



# DO NOT OPEN

## UNTIL INSTRUCTED TO DO SO

*CHEM 110 – Dr. McCorkle – Exam #5*

While you wait, please complete the following information:

**Name:** \_\_\_\_\_

**Student ID:** \_\_\_\_\_

*Turn off cellphones and stow them away. No headphones, mp3 players, hats, sunglasses, food, drinks, restroom breaks, graphing calculators, programmable calculators, or sharing calculators. Grade corrections for incorrectly marked or incompletely erased answers will not be made.*

# Periodic Table of the Elements

GROUP	PERIOD																18	
1	IIA																VIIIA	
2	IIIA																17	
3	IVA																VIA	
4	VA																VIIA	
5	VIA																VIIA	
6	VIIA																VIIA	
7	VIIIA																VIIIA	
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H 1.01	He 4.00																
2	3	4																
2	Li 6.94	Be 9.01																
3	11	12																
3	Na 22.99	Mg 24.31																
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
4	K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 52.00	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.69	Cu 63.55	Zn 65.39	Ga 69.72	Ge 72.61	As 74.92	Se 78.97	Br 79.90	Kr 83.80
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
5	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.95	Tc (98)	Ru 101.07	Rh 102.91	Pd 106.42	Ag 107.87	Cd 112.41	In 114.82	Sn 118.71	Sb 121.75	Te 127.60	I 126.90	Xe 131.29
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
6	Cs 132.91	Ba 137.33	La* 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.23	Ir 192.22	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po (209)	At (210)	Rn (222)
7	87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
7	Fr (223)	Ra (226)	Ac** (227)	Rf (267)	Db (268)	Sg (271)	Bh (270)	Hs (277)	Mt (276)	Ds (281)	Rg (280)	Cn (285)	Uut (284)	Fl (289)	Uup (288)	Lv (293)	Uus (294)	Uuo (294)

GROUP	PERIOD																
1	IIA																
2	IIIA																
3	IVA																
4	VA																
5	VIA																
6	VIIA																
7	VIIIA																
58	59	60	61	62	63	64	65	66	67	68	69	70	71				
Ce 140.12	Pr 140.91	Nd 144.24	Pm (145)	Sm 150.36	Eu 151.96	Gd 157.25	Tb 158.93	Dy 162.50	Ho 164.93	Er 167.26	Tm 168.93	Yb 173.05	Lu 174.97				
90	91	92	93	94	95	96	97	98	99	100	101	102	103				
Th 232.04	Pa 231.04	U 238.03	Np (237)	Pu (244)	Am (243)	Cm (247)	Bk (247)	Cf (251)	Es (252)	Fm (257)	Md (258)	No (259)	Lr (262)				

Lanthanide Series \*

Actinide Series \*\*

**Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]**

- Which of the following statements is TRUE?
  - A covalent bond is formed through the transfer of electrons from one atom to another.
  - A pair of electrons involved in a covalent bond is sometimes referred to as a “lone pair.”
  - It is not possible for two atoms to share more than two electrons.
  - Single bonds are shorter than double bonds.
  - In a covalent bond, the shared electrons interact with the nuclei of both the bonding atoms, thus lowering their potential energy.
- Place the following in order of decreasing magnitude of lattice energy (largest to smallest).

$K_2O$	$Rb_2S$	$Li_2O$
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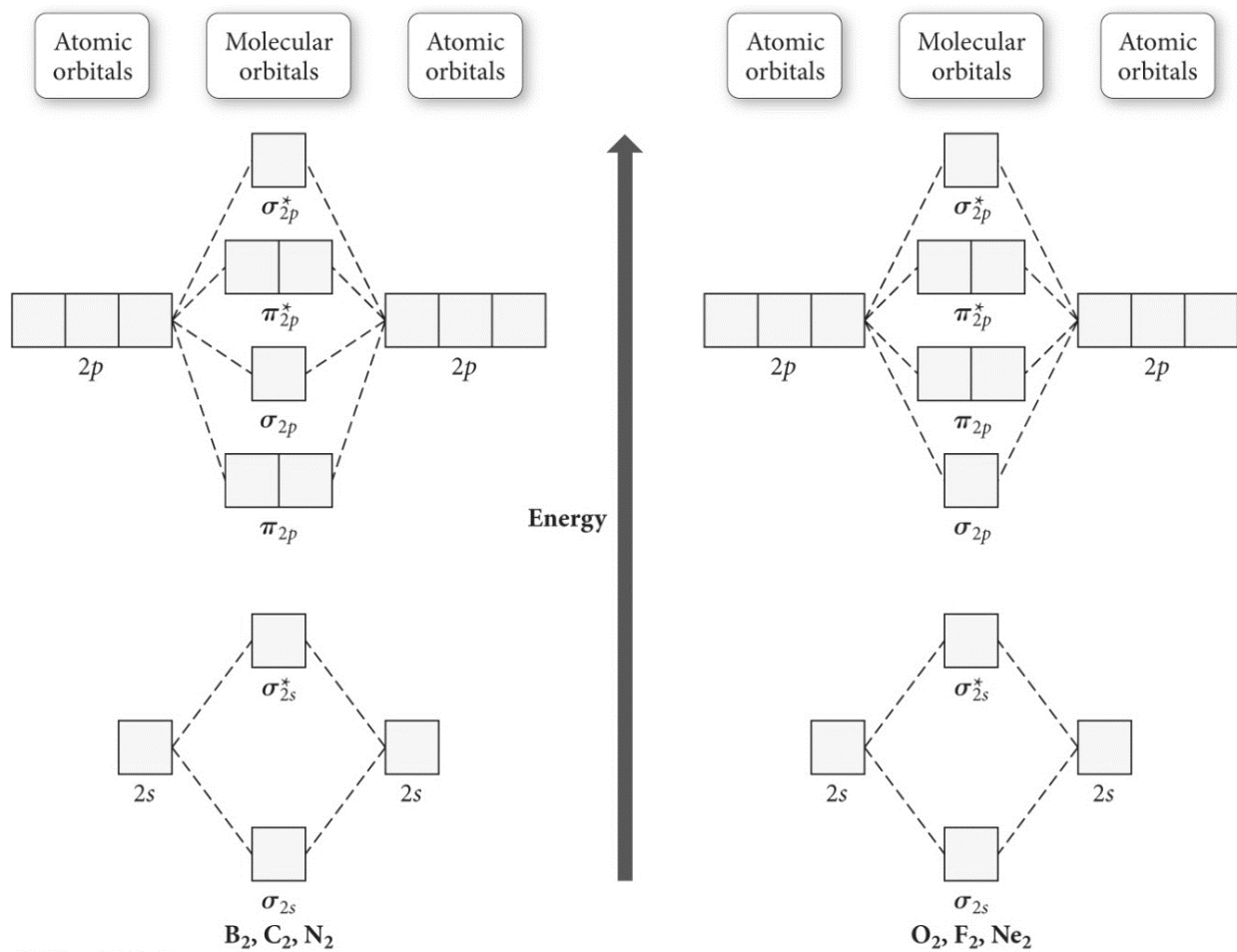
  - $Li_2O > K_2O > Rb_2S$
  - $Li_2O > Rb_2S > K_2O$
  - $Rb_2S > K_2O > Li_2O$
  - $Rb_2S > Li_2O > K_2O$
  - $K_2O > Li_2O > Rb_2S$
- Identify the weakest bond.
  - single covalent bond
  - double covalent bond
  - triple covalent bond
  - All of the above bonds are the same length
- A reaction is exothermic when
  - weak bonds break and strong bonds form.
  - strong bonds break and weak bonds form.
  - weak bonds break and weak bonds form
  - strong bonds break and strong bonds form.
- Place the following in order of decreasing bond length

$H-F$	$H-I$	$H-Br$
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  - $H-F > H-Br > H-I$
  - $H-I > H-F > H-Br$
  - $H-I > H-Br > H-F$
  - $H-Br > H-F > H-I$
  - $H-F > H-I > H-Br$

6. Identify the number of electron groups around a molecule with  $sp^2$  hybridization.  
A) 1                      B) 2                      C) 3                      D) 4                      E) 5
7. A molecule that is  $sp^3d^2$  hybridized and has a molecular geometry of square pyramidal has \_\_\_\_\_ bonding groups and \_\_\_\_\_ lone pairs around its central atom.  
A) 5, 1                      B) 4, 2                      C) 4, 1                      D) 3, 2                      E) 2, 3
8. How many electrons are shared in a C=C bond?  
A) 1                      B) 2                      C) 3                      D) 4                      E) 6
9. Which of the following statements is TRUE?  
A) The total number of molecular orbitals formed doesn't always equal the number of atomic orbitals in the set.  
B) A bond order of 0 represents a stable chemical bond.  
C) When two atomic orbitals come together to form two molecular orbitals, one molecular orbital will be lower in energy than the two separate atomic orbitals and one molecular orbital will be higher in energy than the separate atomic orbitals.  
D) Electrons placed in antibonding orbitals stabilize the ion/molecule.  
E) All of the above are true.

Use the following molecular orbital diagram to answer questions #10-12.



10. Which of the following is most stable?

- A) F<sub>2</sub>      B) F<sub>2</sub><sup>2+</sup>      C) Ne<sub>2</sub><sup>2+</sup>      D) O<sub>2</sub><sup>2+</sup>      E) F<sub>2</sub><sup>2-</sup>

11. Which of the following is paramagnetic?

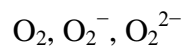
- A) B<sub>2</sub><sup>2+</sup>      B) B<sub>2</sub><sup>2-</sup>      C) N<sub>2</sub><sup>2+</sup>      D) C<sub>2</sub><sup>2-</sup>      E) B<sub>2</sub>

12. Which of the following is most stable?

- A) C<sub>2</sub><sup>2+</sup>      B) N<sub>2</sub><sup>2+</sup>      C) B<sub>2</sub>      D) C<sub>2</sub><sup>2-</sup>      E) B<sub>2</sub><sup>2+</sup>

**Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. For calculations, place a box around your final answer.**

13. According to MO theory, which molecule or ion has the highest bond order? (Show all work.) [6 points]



a. Which has the highest bond energy? Explain. [2 points]

b. Which has the longest bond length? Explain. [2 points]

14. Consider the ion  $\text{IF}_4^+$ :

a. Draw the Lewis structure, including any resonance structures: [2 points]

b. Assign formal charges to each atom in the structure(s) above: [2]

c. Electron geometry? [2]

d. Molecular geometry? [2]

e. Draw  $\text{IF}_4^+$  three-dimensionally using wedge notation AND label all bond angles: [4]

f. Is the molecule polar or nonpolar? Explain. [2]

15. Consider the molecule  $\text{PO}_2^-$ :

a. Draw the Lewis structure, including any resonance structures: [2 points]

b. Assign formal charges to each atom in the structure(s) above: [2]

c. Electron geometry? [2]

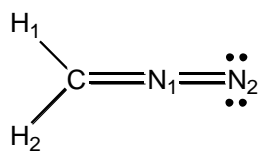
d. Molecular geometry? [2]

e. Draw  $\text{PO}_2^-$  three-dimensionally using wedge notation AND label all bond angles: [4]

e. Is the molecule polar or nonpolar? Explain. [2]

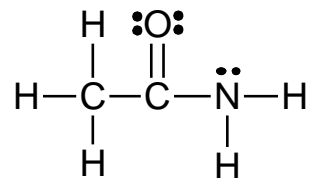


16. Consider the following molecule:



Use valence bond theory to describe the bonding scheme, including the orbitals involved in both  $\sigma$  and  $\pi$  bonds, as well as which orbitals contain any lone pairs. The hydrogen and nitrogen atoms have been numbered for clarity. [8 points]

17. Consider the following molecule:



Describe the following: [2 points each]

1<sup>st</sup> (Left) C Electron Geometry:

1<sup>st</sup> (Left) C Molecular Geometry:

2<sup>nd</sup> C Electron Geometry:

2<sup>nd</sup> C Molecular Geometry:

N Electron Geometry:

N Molecular Geometry:

O–C–N Bond Angle:

H–N–H Bond Angle

18. Describe metallic bonding. Explain why metallic solids are good electrical conductors and why they are good thermal conductors. [6 points]

19. Draw an MO diagram for  $\text{OF}^+$  (use the energy ordering of  $\text{O}_2$  and  $\text{F}_2$ ). [4 points]

a. Calculate the bond order. [2 points]

b. Is the molecule predicted to be stable or unstable? Explain. [2 points]

c. Is the molecule diamagnetic or paramagnetic? [2 points]

20. Use bond energies to calculate  $\Delta H_{\text{rxn}}$  for the following reactions:



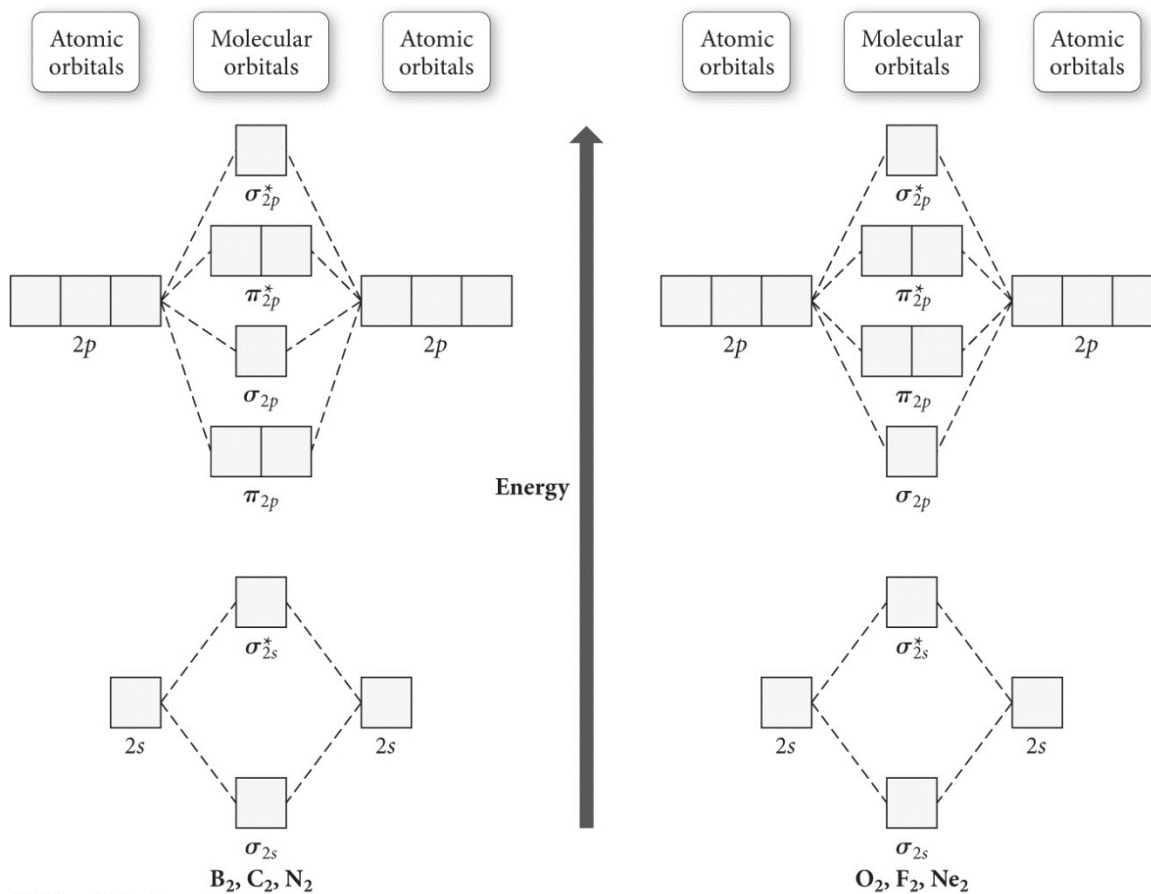
**Extra Credit:** Linus Pauling won the Nobel Prize twice in two different fields. What were they?  
[2 points]

**TABLE 9.3 Average Bond Energies**

Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
H—H	436	N—N	163	Br—F	237
H—C	414	N=N	418	Br—Cl	218
H—N	389	N≡N	946	Br—Br	193
H—O	464	N—O	222	I—Cl	208
H—S	368	N=O	590	I—Br	175
H—F	565	N—F	272	I—I	151
H—Cl	431	N—Cl	200	Si—H	323
H—Br	364	N—Br	243	Si—Si	226
H—I	297	N—I	159	Si—C	301
C—C	347	O—O	142	S—O	265
C=C	611	O=O	498	Si=O	368
C≡C	837	O—F	190	S=O	523
C—N	305	O—Cl	203	Si—Cl	464
C=N	615	O—I	234	S=S	418
C≡N	891	F—F	159	S—F	327
C—O	360	Cl—F	253	S—Cl	253
C=O	736*	Cl—Cl	243	S—Br	218
C≡O	1072			S—S	266
C—Cl	339				

\*799 in CO<sub>2</sub>.**TABLE 9.4 Average Bond Lengths**

Bond	Bond Length (pm)	Bond	Bond Length (pm)	Bond	Bond Length (pm)
H—H	74	C—C	154	N—N	145
H—C	110	C=C	134	N=N	123
H—N	100	C≡C	120	N≡N	110
H—O	97	C—N	147	N—O	136
H—S	132	C=N	128	N=O	120
H—F	92	C≡N	116	O—O	145
H—Cl	127	C—O	143	O=O	121
H—Br	141	C=O	120	F—F	143
H—I	161	C—Cl	178	Cl—Cl	199
				Br—Br	228
				I—I	266



### Electronegativity

1 H 2.1																	Decreasing ↓				
3 Li 1.0	4 Be 1.5											5 B 2.0	6 C 2.5	7 N 3.0	8 O 3.5	9 F 4.0					
		Increasing →										13 Al 1.5	14 Si 1.8	15 P 2.1	16 S 2.5	17 Cl 3.0					
11 Na 0.9	12 Mg 1.2	19 K 0.8	20 Ca 1.0	21 Sc 1.3	22 Ti 1.5	23 V 1.6	24 Cr 1.6	25 Mn 1.5	26 Fe 1.8	27 Co 1.9	28 Ni 1.9	29 Cu 1.9	30 Zn 1.6	31 Ga 1.6	32 Ge 1.8	33 As 2.0	34 Se 2.4	35 Br 2.8			
37 Rb 0.8	38 Sr 1.0	39 Y 1.2	40 Zr 1.4	41 Nb 1.6	42 Mo 1.8	43 Tc 1.9	44 Ru 2.2	45 Rh 2.2	46 Pd 2.2	47 Ag 1.9	48 Cd 1.7	49 In 1.7	50 Sn 1.8	51 Sb 1.9	52 Te 2.1	53 I 2.5					
55 Cs 0.7	56 Ba 0.9	57 La 1.1	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.9	83 Bi 1.9	84 Po 2.0	85 At 2.2					
87 Fr 0.7	88 Ra 0.9	89 Ac 1.1															Electronegativities of the Elements				

**Scratch Page**  
(to be handed in)