Chemistry II

014

13/11/2015 08.30AM - 11.30AM

REB
Rwanda Education Board

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2015

SUBJECT: CHEMISTRY

PAPER II: THEORY

COMBINATIONS: - BIOLOGY-CHEMISTRY-GEOGRAPHY (BCG)
- MATHEMATICS-CHEMISTRY-BIOLOGY (MCB)
- PHYSICS-CHEMISTRY-BIOLOGY (PCB)
- PHYSICS-CHEMISTRY-MATHEMATICS (PCM)

DURATION: 3 HOURS

INSTRUCTIONS:

1. Write your names and index number on the answer booklet as written on your registration form, and **DO NOT** write your names and index number on additional answer sheets of paper if provided.

2. Do not open this question paper until you are told to do so.

3. This paper consists of two sections: **A** and **B**.
   - **Section A**: Attempt **all** questions. **(70marks)**
   - **Section B**: Attempt any **three** questions. **(30marks)**

4. **You do not need the Periodic Table.**

5. Silent non-programmable calculators may be used.

SECTION A: ATTEMPT ALL QUESTIONS. (70MARKS)

1) The atomic number of element represented by the letter **A** is 33.
   (a) Write the electronic configuration of **A** using s, p, d, f notation. **(1mark)**
   (b) Write the molecular formula of all possible oxides of **A**. **(1mark)**
   (c) (i) State whether each oxide of **A** you have given in (b) is acidic, neutral, basic, or amphoteric. **(1mark)**
   (ii) Write the equation of reaction to illustrate your answer. **(1.5marks)**

2) Two isomers **A** and **B** have the same formula C_7H_{14}. The oxidation of **A** by hot solution of $KMnO_4$ gives ketone $CH_3\text{-}CH_2\text{-}CO\text{-}CH_3$ and carboxylic acid $CH_3\text{-}CH_2\text{-}COOH$.
   The oxidation of **B** gives carboxylic acid $(CH_3)_2CH\text{-}CH_2\text{-}CH_2\text{-}COOH$ and a gas is evolved.
   (a) Find and write the structural formula of **A** and **B**. **(2marks)**
   (b) Name **A** and **B**. **(1mark)**

3) (a) The frequency of hydrogen at the point of ionization is 32.8×10^{14}Hz. Calculate the ionization energy of hydrogen.
   (Planck's constant h= 6.6×10^{-34} Js). **(1mark)**
   (b) Calculate the frequency $\sqrt{}$ of the fourth line of Balmer series; given that $\sqrt{} = RC\left(\frac{1}{n_1} - \frac{1}{n_2}\right)$, R (Rydgberg constant) = $1.09 \times 10^7 m^{-1}$
   and C (speed of electromagnetic waves) = 3×10^8 m.s^{-1} **(3marks)**

4) The mass spectrum of a sample of an atom **A** contains three peaks with mass/charge (m/z) ratios and relative intensities shown below:

m/z	**24**	**25**	**26**
Relative intensity	**1**	**0.127**	**0.139**

   (a) Use the information in the table to calculate the accurate value for the relative atomic mass of A. **(1.5marks)**
   (b) After ionization and before deflection,
   (i) What happens to the ions in a mass spectrometer? **(0.5marks)**
   (ii) How is this achieved? **(0.5marks)**
   (c) What is the function of the electron gun and the magnet in a mass spectrometer? **(1mark)**

5) (a) What is a buffer solution? **(1mark)**
   (b) Calculate the number of moles of CH_3COOH and CH_3COONa that are necessary to prepare a buffer solution with pH = 4.47.
   pKa (CH_3COOH)= 4.75 **(3marks)**

6) (a) The following equation shows the reduction of manganate ions in acidic solution: $MnO_4^- + 8\,H^+ + 5e \longrightarrow Mn^{2+} + 4\,H_2O$
   (i) Write the expression of the redox potential (**E**) of the reaction above. **(1mark)**

(ii) If the concentration of MnO_4^- and Mn^{2+} is 0.1 mole/dm^3 each, and the pH is 6, calculate the redox potential of the reaction.
$E^0_{MnO_4^-/Mn^{2+}} = +1.510$ V. **(2marks)**

(b) Can a 1 M $Fe_2(SO_4)_3$ solution be stored in a container made of nickel metal? Explain your answer. ($E^0_{Fe3+/Fe} = -0.040$V; $E^0_{Ni^{2+}/Ni} = -0.231$V). **(1mark)**

(c) Dentists know that it is not acceptable to put dentures of different metals in the mouth of a patient. Give an explanation for this phenomenon. **(1mark)**

7) (a) Empirical formula of an organic compound **A** is $C_4H_{10}O$.
When **A** is vaporized, 0.1g occupies 54.5 cm^3 at 208^0 C and 98.3kPa.
Determine its molecular formula. **(2.5marks)**
Given that:
Ideal gas law: PV = nRT
P: pressure (Pa: Pascal)
V: volume (m^3)
n: number of moles,
R: constant of ideal gas (R= 8.3 J.K^{-1}.mol^{-1})
T: temperature (in Kelvin)

(b) The organic compound **A** reacts with anhydrous zinc chloride and concentrated hydrochloric acid to give a white precipitate immediately. Write the structural formula of **A** and name it. **(1mark)**

(c) Write a detailed mechanism of the formation of the white precipitate. **2marks)**

8) Hess's Law is used to do some simple enthalpy change calculations involving enthalpy changes of reaction, enthalpy of formation and enthalpy of combustion.
(a) What is enthalpy of formation? **(1mark)**
(b) State Hess's law. **(1mark)**
(c) Using Hess diagram, calculate the standard enthalpy of formation of C_2H_2 given the enthalpy of combustion: carbon (ΔH^0_1 = - 393.5 kJ.mol^{-1}), H_2 (ΔH^0_2 = - 285.8 kJ.mol^{-1}) and C_2H_2 (ΔH^0_3 = - 1.300 kJ.mol^{-1}). **(3marks)**

9) (a) (i) State if the two compounds NH_3 and BF_3 are Lewis acid or Lewis base. **(1mark)**

(ii) Explain your answer in (a) i. above. N (Z = 7), B (Z= 5) **(1mark)**

(b) Explain the VSEPR theory in the formation of the shape of different molecules. **(1mark)**

(c) Write the geometric structure of NH_3 and BF_3 and name their shapes. **(2marks)**

10) The dissociation of sulfuryl chloride $SO_2Cl_2 \rightarrow SO_2 + Cl_2$ is a reaction of first order. At the temperature of 600 K, the constant of the rate of reaction is 1.32×10^{-3} min^{-1}.
(a) Calculate the percentage of SO_2Cl_2 dissociated after 30 minutes of reaction. **(3.5marks)**

(b) Find the time necessary for the dissociation of 90% of SO_2Cl_2 to be complete. **(1.5marks)**

(c) Calculate the half- life of the reaction. **(1mark)**

11) (a) A triglyceride represented by the letter **A** is an ester derived from glycerol and three fatty acids: hexadecanoic acid, octadecanoic acid and 2,4-hexadienoic acid. Write the structure of the triglyceride. **(1mark)**

(b) (i) Write the equation of reaction between the triglyceride above and sodium hydroxide. **(1mark)**

(ii) What is the importance of this reaction? **(0.5marks)**

12) Explain the following observations:

(a) The boiling point of CH_3-CH_2-CH_2-NH_2 **(49°C)** is very greater than the boiling point of $(CH_3)_3N$ **(3°C)** although they have the same molecular mass. **(1mark)**

(b) Acyl chlorides fume when left standing in moist air. **(1mark)**

(c) Diamond is a poor conductor of electricity. **(1mark)**

13) C, Si, Ge, Sn and Pb are elements of group IV in the Periodic Table.

(a) Two of these elements form the chlorides of the type MCl_2. Name them. **(1mark)**

(b) One of the tetrachlorides of group IV elements does not react with water. All others (MCl_4) chlorides are hydrolysed.

(i) Give the formula of the chloride which does not react with water. **(1mark)**

(ii) Write a balanced equation of hydrolysis of chlorides MCl_4. Is the final solution acidic or basic? Give the decreasing order of hydrolysis of these tetrachlorides of group IV elements. **(3marks)**

14) $[Cr(NH_3)_5Cl^{2+}]$ and $[CuCl_4]^{2-}$ are complex ions formed by chromium and copper respectively.

(a) Explain briefly what is meant by the term 'complex ion'. **(1mark)**

(b) Determine:

(i) The oxidation states of chromium and copper in $[Cr(NH_3)_5Cl]^{2+}$ and $[CuCl_4]^{2-}$. **(1mark)**

(ii) The co-ordination number of chromium and copper in these complex ions. **(1mark)**

15) (a) Rubber is a natural polymer whose monomer is 2-methylbuta-1, 3-diene.

(i) Write the structural formula of the monomer of rubber and the structural formula of rubber with 3 monomer units. **(1mark)**

(ii) What is the importance of the vulcanization of rubber? **(1mark)**

(b) There are two types of nylon: nylon 6 and nylon 6/6. Their monomers are H_2N-$(CH_2)_6$-COOH for nylon 6 and HOOC-$(CH_2)_4$-COOH with H_2N-$(CH_2)_6$-NH_2 for nylon 6/6.

(i) Explain why the two polymers are named differently by using the numbers 6 and 6/6. **(1mark)**

(ii) Write the structural formula with 3 monomer units each of the polymers nylon 6 and nylon 6/6. **(1mark)**

16) (a) Write a balanced nuclear equation for each disintegration process.

(i) An unknown element emits γ rays plus particles that are readily blocked by paper. The yield contains also a substantial quantity of tin-104. **(1mark)**

(ii) Bombarding $^{253}_{99}Es$ with an alpha particle produces one neutron plus another transuranium isotope. **(1mark)**

(iii) Carbon-14 is generated on bombardment of nitrogen-14 by a neutron. **(1mark)**

Atomic number Z of some nuclides:

3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl
40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

(b) It has been estimated that carbon-14 isotope in the atmosphere is responsible for producing 60 atoms of nitrogen-14 and 60 electrons every hour for each gram of carbon.
This disintegration rate is 60 counts $hour^{-1}g^{-1}$. A sample of a sea shell was found to have a count rate of 4 counts $hour^{-1}g^{-1}$.
Calculate the age of the shell. **(4marks)**
(The half-life of carbon-14 is 5730 years.)

SECTION B: ATTEMPT ANY <u>THREE</u> QUESTIONS. (30MARKS)

17) (a) The Leclanché dry cell is used in a wide range of appliances such as torches, bicycle lamps, radio... It is composed of a zinc container filled with a thick moist paste of manganese (IV) oxide (MnO_2), zinc chloride ($ZnCl_2$), ammonium chloride (NH_4Cl) and water. A graphite (carbon) rod is embedded in the paste.

(i) State the role of the zinc container and the graphite rod. **(2marks)**

(ii) State the role of the thick moist paste. **(1mark)**

(iii) Write the oxidation and reduction reactions during the discharge of the cell. **(2marks)**

(b) A lead acid accumulator or a lead storage battery is a cell that is connected to appliances to generate electricity. It is used in automobiles. The following are the reactions that occur on the electrodes:

Oxidation: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e$
Reduction: $PbO_2 + 4H^+ + SO_4^{2-} + 2e \rightarrow PbSO_4 + 2H_2O$

(i) Indicate where (on anode or cathode) oxidation and reduction take place; **(1mark)**
(ii) Write the overall redox reaction in the battery. **(2marks)**
(iii) The reaction in (b)(ii) is a reaction that occurs when the battery discharges. Deduce the reaction of the recharging of the battery. **(2marks)**

18) This question refers to the Haber process for the synthesis of ammonia. The equation which represents the reaction is given below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H^o = -92 \text{ kJ mol}^{-1}$

(a) Explain what is meant by the term 'dynamic equilibrium'. **(1mark)**

(b) (i) Write the expression for the equilibrium constant Kp, for the above process. **(1mark)**
(ii) If the pressure is measured in atmospheres, what will be the units of Kp? **(1mark)**

(c) State and explain the effect on the above equilibrium:
(i) Increasing the pressure. **(1mark)**
(ii) Increasing the temperature. **(1mark)**

(d) Name the catalyst used in the Haber process. **(0.5marks)**

(e) (i) Describe the function of a catalyst in terms of energy of activation and use a diagram to illustrate its effect. **(2.5marks)**
(ii) Describe the effect of catalysts on the position of equilibrium and its effect on the concentrations of reacting substances at equilibrium. **(2marks)**

19) (a) Compound **A** ($C_{14}H_{12}$) decolorises an orange solution of bromine water. One mole of **A** can react completely with one mole of hydrogen in the presence of nickel at room temperature. Its oxidation produces an organic compound, benzoic acid only. Indicate all observations made and find the possible structure of **A**. A reaction between bromine and **A**, followed by the action of concentrated sodium hydroxide on the compound formed, gives **B** ($C_{14}H_{10}$). **B** reacts with hydrogen in presence of palladium to form **C** (C_4H_{12}) which is different from **A**. At the end **A**, **B** and **C**, give the same compound **D** ($C_{14}H_{14}$) by hydrogenation in presence of nickel.

(i) With the complementary information above, write the structures of **A**, **B**, **C** and **D**. **(2marks)**

(ii) Name **A**, **B**, **C** and **D**. **(2marks)**

(b) Complete the equations of the reaction below: **(3marks)**

(i) $\xleftarrow{h\sqrt{},\ Cl_2}\ C_6H_5CH_2CH_3\ \xrightarrow{Cl_2,\ [AlCl_3]}$

(ii) $C_6H_5CH_2CH_2CH_3 \xrightarrow{KMnO_4\ conc./heat}$

(c) Outline the detailed mechanism of reaction below: **(3marks)**

$C_6H_5CH_2CH_3 + Cl_2 \xrightarrow{h\sqrt{}}$

20) (a) Draw a Born-Haber cycle and use the following data to obtain the enthalpy change of formation of $CuBr_2$. **(9marks)**

Lattice enthalpy of copper (II) bromide, $CuBr_2$: $\Delta H(LA) = -2763\ kJ\ mol^{-1}$
First ionization energy of copper ($\Delta H\ I_1$)= $+ 746\ kJ\ mol^{-1}$
Second ionization energy of copper ($\Delta H\ I_2$)= $+ 1958\ kJ\ mol^{-1}$
Electron affinity of bromine ($\Delta H\ EA$) = $-324.6\ kJ\ mol^{-1}$
Enthalpy change of atomisation of copper (ΔH atm.)= $+ 338.3\ kJ\ mol^{-1}$
Enthalpy change of atomisation of bromine (ΔH atm.)= $+ 111.9\ kJ\ mol^{-1}$

(b) Define :

(ii) Atomisation enthalpy. **(0.5marks)**

(iii) Lattice enthalpy. **(0.5marks)**

21) To study a titration curve, 10 ml of 1M NaOH solution were titrated with 1M HCl.

(a) Copy and complete the table below: **(6marks)**

Volume of HCl added during titration	**pH of the solution in the titrated solution**
0.00 ml	
2.00 ml	
5.00 ml	
8.00 ml	
9.90 ml	
9.99 ml	
10.00 ml	
10.01 ml	
10.10 ml	
15.00 ml	
18.00 ml	
20.00 ml	

(b) Plot the titration curve (added volume of HCl: x-axis, pH: y-axis). **(3marks)**

(c) The following are indicators with their pH change range.

Indicator	**pH change range**
A	1.2 – 2.8
B	5.8 – 7.8
C	8.3 – 10.0

(i) Which one of these indicators must not be used in the titration of NaOH (strong base) with HCl (strong acid)? **(0.5marks)**

(ii) Explain your choice. **(0.5marks)**