Name: ______________________

Part I. Multiple Choice:

1. Which of the following pairs of atoms/ions is isoelectronic?

__ A. O^{-2}, S^{-2}
__ B. Na, Na^{+1}
__ C. Br^{-1}, Kr
__ D. Cu, Zn
__ E. none of these

2. Which of the following quantum number sets describes a 4f orbital?

__ A. n=2, l=0, m_l= 0
__ B. n=3, l=1, m_l= -1
__ C. n=3, l=2, m_l= -1
__ D. n=4, l=2, m_l= +1
__ E. n=4, l=3, m_l= +2

3. Which element below has the largest atomic radius?

__ A. S
__ B. P
__ C. N
__ D. B
__ E. F

4. Which element below has the highest electronegativity?

__ A. C
__ B. P
__ C. N
__ D. B
__ E. Be

5. Order the elements S, Cl, and F in terms of increasing atomic radii.

__ A. S, Cl, F
__ B. Cl, F, S
__ C. F, S, Cl
__ D. F, Cl, S
__ E. S, F, Cl

6. Which of the following statements is true?
__ A. Electrons are never found in an antibonding MO.
__ B. All antibonding MOs are higher in energy than the atomic orbitals of which they are composed.
__ C. Antibonding MOs have electron density mainly outside the space between the two nuclei.
__ D. None of the above is true.
__ E. Two of the above statements are true.

<u>Part II. Short Answers and Calculations</u> *To get full credit you must show all your work!*

7. Give the electron configuration for the following atoms and ions (condensed notation is OK).

Zr ____

V^{+3} ____

8. Circle the correct answer for each of the following:

a) The lowest (least endothermic) 1st ionization energy: Li, Na, Mg

b) The greatest (most exothermic) electron affinity: As, Se, Br

9. Rank the following orbitals in an atom of <u>hydrogen</u> from lowest to highest energy (list them below in order using the < symbol and the = symbol if any orbitals are the same energy): 1s, 2s, 2p, 3s

lowest energy ***highest energy***

10. Rank the following orbitals in an atom of <u>sodium</u> from lowest to highest energy (list them below in order using the < symbol and the = symbol if any orbitals are the same energy): 1s, 2s, 2p, 3s

lowest energy ***highest energy***

11. How many electrons can be accommodated in the $n = 4$ quantum shell? ________

12. In <u>one sentence</u>, clearly explain why NO has a small bond dipole (polar compound) and the oxygen has a partial negative charge. *You can draw a picture to support your answer*.

13. In one sentence, clearly explain why CO has a small bond dipole (polar compound) and the oxygen has a partial positive charge. *You can draw a picture to support your answer.*

14. In one sentence, clearly explain why MgO has a much higher lattice energy than NaF.

15. For laughing gas, N_2O

a) Draw a valid Lewis structure below (connectivity N–N–O). Assign formal charges to all atoms.

b) Draw two additional resonance structures of the structure you drew in part (a). Assign formal charges to all atoms.

c) Circle the single structure above (from the three structures in parts (a) and (b)) that most closely represents the true structure of N_2O and briefly explain your choice.

16. Phosgene ($COCl_2$) was used as a chemical warfare agent in World War I. It can be synthesized by reacting carbon monoxide with chlorine as shown below. Use the table of bond enthalpies to estimate the heat of reaction (ΔH_{rxn}) for the formation of phosgene.

$$CO + Cl_2 \rightarrow COCl_2$$

Bond type	*Bond Enthalpy* (kJ/mol)
C–O	360
C=O	750
C≡O	1070
C–Cl	330
Cl–Cl	240

16. Complete the following Table:

Chemical Formula: SiF_4	**Chemical Formula:** NO_2^+
Lewis Structure:	**Lewis Structure:** (*nitrogen is the central atom)*
Molecular Geometry: (words only, you do not have to draw the molecule in three dimensions)	**Molecular Geometry:** (words only, you do not have to draw the molecule in three dimensions)
Molecular Polarity (yes/no):	**Molecular Polarity** (yes/no):
Hybridization of the Si atom:	**Hybridization** of the N atom:
Bond Angle for F–Si–F	**Bond Angle** for O–N–O
Number of σ bonds for SiF_4	**Number of σ bonds** for NO_2^+
Number of π bonds for SiF_4	**Number of π bonds** for NO_2^+

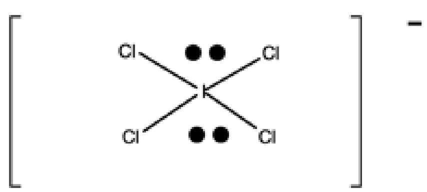
Extra Practice Problems (beyond the length of a 60-min exam)

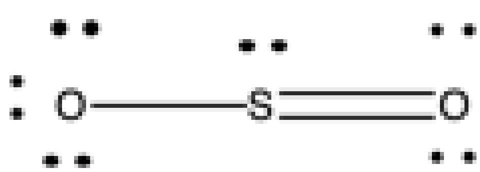
11. Draw a valid Lewis dot structure for the following molecules:

a) NCO^-

b) NF_3

12. Indicate the shape and bond angles and polarity of each molecule given the following Lewis structures:





13. Which of the following molecules are polar (SHOW WORK)?

CCl_4 H_2O CO_2 O_3

14. Draw three possible resonance structures for OCS. Indicate and briefly explain which structure is the most important.

15. Indicate the geometric shape and polarity of the following molecules. Use VSEPR theory; you must draw diagrams for each molecule.

a) ClO_3^-

b) ICl_2^-

16. Using a MO diagram, determine the bond order and magnetic properties of the following diatomic molecules: BN, BN^+, and BN^-. Which molecule is most stable?

17. Draw a molecular orbital diagram for the molecule NO, nitrogen oxide. Using the diagram answer the following questions.

(i) What is the highest energy molecular orbital to which an electron or electrons have been assigned? ____________

(ii) How many net sigma (σ) bonds are there? ____________

(iii) How many net pi (π) bonds? ____________

(iv) What is the N-O bond order? ____________

(v) Is the molecule diamagnetic or paramagnetic? ____________

(vi) If the molecule is oxidized to the nitrosonium ion, NO^+, the N-O bond is (longer)(shorter) ____________ and it is (stronger)(weaker) ____________ than in NO.

15. Propose a hybridization and bonding scheme that will explain the geometry and bond character of the NO_2^- anion given the following lewis structure.

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.008																	2 **He** helium 4.003
3 **Li** lithium 6.941(2)	4 **Be** beryllium 9.012											5 **B** boron 10.81	6 **C** carbon 12.01	7 **N** nitrogen 14.01	8 **O** oxygen 16.00	9 **F** fluorine 19.00	10 **Ne** neon 20.18
11 **Na** sodium 22.99	12 **Mg** magnesium 24.31											13 **Al** aluminium 26.98	14 **Si** silicon 28.09	15 **P** phosphorus 30.97	16 **S** sulfur 32.07	17 **Cl** chlorine 35.45	18 **Ar** argon 39.95
19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.72	32 **Ge** germanium 72.64	33 **As** arsenic 74.92	34 **Se** selenium 78.96(3)	35 **Br** bromine 79.90	36 **Kr** krypton 83.80
37 **Rb** rubidium 85.47	38 **Sr** strontium 87.61	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.96(2)	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57-71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.9	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium						

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.1	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

www.iupac.org/reports/periodic_table

This periodic table is dated 19 February 2010

Equations and Constants

$q = C\Delta T = mc\Delta T$

$\Delta E_{universe} = 0$ $\Delta E_{system} + \Delta E_{surroundings} = 0$

$\Delta E_{system} = -\Delta E_{surroundings}$ $q_{system} = -q_{surroundings}$

$E_k = \frac{1}{2} mv^2$ $E_P = mgh$ $\Delta E = q + w$

$w = F\,d = F\,\Delta x$ $w = -P\Delta V$

$\Delta H = \Delta E + P\Delta V = q_P$ $q_V = \Delta E$

$\Delta H_{rxn} = \sum n\,\Delta H_f(\text{products}) - \sum m\,\Delta H_f(\text{reactants})$

ΔH_{rxn} = bonds broken – bonds formed

$N_A = 6.022\text{x}10^{23}\ \text{mol}^{-1}$ $h = 6.626\text{x}10^{-34}\ \text{J s}$ $c = 2.998\text{x}10^{8}\ \text{m s}^{-1}$

$e = 1.602\text{x}10^{-19}\ \text{C}$ $m_e = 9.109\text{x}10^{-31}\ \text{kg}$ $1\ \text{Å} = 1\text{x}10^{-10}\ \text{m}$

$R_H = 1.0968\text{x}10^{7}\ \text{m}^{-1}$ $hcR_H = 2.178\text{x}10^{-18}\ \text{J}$

$E_K = \frac{1}{2} m \upsilon^2$ $\Delta E = h\nu$ $\nu\lambda = c$

$\Delta E = \frac{hc}{\lambda}$ $p = \frac{h}{\lambda}$ $\lambda = \frac{h}{m\upsilon}$ $\Delta x\,\Delta p \geq \frac{h}{4\pi}$

$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ $\Delta E = 2.178\text{x}10^{-18}\ \text{J} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$V = \frac{\kappa\, Q_1 Q_2}{d}$ $\kappa = 8.99\text{x}10^{9}\ \text{J-m/C}^2$ $\mu = Q\,r$ $1\ \text{D} = 3.336\text{x}10^{-30}\ \text{C•m}$