2019 Spring Semester Quiz 1
For General Chemistry I (CH101)

Date: Mar 18 (Mon),   Time: 19:00 ~ 19:45

Professor Name	Class	Student I.D. Number	Name

Use the following constants to solve problems. The periodic table is given in the last page of this quiz.
(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)
(Speed of light c = 2.998 × 10^8 m/s) (π = 3.1416) (Avogadro's number N_A = 6.022 × 10^{23})

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1. (Total 10 pts, 2 pts for each) **Answer the following questions.**

(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^+.**

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

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

2 pts for correct calculation or correct explanation (that reaction proceeds in a pathway with lower ΔE)

1 pt for explaining that reaction proceeds with lower energy barrier

b) (5 pts) **Estimate the energy of dissociation (ΔE_d) to neutral atoms for KCl, which has a bond length 2.67×10^{-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

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

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

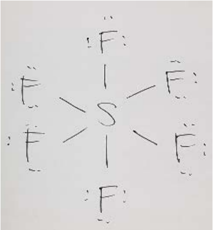
$$= -(-520 \text{ kJ mol}^{-1}) - (418.8 \text{ kJ mol}^{-1} - 349.0 \text{ kJ mol}^{-1}) = \boxed{450 \text{ kJ mol}^{-1}}$$

--- V_{coulomb}, ΔE_d +1 pt each

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

3. (Total 8 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>**

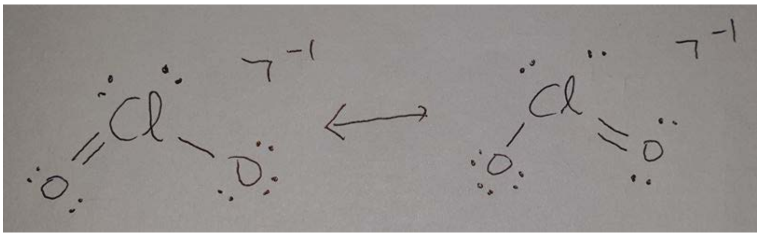
(a) $\mathbf{SF_6}$



Correct Lewis diagram -- + 1 pt

Geometry: Octahedral -- + 1 pt

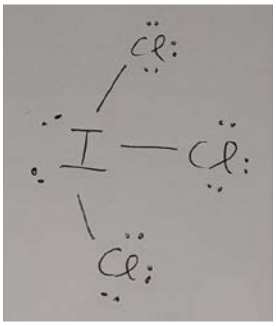
(b) $\mathbf{ClO_2^-}$



0.5 pt for one resonance structure; 0.5 pt for full resonance -------------------------------------- + 1 pt

Geometry: bent-- + 1 pt

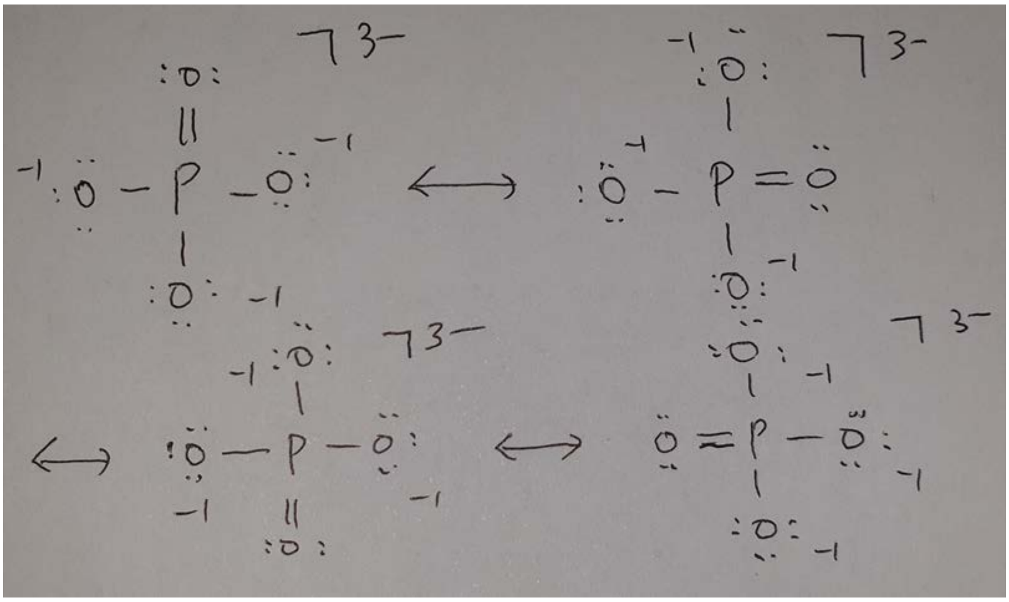
(c) $\mathbf{ICl_3}$



Correct Lewis diagram-- + 1 pt

Geometry: T-shaped-- + 1 pt

(d) $\mathbf{PO_4^{3-}}$



0.5 pt for one resonance structure; 0.5 pt for full resonance ------------------------------------ + 1 pt

Geometry: tetrahedral-- + 1 pt

4. (Total 7 pts) **Consider a universe with a <u>different value</u> of the Planck constant. When lithium is irradiated with light in this universe, the kinetic energy of the ejected electrons is 2.935J for λ=300.0nm and 1.280J for λ=400.0nm (λ is the wavelength of the light).**

(a) (2 pts) **Calculate the Planck constant in this universe.**

$$2.935J = \frac{hc}{\lambda_1} - \phi$$

$$1.280J = \frac{hc}{\lambda_2} - \phi$$

$$\therefore 2.935J - 1.280J = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) \ldots + 1pt$$

$$1.655J = h(2.998 \times 10^8 m \cdot s^{-1})\left(\frac{1}{300 \times 10^{-9} m} - \frac{1}{400 \times 10^{-9} m}\right)$$

$$\therefore h = \frac{1.655J}{2.498 \times 10^{14} s^{-1}} = 6.625 \times 10^{-15} J \cdot s \ldots + 1pt$$

+1 pt for the correct equation, +1 pt for the correct answer

(b) (1 pt) **Calculate the work function of lithium in this universe.**

$$\phi = \frac{hc}{\lambda_1} - 2.935J = \frac{(6.625 \times 10^{-15} J) \times (2.998 \times 10^8 m \cdot s^{-1})}{300 \times 10^{-9} m} - 2.935J = 3.686J$$

+1 pt for the correct answer; no partial points

(c) (2 pts) **In this universe, what is the maximum kinetic energy of electrons ejected from lithium by the light of wavelength of 200.0 nm?**

$$E_{max} = \frac{hc}{\lambda} - \phi = \frac{(6.625 \times 10^{-15} J) \times (2.998 \times 10^{8} m \cdot s^{-1})}{200 \times 10^{-9} m} - 3.686J = 6.245J$$

+1 pt for the $E_{max} = \frac{hc}{\lambda} - \phi$ equation, +1 pt for the correct answer

(d) (2 pts) **Suppose the electrons described in (c) were used in a diffraction experiment. What would be their wavelength in this universe? Use the maximum kinetic energy value from (c).**

$$KE = \frac{1}{2} m_e v^2 = \frac{p^2}{2m}$$

$$\therefore p = \sqrt{2m \times KE} \ldots + 1pt$$

$$de\ \ Broglie\ \ wavelength\ \ \lambda = \frac{h}{p} = \frac{(6.625 \times 10^{-15} J \cdot s)}{\sqrt{2 \times 9.109 \times 10^{-31} kg \times 6.245J}} = 1.964m \ldots + 1pt$$

+1 pt for the correct equation, +1 pt for the correct answer

5. (Total 7 pts) **Consider an electron in a one-dimensional box with length L, where potential V = 0 everywhere inside the box. The solution for the Schrödinger's equation of this system is as follows:**

$$\psi_n(x) = \sqrt{\frac{2}{L}} sin\left(\frac{n\pi x}{L}\right) \quad n = 1, 2, 3, \ldots$$

(a) (4 pts) **Using the given wavefunction, show that the energy level of this particle in a box is as follows:**

$$E_n = \frac{n^2 h^2}{8mL^2} \quad n = 1, 2, 3, \ldots$$

To find the energy E_n for a particle described by the wave function ψ_n, we calculate the second derivative:

$$\frac{d^2\psi_n(x)}{dx^2} = \frac{d^2}{dx^2}\left[\sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)\right]$$
$$= -\left(\frac{n\pi}{L}\right)^2 \left[\sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)\right]$$
$$= -\left(\frac{n\pi}{L}\right)^2 \psi_n(x)$$

This must be equal to $-\frac{8\pi^2 m E_n}{h^2}\psi_n(x)$. Setting the coefficients equal to one another gives

$$\frac{8\pi^2 m E_n}{h^2} = \frac{n^2\pi^2}{L^2} \quad \text{or}$$

$$E_n = \frac{n^2h^2}{8mL^2} \qquad n = 1, 2, 3, \ldots$$

+1 pt for the correct Schrödinger's equation:

$$-\frac{\mathbf{h}^2}{8\pi^2 m}\frac{d^2\psi_n(x)}{dx^2} = E\psi_n(x)$$

+2 pts for correct differentiation:

$$\frac{\mathrm{d}^2\psi_n(x)}{dx^2} = -\left(\frac{\mathrm{n}\pi}{L}\right)^2 \psi_n(x)$$

+1 pt for correct derivation

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

$$\Delta E = \frac{h^2}{8mL^2}(2^2 - 1^2) = \frac{3h^2}{8mL^2} = \frac{hc}{\lambda}$$

$$L^2 = \frac{3h\lambda}{8mc} \quad \therefore L = \sqrt{\frac{3h\lambda}{8mc}} \ldots + 1pt$$

$$= \sqrt{\frac{3 \times (6.626 \times 10^{-34} J \cdot s) \times (500 \times 10^{-9} m)}{8 \times (9.109 \times 10^{-31} kg) \times (2.998 \times 10^{8} m \ \ s^{-1})}} = 6.745 \times 10^{-10} m = 6.745 \text{Å} \ldots + 2pt$$

+1 pt for the correct equation, +2 pts for the correct answer

****Any final answer WITHOUT the correct units got 0.5 pt deduction.**

PERIODIC TABLE OF THE ELEMENTS

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

GROUP NUMBERS IUPAC RECOMMENDATION (1985): 13
GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986): IIIA
ATOMIC NUMBER: 5
RELATIVE ATOMIC MASS (1): 10.811
SYMBOL: B
ELEMENT NAME: BORON

PERIOD	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	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				

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.

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