PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

FIRST SEMESTER EXAMINATIONS

AS 111 – FOUNDATION CHEMISTRY

MONDAY 22ND JUNE 2020 – 08:20 AM

TIME ALLOWED: 3 HOURS

INFORMATION FOR CANDIDATES:

1. Mobile phones are not allowed. Switch off the mobile phones and leave them at the entrance of the exam hall.
2. You will have 10 minutes to read the question paper. You MUST NOT begin writing in the answer book during this time.
3. ANSWER ALL QUESTIONS precisely and to the point
4. Draw the structure and provide the equations WHEREVER REQUIRED.
5. All answers MUST be written on the answer book provided
6. Calculators are permitted in the examination room. Lecture notes, notebooks and text books are NOT allowed.
7. Show ALL workings and calculations in the answer book ONLY.
8. Write your name and student id number clearly on the front page. DO IT NOW.
9. Use the data sheet attached for formulas and equations.

MARKING SCHEME: [100 MARKS]

1. In a photoelectric effect experiment, electrons are ejected from titanium
   surface (work function, ϕ = 4.33 eV) following irradiation with UV light.
   The energy of the incident UV light is 7.2 x 10^{-19} J per photon.
   (a) Calculate the wavelength of the incident UV light. [4 marks]

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

$$\lambda = \frac{6.6261 \times 10^{-34} Js \times 2.998 \times 10^{8} m/s}{7.2 \times 10^{-19} J} = 2.759 \times 10^{-7} m$$

   (b) Calculate the wavelength of the ejected electrons. [4 marks]

$$KE = E_i - \Phi$$

$$KE = 7.2 \times 10^{-19} J - (4.33 \times 1.60218 \times 10^{-19} J) = 2.6256 \times 10^{-20} J$$

$$K.E = 1/2mv^2$$

$$v = \sqrt{\frac{2 \times K.E}{m}}$$

$$= \sqrt{\frac{2 \times 2.6256 \times 10^{-20} kg.m^2.s^{-2}}{9.10939 \times 10^{-31} kg}} = 2.4 \times 10^{5} m.s^{-1}$$

$$\lambda = \frac{h}{mv}$$

$$= \frac{6.6261 \times 10^{-34} Js}{9.109 \times 10^{-31} kg \times 2.4 \times 10^{5} m.s^{-1}}$$

$$= \frac{6.6261 \times 10^{-34} kg.m^2.s^{-2}.s}{9.109 \times 10^{-31} kg \times 2.4 \times 10^{5} m.s^{-1}}$$

$$\therefore \lambda = 3.029 \times 10^{-9} m$$

   (c) Would an iron surface (ϕ = 4.7 eV) require longer or shorter
       wavelength photons to eject electrons with the same wavelength
       as calculated in part (b)? Briefly explain. [3 marks]

**Iron has a larger work function, so it would require more energy and thus shorter
wavelength photons.**

                                                                      (11 marks)

2. For the B^{4+} ion,
   (a) Calculate the binding energy of an electron at the ground state. [5 marks]

$E_n = -Z^2 R_H/n^2$

ground state → n = 1
$E_1 = -5^2(2.1799 \times 10^{-18} J)/1^2$
$E_1 = -5.45 \times 10^{-17} J$

(b) If an electron falls from the n=3 to n=1 state, calculate the
wavelength of light emitted. [5 marks]
Second excited state → n = 3
$E_3 = -5^2(2.1799 \times 10^{-18} J)/3^2$
$E_3 = -6.06 \times 10^{-18} J$
ground state → n = 1

$E_1 = -5^2(2.1799 \times 10^{-18} J)/1^2$
$E_1 = -5.45 \times 10^{-17} J$

$\Delta E = E_3 - E_1$
$\Delta E = (-6.06 \times 10^{-18} J) - (-5.45 \times 10^{-17} J)$
$\Delta E = 4.84 \times 10^{-17} J$

$E = hc / \lambda$
$4.84 \times 10^{-17} J = (6.626 \times 10^{-34} Js)(2.9979 \times 10^8 m/s) / \lambda$
$\lambda = 4.10 \times 10^{-9} m$

(c) Without doing any calculations, would you expect an electron in the
ground state of Li^{2+} to be bound more tightly or less tightly than an
electron in the ground state of B^{4+}. Explain your answer. [4 marks]
The electron in Li^{2+} should be bound less tightly because B^{4+} has more protons,
therefore, the nucleus of B^{4+} will more strongly attract its electron.

(14 marks)

3. Answer the following questions for 3s, 3p, and 3d orbitals
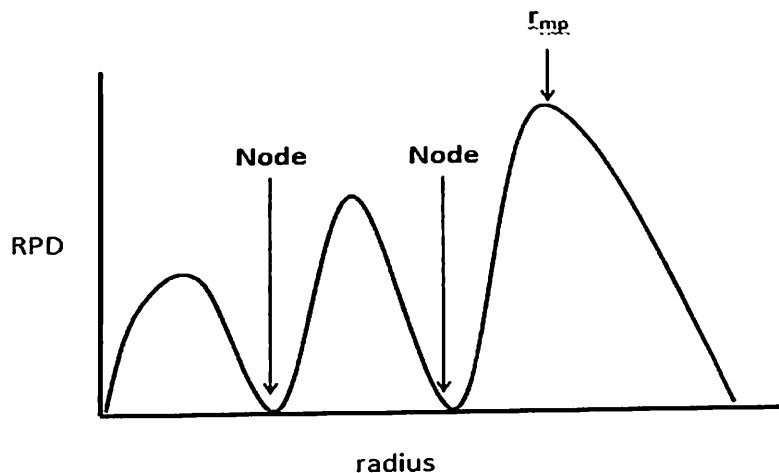   (a) Which of these three orbitals has the highest number of angular nodes? [2 marks]
   3d, l=2

   (b) Which of these three orbitals has the largest r_{mp}? [2 marks]
   3s

(c) Draw the radial probability distribution (RPD) for the electron in
the 4p orbital. Label the r_{mp} and any nodes. [6 marks]

(10 marks)

4. (a) The binding energy of a calcium 2p electron is -349.7 eV. Calculate
the effective nuclear charge experienced by a calcium 2p electron. [7 marks]

$-E_{2p} = 349.7$ eV

$-E_{2p} = (349.7$ eV$)(1.6022 \times 10^{-19}$ J/eV$) = 5.6029 \times 10^{-17}$ J

$-E_{nl} = [(Z_{eff})^2 R_H] / n^2$

5.6029×10^{-17} J $= \dfrac{(Z_{eff})^2 (2.18 \times 10^{-18}$ J$)}{(2)^2}$

$Z_{eff} = 10.14$

(b) Would a 2s electron feel more or less shielding than a 2p electron?
Briefly explain your answer. [3 marks]

Less. The 2s electron is closer on average to the nucleus than a 2p electron (even
though its most probable radius is farther than for a 2p electron).

or

Less. The 2s electron penetrates closer to the nucleus or any other reasonable
explanation.

(10 marks)

5. (a) Which of the following (**Li, Be, B, Na, K**) has the highest second
ionization energy (IE_2)? [2 marks]

Li

(b) Rank the following from the smallest to largest atomic
radius: Na, Na$^+$, Rb. [3 marks]

Samllest ..... Na$^+$, Na, Rb ..... Largest

(c) Rank the electron affinity from smallest to largest for **P, Cl, Ar**. [3 marks]

Samllest ... Ar, P, Cl .... largest

(8 marks)

6. The ionic bond length of KF is 0.217 nm. Calculate the energy
(in units of kJ/mol) required to dissociate a single molecule of KF
into the **neutral atoms** of K and F, using the information provided
below. For this calculation, assume that the potassium and fluorine
ions are point charges. (Hint: First calculate the energy for **ions** than
use it to calculate for neutral atoms).

element	Ionization energy	Electron affinity
Potassium (K)	418 kJ/mol	48 kJ/mol
Fluorine (F)	1680 kJ/mol	328 kJ/mol
Chlorine (Cl)	1255 kJ/mol	394 kJ/mol

(10 marks)

First calculate the ΔE for the dissociation into ions: (-U(r))

$$U(r) = \frac{z_1 z_2 e^2}{4\pi\varepsilon_0 r} = \frac{(-1)(+1)(1.602 \times 10^{-19}C)^2}{4\pi(8.854 \times 10^{-12}C^2J^{-1}m^{-1})(0.217 \times 10^{-9}m)}$$

$$U(r) = -1.063 \times 10^{-18}J$$

$$-U(r) = 1.063 \times 10^{-18}J$$

Next, convert –U(r) to kJ/mol

(1.063 x 10^{-18} J) x (k)/1000 J) x (6.022 x 10^{23}/mol) = 640.2 kJ/mol

$\Delta E_{total} = -IE_K - EA_F - U(r)$

$K^+ + e^- \rightarrow K \equiv -IE_K$ – 418 kJ/mol

$F^- \rightarrow e^- + F \equiv EA_F$ + 328 kJ/mol

$\underline{KF \rightarrow K^+ + F^- \equiv -U(r)}$ $\underline{+ 640.2 \text{ kJ/mol}}$

+550.2 kJ/mol

7. (a) Draw the most stable Lewis structure for SF_4 including lone pairs. Indicate any non-zero formal charge(s) and draw any resonance structures if appropriate. [4 marks]
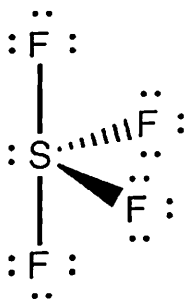
(b) Give the SN for SF_4. [2 marks]

      5

(c) Give the geometry of SF_4. [2 marks]

      See -saw

(d) Choose the expected F-S-F angle or angles from the list below [2 marks]

      <90°; 90°; >90°; <109.5°; 109.5°; >109.5°; <120°; 120°; >120°

(10 marks)

8. (a) Give the chemical formula for Sodium perchlorate [2 marks]

      $NaClO_4$

(b) Explain the properties of metals such as ductility, malleability and conduction of electricity in terms of **metallic bonding**. [3 marks]

(5 marks)

9. What is the limiting reagent if 76.4 grams of $C_2H_3Br_3$ were reacted with 49.1 g of O_2 according to the equation below:

$$4\,C_2H_3Br_3 + 11\,O_2 \rightarrow 8\,CO_2 + 6\,H_2O + 6\,Br_2$$

(6 marks)

A. $76.4 \text{ g} \times \dfrac{1 \text{ mole}}{266.72 \text{ g}} = 0.286$ moles of $C_2H_3Br_3$

$49.1 \text{ g} \times \dfrac{1 \text{ mole}}{32 \text{ g}} = 1.53$ moles of O_2

Assuming that all of the oxygen is used up, 1.53 x 4/11 or 0.556 moles of $C_2H_3Br_3$ are required. Because there are only 0.286 moles of $C_2H_3Br_3$ available, $C_2H_3Br_3$ is the limiting reagent
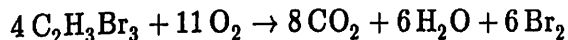
10. (a) A sample of CO_2 gas has a volume of 575 cm^3 at 752 torr
and 22.2 ^{0}C. What is the mass of carbon dioxide in this sample?   [6 marks]

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{(752 \text{ } torr)(\frac{1}{760} torr)(575 \text{ } cm^3)(\frac{1L}{1000} cm^3)}{0.0821 \text{ } L.\frac{atm}{mol}.K(22.220C + 273.15)} = 0.0122 \text{ } mol$$

$$mass = molar \text{ } mass \text{ } x \text{ } mols$$

$$mass = 44g/mol \text{ } x \text{ } 0.0122 \text{ } mol = 0.5368 \text{ } g$$

(b) An empty 49.0 L methane storage tank has an empty mass of
55.85 kg and, when filled, has a mass of 62.07 kg. Calculate the
pressure of CH_4 in the tank at 21°C using;
(i)   the ideal gas equation   [3 marks]

$$Mass \text{ } of \text{ } CH_4 = mass \text{ } of \text{ } full \text{ } cylinder - mass \text{ } of \text{ } empty \text{ } cylinder$$
$$= 62.07 \text{ kg} - 55.85 \text{kg} = 6.22 \text{ kg}$$
$$= 6220 \text{ g}$$

$$Moles \text{ } of \text{ } gas = 6220 \text{ g } CH_4 \text{ } x \frac{1 \text{ } molCH_4}{16.04 \text{ } gCH_4} = 388 \text{ } mol \text{ } CH_4$$

$$Ideal \text{ } Gas: \text{ } P = \frac{nRT}{V}$$

$$= \frac{(388 \text{ } mol)(0.08206 \text{ } L.atm.mol^{-1}K^{-1})(294 \text{ } K)}{49.0 \text{ } L}$$

$$= 191 \text{ } atm$$

(ii)   the van der Waals equation.   [5 marks]

$$van\ der\ Waals: \quad a = 2.253\ L^2.atm.mol^{-2}, \quad b = 0.04278\ L.mol^{-1}$$

$$P = \frac{nRT}{V - nb} - \frac{n^2 a}{V^2}$$

$$= \frac{(388\ mol)(0.08206\ L.atm.mol^{-1}.K^{-1})(294\ K)}{49.0\ L - (387.5\ mol)(0.0428\ L.mol^{-1}}$$

$$- \frac{(388mol)^2(2.25\ L^2.atm.mol^{-2})}{(49.0\ L)^2} = 148\ atm$$

(iii)   what is the percentage correction achieved by using the more
        realistic van der Waals equation.   [2 marks]

$$Percentage\ correction: \quad \frac{191 - 148}{191}\ x\ 100 = 23\%$$

(16 marks)

DATA SHEET

$c = 2.9979 \times 10^8$ m/s

$h = 6.6261 \times 10^{-34}$ J s

$N_A = 6.022 \times 10^{23}$ mol^{-1}

$m_e = 9.1094 \times 10^{-31}$ kg

$a_o = 5.292 \times 10^{-11}$ m

1 amu $= 1.66 \times 10^{-27}$ kg

$R_H = 2.1799 \times 10^{-18}$ J

$\mathfrak{R} = R_H/h = 3.2898 \times 10^{15}$ Hz

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

$$E_{nl} = -\frac{Z_{eff}^2 R_H}{n^2}$$

$1\ W = 1\ J\ s^{-1}$

$1\ J = 1\ kgm^2s^{-2}$

$1\ eV = 1.6022 \times 10^{-19}$ J

$E = h\nu = hc/\lambda$

$c = \nu\lambda$

$KE = (\tfrac{1}{2})mv^2$

$p = mv$

$$\lambda = \frac{h}{p}$$

for s wavefunction:

$RPD = 4\pi r^2 \Psi^2 dr$

for $n_f < n_i$ ......

$$\nu = \frac{Z^2 R_H}{h}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

for $n_f > n_i$ .....

$$\nu = \frac{Z^2 R_H}{h}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$1\ eV = 1.60218 \times 10^{-19}$ J

$m_e = 9.10939 \times 10^{-31}$ kg

$e = 1.60218 \times 10^{-19}$ C

$U(r) = (z_1 z_2 e^2)/(4\pi\varepsilon_0 r)$

$\varepsilon_0 = 8.8542 \times 10^{-12}$ C^2/(Jm)

Electronegativity $= (IE + EA)/2$

$$PV = nRT$$

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

Van der Waals constants for several common gases		
Gas	a (atm L^2 mol^{-2})	b (L mol^{-1})
Ammonia, NH_3	4.170	0.03707
Argon, Ar	1.345	0.03219
Carbon dioxide, CO_2	3.592	0.04267
Helium, He	0.034	0.0237
Hydrogen, H_2	0.2444	0.02661
Hydrogen fluoride, HF	9.433	0.0739
Methane, CH_4	2.253	0.04278

Periodic Table

Legend:
- ▢ Metals
- ▢ Semimetals
- ▢ Nonmetals

Transition elements

I	II		III	IV	V	VI	VII	VIII
1 **H** 1.0079 Hydrogen								2 **He** 4.0026 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.0122 Beryllium		5 **B** 10.811 Boron	6 **C** 12.011 Carbon	7 **N** 14.007 Nitrogen	8 **O** 15.999 Oxygen	9 **F** 18.998 Fluorine	10 **Ne** 20.180 Neon
11 **Na** 22.990 Sodium	12 **Mg** 24.305 Magnesium		13 **Al** 26.982 Aluminium	14 **Si** 28.086 Silicon	15 **P** 30.974 Phosphorus	16 **S** 32.065 Sulfur	17 **Cl** 35.453 Chlorine	18 **Ar** 39.948 Argon

Transition elements block (Period 4):

| 19 **K** 39.098 | 20 **Ca** 40.078 | 21 **Sc** 44.956 | 22 **Ti** 47.867 | 23 **V** 50.942 | 24 **Cr** 51.996 | 25 **Mn** 54.938 | 26 **Fe** 55.845 | 27 **Co** 58.933 | 28 **Ni** 58.693 | 29 **Cu** 63.546 | 30 **Zn** 65.409 | 31 **Ga** 69.723 | 32 **Ge** 72.64 | 33 **As** 74.922 | 34 **Se** 78.96 | 35 **Br** 79.904 | 36 **Kr** 83.798 |

Period 5:

| 37 **Rb** 85.468 | 38 **Sr** 87.62 | 39 **Y** 88.906 | 40 **Zr** 91.224 | 41 **Nb** 92.906 | 42 **Mo** 95.94 | 43 **Tc** (98) | 44 **Ru** 101.07 | 45 **Rh** 102.91 | 46 **Pd** 106.42 | 47 **Ag** 107.87 | 48 **Cd** 112.41 | 49 **In** 114.82 | 50 **Sn** 118.71 | 51 **Sb** 121.76 | 52 **Te** 127.60 | 53 **I** 126.90 | 54 **Xe** 131.29 |

Period 6:

| 55 **Cs** 132.9 | 56 **Ba** 137.33 | 71 **Lu** 174.97 | 72 **Hf** 178.49 | 73 **Ta** 180.95 | 74 **W** 183.84 | 75 **Re** 186.21 | 76 **Os** 190.23 | 77 **Ir** 192.22 | 78 **Pt** 195.08 | 79 **Au** 196.97 | 80 **Hg** 200.59 | 81 **Tl** 204.38 | 82 **Pb** 207.2 | 83 **Bi** 208.98 | 84 **Po** (209) | 85 **At** (210) | 86 **Rn** (222) |

Period 7:

| 87 **Fr** (223) | 88 **Ra** (226) | 103 **Lr** (262) | 104 **Rf** (261) | 105 **Db** (262) | 106 **Sg** (266) | 107 **Bh** (264) | 108 **Hs** (277) | 109 **Mt** (268) | 110 **Uun** (281) | 111 **Uuu** (272) | 112 **Uub** (285) | 114 **Uuq** (289) | | | | | |

Lanthanide series

| 57 **La** 138.91 | 58 **Ce** 140.12 | 59 **Pr** 140.91 | 60 **Nd** 144.24 | 61 **Pm** (145) | 62 **Sm** 150.36 | 63 **Eu** 151.96 | 64 **Gd** 157.25 | 65 **Tb** 158.93 | 66 **Dy** 162.50 | 67 **Ho** 164.93 | 68 **Er** 167.26 | 69 **Tm** 168.93 | 70 **Yb** 173.04 |

Actinide series

| 89 **Ac** (227) | 90 **Th** 232.04 | 91 **Pa** 231.04 | 92 **U** 238.03 | 93 **Np** (237) | 94 **Pu** (244) | 95 **Am** (243) | 96 **Cm** (247) | 97 **Bk** (247) | 98 **Cf** (251) | 99 **Es** (252) | 100 **Fm** (257) | 101 **Md** (258) | 102 **No** (259) |