Classes of Materials

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

Why study bonding?

• Because the properties of materials (*strength, hardness, conductivity, etc.*.) are determined by the manner in which atoms are connected.

What determines the nature of the chemical bond between atoms?

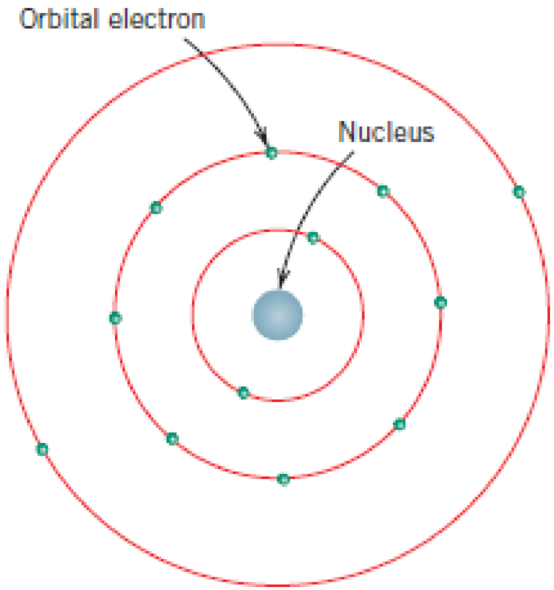
• Electronic structure (distribution of electrons in atomic orbitals)

• Number of electrons and protons (tendency for an atom to attract an electron)

Atomic Structure

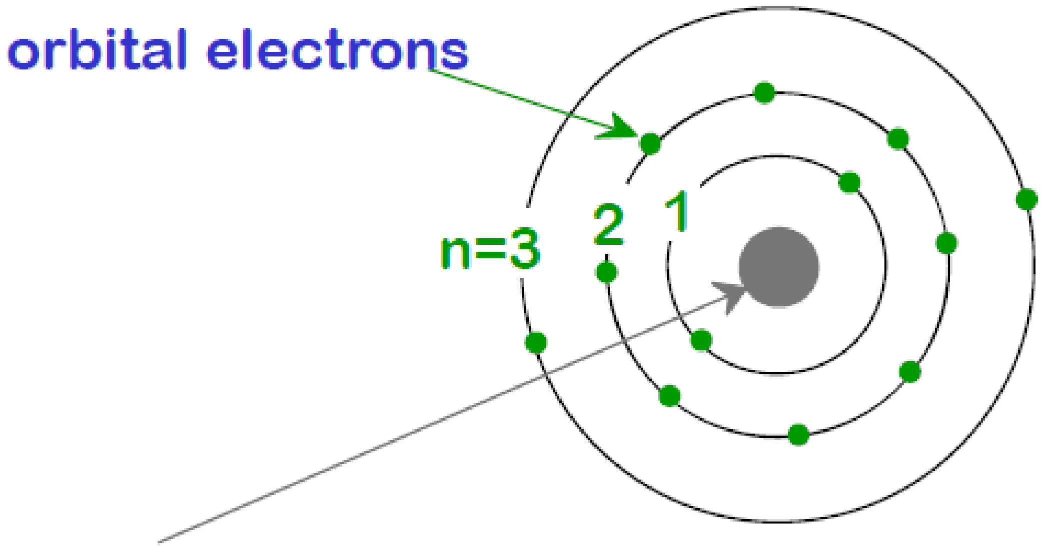
❑ Bohr model of the atom: (1913)

– 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

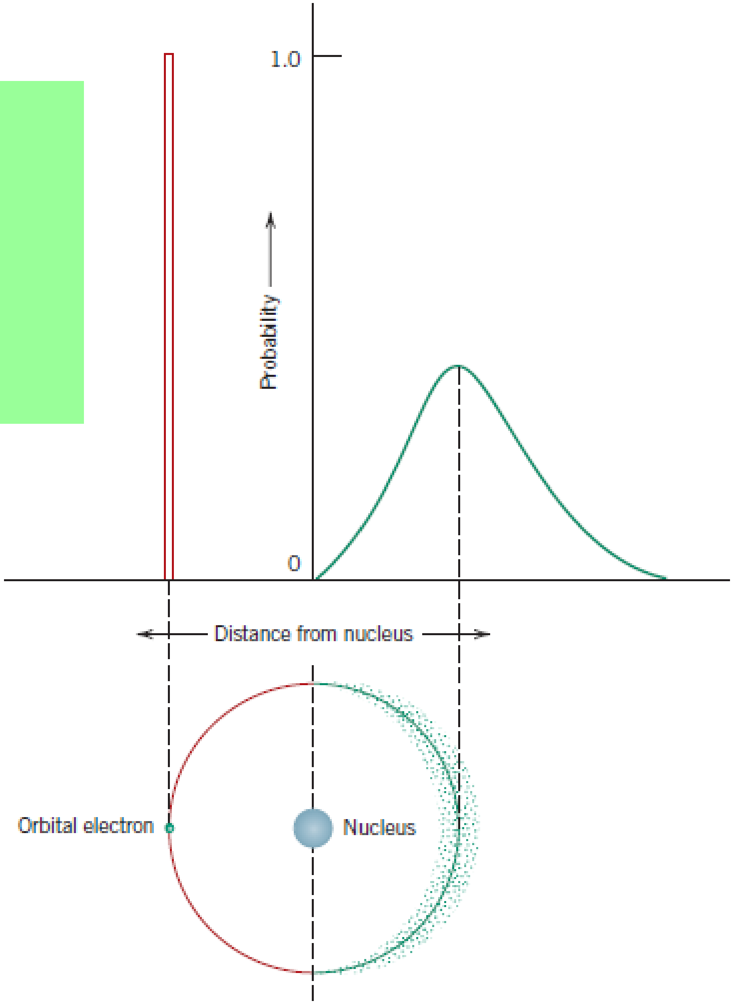
N = # neutrons

Atomic mass A $\approx$ Z + N

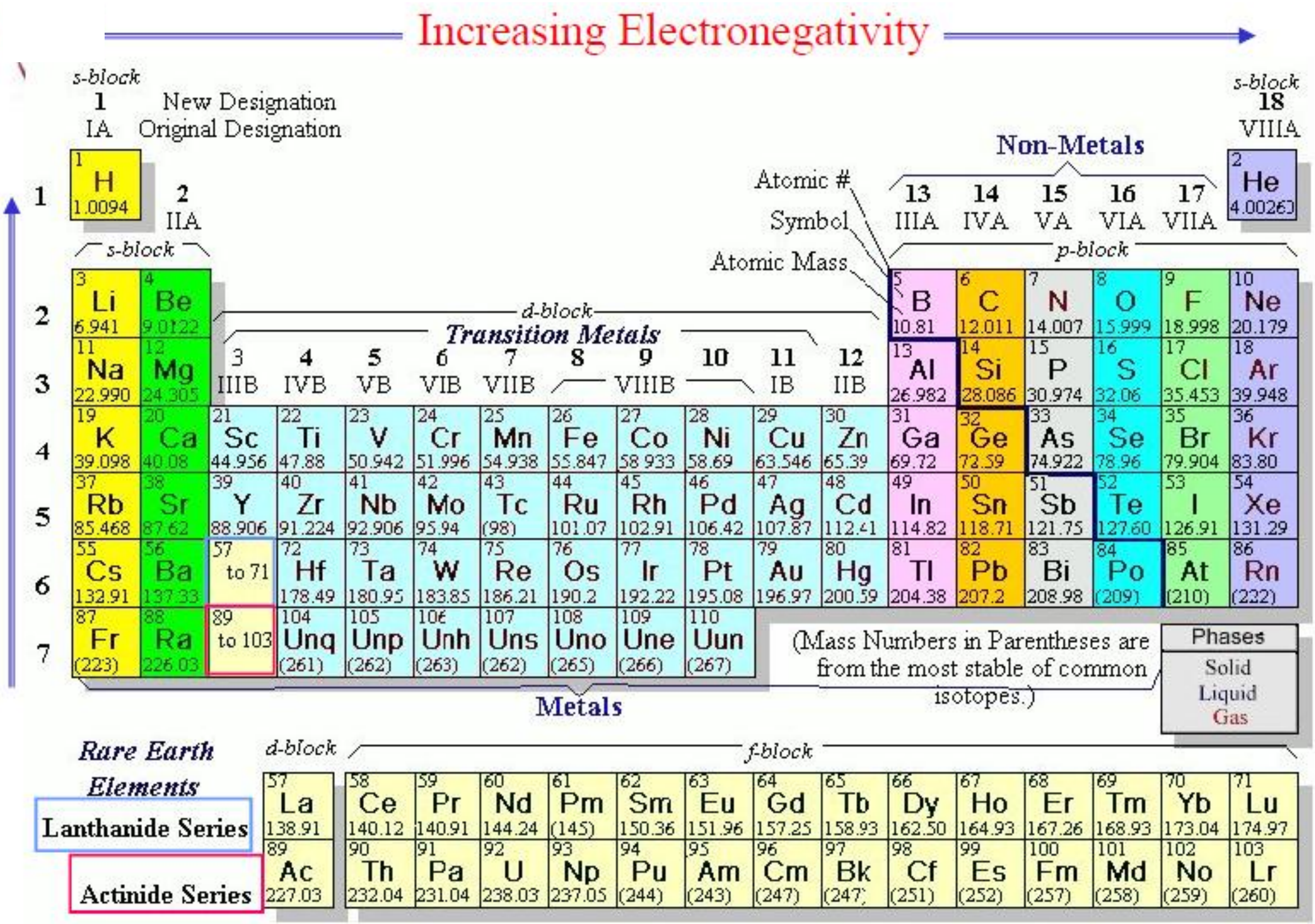
Bohr vs. Quantum-Mechanical Model: (1927)

❑ 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 of the atom</u>.*



Increasing Electronegativity
s-block
1 New Designation
IA Original Designation
s-block
18
VIIIA
Non-Metals
1
2
3
4
5
6
7
1 H 1.0094
2 IIA
s-block
Atomic #
Symbol
Atomic Mass
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
p-block
2 He 4.00260
d-block
Transition Metals
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8 9 10 VIIIB
11 IB
12 IIB
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
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
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
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
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)
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)
(Mass Numbers in Parentheses are from the most stable of common isotopes.)
Phases
Solid
Liquid
Gas
Metals
Rare Earth Elements
d-block
f-block
Lanthanide Series
Actinide 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
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 "electronattracting" power of each atom can be listed numerically 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*

The Periodic Table

- **Columns**: Similar Valence Structure

Give up 1e | Give up 2e | Give up 3e | Accept 2e | Accept 1e | Inert gases

Key: 29 ← Atomic number; Cu ← Symbol; 63.54 ← Atomic weight

Metal | Nonmetal | Intermediate

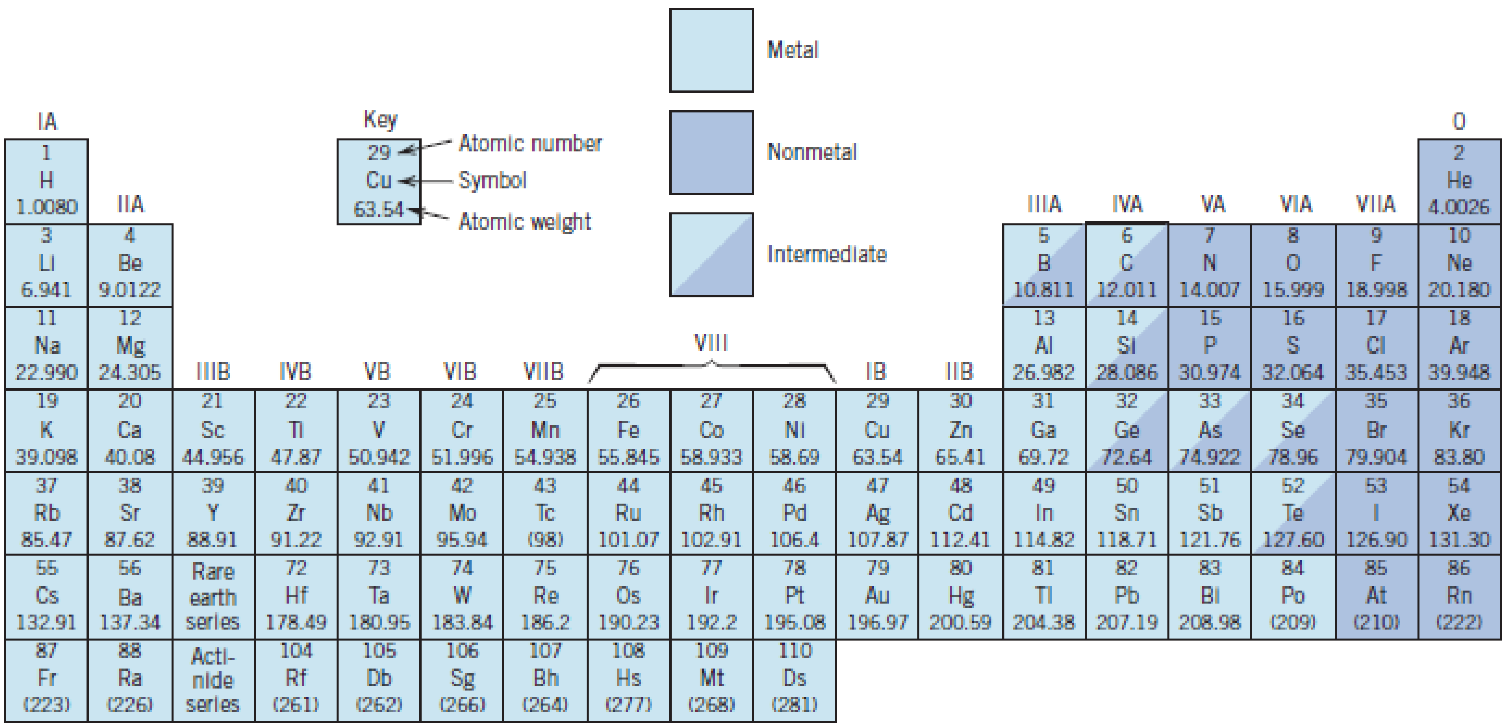
IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.0080																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.87	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.54	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	Rare earth series	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.2	76 Os 190.23	77 Ir 192.2	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.19	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	Acti-nide series	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)								

← 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

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

1 amu/atom or molecule = 1 g/mol

In one **mole** of a substance there are $6.023*10^{23}$(Avogadro's number) atoms or molecules

Review Problems

- How many atoms in 6 grams of carbon?

$$Number\ of\ moles = \frac{Mass}{Mwt}$$

$$= \frac{6}{12} = 0.5$$

Number of atoms = 0.5*6.023*10^{23}

- **Calculate the volume of 1 mole of Au.**

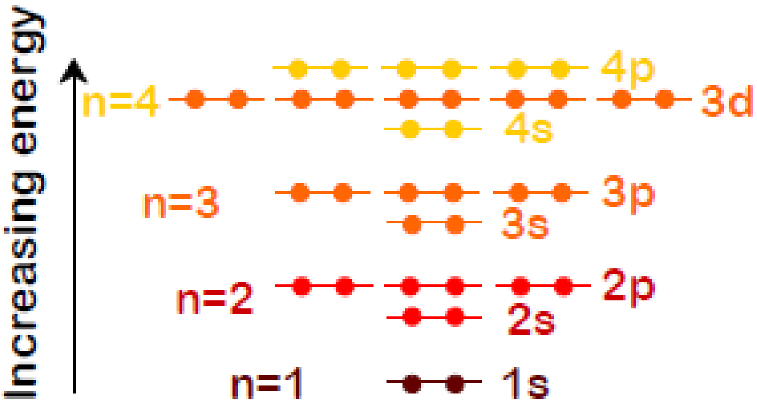
$$mass = \ \ of\ moles * Mwt = 1 * 196.97$$

$$Volume = \frac{Mass}{\rho_{Au}} = \frac{196.96\ (g)}{19.3\ (\frac{g}{mL})}$$

Electron energy state

Electrons

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

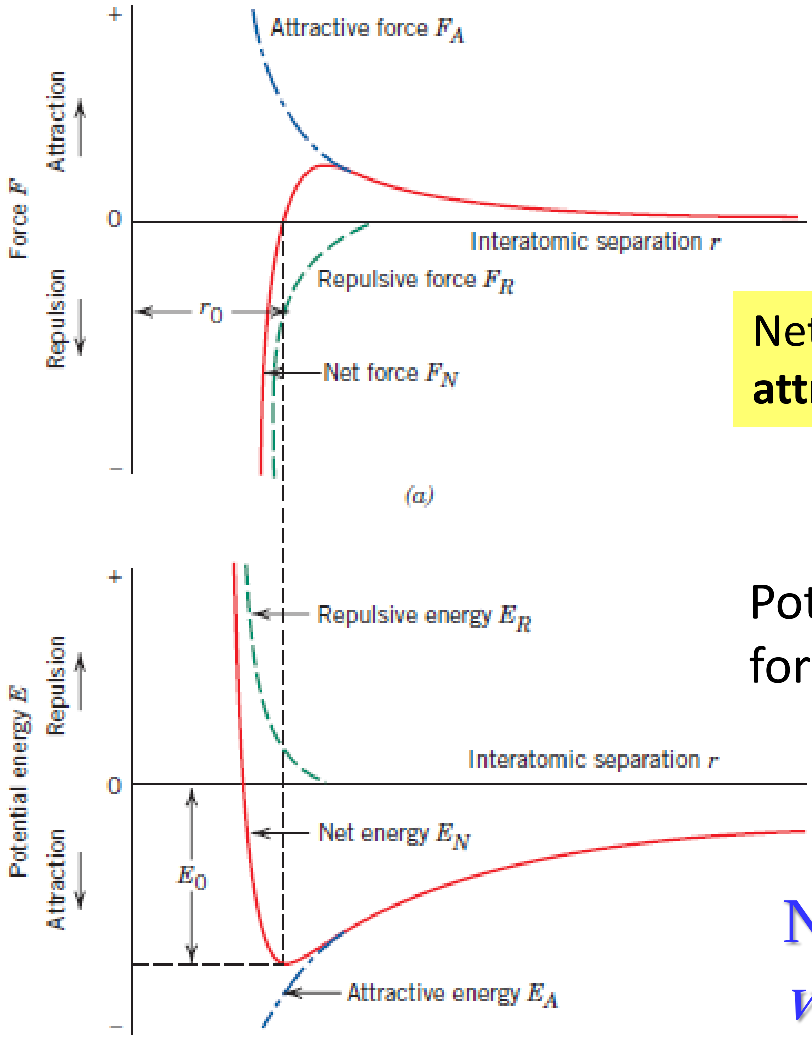


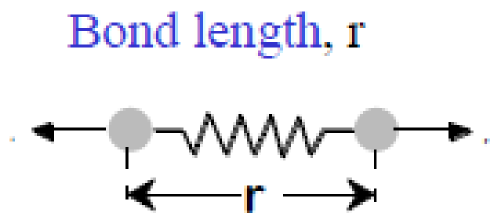
Stable electron configurations...

- have complete s and p subshells

- Most elements: Electron configuration not stable.

Bonding Forces and Energies





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:

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

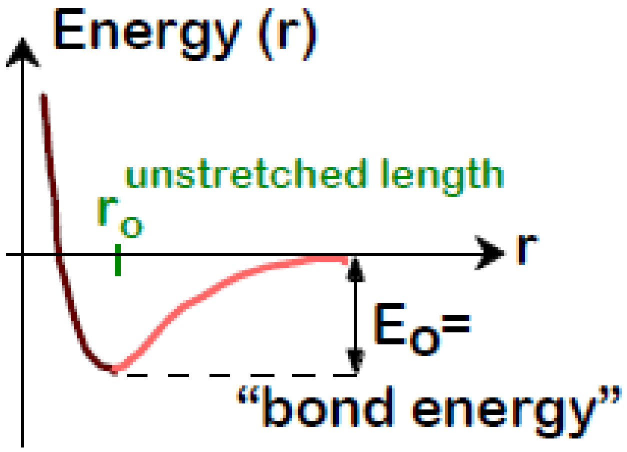
Note: *equilibrium separation occurs where the net force = 0*

Bonding 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 === strongly bounded
- Shallow well === weakly bounded



Bound energy

❑ The higher the bond energy

- Higher melting temperature
- Solid material

❑ State as function of bonding energy

- Solid: high bonding energy
- Liquid: Moderate BE
- Gas: Low BE