Chemistry 1A, Spring 2008

Midterm Exam II, Version A

March 10, 2008

(90 min, closed book)

Name:____KEY________

SID:___________________________

TA Name:________________________

1.) Write your name on every page of this exam.

2.) This exam has 20 multiple-choice questions and 3 short answer questions. Fill in the Scantron form AND circle your answer on the exam.

3.) There is no penalty for guessing, so answer every question.

4.) Select **one** answer for each question. There are no questions with multiple answers.

5.) Show all work to receive credit on short answer questions.

Question	Page	Points	Score
Multiple Choice	3-5	60	
21) Periodic Trends	6	12	
22) Molecular Orbitals	7	12	
23) Kinetic Gas Theory	8-9	16	
Total		**100**	

Name________________________________

$E = h\nu$

$\lambda\nu = c$

$\lambda_{deBroglie} = h / p = h / mv$

E_{kin} (e-) $= h\nu - \Phi = h\nu - h\nu_0$

$$E_n = -\frac{Z^2}{n^2} R_\infty$$

$$E_{i\to f} = -R_\infty\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$\Delta x \, \Delta p \geq h/4\pi$

$p = mv$

Particle in a box (1-D Quantum):

$E_n = h^2n^2/8mL^2$; n = 1, 2, 3...

PV = constant

PV = nRT

$$E_{kin} = \frac{3}{2}RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$\Delta E = q + w$

$w = -P_{ext}\Delta V$

$$\Delta E = \frac{3}{2} nR\Delta T$$

$N_0 = 6.02214 \times 10^{23}$ mol^{-1}

$R_\infty = 2.179874 \times 10^{-18}$ J

$R_\infty = 3.28984 \times 10^{15}$ Hz

$k = 1.38066 \times 10^{-23}$ J K^{-1}

$h = 6.62608 \times 10^{-34}$ J s

$m_e = 9.101939 \times 10^{-31}$ kg

$c = 2.99792 \times 10^{8}$ m s^{-1}

Gas Constant:

$R = 8.31451$ J K^{-1} mol^{-1}

$R = 8.20578 \times 10^{-2}$ L atm K^{-1} mol^{-1}

T (K) = T (C) + 273.15

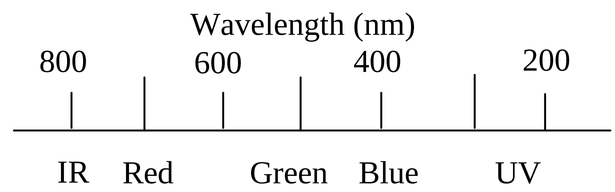
F = 96,485 C / mol

1 V = 1 J / C 1 nm = 10^{-9} m

1 kJ = 1000 J

1 atm = 760 mmHg = 760 torr = 101,325 Pa

Color and Wavelength of Light



$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \Sigma\, \Delta H°_f$ (products) $- \Sigma\, \Delta H°_f$ (reactants)

$\Delta S° = \Sigma\, S°$ (products) $- \Sigma\, S°$ (reactants)

$\Delta G° = \Sigma\, \Delta G°_f$ (products) $- \Sigma\, \Delta G°_f$ (reactants)

$S = k_B \ln W$

Bond Order = (# of bonding electrons - # of anti-bonding electrons) ÷ 2

$\Delta G° = -RT\ln K$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta G° = -nF\Delta\epsilon^{o}$

$pX = -\log X$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Name________________________________

Multiple Choice Questions (3 points each)

1) Arrange the following from smallest to largest radii: F^-, Ne, Mg^{2+}, O^{2-}, Na^+.

A) $Na^+ < Mg^{2+} < O^{2-} < F^- < Ne$
B) $O^{2-} < F^- < Ne < Na^+ < Mg^{2+}$
C) $F^- < Ne < O^{2-} < Mg^{2+} < Na^+$
D) $Ne < F^- < O^{2-} < Mg^{2+} < Na^+$
E) $\boxed{Mg^{2+} < Na^+ < Ne < F^- < O^{2-}}$

2) In the ionization of selenium, from which of the following orbitals would the electron come from?

A) $\boxed{4p}$ B) 3d C) 4s D) 3s E) 3p

3) Which of the following atoms or ions will become more paramagnetic upon ionization?

A) Li B) Al^{2+} C) Mg^+ $\boxed{\text{D) O}}$ E) Si

4) Which compound has an ionic bond?

A) $\boxed{CsCl}$ B) C_2H_4 C) ICl_3 D) BH_3 E) H_2S

5) Which of the following statements is always true according to VSEPR theory?

A) The shape of a molecule is determined by repulsions among bonding electron groups.
B) The shape of a molecule is determined by repulsions among nonbonding electron groups.
C) The shape of a molecule is determined by the polarity of its bonds.
D) The shape of a molecule is determined by repulsions among all electron groups of the atom
E) The shape of a molecule is determined by the orbital shapes.

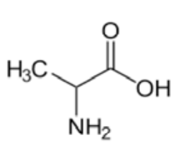
6) How many total isomers (structural and stereo) are there for $C_2H_2F_2$?

A) $\boxed{3}$ B) 5 C) 4 D) 2 E) 6

7) Which of the following molecules does not have a dipole moment?

A) PF_3 B) BCl_2F C) CH_3OH D) Cl_2O $\boxed{\text{E) } XeCl_2}$

8) Which of the following amino acids is NOT chiral?

A)


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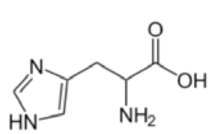
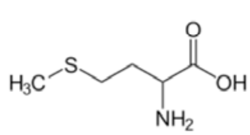


C)


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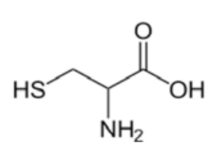
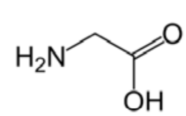


E)


Name________________________________

9) How does the hybridization around C change when ethylene ($H_2C = CH_2$) is polymerized to make polyethylene $(-CH_2-CH_2-CH_2-)_n$

A) $sp^3 \rightarrow sp$ $\boxed{\text{B) } sp^2 \rightarrow sp^3}$ C) $sp \rightarrow sp^2$ D) $sp^3 \rightarrow sp^2$ E) $sp^3d \rightarrow sp^3d^2$

10) What is the formal charge on the central atom in O_3?

A) $\boxed{+1}$ B) -1 C) +2 D) -2 E) 0

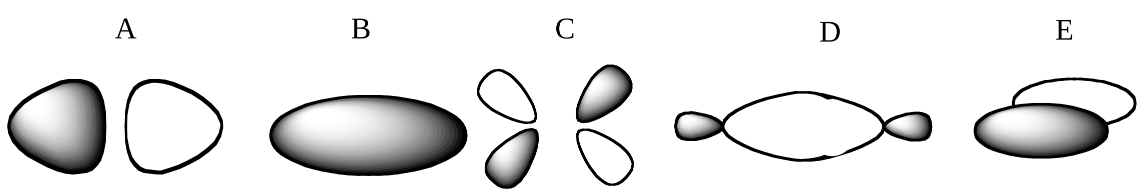
11) What is the electronic geometry of the formate anion HCO_2^-?

A) Trigonal pyradimal
B) T-shaped
C) $\boxed{\text{Trigonal planar}}$
D) Linear
E) Seesaw

12) What is the bond order of the C-O bond in the formate anion HCO_2^-?

A) $\boxed{1\frac{1}{2}}$ B) $1\frac{1}{4}$ C) 1 D) $1\frac{1}{3}$ E) 2

Use the following molecular orbitals for a diatomic molecule to answer questions 13-16.



13) Which diagram represents the antibonding orbital formed between atomic s orbitals?

A) $\boxed{\text{A}}$ B) B C) C D) D E) E

14) Which diagram represents a pi bonding orbital formed between atomic p orbitals?

A) A B) B C) C D) D $\boxed{\text{E) E}}$

15) Which diagram represents the antibonding orbital formed between atomic p orbitals?

A) A B) B $\boxed{\text{C) C}}$ D) D E) E

16) Which is the highest energy molecular orbital?

A) A B) B $\boxed{\text{C) C}}$ D) D E) E

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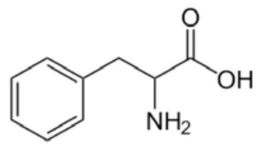
17) How many sigma bonds are found in the following amino acid, phenylalanine?



A) 12 $\boxed{\text{B) 15}}$ C) 14 D) 18 E) 16

Answer: Any of these answers were acceptable since the correct answer of 22 was not provided as a choice. Everyone was given 3 points for this question.

18) A student collects absorption data on sunscreen with an SPF of 45. The absorbance is 0.58 for a sample with a molarity of 0.37 M. After diluting the sample to 0.14 M, the absorbance is 0.24. What is the molarity of a sample that measures an absorbance reading of 0.98?

A) 1.4 M B) 0.28 M C) 0.17 M $\boxed{\text{D) 0.66 M}}$ E) 0.86 M

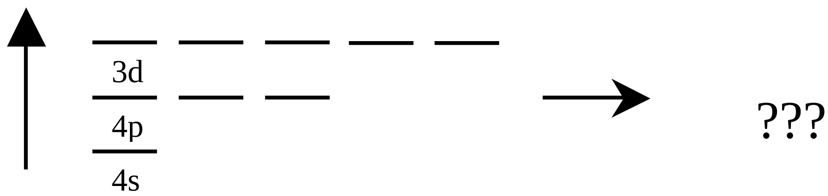
Answer: As with the sunscreen lab, the extinction coefficient is determined by determining the slope of the line. Given the two data points, the slope is found to be 1.48 M^{-1}*cm^{-1}.
The concentration corresponding to an absorbance of 0.98 is then equal to 0.98/1.48 M^{-1}*cm^{-1} = 0.66 M.

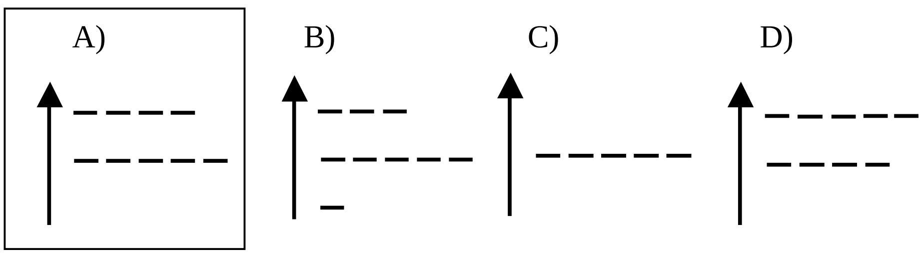
19) Titration is one way to determine the concentration of an unknown base solution. Upon adding 17.8 mL of 0.146 M HCl to 20.0 mL of a base solution, the indicator turns green indicating you have reached the endpoint of the titration. What is the concentration of the base solution?

A) 0.146 M
B) 0.069 M
C) 1.30×10^{-4} M
D) 6.9×10^{-5} M
E) $\boxed{0.130\ \text{M}}$

Answer: The endpoint of the titration marks the equivalence point where moles acid=moles base. From the information given, the number of moles of acid is determined (0.0178 L*0.146 M = 2.60×10^{-3} moles). The number of moles base equals this and the concentration is 2.60×10^{-3} moles/ 0.020 L = 0.130 M

20) Which is the energy diagram for the arsenic hybrid atomic orbitals in AsF_5 after hydridization?





E) None of these

Answer: The solution to this problem lies in realizing that As atomic orbitals must be hybridized to sp3d in order to form bonds to 5 fluorine atoms. After hybridization, there should be 5 orbitals with equal energy corresponding to the sp3d orbitals and 4 d orbitals remaining that were not hybridized. The only diagram that shows this combination of hybridized and unhybridized orbitals is choice A.

Name________________________________

Short Answer Questions

21) Periodic Trends (12 points)

Consider the reaction Na (g) + F (g) → Na^+ (g) + F^- (g).

	Na	F
Ionization Energy (kJ/mol)	496	1681
Electron Affinity (kJ/mol)	-53	-328

A) Calculate the change in energy for this reaction. From the data given, is energy absorbed or released? Show all work. (3 pts)

For this reaction Na is ionized, which requires 496 kJ/mol. F acquires the electron lost by Na and releases 328 kJ/mol. The energy for this reaction is the sum of these two numbers yielding an energy of 168 kJ/mol that is absorbed.

B) If we wanted to form Na^{2+}, how would you expect the second ionization energy (IE_2) to compare to the first ionization energy (IE_1)? Circle your answer. (1 pt)

$\boxed{IE_2 > IE_1}$ $IE_2 = IE_1$ $IE_2 < IE_1$

Explain your choice. (2 pts)

First ionization: Na → Na^+ + e-
Second ionization: Na^+ → Na^{2+} + e-
This second ionization requires the removal of a core electron, which requires much more energy than the removal of the valence electron.

C) How does the radius of fluorine (r_F) compare with the radius of the fluoride anion (r_{F-})? Circle your answer. (1 pt)

$r_F > r_{F-}$ $r_F = r_{F-}$ $\boxed{r_F < r_{F-}}$

Explain your answer. (2 pts)

Fluoride has an additional electron, but the same number of protons as fluorine. This extra electron increases the repulsion among the outer electrons resulting in a larger radius. This happens because the anion only gains an electron but not a proton, so in effect the Z_{eff} is smaller.

D) How would the overall energy of the reaction change if we used Li (E_{Li}) instead of Na (E_{Na})? Circle your answer. (1 pt)

$\boxed{E_{Li} > E_{Na}}$ $E_{Li} = E_{Na}$ $E_{Li} < E_{Na}$

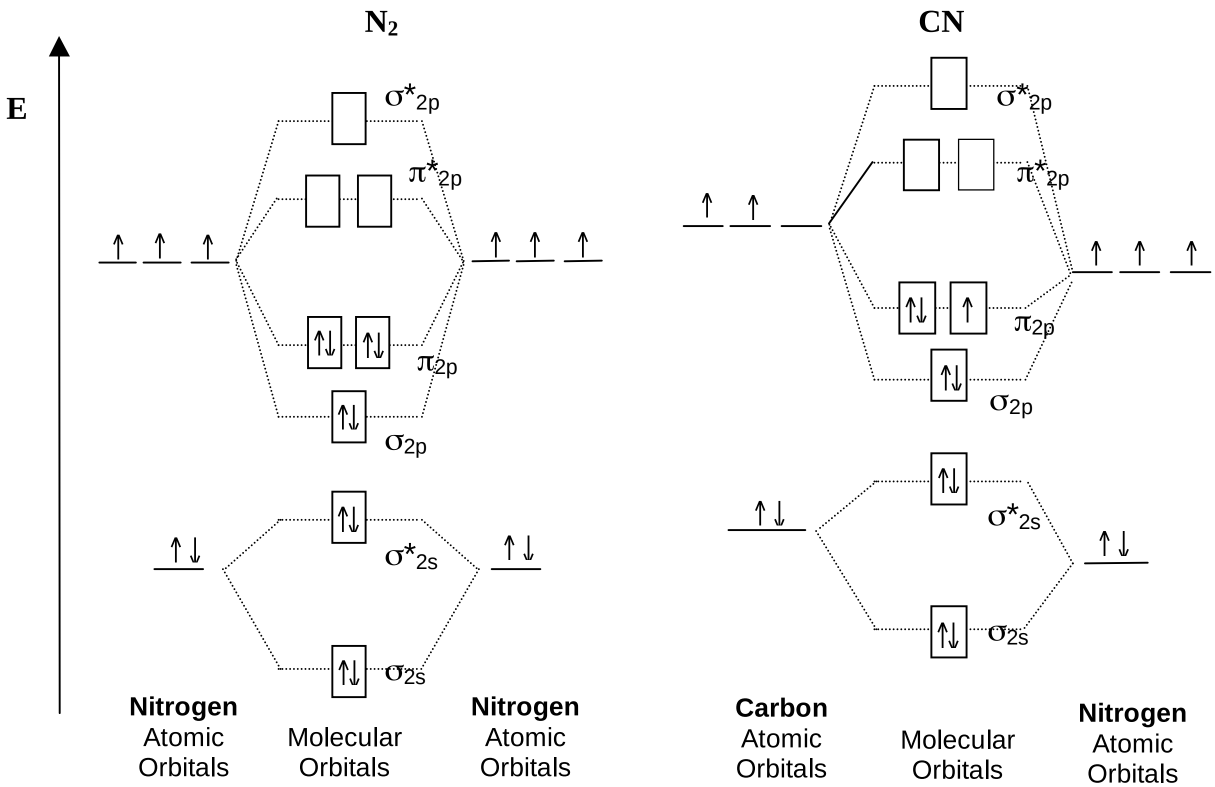
Explain your choice. (2 pts)

Ionizing Li requires more E than Na since Z_{eff} is greater for Li, so the overall energy of the reaction would increase.

Name________________________________

22) Molecular Orbitals (12 points)
Given the atomic orbitals and the molecular orbitals shown, complete the following tasks.

A) Fill in the 2s and 2p electrons for nitrogen and carbon <u>atomic</u> orbitals. (2pts)
B) Fill in the electrons for molecular nitrogen (N_2) on the left and cyanyl (CN) on the right into the molecular orbital diagram. (2pts)



C) What is the bond order for molecular nitrogen and cyanyl, CN? (show your work) (2 pts)

B.O. (N2) = (8-2)/2 = 3   B.O. (CN) = (7-2)/2 = 2.5

D) Are either of these molecules paramagnetic? If so, which one? (2 pts)

Yes, CN is paramagnetic.

E) Cyanyl is very reactive. Draw the Lewis Structure for CN below minimizing formal charge. Explain why CN is reactive based on your structure. (4 pts)

$\cdot C \equiv N:$
It is highly reactive because C does not have an octet. Through a reaction it can complete its octet.

Name________________________________

23) Kinetic Gas Theory (16 points)
Consider the demo in which the balloon was immersed in liquid nitrogen. Assume all gases are ideal and the total pressure is 750 mmHg.

A) The balloon was initially inflated to 2.24 L at 25ºC. What was the volume of the balloon when it was cooled to -196ºC with liquid nitrogen? Show your work. (4 pts)

PV = nRT. Since n and R and P are not changing, this equation can be written as V/T = constant and $V_1/T_1 = V_2/T_2$.
Rearranging $V_2 = V_1T_2/T_1$ = (2.24 L)*(77K/298K) = 0.58 L

B) If Lonnie inflated this balloon, it would have 18% O_2, 78% N_2 and 4.0% CO_2 by volume. What is the partial pressure (in atm) of CO_2? Show all work. (3 pts)

The partial pressure is equal to the mole fraction multiplied by the total pressure.
Therefore, the partial pressure = 0.04*(750 mmHg) = 30 mmHg
In atm, this is 30 mmHg*(1 atm/760 mmHg) = 0.04 atm

C) When the balloon from Part B is immersed in liquid nitrogen, the CO_2 undergoes deposition (a phase transition from gas to solid) while the other gases do not. What mass of solid CO_2 is formed? Show all work. (Density of CO_2(g) = 1.75 g/L at 25ºC) (3 pts)

$P_{CO2}V = n_{CO2}RT$, so $n_{CO2} = P_{CO2}V_{CO2}/RT$.
n_{CO2} = (0.04 atm*2.24 L)/(298K*0.0821 atm*L*K^{-1}*mol^{-1})
= 3.67 x 10^{-3} mol
mass CO_2 = (3.67 x 10^{-3} mol)(44 g/mol)
= 0.161 g of CO_2

This can also be solved by using the density.
V_{CO2} = 0.04*2.24 L = 0.0896 L
Now the mass is 0.0896 L*(1.75g/L) = 0.157 g of CO_2

Name________________________________

23) Kinetic Gas Theory (continued)

D) Calculate the root mean square velocity of O_2 at 25ºC and -196ºC. Show all work. (4 pts)

At 298 K, $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.314 JK^{-1}mol^{-1})(298K)}{(32g/mol)(1kg/1000g)}} = 482 m/s$

At 77 K, $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.314 JK^{-1}mol^{-1})(77K)}{(32g/mol)(1kg/1000g)}} = 245 m/s$

E) At 25ºC, how does the kinetic energy of O_2 compare with the kinetic energy of N_2? Explain. (2 pts)

The kinetic energy of both gases should be the same since the kinetic energy only depends on temperature.