Outline

- Classes of materials
- Chemistry review
- Review of atomic structure
- Review of the periodic table
- Density, atomic # & wt, mole, Avogadros #
- Bonding forces and energy

Classes of materials

	POLYMERS	CERAMICS	METALS
DUCTILITY	Varies	Poor	Good
CONDUCTIVITY (ELECTRICAL & THERMAL)	Low	Low	High
HARDNESS/STRENGTH	Low – medium	………..	Medium – high
CORROSION RESISTANCE	Fair – good	Good	Fair – poor
STIFFNESS	Low	High	Fair
FRACTURE TOUGHNESS	Low – medium	Low	High
MACHINABILITY	Good	………	……..

Why study bonding?

- Because the properties of materials (*strength, hardness, conductivity, etc.*.) are determined by the manner in which atoms are connected.
- Also by how the atoms are arranged in space → ……….

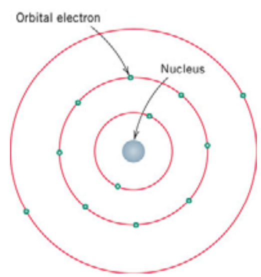
What determines the nature of the chemical bond between atoms?

- Electronic structure (distribution of electrons in atomic orbitals)
- Number of electrons and ……………… (tendency for an atom to attract an electron)

Atomic Structure

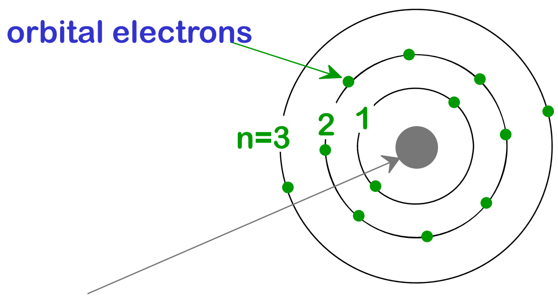
Bohr model of the atom: (1913)

– Bohr atomic model
  - electrons revolve around nucleus in discrete orbitals



Based on earlier work of Rutherford and his own from spectral emission studies

BOHR ATOM



Adapted from Fig. 2.1, *Callister 6e.*

Nucleus: Z = # protons

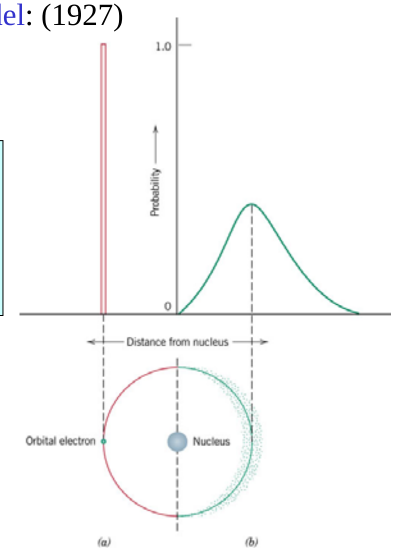
= 1 for hydrogen to 94 for plutonium

N = # neutrons

Atomic mass A ≈ Z + N

Bohr vs. Quantum-Mechanical Model: (1927)

❖ Wave-mechanical atomic model
- Position of electron is imprecisely known; only a probability distribution.
- Electron exhibits both particle and wave characteristics



Schroedinger, Heisenburg, Planck and others developed this model (wave mechanics), which allows a <u>more precise description</u> of the atom.

Increasing Electronegativity →

s-block 1 IA: New Designation / Original Designation; Non-Metals; *p-block*; *d-block* Transition Metals; Atomic # / Symbol / Atomic Mass

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.0094																	2 He 4.00260
2	3 Li 6.941	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.91	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 to 71	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.03	89 to 103	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)	110 Uun (267)								

Metals

(Mass Numbers in Parentheses are from the most stable of common isotopes.)

Phases: Solid, Liquid, Gas

Rare Earth Elements — *d-block*, *f-block*

Lanthanide Series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinide Series	89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

- http://www.webelements.com

Electronegativity - each kind of atom has a certain attraction for the electrons involved in a chemical bond. This "electron-attracting" power of each atom can be listed <u>numerically</u> on an electronegativity scale.

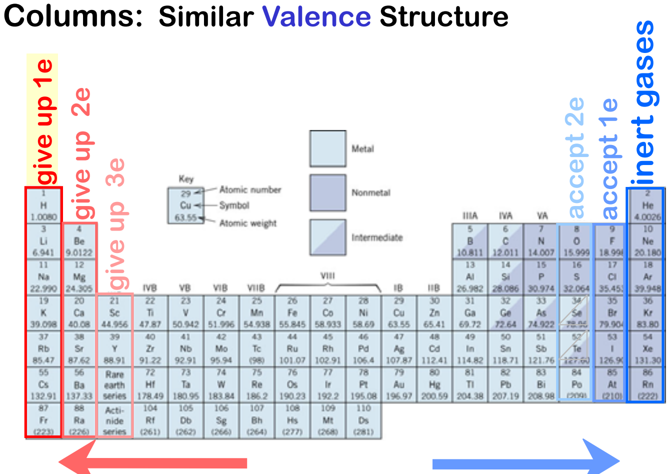
Electronegativity Values of Selected Elements

Metallic Elements			Nonmetallic Elements			
Li (1.0)	Be (1.5)		C (2.5)	N (3.0)	O (3.5)	F (4.0)
Na (1.0)	Mg (1.2)	Al (1.5)		P (2.1)	S (2.5)	Cl (3.0)
K (0.9)	Ca (1.0)	Sc (1.3)			Se (2.4)	Br (2.8)

Electronegativity was originally worked out by Linus Pauling in 1939 – see "<u>The Nature of the Chemical Bond</u>"

THE PERIODIC TABLE

- **Columns: Similar Valence Structure**



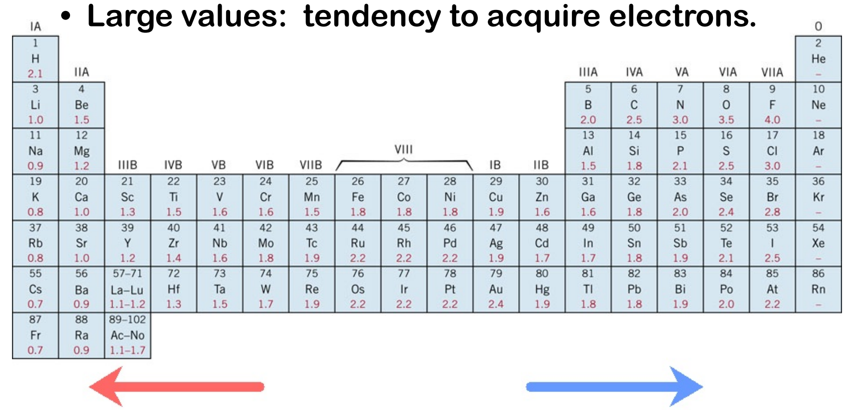
Adapted from Fig. 2.6, *Callister 8e.*

Electropositive elements: Readily give up electrons to become + ions.

Electronegative elements: Readily acquire electrons to become - ions.

ELECTRONEGATIVITY

- **Ranges from 0.7 to 4.0,**
- **Large values: tendency to acquire electrons.**



Smaller electronegativity **Larger electronegativity**

Adapted from Fig. 2.7, *Callister 8e.* (Fig. 2.7 is adapted from Linus Pauling, *The Nature of the Chemical Bond*, 3rd edition, Copyright 1939 and 1940, 3rd edition. Copyright 1960 by Cornell University.

ELECTRONEGATIVITY

- High electronegativity → strong tendency to accept an electron (i.e., Group VIIA: F, Cl)

- Low electronegativity (called “electropositive”) → strong tendency to give up an electron, i.e., Group IA: Li, Na, K)

The difference in electronegativity between two atoms determines the resulting *electron distribution* and the *type of bond*

Density, Atomic # & Wt, Mole & Avogadros

- Density
  - g/cm^3 (most solids range ~ 1 - 23 g/cm^3)
- Atomic number = number of protons (Z)
- Atomic weight (A)
  - g/mole

  A ≅ number protons (Z) + neutrons (N)

  ≅ Z+N

- Mole = number of particles
  - N_A = ………….. part/mole

Review Problems

- How many atoms in 6 grams of carbon?

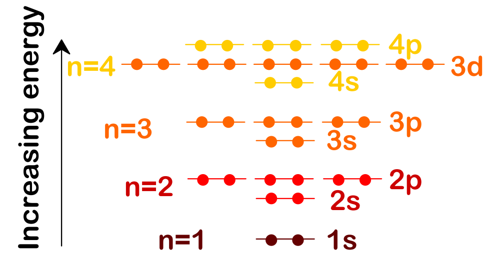
- Calculate the volume of 1 mole of Au.

Useful tip: many problems can be worked by suitable manipulation of density (g/cm^3), atomic mass (g/mole), and Avagadro's number (atoms/mole) (use dimensional analysis!)

ELECTRON ENERGY STATES

Electrons...

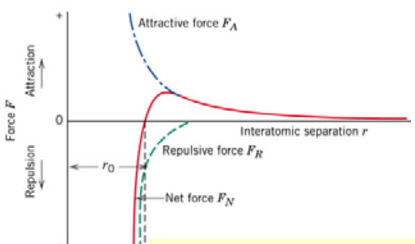
- have discrete energy states
- tend to occupy lowest available energy state.



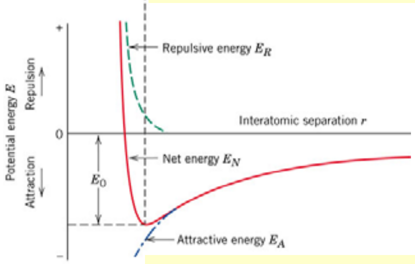
Stable electron configurations...
- have complete s and p subshells
- tend to be …………..

- Most elements: Electron configuration …………...

Bonding Forces and Energies

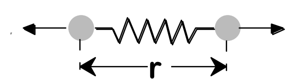


*repulsive, attractive, and net **forces***



*repulsive, attractive, and net **energies***

Bond length, r



Net force is given by the **sum** of an **attractive** force and a **repulsive** force

Potential is given by the integral of the net force curve with respect to distance:

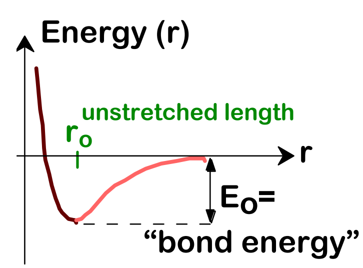
$$E = \int F \bullet dr$$

Note: *equilibrium separation occurs where the net force = 0*

Bonding Forces and Energies

Bonding energy: *Minimum of the potential vs. distance curve.*

- ➢ Indicates how much energy must be supplied to completely disassociate the two atoms
- ➢ Depth of the potential well indicates bonding strength
  - Deep well → ………….. bonded
  - Shallow well → ………. bonded



Bond Energy

The higher the bond energy

- ………….
- ………….

- State as function of bonding energy
  - Solid (…….)
  - Liquid (…………..……)
  - Gaseous (……..)

Next time:

Types of Atomic Bonds