic trends. Trends are general patterns.

VI. Periodic Trends in Atomic Size

A. **<u>atomic radius</u>**—half the distance between two nuclei in a diatomic molecule
   1) *diatomic = consisting of two identical atoms*
   2) **seven <u>diatomic molecules</u> ("Super Seven"): H_2, N_2, O_2, F_2, $C1_2$, Br_2, I_2**

B. *group trends*
   1) *atomic size increases from top to bottom*
   2) reason: *adding n #s = adding electrons = adding shells*

C. *periodic trends*
   1) *atomic size decreases from left to right*
   2) reason: *adding electrons to the same shell pulls the electron clouds in more, as more protons are added to attract more electrons*
   3) *"shielding effect" of inner electrons - also called nuclear shielding*

VII. Periodic Trends in *Ionic Radius*

A. review of ions

1) **ion** – *charged atom*, positive or negative
2) **cation** – *positive ion*
3) **anion** – *negative ion*

CP AN	**Cations Positive, Anions Negative**	"Cat People Are Nice"

B. cations (positive ions)

1) *cations are smaller than their neutral atoms*
2) reason: *electrons have been removed*

C. anions (negative ions)

1) *anions are larger than their neutral atoms*
2) *electrons have been added*

D. *group trends*

1) *ionic radius increases from top to bottom*
2) reason: reason: *adding n #s = adding electrons = adding shells*

E. *periodic trends*

1) *ionic radius decreases from left to right*
2) reason: *adding electrons to the same shell pulls the electron clouds in more, as more protons are added to attract more electrons*
3) *"shielding effect"* of inner electrons

VIII. Periodic Trends in Ionization Energy

A. **ionization energy**—the *energy needed to remove an electron* from an atom, in kJ/mol

B. first ionization energy—the energy needed to remove the first electron

C. *group trends*

1) *(first) ionization energy decreases from top to bottom*
2) *reason: outermost electron is farther and farther from the nucleus in larger atoms, so it is more easily removed*

D. *periodic trends*

1) *(first) ionization energy increases from left to right*
2) reason: *"nuclear charge" increases; more attraction between electrons and protons*

IX. Periodic Trends in Electronegativity

A. **electronegativity**—the *"greediness" of an atom for electrons* when chemically reacting

B. noble gases do not have electronegativity values

C. electronegativity trends not completely regular

1) *fluorine = most electronegative element* with a value of 4.0 (smallest anion formed)
2) cesium = least electronegative element (largest cation formed)

D. *group trends: electronegativity decreases from top to bottom*

E. *periodic trends: electronegativity increases from left to right*

F. chemical bond character is determined by electronegativity differences between the bonding partners

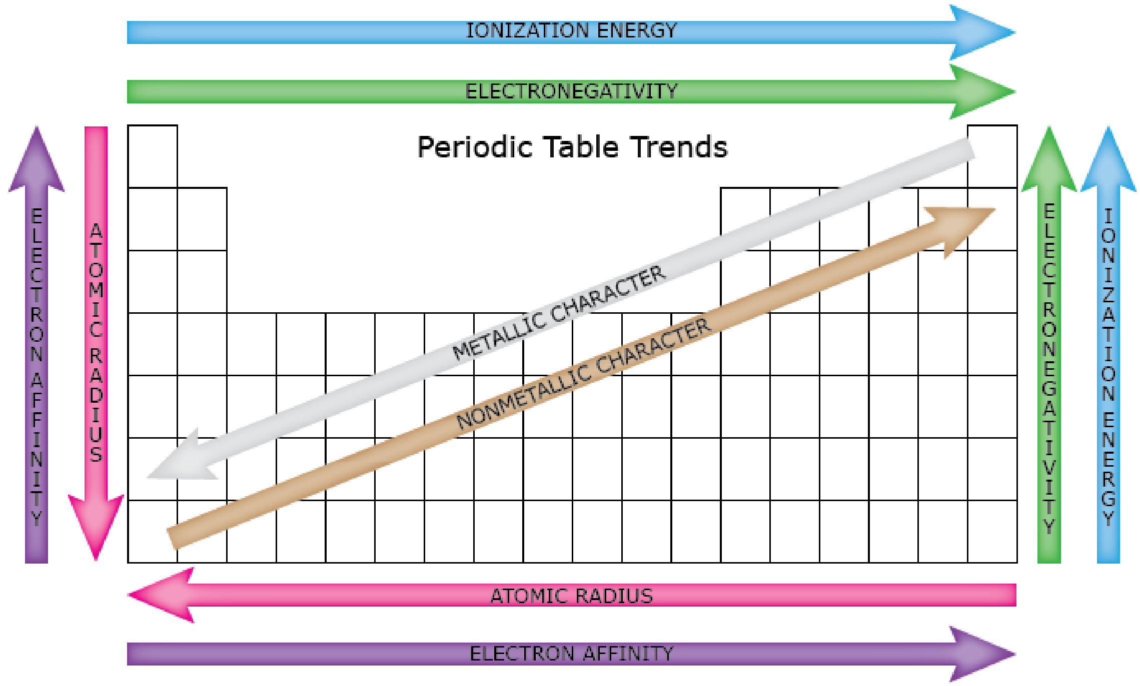
X. Periodic Trends in Electron Affinity

A. *electron affinity (EA)—energy required to add an electron to a gaseous atom*

B. EA hard to determine; trends less clear

C. …but usually increases from left to right and decreases from top to bottom

PERIODIC TREND SUMMARY (from slideshare)



SUMMARY OF PERIODIC TRENDS
(trends are generalizations)

"ALL TRENDS INCREASE TOWARD FLUORINE, EXCEPT FOR RADIUS"

	TOP to BOTTOM	**LEFT to RIGHT**
ATOMIC RADIUS	**increases ↑**	**decreases ↓**
IONIZATION ENERGY	**decreases ↓**	**increases ↑**
ELECTRO-NEGATIVITY	**decreases ↓**	**increases ↑**
ELECTRON AFFINITY (generally)	**decreases ↓**	**increases ↑**

IONIC RADIUS:

cation (+) < neutral atom
anion (-) > neutral atom