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CHEM 110 – Dr. McCorkle – Exam #5 ***KEY***

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

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La * 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac ** (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

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

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

1. Which of the following statements is TRUE?
   A) A covalent bond is formed through the transfer of electrons from one atom to another.
   B) A pair of electrons involved in a covalent bond is sometimes referred to as a "lone pair."
   C) It is not possible for two atoms to share more than two electrons.
   D) Single bonds are shorter than double bonds.
   E) In a covalent bond, the shared electrons interact with the nuclei of both the bonding atoms, thus lowering their potential energy.

2. Place the following in order of <u>decreasing</u> magnitude of lattice energy (largest to smallest).

   K_2O Rb_2S Li_2O

   A) $Li_2O > K_2O > Rb_2S$
   B) $Li_2O > Rb_2S > K_2O$
   C) $Rb_2S > K_2O > Li_2O$
   D) $Rb_2S > Li_2O > K_2O$
   E) $K_2O > Li_2O > Rb_2S$

3. Identify the <u>weakest</u> bond.
   A) single covalent bond
   B) double covalent bond
   C) triple covalent bond
   D) All of the above bonds are the same length

4. A reaction is exothermic when
   A) weak bonds break and strong bonds form.
   B) strong bonds break and weak bonds form.
   C) weak bonds break and weak bonds form
   D) strong bonds break and strong bonds form.

5. Place the following in order of <u>decreasing</u> bond length

   H-F H-I H-Br

   A) H-F > H-Br > H-I
   B) H-I > H-F > H-Br
   C) H-I > H-Br > H-F
   D) H-Br > H-F > H-I
   E) H-F > H-I > H-Br

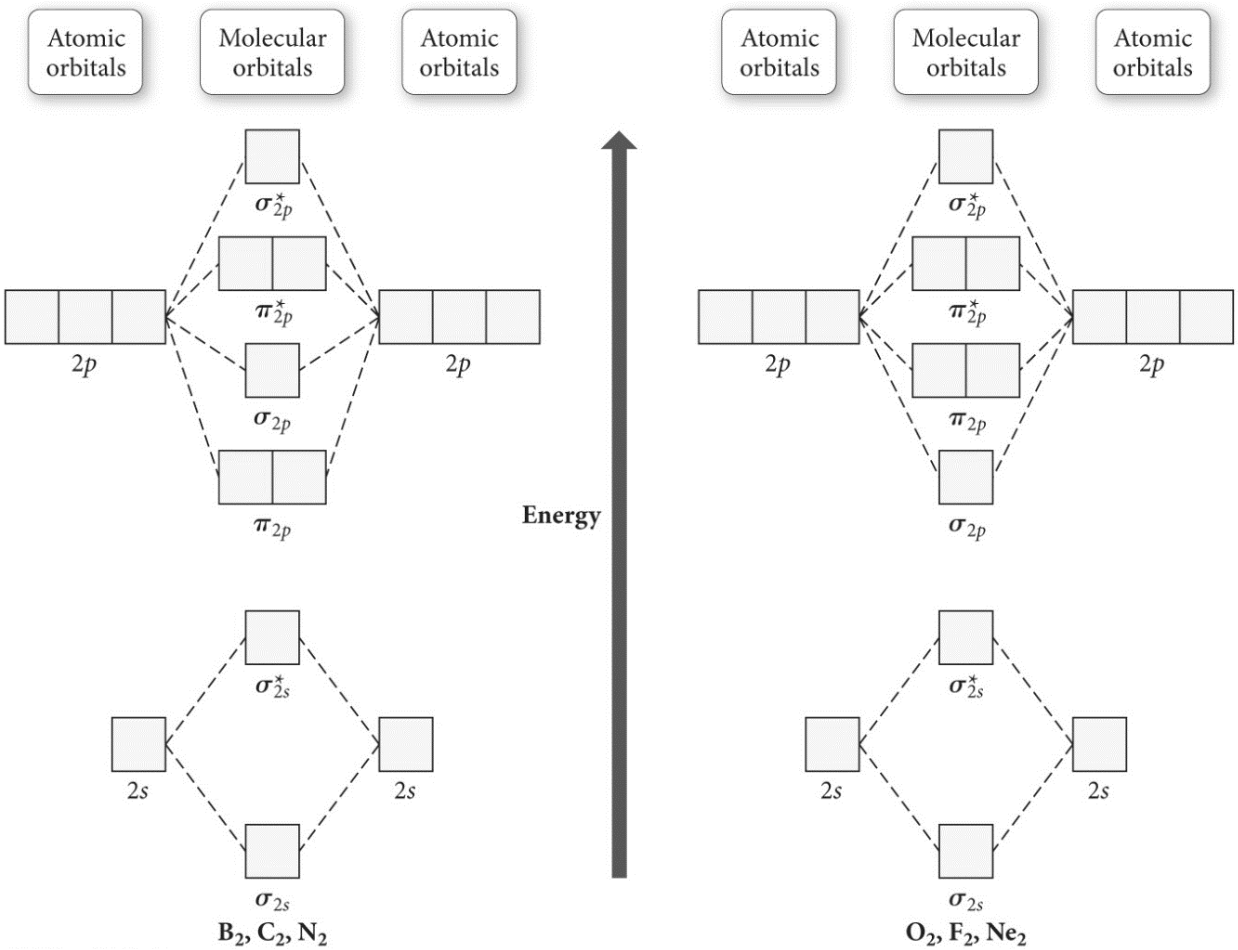
6. Identify the number of electron groups around a molecule with sp^2 hybridization.
   A) 1 B) 2 **C) 3** D) 4 E) 5

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 <u>most</u> stable?

A) F_2 B) F_2^{2+} C) Ne_2^{2+} **D) O_2^{2+}** E) F_2^{2-}

11. Which of the following is paramagnetic?

A) B_2^{2+} B) B_2^{2-} C) N_2^{2+} D) C_2^{2-} **E) B_2**

12. Which of the following is <u>most</u> stable?

A) C_2^{2+} B) N_2^{2+} C) B_2 **D) C_2^{2-}** E) B_2^{2+}

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]

O_2, O_2^-, O_2^{2-}

$$\text{Bond Order} = \frac{\text{Bonding Electrons} - \text{Antibonding Electrons}}{2}$$

O_2 $\quad$ $\text{BO} = \frac{8-4}{2} = 2$

O_2^- $\quad$ $\text{BO} = \frac{8-5}{2} = 1.5$

O_2^{2-} $\quad$ $\text{BO} = \frac{8-6}{2} = 1$

O_2 has the highest bond order.

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

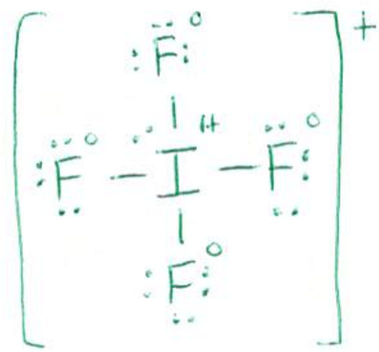
O_2 has the highest bond order and thus the strongest bond, meaning it also has the highest bond energy. (i.e. It takes the most energy to break.)

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

O_2^{2-} has the smallest bond energy meaning its bond is the weakest and thus the longest.

14. Consider the ion 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]

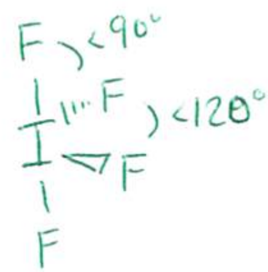
c. Electron geometry? [2]

Trigonal bipyramidal

d. Molecular geometry? [2]

Seesaw

e. Draw IF_4^+ three-dimensionally using wedge notation AND label all bond angles: [4]

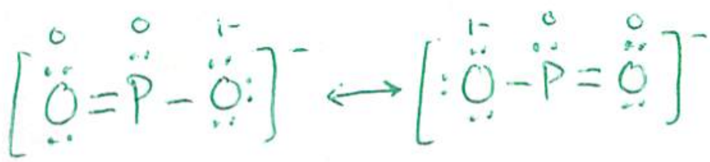


f. Is the molecule polar or nonpolar? Explain. [2]

Polar. The individual bonds are polar and overall molecule is asymmetrical.

15. Consider the molecule 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]

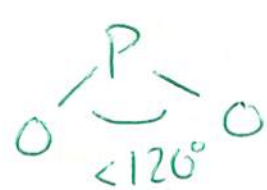
c. Electron geometry? [2]

Trigonal planar

d. Molecular geometry? [2]

Bent

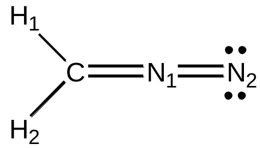
e. Draw PO_2^- three-dimensionally using wedge notation AND label all bond angles: [4]



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

Polar. The individual bonds are polar and overall molecule is asymmetrical.

16. Consider the following molecule:



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

2 C-H σ bonds: C sp^2 + H 1*s*

C-N_1 σ bond: C sp^2 + N_1 sp

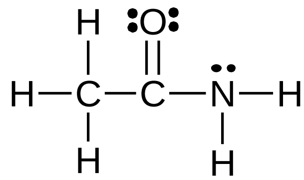
C-N_1 π bond: C 2*p* + N_1 2*p*

N_1-N_2 σ bond: N_1 sp + N_2 2*p*

N_1-N_2 π bond: N_1 2*p* + N_2 2*p*

N_2 lone pairs are in 2*s* and 2*p*

17. Consider the following molecule:



Describe the following: [2 points each]

1st (Left) C Electron Geometry:

Tetrahedral

1st (Left) C Molecular Geometry:

Tetrahedral

2nd C Electron Geometry:

Trigonal planar

2nd C Molecular Geometry:

Trigonal planar

N Electron Geometry:

Tetrahedral

N Molecular Geometry:

Trigonal pyramidal

O−C−N Bond Angle:

120º

H−N−H Bond Angle

< 109.5º

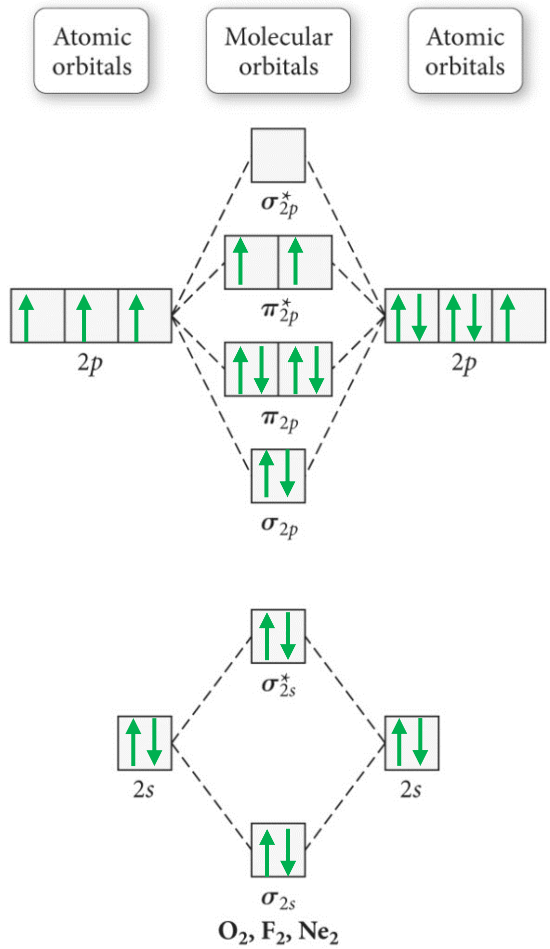
18. Describe metallic bonding. Explain why metallic solids are good electrical conductors and why they are good thermal conductors. [6 points]

Metals release their valence electrons to be shared as a pool by all the atoms/ions in the metal. The electrons are delocalized throughout the metal structure. It is similar to metal cation islands in a sea of electrons.

Because the valence electrons are delocalized they are able to easily move through the metallic crystal, thus easily conducting electricity.

Heat is a form of kinetic energy that is transferred through collisions from one particle to another. Because the metal contains a sea of mobile, small, light electrons it can quickly and easily transfer heat (kinetic energy).

19. Draw an MO diagram for OF^+ (use the energy ordering of O_2 and F_2). [4 points]



a. Calculate the bond order. [2 points]

$$\textbf{Bond Order} = \frac{\textbf{Bonding Electrons} - \textbf{Antibonding Electrons}}{\textbf{2}}$$

$$\textbf{BO} = \frac{\textbf{8} - \textbf{4}}{\textbf{2}} = \textbf{2}$$

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

With a bond order of 2 it is predicted to be stable.

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

Paramagnetic (two unpaired electrons)

20. Use bond energies to calculate ΔH_{rxn} for the following reactions:

a. $2\ NOCl(g) \rightarrow 2\ NO(g) + Cl_2(g)$ [6 points]

ΔH_{rxn} = [2(N=O) + 2(N−Cl)] + [2(N=O) + 1(Cl−Cl)]

ΔH_{rxn} = [2(590 kJ) + 2(200 kJ)] + [2(−590 kJ) + 1(−243 kJ)] = 157 kJ/mol

b. $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$ [6 points]

ΔH_{rxn} = [8(C−H) + 2(C−C) + 5(O=O)] + [6(C=O) + 8(H−O)]

ΔH_{rxn} = [8(414 kJ) + 2(347 kJ) + 5(498 kJ)] + [6(−799 kJ) + 8(−464 kJ)]

ΔH_{rxn} = −2010 kJ/mol

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

Chemistry and Peace

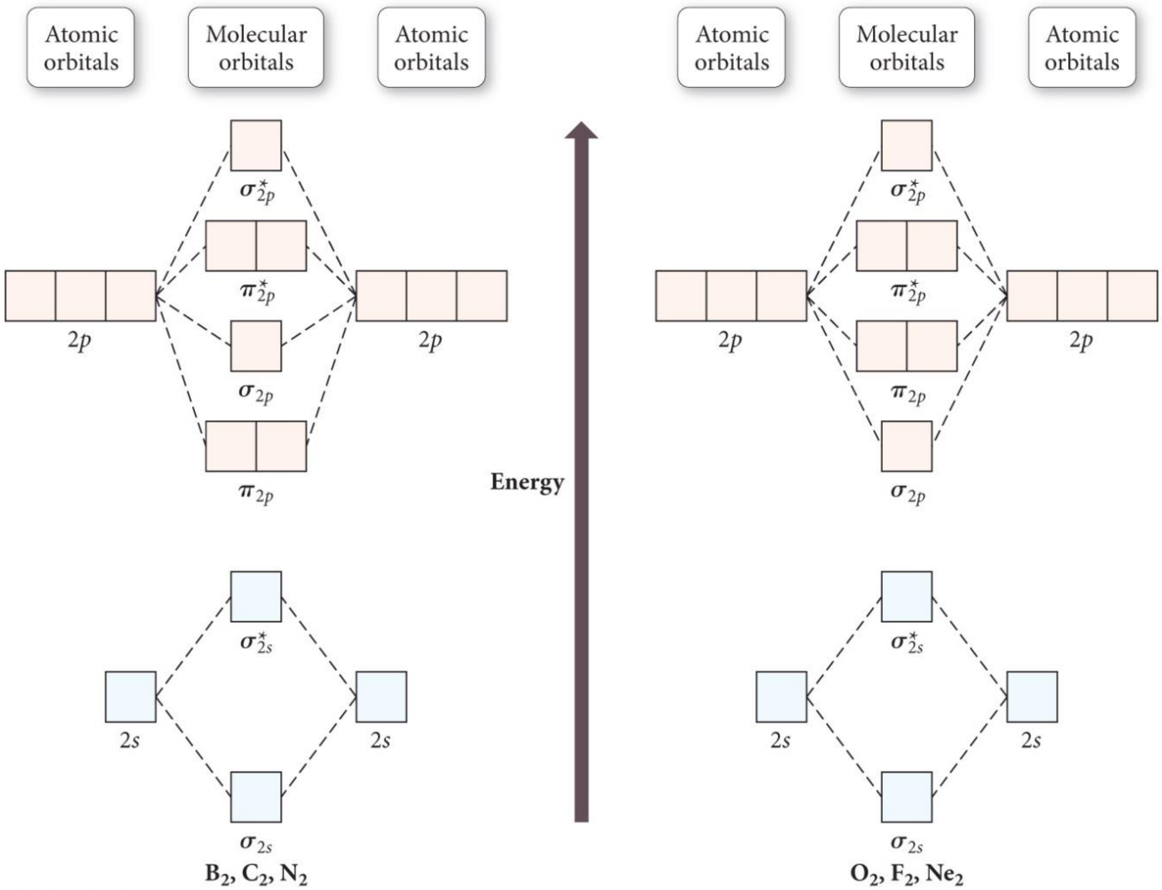
TABLE 9.3 Average Bond Energies

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_2.

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

Increasing →

Decreasing ↓

1 H 2.1																
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
11 Na 0.9	12 Mg 1.2											13 Al 1.5	14 Si 1.8	15 P 2.1	16 S 2.5	17 Cl 3.0
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

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