Chemistry II

014

31 Oct. 2014 08.30AM - 11.30AM

REB
Rwanda Education Board

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2014

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. **(70 marks)**
   - **Section B**: Attempt any **three** questions. **(30 marks)**
4. **You do not need the Periodic Table.**
5. Silent non-programmable calculators may be used.

SECTION A: Attempt all questions. (70 marks)

1. Iodine exists as two isotopes : $^{131}_{53}I$ and $^{127}_{53}I$.

   (a) Calculate the neutron and proton numbers in each isotope. ***(2 marks)***

   (b) Why do isotopes of iodine have similar chemical properties? ***(1 mark)***

2. The atomic number of germanium (Ge) is 32.

   (a) Using the s, p, d... notation, write the electronic configuration of germanium (Ge). ***(1 mark)***

   (b) In which group of the Periodic Table is Ge? Give a reason for your answer. ***(2 marks)***

   (c) Write the chemical formula of a compound formed between Ge and fluorine (F). ***(1 mark)***

   (d) Calculate the relative atomic mass of germanium from the percentage abundance of its isotopes :
   Ge-70:20%, Ge-71:27%, Ge-72:8%, Ge-73:37% and Ge-74:8%. ***(2 marks)***

3. When chlorine is dissolved in water, it establishes dynamic equilibrium as shown by the equation below :

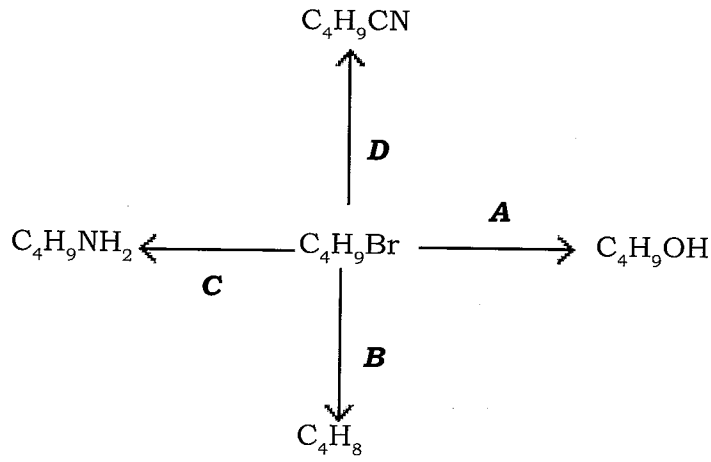
   $$Cl_{2\,(aq)} + H_2O_{\,(l)} \rightleftharpoons HCl_{\,(aq)} + HClO_{\,(aq)}$$

   (a) What is meant by the term 'dynamic equilibrium'? ***(1 mark)***

   (b) Explain how the position of equilibrium in the above reaction is affected by addition of sodium chloride solution. ***(2 marks)***

   (c) The aqueous solution of chlorine in water has a pH of 1.8.
   Calculate the concentration of hydrogen ions ($[H^+]$) in the solution.
   Give your answer to 3 decimal places. ***(2 marks)***

4. The scheme below shows some reactions of the halogenoalkane represented by the formula C_4H_9Br.



(a) State a reagent and conditions for carrying out step ***A***. ***(2 marks)***

(b) Name the type of reaction involved in step ***D***. ***(1 mark)***

(c) State a reagent and conditions for carrying out step ***C***. ***(2 marks)***

(d) What reagent and condition would be used to convert C_4H_9OH to C_4H_8? ***(1 mark)***

5. Two gases reacted to form a gaseous product as shown by the following equation : $2A\ (g) + B\ (g) \rightleftharpoons 2C\ (g)\ \Delta H = -100kJmol\text{-}1$.

(a) Write an expression for the equilibrium constant, K_C, for the above reaction and state its units. ***(2 marks)***

(b) How is the yield of C affected by an increase in temperature? Explain your answer. ***(1 mark)***

(c) 2 mol of gas A were reacted with 1 mol of gas B to form gas C in a closed vessel of a volume of 1 dm^3. After reaching dynamic equilibrium, it was found that 0.6 mol of A remained in the gaseous mixture.

(i) Calculate the number of moles of A that reacted. ***(1 mark)***

(ii) Calculate the number of moles of C that were produced.

Hence calculate the value of the equilibrium constant, K_C, for the reaction. ***(2 marks)***

6. Boron and aluminium show similar chemical properties.

(a) Give the name of the shape of boron trichloride and state its bond angle. ***(2 marks)***

(b) What type of oxide does boron form? ***(1 mark)***

(c) Write a balanced chemical equation for the reaction of aluminium oxide with sodium hydroxide. ***(2 marks)***

7. Hydrides of halogens (Hydrogen halides) show regular patterns in their physical and chemical properties.

(a) State and explain the trend in

(i) Their acid strength ***(2 marks)***

(ii) Their reducing power. ***(2 marks)***

(b) Why does hydrogen fluoride have the highest boiling point among hydrides of halogens? ***(1 mark)***

8. (a) What is meant by the standard enthalpy change of combustion? ***(1 mark)***

(b) Calculate the standard enthalpy change of combustion of

ethanol (C_2H_5OH) from the data below:

$\Delta H_f^{\theta}(C_2H_5OH) = -327\ KJmol^{-1}$

$\Delta H_C^{\theta}(C) = -394\ KJmol^{-1}$

$\Delta H_C^{\theta}(H_2) = -286\ KJmol^{-1}$ **(2 marks)**

(c) Calculate the enthalpy change of the reaction from the bond enthalpies given below :

$$C_3H_{8\,(g)} + Cl_{2\,(g)} \rightarrow C_3H_7Cl_{(g)} + HCl_{(g)}$$

Bond enthalpies in $KJmol^{-1}$:

C – H = 413

C – Cl = 346

H – Cl = 432

Cl – Cl = 243 **(2 marks)**

9. Three alcohols A, B and C of molecular formula $C_4H_{10}O$ were separately heated with acidified $K_2Cr_2O_7$ (potassium dichromate).

Alcohol C did not undergo any change while A and B did. Alcohol A produced compound D which reacted further to form compound E.

Alcohol B reacted to form compound F. Compound F did not react with Fehling's solution but reacted with 2,4-dinitrophenylhydrazine.

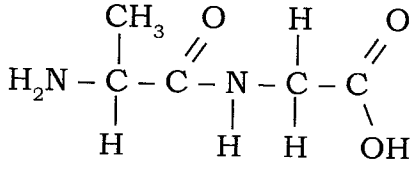
(a) Suggest a structural formula of C and give a reason for your answer. **(2 marks)**

(b) Give the structural formulae of compounds D and F. **(2 marks)**

(c) Give the structural formulae of alcohols A and B. **(2 marks)**

10. (a) Describe a chemical test that is used to distinguish between reducing sugars and non-reducing sugars. State the reagent, conditions and expected observations. **(2 marks)**

(b) A dipeptide has the structure



(i) What reagent and condition would use to hydrolyse the dipeptide? **(2 marks)**

(ii) Write the structural formulae of two amino acids obtained by hydrolysing the dipeptide. **(2 marks)**

11. (a) What reagent would be used to prepare pentanoyl chloride ($CH_3CH_2CH_2CH_2COCl$) from pentanoic acid? **(1 mark)**

(b) Give the structural formulae of the organic products formed when pentanoyl chloride is reacted with

(i) Ammonia

(ii) Ethanol

(iii) Methylamine. **(3 marks)**

12. A buffer solution contains 0.2 mol dm^{-3} propanoic acid and 0.5 mol dm^{-3} sodium propanoate.

(a) What is meant by the term 'buffer solution'? **(1 mark)**

(b) Calculate the pH of the buffer solution (Ka of propanoic acid=1.35×10^{-5} mol dm^{-3}). **(2 marks)**

(c) Using a relevant equation, explain how the buffer solution reacts when a small amount of hydrochloric acid is added. **(1 mark)**

13. Benzene reacts with chloromethane in the presence of aluminium chloride to form organic compound ***B***. ***B*** reacts with chlorine gas in the presence of UV light to form organic compound **C**.

(a) Using equations and appropriate symbols, describe the mechanism of the reaction between benzene and chloromethane in the presence of $AlCl_3$. **(3 marks)**

(b) Write the structural formula of compound **C**. **(1 mark)**

(c) What is the role of UV light in the reaction of compound ***B*** with chlorine? **(1 mark)**

14. (a) A thorium atom $^{231}_{90}Th$ decays by emitting a beta particle to form an isotope of protactinium (Pa) whereas a uranium atom $^{238}_{92}U$ disintegrates by emission of an alpha particle to form an isotope of thorium atom. Write balanced nuclear reactions showing the disintegration of thorium and uranium respectively. **(2 marks)**

(b) If the radioactive nickel-63 has a half-life of 100.1 years and decays to copper-63, how long will it take for three-quarters of the Ni-63 to change to copper (Cu-63)? **(2 marks)**

SECTION B : Attempt any THREE questions. (30 marks)

15. An impure sample of ammonium iron (II) sulphate crystals ($(NH_4)_2SO_4.FeSO_4.6H_2O$) was analysed to determine the percentage by mass of Fe^{2+} in it. 1.5 g of the sample were dissolved in dilute sulphuric acid and the solution made up to 30 cm^3 with distilled water.

The resulting solution was titrated with 0.02 $moldm^{-3}$ $KMnO_4$. 25.0 cm^3 of $KMnO_4$ were required to react completely with Fe^{2+}.

(a) Calculate the theoretical percentage by mass in pure ammonium iron (II) sulphate crystals based on the chemical formula given (N=14, H=1, S=32, O=16, Fe=56). ***(2 marks)***

(b) Use the half-equations below to write a balanced equation for the REDOX reaction between Fe^{2+} and acidified MnO_4^- :

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ ***(2 marks)***

(c) Calculate the number of moles of MnO_4^- in 25.0 cm^3 of the solution of $KMnO_4$. ***(1 mark)***

(d) Hence deduce the number of moles and mass of Fe^{2+} in 30 cm^3 of the solution containing the sample (Fe=56). ***(2 marks)***

(e) Calculate the percentage of Fe in the sample of 1.5g. ***(1 mark)***

(f) Give the electronic configuration of Fe^{2+} and Fe^{3+} and explain which of the two ions is more stable. ***(2 marks)***

16. The manufacture of ammonia in the Haber process is a key industry that is linked to other useful chemicals.

(a) Write a balanced equation for the reaction that occurs in the Haber process and state the conditions of temperature, pressure and catalyst used. ***(3 marks)***

(b) Using the principles of equilibrium kinetics and cost, justify the conditions used in (a) above. ***(2 marks)***

(c) With the help of balanced equations, outline the steps involved in the manufacture of nitric acid from ammonia. ***(3 marks)***

(d) What colour change would you observe if a mixture of dinitrogen tetroxide and nitrogen dioxide is subjected to higher pressure?

Explain your answer.

$$N_2O_{4\,(g)} \rightleftharpoons 2NO_{2\,(g)}$$

Light brown Dark brown **(2 marks)**

17. (a) Briefly explain why a catalyst increases the rate of a chemical reaction. **(2 marks)**

(b) What is a homogeneous catalyst? Why do transition metal ions often act as homogeneous catalysts? **(2 marks)**

(c) A reaction between X and Y was investigated in order to determine its rate equation. The results below were obtained:

Experiment Number	[X] (mol dm^{-3})	[Y] (mol dm^{-3}]	Initial Rate (mol $dm^{-3}s^{-1}$)
1	0.5	1.0	2
2	0.5	2.0	8
3	0.5	3.0	18
4	1.0	3.0	36
5	2.0	3.0	72

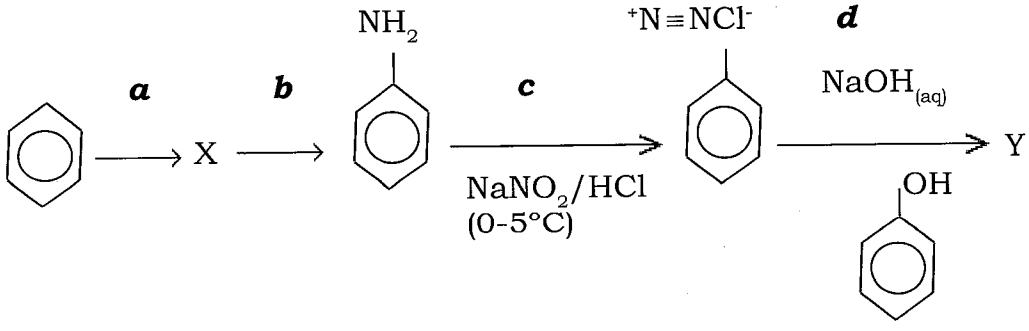
(i) Deduce the order of reaction with respect to X and Y. Explain your reasoning. **(2 marks)**

(ii) Write the rate equation or rate expression for the reaction. **(1 mark)**

(iii) Calculate a value for the rate constant and give its units. **(2 marks)**

(d) How does the rate of a zero order reaction change with concentration? **(1 mark)**

18. (a) An azo dye (diazo dye) was synthesized from benzene as shown in the reaction scheme below :



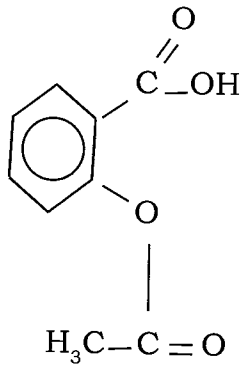
(i) Write the structural formula of compound X. **(1 mark)**

(ii) What reagents and conditions are used in step (***a***)? **(2 marks)**

(iii) What reagents are used in step (*b*)? ***(2 marks)***

(iv) Write the structural formula of azo dye Y. ***(1 mark)***

(b) The structural formula of a medicine called "aspirin" is shown below:



(i) State the names of two functional groups present in "aspirin". ***(2 marks)***

(ii) Give the structural formulae of the products formed when "aspirin" is warmed with excess aqueous sodium hydroxide. ***(2 marks)***

19. (a) Distinguish between a strong electrolyte and a weak electrolyte. ***(1 mark)***

(b) State and explain how the molar conductivity of a weak electrolyte changes with dilution. ***(2 marks)***

(c) An electrochemical cell (voltaic cell) was set up using two electrode systems shown below:

$$Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(S)}\ ,\ E^\theta = -0.45\ V$$

$$Mn^{2+}_{(aq)} + 2e^- \rightleftharpoons Mn_{(S)}\ ,\ E^\theta = -1.19\ V$$

(i) Draw a labelled diagram to show the cell set up. On your diagram show with an arrow the direction of electron flow. ***(3 marks)***

(ii) Calculate the cell e.m.f. (cell voltage) and write a balanced equation for the cell reaction that occurs. ***(2 marks)***

(d) A current of 5.00A was passed through an aqueous solution of copper (II) sulphate for 40 minutes. Calculate the mass of copper deposited on the cathode during electrolysis.

(Faraday constant, F = 96,500 C mol^{-1}; Cu = 63.5) ***(2 marks)***