Announcements Week Sept 23th to 27th

Quiz 3 Closes on Friday at 5:00 PM

Review 2 this week (can attend either Thursday or Friday)

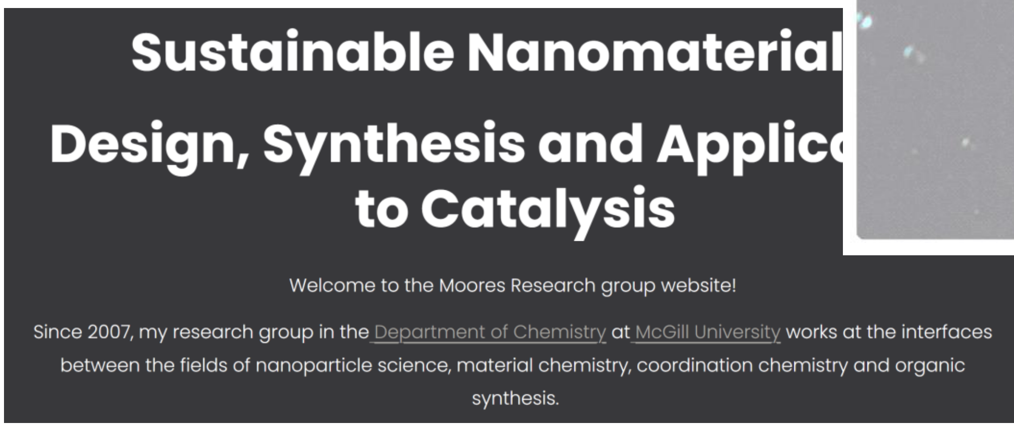
PeerCollab:
Monday and Wednesday : 3:00 to 5:00 PM

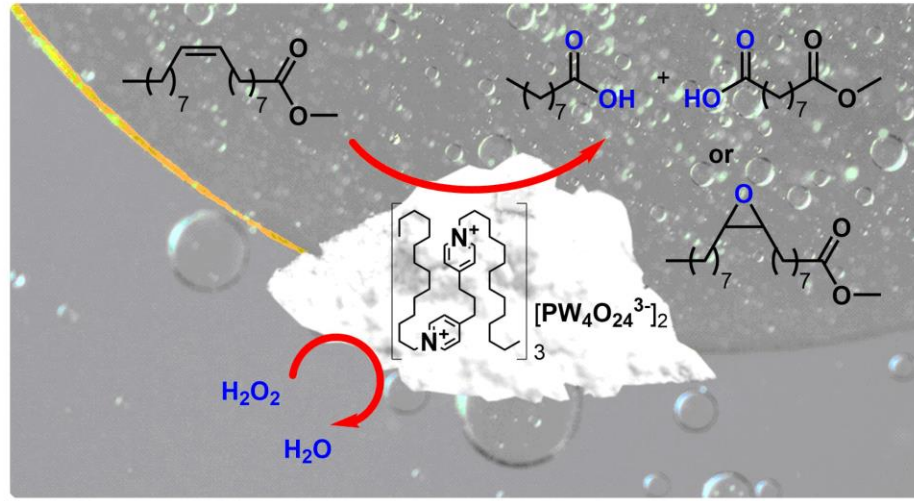
Office Hour:
Thursday 3:00 to 4:30 pm Otto Maass 100

This week in Chem110

- We will use our understanding of orbitals/electronic configurations to:
- Determine how bonds are formed
- Understand why there is a difference in the types of bonds
- Compare bond strengths between different bonds
- Draw 2-dimensional representation of covalent bonds in simple molecules

Department of Chemistry Research





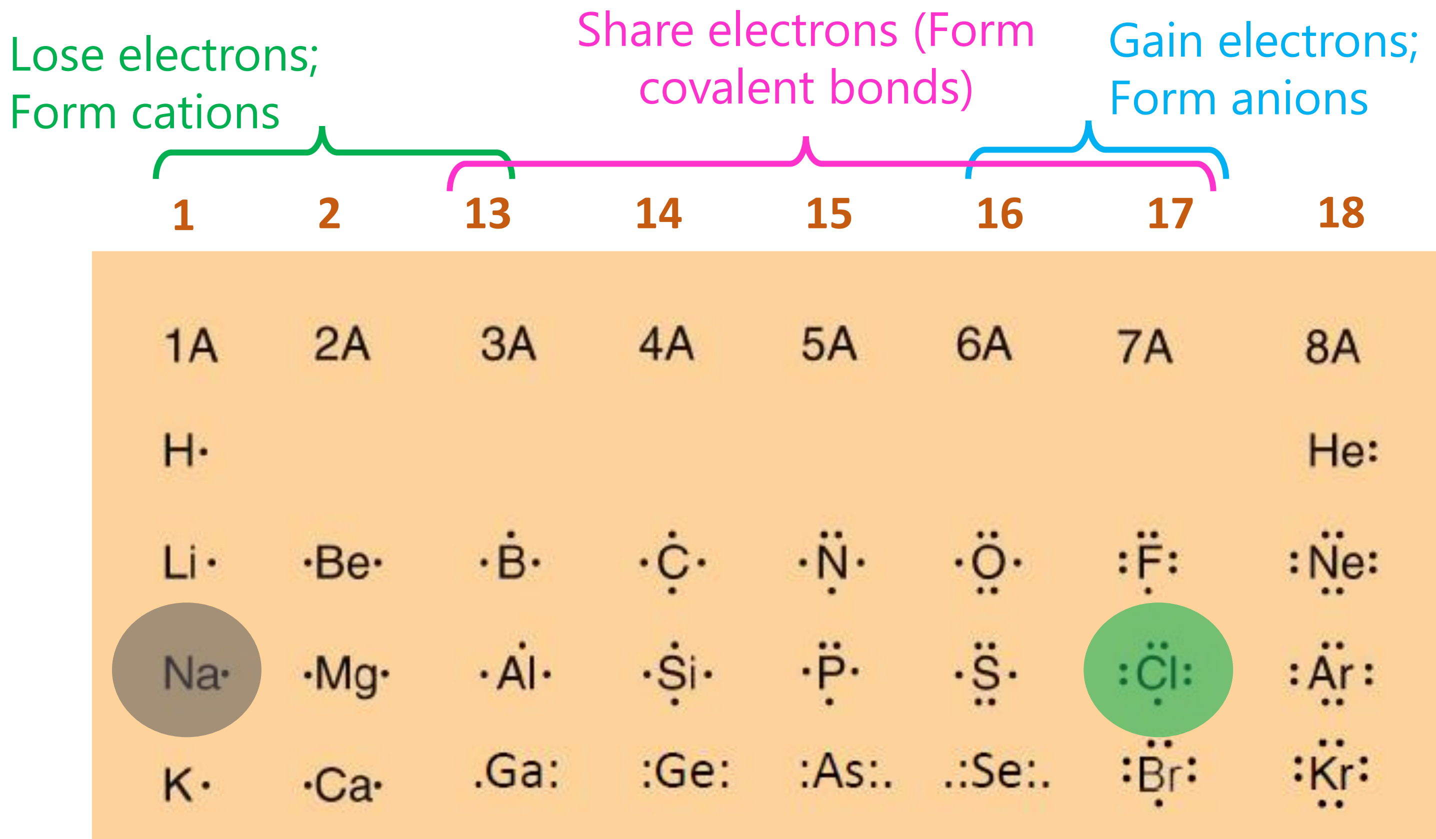
Selective and recyclable catalyst

https://www.mooresresearch.org/

Audrey Moores

Lewis or Electron Dot Structures

Octet Rule: Atoms tend to fill their valence orbital with eight electron (ns^2np^6 except He-like configuration). Atoms lose (form cations), share (covalent bonds), gain (form anions) to achieve noble gas configuration



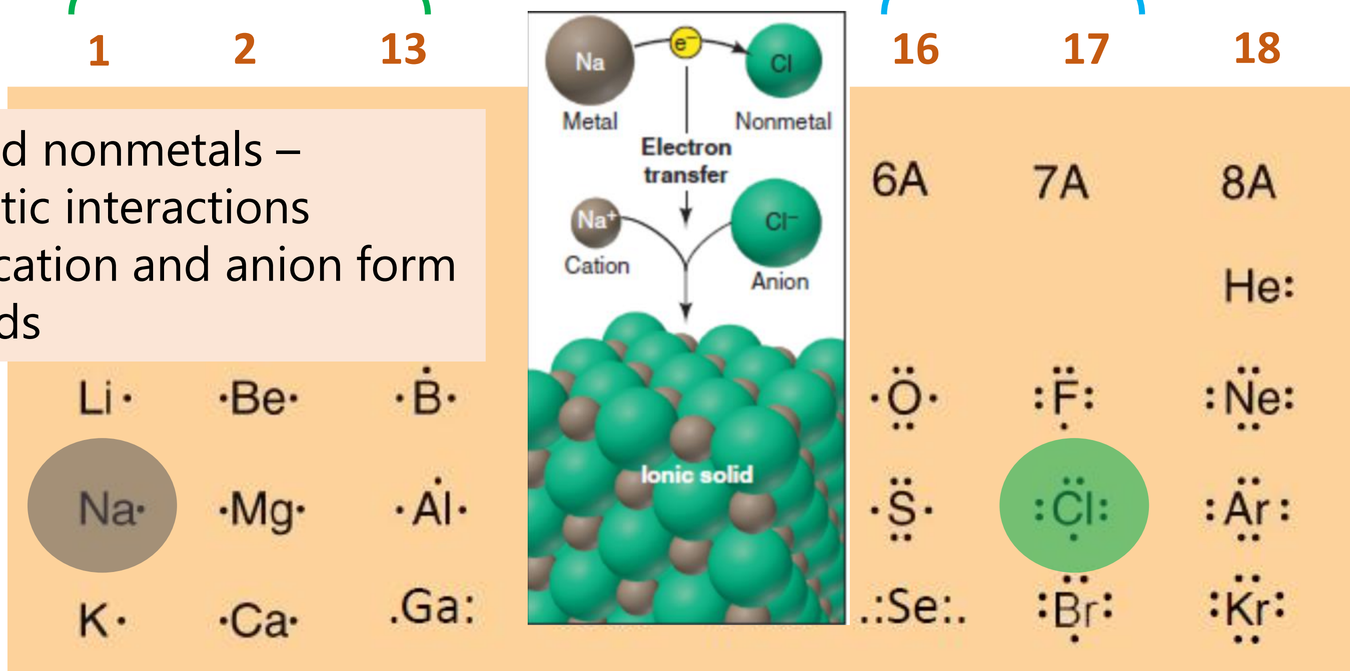
Lewis or Electron Dot Structures

Octet Rule: Atoms tend to fill their valence orbital with eight electron (ns^2np^6 except He-like configuration). Atoms lose (form cations), share (covalent bonds), gain (form anions) to achieve noble gas configuration

Lose electrons;
Form cations

Gain electrons;
Form anions

Metals and nonmetals – electrostatic interactions between cation and anion form Ionic Bonds



Lewis or Electron Dot Structures

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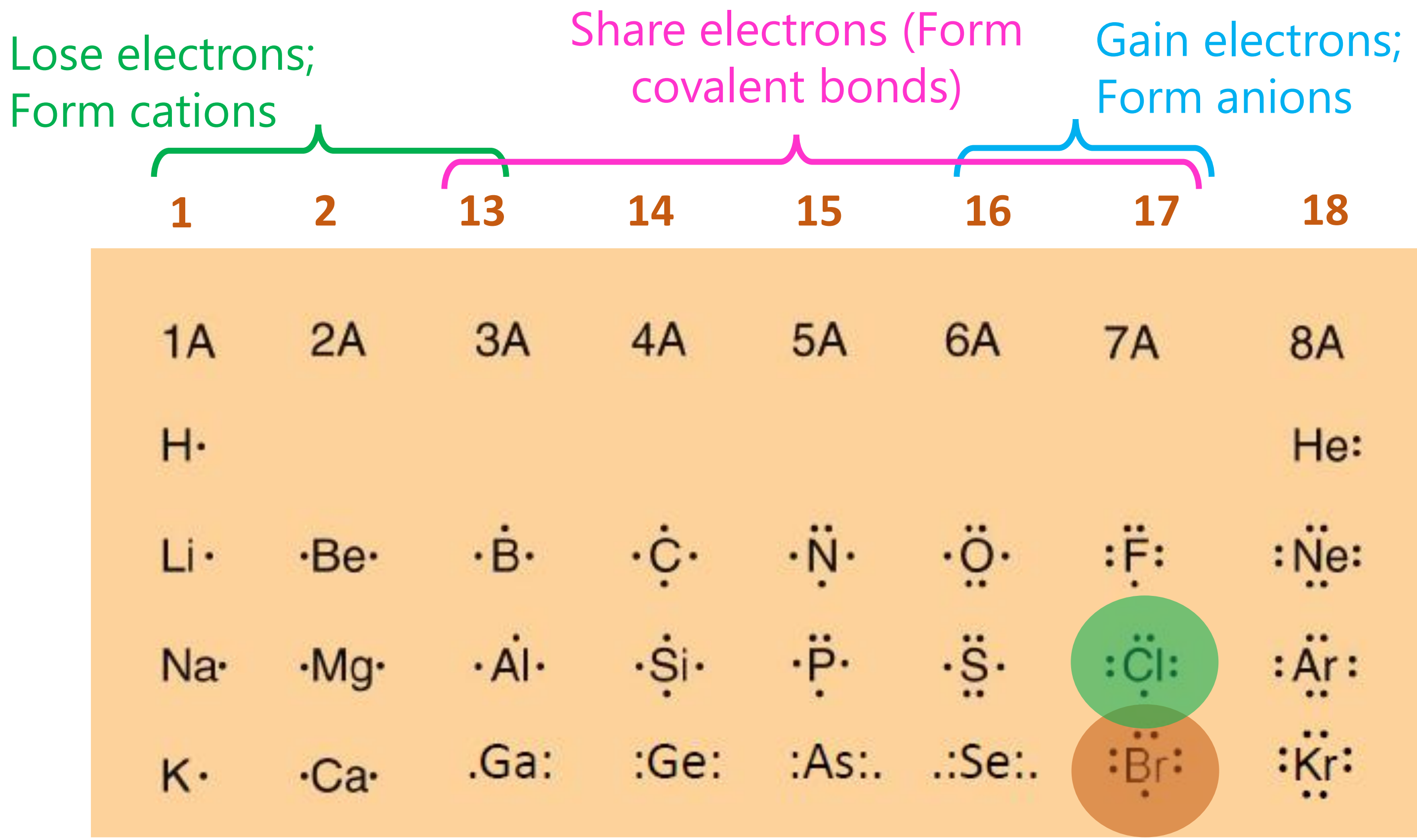


Lewis or Electron Dot Structures

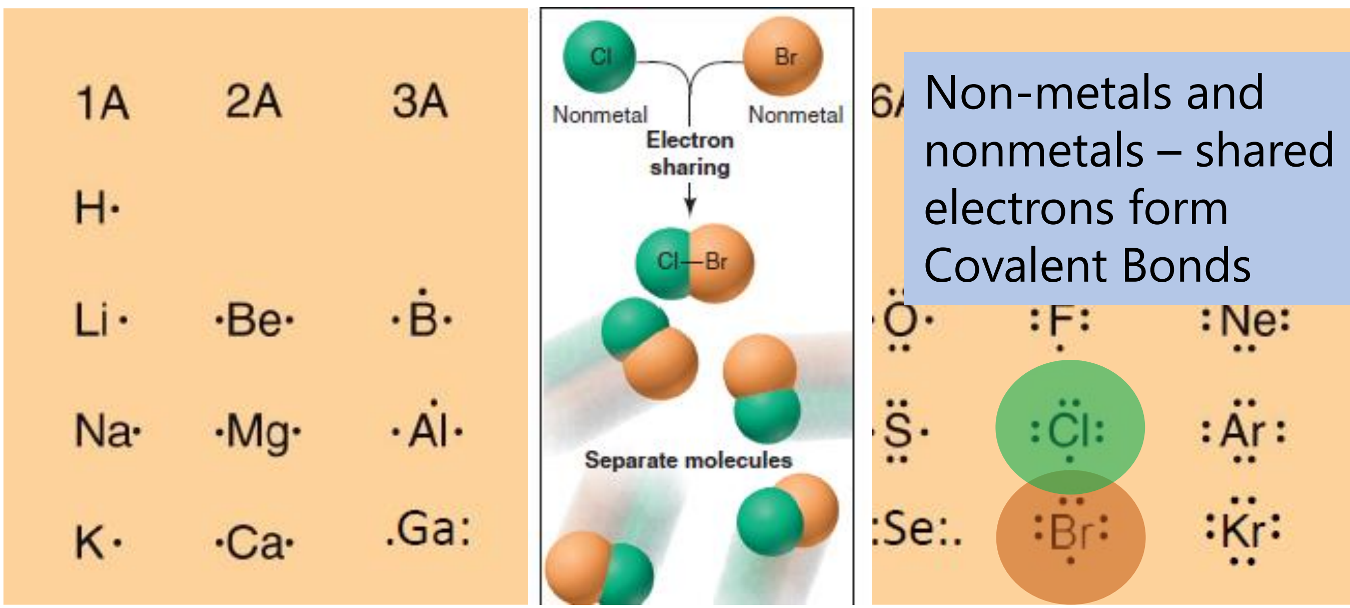
Octet Rule: Atoms tend to fill their valence orbital with eight electron (ns^2np^6 except He-like configuration). Atoms lose (form cations), share (covalent bonds), gain (form anions) to achieve noble gas configuration

Lose electrons; Form cations

Share electrons (Form covalent bonds)

Gain electrons; Form anions

1 2 13 14 15 16 17 18



Non-metals and nonmetals – shared electrons form Covalent Bonds

Comparison of Lattice Energy (Periodic Trend)

Lattice energy depends upon the electrostatic interactions between the cation and the anion

$$\boxed{E \propto q_1\, q_2 / r^2}$$

q_1 and q_2 are the anionic and cationic charge

r is the distance between them

The factors that determine lattice energy:

1) **Charge of the ions – higher the charge, higher the lattice energy**

2) **Size – Larger the ions (larger the radius), lower the lattice energy**

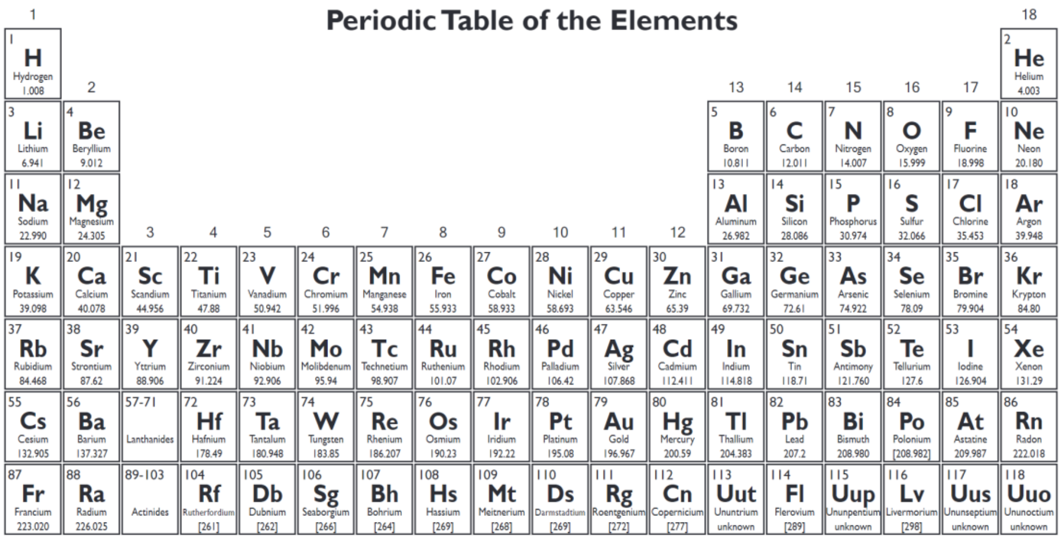
Practice Question 1

Which of the following has higher lattice energy?

KCl or CaS

CsCl or $MgCl_2$

RbI or NaBr



Practice Question 1

Which of the following has higher lattice energy?

CsCl or **$MgCl_2$**

Mg^{2+} smaller than Cs^{+}

Mg2+ higher charge

RbI or **NaBr**

Na^{+} smaller than Rb^{+}

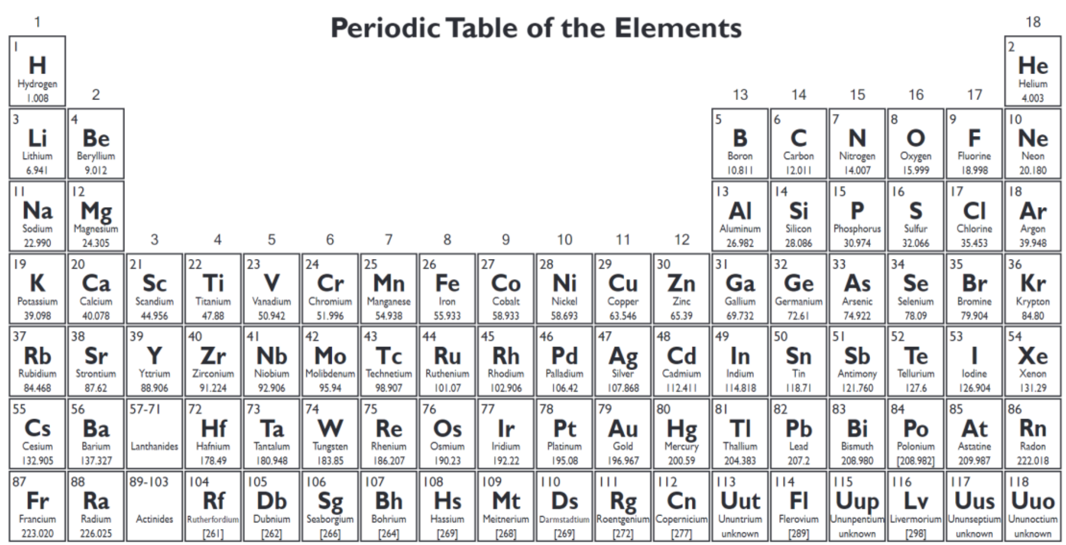
Br- is smaller than I-

KCl or **CaS**

Higher charge for both Ca^{2+} and S^{2-}

Ca^{2+} smaller than K^{+}

Even though Cl- is smaller than S2-; the higher charge of both cation and anion and the smaller size of cation results in CaS with a higher lattice energy **(In an exam, you will not have opposing trends like in this question)**



Practice Question 2

Compare the bond energy and bond order of the following:

A $\mathrm{C{-}O}$ $\mathrm{C{=}O}$ $\mathrm{C{\equiv}O}$

B $\mathrm{C{=}C}$ $\mathrm{C{=}N}$ $\mathrm{C{=}O}$

C $\mathrm{H{-}F}$ $\mathrm{H{-}Cl}$ $\mathrm{H{-}Br}$ $\mathrm{H{-}I}$

Practice Question

Compare the bond energy and bond order of the following:

A

1	2	3	BOND ORDER
$C-O$	$C=O$	$C\equiv O$	BOND ENERGY

B

2	2	2	BOND ORDER
$C=C$	$C=N$	$C=O$	BOND ENERGY

C

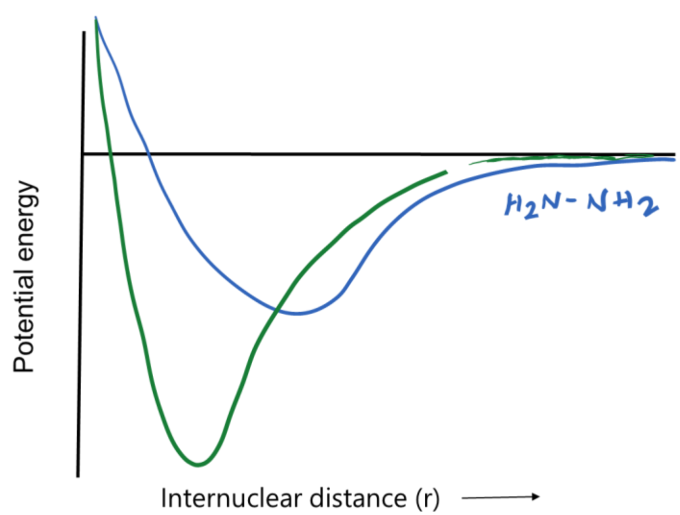
1	1	1	1	BOND ORDER
$H-F$	$H-Cl$	$H-Br$	$H-I$	BOND ENERGY

Higher the bond order – stronger the bond (bond energy is higher)

If the bond order is the same, then compare the bond length.
Shorter the bond length – stronger the bond (bond energy is higher)

slido

Which molecule has higher bond energy?



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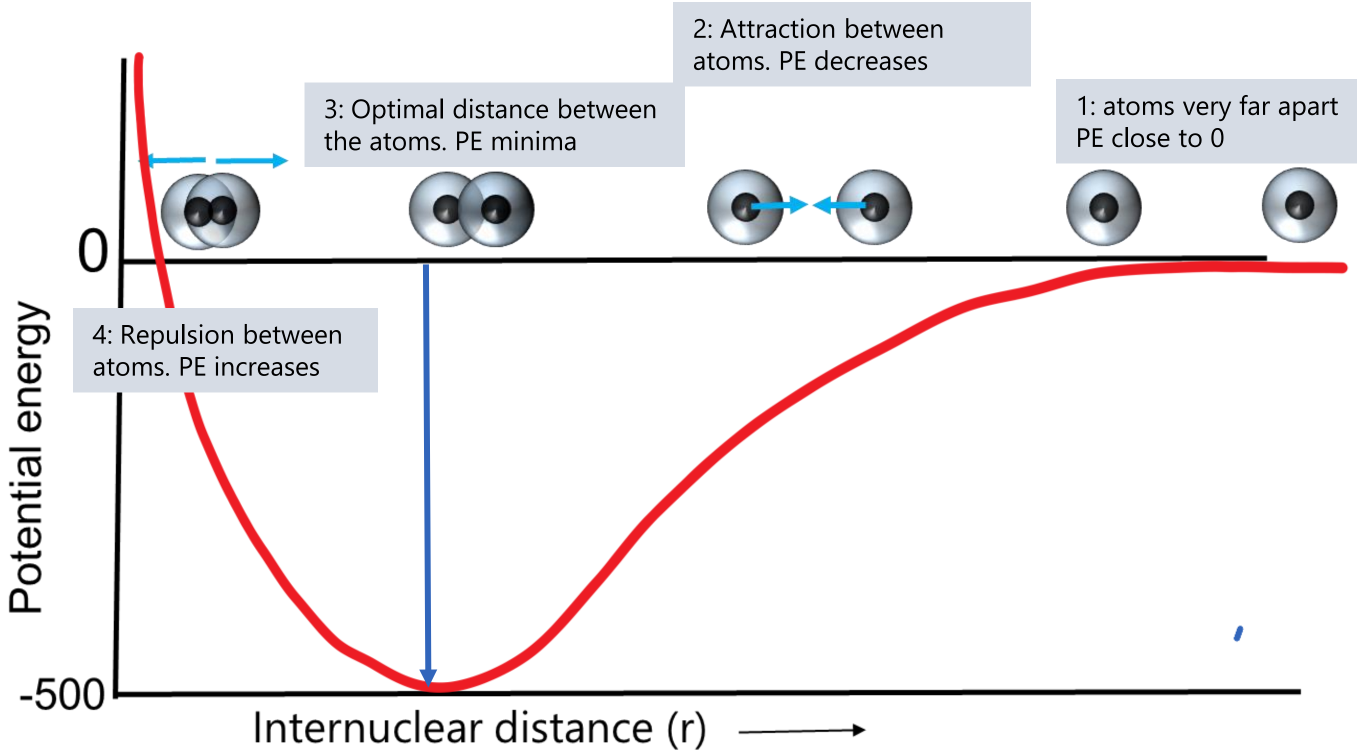
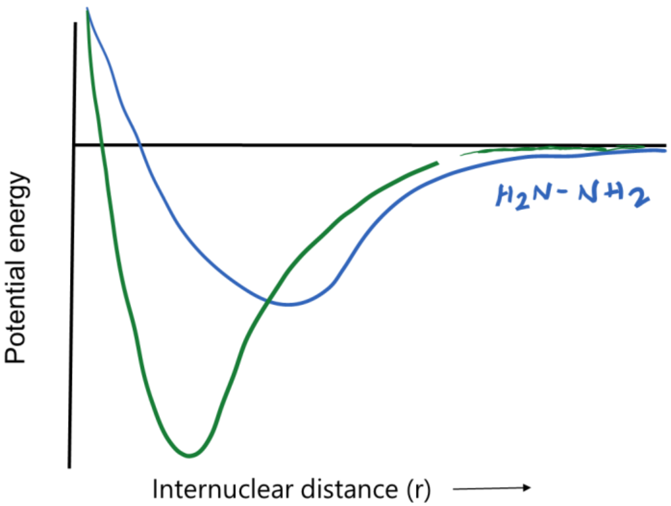
How are covalent bonds formed?

We can plot the energy of the two atoms forming a covalent bond as a function of the distance between them



slido

Which molecule has higher bond energy?



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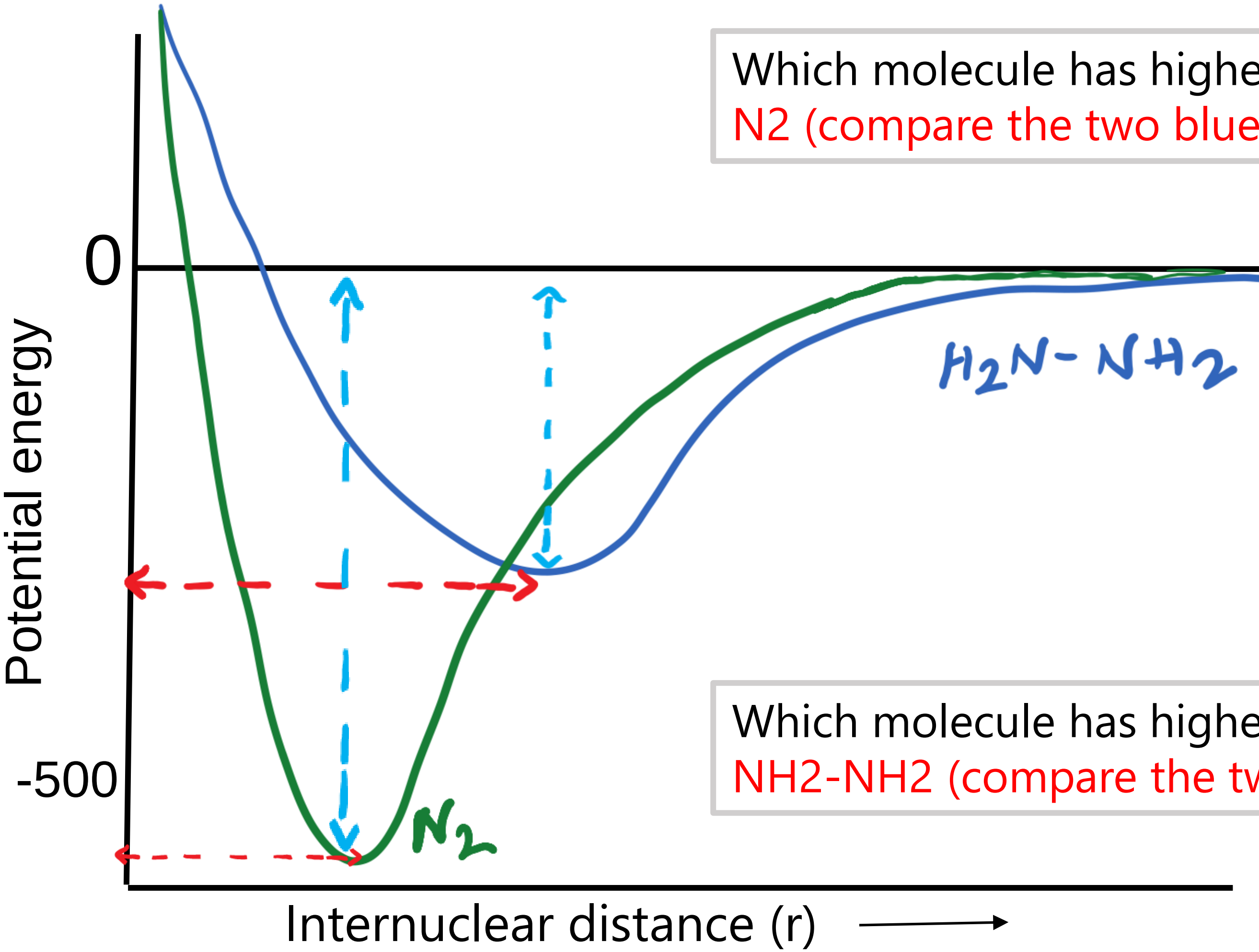
Practice Question 3



Which molecule has higher **bond energy**?
N2 (compare the two blue lines – y axis)

Which molecule has higher **bond length**?
NH2-NH2 (compare the two red lines, x axis)

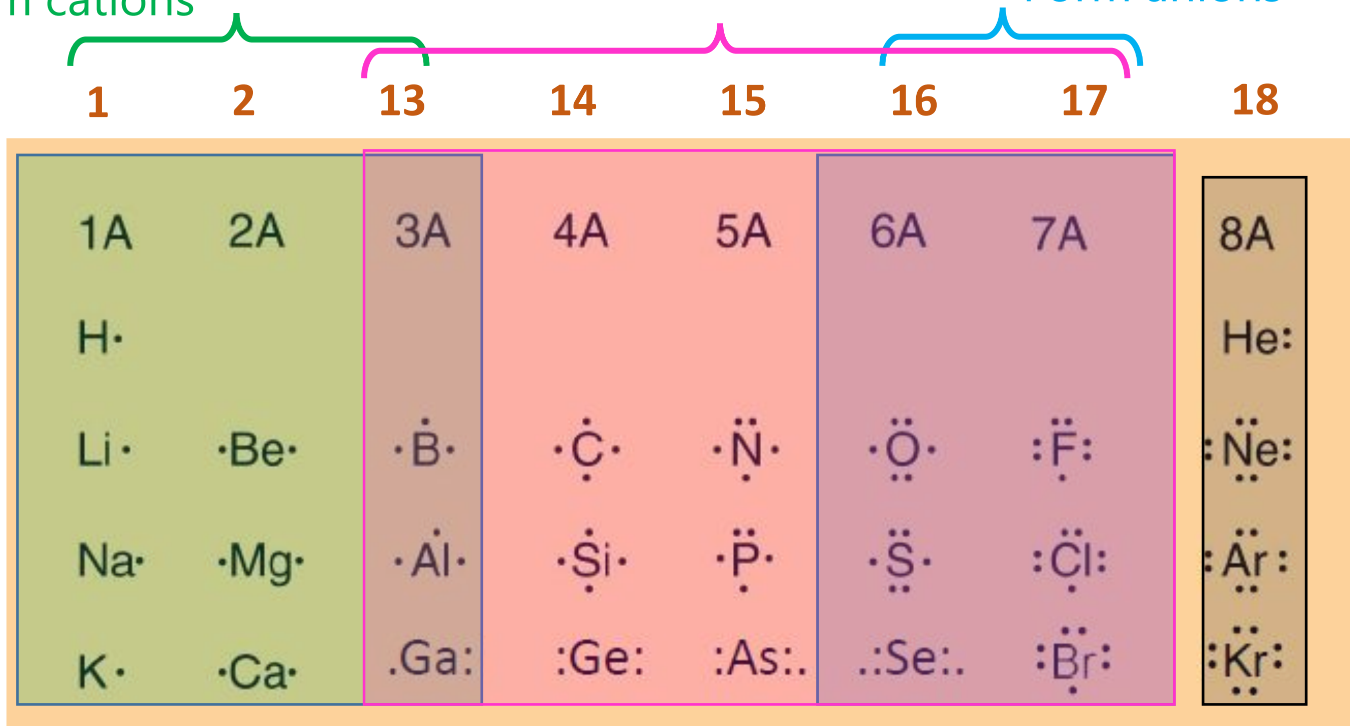
Lewis or Electron Dot Structures

Octet Rule: Atoms tend to fill their valence orbital with eight electron (ns^2np^6 except He-like configuration). Atoms lose (form cations), share (covalent bonds), gain (form anions) to achieve noble gas configuration

Lose electrons; Form cations

Share electrons (Form covalent bonds)

Gain electrons; Form anions



Noble Gases

Practice Question 4

Practice the Lewis Structure for the following molecules:

H_2O H_2 O_2

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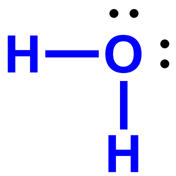
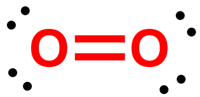
H_2O H_2 O_2





Practice Question 5

Calculate the enthalpy of reaction for the following reaction

$$2H_2O\ (l) \longrightarrow 2H_2\ (g) + O_2\ (g)$$

BOND ENERGIES:

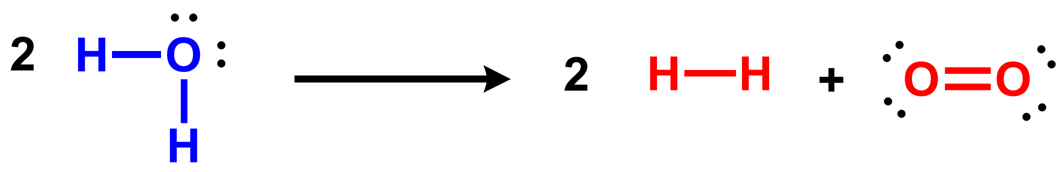
H–H: 436 kJ

O=O: 498 kJ

O-H: 464 kJ

Practice Question

Calculate the enthalpy of reaction for the following reaction



<u>BOND ENERGIES:</u>
H–H: 436 kJ/mol
O=O: 498 kJ/mol
O-H: 464 kJ /mol

<u>BREAK</u>
4 mol O–H: <u>4(+ 464 kJ)</u>
+ 1856 kJ

<u>MAKE</u>
2 mol H–H: 2(- 436 kJ)
1 mol O=O: <u>- 498 kJ</u>
- 1370 kJ

$$\Delta_r H^\circ = (1856 - 1370) = 486 \text{ kJ} > 0 \text{ (positive, endothermic)}$$

IONIC BONDING

Hypothetical steps in the formation of an ionic solid

$Li(s) + ½\ F_2\ (g) \longrightarrow LiF(s)$

i. Formation of gaseous metal atoms — $Li(s) \longrightarrow Li(g)$

ii. Formation of gaseous metal cations — $Li(g) \longrightarrow Li^+(g)$

iii. Formation of gaseous non-metal atoms — $½\ F_2(g) \longrightarrow F(g)$

iv. Formation of gaseous non-metal anions — $F(g) \longrightarrow F^-(g)$

v. Formation of ionic solid/lattice — $Li^+(g) + F^-\ (g) \longrightarrow LiF(s)$

Step v releases a lot of heat (-ve enthalpy), compensating for i to iv

Reverse of step v – gives us the Lattice Energy

Destruction of ionic lattice (Lattice Energy) — $LiF(s) \longrightarrow Li^+(g) + F^-\ (g)$

The enthalpy change associated with **lattice destruction** is called lattice energy

IONIC BONDING

Lattice Energy

Formation of ionic solid

$$Li^+(g) + F^-(g) \longrightarrow LiF(s)$$

$\Delta H = -1050$ kJ/mol

The ΔH for the above reaction is a high negative value (Exothermic reaction)

Destruction of ionic lattice

$$LiF(s) \longrightarrow Li^+(g) + F^-(g)$$

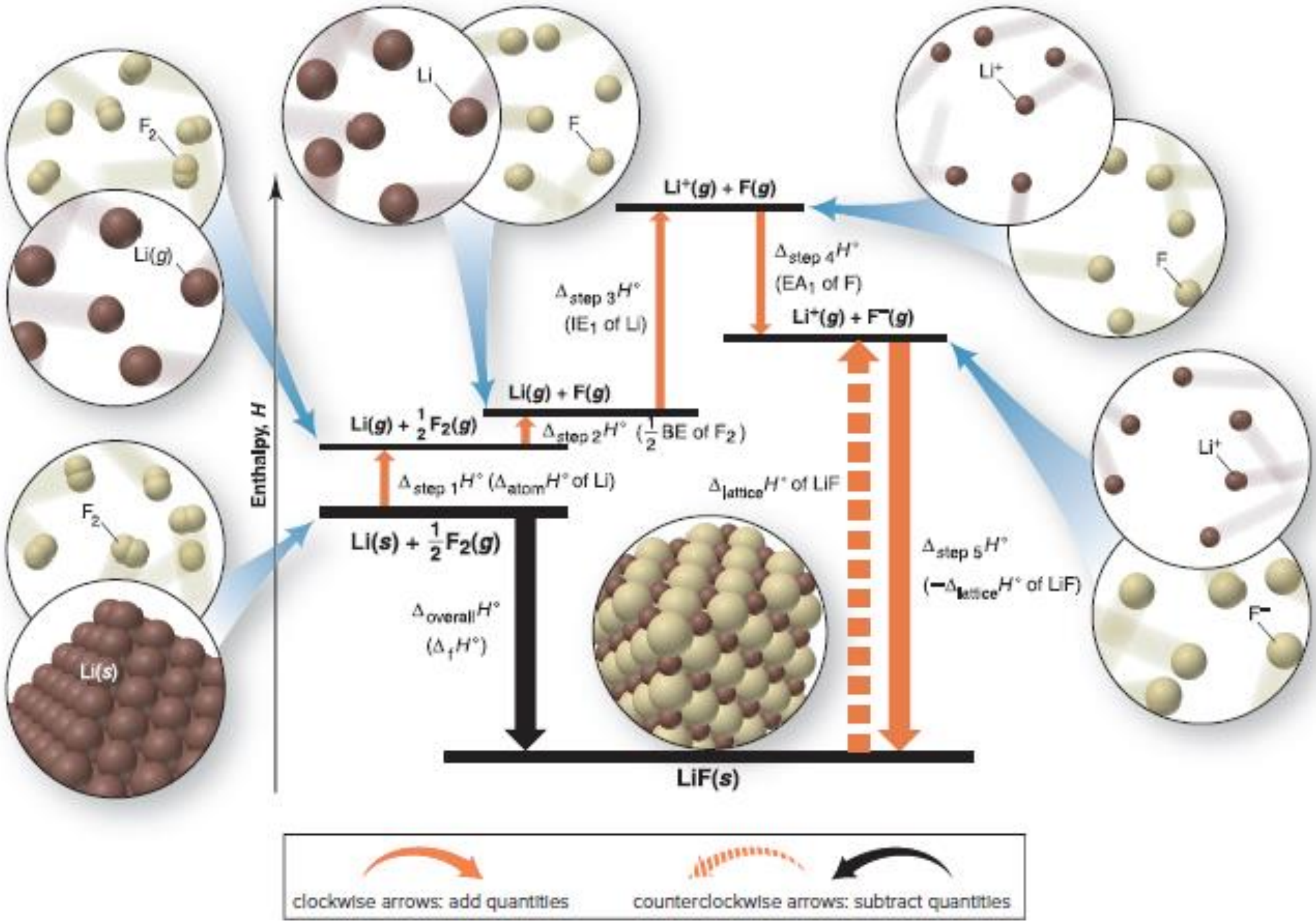
$\Delta H = 1050$ kJ/mol

The enthalpy change associated with **lattice destruction** is called lattice energy

How do we determine lattice energy?

Lattice Energy: Born Haber Cycle

We can't measure lattice energy directly: We determine it indirectly using Born Haber Cycle



Practice Question 6

Calculate the lattice energy of magnesium sulfide from the data given below.

$Mg(s) \dashrightarrow Mg(g)$ $\Delta H° = 148$ kJ/mol

$Mg(g) \dashrightarrow Mg^{2+}(g) + 2e^-$ $\Delta H° = 2186$ kJ/mol

$S_8(s) \dashrightarrow 8S(g)$ $\Delta H° = 2232$ kJ/mol

$S(g) + 2e^- \dashrightarrow S^{2-}(g)$ $\Delta H° = 450$ kJ/mol

$8Mg(s) + S_8(s) \dashrightarrow 8MgS(s)$ $\Delta H° = -2744$ kJ/mol

Practice Question 6

Calculate the lattice energy of magnesium sulfide from the data given below.

$Mg(s) \text{ ---> } Mg(g)$ $\Delta H° = 148$ kJ/mol

$Mg(g) \text{ ---> } Mg^{2+}(g) + 2e^-$ $\Delta H° = 2186$ kJ/mol

$S_8(s) \text{ ---> } 8S(g)$ $\Delta H° = 2232$ kJ/mol

$(1/8)\ S_8(s) \text{ ---> } S(g)$ $\Delta H° = 279$ kJ/mol

$S(g) + 2e^- \text{ ---> } S^{2-}(g)$ $\Delta H° = 450$ kJ/mol

$8Mg(s) + S_8(s) \text{ ---> } 8MgS(s)$ $\Delta H° = -2744$ kJ/mol

$(8/8)\ Mg(s) + (1/8)\ S_8(s) \text{ ---> } (8/8)\ MgS(s)$ $\Delta H° = (-2744/8)$ kJ/mol

$Mg(s) + (1/8)\ S_8(s) \text{ ---> } MgS(s)$ $\Delta H° = -343$ kJ/mol

$MgS(s) \text{ ---> } Mg(s) + (1/8)\ S_8(s)$ $\Delta H° = 343$ kJ/mol

Lattice Energy Reaction:

$MgS\ (s) \text{ ---> } Mg^{2+}(g) + S^{2-}(g)$ $\Delta H° = ?$

Practice Question 6

Calculate the lattice energy of magnesium sulfide from the data given below.

$\cancel{Mg(s)}$ ---> $\cancel{Mg(g)}$ $\Delta H° = 148$ kJ/mol

$\cancel{Mg(g)}$ ---> $Mg^{2+}(g)$ $\cancel{+ 2e^-}$ $\Delta H° = 2186$ kJ/mol

$(1\cancel{/8)\ S_8}(s)$ ---> $\cancel{S(g)}$ $\Delta H° = 279$ kJ/mol

$\cancel{S(g)}$ $\cancel{+ 2e^-}$ ---> $S^{2-}(g)$ $\Delta H° = 450$ kJ/mol

$MgS(s)$ ---> $\cancel{Mg(s)}$ + $(1\cancel{/8)\ S_8(s}$) $\Delta H° = 343$ kJ/mol

These reactions can now be added together to get the reaction representing the lattice energy reaction

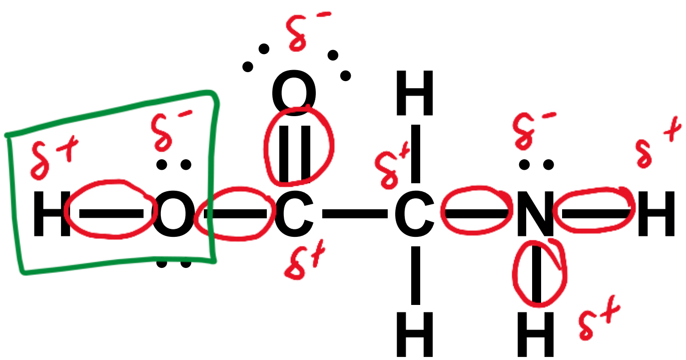
Lattice Energy Reaction:

$MgS\ (s)$ ---> $Mg^{2+}(g) + S^{2-}(g)$ $\Delta H° = ?$

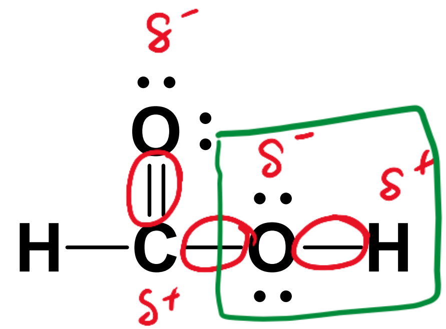
$\Delta H°$ (Lattice energy) = 148 + 2186 + 279 + 450 +343 = 3406 kJ/mol

Practice Question 7

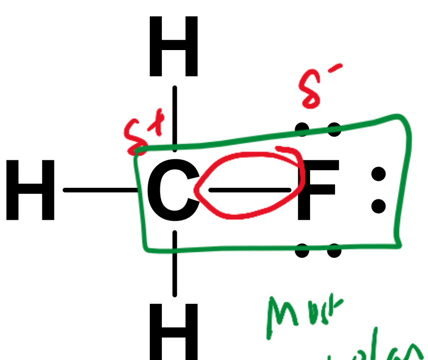
Label the polar covalent bonds in the structures below, indicate δ+ and δ–.
Which bond is the *most* polar? (Use the Datasheet – posted on myCourses has the electronegativity chart)



Most polar



Most polar



Most polar

Electronegativity values of the elements (Pauling scale)

H 2.1																	He
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe 2.6
Cs 0.7	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn 2.4
Fr 0.7	Ra 0.7	Ac 1.1															

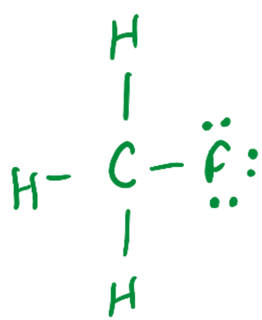
Ce 1.1	Pr 1.1	Nd 1.1	Pm 1.1	Sm 1.1	Eu 1.1	Gd 1.1	Tb 1.1	Dy 1.1	Ho 1.1	Er 1.1	Tm 1.1	Yb 1.1	Lu 1.2
Th 1.3	Pa 1.5	U 1.7	Np 1.3	Pu 1.3	Am 1.3	Cm 1.3	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr

Practice Question 8: Determining Lewis Structures

Lewis structures to determine the bonding in complex molecules

1. Determine total number of valence electrons
2. Any charges? YES – add (-ve charge)/subtract (+ve charge)
3. Build skeleton structure (incomplete Lewis Structure)
   a) Group 14,15,16 atoms usually “central”
   b) Hydrogen and Group 17 atoms “terminal”
   c) Make *multiple bonds* only when necessary
4. Check - Noble gas electronic configuration at each atom?

CH_3F



CH_2CH_2