THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES

2014 ACADEMIC YEAR FIRST TERM
TEST 1

CHE1000: INTRODUCTORY CHEMISTRY
TIME: Two hours (9:00- 11:00 hrs.) 5th December 2014

TG 9

STUDENT ID NUMBER 14018357

INSTRUCTIONS TO THE CANDIDATES

1. Indicate your **student ID number** and **TG number** in space provided.
2. The test consists of two **(2)** sections: **A** and **B**
3. Section **A** has eight **(8)** short answer questions. Questions carry equal marks. (Total marks = **40**).
4. Section **B** has four **(4)** long answer questions. Questions carry equal marks. (Total marks = **60**).
5. **ATTEMPT ALL QUESTIONS IN SECTION A; AND B1 AND ANY OTHER TWO QUESTIONS IN SECTION B.**
6. **YOU ARE REMINDED OF THE NEED TO ORGANISE AND PRESENT YOUR WORK CLEARLY AND LOGICALLY.**

INFORMATION TO THE CANDIDATES:

1. **Useful data** is printed on **page 14.**
2. **Periodic table is printed on the last page.**

For official use

QUESTION	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4
MKS	5	5	5	3	2	5	05	05	2	12	7½	—

TOTAL %
56.5

Checked by______________

SECTION A **ANSWER ALL QUESTIONS**

QUESTION A1.
Calculate the mass of 2 moles of iron (Fe).

mass = moles X $\frac{\text{molarmass}}{1\text{mol}}$

= ~~2mol X 55.85~~

= 2 ~~mol~~ X $\frac{55.85g}{1\ \text{mol}}$

= 111.7g

5

[5 mks]

QUESTION A2.
Balance and write the net ionic equation for the precipitation reaction below.

$K_2S_{(aq)} + Ni(NO_3)_{2(aq)} \rightarrow KNO_{3(aq)} + NiS_{(s)}$

$K_2S_{(aq)} + Ni(NO_3)_{2(aq)} \rightarrow 2KNO_{3(aq)} + NiS_{(s)}$

$2K^+_{(aq)} + S^{2-}_{(aq)} + Ni^{2+}_{(aq)} + 2NO^-_{3(aq)} \rightarrow 2K^+_{(aq)} + 2NO^-_{3(aq)} + NiS_{(s)}$

$S^{2-}_{(aq)} + Ni^{2+}_{(aq)} \rightarrow NiS_{(s)}$

5

[5 mks]

QUESTION A3.
A gas at constant pressure is heated from 35°C to 80°C, calculate the new volume if the initial volume was 5.6 L.

35°c + 273 = 308 K
80°c + 273 = 353 K

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{5.6}{308} = \frac{V_2}{353}$

$\frac{308V_2}{308} = \frac{1976.8}{308}$ ∴ $V_2 = 6.4L$

5

[5 mks]

QUESTION A4.

Calculate the ratio of the rate of effusion of helium gas to laughing gas (N_2O) at the same temperature.

$$\frac{\text{rate of effusion of He}}{\text{rate of effusion of } N_2O} = \sqrt{\frac{M_{N_2O}}{M_{He}}}$$

molar mass N_2O

$(14.01 \times 2) + 16.00$

$= 44.02g$

$$= \sqrt{\frac{44.02g}{4g}}$$

$$= \sqrt{11.01}$$

$\Rightarrow 3.32$

3

[5 mks]

QUESTION A5.

Calculate the mean root velocity (U_{rms}) of tear gas (C_8H_7ClO, Molar mass =154.6g mol^{-1}) at 25 °C

$$U_{rms} = \sqrt{\frac{3RT}{M}}$$ 1

$T = 25°C + 273 = 298K$

$$= \sqrt{\frac{3(0.08206 \frac{L \cdot atm}{K \cdot mol})(298K)}{154.6\ g/mol}}$$ 1

8.3145 J mol⁻¹ K⁻¹ ; 0.1546

$$= \sqrt{\frac{73.4}{154.6}}$$

$= \sqrt{0.475}$

$= 0.689 m/s$

$PV = nRT$

$P = \frac{nRT}{V}$

$P = nRT$

2/5

[5mks]

QUESTION A6.

Ozone (O_3) in the stratosphere filters out ultraviolet radiation by absorbing light at a wavelength of 250 nm. What is the energy of a mole of photons at this wavelength (J mol^{-1})?

$E_{photon} = h\nu$

$= h\left(\frac{c}{\lambda}\right)$

$= 6.626 \times 10^{-34}\ J.s \left(\frac{3.00 \times 10^{8}\ m/s}{2.5 \times 10^{-7}\ m}\right)$

$= 6.626 \times 10^{-34}\ J.s \times 1.2 \times 10^{15}$

$= 8.0 \times 10^{-19}\ J$

250 nm

1 meter — 10^9 nm

$\frac{250\ nm}{10^9} = 2.5 \times 10^{-7}\ m$

E of a mole $= 8.0 \times 10^{-19}\ J \times 6.022 \times 10^{23}\ mol^{-1} \times \frac{1\ kJ}{1000\ J}$

$= 478.821\ kJ$

5

[5 mks]

QUESTION A7.

Calculate the de Broglie wavelength in nanometers for an electron travelling at a velocity of 1.326 x10^{7} m s^{-1}.

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

$= \frac{6.626 \times 10^{-34}\ J.S}{9.11 \times 10^{-31}\ kg}$

$= \frac{6.626 \times 10^{-34}\ kg.m^2/s^2/s}{(9.11 \times 10^{-31}\ kg)(1.326 \times 10^{7}\ m/s)}$

$= \frac{6.626 \times 10^{-34}\ m}{1.207986 \times 10^{-23}}$

$= 5.4852 \times 10^{-11}\ m$

In nm: $5.4852 \times 10^{-11} \times 10^{9} = 0.054852\ nm$

5

[5 mks]

QUESTION A8.

Determine the allowed orbitals for n=1 and n =2.

n_1	L ($0 : n-1$)		m_L	orbitals
1	0	1s	0	1
2	0	2s	0	1
	1	2p	-1, 0, +1	3

[5 mks]

SECTION B **ANSWER B1 AND ANY TWO QUESTIONS**

QUESTION B1

In experiment 6, a sample of 0.700 g of $FeSO_4.XH_2O$ solution was acidified with sulphuric acid and titrated with a standardized potassium permanganate solution according to the balanced reaction:

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

It required exactly a mean volume of 25.05 mL of 0.02010 M of potassium permanganate solution to reach the end-point.

(a) Explain how the titration was self-indicating in terms of stoichiometric point and end point. **[4 Marks]**

The stoichiometric point is the ~~the~~ initial reading on the burette ~~and~~ filled with sulphuric acid, and while the burette tap is open and the acid is poured into the ~~stotel~~ potassium permanganate, the point at ~~which~~ colour change is observed is the end point.

Stoichiometric point: $n_{MnO_4^-}$ (reacted) $= n_{Mn^{2+}}$ (produced) → $MnSO_4$ colourless

At end point: a faint pink is produced after a few drops.

(b) Calculate the number of moles of Fe^{2+} ions in $FeSO_4.XH_2O$ solution. **[6 Marks]**

n = mass x molar mass

= x ~~55.85~~ g/mol

Molarity = number of moles of solute / volume of solution

$n = M \times V$

$= 0.02010 \text{ mol} \times \left(\frac{25.05}{1000}\right)$

$= 0.0005035$ mol

of MnO_4^-

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mols of $KMnO_4$ = concentration x volume

$= 0.02010 \times \frac{25.05}{1000}$

$= 5.03505 \times 10^{-4}$ mols of $KMnO_4$

$\frac{n_{Fe^{2+}}}{5} = \frac{n_{MnO_4^-}}{1}$

$n_{Fe^{2+}} = 5 \times 5.03505 \times 10^{-4}$ mols

$= 2.517525 \times 10^{-3}$ mols $= 2.518 \times 10^{-3}$ mols of Fe^{2+}

(c) The number of moles of $FeSO_4.XH_2O$ in the conical flask was given by an equation:

$$n_{FeSO_4.XH_2O} \cdot = \frac{0.70\,g}{(151.92 + X18.02)\,g\,mol^{-1}}$$

(i) Calculate the molar mass of the $FeSO_4.XH_2O$. **[6 Marks]**

$n\,feSO_4 \cdot X\,H_2O = \frac{0.70g}{(151.92 + x\,18.02)\,g/mol}$

2.51×10^{-3} mols $= \frac{0.7g}{M.M}$

$Mm = \frac{0.70g}{2.518 \times 10^{-3}\,mols}$

$MM = 278.05\,g/mol$

(ii) Determine water of crystallization. **[4 Marks]**

mass of $feSO_4$ = mols × MM

$= 2.518 \times 10^{-3} \times 151.92g$

$= 0.382534 56g$

$0.7 - 0.3825\,g$ = mass of water

$0.3175g$ = mass of water

$\frac{0.3175g}{x} = \frac{0.7g}{278.05g/mol}$

$x = \frac{126.1155357}{18.02}$

$x = 6.998642381$

$x = 7.00g$

[TOTAL = 20 mks]

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water of crystallisation = 7.00g

QUESTION B2.

When 0.400 g of impure zinc reacted with an excess of hydrochloric acid, 127 mL of hydrogen was collected over water at 10°C. The external pressure was 737.7 torr. The vapor pressure of water at 10°C is 9.21 torr

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) \quad + H_2(l)$$

(a) Calculate the partial pressure of dry hydrogen. **[4 Marks]**

$P_{Total} = P_1 + P_2$

$737.7 = 9.21 + P_H$

$P_H = 737.7 - 9.21$

$P_H = 728.49$ torr

4

(b) What amount (in moles) of H_2 was collected? **[6 Marks]**

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

$P = \frac{728.49 \text{ torr}}{760} = 0.959$ atm

$T = 10°c + 273 = 283K$

$V = 127mL \times \frac{1L}{1000mL} = 0.127L$

$n = \frac{(0.959 \text{ atm})(0.127 L)}{(0.08206 \frac{L \cdot atm}{K \cdot mol})(283K)}$

$n = \frac{0.121793}{23.22298}$

$n = 0.00524$ mol

6

(c) (i) Calculate the number of moles of zinc that reacted with HCl to give hydrogen gas. **[4 Marks]**

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(l)}$

$n = \text{mass} \times \frac{1 mol}{\text{molar mass}}$

$= 0.400g \times \frac{1mol}{65.39g}$

$= 0.00612$ mol

$\frac{n_{Zn}}{1} = \frac{n_{H_2}}{1}$

$n_{Zn} = 5.24 \times 10^{-3}$ mols

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

$\Rightarrow \frac{n_{Zn}}{1} = \frac{n_{H_2}}{1}$

$n_{Zn} = 5.24 \times 10^{-3}$ mols

(ii) Calculate the mass of zinc present in the sample. **[2 Mark]**

mass = number of moles × molar mass
= 0.00524 × 65.39 g/mol
= 0.343 g

(d) What is the percentage purity of the zinc, assuming that all the zinc present reacted completely with HCl and that the impurities did not react with HCl to produce hydrogen? **[4 Marks]**

molar mass of $ZnCl_2$
65.39 + 35.45 = 100.84

$Zn\% = \frac{65.39}{100.84} \times 100 = 64.8\%$

$Cl\% = \frac{35.45}{100.84} \times 100 = 35.2\%$

Percentage purity = $\frac{\text{mass of pure Zn}}{\text{Mass of impure}} \times 100$

% purity ⇒ $\frac{0.343g}{0.400g} \times 100\%$

% purity ⇒ 0.8575 × 100

% purity = 85.75%

% purity = 85.75%

[TOTAL =20 mks]

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QUESTION B3
Tin chloride ($SnCl_2$) is titrated with potassium dichromate according to following reaction:

$$\mathbf{Sn}Cl_2(aq) + K_2\mathbf{Cr}_2O_7(aq) + HCl\ (aq) \rightarrow KCl(aq) + \mathbf{Sn}Cl_4(aq) + \mathbf{Cr}Cl_3(aq) + H_2O(l)$$

(a) Give the oxidation states of the elements in bold in the equation given above.

[4 Marks]

$SnCl_{2(aq)} + K_2Cr_2O_{7(aq)} + HCl_{(aq)} \rightarrow KCl_{(aq)} + SnCl_{4(aq)} + CrCl_{3(aq)} + H_2O_{(l)}$

Sn: +2 ; Cr: +6 ; Sn: +4 ; Cr: +3

(b) Identify the reductant and the oxidant in the reaction. Give reason(s) for your answer.

[3 Marks]

In the reaction Sn loses 2e- and hence its oxidised and is the reducing agent.
While Cr gains 3e- and hence its been reduced and is the oxidising agent

reductant → Sn^{2+} because it has lost 2e- to have an oxidation number +4 in the reactants.

oxidant → Cr_2O_7 because it has gained electrons, thus from Cr with oxidation +6 to Cr with oxidation +3.

(c) Balance the redox reaction. **[8 Marks]**

$\overset{+2}{Sn}\underset{-1}{Cl}_{2(aq)} + \overset{+1}{K}_2\underset{+6}{Cr}_2\underset{-2}{O}_{7(aq)} + \overset{+1}{H}\underset{-1}{Cl}_{(aq)} \rightarrow \overset{+1}{K}\underset{-1}{Cl}_{(aq)} + \overset{+4}{Sn}\underset{-1}{Cl}_{4(aq)} + \overset{+3}{Cr}\underset{-1}{Cl}_{3(aq)} + \underset{+1}{H}_2\overset{-2}{O}_{(l)}$

gains 3e⁻

$Sn^{+2}_{(aq)} + 2Cr^{+6}_{(aq)} \longrightarrow Sn^{+4}_{(aq)} + Cr^{+3}_{(aq)}$

loses 2e⁻

$3Sn^{+2} + 4Cr^{+6}_{(aq)} \longrightarrow 3Sn^{+4}_{(aq)} + 2Cr^{+3}_{(aq)}$

$3SnCl_{2(aq)} + 4K_2Cr_2O_{7(aq)} + 6HCl_{(aq)} \longrightarrow KCl_{(aq)} + 3SnCl_{4(aq)} + 2CrCl_{3(aq)} + 3H_2O_{(l)}$

(d) Calculate the mass of tin chloride in the sample that required 20.00 mL of 0.1000 mol dm^{-3} of potassium dichromate for the titration. **[5 Marks]**

[TOTAL = 20 mks]

QUESTION B4

(a) The ground state 1s orbital, $\Psi_{1s}(r)$, of H has an energy of $-2.18\,x10^{-18}\,J\frac{1}{n^2}$.

(i) How does the energy of H depend on quantum numbers n and l? **[2 Marks]**

(ii) An electron in 1s orbital is excited to 5s orbital energy of H and returns to the ground state. Calculate the transition energy. **[6 Marks]**

(iii) What is the wavelength of the photon emitted in the transition? **[4 Marks]**

(b) Nitrogen has seven electrons in n= 1 and n =2. Complete the table showing n, l, m_l, orbital, and number of electrons in each orbital according to Hund's rule.

[8 Marks]

n	**l**	**m_l**	**Orbital**	**Number of electrons**

[TOTAL = 20 mks]

END OF TEST

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic number **X** Atomic mass Name of the element X

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01 Hydrogen																1 H 1.01 Hydrogen	2 He 4.00 Helium
3 Li 6.94 Lithium	4 Be 9.01 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 23.00 Sodium	12 Mg 24.31 magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.99 Phosphorus	16 S 32.07 Sulphur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 71.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc 97.91 Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Inidum	50 Sn 118.71 Tin	51 Sb 121.76 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
55 Cs 132.91 Caesium	56 Ba 137.33 Barium	57 – 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.84 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Tl 204.38 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po 208.98 Polonium	85 At 209.99 Astatine	86 Rn 222.02 Radon
87 Fr (223.02) Francium	88 Ra 226.03 Radium	89 - 103	104 Unq 261.11	105 Unp 262.11	106 Unh 263.12	107 Uns 262.12	108 Uno 265.00	109 Une 265									

57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm 144.91 Promethium	62 Sm 150.36 Samarium	63 Eu 151.97 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium
89 Ac 227.03 Actinium	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium	93 Np 237.05 Neptunium	94 Pu 244.0 Plutonium	95 Am 243.06 Americium	96 Cm 247.07 Curium	97 Bk 247.07 Berkelium	98 Cf 251.08 Californium	99 Es 252.08 Einstienium	100 Fm 257.10 Fermium	101 Md 260 Mendelevium	102 No 259.10 Nobelium	103 Lr 262.11 Lawrencium