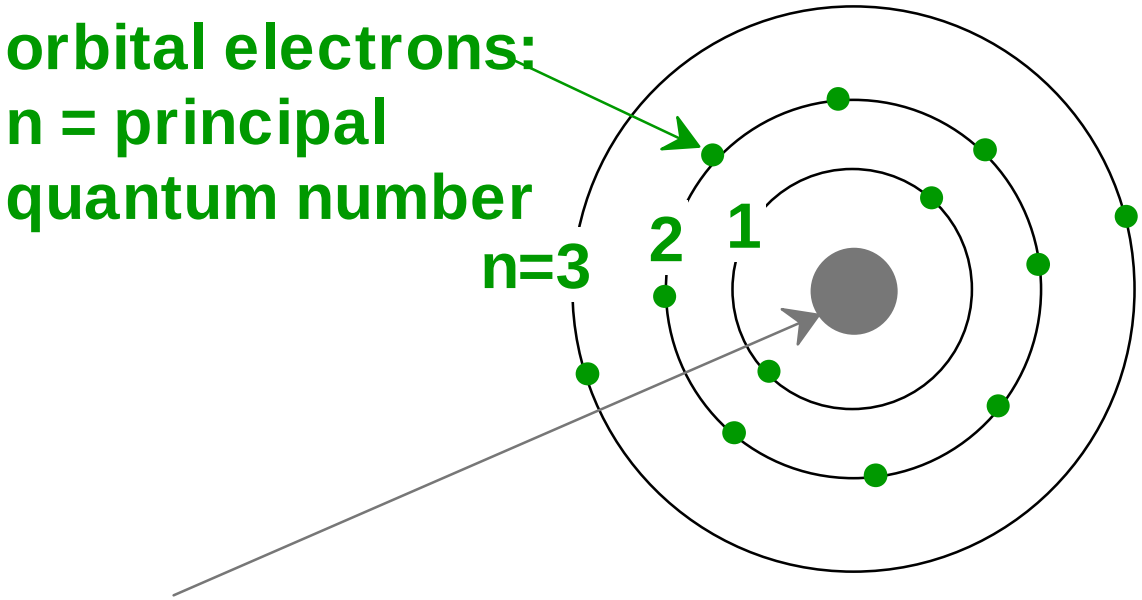
CHAPTER 2:
BONDING AND PROPERTIES

ISSUES TO ADDRESS...

- What promotes bonding?
- What types of bonds are there?
- What properties are inferred from bonding?

BOHR ATOM



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

Nucleus: Z = # protons

= 1 for hydrogen to 94 for plutonium

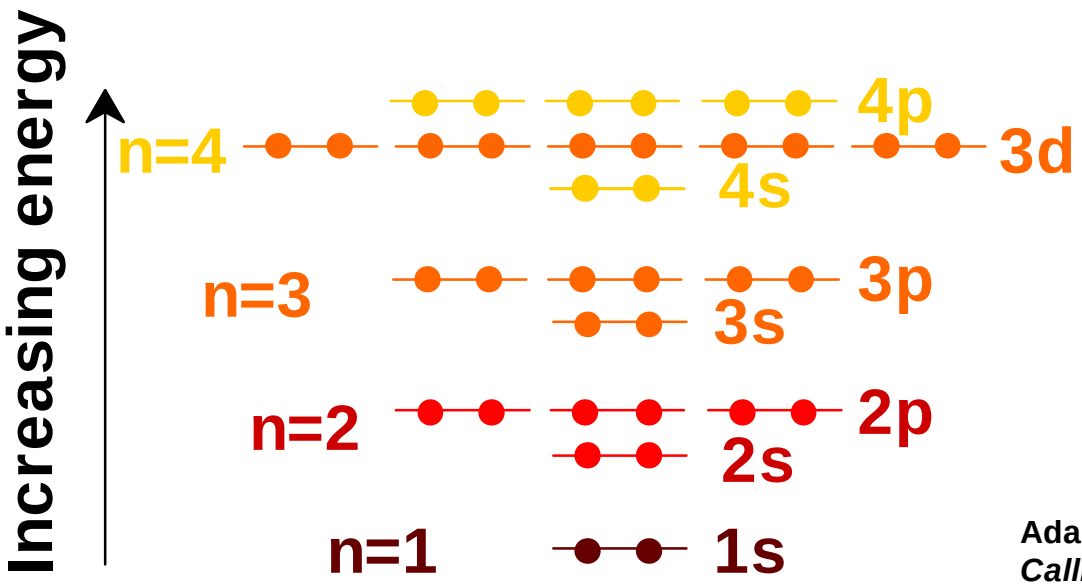
N = # neutrons

Atomic mass A ≈ Z + N

ELECTRON ENERGY STATES

Electrons...

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



Adapted from Fig. 2.5, *Callister 6e.*

STABLE ELECTRON CONFIGURATIONS

Stable electron configurations...

- **have complete s and p subshells**
- **tend to be unreactive.**

Z	Element	Configuration
2	He	$1s^2$
10	Ne	$1s^2 2s^2 2p^6$
18	Ar	$1s^2 2s^2 2p^6 3s^2 3p^6$
36	Kr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

Adapted from Table 2.2, *Callister 6e.*

SURVEY OF ELEMENTS

- **Most elements: Electron configuration not stable.**

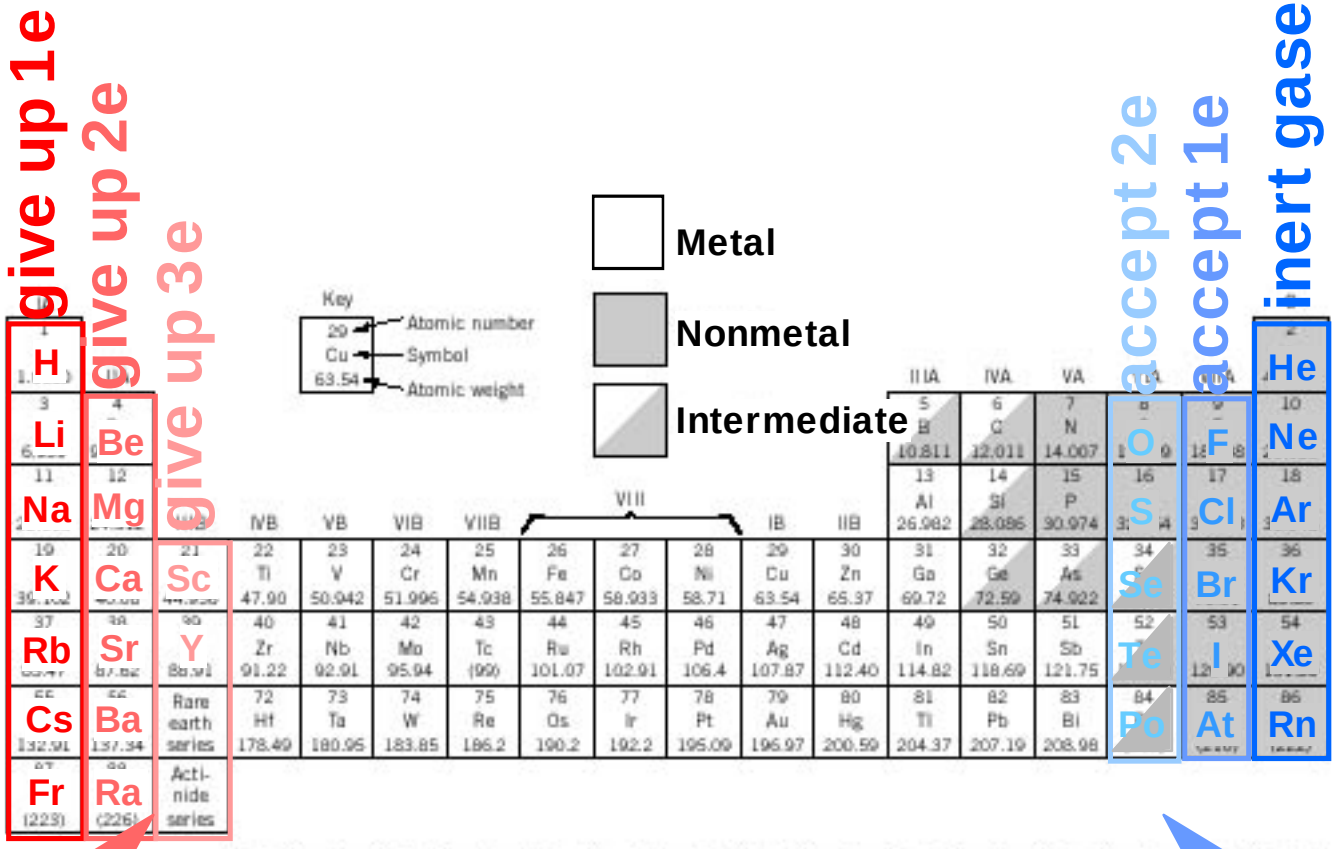
Element	Atomic #	Electron configuration	
Hydrogen	1	$1s^1$	
Helium	2	$1s^2$	(stable)
Lithium	3	$1s^2 2s^1$	
Beryllium	4	$1s^2 2s^2$	
Boron	5	$1s^2 2s^2 2p^1$	
Carbon	6	$1s^2 2s^2 2p^2$	
...		...	
Neon	10	$1s^2 2s^2 2p^6$	(stable)
Sodium	11	$1s^2 2s^2 2p^6 3s^1$	
Magnesium	12	$1s^2 2s^2 2p^6 3s^2$	
Aluminum	13	$1s^2 2s^2 2p^6 3s^2 3p^1$	
...		...	
Argon	18	$1s^2 2s^2 2p^6 3s^2 3p^6$	(stable)
...	...	...	
Krypton	36	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4^6$	(stable)

Adapted from Table 2.2, *Callister 6e.*

- **Why? Valence (outer) shell usually not filled completely.**

THE PERIODIC TABLE

- **Columns: Similar Valence Structure**



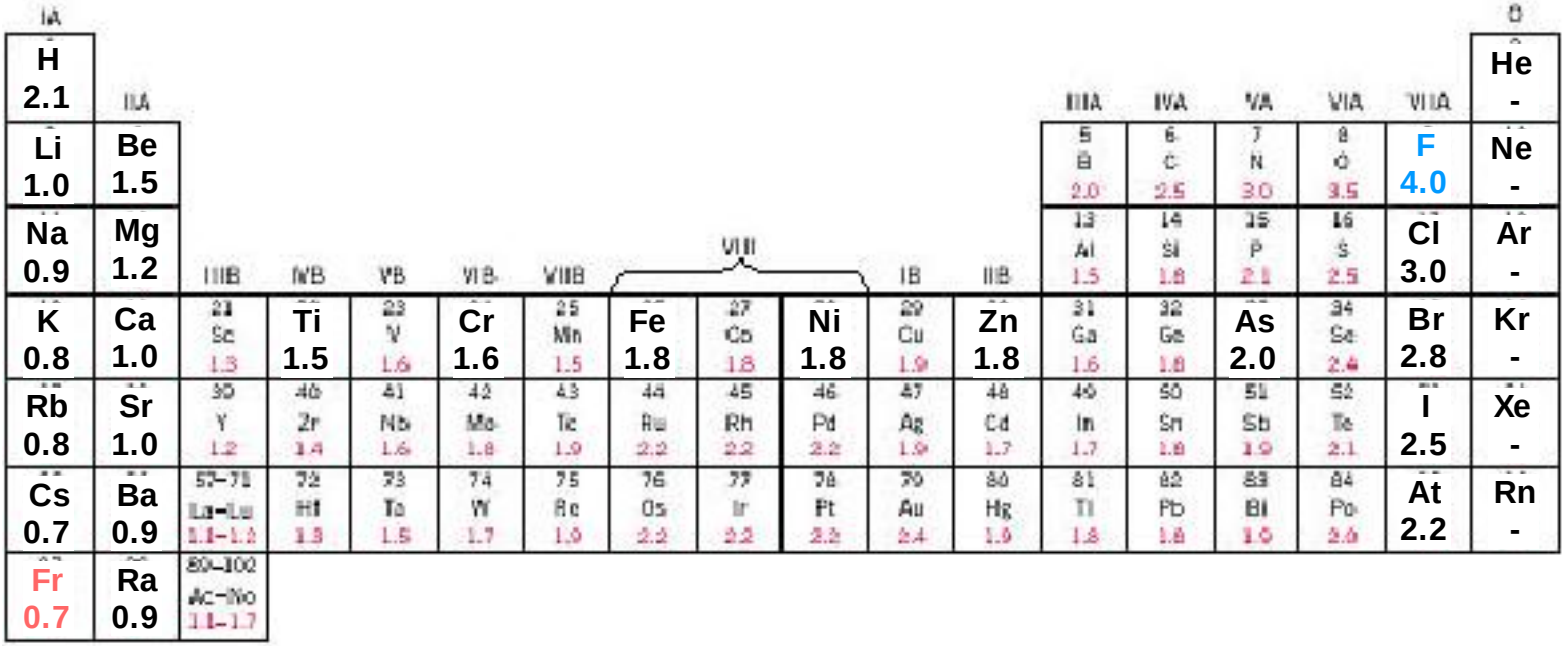
Adapted from Fig. 2.6, *Callister 6e.*

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

Electronegative elements: Readily acquire electrons to become - ions.

ELECTRONEGATIVITY

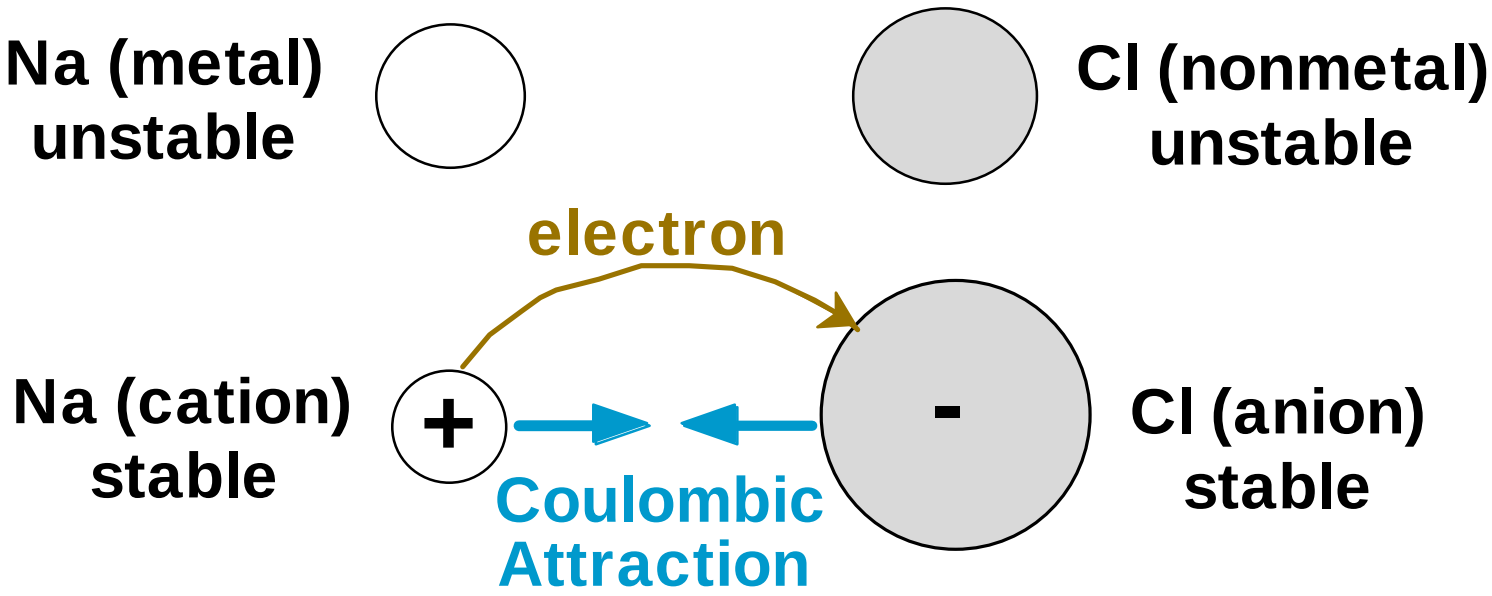
- **Ranges from 0.7 to 4.0,**
- **Large values: tendency to acquire electrons.**



Adapted from Fig. 2.7, *Callister 6e.* (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.

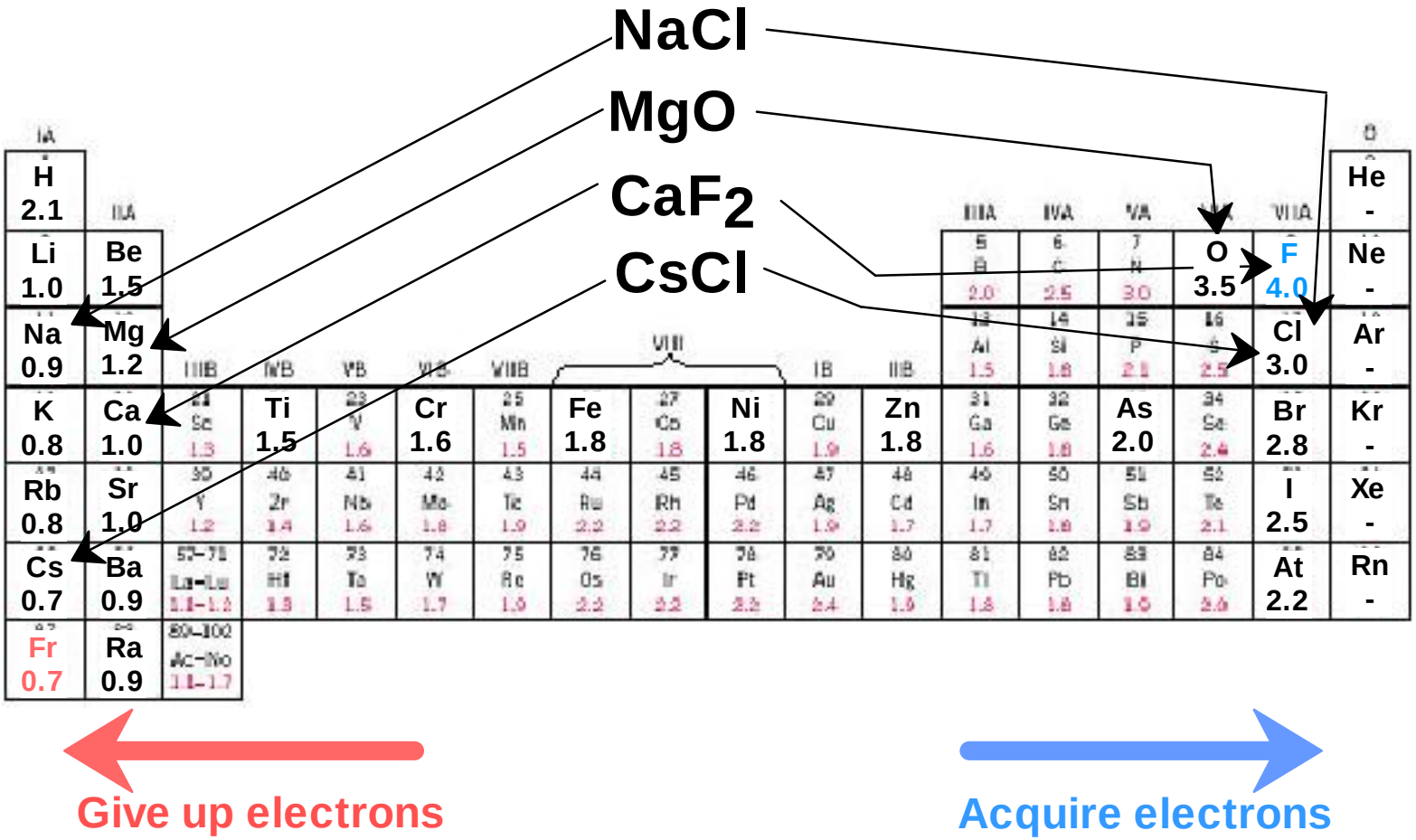
IONIC BONDING

- Occurs between + and - ions.
- Requires electron transfer.
- Large difference in electronegativity required.
- Example: NaCl



EXAMPLES: IONIC BONDING

- **Predominant bonding in Ceramics**



Adapted from Fig. 2.7, *Callister 6e.* (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.

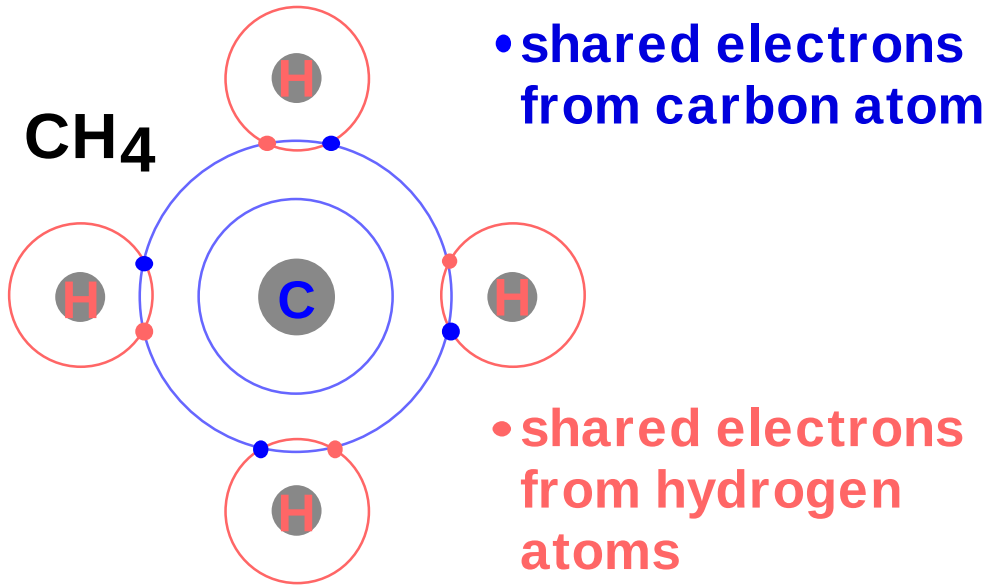
COVALENT BONDING

- Requires shared electrons
- Example: CH_4

  C: has 4 valence e, needs 4 more

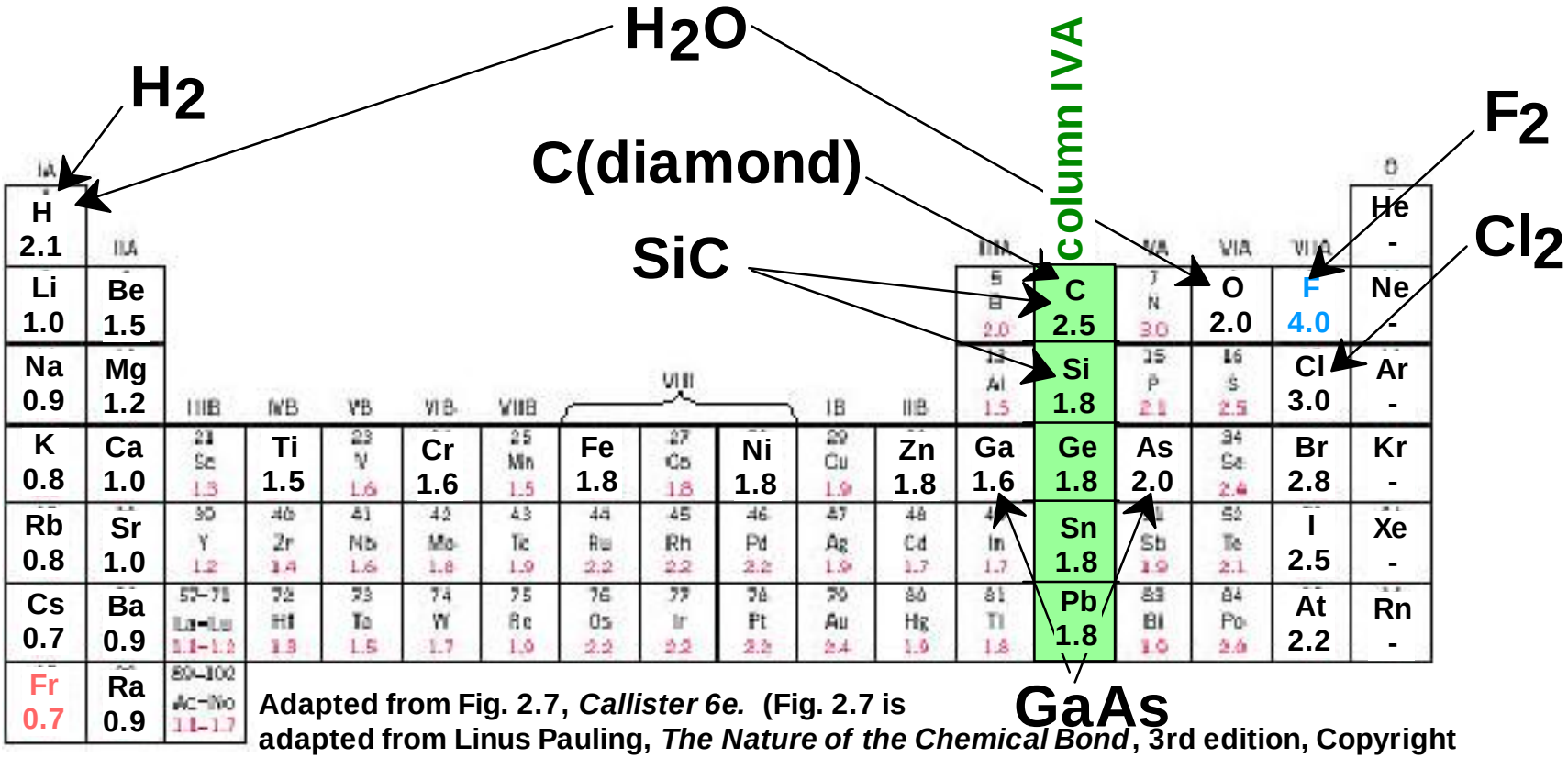
  H: has 1 valence e, needs 1 more

  Electronegativities are comparable.



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

EXAMPLES: COVALENT BONDING

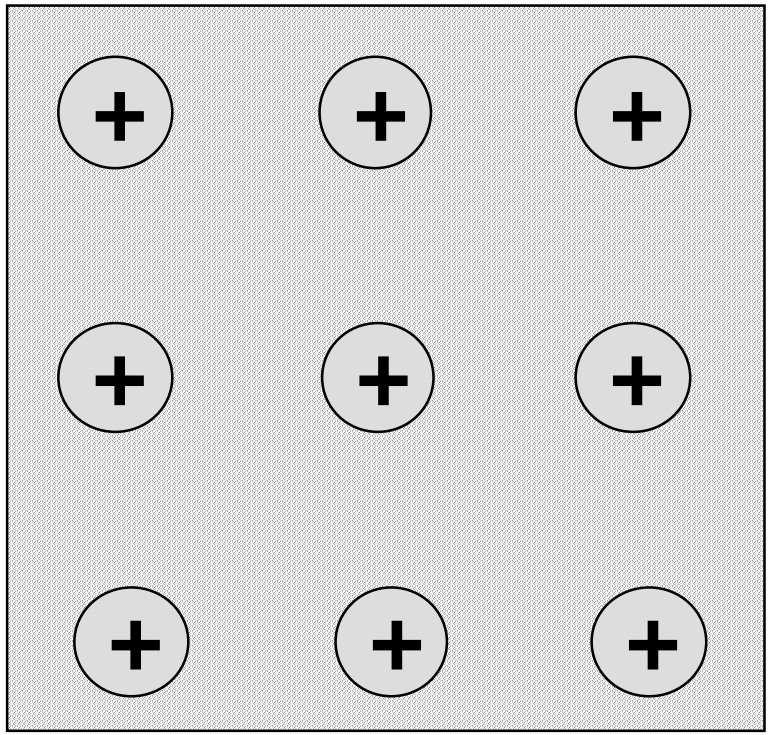


Adapted from Fig. 2.7, *Callister 6e.* (Fig. 2.7 is adapted from Linus Pauling, *The Nature of the Chemical Bond*, 3rd edition, Copyright 1939 and 1940, 3rd edition. Copyright 1960 by Cornell University.

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

METALLIC BONDING

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



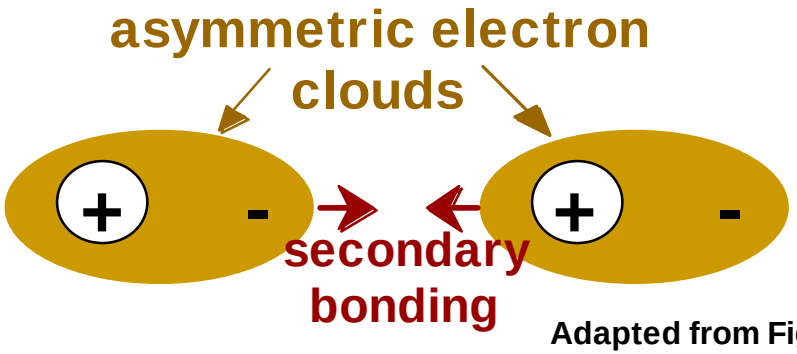
Adapted from Fig. 2.11, *Callister 6e.*

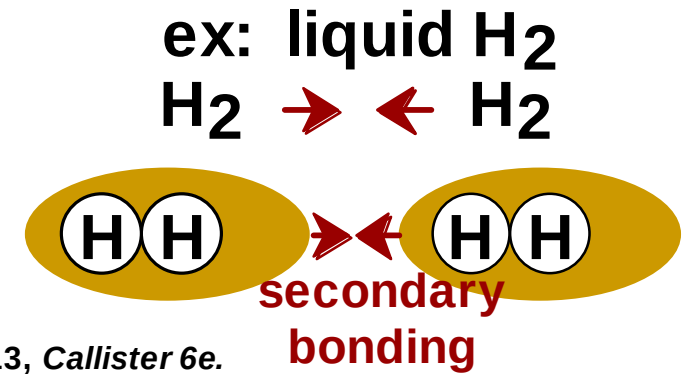
- **Primary bond for metals and their alloys**

SECONDARY BONDING

Arises from interaction between dipoles

- **Fluctuating dipoles**





Adapted from Fig. 2.13, *Callister 6e.*

- **Permanent dipoles-molecule induced**

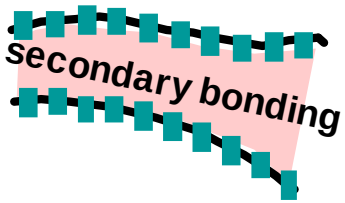
-general case:

Adapted from Fig. 2.14, *Callister 6e.*

-ex: liquid HCl

Adapted from Fig. 2.14, *Callister 6e.*

-ex: polymer

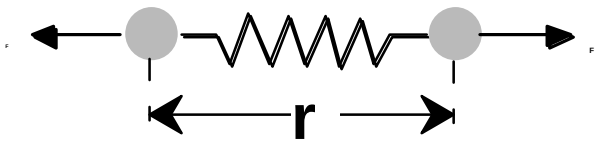


SUMMARY: BONDING

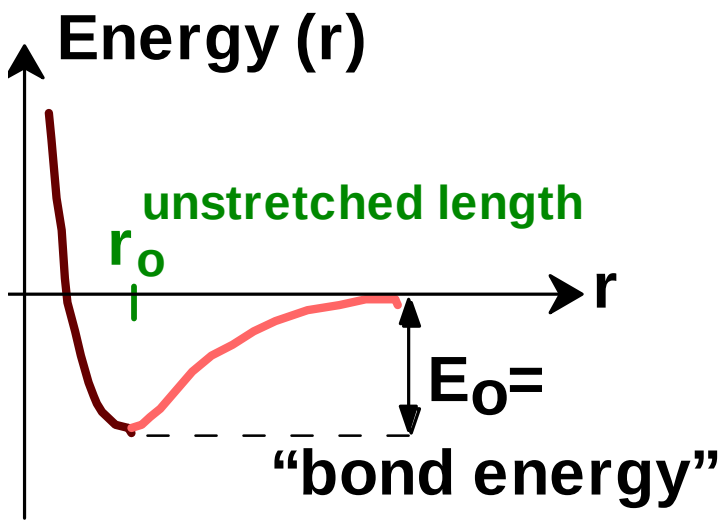
Type	Bond Energy	Comments
Ionic	Large!	Nondirectional (ceramics)
Covalent	Variable large-Diamond small-Bismuth	Directional semiconductors, ceramics polymer chains)
Metallic	Variable large-Tungsten small-Mercury	Nondirectional (metals)
Secondary	smallest	Directional inter-chain (polymer) inter-molecular

PROPERTIES FROM BONDING: T_M

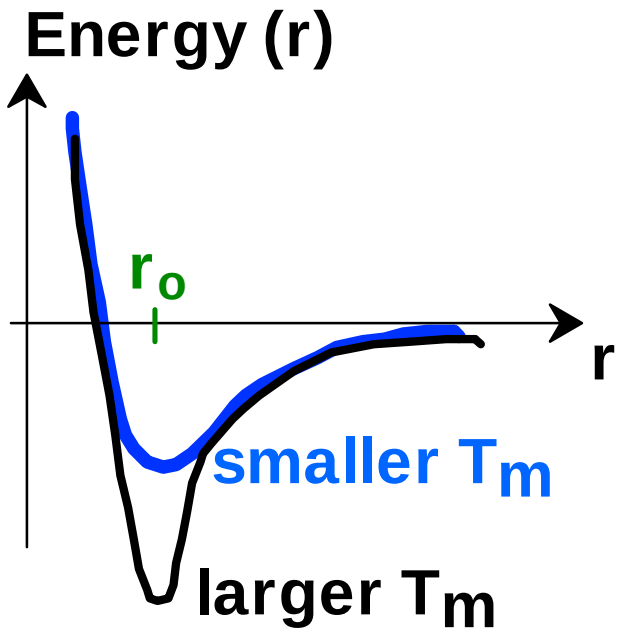
- **Bond length**, r



- **Bond energy**, E_o



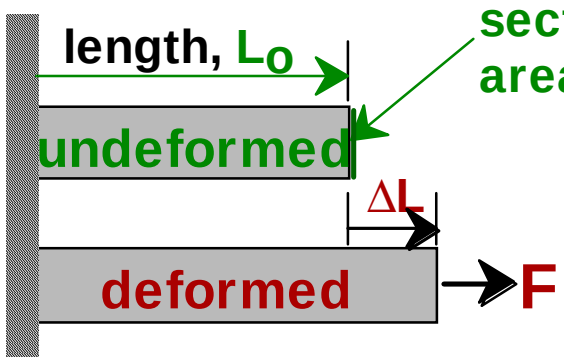
- **Melting Temperature**, T_m



T_m is larger if E_o is larger.

PROPERTIES FROM BONDING: E

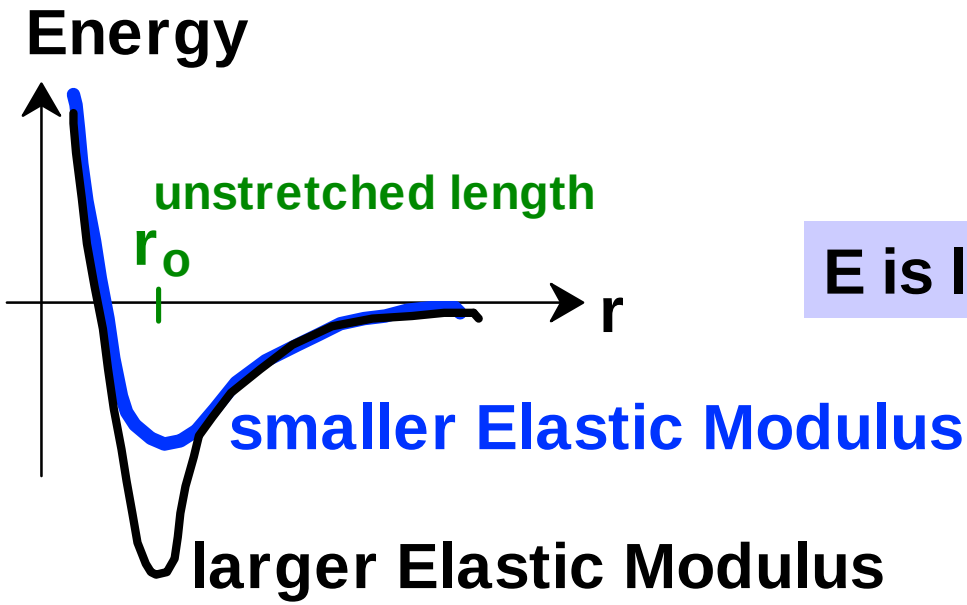
- **Elastic modulus, E**



Elastic modulus

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

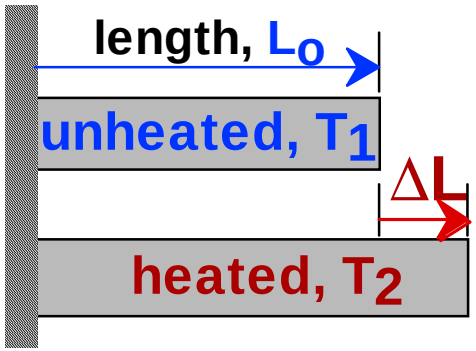
- **E ~ curvature at r_o**



E is larger if E_o is larger.

PROPERTIES FROM BONDING: α

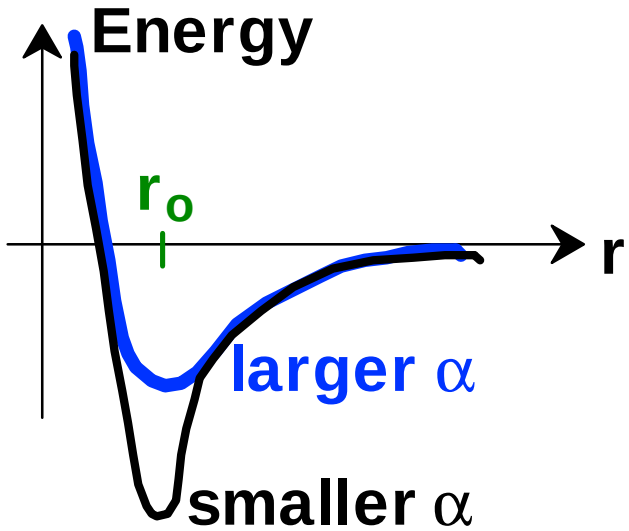
- **Coefficient of thermal expansion**, α



coeff. thermal expansion

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

- α ~ **symmetry at r_o**



α is larger if E_o is smaller.

SUMMARY: PRIMARY BONDS

Ceramics

(Ionic & covalent bonding):

Large bond energy

large T_m
large E
small α

Metals

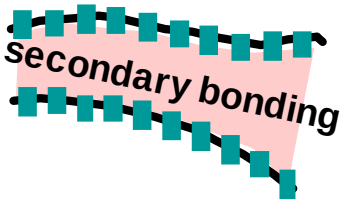
(Metallic bonding):

Variable bond energy

moderate T_m
moderate E
moderate α

Polymers

(Covalent & Secondary):



Directional Properties

Secondary bonding dominates

small T
small E
large α