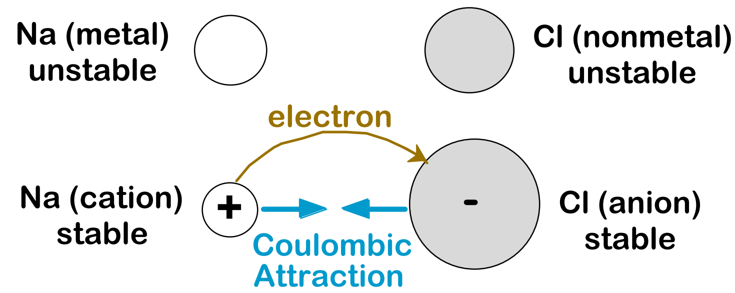
Outline:

- Types of bonds:
  - Ionic
  - Covalent
  - Metallic
  - Secondary bonding
- Examples:
  - *relation between bond energy and properties*
- Summary

IONIC BONDING

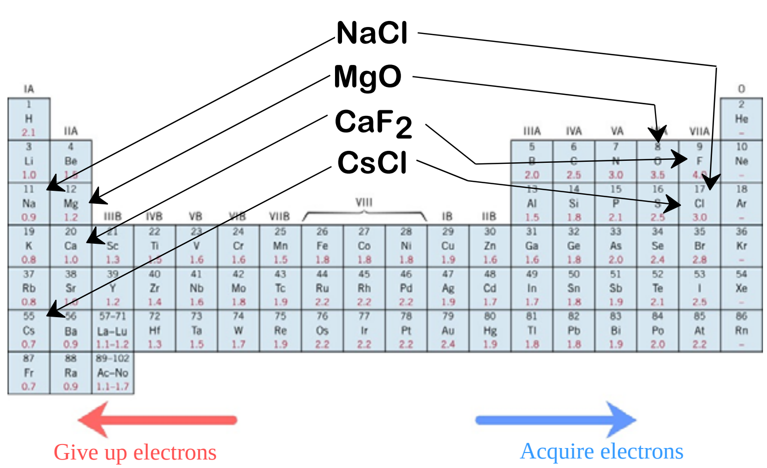
- Example: *NaCl*



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

EXAMPLES: IONIC BONDING

- Predominant bonding in Ceramics



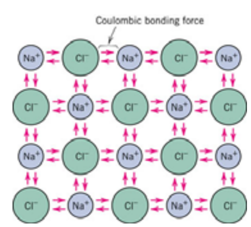
IONIC BONDING: *Summary*

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…

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



Typical characteristics of ionically-bonded materials:
- ……. melting temperature
- Hard
- Brittle
- …….. (electrical and thermal)

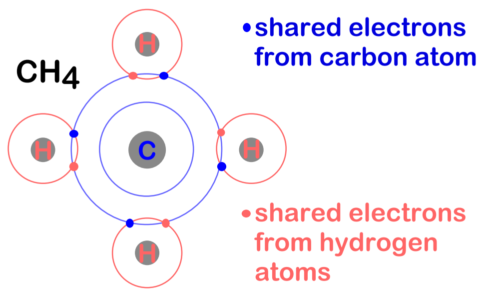
COVALENT BONDING

- Requires shared electrons
- Example: CH_4

C: has 4 valence e,
needs 4 more

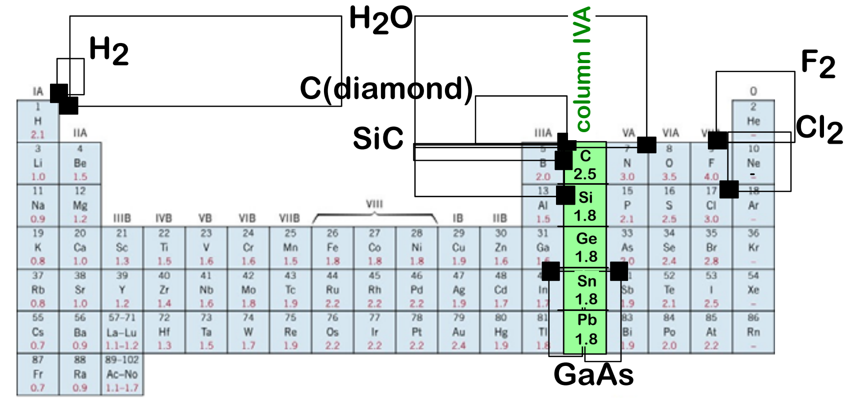
H: has 1 valence e,
needs 1 more

Electronegativities are comparable.



Adapted from Fig. 2.10, *Callister 6e.*

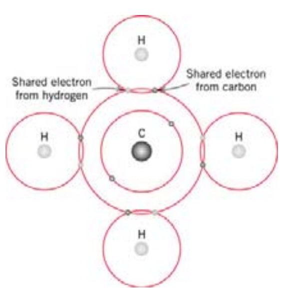
EXAMPLES: *COVALENT BONDING*



- Molecules with nonmetals
- Molecules with metals and nonmetals
- Elemental solids (RHS of Periodic Table)
- Compound solids (about column IVA)

COVALENT BONDING: *Summary*

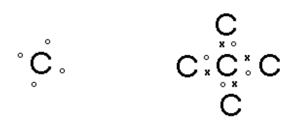
Covalent: electron sharing between atoms each atom contributes (at least) one electron to the bond



- Each atom tries to achieve a more stable orbital filling configuration
- Tends to be a highly directional bond
- 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:

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

Difficult to assign general characteristics to covalently-bonded materials:

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

Ionic Character

MOST MATERIALS ARE NEITHER 100% IONIC NOR 100% COVALENT

% ionic character = $[1 - \exp\{-0.25(X_A - X_B)^2\}]$ x 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 TiO_2 and ZnTe.

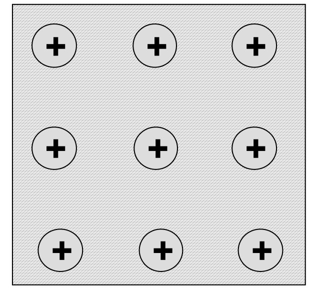
• For TiO_2, X_{Ti} = 1.5 and X_O = 3.5, and therefore,

The electronegativities of the elements are found in Figure 2.7

• For ZnTe, X_{Zn} = 1.6 and X_{Te} = 2.1, and therefore,

METALLIC BONDING

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



Adapted from Fig. 2.11, *Callister 6e.*

• 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 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

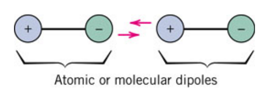
• Van der Waals bonding

• 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

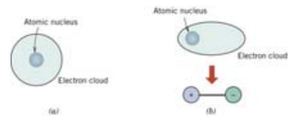


– *Physical bonds, not chemical*

Secondary Bonding

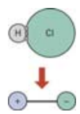
- Thermal vibration fluctuations can disrupt charge symmetry which leads to a dipole.

  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

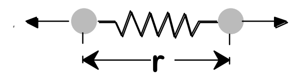


Unshielded, bare proton in H-O, H-F and H-N bonds lead to strong, hydrogen bonding

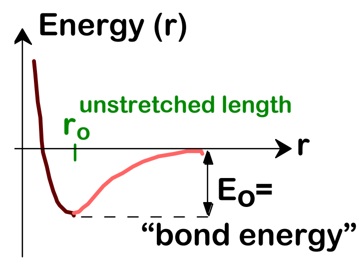
- **Hydrogen bonding is a special case of secondary bonding.**
- The hydrogen bond is generally stronger than ……………..

PROPERTIES FROM BONDING: T_M

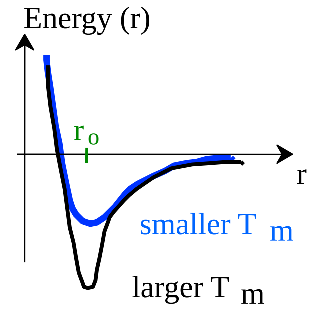
- Bond length, r



- Bond energy, E_o



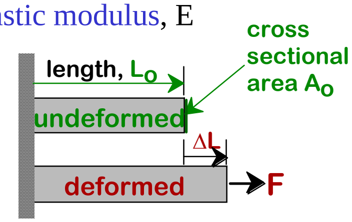
- Melting Temperature, T_m



T_m is larger if E_o is larger.

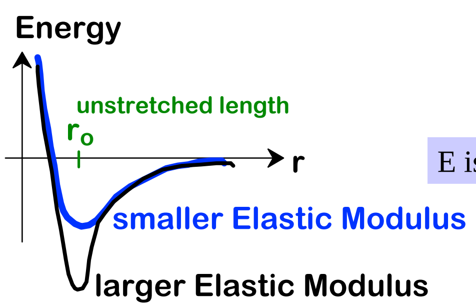
PROPERTIES FROM BONDING: E

- Elastic modulus, E



Elastic modulus

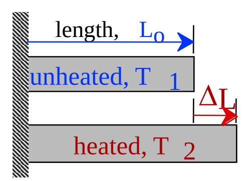
$$\frac{F}{A_o} = E\,\frac{\Delta L}{L_o}$$



E is larger if E_o is larger.

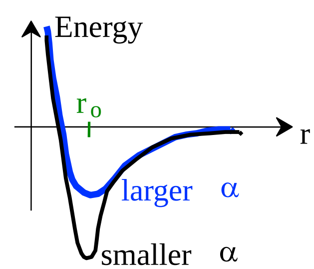
PROPERTIES FROM BONDING: α

- Coefficient of thermal expansion, α



coeff. thermal expansion

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



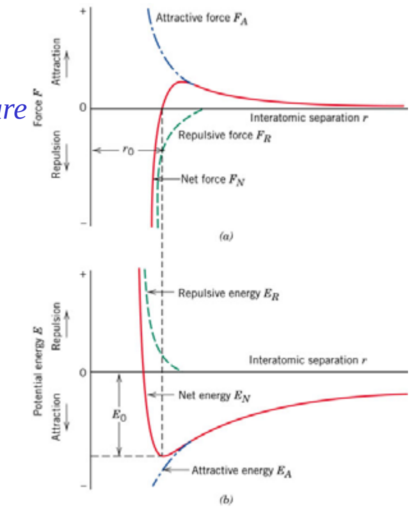
α is larger if E_o is smaller.

Bond Energy

The higher the bond energy

- ………… the *melting temperature*
- ………… the *hardness*
  …. etc

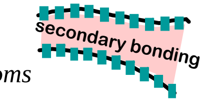
- State as function of bonding energy
  - Solid (…….)
  - Liquid (……….……)
  - Gaseous (……..)



Bonding Types: *Summary*

A comparison of the type of bonding found in different materials:

- For brass, the bonding is …….. since it is a metal alloy.
- For rubber, the bonding is ……… with some ………
  Rubber is composed primarily of carbon and hydrogen atoms



- For BaS, the bonding is predominantly ….. (*but with some covalent character*) on the basis of the relative positions of Ba and S in the periodic table.
- For solid xenon, the bonding is ……………. since xenon is an inert gas.
- For nylon, the bonding is …….. with perhaps some ………..
  Nylon is composed primarily of carbon and hydrogen
- For AlP the bonding is predominantly ……… (but with some ionic character)
  on the basis of the relative positions of Al and P in the periodic table.

Next time:
Crystal structure, lattice directions and planes