Outlines

- **Types of bonds**:

- Ionic
- Covalent
- Metallic
- Secondary bonding

- **Examples**:

- *relation between bond energy and properties*

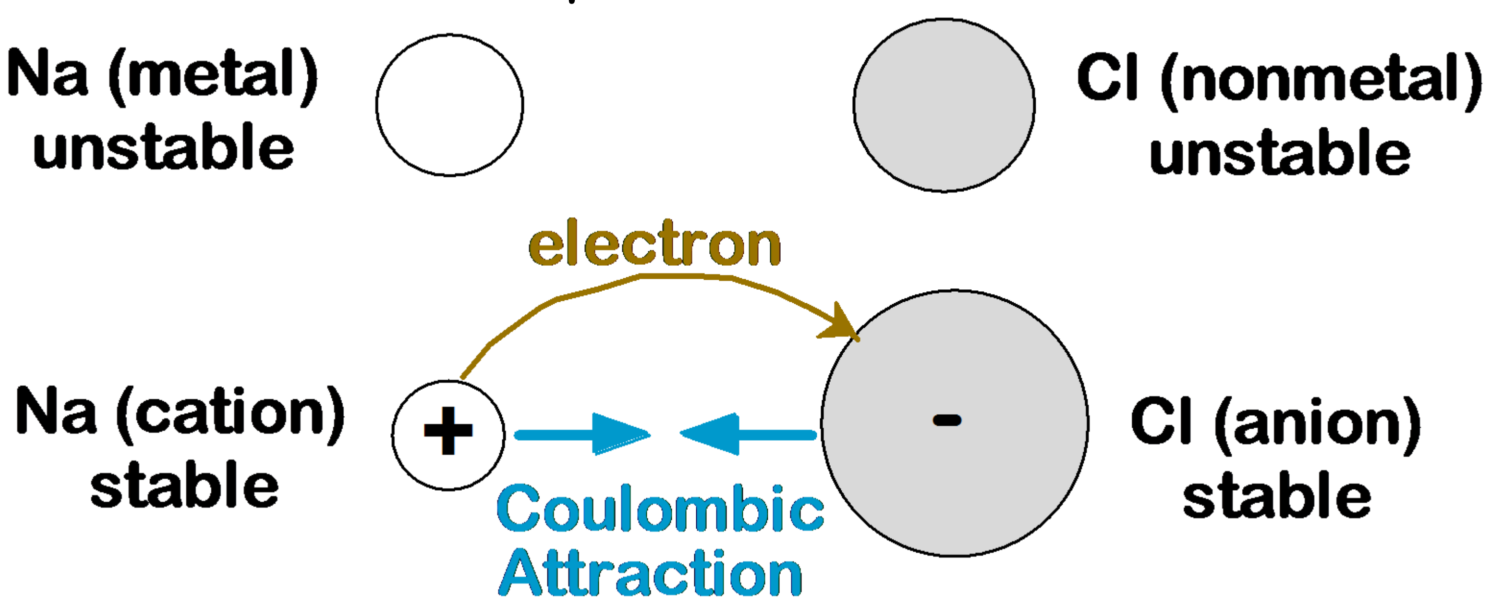
- Summary

IONIC BONDING

Electrostatic attraction between oppositely charged ions

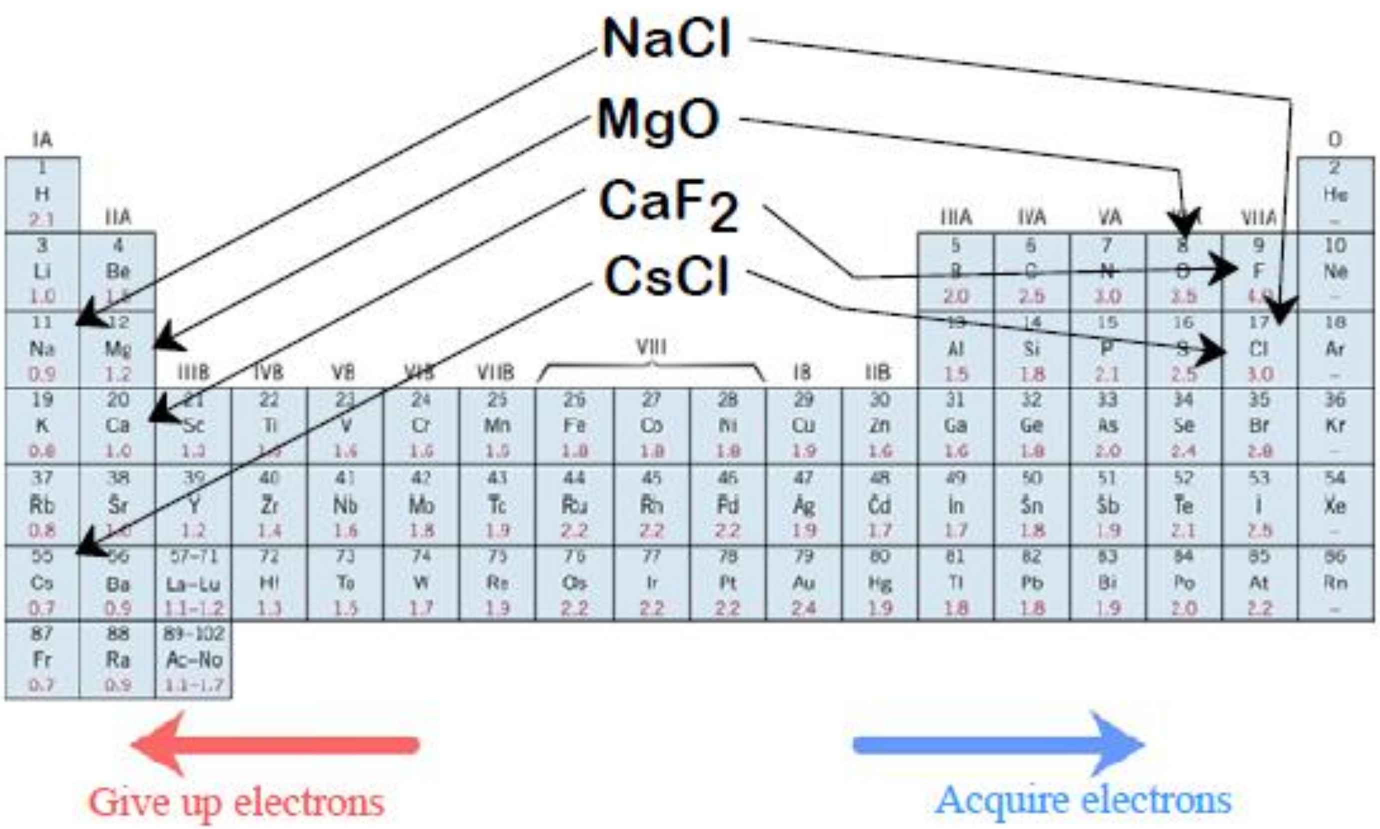
- **Occurs between + and - ions.**
- **Requires electron transfer.**
- **Large difference in electronegativity required.**

- **Example: NaCl**



EXAMPLES: IONIC BONDING

- Predominant bonding in Ceramics

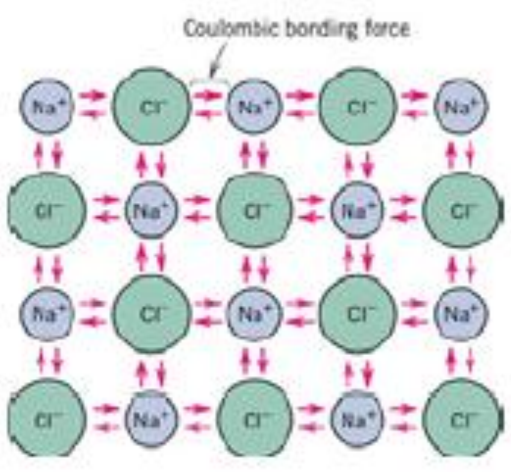


IONIC BONDING: *Summary*

Ionic: electron transfer from one atom (cation) to the other (anion).

- More likely between atoms with large **electronegativity differences**
- Typically found between metal and non-metal atoms:
  NaCl, KF, CsBr, MgO…
- Ionic bonding is non-directional : the magnitude of the bond is equal in all direction around an ion

Typical bonding energies: 600 to 1500 KJ/mole (3 to 8 eV/atom)



Typical characteristics of ionically-bonded materials:

- High melting temperature
- Hard
- Brittle
- Isulative material (very low electrical and thermal)

COVALENT BONDING

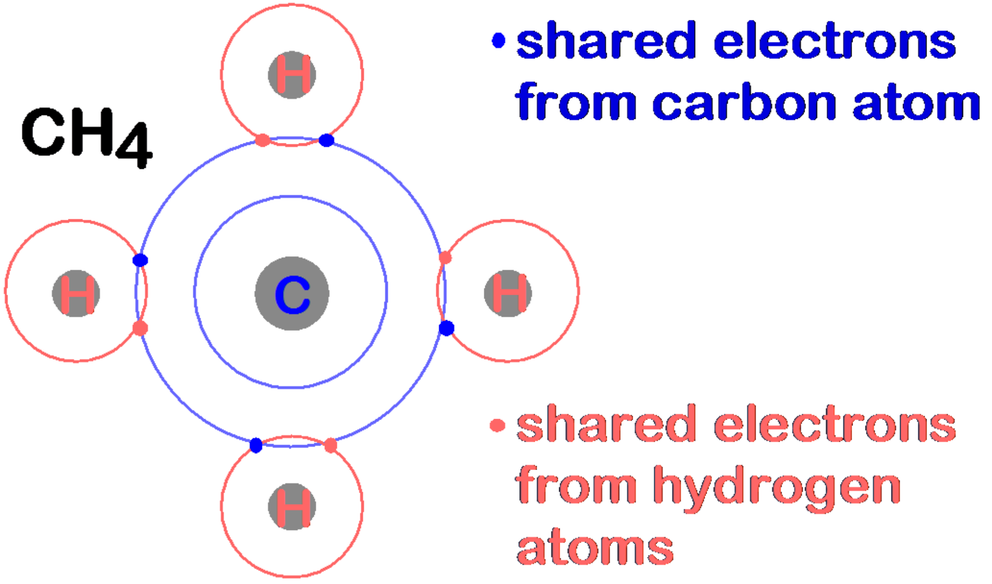
There is electron sharing between two adjacent atoms such that each atom assumes a stable electron configuration.

- Requires shared electrons
- Example: CH4

C: has 4 valence e,
needs 4 more

H: has 1 valence e,
needs 1 more

Electronegativities
are comparable.



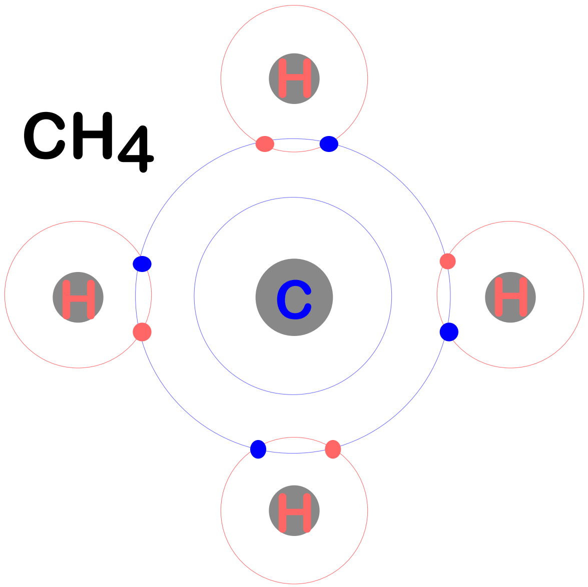
EXAMPLES: *COVALENT BONDING*

IA	IIA	IIIB	IVB	VB	VIB	VIIB	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)								

- Molecules with nonmetals (Cl_2, F_2, H_2)
- Molecules with metals and nonmetals (CH4, H2O, HNO3 and HF)
- Elemental solids (RHS of Periodic Table) (Diamond C, Si,..etc)
- Compound solids (about column IVA) such as GaAs, InSb and SiC

COVALENT BONDING: *Summary*

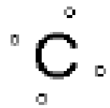
Covalent: electron sharing between atoms each atom contributes (at least) one electron to the bond

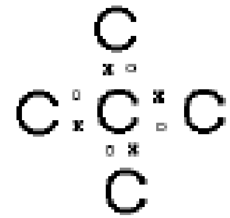


- Tends to be a highly directional bond
- Each atom tries to achieve a more stable orbital filling configuration
- Gives rise to a fixed orientation of the atoms
- Shared electrons may be considered to belong to each atom

COVALENT BONDING: *Summary*

Carbon:





Note how the sharing of electrons acts to complete the filling of electronic states in each respective atom:

$$1s^2(2s^22p^2) \rightarrow 1s^2(2s^22p^6)$$

Difficult to assign general characteristics to covalently-bonded materials:

- Bonds may be strong (diamond, Tm > 3550°C) or weak (Bi, Tm = 270°C)
- Materials may be conductive (GaAs) or insulating (diamond)

Ionic Character

MOST MATERIALS ARE NEITHER 100% IONIC NOR 100% COVALENT

$$\% \text{ ionic character} = \{1 - \exp[-(0.25)(X_A - X_B)^2]\} \times 100$$

Where X_A, X_B are the electronegativities of the A and B atoms, respectively.

Example:

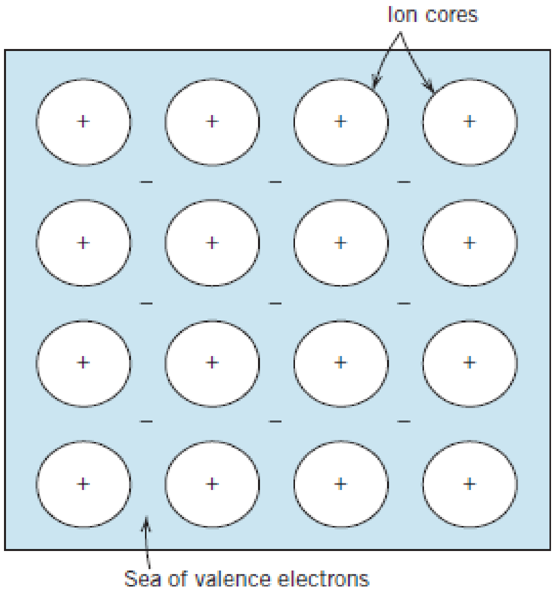
Compute the percentage ionic character of the interatomic bonds for TiO2 and ZnTe.

- For ZnTe, X_{Zn} = 1.6 and X_{Te} = 2.1, and therefore, **Ionic character % = 6.1 %**

- For TiO2, X_{Ti} = 1.5 and X_O = 3.5, and therefore, **Ionic character % = 63.2 %**

METALLIC BONDING

- Arises from a sea of ***donated*** valence electrons (1, 2, or 3 from each atom).



- Valence electrons are not bound to any specific atom but are free to drift throughout the material
- Active bonding electrons form an "***electron sea***"

- Primary bond for (*not surprisingly*) metals and their alloys
- metallic bond is nondirectional in character

METALLIC BONDING

- ✓ Metallic bonding can be either weak (68 kJ/mole or 0.7 eV/atom for Hg) or strong (850 kJ/mole or 8.8 eV/atom for W)

- ✓ Metallic bonding gives rise to high electrical and thermal conductivity

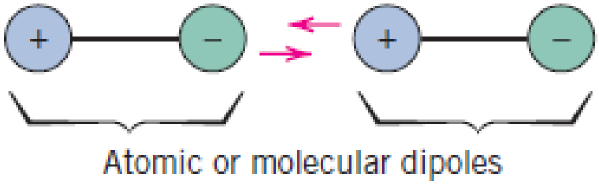
- ✓ Metallic bonding also gives rise to ductility (*at least more than in most covalent and ionic solids*). Think about why this might be so?.

The electrons are loosely held since each atom has several unoccupied valence orbitals; it is relatively easy for the electrons to move about. In this manner the electrons allow atoms to ***slide past each other***

Secondary Bonding

- Van der Waals bonding
- Bond energy is very weak compared to others

Compare typical secondary bonding strengths (10 kJ/mole) with typical primary bonding strengths (50 to 1000 kJ/mole)



- Exists between almost all atoms and molecules
- Arise from atomic or molecular dipoles

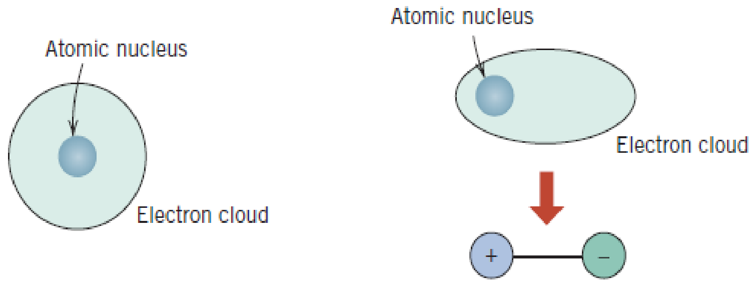
Physical bonds, not chemical

Secondary Bonding

✓ **Fluctuating Induced Dipole Bonds**

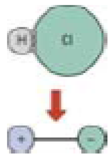
- Thermal vibration fluctuations can disrupt charge symmetry which leads to a dipole.

The presence of one dipole can induce a dipole in an adjacent molecule (or atom) and so on.



- Polar molecule induced dipoles & hydrogen bonding

Due to permanent dipole moments in molecules

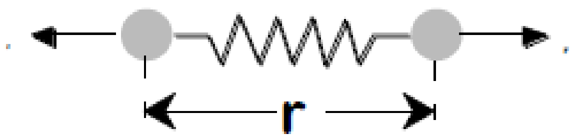


Unshielded, bare proton in H-O, H-F and H-N bonds lead to strong, hydrogen bonding

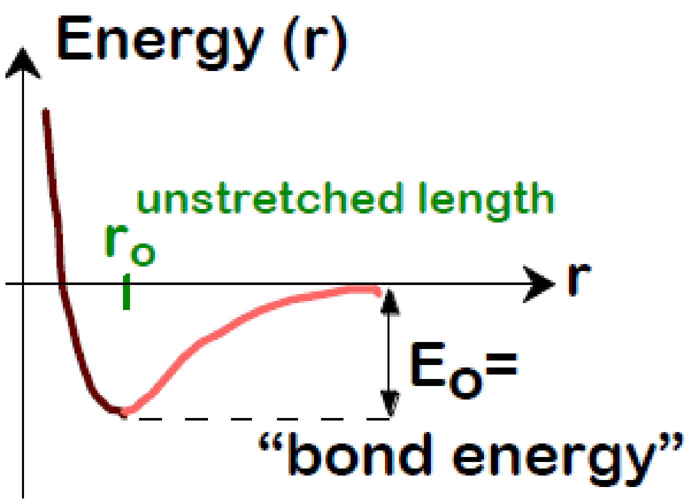
- **Hydrogen bonding is a special case of secondary bonding.**
- The hydrogen bond is generally stronger than for fluctuating induced dipoles

PROPERTIES FROM BONDING: T_M

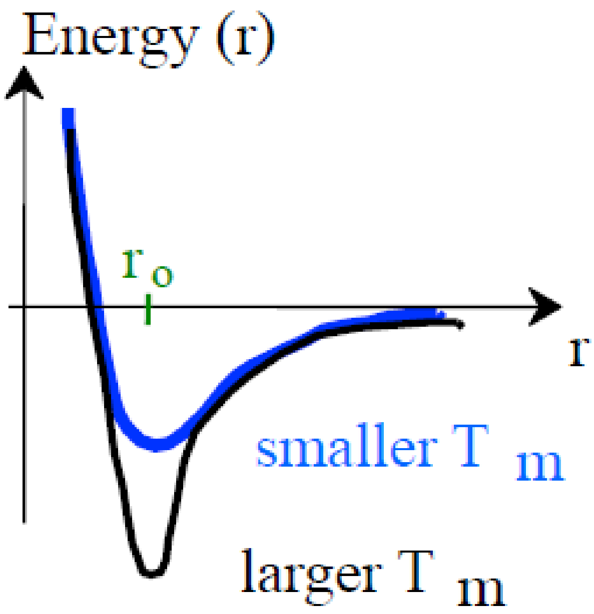
- Bond length, r



- Bond energy, E_o



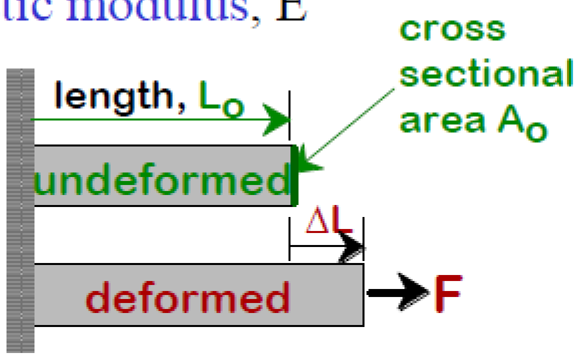
- Melting Temperature, T_m



T_m is larger if E_o is larger.

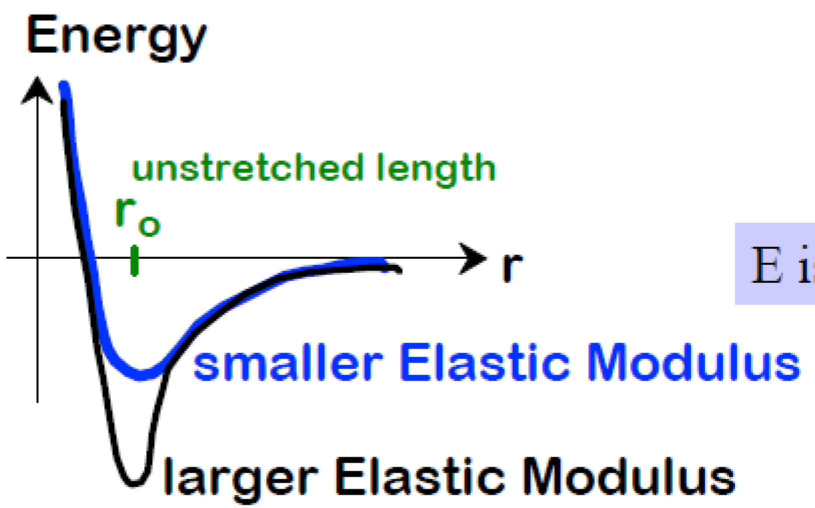
PROPERTIES FROM BONDING: E

- Elastic modulus, E



Elastic modulus

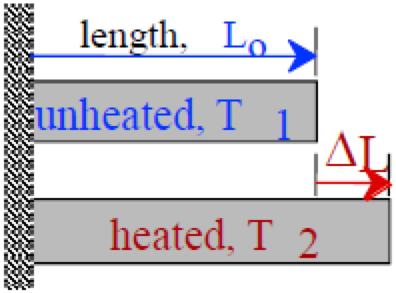
$$\frac{F}{A_o} = E \frac{\Delta L}{L_o}$$



E is larger if E_o is larger.

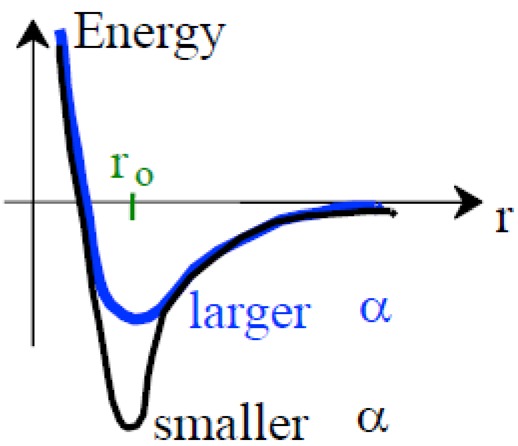
PROPERTIES FROM BONDING: α

- Coefficient of thermal expansion, α



coeff. thermal expansion

$$\frac{\Delta L}{L_o} = \alpha (T_2 - T_1)$$



α is larger if E_o is smaller.

Problem 2.22 p. 42

What type(s) of bonding would be expected for each of the following materials?

Answer:

1. Brass (copper-zinc alloy) – metallic since metal alloy
2. Rubber – covalent with some van der Waals
3. Barium sulfide (BaS) – mainly ionic (some covalent char)
4. Solid xenon – van der Waals because inert gas
5. Bronze (copper-tin alloy) – metallic since metal alloy
6. Nylon – covalent with some van der Waals
7. Aluminum phosphide (AlP) - mainly covalent (some ionic char)