

# Announcements Week Sept 23<sup>th</sup> to 27<sup>th</sup>

**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

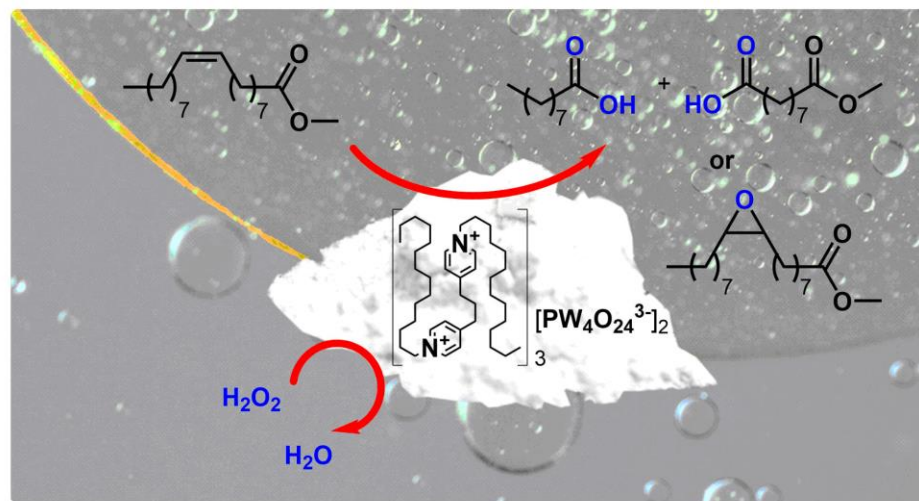
- We will use our understanding of orbitals/electronic configurations to:
- Determine how bonds are formed
- Understand why there is a difference in the types of bonds
- Compare bond strengths between different bonds
- Draw 2-dimensional representation of covalent bonds in simple molecules

## Sustainable Nanomaterial Design, Synthesis and Application to Catalysis

Welcome to the Moores Research group website!

Since 2007, my research group in the [Department of Chemistry at McGill University](#) works at the interfaces between the fields of nanoparticle science, material chemistry, coordination chemistry and organic synthesis.

<https://www.mooresresearch.org/>



Selective and recyclable catalyst



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

Lose electrons;  
Form cations

Share electrons (Form  
covalent bonds)

Gain electrons;  
Form anions

1 2 13 14 15 16 17 18

1A	2A	3A	4A	5A	6A	7A	8A
H·							He:
Li·	·Be·	·B·	·C·	·N·	·O·	·F·	·Ne·
Na·	·Mg·	·Al·	·Si·	·P·	·S·	·Cl·	·Ar·
K·	·Ca·	·Ga·	·Ge·	·As·	·Se·	·Br·	·Kr·

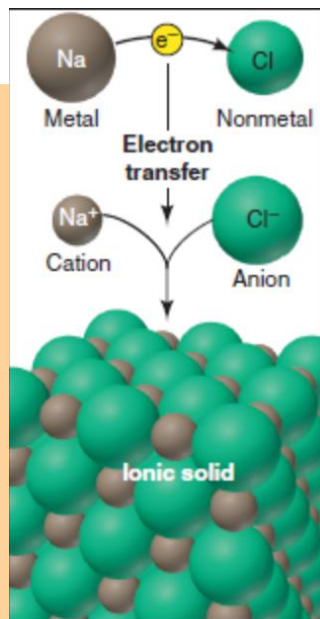
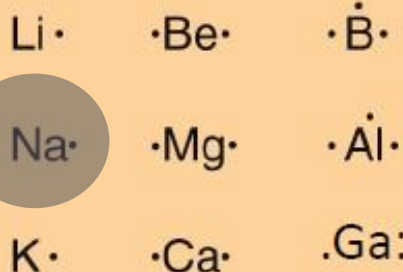
# Lewis or Electron Dot Structures

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Lose electrons;  
Form cations

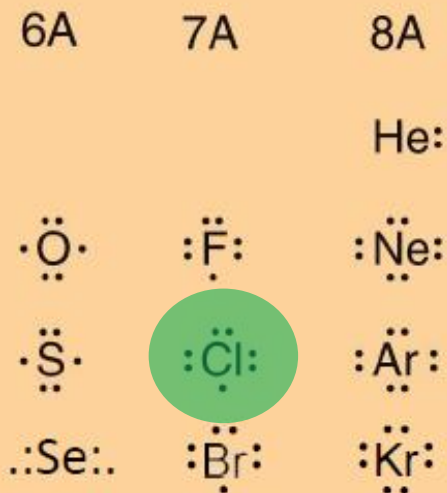
1 2 13

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



Gain electrons;  
Form anions

16 17 18



# 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
1A	2A	3A	4A	5A	6A	7A	8A
H·							He:
Li·	·Be·	·B·	·C·	·N·	·O·	·F·	·Ne:
Na·	·Mg·	·Al·	·Si·	·P·	·S·	·Cl·	·Ar:
K·	·Ca·	·Ga:	·Ge:	·As:	·Se:	·Br:	·Kr:

# 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

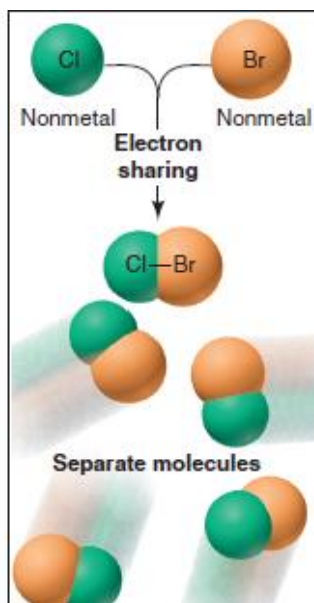
Lose electrons;  
Form cations

Share electrons (Form  
covalent bonds)

Gain electrons;  
Form anions

1 2 13 14 15 16 17 18

1A	2A	3A
H·		
Li·	·Be·	·B·
Na·	·Mg·	·Al·
K·	·Ca·	·Ga·



Non-metals and nonmetals – shared electrons form Covalent Bonds

·Ö·	·F·	·Ne·
·S·	·Cl·	·Ar·
·Se·	·Br·	·Kr·

# Comparison of Lattice Energy (Periodic Trend)

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

$$E \propto q_1 q_2 / r^2$$

$q_1$  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<sub>2</sub>

RbI or NaBr

Periodic Table of the Elements																																	
																2																	
																13	14	15	16	17	18												
																5	6	7	8	9	10												
																13	14	15	16	17	18												
																Aluminum	Silicon	Phosphorus	Sulfur	Chlorine	Argon												
																26.982	28.086	30.974	32.066	35.453	39.948												
																3	4	5	6	7	8	9	10	11	12								
																19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
																Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton
																39.098	40.078	44.956	47.88	50.942	51.996	54.938	55.933	58.933	58.693	63.546	65.39	69.723	72.61	74.922	78.96	79.904	84.80
																37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
																Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon
																84.468	87.62	88.906	91.224	92.906	95.94	98.907	101.07	102.906	106.42	107.868	112.411	114.818	118.71	121.760	127.6	126.904	131.29
																55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
																Cesium	Barium	Lanthanides	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
																132.905	137.327		178.49	180.948	183.85	186.207	190.23	192.22	195.08	196.967	200.59	204.383	207.2	208.980	[209]	209.987	222.018
																87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
																Francium	Radium	Actinides	Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Meitnerium	Darmstadtium	Roentgenium	Copernicium	Ununtrium	Flerovium	Ununpentium	Livermorium	Ununseptium	Ununoctium
																223.020	226.025		[261]	[262]	[266]	[264]	[269]	[268]	[269]	[272]	[277]	unknown	[289]	unknown	[293]	unknown	unknown

# Practice Question 1

Which of the following has higher lattice energy?

KCl or **CaS**

CsCl or **MgCl<sub>2</sub>**

Mg<sup>2+</sup> smaller than Cs<sup>+</sup>

Mg<sup>2+</sup> higher charge

RbI or **NaBr**

Na<sup>+</sup> smaller than Rb<sup>+</sup>

Br<sup>-</sup> is smaller than I<sup>-</sup>

Higher charge for both Ca<sup>2+</sup> and S<sup>2-</sup>

Ca<sup>2+</sup> smaller than K<sup>+</sup>

Even though Cl<sup>-</sup> is smaller than S<sup>2-</sup>; 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)**

**Periodic Table of the Elements**

1																	2
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

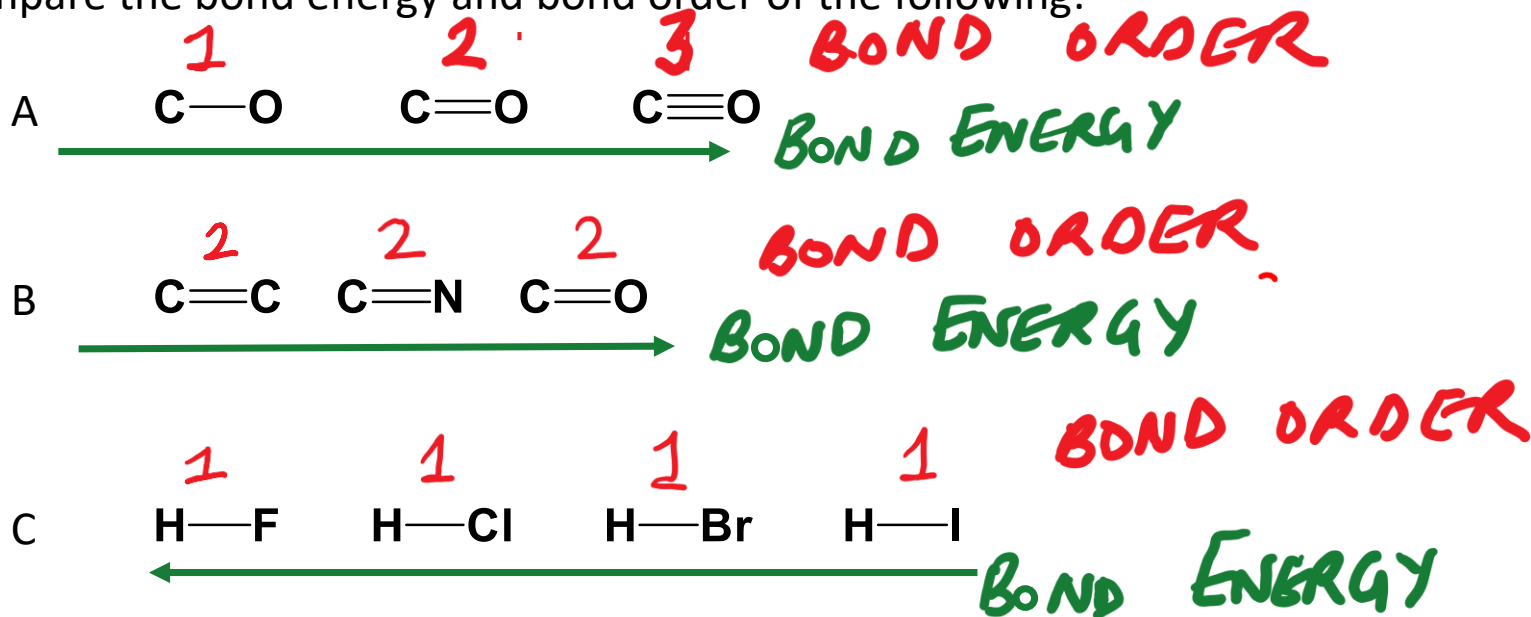
# Practice Question 2

Compare the bond energy and bond order of the following:



# Practice Question

Compare the bond energy and bond order of the following:



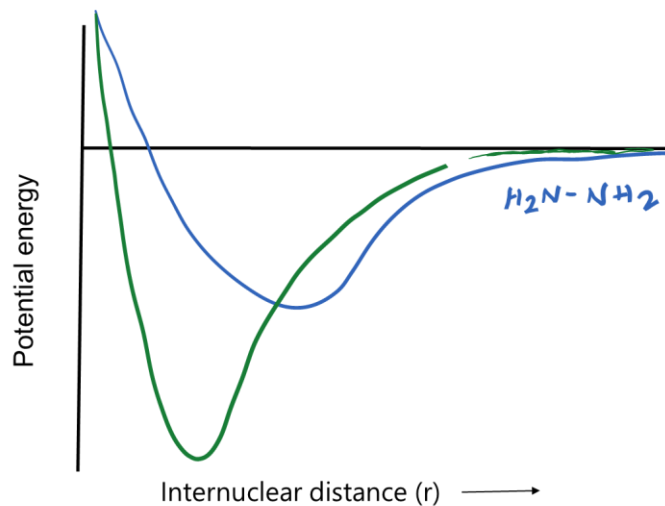
Higher the bond order – stronger the bond (bond energy is higher)

If the bond order is the same, then compare the bond length.

Shorter the bond length – stronger the bond (bond energy is higher)



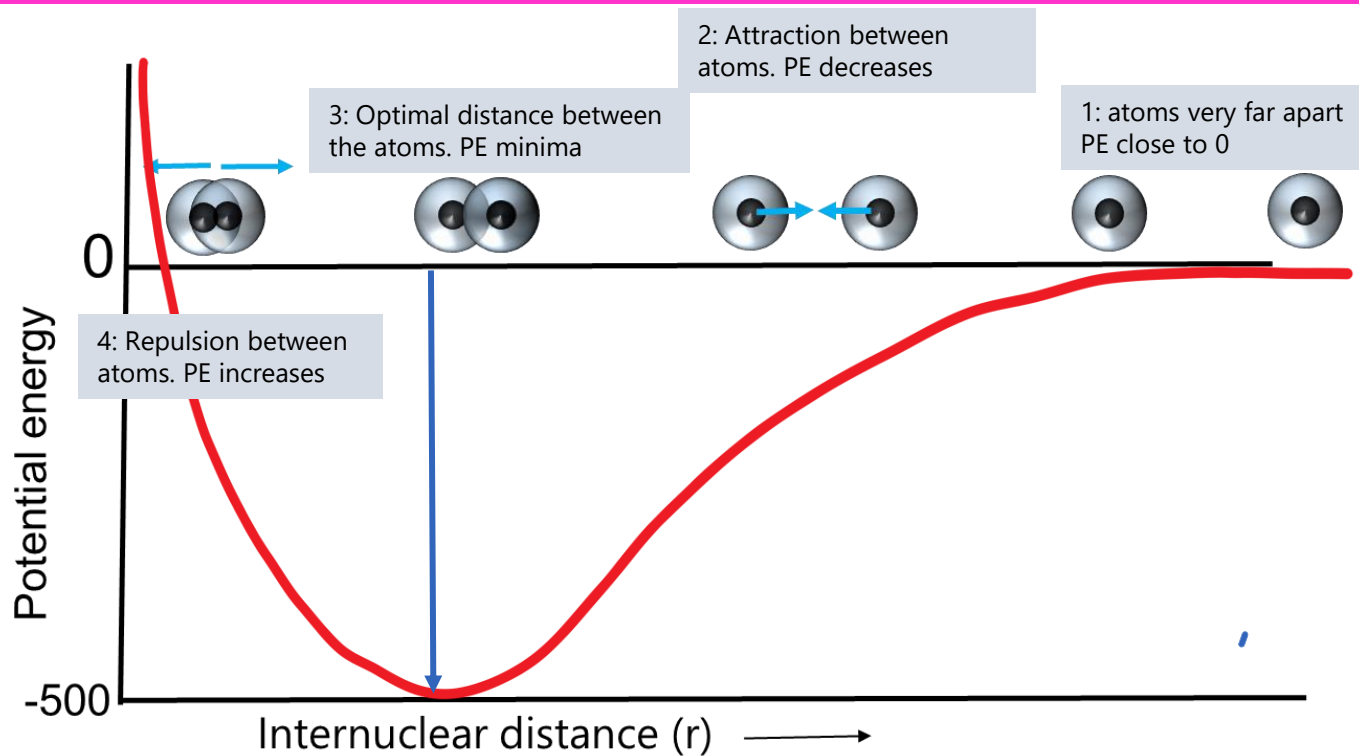
# Which molecule has higher bond energy?



① Start presenting to display the poll results on this slide.

# How are covalent bonds formed?

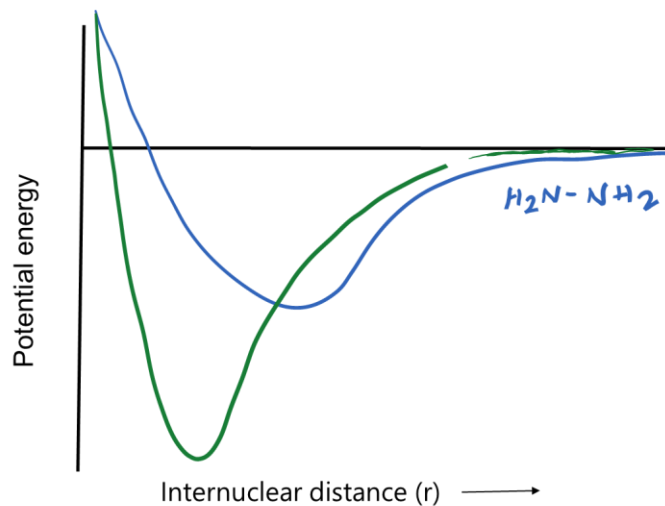
We can plot the energy of the two atoms forming a covalent bond as a function of the distance between them



H atom

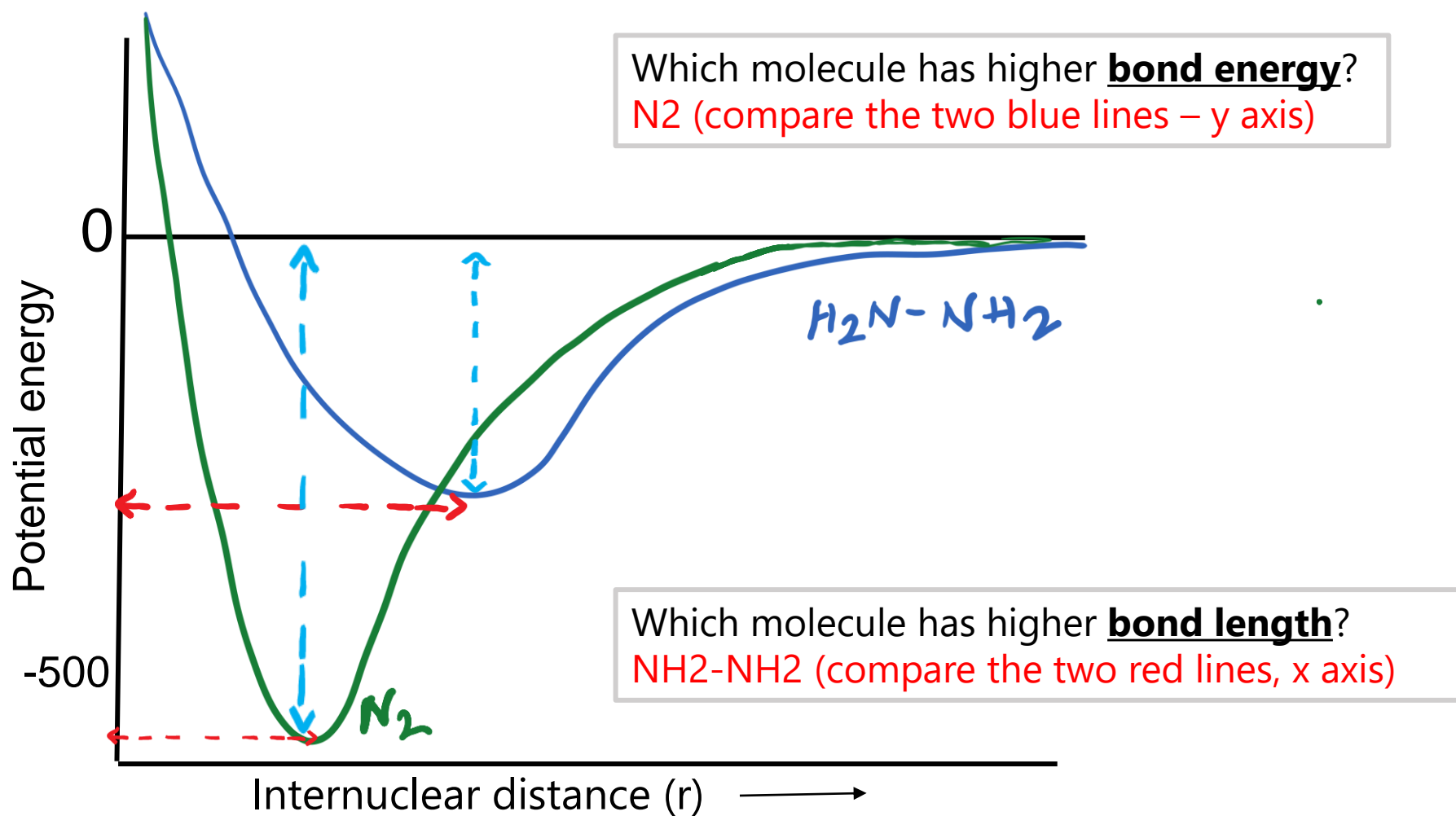


# Which molecule has higher bond energy?



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# Practice Question 3





# 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

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Li·	·Be·	·B·	·C·	·N·	·O·	·F·	·Ne·
Na·	·Mg·	·Al·	·Si·	·P·	·S·	·Cl·	·Ar·
K·	·Ca·	·Ga:	:Ge:	:As:	:Se:	·Br·	·Kr·

Noble Gases

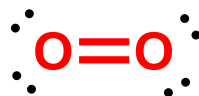
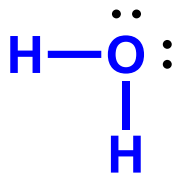
# Practice Question 4

Practice the Lewis Structure for the following molecules:



# Practice Question 4

Practice the Lewis Structure for the following molecules:



# Practice Question 5

Calculate the enthalpy of reaction for the following reaction



**BOND ENERGIES:**

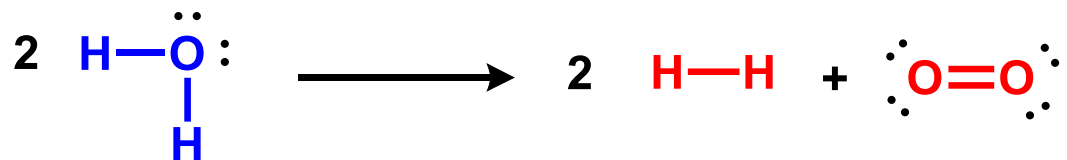
**H-H: 436 kJ**

**O=O: 498 kJ**

**O-H: 464 kJ**

# Practice Question

Calculate the enthalpy of reaction for the following reaction



## BOND ENERGIES:

H-H: 436 kJ/mol

O=O: 498 kJ/mol

O-H: 464 kJ/mol

### BREAK

4 mol O-H: 4(+ 464 kJ)  
+ 1856 kJ

### MAKE

2 mol H-H: 2(- 436 kJ)  
1 mol O=O: - 498 kJ

- 1370 kJ

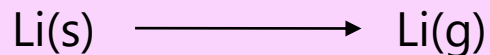
$$\Delta_r H^\circ = (1856 - 1370) = 486 \text{ kJ} > 0 \text{ (positive, endothermic)}$$

# IONIC BONDING

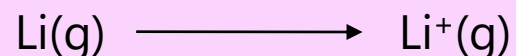
Hypothetical steps in the formation of an ionic solid



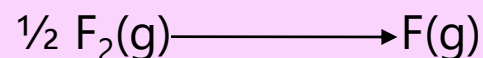
i. Formation of gaseous metal atoms



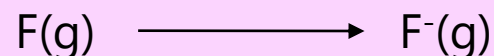
ii. Formation of gaseous metal cations



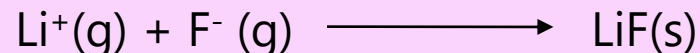
iii. Formation of gaseous non-metal atoms



iv. Formation of gaseous non-metal anions



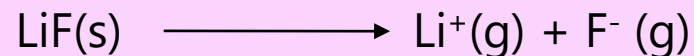
v. Formation of ionic solid/lattice



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)

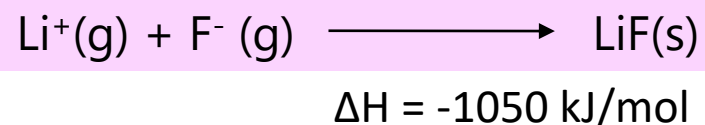


The enthalpy change associated with **lattice destruction** is called lattice energy

# IONIC BONDING

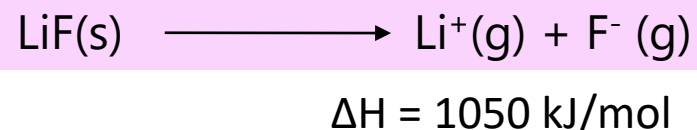
## Lattice Energy

Formation of ionic solid



The  $\Delta H$  for the above reaction is a high negative value (Exothermic reaction)

Destruction of ionic lattice

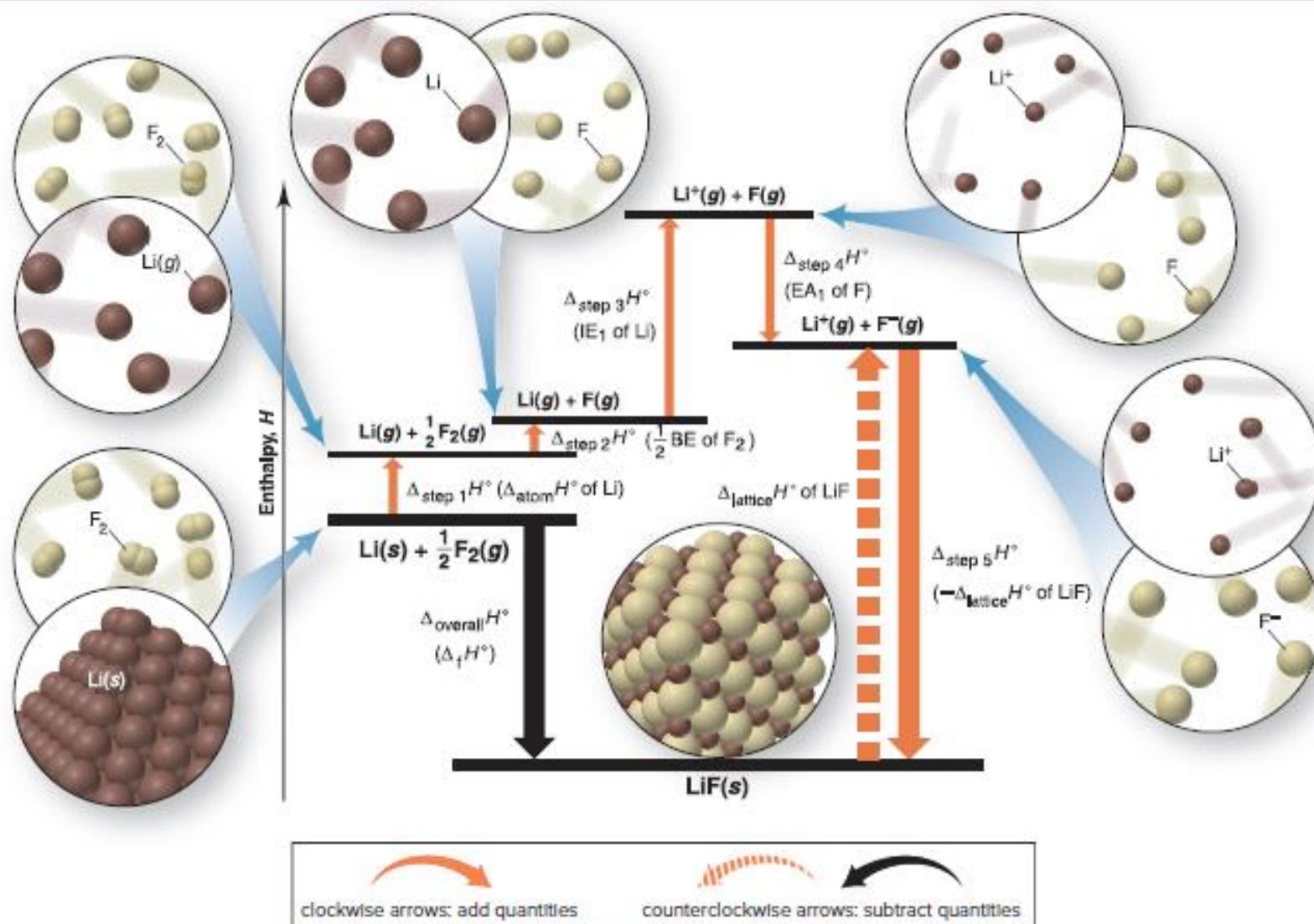


The enthalpy change associated with **lattice destruction** is called lattice energy

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





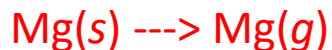
# Practice Question 6

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



# Practice Question 6

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



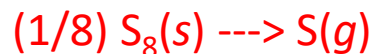
$$\Delta H^\circ = 148 \text{ kJ/mol}$$



$$\Delta H^\circ = 2186 \text{ kJ/mol}$$



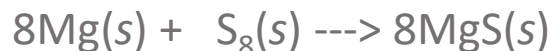
$$\Delta H^\circ = 2232 \text{ kJ/mol}$$



$$\Delta H^\circ = 279 \text{ kJ/mol}$$



$$\Delta H^\circ = 450 \text{ kJ/mol}$$



$$\Delta H^\circ = -2744 \text{ kJ/mol}$$



$$\Delta H^\circ = (-2744/8) \text{ kJ/mol}$$



$$\Delta H^\circ = -343 \text{ kJ/mol}$$



$$\Delta H^\circ = 343 \text{ kJ/mol}$$

Lattice Energy Reaction:



$$\Delta H^\circ = ?$$

# Practice Question 6

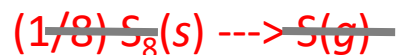
Calculate the lattice energy of magnesium sulfide from the data given below.



$\Delta H^\circ = 148 \text{ kJ/mol}$



$\Delta H^\circ = 2186 \text{ kJ/mol}$



$\Delta H^\circ = 279 \text{ kJ/mol}$



$\Delta H^\circ = 450 \text{ kJ/mol}$



$\Delta H^\circ = 343 \text{ kJ/mol}$

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

Lattice Energy Reaction:

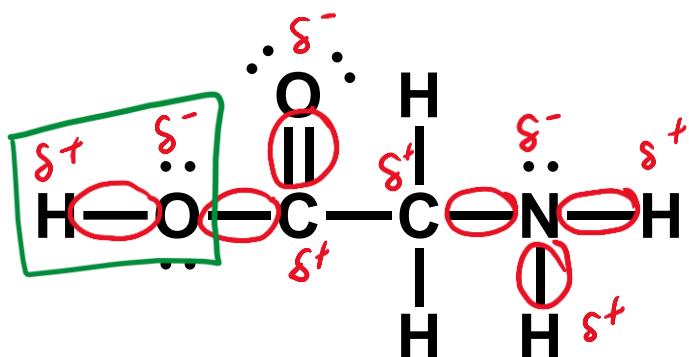


$\Delta H^\circ = ?$

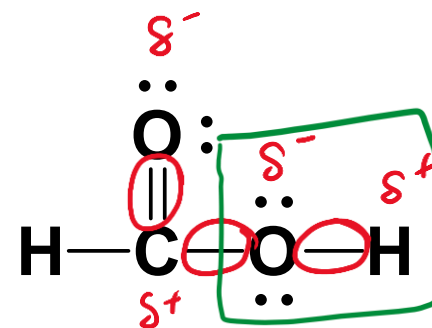
$\Delta H^\circ (\text{Lattice energy}) = 148 + 2186 + 279 + 450 + 343 = 3406 \text{ kJ/mol}$

# Practice Question 7

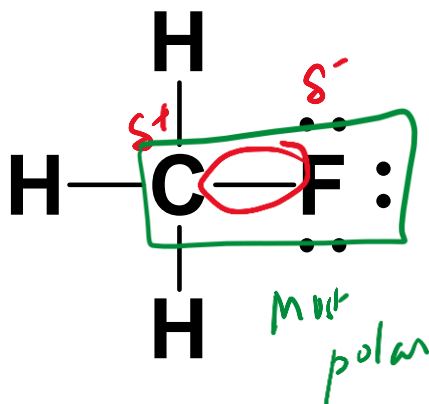
Label the polar covalent bonds in the structures below, indicate  $\delta+$  and  $\delta-$ . Which bond is the *most* polar? (Use the Datasheet – posted on myCourses has the electronegativity chart)



Most polar



Most polar



Electronegativity values of the elements (Pauling scale)

Electronegativity values of the elements (Pauling scale)																		He
H 2.1																		Ne
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ar	
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Kr	
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	Xe	
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	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	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?

