2018 Fall Semester Quiz 1
For General Chemistry I (CH101)

Date: Sep 17 (Mon), ***Time: 19:00 ~ 19:45***

Professor Name	Class	Student I.D. Number	Name

Use the following constants to solve problems.
(Planck constant h = 6.626 × 10^{-34} J s) **(Mass of electron m_e = 9.109 × 10^{-31} kg)**
(Permittivity of the vacuum ε_0 = 8.854 × 10^{-12} C^2 J^{-1} m^{-1}) (Charge of the electron e = 1.602 × 10^{-19} C)
(Avogadro's number N_A = 6.022 × 10^{23} mol^{-1}) (Ratio of a circle's circumference to its diameter π = 3.142)

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1. (Total 10 pts, 2 pts for a right answer, -1 pt for a wrong answer, 0 pt for no answer) **Answer the following questions.** (2 pts for a right answer, -1 pt for a wrong answer, 0 pt for no answer)

(a) Which atom has the highest ionization energy?

F, Ne, Na, Ar

Answer: ______**Ne**_______

(b) Which atom is most electronegative?

K, Ca, Br, I

Answer: ______**Br**_______

(c) Which compound has the most ionic bonding character?

IF, ICl, ClF, BrCl, Cl_2

Answer: ______**IF**_______

(d) Which electromagnetic radiation has the longest wavelength?

X-ray, microwave, violet light, red light

Answer: ______**Microwave**_______

(e) Which one has the longest de Broglie wavelength, if they are moving at the same velocity?

Electron, proton, H atom, He atom

Answer: ______**Electron**_______

2. (Total 8 pts) **Consider the ionic compound KCl. The ionization energy (IE) and electron affinity (EA) of potassium and chlorine are as follows:**

	K	**Cl**
IE (kJ/mol)	**418.8**	**1251.1**
EA (kJ/mol)	**48.384**	**349.0**

(a) (3 pts) **Using the given data, explain why K^+Cl^- form in preference to K^-Cl^+.**

$$\Delta E \text{ (for } K^+Cl^-)(g) = 418.8 + (-349.0) = \boxed{69.8 \text{ kJ mol}^{-1}}$$

$$\Delta E \text{ (for } K^-Cl^+)(g) = 1251.1 + (-48.384) = \boxed{1202.7 \text{ kJ mol}^{-1}}$$

맞게 계산하면 2점, 에너지 변화가 더 낮은 방향으로 반응이 진행된다는 점을 설명하면 1점

2 pts for correct calculation or correct explanation

1 pt for explaining that reaction proceeds with lower energy barrier

b) (5 pts) **<u>Estimate the energy of dissociation (ΔE_d) to neutral atoms for KCl</u>, which has a bond length 2.67 x 10^{-10} m.**

$$V_{\text{Coulomb}} = \frac{q_{K^+}q_{Cl^-}}{4\pi\epsilon_0 R_e} = \frac{(+1.602 \times 10^{-19}\text{ C})(-1.602 \times 10^{-19}\text{ C})}{4(3.1416)(8.854 \times 10^{-12}\text{ C}^2\text{ J}^{-1}\text{m}^{-1})(2.67 \times 10^{-10}\text{ m})} = -8.64 \times 10^{-19}\text{ J}$$

This potential energy is for one K^+ to Cl^- interaction. For a *mole* of these pair-wise interactions, multiply by Avogadro's number

$$V_{\text{Coulomb}} = (-8.64 \times 10^{-19}\text{ J pair}^{-1}) \times (6.022 \times 10^{23}\text{ pair mol}^{-1}) = -520 \times 10^3\text{ J mol}^{-1}$$

$$\Delta E_d = -V_{\text{Coulomb}} - \Delta E_\infty$$

$$= -(-520\text{ kJ mol}^{-1}) - (418.8\text{ kJ mol}^{-1} - 349.0\text{ kJ mol}^{-1}) = \boxed{450\text{ kJ mol}^{-1}}$$

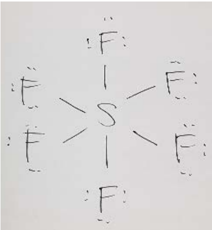
--- $V_{coulomb}$, ΔE_d 식쓰면 각각 +1 pt

--- 답 +3 pts

1 pt each for correct equations, 3 pts for the correct answer

3. (Total 6 pts, each 2 pts) **Based on VSEPR theory, <u>draw Lewis diagrams with the smallest formal charges, and name the geometry for given molecules.</u> <u>If there are possible resonance forms, please draw all of them.</u>**

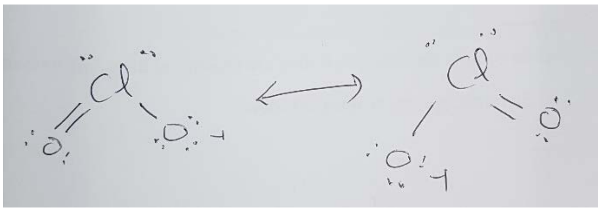
(a) $\mathbf{SF_6}$



Correct Lewis diagram -- + 1 pt

Geometry: Octahedral -- + 1 pt

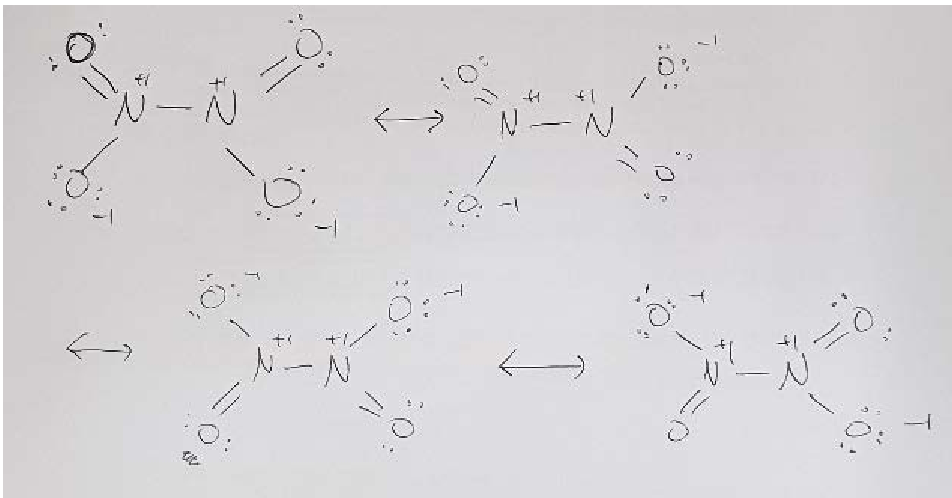
(b) $\mathbf{ClO_2^-}$



0.5 pt for each resonance structure --- + 1 pt

Geometry: bent-- + 1 pt

(c) $\mathbf{N_2O_4}$ (Hint: The two N atoms are bonded in the center)



0.25 pt for each resonance structure--- + 1 pt

Geometry: planar -- + 1 pt

4. (8 pts) **The correspondence principle states that quantum mechanical results and classical mechanical results tend to be equivalent in the limit of large quantum numbers. The following questions demonstrate how quantum mechanical results become negligible or converge to classical mechanical results.**

(a) (2 pts) **In the macroscopic world, de Broglie wavelength and the Heisenberg uncertainty becomes negligible. Consider a baseball (0.1kg) traveling at 40m/s. What is its de Broglie wavelength? If we want to locate the same baseball within 1mm, what is the minimum uncertainty in its velocity?**

$p = mv = 4\,kg \cdot m/s$

$\lambda = \frac{h}{p} = \frac{6.626 \times 10^{-34}\,J \cdot s}{4\,kg \cdot m/s} = 1.6565 \times 10^{-34}\,m$

$\Delta x = 10^{-3}\,m \quad \Delta x \Delta p = \Delta x \cdot m \Delta v \geq \frac{h}{4\pi} \quad \therefore \Delta v \geq \frac{h}{4\pi} \times \frac{1}{10^{-3}\,m} \times \frac{1}{0.1\,kg}$

$\therefore \Delta v \geq 5.273 \times 10^{-31}\,kg \cdot m/s$

De Broglie wavelength +1 pt

Velocity uncertainty +1 pt

(b) (3 pts, no partial pts) **Planck derived the following equation for blackbody radiation intensity:**

$$\rho_T(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{h\nu/k_B T} - 1}$$

using his ad hoc assumption that energy is quantized, or $\Delta E = h\nu$. This assumption implies that, at low frequencies (or $\nu \to 0$), $\Delta E \to 0$ and E becomes continuous. Derive the classical equation for blackbody radiation intensity by reducing the above equation with the condition $\nu \to 0$. (Hint: $e^x \approx 1 + x$ when x is really small)

$\rho_T(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{h\nu/k_B T} - 1}$

As $\nu \to 0$, $h\nu/k_B T \to 0$

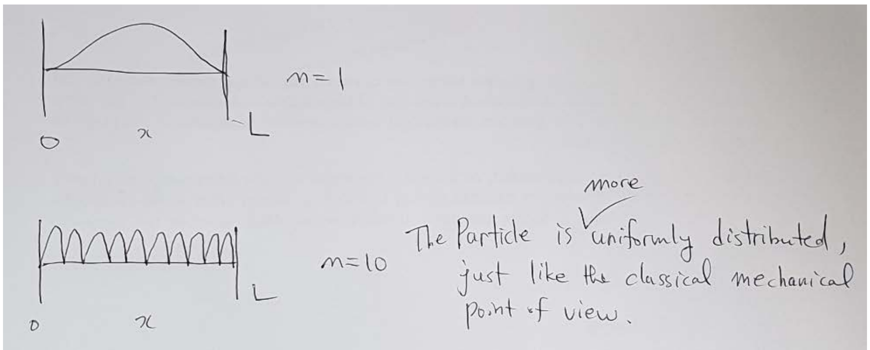
$\therefore e^{h\nu/k_B T} \simeq h\nu/k_B T + 1$

$\therefore \rho_T(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{1 + \frac{h\nu}{k_B T} - 1} = \frac{8\pi h\nu^3}{c^3} \cdot \frac{k_B T}{h\nu}$

$= \frac{8\pi k_B T \nu^2}{c^3}$

Partial points will be given if part of deduction is correct

(c) (3 pts) **Draw the probability distribution diagram for a particle in a box of length L in the quantum states n=1 and n=10. How do these diagrams show the correspondence principle?**



그래프를 잘 그리면 +2점, 설명을 제대로 하면 +1점

2 pts for the correct schematic diagram, 1 pt for correct explanation

5. (Total 8 pts) **Consider an electron in a 3-dimensional box with the length of L=$L_x = L_y = 1.5L_z$.**

(a) (5 pts) **Draw the first three energy levels in the energy level diagram of this system. Label each energy level with the energy value (in $h^2/8mL^2$ units).**

$$E = \frac{h^2}{8m}\left(\frac{n_x^2 + n_y^2 + 2.25n_z^2}{a^2}\right)$$

Energy level	(n_x, n_y, n_z)	Degeneracy	$E/(h^2/8ma^2)$
E_{111}	(1, 1, 1)	1	4.25
E_{211}	(2, 1, 1)(1, 2, 1)	2	7.25
E_{221}	(2, 2, 1)	1	10.25

- **ΔE 식 쓰면 + 1 pt**
- **Energy diagram 맞게 그리면 +2 pt**
- **Energy value가 맞으면 +2 pt**
- **1 pt for correct delta E equation**

- 2 pts for the correct energy diagram
- 2 pts for the correct energy value

(b) (3 pts) **Suppose the electron is in the ground state. The light with the wavelength of 500nm excited this electron into the first excited state. What are the three lengths of this box?**

$$\Delta E = \frac{E}{8mL^2}$$

$$\Delta E = \frac{h^2}{8mL^2}(7.25 - 4.25) = \frac{3h^2}{8mL^2} = h\frac{c}{\lambda}$$

$$L^2 = \frac{3h\lambda}{8mc} \quad \therefore L = \sqrt{\frac{3h\lambda}{8mc}}$$

$$= \sqrt{\frac{3\times(6.626\times10^{-34}\,J\cdot s)\times(500\times10^{-9}\,m)}{8\times(9.109\times10^{-31}\,kg)\times(3\times10^{8}\,m/s)}} = 6.743\,\mathring{A}$$

$$\therefore L_x = L_y = 6.743\,\mathring{A}$$

$$L_z = \frac{L_x}{1.5} = 4.495\,\mathring{A}$$

- ΔE 식 쓰고 값이 맞으면 + 1 pt

- L을 식으로 맞게 표현했으면 +1 pt

- 답이 맞으면 +1 pt

1 pt for correct delta E equation and value

1 pt for correct equation for L

1 pt for the correct answer