2013 Fall Semester Midterm Examination
CH101 General Chemistry I

Date: October 23 (Wednesday), 2013 ***Time Limit: 7:00 ~ 9:00 p.m.***

Write down your information neatly in the space provided below; print your Student ID in the upper right corner of every page.

Professor Name	Class	Student I.D.	Student Name

Problem	points	Problem	points	TOTAL pts
1	/8	**6**	/6	**/100**
2	/16	**7**	/10	
3	/10	**8**	/12	
4	/6	**9**	/12	
5	/10	**10**	/10	

** This paper consists of 10 sheets with 10 problems. Please check all page numbers before taking the exam.
Write down your work and answers in the Answer sheet.
Include the *unit (e.g. kJ/mol)* of your answer when applicable. You will get 30% deduction for a missing unit.

NOTICE: SCHEDULES on RETURN and CLAIM of the MARKED EXAM PAPER.
(채점답안지 분배 및 이의신청 일정)

1. Period, Location and Procedure
   (i) Return and Claim Period: ***October 28 (Mon), 6: 30 ~ 7:30 p.m.***
   (ii) Location: Room for quiz session
   (iii) Procedure:
   Rule 1: Students cannot bring their own writing tools into the room. (Use a pen only provided by TA)
   Rule 2: With or without claim, you must submit the paper back to TA. (Do not go out of the room with it)
   If you have any claims on it, you can submit the claim paper with your opinion. After writing your opinions on the claim form, attach it to your mid-term paper with a stapler. Give them to TA. A solution file will be uploaded on 10/27(Sun).
2. Final Confirmation
   (i) Period: October 31 (Thu)-November 1 (Fri)
   (ii) Procedure: During this period, you can check final score of the examination *on the website* again.

** For further information, please visit a *General Chemistry website* at www.gencheminkaist.pe.kr.

1. (a) Calculate the maximum wavelength of light needed to eject electrons from the surface of cesium, if light of wavelength 400 nm strikes the surface of the metal giving photoelectrons whose maximum kinetic energy is 1.54×10^{-19} J. (4 points)
(b) During an experiment, the maximum kinetic energy of ejected photoelectrons from the surface of cesium was found to be 11.4 eV. Determine the de Broglie wavelength of an electron with this energy. (4 points)
[Planck's constant $h = 6.63 \times 10^{-34}$ J s; velocity of $c = 3.00 \times 10^{8}$ m/s; electron mass $m_e = 9.11 \times 10^{-31}$ kg; 1eV = 1.60×10^{-19} J]

(a) Using the Einstein equation,

$$h\nu = \Phi + 1/2mv_{max}^2$$

or $$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + KE_{max}$$ **where λ_0 is the maximum wavelength of light needed to eject electrons from the surface of cesium**

$$\frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m/s})}{(4.00 \times 10^{-7}\ \text{m})} = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m/s})}{\lambda_0} + 1.54 \times 10^{-19}\ \text{J}$$

$$3.43 \times 10^{-19}\ \text{J} = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m/s})}{\lambda_0}$$

$\lambda_0 = \underline{5.80 \times 10^{-7}\ \text{m or 580}}$ **nm** **(4 points)**

Allow partial points or alternative correct working

(b) Using the de Brolie matter wave equation,

$$\lambda = \frac{h}{m_e v} = \frac{h}{\sqrt{2m_e KE_{max}}}$$ **KE_{max} is maximum kinetic energy**

$$= \frac{(6.63 \times 10^{-34}\ \text{Js})}{\sqrt{2\,(9.11 \times 10^{-31}\ \text{kg})(11.4\ \text{eV} \times 1.60 \times 10^{-19}\ \text{J/eV})}}$$

$$= \underline{3.64 \times 10^{-10}\ \text{m or } 3.64\ \text{Å or } 0.364\ \text{nm}}$$

Allow partial points **(4 points)**

2. (a) The energy of a particle, such as an electron, confined to a one-dimensional box of length L, such that its potential energy is 0 for x = 0-L and ∞ for all other values of x, is given by

$$E_n = \frac{h^2}{8m_e}\frac{n^2}{L^2}$$

Calculate the energy difference in kJ/mol between the ground state and first excited state for an electron,

(i) in a 1.0 Å box, and

(ii) in a 1.0 m box (total 6 points for (i) and (ii)).

(iii) Comment on the result. (2 points)

[Electron mass $m_e = 9.110 \times 10^{-31}$ kg; Planck's constant $h = 6.626 \times 10^{-34}$ Js; Avogradro's number is 6.022×10^{23} /mol; 1 Å = 10^{-10} m]

(b) Write an equation for the energy of an electron confined to a 3-dimensional cubic box of length L, under the conditions described above. (2 points)

(c) Write an equation for the ground state energy level. (2 points)

(d) Write an equation for one of the first excited state energy levels. (2 points)

(e) State how many first excited energy levels exist and state whether or not they are degenerate (of equal energy). (2 points)

(a)

(i) $$E_2 - E_1 = \frac{3h^2}{8m_eL^2} = \frac{3(6.626 \times 10^{-34}\ \text{Js})^2}{8(9.11 \times 10^{-31}\ \text{kg})(1.0 \times 10^{-10}\ \text{m})^2} = 1.8 \times 10^{-17}\ \text{J}$$

$$= \frac{(1.8 \times 10^{-17}\ \text{J}) \times (6.022 \times 10^{23}\ /\text{mol})}{10^3\ (\text{J/kJ})} = \underline{11{,}000\ \text{kJ/mol}}$$

(ii) Same calculation as above, but $L^2 = 1.0\ m^2$, so $E_2 - E_1 = 1.8 \times 10^{-37}$ J = $\underline{1.1 \times 10^{-16}\ \text{kJ/mol}}$

(6 points for (i) and (ii) combined)

(iii) In (i) the electron is confined in a box of atomic dimensions and therefore quantization of energy levels is clear, whereas in (ii), the electron is confined in a very much larger box, is almost classical in its behavior and the energy levels are almost continuous.

(2 points)

(b) $$E_{n_1n_2n_3} = \frac{h^2}{8m_eL^2}(n_1^2 + n_2^2 + n_3^2)$$

(2 points)

(c) $E_{111} = \frac{3h^2}{8m_eL^2}$ **$(n_1 = n_2 = n_3 = 1)$ (2 points)**

(d) $E_{211} = \frac{3h^2}{4m_eL^2}$ **$(n_1 = 2;\ n_2 = n_3 = 1)$ (for example; there is also E_{121} and E_{112}) (2 points)**

(e) There are 3 energy levels and they are degenerate. (2 points)

3. Give the value of quantum numbers (*n*, *l*, and *m*) and the number of radial nodes and angular nodes for each of the following hydrogen atomic orbitals in the table. (5 x 2 points)

Orbital	n	l	m	No. of radial nodes	No. of angular nodes
2s	**2**	**0**	**0**	**1**	**0**
$2p_y$	**2**	**1**	**±1**	**0**	**1**
4s	**4**	**0**	**0**	**3**	**0**
$5p_x$	**5**	**1**	**±1**	**3**	**1**
$4d_{z2}$	**4**	**2**	**0**	**1**	**2**

2 points for completely correct entries for each orbital, otherwise zero.

4. The cesium atom has one of the lowest ionization energies of all neutral atoms in the periodic table (375.5 kJ/mol). Calculate the longest wavelength of light that could ionize a cesium atom (in the gas phase) and state the region of the electromagnetic spectrum to which this light belongs. (6 points)
[Planck's constant h = 6.626×10^{-34} Js; Avogradro's number is 6.022×10^{23} /mol; velocity of light c = 2.998×10^{8} m/s]

IE = 375.7 kJ/mol = $\dfrac{375700\ (J)}{6.022 \times 10^{23} (/mol)}$ **J**

IE = hν = hc/λ

Hence $\lambda = \dfrac{6.626 \times 10^{-34}\ (Js) \times 2.998 \times 10^{8}\ (m/s) \times 6.022 \times 10^{23}\ (/mol)}{375700\ (J/mol)}$

= 3.184×10^{-7} **m or 318.4 nm**

This is in the near ultraviolet region of the electromagnetic spectrum (close to the low wavelength-violet-visible region). (6 points)

5. (a) Using the standard notation, write ground state electronic configurations for the following species and describe each one as diamagnetic or paramagnetic.
(i) Li^- (ii) S^- (iii) Br^+ (iv) Te^{2-} (v) Xe^+ (2.5 points)

(b) For each of the following pairs of atoms or ions, state which you expect to have the larger radius. No explanation is needed.
(i) Ge or As (ii) Sm and Sm^{3+} (iii) Rb^+ or Kr (iv) Sr^+ or Rb (v) I^- or Xe (2.5 points)

(c) (i) Arrange the following in order of their first ionization energies: Li, Be, B.
No explanation is needed. (2 points)
(ii) Explain briefly which of the following atoms has the smallest radius: Si, S, Mg.
(3 points)

(a) (i) Li^-: $1s^22s^2$ diamagnetic (ii) S^-: $1s^22s^22p^63s^23p^5$ or $[Ne]3s^23p^5$ paramagnetic (iii) Br^+: $[Ar]3d^{10}4s^24p^4$ paramagnetic (iv) Te^{2-}: $[Kr]4d^{10}5s^25p^6$ diamagnetic (v) Xe^+: $[Kr]4d^{10}5s^25p^5$ paramagnetic. (2.5 points)

(b) (i) Ge (ii) Sm (iii) Kr (iv) Rb (v) I^- (2.5 points)

(c) (i) Be > B > Li (2 points)

(ii) S, because all three elements are in period (row) 3, but S has highest Z and radius decreases with increase in Z across a period. (3 points)

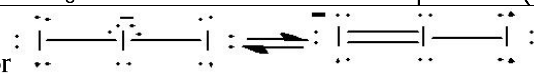
6. (a) Write the equation that defines the lattice energy of calcium oxide. (2 points)
(b) Predict which of the following pairs of ions would have the greater coulombic attraction in a solid compound: (i) K^+, O^{2-} (ii) Ga^{3+}, O^{2-} (iii) Ca^{2+}, O^{2-} (2 points)
(c) Predict which of LiCl(s) or RbCl(s) would have the higher lattice energy, given that they have similar arrangements of ions in the crystal lattice. (2 points)

(a) CaO(s) (or $Ca^{2+}O^{2-}$(s)) $\rightarrow$ Ca^{2+}(g) + O^{2-}(g) (2 points)

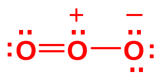
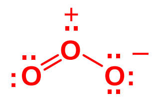
(b) (ii) Ga^{3+}, O^{2-} (2 points)

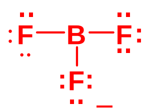
(c) LiCl(s) (2 points)

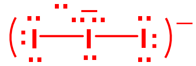
7. (a) Draw one Lewis structure for each of the following, showing all valence electron pairs and all nonzero formal charges.
(i) Ozone (O_3) (ii) Boron trifluoride (BF_3) (iii) Triiodide ion (I_3^-) (iv) Xenon octafluoride dianion (XeF_8^{2-}). (4 x 1.5 = 6 points)
(b) Explain why the observed structure of ozone has O-O bonds that are both identical and intermediate in length between O-O and O=O. (2 points)
(c) Explain why the B-F bonds in BF_3 are rather shorter than expected. (2 points)

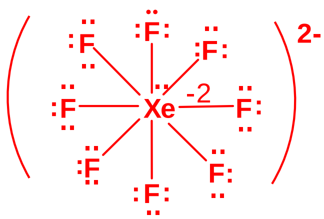
a)-(iii) or 

(a)

(i)  **or** 

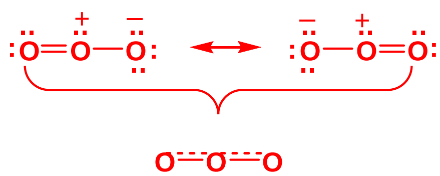
(ii) 

(iii) 

(iv) 

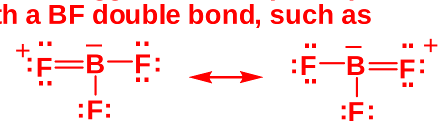
(4 x 1.5 points)

(b) The true structure of ozone is not satisfactorily represented by just one Lewis structure. Instead a combination of resonance structures is needed.



(2 points)

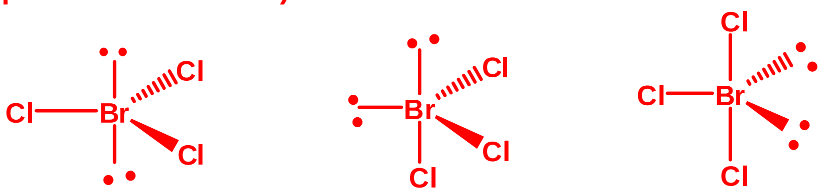
(c) This suggests some (minor) contribution from resonance structures with a BF double bond, such as

 **etc** **(2 points)**

8. Consider the molecule bromine trichloride ($BrCl_3$) and answer the following questions.

(a) Draw the three possible structures of $BrCl_3$, according to the VSEPR model. (6 points)
(b) Select the most stable structure. (2 points)
(c) State whether the geometry of the most stable structure is regular or distorted. (2 points)
(d) State whether the most stable structure has a dipole moment. (2 points)

(ii) (The Lewis diagram requires 5 electron pairs around the central atom Br, meaning its geometry is based on a trigonal bipyramid. Hence there are three possible structures.)



1 **2** **3**

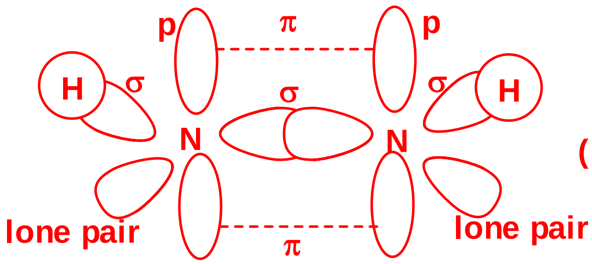
(3 x 2 points)

(iii) The most stable structure is the T-shaped geometry (3, as written above) (2 points)

(iv) Distorted geometry (2 points)

(v) It has a dipole moment (2 points)

9. (a) Sketch a valence bond (VB) model of the *cis* stereoisomer of diazene (HNNH), showing the hybridization on the N atoms, the σ skeletal structure, lone pair electrons and π-bonding. (5 points)
(b) State whether *cis*-diazene has a molecular dipole moment. (1 point)



(N is sp^2 hybridized)

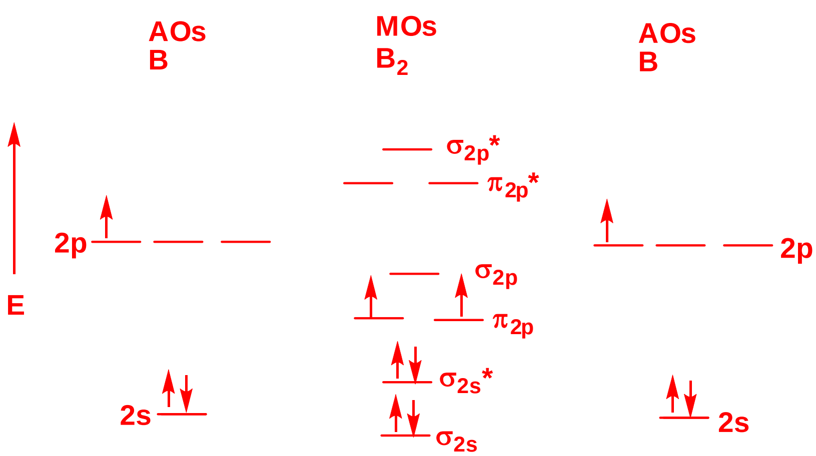
(5 points)

Allow other styles of sketch that give correct information.
Allow partial points

(b) It has a dipole moment (1 point)

(c) Sketch a molecular orbital energy diagram (showing all relevant atomic and molecular orbitals) for the homonuclear diatomic molecule B_2. (5 points)
(d) Determine, from its electronic structure, whether B_2 is paramagnetic or diamagnetic. (1 point)

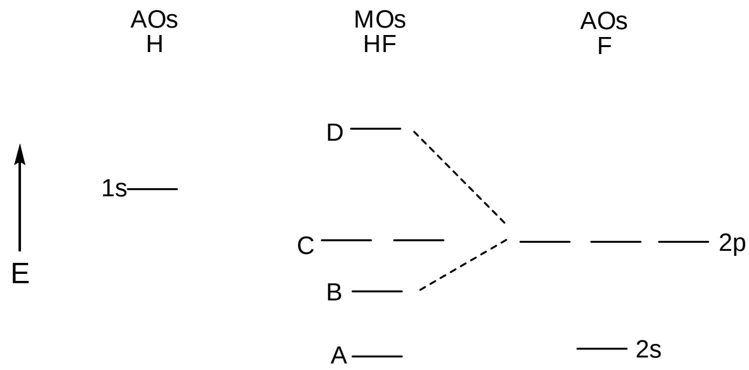
(c)



(5 points)

(d) B_2 is paramagnetic (1 point)

10. Consider the LCAOMO diagram for HF below and answer the following questions.



(a) Label the MOs of HF. (4 points)

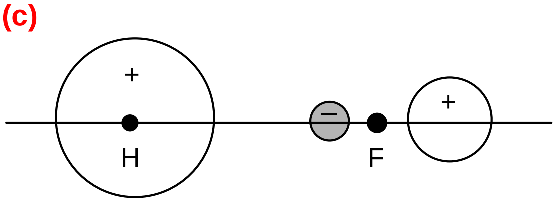
(a) A = σ_{2s}, B = σ_{2p}, C = n_{2p}, D = σ^*_{2p} (4 points)

(b) Write the electron configuration of HF and determine the highest (energy) occupied MO (HOMO) and the lowest (energy) unoccupied MO (LUMO). (3 points)

(b) $(\sigma_{2s})^2(\sigma_{2p})^2(n_{2p})^4(\sigma^*_{2p})$ HOMO is n_{2p} LUMO is σ^*_{2p} (3 points)

(c) Sketch the LUMO of HF. (3 points)

(c)



or similar diagram, emphasizing higher concentration on H

(3 points)