2018 SPRING Semester Midterm Examination
For General Chemistry I

Date: April 18 (Wed), Time Limit: 19:00 ~ 21:00

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. Number	Name

Problem	points	Problem	points	TOTAL pts
1	/8	**6**	/10	**/100**
2	/11	**7**	/11	
3	/6	**8**	/11	
4	/10	**9**	/12	
5	/10	**10**	/11	

** This paper consists of 13 sheets with 10 problems (page 11 - 12: constants & periodic table, page 13: claim form). Please check all page numbers before taking the exam. Write down your work and answers in the Answer sheet.

Please write down the unit 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

1) Return and Claim Period: ***April 23 (Mon, 19: 00 ~ 20:00 p.m.)***
2) ***Location: Room for quiz session***
3) 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.

(The claim is permitted only on the period. Keep that in mind! A solution file with answers for the examination will be uploaded on 4/27 on the web.)

2. Final Confirmation

1) Period: April 26 (Thu) – April 27 (Fri)
2) Procedure: During this period, you can check final score of the examination *on the website* again.

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

1. (total 8 pts) An ionic compound used as a chemical fertilizer has the composition (by mass) 48.46% O, 23.45% P, 21.21% N, 6.87% H.

(a) Give the name and chemical formula of the compound. Note that this compound contains ammonium ions.

(Answer)

(b) Draw Lewis diagrams for the two types of ions that make it up.

(Answer)

2. (total 11 pts) An unknown gas molecule XF_3 which consists of mysterious atom X as a central atom is given to you to be identified. The only clue is that X is known to be one of period 3 (from Na to Ar) elements.

(a) Monomer XF_3 has a stable Lewis structure without any formal charges on atoms. Also, there is no radical (an atom that has an unpaired valence electron) in this molecule. Give all the available XF_3 molecules. (Note that the central atom X may satisfy or not satisfy the octet rule.)

(Answer)

(b) Draw a Lewis diagram and name the approximate molecular geometry for every available XF_3 molecule from problem (a) based on VSEPR.

(Answer)

(c) To identify this unknown molecule XF_3, total dipole moment of given molecule was measured. In result, XF_3 molecule is identified to be non-polar. Among the molecules from the answer of problem (a), identify all the available XF_3 molecule(s).

(Answer)

3. (total 6 pts) Suppose we picture an electron in a chemical bond as being a wave with fixed ends. Take the length of the bond to be 1.0 Å.

(a) Calculate the wavelength of the electron wave in its ground state and in its first excited state.

(Answer)

(b) How many nodes does the first excited state have?

(Answer)

4. (total 10 pts) Light with a wavelength of 525 nm strikes the surface of cesium in a photocell. The work function of cesium is 3.43×10^{-19} J.

(a) Calculate the maximum velocity of the photoelectrons.

(Answer)

(b) Compute the de Broglie wavelength for the photoelectron in (a).

(Answer)

(c) Determine the longest wavelength of light that is capable of ejecting electrons from the surface of cesium.

(Answer)

5. (total 10 pts) The motion of an electron in a bond can be treated crudely as motion in an one-dimensional box. Consider electrons in O_2 and ozone. Note that the lengths of the O-O and O=O bonds are 1.48 and 1.21 Å, respectively

(a) Calculate the energy of an electron in each of its three lowest allowed states if it is confined to move in a one-dimensional box.

(Answer)

(b) Calculate the wavelength of light necessary to excite the electron from its ground state to the first excited state.

(Answer)

6. (total 10 pts) The ionization energy of a 1s electron of an hydrogen atom is 2.18 X 10^{-18} joule (or 1312 KJ/mol).

(a) What is the ionization energy of a 2p electron of a hydrogen atom?

(Answer)

(b) What is the ionization energy of a 1s electron of a He^{+} ion?

(Answer)

(c) Without attempting a detailed calculation, determine the lowest and highest first ionization energy values possible for a ground-state helium atom.

(Answer)

7. (total 11 pts) One orbital of a hydrogen atom is

$$\psi = re^{-r/2a}\sin\theta\cos\phi$$

(a) Show that this satisfies the Schrödinger equation,

$$-\frac{\hbar}{2m_e}\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]\psi-\frac{e^2}{4\pi\varepsilon_0}\frac{1}{r}\psi=E\psi$$

and obtain the corresponding energy eigenvalue *E* in the unit of eV. To solve this problem, you will need $a = 4\pi\varepsilon_0\hbar^2/(e^2m_e)$, or equivalently $e^2/(4\pi\varepsilon_0) = \hbar^2/(m_e a)$. Also, $h = 2\pi\hbar$.

(Answer)

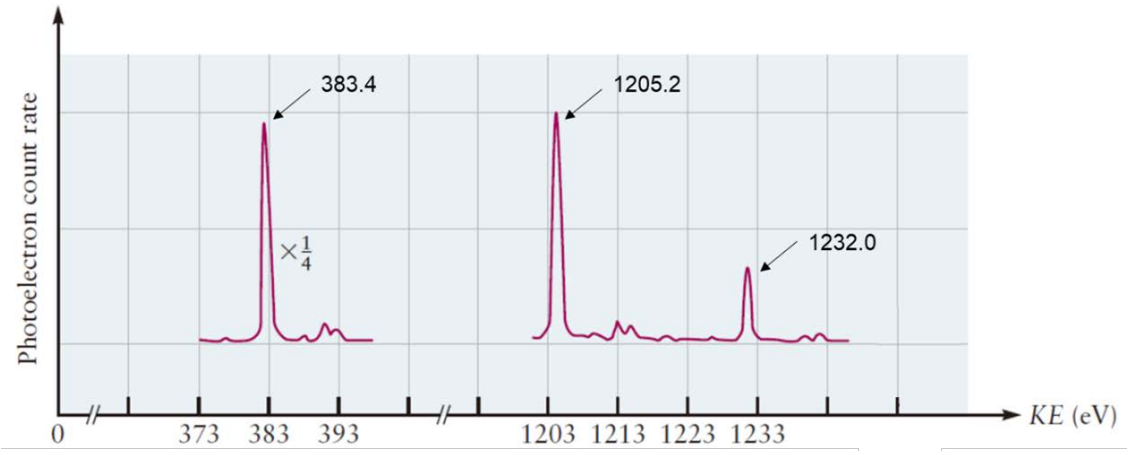
(b) How many radial nodes does this function have?

(Answer)

(c) Sketch the 3-dimensional shape of this orbital.

(Answer)

8. (total 11 pts) Below is the measured photoelectron spectrum for neon excited by X-rays with wavelength 9.890 Å. Answer the following questions.



(a) Write the electron configuration of neon.

(Answer)

(b) Calculate the ionization energy for each kinetic energy detected from the above spectrum and write the corresponding atomic orbital.

(Answer)

(c) Estimate the value of Z_{eff} for neon in each orbital.

(Answer)

9. (total 12 pts) Consider heteronuclear diatomic molecule NO.

(a) Describe its magnetic property.

(Answer)

(b) Provide its correlation diagram.

(Answer)

(c) Sketch the shape of the highest occupied molecular orbital. Do not forget to specify the nuclear centers by N or O.

(Answer)

10. (total 11 pts) Use valence bond (VB) theory to answer the following questions.

(a) Draw the molecular structure of allene ($H_2C=C=CH_2$). Using this molecular structure, show hybridization modes of all carbons.

(Answer)

(b) Sketch the σ and π frameworks of allene. Show all hybrid orbitals and p orbitals and assign σ and π-bonds clearly.

(Answer)

(c) Construct a putative molecular orbital diagram for the π-system. Sketch π-MOs and label them with π, π* or π_{nb}.

(Answer)

Physical Constants

Avogadro's number	$N_A = 6.02214179 \times 10^{23}\ mol^{-1}$
Bohr radius	$a_0 = 0.52917720859\ Å = 5.2917720859 \times 10^{-11}\ m$
Boltzmann's constant	$K_B = 1.3806504 \times 10^{-23}\ J\ K^{-1}$
Electronic charge	$e = 1.602176487 \times 10^{-19}\ C$
Faraday constant	$F = 96485.3399\ C\ mol^{-1}$
Masses of fundamental particles:	
Electron	$m_e = 9.10938215 \times 10^{-31}\ kg$
Proton	$m_P = 1.672621637 \times 10^{-27}\ kg$
Neutron	$m_n = 1.674927211 \times 10^{-27}\ kg$
Permittivity of vacuum	$\varepsilon_o = 8.854187817 \times 10^{-12}\ C^{-2}\ J^{-1}\ m^{-1}$
Planck's constant	$h = 6.62606896 \times 10^{-34}\ J\ s$
Ratio of proton mass to electron mass	$m_P / m_e = 1836.15267247$
Speed of light in a vacuum	$c = 2.99792458 \times 10^{8}\ m\ s^{-1}$ (exactly)
Standard acceleration of terrestrial gravity	$g = 9.80665\ m\ s^{-2}$ (exactly)
Universal gas constant	$R = 8.314472\ J\ mol^{-1}\ K^{-1}$ $= 0.0820574\ L\ atm\ mol^{-1}\ K^{-1}$

Values are taken from the 2006 CODATA recommended values,
as listed by the National Institute of Standards and Technology.

Conversion factors

Ångström	$1\ Å = 10^{-10}\ m$
Atomic mass unit	$1\ u = 1.660538782 \times 10^{-27}\ kg$
	$1\ u = 1.492417830 \times 10^{-10}\ J = 931.494028\ MeV$ (energy equivalent form $E = mc^2$)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	$1\ eV = 1.602177 \times 10^{-19}\ J = 96.485335\ kJ\ mol^{-1}$
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U. S.)	1 gallon = 4 quarts = 3.785412 L (exactly)
Liter	$1\ L = 10^{-3}\ m^{-3} = 10^{3}\ cm^{3}$ (exactly)
Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 t = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.4539237 kg (exactly)
Rydberg	$1\ Ry = 2.17987197 \times 10^{-18} J = 1312.7136\ kJ\ mol^{-1} = 13.60569193\ eV$
Standard atmosphere	$1\ atm = 1.01325 \times 10^{5}\ Pa = 1.01325 \times 10^{5}\ kg\ m^{-1}\ s^{-2}$ (exactly)
Torr	1 torr = 133.3224 Pa

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 **H** HYDROGEN																	2 4.0026 **He** HELIUM
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.007 **N** NITROGEN	8 15.999 **O** OXYGEN	9 18.998 **F** FLUORINE	10 20.180 **Ne** NEON
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.974 **P** PHOSPHORUS	16 32.065 **S** SULPHUR	17 35.453 **Cl** CHLORINE	18 39.948 **Ar** ARGON
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.39 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.922 **As** ARSENIC	34 78.96 **Se** SELENIUM	35 79.904 **Br** BROMINE	36 83.80 **Kr** KRYPTON
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.94 **Mo** MOLYBDENUM	43 (98) **Tc** TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.76 **Sb** ANTIMONY	52 127.60 **Te** TELLURIUM	53 126.90 **I** IODINE	54 131.29 **Xe** XENON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 **La-Lu** Lanthanide	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.98 **Bi** BISMUTH	84 (209) **Po** POLONIUM	85 (210) **At** ASTATINE	86 (222) **Rn** RADON
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 **Ac-Lr** Actinide	104 (261) **Rf** RUTHERFORDIUM	105 (262) **Db** DUBNIUM	106 (266) **Sg** SEABORGIUM	107 (264) **Bh** BOHRIUM	108 (277) **Hs** HASSIUM	109 (268) **Mt** MEITNERIUM	110 (281) **Uun** UNUNNILIUM	111 (272) **Uuu** UNUNUNIUM	112 (285) **Uub** UNUNBIUM		114 (289) **Uuq** UNUNQUADIUM				

GROUP NUMBERS IUPAC RECOMMENDATION (1985) — GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986)

ATOMIC NUMBER — 5 10.811 — RELATIVE ATOMIC MASS (1)

SYMBOL — B

BOREN — ELEMENT NAME

LANTHANIDE

57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) **Pm** PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.26 **Er** ERBIUM	69 168.93 **Tm** THULIUM	70 173.04 **Yb** YTTERBIUM	71 174.97 **Lu** LUTETIUM

ACTINIDE

89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) **Np** NEPTUNIUM	94 (244) **Pu** PLUTONIUM	95 (243) **Am** AMERICIUM	96 (247) **Cm** CURIUM	97 (247) **Bk** BERKELIUM	98 (251) **Cf** CALIFORNIUM	99 (252) **Es** EINSTEINIUM	100 (257) **Fm** FERMIUM	101 (258) **Md** MENDELEVIUM	102 (259) **No** NOBELIUM	103 (262) **Lr** LAWRENCIUM

(1) Pure Appl. Chem., **73**, No. 4, 667-683 (2001)

Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adivar@nettlinx.com)

Claim Form for General Chemistry Examination

Class:_____, Professor Name:_____, I.D.# :_____, Name:_____

If you have any claims on the marked paper, please write down them on this form and ***submit this with your paper in the assigned place***. (And this form should be attached ***on the top of the marked paper with a stapler***.) Please, ***copy this sheet if you need more before use***.

By Student		By TA	
		Accepted? Yes(√) or No(√)	
Question #	Claims	Yes: ☐	No: ☐
		Pts (+/-)	Reasons