Rwanda National Chemistry II S6 Collection (2003 - 2023)

BIOLOGY-CHEMISTRY-GEOGRAPHY (BCG)

- MATHEMATICS-CHEMISTRY-BIOLOGY (MCB)

- PHYSICS-CHEMISTRY-BIOLOGY (PCB)

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Chemistry II

014

28/07/2023 08:30 AM – 11:30 AM

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2022-2023

SUBJECT: CHEMISTRY II

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 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.
6) Use a **blue** or **black** pen for answering and a **pencil** for drawing.

SECTION A: ATTEMPT ALL QUESTIONS (70 marks)

1) Hydrocarbons constitute a major group of organic compounds and they are classified into three main classes: aliphatic, alicyclic and aromatic compounds.

a) Define the term "aliphatic hydrocarbon". **(1 mark)**

b) Name the remarkable property of carbon atoms to bond amongst themselves and allow hydrocarbons to form long chain molecules. **(1 mark)**

c) State which one among the four organic compounds below is an unsaturated alicyclic hydrocarbon. **(1 mark)**

A. Cyclohexene C. Benzene

B. n-hexane D. Cyclohexane

2) Sodium (Na), aluminium (Al) and phosphorus (P) are members of the third period of the Periodic Table and their atomic numbers are 11, 13 and 15, respectively.

a) Write down the formulae of the possible chlorides formed by each of **Na**, **Al** and **P**. **(2 marks)**

b) Two among the chlorides in (a) above, do not conduct electricity neither in molten state nor in aqueous solution. Mention the two chlorides. **(1 mark)**

c) One among the chlorides in (a) above, when dissolved in water, it gives a solution of pH = 7. Which one is that? **(1 mark)**

3) One of the characteristics of transition metals is to form complexes. Given two complexes **A** and **B** of cobalt, **A**= $[Co(NH_3)_5Br]SO_4$ and **B**=$[Co(NH_3)_5SO_4]Br$.

a) Give the systematic IUPAC name of **A**. **(1 mark)**

b) Show the ions released when **B** is in solution. **(1 mark)**

c) Suggest the reagent and expected observable change to describe a chemical test which could be used to distinguish between **A** and **B**. **(2 marks)**

4) At 25^0C the molar solubility of chromium (III) hydroxide, $Cr(OH)_{3(s)}$, is 2.47×10^{-9} mol dm^{-3}.

a) Write the equilibrium dissociation equation for $Cr(OH)_{3(s)}$. **(1 mark)**

b) Give the expression of Ksp for the dissociation equation of $Cr(OH)_{3(s)}$. **(1 mark)**

c) Calculate the solubility product constant, Ksp of $Cr(OH)_{3(s)}$ at 25^0C and show its units. **(2 marks)**

5) Consider the following enthalpy changes of reactions (**1**), (**2**), (**3**) and (**4**):

(1) $2C_{(s)} + 2H_{2(g)} + O_{2(g)} \rightarrow CH_3COOH_{(l)}$ $\Delta H_1 = -487$ kJ/mol

(2) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H_2 = -393$ kJ/mol

(3) $H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H_3 = -285.6$ kJ/mol

(4) $CH_3COOH_{(l)} + 2O_{2(g)} \rightarrow 2H_2O_{(l)} + 2CO_{2(g)}$ $\Delta H_4 = ?$

a) In terms of energy conservation, explain why using firewood is better than using charcoal in domestic kitchens while cooking food. **(1 mark)**

b) Find out the enthalpy change, ΔH_4 for the reaction (4), by using the reaction equations (1), (2) and (3), as provided above. **(4 marks)**

6) Propan-1-ol is an alcohol and can be converted into an alkene **A.**

a) Give the name of the alkene **A**. **(1 mark)**

b) State the necessary conditions for this reaction. **(2 marks)**

c) Write the equation of the reaction that takes place. **(2 marks)**

7) The geometry of molecules is governed by a theory called VSEPR.

a) Write VSEPR in full words. **(1 mark)**

b) Draw the shapes and state the name of shape for each of the following molecules (consider the VSEPR theory). **(4 marks)**

i) F_2O

ii) $COCl_2$ (Atomic numbers: F = 9, O=8, C=6, Cl=17)

8) Carbon-14 (C-14) is a radioactive atom and has a half-life of 5,730 years.

a) Explain the term "half-life" of a radioisotope. **(1 mark)**

b) Carbon-14 emits beta particles (beta minus) to form an element **Y**. Write the radiochemical equation for this process. (Atomic number, C=6). **(2 marks)**

c) State any two health hazards which are caused by radioactive substances. **(2 marks)**

9) Figure 1 below shows the variation in first electron affinity (kJ/mol) for s- and p-block elements in the Periodic Table. Observe and answer the related questions.

1							18
H −73	2	13	14	15	16	17	He > 0
Li −60	Be > 0	B −27	C −122	N > 0	O −141	F −328	Ne > 0
Na −53	Mg > 0	Al −43	Si −134	P −72	S −200	Cl −349	Ar > 0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr > 0
Rb −7	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe > 0

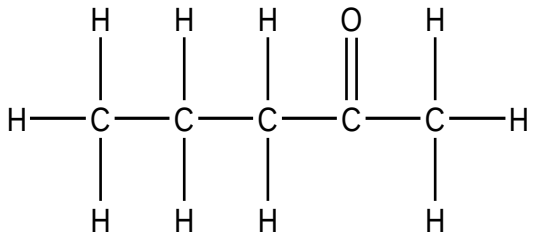
Figure 1

a) Define the term "first electron affinity". **(1 mark)**

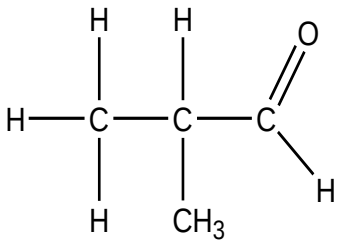
b) State and explain the general trend in variation of first electron affinity across the period and down the group of the Periodic Table. **(2 marks)**

c) Suggest a reason why the electron affinities of Group 14 elements (C, Si, Ge, Sn), are more negative than those of the Group 15 elements (N, P, As, Sb). **(2 marks)**

10) Study the structural formulae of the following organic compounds and answer the questions that follow.



Compound X

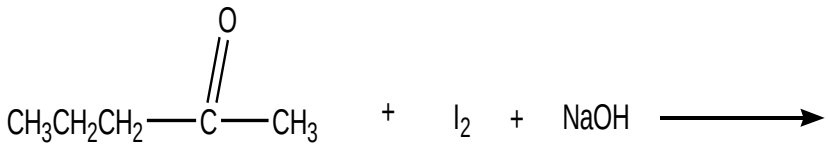


Compound Y

a) Give the systematic IUPAC name of compound **X** shown above. **(1 mark)**

b) **Y** can be converted into a new product **Z** by using PCl_5 or $SOCl_2$ as reagent. Give the structural formula of **Z** as well as the possible by-product(s). **(2 marks)**

c) Complete the chemical equation given below by writing the structural formulae of all organic products and molecular formulae of inorganic products. **(2 marks)**



11) Some substances, when added to solvents, produce solutions with colligative properties.

a) Choose a correct option about colligative properties.

Colligative properties are observed when: **(1 mark)**

i) a non-volatile solid or liquid is dissolved in a non-volatile liquid:

ii) a gas is dissolved in a non-volatile liquid;

iii) a non-volatile solid or liquid is dissolved in a volatile liquid;

iv) a volatile liquid is dissolved in an another volatile liquid.

b) An automotive antifreeze consists of ethylene glycol, $CH_2(OH)CH_2(OH)$, a non-volatile non-electrolyte solute. A driver adds 1.00 kg of ethylene glycol to 4450 g of water in his car's radiator. Given that the boiling point of pure water is100^oC and the boiling point elevation constant, K_b of water is 0.512 °C/m. Determine the boiling point of the solution in the radiator. (Atomic mass: C =12, O=16, H=1). **(4 marks)**

12) P3HB stands for poly(3-hydroxybutanoate) or poly(3-hydroxybutyrate). It is a biodegradable polymer which has a trade name of Biopol®.

a) Write the structural formula of 3-hydroxybutanoic acid. **(1 mark)**

b) The —CO_2H group of one molecule of 3-hydroxybutanoic acid links with the —OH group of a second molecule of 3-hydroxybutanoic acid. Write the structural formula of the resulting compound. **(1 mark)**

c) Write the repeating unit in a long chain of poly(3-hydroxybutanoate). **(1 mark)**

d) State the class of polymers to which poly (3-hydroxybutanoate) belongs. **(1 mark)**

e) State any one application of biodegradable polymers. **(1 mark)**

13) When 2.00 mol of SO_2Cl_2 were placed in a 5.00-L flask at 310 K, 40% of the SO_2Cl_2 decomposed to SO_2 and Cl_2 according to the following equilibrium:

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$$

a) Express the Kc for the above equation. **(1 mark)**

b) Calculate Kc for this reaction at 310 K and show its units. **(3 marks)**

c) State how the position of equilibrium will shift if the volume of the flask is reduced to 1.00-L. **(1 mark)**

14) Figure 2 below shows the variation of molar conductivity, Λ/Sm^2mol^{-1}, with dilution, $\frac{1}{c}$ (m^3 mol^{-1}).

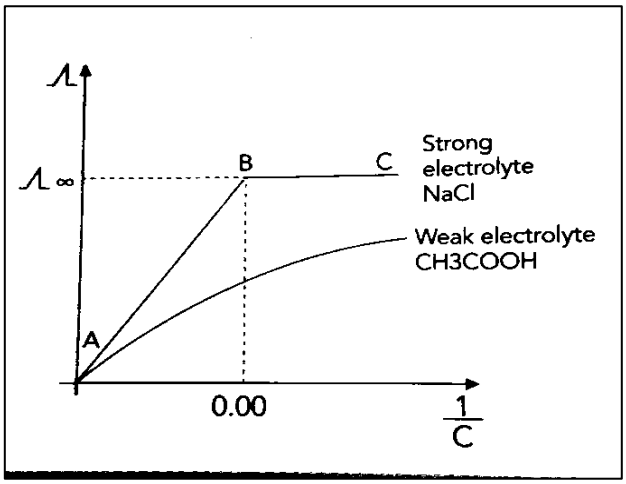


Figure 2

a) Explain the trend of the portions **AB** and **BC** on the curve of NaCl. **(3 marks)**

b) Suggest a reason why the curve of CH_3COOH does not contain a point similar to the point **B** found on the curve of NaCl. **(2 marks)**

15) Given the following overall cell notation between zinc and iron.

$Zn(s) / Zn^{2+}(aq)$ (1.0M) // $Fe^{2+}(aq)$ (1.0M) / Fe(s)

	$E^{\emptyset}/V$
$Zn^{2+} + 2e- = Zn$	-0.76
$Fe^{2+} + 2e^{-} = Fe$	-0.44

a) Write the overall redox reaction equation between zinc and iron. **(2 marks)**

b) Calculate the e.m.f of the cell. **(2 marks)**

c) Give a reason why zinc is suitable to protect iron against corrosion. **(1 mark)**

SECTION B: ATTEMPT ANY THREE QUESTIONS (30 marks)

16) An electron in a given orbital is described by a set of numbers called quantum numbers. An atom of element **X** has its outermost electron which is defined by four (4) quantum numbers below.

n=3, ℓ=1, $\boldsymbol{m_\ell}$ = -1 and $\boldsymbol{m_s}$= -1/2

a) Define the term "quantum numbers". **(1 mark)**

b) Use information provided and write the electron configuration of **X** in terms of s, p, d, f notation. **(4 marks)**

c) How many total electrons does **X** contain? **(1 mark)**

d) State the group, period and block of **X**. **(3 marks)**

e) Use a reaction equation to show the compound formed between **X** and hydrogen.(Atomic number: H=1) **(1 mark)**

17) The science and technology of metals extraction from their respective ores and preparing them for daily uses involves different techniques. Some of these techniques are pyrometallurgy, hydrometallurgy and electrometallurgy.

a) Explain the term "hydrometallurgy". **(1 mark)**

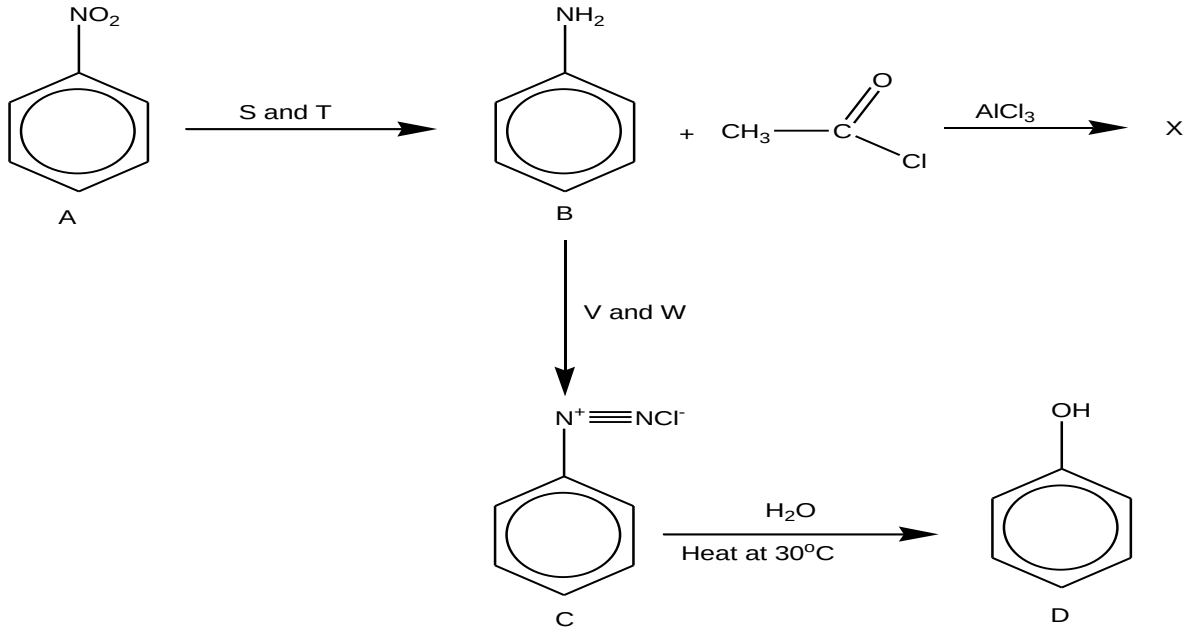
b) Iron (III) oxide was found to be contaminated with copper (II) sulphate. Describe how a sample of iron (III) oxide, free of copper (II) sulphate, can be obtained. **(2 marks)**

c) The mining industry often reports the concentration of a metal in an ore in terms of the amount of oxide formed by that metal. Naturally, this figure does not represent the actual amount of metal present. If a rock ore sample is analyzed as containing 1% by mass of Fe_2O_3, what is the percentage by mass of iron in the rock? (Fe=56; O=16). **(3 marks)**

d) State two disadvantages (one economical and one environment related) of pyrometallurgy. **(2 marks)**

e) A metal **M** is more reactive than hydrogen, higher in electromechanical series than hydrogen and therefore can reduce hydrogen. Predict which technique among pyrometallurgy, hydrometallurgy and electrometallugy is more suitable to extract **M** from its molten chloride ore $\mathbf{MCl_x}$ (where x is the number of chlorides combined to **M**). Support your answer. **(2 marks)**

18) The diagram below illustrates some benzene derivatives. Study it and answer the questions that follow.



a) Give the names and chemical formulae of reagents **S** and **T** which are required to transform **A** to **B**. **(2 marks)**

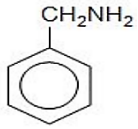
b) Draw the structure of the major product **X**. **(1 mark)**

c) Write the structure of another major product **P** (not shown in the diagram), formed when **B** reacts with CH_3-COCl in presence of excess strong base. **(1 mark)**

d) Write the names or chemical formulae of reagents **V** and **W**. **(2 marks)**

e) Suggest the IUPAC name for the organic compound **D**. **(1 mark)**

f) Describe a chemical test which could be used to distinguish between the organic compound **B** and phenylmethylamine. In your description include the reagent, condition and expected observable change. **(3 marks)**



= Phenylmethylamine

19) The acid-base theory has been successively formulated by different scientists.

a) What is meant by 'acid' and 'base' according to Svante Arrhenius and which limitation is shown by this theory? **(2 marks)**

b) Determine the colour of phenolphthalein in a solution of sodium hydroxide, NaOH 0.02M, given that the pH range of phenolphthalein is 8.2-10.0: colourless-red. **(2 marks)**

c) A hypothetical weak acid, **HA**, was combined with NaOH in the following proportions: 0.20 mol of HA and 0.080 mol of NaOH. The mixture was diluted to a total volume of 1.0L, and the pH measured. If pH =4.80, find out the pKa of HA. **(3 marks)**

d) Equal volumes of two different acids were titrated with 0.10M NaOH resulting into two titration curves **X** and **Y** shown in the Figure 3.

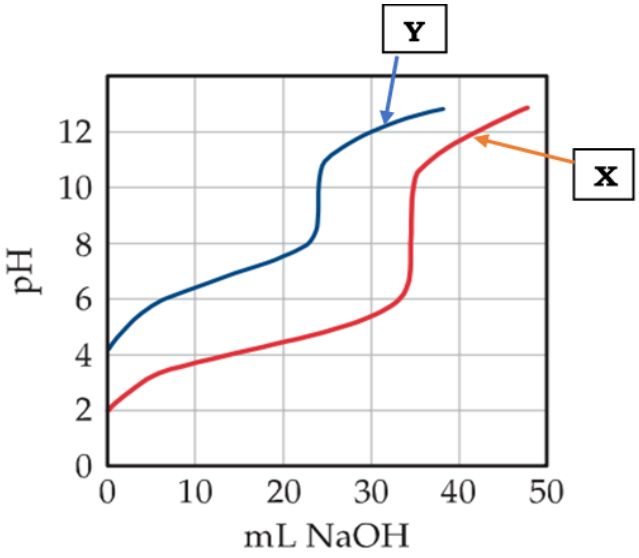


Figure 3

(i) Which curve corresponds to a more concentrated acid solution? Explain. **(1.5 marks)**

(ii) Which curve corresponds to an acid with the largest Ka? Explain. **(1.5 marks)**

20) The table below contains the values of initial rates measured for the reaction: $2X + Y \rightarrow Z + W$

Experiments	[X]/mol dm^{-3}	[Y]/mol dm^{-3}	Initial rate/mol dm^{-3} min^{-1}
1	0.150	0.25	$1.4x10^{-5}$
2	0.150	0.50	$5.6x10^{-5}$
3	0.075	0.50	$2.8x10^{-5}$
4	0.075	0.25	$7.0x10^{-6}$

a) Find the order with respect to **X** and the order with respect to **Y**. **(4 marks)**

b) Determine the overall order of the reaction. **(1 mark)**

c) Write the rate expression. **(1 mark)**

d) A catalyst speeds up a reaction rate by lowering the activation energy. Sketch a graph of potential energy as a function of reaction progress for the reaction: $A + BC \rightarrow AC + B$**,** to show the energy profiles for both uncatalyzed and catalyzed reactions. The graph must present elements like: reactants and products, activated complex ABC*, path of uncatalyzed reaction, path of catalyzed reaction, activation energy (E_A) of uncatalyzed reaction and activation energy (E_A**'**) of catalyzed reaction. **(4 marks)**

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Chemistry II

014

29/07/2022 8:30 AM-11:30AM

NESA NATIONAL EXAMINATION AND SCHOOL INSPECTION AUTHORITY

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2021-2022

SUBJECT: CHEMISTRY II

PAPER II: THEORY

COMBINATIONS:

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4) You do not need the periodic table.
5) Silent non-programmable calculators may be used.
6) Use a **blue** or **black** pen for answering and a **pencil** for drawing.

SECTION A: ATTEMPT ALL QUESTIONS (70 marks)

1) a) What is an amphoteric compound? **(1 mark)**

b) Which one of the following chemical species H_2S, HS^- and S^{2-} has an amphoteric character? **(1 mark)**

c) Write a balanced chemical equation of a reaction between that amphoteric compound and water to explain your answer in (b) above. **(2 marks)**

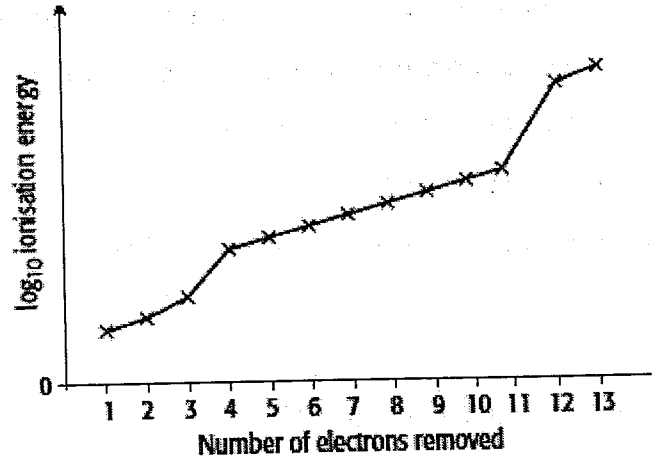
2) Read the text and use the list of words given below to fill in the blank spaces. Each word should be used once:

Vaporization chamber, mass spectrum, velocity, ionization, deflection, detector, acceleration.

A sample of the element is placed in the _____ where it is converted into gaseous atoms. The gaseous atoms are ionized by bombardment of high energy electrons emitted by a hot cathode to become positive ions (in practice, the voltage in the _____chamber is set in such a way that only one electron is removed from each atom). The positive ions (with different masses) are then given a high and constant _____by two negatively charged plates: the process is called_____. The positive ions are then deflected by the magnetic field. This process is called _____ (ions with smaller mass will be deflected more than the heavier ones). These ions are then detected by the ion _____. The information is fed into a computer which prints out the_____ of the element.

(3.5 marks)

3) The sketch graph below shows 13 successive ionization energies of Aluminium.



a) Define the term 1st ionisation energy of an element. **(2 marks)**

b) How does the graph provide evidence for the existence of three electron shells in an Aluminium atom? **(4 marks)**

c) Write an equation, including state symbols, to represent the 2nd ionization energy of Aluminium. **(1 mark)**

d) Write the electronic configuration of an Aluminium ion. **(1 mark)**

4) Chromium belongs to the transition metal elements in the periodic table. State five properties of the transition metal elements. **(5 marks)**

5) Nitrogen and phosphorous are the first two elements in group 15 of the periodic table. Their hydrides are ammonia (NH_3) and phosphine (PH_3).

a) Draw a diagram of an ammonia molecule showing its shape. Show the bond angles. *(Atomic Number: N =7), H=1)* **(1 mark)**

b) The boiling point of NH_3 and PH_3 are -33^{0}C and -88^{0}C respectively. Suggest the reasons for this difference in boiling points. **(2 marks)**

c) Explain why ammonia is a polar molecule. **(2 marks)**

6) An isotope of an element Uranium $^{235}_{92}U$,emits successively seven alpha particles and four beta particles to form a stable isotope of another element **X**.

Deduce:

a) The mass number of **X** **(2 marks)**

b) The atomic number of **X** **(2 marks)**

c) Identify **X** (Chose among $^{207}_{82}Pb$, $^{209}_{84}Po$, $^{204}_{81}Tl$) **(1 mark)**

7) The burning of fossil fuels can produce atmospheric pollutants.

a) The combustion of petrol in an internal combustion engine can lead to the formation of carbon monoxide, CO, and nitrogen monoxide, NO.

i) Write a chemical equation for the incomplete combustion of octane, C_8H_{18}, to produce CO and water only. **(2 marks)**

ii) Write a chemical equation for the formation of Nitrogen Oxide (NO) in an engine. **(2 marks)**

b) Some new petrol-engined cars are fitted with a catalytic converter.

i) Name one of the metals used as a catalyst in a catalytic converter. **(1 mark)**

ii) Write a chemical equation to show how CO and NO react with each other in a catalytic converter (the way to eliminate the two pollutants). **(2 marks)**

c) State why sulphur dioxide gas is sometimes found in the exhaust gases of petrol-engined cars. **(1 mark)**

d) Give one adverse effect of sulphur dioxide on the environment. **(1 mark)**

8) A complex is made of Co(III) and consists of four NH_3 molecules and two chloride ions as ligands.

a) Calculate the charge number of the whole complex ion. **(1 mark)**

b) Write the formula of the complex ion. **(2 marks)**

c) Name the above complex ion using IUPAC. **(1 mark)**

d) What is the coordination number of the metal ion in such a complex ion? **(1 mark)**

9) a) Give the electron structure of Copper (Z=29) using s,p,d,f,... notations. **(1 mark)**

b) Explain why Cu^{2+} is coloured and Cu^{+} is not coloured. **(2 marks)**

10) Explain the following statements:

a) Sodium Chloride in solid state does not conduct electricity. **(2 marks)**

b) Ionic compounds have high boiling and melting points. **(2 marks)**

11) Agricultural lime is manufactured from limestone (calcium carbonate) in two stages. Limestone is heated strongly in a limekiln (in which limestone is burnt). The product (quicklime or burnt lime) is cooled and a calculated amount of water is added. The highly exothermic reaction yields a white powder called slaked lime.

a) Write balanced chemical equations for the two stages (production of quicklime and slaked lime) showing state symbols. **(2 marks)**

b) Give one reason why slaked lime is used by farmers in agriculture. **(1 mark)**

c) How may the manufacture of burnt lime have an effect on the environment? Give 2 reasons. **(2 marks)**

d) What is the mass of limestone required to produce 280g of quicklime? (Ca=40,H=1,O=16,C=12) **(2 marks)**

12) The resistance of a 0.01M NH_4OH solution was found to be 3000 ohms in a conductivity cell of cell constant of 0.345 cm^{-1}. Given that the ionic conductance of ammonium ions (NH_4^+) and hydroxide ions (OH^-) are $73.4\ S\ cm^2mol^{-1}$ and $197.6\ S\ cm^2mol^{-1}$ respectively. Calculate:

a) The conductivity of NH_4OH. **(2 marks)**

b) The degree of dissociation NH_4OH. **(2 marks)**

13) a) Arrange the following carboxylic acids in order of increasing acid strength.

i) CH_2Cl-COOH,
ii) CH_3COOH,
iii) CH_2FCOOH **(1.5 marks)**

b) Name two compounds that are required to make soap. **(1 mark)**

14) Calculate the pH of a solution made by mixing 10 ml of 0.1M HCl and 10.1ml of 0.1M NaOH **(5 marks)**

SECTION B: ATTEMPT ANY THREE QUESTIONS. (30marks)

15) Benzoic acid, C_6H_5COOH, is a weak monoacid. ($K_a = 6.4 \times 10^{-5}$)

a) Explain how a mixture of benzoic acid and sodium benzoate can act as a buffer solution on the addition of small amounts of either HCl (aq) or NaOH (aq). **(3 marks)**

b) What is the $[H^+]$ in 0.02 $mol.dm^{-3}$ benzoic acid? **(2.5 marks)**

c) What is the pH of 0.02 $mol.dm^{-3}$ benzoic acid? **(1 mark)**

d) What is the pH of a solution containing 0.05 $mol.dm^{-3}$ of sodium benzoate in 1 dm^3 of 0.02 $mol.dm^{-3}$ benzoic acid? **(3.5 marks)**

(C: 12, H: 1, O: 16, Na: 23)

16) The two compounds **V** and **W** are isomers with the molecular formula C_4H_8O, and show the following properties and reactions:
Both compounds react with sodium metal, and both decolorize bromine water. Compound **V** forms a yellow precipitate with alkaline aqueous iodine, whereas compound **W** does not. When reacted with cold $KMnO_4$(aq), both **V** and **W** produce the same neutral compound **X**, $C_4H_{10}O_3$.
Both **V** and **W** exist as pairs of stereoisomers.

a) Suggest which functional groups are responsible for the reactions with:
i) Sodium. **(1mark)**
ii) Bromine water. **(1mark)**
iii) Alkaline aqueous iodine. **(1mark)**

b) Suggest structures for **V** and **W**. **(2 marks)**

c) State the type of stereoisomerism shown by compound **V** and draw the structures of the stereoisomers. **(3 marks)**

d) Suggest the structure of the neutral compound **X**. **(2 marks)**

17) Consider the equilibrium: $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$

a) i) One mole of dinitrogen tetroxide, N_2O_4 was introduced into a vessel of volume 10.0 dm^3 at a temperature of 80°C. At equilibrium, 60% had dissociated. Calculate Kc. **(3 marks)**

ii) Using the following data, calculate the enthalpy change for the forward reaction. **(2 marks)**

	H_f^0 (kJ. mol^{-1})
N_2O_4	+9.70
NO_2	+33.90

iii) If the same experiment is carried out at 100°C, state qualitatively, giving your reasons, how the equilibrium composition will change. **(2 marks)**

b) What is the effect of a catalyst on the following?

i) The value of K_c. **(1 mark)**

ii) The equilibrium position. **(1 mark)**

iii) The rate of attainment of equilibrium. **(1 mark)**

18) For each of the following pairs of isomers, suggest a test that will distinguish between the two compounds. **(10 marks)**

a) $CH_3CH_2CH_2CHO$ and $CH_3CH_2COCH_3$

b) $(CH_3)_3COH$ and $(CH_3)_2CHCH_2OH$

c) $CH_2{=}CHCH_2OH$ and CH_3CH_2CHO

19) The list below gives the standard electrode potentials for five half-reactions.

$Cu^{2+}(aq) + e^- \longrightarrow Cu(s)$ $\quad E = +0.34$ V

$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$ $\quad E = -0.44$ V

$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$ $\quad E = +0.77$ V

$I_2(aq) + 2e^- \longrightarrow 2I^-_{(aq)}$ $\quad E = +0.54$ V

$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$ $\quad E = -0.76$ V

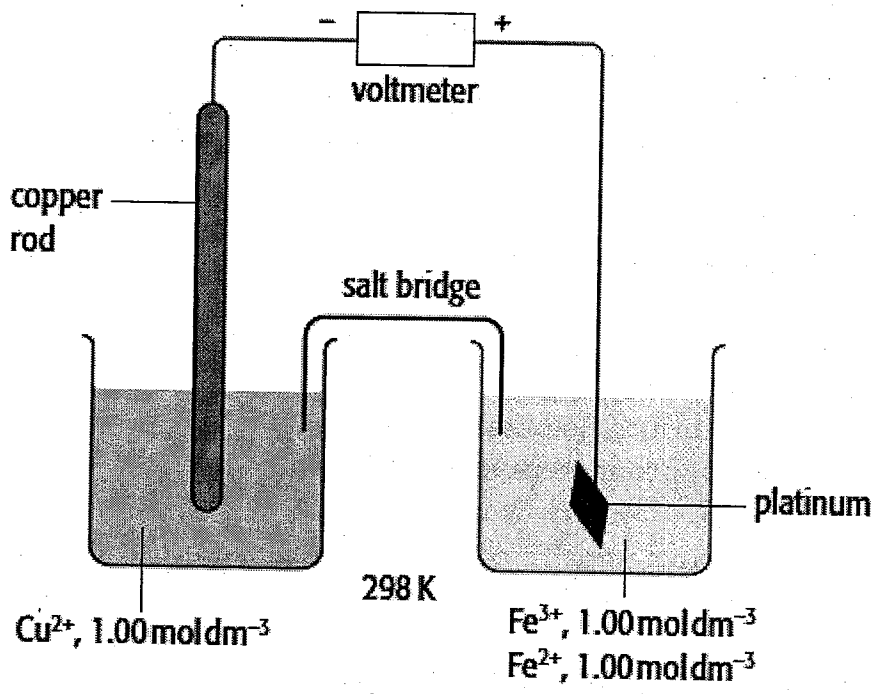
a) What is the meaning of standard electrode potential? **(3 marks)**

b) Which species in the list is:

i) The strongest oxidizing agent? **(1 mark)**

ii) The strongest reducing agent? **(1 mark)**

c) A cell was set up as shown below.



i) Calculate the standard cell potential of this cell. **(1 mark)**

ii) In which direction do the electrons flow in the external circuit? Explain your answer. **(2 marks)**

iii) Write a chemical equation for the complete cell reaction. **(2 marks)**

20) 50cm^3 of 0.1M aqueous ammonia solution was shaken to equilibrium with 50cm^3 of trichloromethane in a stoppered bottle, at 25^{0}C. The two solvent layers were allowed to separate. 25 cm^3 of the aqueous layer reacted completely with 24cm^3 of 0.1M HCl solution.

a) What is the concentration of ammonia in the aqueous layer at equilibrium? **(4 marks)**

b) What is the concentration of ammonia in the trichloromethane layer at equilibrium? **(3 marks)**

c) Calculate the distribution coefficient K_D for ammonia between water and trichloromethane at 25^{0}C. **(3 marks)**

- END -

Chemistry II

014

23/07/ 2021 08.30 AM - 11.30 AM

NESA NATIONAL EXAMINATION AND SCHOOL INSPECTION AUTHORITY

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2020-2021

SUBJECT: CHEMISTRY II

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 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 **only three** questions. **(30 marks)**
4) **Geometrical instruments and silent non-programmable calculators may be used.**
5) **You do not need the periodic table.**
6) Use a **blue** or **black** pen for answering and a **pencil** for drawing.

SECTION A: Attempt all questions (70 marks)

1) The atomic number of manganese (Mn) is 25.

a) Write the electronic configuration of manganese in terms of s, p, d and f notation. **(1 mark)**

b) Give two reasons to explain why Mn is considered to be a transition metal. **(2 marks)**

c) Explain why Mn^{2+} ions are more stable than Mn^{3+} ions. **(2 marks)**

2) a) The first seven ionization energies of element W are shown below:

1st	2nd	3rd	4th	5th	6th	7th
785	1581	3231	4361	16002	20001	23602

(i) What is meant by the term "**first ionization energy**" of an element? **(1 mark)**

(ii) State two factors that determine the magnitude of the first ionization energy. **(2 marks)**

b) (i) What is meant by the term "**electronegativity**"? **(2 marks)**

(ii) What are the factors that determine the magnitude of electronegativity of an element? **(2 marks)**

3) Ions of F^- , Na^+ and Mg^{2+} have the same number of electrons.
(Atomic number: F=9, Na =11, Mg =12)

a) Write the electronic configuration of Mg^{2+} using s, p, d and f notation. **(1 mark)**

b) Arrange the ions given above in order of ascending ion size (ionic radius). **(2 marks)**

4) Hydrogen sulfide, H_2S is a gas at room temperature and pressure whereas sodium fluoride, NaF is a solid with a high melting point.
a) Mention the type of bond that form each of the compounds. **(2 marks)**

b) Explain, in terms of bond nature, why their melting points are different. **(2 marks)**

5) An electrochemical cell is represented as follows:

$Mn_{(s)}$ /$Mn^{2+}_{(aq)}$ // $Cu^{2+}_{(aq)}$/ $Cu_{(s)}$

Use the data given below to answer the questions that follow:

$Mn^{2+}_{(aq)} + 2e \rightleftharpoons Mn_{(s)}$ $E^{\theta} = -1.18$ V

$Cu^{2+}_{(aq)} + 2e \rightleftharpoons Cu_{(s)}$ $E^{\theta} = +0.34$ V

(a) Calculate the e.m.f of this cell. **(2 marks)**

(b) Indicate and explain (using chemical equations) how the e.m.f of the cell would change if the concentration of $Mn^{2+}_{(aq)}$ was increased on the left side of the cell. **(3marks)**

(c) Describe the difference between an electrochemical cell and an electrolytic cell. **(2 marks)**

6) A solution contains 0.089 gl^{-1} of anhydrous calcium chloride, $CaCl_2$ and has an electrolytic conductivity of 2.69 X 10^{-4} Ohm^{-1} cm^{-1} at 25 ^{0}C.

a) Calculate the molar conductivity of calcium chloride in this solution.
(Atomic mass: Ca=40, Cl=35,5) **(2 marks)**

b) The molar ionic conductivity of calcium ions at 25 ^{0}C is 104 Ohm^{-1} cm^2 mol^{-1}. Calculate the molar ionic conductivity of chloride ions in the solution. **(3 marks)**

7) a) One of the properties of transition metals is complex ion formation.
(i) Define the term "complex ion" **(1 mark)**

(ii) Explain why transition metals form many complexes. **(2 marks)**

b) $Fe(CN)_6^{3-}$ and $CuCl_4^{2-}$ are complexes formed by iron and copper respectively. Deduce the:
(i) Oxidation number of iron and copper in the above complexes. **(1 mark)**

(ii) Co-ordination numbers of iron. **(1 mark)**

8) Explain each of the following observations:

a) Propan-1-ol boils at 97 ^{0}C and 1-aminopropane boils at 49 ^{0}C although both compounds have almost the same molecular masses. **(2 marks)**

b) Phenol is more acidic than phenyl methanol. **(2 marks)**

c) Beryllium chloride is more soluble in ethanol than in water whereas magnesium chloride is more soluble in water than in ethanol. **(1 mark)**

9) The dissociation constant, Ka of propanoic acid (CH_3CH_2COOH) is $1.3x10^{-5}$ mole dm^{-3}.

a) Calculate the concentration of H^+ ions in mole dm^{-3} of a 0.1 mole dm^{-3} CH_3CH_2COOH solution. **(2 marks)**

b) Calculate the pH of the 0.1 mole dm^{-3} CH_3CH_2COOH solution. **(2 marks)**

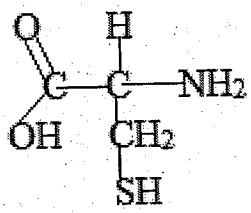
10) The atomic number of aluminium and bromine are 13 and 35 respectively.

a) Draw the Lewis structure of Al_2Br_6 . **(1 mark)**

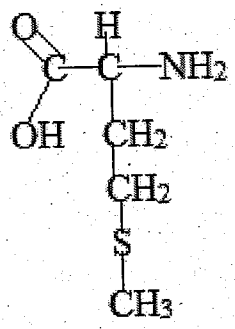
b) Explain why $AlBr_3$ is considered to be an acid according to Lewis theory of acid-base. **(2 marks)**

c) Explain why $MgBr_2$ is more ionic than $AlBr_3$ **(2 marks)**

11) Study the structure of cysteine and methionine amino acids given below and answer the questions that follow:



Cysteine amino acid



Methionine amino acid

a) Draw the structure of the zwitterion form of cysteine amino acid shown above. **(2 marks)**

b) Draw the structure of the dipeptide formed when cysteine amino acid combines with methionine amino acid in aqueous solution at 30 ^0C **(2 marks)**

12) An alkyne Z reacts with a solution of copper I chloride in aqueous ammonia to give a red precipitate and has the molecular formula C_5H_8.

a) Write the structural formula of Z. **(1 mark)**

b) Write the names and structural formulae of 2 possible isomers of Z. **(2 marks)**

c) Write the equation for the reaction between Z and excess hydrogen bromide HBr. **(1 mark)**

13) Explain the following observations:

a) Iodine is sparingly soluble in water but dissolves readily in aqueous potassium iodide. **(2 marks)**

(a) Hydrogen fluoride, HF has a higher boiling point than hydrogen chloride, HCl. **(2 marks)**

14) The addition of 114 grams of substance Q to 1000 grams of water lowers the vapour pressure of water from 17.540 KPa to 17.435 KPa. Calculate the molecular mass of substance Q. **(4 marks)**
(Molar mass of water = 18g/mole)

15) The volume of 20 cm^3 of a sample of a saturated solution of calcium hydroxide $Ca(OH)_2$ was neutralized by 18.2 cm^3 of a 0.022 mole dm^{-3} hydrochloric acid HCl.

a) Calculate the concentration of OH^- (mole dm^{-3}) in the saturated solution of $Ca(OH)_2$. **(2 marks)**

b) Calculate the solubility product, Ksp of $Ca(OH)_2$. **(2 marks)**
Equation: $Ca(OH)_{2(aq)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(l)}$

SECTION B: Attempt three questions only (30 marks)

16) An organic compound Q, with the molecular formula $C_2H_4O_2$ contains two functional groups.

a) The first functional group was tested as follows:

I. The pure compound Q reacted with sodium to give out hydrogen gas and a compound with the molecular formula of $C_2H_3O_2Na$.

II. When compound Q was heated with ethanoic acid with some drops of concentrated sulphuric acid, the product with the molecular formula of $C_4H_6O_3$ was formed and gave out a sweet smell.

(i) Write the formula and the name of the first functional group. **(2 marks)**

(ii) Write the name of the functional group formed in a)(II). **(1 mark)**

b) The second functional group was tested as follows:

I. Some drops of Q were added to 2,4-dinitrophenyl hydrazine and a yellow precipitate was formed.

II. A drop of Q was mixed in a solution of $[Ag(NH_3)_2]^+$, Tollens reagent and heated. A silver mirror was formed on the interior side of the test tube.

Write the name and the formula of the second functional group. **(1 mark)**

c) Write the structural formula of organic compound Q. **(1 mark)**

d) Write the structural formula of two possible geometric isomers of the compound with the molecular formula $C_2H_4O_2$. **(2 marks)**

e) Compound Q was oxidized to give an acid with the molecular formula $C_2H_2O_4$. Write the structural formula of $C_2H_2O_4$. **(1 mark)**

f) Compound Q was reduced to give a compound with the molecular formula $C_2H_6O_2$. Write the structural formula of $C_2H_6O_2$. **(1 mark)**

g) Write the structural formula of the compound formed from the reaction of $C_2H_6O_2$ with excess HBr. **(1 mark)**

17) Nitrogen monoxide reacts with chlorine as shown in the following equation:

$$2NO_{(g)} + Cl_{2(g)} \rightarrow 2NOCl_{(g)}$$

The variations of concentrations of reactants and the rate of the reaction at a certain temperature and constant pressure are shown in the table below:

Experiment	**Initial [NO] concentration in (mol dm^{-3})**	**Initial [Cl_2] concentration in (mol dm^{-3})**	**Initial rate of the reaction in (mol $dm^{-3}S^{-1}$)**
1	0.03	0.01	$3.4x10^{-4}$
2	0.015	0.01	$8.5x10^{-5}$
3	0.015	0.04	$3.4x10^{-4}$

a) Determine the order of the reaction with respect to NO and the order of the reaction with respect to Cl_2 . **(3 marks)**

b) Write the mathematical expression for the rate of the reaction between NO and Cl_2 . **(1 mark)**

c) Calculate the rate constant by using values of experiment 1 and give its units. **(2 marks)**

d) Briefly explain the effect of increasing the temperature on the rate of the reaction. **(2 marks)**

e) Using the concept of activation energy, briefly explain how a catalyst affects the rate of the reaction. **(2 marks)**

18) The atomic number of beryllium and aluminium are 4 and 13 respectively.

a) State 2 similarities between Be and Al in terms of chemical properties. **(2 marks)**

b) Explain why the solubility of sulphates of group 2 elements decreases as you move down the group. **(2 marks)**

c) Study the standard electrode potentials given below and answer the question that follow:

$Mg^{2+}_{(aq)} + 2e \rightarrow Mg_{(s)}$ $\quad E^{\theta} = -2.37$ V

$Fe^{2+}_{(aq)} + 2e \rightarrow Fe_{(s)}$ $\quad E^{\theta} = -0.44$ V

(i) Explain why magnesium is used to galvanize iron. **(2 marks)**

(ii) State the colour change that takes place when an excess amount of magnesium metal is put in a green aqueous solution of $Fe^{2+}_{(aq)}$ then is left to react completely and explain why. **(3 marks)**

d) State 1 use of beryllium on a large scale. **(1 mark)**

19) a) State "Raoult's law" for ideal mixtures of liquids. **(2 marks)**

b) An ideal mixture of two liquids A and B contained 1 mole of A and 4 moles of B. The vapour pressure of pure A was 10 KPa and that of B was 12.5 KPa.

(i) Calculate the partial vapour pressure of A in the mixture. **(1.5 marks)**

(ii) Calculate the partial vapour pressure of B in the mixture. **(1.5 marks)**

(iii) Calculate the total vapour pressure of the liquid. **(1 mark)**

c) Calculate the osmotic pressure in atmospheres at 298 K of a solution (suspension) containing 60 g/litre of solid particles each particle having a mass of $1.10X10^{-19}$ gram. **(4 marks)**

(Avogadro constant = 6.02 X 10^{23})

(Gas constant, R = 0.0823 litre.atm/mol.K)

20) The mass of 6.5g impure copper was dissolved in excess concentrated nitric acid (HNO_3). The solution obtained was made up to 200 ml with water. To 20 ml of this solution, excess aqueous potassium iodide (KI) was added. The reaction that took place is given by the following equation:

$$2Cu^{2+}_{(aq)} + 4I^-_{(aq)} \rightarrow 2CuI_{(aq)} + I_{2(aq)}$$

The iodine (I_2) liberated reacted with 20 ml of 0.5 M sodium thiosulphate ($Na_2S_2O_3$) solution according to the equation:

$$I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \rightarrow 2I\text{-}(aq) + S_4O_6^{2-}{}_{(aq)}$$

a) Calculate the number of moles of thiosulphate ions, $S_2O_3^{2-}$ that reacted in the 20 ml solution. **(2 marks)**

b) Calculate the number of moles of iodine molecules, I_2 formed. **(2 marks)**

c) Calculate the number of moles of copper ions, Cu^{2+} formed in the 200 ml solution. **(2 marks)**

d) Calculate the mass of copper, Cu that reacted in the 6.5g impure sample. **(2 marks)**

e) Calculate the percentage purity by mass of copper, Cu in the 6.5g impure sample. **(2 marks)**

(Atomic mass: Cu=63.5)

CHEMISTRY II

014

15/11/ 2019 8:30 AM – 11:30 AM

REB
Rwanda Education Board

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2019

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 are not allowed to use the periodic table.
5) Silent non-programmable calculators may be used.
6) Use only a **blue** or **black** pen for answering and a **pencil** for drawing.

SECTION A: Attempt all questions (70 marks)

1) a) Describe what takes place in the ionization chamber of a mass spectrometer so that positive ions of a sample can be produced. **(2 marks)**

b) The percentage abundance of chromium isotopes ^{50}Cr, ^{52}Cr, ^{53}Cr and ^{54}Cr are 4.345 %, 83.789 %, 9.501 % and 2.365 % respectively.

i) Calculate the relative atomic mass of chromium. **(2 marks)**

ii) Describe 2 useful applications of isotopes by man. **(2 marks)**

2) Draw diagrams of the shapes of the following molecules and in each case state the name of the shape.

a) CO_2 **(1.5 marks)**

b) BCl_3 **(1.5 marks)**

(Atomic number: B=5, Cl=17, C=6, O=8)

3) a) Describe 2 similarities in terms of chemical properties between beryllium and aluminium elements. **(2 marks)**
(Beryllium is in group 12 and aluminium is in group 13 of the periodic table)

b) Explain why $PbBr_4$ and PbI_4 do not exist whereas $PbCl_4$ exists. **(2 marks)**

c) Evaluate the social-economic importance of aluminium and boron compounds to the Rwandan society. **(2 marks)**

4) a) Write the equation of the reaction between concentrated H_2SO_4 and HI. **(1 mark)**

b) Explain why HF has a higher boiling point than HCl, HBr and HI despite its lower molecular mass than the rest. **(2 marks)**

c) Evaluate the important uses and hazards of chlorine compounds. **(2 marks)**

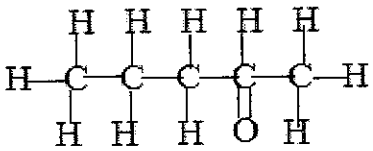
5) During the reaction of formation of Al_2O_3 from 5.4 g of Al and enough of O_2, the temperature liberated increased the temperature of 2 Kg of water by 20^0C.
Find the value of the standard enthalpy of formation of Al_2O_3 . **(3 marks)**
(Atomic mass: Al=27, specific heat capacity of water =4.2 J/g ^0C)

6) Petrol is composed of isomers of C_8H_{18} .
a) Write the structural formula of 2,3,3-Trimethyl pentane. **(1 mark)**

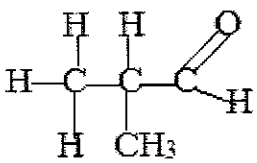
b) Give one reason to explain why 2,3,3-Trimethyl pentane is a better fuel component in vehicle engines than n-octane. **(1 mark)**

c) Explain the reason why unleaded petrol is recommended for use in vehicles in most parts of the world than leaded petrol. **(2 marks)**

7) a) Study the structural formula of the following organic compounds and answer the questions that follow:



Compound X

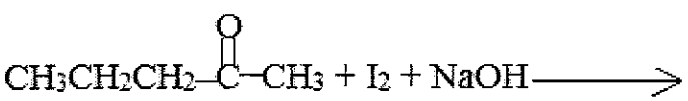


Compound Y

i) Write the IUPAC name of compound X and of compound Y shown above. **(2marks)**

ii) Suggest a chemical test reagent that can be used to distinguish between the organic substance X and Y shown above and mention the observable change in each case. **(2marks)**

b) Complete the chemical equation given below by writing the semi-developed formulae of all organic products and molecular formulae of inorganic products. **(2marks)**



8) Balance the following reduction-oxidation chemical reaction equations.

a) $Fe^{2+}_{(aq)} + H^{+}_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} \rightarrow Cr^{3+}_{(aq)} + Fe^{3+}_{(aq)} + H_2O_{(l)}$ **(2 marks)**

b) $I_{2(aq)} + NO_3^{-}{}_{(aq)} + H^{+}_{(aq)} \rightarrow NO_{2(g)} + IO_3^{-}{}_{(aq} + H_2O_{(l)}$ **(2 marks)**

9) Use the data given below to calculate the standard enthalpy of formation ΔH_4 of octane, $C_8H_{18(l)}$: **(4 marks)**

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H_1 = -393.5$ KJ mol^{-1}

$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H_2 = -286$ KJ mol^{-1}

$C_8H_{18(l)} + \frac{25}{2} O_{2(g)} \rightarrow 8CO_{2(g)} + 9H_2O_{(l)}$ $\Delta H_3 = -5471$ KJ mol^{-1}

$8C_{(s)} + 9H_{2(g)} \rightarrow C_8H_{18(l)}$ $\Delta H_4 = ?$

10) The dissociation constant (Kb) of a 0.2 mole/litre solution of methyl amine is $4.4X10^{-4}$. Calculate:

a) The number of moles of OH^- in 1 litre of the methyl amine solution. **(2 marks)**

b)The pH of the 0.2 mole/litre solution of methyl amine. **(3 marks)**

Equation:

$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$

(Methyl amine is a weak base)

11) Using appropriate steps with equations of reactions, show how you can synthesize $CH_3CH_2NH_2$ from $CH_3CH_2CH_2OH$ **(4 marks)**

12) The solubility product (Ksp) of silver chromate, Ag_2CrO_4 in water is $3X10^{-12}$

$$Ag_2CrO_{4(s)} \rightleftharpoons 2\,Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}$$

a) Calculate the solubility in g dm^{-3} of silver chromate VI (Ag_2CrO_4) in water. **(2 marks)**

b) Calculate the solubility in mole/litre of Ag_2CrO_4 in 1 litre of a solution of 0.02 mole/litre Na_2CrO_4. **(2 marks)**

(0.02 mole/litre Na_2CrO_4 solution dissolves completely in water)
(Atomic mass, Ag=107, Cr=52, O=16).

c) Discuss 2 important applications of solubility in the Rwandan society. **(2 marks)**

13) a) Write the structural formula of 2-bromo-4-methyl pentane. **(1 mark)**

b) Write the equation for the reaction of nucleophilic substitution between 2-bromo-4-methyl pentane and aqueous sodium hydroxide, NaOH.
(use semi-developed formulae) **(2 marks)**

c) 2-bromo-4-methyl pentane is made to react with sodium cyanide, NaCN to form organic product A.
The resultant organic product A is reacted with $LiAlH_4$ in the presence of H_2O to give organic product B.
Give the IUPAC name or the structural formula of compounds A and B. **(2 marks)**

14) Nickel-Cadmium cells are used to power electrical equipments such as drills and shavers.
The electrode reaction equations are given below:

$NiO_2 + 2H_2O + 2e \longrightarrow Ni(OH)_2 + 2OH^-$ $E^\theta = +0.52$ V

$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e$ $E^\theta = -0.88$ V

a) Calculate the standard e.m.f of a Nickel-Cadmium cell. **(1.5 marks)**

b) Deduce the overall equation for the reactions that occur in the cell when it is used. **(1.5 marks)**

c) Describe the difference between rechargeable cells such as those used in mobile telephones and the non-rechargeable cells. **(2 marks)**

15) a) Describe the term "thermosoftening polymer" and indicate an example of such a polymer. **(2 marks)**

b) Explain how tyres used in vehicles and bicycles are made hard during the process of polymerization (synthesis) in industry. **(2 marks)**

SECTION B : Attempt THREE questions (30 marks)

16) a) Glass is essentially made of silicon and boron compounds.
(i) Explain the reason why glass is not used to make containers of NaOH solution (use chemical equations to support your answer). **(2 marks)**

(ii) State 2 similarities between silicon and boron. **(2 marks)**

b) Tin, SnO_2 is mined in some parts of Rwanda.
(i) Write the equation of the reaction between SnO_2 and hot concentrated H_2SO_4. **(2 marks)**

(ii) Write the equation of the reaction between SnO_2 and NaOH. **(2 marks)**

(iii) Describe the important applications of tin on a large scale. **(2 marks)**

17) Organic acid X has the formula $(CH_2)n(COOH)_2$ and reacts with dilute sodium hydroxide, NaOH according to the following equation:
$(CH_2)n(COOH)_2 + 2NaOH \longrightarrow (CH_2)n(COONa)_2 + 2H_2O$

The mass of 2.0 g of organic acid X is dissolved in water and the solution made up to 250 cm^3.
This organic acid X solution is filled in a burette and 18.40 cm^3 of $(CH_2)n(COOH)_2$ is required to neutralize 25 cm^3 of a 0.1 mol dm^{-3} NaOH.

a) Calculate the number of moles of NaOH in 25 cm^3 solution. **(2 marks)**

b) Determine the number of moles of $(CH_2)n(COOH)_2$ that reacted with 25 cm^3 of the 0.1 mol dm^{-3} NaOH solution. **(1 mark)**

c) Calculate the number of moles of $(CH_2)n(COOH)_2$ present in 250 cm^3 solution. **(2 marks)**

d) Deduce the molecular mass of $(CH_2)n(COOH)_2$ acid. **(3 marks)**

e) Find the value of n. **(2 marks)**
(Atomic mass: C=12, H=1 and O=16)

18) Study the data of the enthalpy changes in the table below and answer the questions that follow:

Equations of reactions	Enthalpy change /KJ mol^{-1}
$AgI_{(s)} \rightarrow Ag^+_{(aq)} + I^-_{(aq)}$	$\Delta H_2 = +112$
$Ag^+_{(g)} \rightarrow Ag^+_{(aq)}$	$\Delta H_3 = -464$
$I^-_{(g)} \rightarrow I^-_{(aq)}$	$\Delta H_4 = -293$
$Ag^+_{(g)} + I^-_{(g)} \rightarrow AgI_{(s)}$	ΔH_1

a) Define the term " **enthalpy of lattice formation**" **(2 marks)**

b) Write the chemical symbol or formula of a reagent that can be used to test for the presence of iodide ions in aqueous solution and describe the observable change. **(2 marks)**

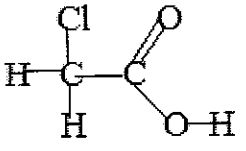
c) Calculate the enthalpy of lattice formation of AgI, ΔH_1. **(4 marks)**

d) Explain why the use of butane alkane is preferred for use in combustion gas cylinders rather than ethane alkane. **(2 marks)**

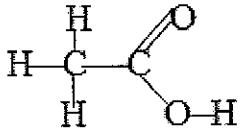
19) a) Two different organic molecules react to form an amide bond in the resultant molecule.
(i) Write the structural formula of the resultant molecule showing the location of the amide bond. **(1 mark)**

(ii)Explain the reason why amide bonds are strong. **(2 marks)**

b) Study the diagrams given below and answer the questions that follow:



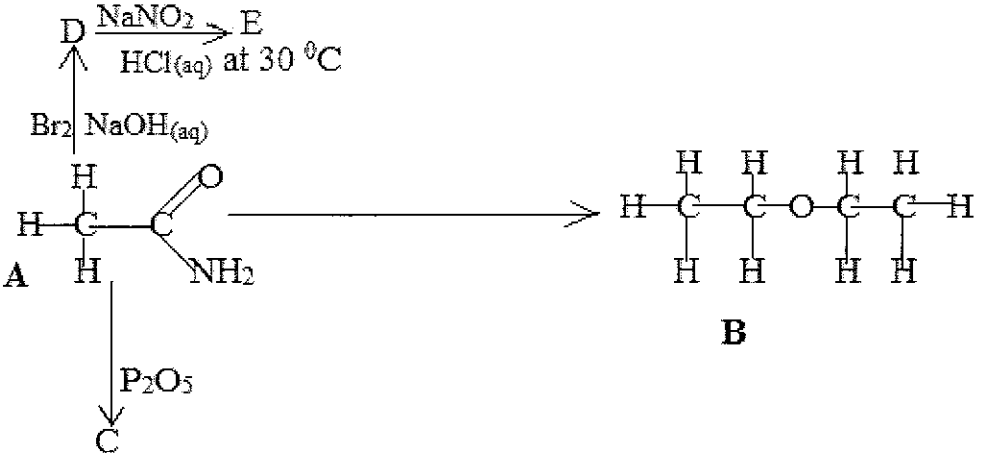
Chloroethanoic acid



Ethanoic acid

Explain why chloroethanoic acid is a stronger acid than ethanoic acid. **(2 marks)**

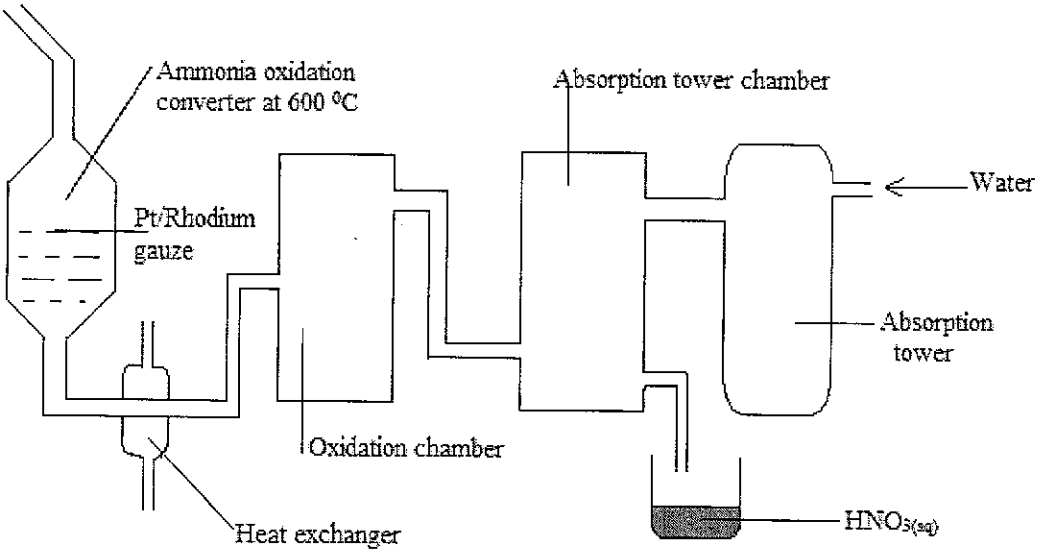
c) Study the diagram given below and answer the questions that follow:



(i) Write the semi-developed molecular formula of organic substance: C, D and E **(2 marks)**

(ii) Write different chemical equations of reactions (not more than 5 equations) that can be used to illustrate the conversion of 2 moles of organic substance A into 1 mole of substance B. Include reagents and conditions. **(3 marks)**

20) Study the diagram given below for the production of nitric acid and answer the questions that follow:



Equations:

I: $4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$ $\Delta H = -905.2$ KJ mol^{-1}

II: $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$ $\Delta H = -114$ KJ mol^{-1}

III: $3NO_{2(g)} + H_2O_{(l)} \rightleftharpoons 2HNO_{3(aq)} + NO_{(g)}$ $\Delta H = -117$ KJ mol^{-1}

a) Explain the effect of increasing the temperature (in the oxidation converter) on the position of equilibrium when NO is produced from NH_3 in equation I. **(2 marks)**

b) Explain the importance of reduction of temperature of the reacting mixture by the heat exchanger. **(1.5 marks)**

c) State the name of a substance (reagent) that can be used to test for the presence of concentrated nitric acid, HNO_3 and give the observable change. **(2 marks)**

d) Explain the importance of platinum/Rhodium catalyst to the reacting mixture in the oxidation converter. **(1.5 marks)**

e) State 1 physical properties of concentrated nitric acid, HNO_3 acid. **(1 mark)**

f) Evaluate the importance of the manufacturing of nitric acid, HNO_3 to agricultural farmers in our society. **(2 marks)**

Chemistry II

014

11/11/ 2016 08.30am - 11.30am

REB
Rwanda Education Board

ADVANCED LEVEL NATIONAL EXAMINATIONS, 2016

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

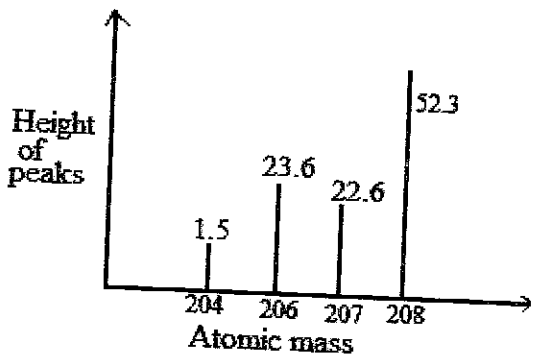
INSTRUCTIONS:

1. Do not open this question paper until you are told to do so.
2. 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.
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 calculator may be used.
6. Use a **blue** or **black** pen.

SECTION A: ATTEMPT ALL QUESTIONS. **(70marks)**

1) (a) Describe the term "isotopes" of an element. **(2marks)**

(b) The figure below shows the mass spectrum of lead (Pb). The heights of the peaks and the mass numbers of the isotopes are shown on the figure.
Calculate the relative atomic mass of lead. **(3marks)**



2) If $^{226}_{88}Ra$ undergoes a series of decays in which five α and four β particles are produced, what would be the final product? **(4marks)**

3) Aluminium oxide Al_2O_3, reacts readily with sodium hydroxide (NaOH) in the presence of water (H_2O) to produce sodium aluminate.

(a) Write a balanced equation of the reaction between Al_2O_3 and NaOH in the presence of H_2O. **(2marks)**

(b) Determine the mass of $NaAl(OH)_4$ produced when 4.5g of Al_2O_3 react completely with aqueous sodium hydroxide. **(2marks)**
(Atomic mass: Al=27, Na=23, O=16, H=1)

4) Methyl propan-1-ol and butan-1-ol are structural isomers.
(a) Explain the reason why methyl propan-1-ol has a lower boiling point than butan-1-ol. **(2marks)**

(b) State a reagent that can be used to distinguish the two isomers and the expected observable changes. **(2marks)**

(c) Write the structural formula of the two isomers. **(2marks)**

5) The solubility product (Ksp) of CaF_2 in pure water is 3.2×10^{-11} at 25^0C.

(a) Calculate the molar solubility of CaF_2 in pure water at 25^0C. **(3marks)**

(b) Calculate the mass (in g) of CaF_2 present in 200 ml of its saturated solution. **(2marks)**

Equation:

$CaF_{2\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$

(Molar mass: Ca = 40, F =19)

6) (a) Complete combustion of 50 cm^3 of a saturated hydrocarbon vapour gave 350 cm^3 of carbon dioxide gas. Both gas volumes being measured at the same temperature and pressure.
Determine the molecular formula of the hydrocarbon. **(3marks)**

(b) A buffer solution with pH of 4.0 is made using benzene carboxylic acid and sodium benzene carboxylate.
Calculate the mass of sodium benzene carboxylate (molecular mass = 144) that should be dissolved in 1.0 dm^3 of a 0.012 mol dm^{-3} solution of benzene carboxylic acid to produce a buffer solution with pH of 4.0. **(3marks)**
(Ka for $C_6H_5COOH = 6.31 \times 10^{-5}$ mol dm^{-3})

7) (a) Copper is a metal with a high melting point.
(i) Indicate the block in the periodic table that contains copper. **(1mark)**
(ii) Explain in terms of its structure and bonding why copper has a high melting point. **(2marks)**
(iii) Explain why copper is ductile (can be stretched into wires). **(2marks)**

(b) Copper forms the compound copper I chloride (CuCl)
Write the full electronic configuration of Cu^+ ion
(in terms of s, p, d and f notation). **(1mark)**
(Atomic number: Cu =29)

8) The table below shows the electronegativity values of some elements.

Element	H	Li	B	C	O	F
Electronegativity	2.1	1.0	2.0	2.5	3.5	4.0

Describe the meaning of the term "electronegativity". **(2marks)**

(a) Suggest the formula of an ionic compound that is formed by the chemical combination of two different elements from the table. **(1mark)**

(b) Suggest the formula of the compound that forms the strongest hydrogen bonds and is formed by chemical combination of two of the elements from the table.

9) (a) State the name of the shape of boron trichloride, BCl_3. **(1mark)**

(b) Aluminium chloride dissolves in water to give Al^{3+} ions that hydrolyze H_2O molecules. **(1mark)**

(i) Write a balanced equation for the hydrolysis of H_2O by Al^{3+} ions. **(2marks)**

(ii) State 2 uses of aluminium metal on a large scale. **(2marks)**

(Atomic number: B=5, Cl=17)

10) (a) Define the term "first ionization energy" of an element. **(2marks)**

(b) The elements nitrogen and phosphorous are found in group Va of the periodic table.

(i) Explain the trend in first ionization energy as you move down the group. **(2marks)**

(ii) Explain the reason why P forms chlorides of PCl_3 and PCl_5 but N forms NCl_3 only. (Atomic number: N=7, P= 15, Cl=17) **(2marks)**

11) Distillation of crude oil is effected to separate different components.

(a) Describe the principle that is based on during separation of oil components by fractional distillation. **(2marks)**

(b) What name is given to the process of breaking down long chain hydrocarbons into smaller molecules? **(1mark)**

(c) Describe the term "catalytic reforming" of alkanes. **(2marks)**

(d) State the name of a pollutant substance that is present in unsafe petrol. **(1mark)**

12) An organic compound, Y containing 0.0173g by mass was mixed with 0.42g of camphor to form a homogeneous mixture melting at 170 ^{0}C. Determine the molecular mass of the organic compound Y. **(3marks)**

(Melting point of pure camphor is 178.4 ^{0}C; freezing point depression constant of camphor, K_f =37.7 ^{0}C/m; m= number of moles of solute/1Kg of solvent).

13) Balance the following redox reaction by first establishing half redox equations of $Mn^{2+}$and BiO_3^-, then give the overall equation: **(3marks)**

$Mn^{2+} + BiO_3^- + H^+ \longrightarrow MnO_4^- + Bi^{3+} + H_2O$

14) Nickel-Cadmium cells are used to power electrical equipments such as drills and shavers.

The electrode reactions are shown below:

$NiO_2 + 2H_2O + 2e \longrightarrow Ni(OH)_2 + 2OH^-$ $\quad E^\theta = +0.52$ V

$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e$ $\quad E^\theta = -0.88$ V

(a) Calculate the standard e.m.f of a Nickel-Cadmium cell. **(2marks)**

(b) Deduce the overall equation for the reaction that occurs in the cell when it is used. **(2marks)**

15) Determine the values for a, b, c and d in the equations: **(3marks)**

(a) ${}^{35}_{17}Cl + {}^{1}_{0}n \longrightarrow {}^{a}_{b}X + {}^{1}_{1}H$

(b) ${}^{7}_{3}Li + {}^{2}_{1}H \longrightarrow {}^{c}_{d}Y + {}^{1}_{0}n$

SECTION B: ATTEMPT ANY THREE QUESTIONS. (30MARKS)

16) (a) The initial rate of reaction between ester A and aqueous sodium hydroxide was measured in a series of experiments at constant temperature. The data obtained are shown below:

Experiment	Initial concentration of NaOH (mol dm^{-3})	Initial concentration of A (mol dm^{-3})	Initial rate (mol $dm^{-3}s^{-1}$)
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}
3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	To be calculated

(i) Use the data in the table to deduce the order of reaction with respect to A and the order of reaction with respect to NaOH. **(3marks)**

(ii) Determine the value of the rate constant K for the reaction. **(1mark)**

(iii) Calculate the initial rate of reaction in experiment 4. **(2marks)**

(b) In a further experiment at a different temperature, the initial rate of reaction was found to be 9.0×10^{-3} mol $dm^{-3}s^{-1}$ when the initial concentration of A was 0.020 mol dm^{-3} and the initial concentration of NaOH was 2.00 mol dm^{-3}.

Under these new conditions with the much higher concentration of NaOH, the reaction is first order with respect to A and appears to be zero order with respect to NaOH.

(i) Write a rate equation for the reaction under these new conditions. **(1mark)**

(ii) Calculate a value for the rate constant under these new conditions and state its units. **(2marks)**

(iii) Describe the nature of a "zero order" reaction. **(1mark)**

17) A student carried out an experiment on a pure sample of 2-methyl propan-2-ol, $(CH_3)_3COH$) to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner to heat 50 cm^3 of water. The spirit burner was ignited and allowed to burn for several minutes. The results for the experiment are shown in the table below:

Initial temperature of water /^{0}C	18.1
Final temperature of water /^{0}C	45.4
Initial mass of spirit burner and alcohol /g	208.80
Final mass of spirit burner and alcohol /g	208.58

(a) Calculate the value for the heat energy absorbed by 50 cm^3 water to be raised from 18.1^{0}C to 45.4 ^{0}C. **(2marks)**
(The specific heat capacity of water is 4.18 $JK^{-1}g^{-1}$)
(The density of water = 1g cm^{-3})

(b) Calculate the number of moles of 2-methyl propan-2-ol burned in the experiment. **(3marks)**
(Atomic mass: C =12, O =16, H =1)

(c) Calculate a value, in KJ mol^{-1} for the enthalpy of combustion of one mole of 2-methyl propan-2-ol (experiment value). **(3marks)**
(If you are unable to calculate the answer for17.a), you should assume that the heat energy released by 2-methyl propan-2-ol was 5580 J)

(d) Equation for the combustion of 2-methyl propan-2-ol is:

$$(CH_3)3COH_{(l)} + 6O_{2(g)} \longrightarrow 4CO_{2(g)} + 5H_2O_{(l)}$$

The table below contains some standard enthalpy of formation data.

Substance	$(CH_3)_3COH_{(l)}$	$O_{2(g)}$	$CO_{2(g)}$	$H_2O_{(l)}$
ΔH^{θ}_f KJmol^{-1}	-360	0	-393	-286

Using the data given above in the table:
Calculate the value for the standard enthalpy of combustion of 2-methyl propan-2-ol (theoretical value). **(2marks)**

18) (a) Sea water is a major source of iodine. The iodine extracted from sea water is impure. It is purified in a two-stage process.

Stage 1: $I_2 + 2H_2O + SO_2 \longrightarrow 2HI + H_2SO_4$.

Stage 2: $2HI + Cl_2 \longrightarrow I_2 + 2HCl$

(i) Deduce the oxidation state of sulphur in SO_2 and in H_2SO_4. **(2marks)**

(ii) State in terms of electrons, what has happened to chlorine in stage 2. **(1mark)**

(b) When concentrated sulphuric acid is added to potassium iodide, iodine is formed in the following redox equations.

$KI + H_2SO_4 \longrightarrow KHSO_4 + I_2 + S + H_2O$

$8KI + 9\ H_2SO_4 \longrightarrow 8\ KHSO_4 + 4\ I_2 + H_2S + 4H_2O$

(i) Balance the equation for the reaction that forms sulphur, S. **(2marks)**

(ii) Deduce the half-equation for the formation of iodine (I_2) from iodide ions. **(2marks)**

(iii) Deduce the half-equation for the formation of hydrogen sulphide (H_2S) from concentrated sulphuric acid. **(2marks)**

(c) A yellow precipitate is formed when silver nitrate solution ($AgNO_{3(aq)}$), acidified with dilute nitric acid is added to an aqueous solution containing iodide ions.
State what is observed when concentrated ammonia solution is added to this yellow precipitate. **(1mark)**

19) (a) Acid strength of hydrogen halides (group VII halides) increases down the group.

(i) Describe the term "acid" according to Lowry- BrÖnsted theory. **(2marks)**

(ii) Explain the reason why HBr is a stronger acid than HCl. (Atomic number : Cl = 17, Br = 35) **(2marks)**

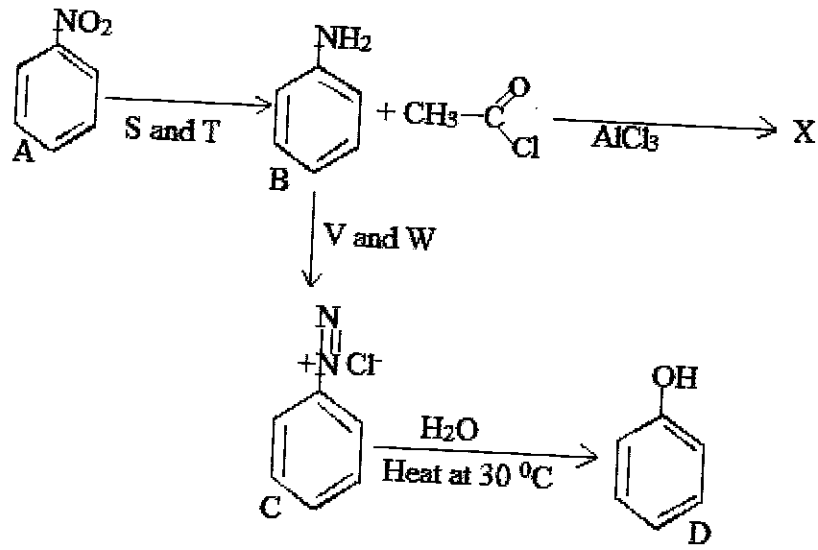
(b) (i) Define the term "Lewis acid". **(2marks)**

(ii) Write the chemical formula of 2 Lewis acids. **(1mark)**

(c) (i) Explain the reason why ethyl amine, $CH_3CH_2NH_2$ is a stronger base than ammonia, NH_3 . **(2marks)**

(ii) State 2 important uses of buffer solutions on a large scale. **(1mark)**

20) Study the diagram of benzene derivatives illustrated below and answer the questions that follow.



(a) Write the names or the chemical formulae of reagents S and T which are required to transform A into B. **(2marks)**

(b) Draw the structure of the organic compound X. **(1mark)**

(c) Write the name or the chemical formula of reagents V and W. **(2marks)**

(d) Give the scientific name of the organic compound D. **(1mark)**

(e) State 1 physical property of the organic compound D. **(1mark)**

(f) State a test (reagent) that can be used to differentiate organic compound B and amino butane ($CH_3CH_2CH_2CH_2NH_2$) and describe the observation of the reaction for each compound. **(3marks)**

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)**

REPUBLIC OF RWANDA

Chemistry II

014

01 Nov. 2013 08.30am - 11.30am

RWANDA EDUCATION BOARD

ADVANCED LEVEL NATIONAL EXAMINATIONS 2013

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) Don't open this question paper until you are told so.
2) This paper consists of **two** sections: **A** and **B**.
   - **Section A**: Attempt **all** questions. **(70 marks)**
   - **Section B**: Attempt any **three** questions. **(30 marks)**
3) **You do not need the Periodic Table.**
4) Silent non-programmable calculators may be used.

SECTION A: ATTEMPT ALL QUESTIONS. **(70 marks)**

1. Explain the following observations:
   a) Atomic radius of fluorine is smaller than that of Lithium. (Atomic number: F=9, Li=3) ***(2 marks)***
   b) Solubility of sulphates of group II (a) elements ($MgSO_4$, $CaSO_4$, $SrSO_4$, $BaSO_4$) decreases as you move down the group. ***(2 marks)***
   c) Lead chloride (IV), $PbCl_4$, is a covalent compound whereas lead chloride (II), $PbCl_2$, is ionic. ***(2 marks)***

2. a) Atomic number of magnesium is 12, atomic number of chlorine is 17:
      i. Write the electronic configuration of magnesium and that of chlorine (in terms of s, p, d...). ***(2 marks)***
      ii. Write a balanced chemical equation of the reaction between magnesium and chlorine. ***(1 mark)***
   b) In terms of advantages and disadvantages; give four (4) differences between soap and detergents. ***(2 marks)***

3. Write a balanced chemical equation for the reaction between:
   a) Cold dilute nitric acid (HNO_3) and Iron metal (Fe). ***(2 marks)***
   b) Copper metal (Cu) and concentrated nitric acid (HNO_3). ***(2 marks)***

4. a) Define "enthalpy of solution". ***(2 marks)***
   b) Calculate the enthalpy change (in joules) when 400g of water at 25°C is heated up to 100°C. (Specific heat capacity of water is 4.2 J/g°C). ***(2 marks)***

5. An electric current of 3.0 amperes is passed through a solution of Copper sulphate ($CuSO_4$) for 280 minutes.
   Equations:
   Anode : $4\ OH^-_{(aq)} \longrightarrow 2\ H_2O_{(l)} + O_{2(g)} + 4e$
   Cathode: $Cu^{2+}_{(aq)} + 2e \longrightarrow Cu_{(s)}$ ***(2 marks)***
   a) Calculate the mass (in g) of copper that is deposited.
   b) Calculate the volume of $O_{2(g)}$ liberated at the anode (at room temperature and pressure). (1 mole of a gas occupies 24 dm^3 at room temperature and pressure, 1 Faraday = 96500 C/mol, Atomic mass of Cu = 63.5) ***(2 marks)***

6. This question deals with colligative properties of solutions **(a)** and **(b)**:
   a) An aqueous solution of 1.10 g of a protein in 100 ml of a solution has an osmotic pressure of 3.93×10^{-3} atmosphere at 25°C (298K). Calculate the molar mass of the protein.($R = 0.08203$ L. atm.mol^{-1} .K^{-1}) ***(3 marks)***
   b) A solution of 2.95 g of sulphur (molecules) in 100 g cyclohexane has a freezing point of 4.18°C. Pure cyclohexane has a freezing point of 6.5°C. ***(3 mark)***
      i. Calculate the molecular mass of sulphur.
      ii. Calculate the molecular formula of sulphur. ***(2 marks)***
      (Atomic mass of sulphur=32, Kf = 20.2°C Kg mol^{-1}).

7. a) Draw 4 different structural isomers (that are non cyclic) of a compound that is represented by the molecular formula of $C_4H_8O_2$. ***(4 marks)***
   b) Complete and balance the following chemical equation: ***(2 marks)***
   $Cl_2 + NaOH_{(hot,\ concentrated)} \longrightarrow$

8. Ammonia is produced by Haber-Bosch process according to the following equation: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, $\Delta H = -92 KJmol^{-1}$
Indicate and explain what will happen to the position of equilibrium if: *(4 marks)*
a) Pressure is decreased. b) Temperature is decreased.

9. Write the mechanism of reaction of each chemical equation:
a) $CH_2 = CH_2 + Br_2 \longrightarrow CH_2Br - CH_2Br$ *(2 marks)*
b) $CH_3CH_2Cl + OH^- \longrightarrow CH_2 = CH_2 + H_2O + Cl^-$ *(2 marks)*

10. An organic compound A is constituted of C, H and O.
Its percentage composition by mass is as follows:
C=66.7%; H=11.1%; and O=22.2% (Atomic mass: C=12, H=1, O=16)
a) Find the empirical formula of compound A. *(2 marks)*
b) Find the molecular formula of compound A if its molecular mass is 72. *(2 marks)*

11. By using appropriate equations, illustrate how propan-1-ol can be converted (by using one step reaction equation or more than one step) into the following compounds indicating reactants and conditions required.
a) 2-Chloro propane. b) Amino butane (butyl amine). *(4 marks)*

12. a) Write 2 characteristics of transition metals. *(1 mark)*
b) Explain the reason why Zinc is not generally considered to be a transition metal. (Atomic number of Zinc=30) *(1 mark)*
c) Explain the reason why transition metals are coloured. *(2 marks)*

13. a) Write a chemical equation (or equations) to describe how zinc ions (Zn^{2+}) act as: i. An acid; ii. A base. *(2 marks)*
b) Write a balanced chemical equation for the reaction between:
i. Hot Concentrated sulphuric acid (H_2SO_4) and Carbon (C). *(2 marks)*
ii. Hot Concentrated nitric acid (HNO_3) and Sulphur (S). *(2 marks)*

14. Aluminium is obtained on a large scale by electrolysis.
a) Draw a labelled diagram for industrial production of Aluminium. *(2 marks)*
b) Write chemical equations that represent the reactions which take place on the cathode and on the anode during this electrolysis. *(2 marks)*

15. Draw the shapes of the following molecules and give the name of each shape. a) NH_3 b) IF_5 c) H_2O *(3 marks)*

SECTION B: Attempt any three questions. *(30 marks)*

16. Using appropriate equations of reaction by showing clearly the reagents, conditions and using structural formulae of the organic compounds, describe how the following compounds can be synthesized:
a) Phenol to 4-Nitrobenzoic acid. b) Nitro Benzene to 2-Bromo Phenol. *(10 marks)*

17. a) The pKa of phosphoric acid (H_3PO_4) is 2.1. Given a 0.1M solution of H_3PO_4 and you are required to obtain a buffer solution of pH=2 by adding solution of NaH_2PO_4. What should be the concentration of the salt (NaH_2PO_4)? (Atomic mass: H=1, O=16, Na=23, P=31). *(3 marks)*
b) The table below shows the rates of reaction between substance A and B at different concentrations.

Experiment	[A] $moldm^{-3}$	[B] $moldm^{-3}$	Initial rate of reaction in $moldm^{-3}s^{-1}$
1.	0.50	0.50	2.0×10^{-2}
2.	1.00	0.50	8.0×10^{-2}
3.	1.00	1.00	16.0×10^{-2}

i. Determine the overall order of reaction. *(3 marks)*

ii. Calculate the rate constant indicating clearly its units. *(2 marks)*

c) Suggest 2 processes used to obtain hydrogen gas on a large scale from water. *(2 marks)*

18. a) The molecular formula of alanine amino acid is CH_3CHNH_2COOH.

i. Why does alanine amino acid present optical stereoisomerism? *(1 mark)*

ii. Draw the 2 structures of alanine that represent its optical stereoisomers. *(2 marks)*

b) i. Draw the 2 structures of 1, 2-dichloroethene that represent its geometrical stereoisomerism. *(2 marks)*

ii. Write the structural formula of the monomer which is used to synthesize natural rubber (Isoprene) *(1 mark)*

iii. State 2 requirements for improving the physical properties of rubber when tyres are manufactured. *(2 marks)*

iv. State 2 monomers (or draw the structural formulae of the monomers) that are used to make polyester (terylene). *(2 marks)*

19. a) i. Define HESS' law. *(2 marks)*

ii. Calculate the enthalpy of reaction (**X**) *(3 marks)*

$$CO_{(g)} + 2H_{2(g)} + \frac{3}{2}O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)} \; ; \; \Delta H_1^0 = -204.2\text{Kcal}$$

$$CH_3OH_{(l)} + \frac{3}{2}O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)} \; ; \Delta H_2^0 = -182.5 \text{ Kcal}$$

$$CO_{(g)} + 2H_{2(g)} \longrightarrow CH_3OH_{(l)} \; ; \Delta H_3^0 = \mathbf{X} \text{ Kcal}$$

b) According to the data given below in relation to the reaction:

$[I^-]$ (mol/dm^3)	$[BrO^{3-}]$ (mol/dm^3)	$[H^+]$ (mol/dm^3)	Rate $(moldm^{-3}s^{-1})$
0.10	0.10	0.10	3.0×10^{-4}
0.14	0.18	0.10	7.56×10^{-4}
0.10	0.18	0.10	5040×10^{-4}
0.31	0.18	0.20	1.67×10^{-3}

Equation

$$BrO_{3\,(aq)}^- + 9\,I_{(aq)}^- + 6\,H^+ \longrightarrow 3I_{3\,(aq)}^- + Br_{(aq)}^- + 3H_2O_{(l)}$$

i. Find the order of reaction with respect to:

I^-, BrO_3^- and H^+ *(3 marks)*

ii. Find the overall order of reaction. *(1 mark)*

iii. Find the rate constant K for the reaction. *(1 mark)*

20. a) Write the structural formula of the following molecules:

i. 3-Ethyl 2, 4-dimethyl pentane. *(2 marks)*

ii. 3, 4-Dimethyl pentan-2-ol. *(2 marks)*

b) Write a chemical equation for the cracking n-octane ($CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$). *(2 marks)*

c) Explain the following observations (use chemical equations to clarify your answer):

i. Zinc hydroxide precipitate, $Zn(OH)_2$, disappears (becomes soluble) when a solution of ammonia, NH_3, is added to it. *(2 marks)*

ii. Calcium phosphate, $Ca_3(PO4)_2$ is sparingly soluble in water but it dissolves in a solution of Nitric acid (HNO_3). *(2 marks)*

Chemistry II **014** 16 Nov. 2012 08.30am - 11.30am

REPUBLIC OF RWANDA

RWANDA EDUCATION BOARD (REB)

ADVANCED LEVEL NATIONAL EXAMINATIONS 2012

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:

This paper consists of **two** sections: **A** and **B**.

Section A: Attempt **all** questions. **(70 marks)**

Section B: Attempt any **three** questions. **(30 marks)**

You do not need the Periodic Table.

Silent non-programmable calculators may be used.

SECTION A : Attempt all questions. ***(70 marks)***

01. The molecular formula C_3H_6O represents two isomers.

(a) Define the term "isomers". ***(1 mark)***

(b) Give the structural formulae of the two isomers and name them. ***(4 marks)***

(c) Give a chemical test that could be used to distinguish between the two isomers, clearly stating the expected observations. ***(2 marks)***

02. Manganese (atomic number 25) is a transition element. It forms several compounds in which it shows different oxidation state.

(a) Give the electronic configuration of manganese (Mn) using the s, p, d ... notation. ***(1 mark)***

(b) Give the formula of an ion or compound in which the oxidation state/number of manganese is +7. ***(1 mark)***

(c) Manganese (IV) oxide is used to prepare chlorine gas according to the reaction below:

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + H_2O(l)$$

(i) Which element/ion is reduced and which one is oxidised? ***(2 marks)***

(ii) How could you show by a chemical test that chlorine gas is evolved? ***(1 mark)***

03. Silicon exists as three isotopes whose abundance is shown below:

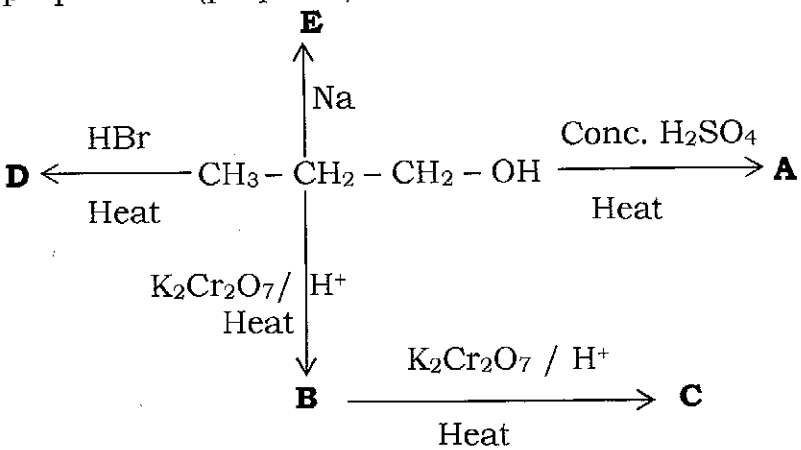
92% as $^{28}_{14}Si$, 5% as $^{29}_{14}Si$ and 3% as $^{30}_{14}Si$.

(a) Explain what is meant by the term "isotopes". ***(1 mark)***

(b) Calculate the relative atomic mass of silicon. ***(2 marks)***

(c) Silicon dioxide (silicon (IV) oxide) is a solid of high melting point. Explain in terms of bonding and structure why silicon dioxide has a high melting point. ***(1 mark)***

04. The reaction scheme below shows some reactions of propan-1-ol (propanol).



(a) Give the formulae or the names of the organic compounds **A**, **B**, **C**, **D** and **E**. ***(5 marks)***

(b) Why do alcohols have high boiling points compared to alkanes? ***(2 marks)***

05. The standard enthalpy change of formation of ethanol may be calculated by enthalpies of combustion of ethanol, carbon and hydrogen. The enthalpies of combustion are given below:

ΔH_C^θ (C_2H_5OH) = - 1368 $kJmol^{-1}$

ΔH_C^θ (H_2) = -286 $kJmol^{-1}$

ΔH_C^θ (C) = -394 $kJmol^{-1}$

(a) Define "standard enthalpy change of formation". ***(2 marks)***

(b) Use the above data to calculate the standard enthalpy change of formation of ethanol. ***(3 marks)***

06. The conversion of sulphur dioxide into sulphur trioxide in the contact process is a reversible reaction.

(a) Write a balanced equation for the reaction. ***(2 marks)***

(b) Write an expression for the equilibrium constant, K_C, for the reaction in (a). ***(1 mark)***

(c) Calculate the value of the equilibrium constant, K_C, and state its units given that the amounts present at equilibrium were: ***(3 marks)***

SO_2 = 0.4 $moldm^{-3}$; O_2 = 0.2 $moldm^{-3}$; SO_3 = 1.2 $moldm^{-3}$.

07. A reaction between A and B is represented by the equation:

$$2A + B \longrightarrow 2C + D$$

The reaction is known to be a second order with respect to A and first order with respect to B.

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

(b) State the overall order of the reaction. ***(1 mark)***

(c) Deduce the units of the rate constant. ***(1 mark)***

(d) If the concentration of both A and B are doubled by what factor does the rate change? ***(1 mark)***

08. The table below shows the boiling points of chlorides of period 3 in the Periodic Table.

Chloride	NaCl	$MgCl_2$	Al_2Cl_6	$SiCl_4$	PCl_3	S_2Cl_2
Boiling point (°C)	1465	1418	423	57	74	136

(a) Explain why the boiling points of $MgCl_2$ and PCl_3 are so different. ***(2 marks)***

(b) Explain the bonding present in Al_2Cl_6. ***(2 marks)***

09. The table below shows standard electrode potentials of some ions of group 7 elements of the Periodic Table.

$Cl_2 + 2e^- \longrightarrow 2Cl^-$ +1.36V

$2IO_3^- + 12H^+ + 10e^- \longrightarrow I_2 + 6H_2O$ +1.19V

$I_2 + 2e^- \longrightarrow 2I^-$ +0.54V

(a) Calculate the oxidation number of I in IO_3^-. ***(1 mark)***

(b) Write a balanced ionic equation for the reaction between IO_3^- and I^- in the presence of an acid. ***(3 marks)***

Calculate the standard cell e.m.f (E^θ cell) for the reaction.

(c) Would you expect a reaction between I_2 and Cl^-? Give a reason for your answer. ***(2 marks)***

10. Ammonia reacts with water as shown by the equation below:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

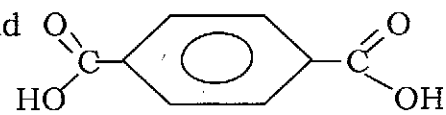
(a) Identify the acid-base conjugate pairs in the reaction. ***(2 marks)***

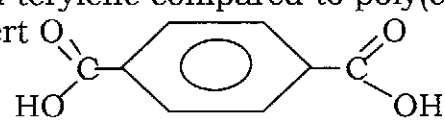
(b) The base dissociation constant (K_b) for ammonia is $1.20\times10^{-5}moldm^{-3}$.

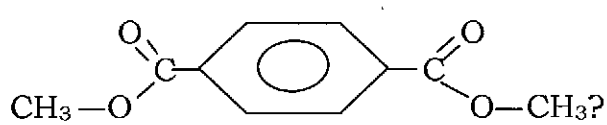
(i) Write an expression for K_b of ammonia. ***(1 mark)***

(ii) Calculate the concentration of OH^- ions in 0.1moldm^{-3} NH_3 (aq) and hence the pH of ammonia solution.
(K_w = 1.0 × 10^{-14} mol^{2}dm^{-6} at 25°C) ***(3 marks)***

11. Terylene is a polymer made from ethane-1,2-diol and benzene-1,4-dicarboxylic acid. The monomers are:

$HO - CH_2 - CH_2 - OH$ and 

(a) Give the structure of terylene showing only one repeat unit. ***(1 mark)***
(b) What type of polymer is terylene? ***(1 mark)***
(c) Give one advantage of terylene compared to poly(ethene). ***(1 mark)***
(d) How would you convert 

into  ***(2 marks)***

State the reagent and conditions.

12. The half-life of cobalt-60 ($^{60}_{27}Co$) is 5.2 years.
(a) What fraction of cobalt-60 would remain after 26 years? ***(2 marks)***
(b) State one medical use of cobalt-60. ***(1 mark)***
(c) One of the complex ions of cobalt is $[Co(NH_3)_4Cl_2]^+$.
Give the oxidation number of cobalt and the name of the shape of this complex ion. ***(2 marks)***

13. Hydrogen gas can be manufactured by reacting methane gas with steam under suitable conditions as shown by the equation:

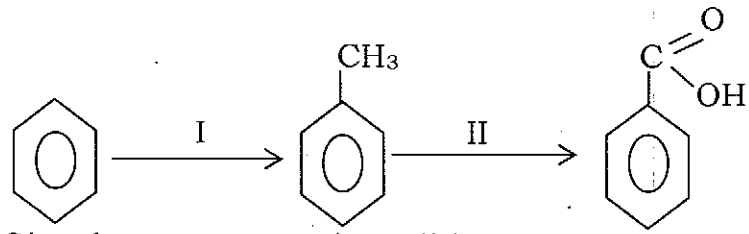
$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

The forward reaction is endothermic.

State and explain the effect on the position of equilibrium when
(a) Pressure is increased. ***(2 marks)***
(b) Temperature is increased. ***(2 marks)***
(c) More carbon monoxide is added. ***(2 marks)***

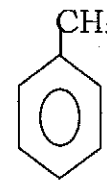
SECTION B: Attempt any three questions. ***(30 marks)***

14. Benzoic acid is prepared from benzene as shown below:



(a) Give the reagents and conditions for step I. ***(2 marks)***

(b) Give the reagent and conditions for step II. ***(2 marks)***

(c) Methylbenzene, 

, reacts with chlorine under conditions to give different products.

(i) Give the structure of the organic product when methylbenzene and chlorine react in the presence of UV light ***(1 mark)***

(ii) Give the structure of two isomers formed when methylbenzene reacts with chlorine in the presence of $FeCl_3$. ***(2 marks)***

(d) Benzoic acid is a weak acid.

(i) What is meant by "a weak acid"? ***(1 mark)***

(ii) The acid dissociation constant of benzoic acid (K_a) is 6.4×10^{-5} mol dm^{-3}.

Calculate the pH of 0.1 mol dm^{-3} benzoic acid solution. (You may use a simpler formula of benzoic acid as C_6H_5COOH.) ***(2 marks)***

15. An alloy of copper was converted into copper (II) ions using a suitable reagent. 4.0g of the alloy was converted into 400cm^3 of a solution of Cu^{2+} ions. 40cm^3 of the Cu^{2+}(aq) was reacted with potassium iodide solution to produce iodine solution. The iodine solution reacted completely with 50.0cm^3 of 0.1moldm^{-3} sodium thiosulphate ($Na_2S_2O_3$) solution. The

following ionic equations represent the main reactions which occurred:

$$2Cu^{2+}_{(aq)} + 4I^{-}_{(aq)} \longrightarrow 2CuI_{(s)} + I_{2(aq)}$$

$$I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2I^{-}_{(aq)}$$

(thiosulphate ions)

(a) Calculate the number of moles of $S_2O_3^{2-}$ present in $50cm^3$ of $0.1moldm^{-3}$ $Na_2S_2O_3$. ***(1 mark)***

(b) Calculate the number of moles of iodine that reacted with $S_2O_3^{2-}$ ions. ***(1 mark)***

(c) Calculate the number of moles Cu^{2+} in $40cm^3$ of solution of Cu^{2+}. ***(1 mark)***

(d) Calculate the number of moles of Cu^{2+} in $400cm^3$ of solution. ***(3 marks)***

(e) Calculate the mass of copper and hence the percentage of Cu in the alloy (Cu = 63.5). ***(2 marks)***

(f) A sample of $Cu^{2+}(aq)$ is reacted with aqueous ammonia until ammonia is in excess. State what would be observed and give the formula of the copper species present.

(g) Calculate the oxidation number of S in $S_2O_3^{2-}$. ***(1 mark)***

16. Electrolysis of brine (concentrated sodium chloride solution) is used to manufacture three different products.

(a) Using equations, explain the formation of the three products, showing clearly what happens at each electrode. ***(3 marks)***

(b) During electrolysis of brine, a current of 0.5A was passed for two and half hours.

(i) Calculate the quantity of electricity (amount of charge) passed. ***(2 marks)***

(ii) Calculate the mass of the product at the anode. ***(2 marks)***

(H = 1, Cl = 35.5, Na = 23, O = 16, 1Faraday = 96 500C.)

(iii) Calculate the mass of the product at the cathode. ***(2 marks)***

(c) What happens to the pH of the solution as electrolysis continues? Give a reason. ***(1 mark)***

17. Describe a chemical test you would use to distinguish between the pairs of compounds below. In each case give the reagent, conditions and the expected observation.

(a) $CH_3 - CH_2 - CH_3$ and $CH_3CH = CH_2$ ***(2 marks)***

(b) $CH_3 - CH_2 - \underset{\underset{OH}{|}}{CH} - CH_3$ and $CH_3 - \overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}} - OH$ ***(2 marks)***

(c) $CH_3 - \overset{\overset{O}{\|}}{C} - O - CH_3$ and $CH_3 - CH_2 - COOH$ ***(2 marks)***

(d) $FeSO_4$ and $CuSO_4$ ***(2 marks)***

(e) $CH_3 - CH_2 - \overset{\overset{O}{\|}}{C} - Cl$ and $CH_3 - CH_2 - CH_2Cl$ ***(2 marks)***

18. The chloride and oxide of phosphorus in the higher oxidation state are: PCl_5 and P_2O_5.

(a) Give the formulae of the chloride and oxide of phosphorus in a lower oxidation state. ***(2 marks)***

(b) Write a balanced equation for the reaction of PCl_5 with water. ***(2 marks)***

(c) Write a balanced equation for the reaction of P_2O_5 with water. ***(2 marks)***

(d) $25cm^3$ of the resulting solution of the reaction between P_2O_5 and water reacted completely with $25cm^3$ of $0.6moldm^{-3}$ NaOH. ***(2 marks)***
Calculate the concentration of the solution.

(e) What is the name of the shape of PCl_5? Give one of the bond angles in that shape. ***(2 marks)***

Chemistry II

013

04 Nov. 2011 08.30am - 11.30am

REPUBLIC OF RWANDA

RWANDA EDUCATION BOARD (REB)
P .O.BOX 3817 KIGALI. TEL/FAX: 586871

ADVANCED LEVEL NATIONAL EXAMINATIONS 2011

SUBJECT: CHEMISTRY II

PAPER II: THEORY

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

DURATION: 3 HOURS

INSTRUCTIONS:

This paper consists of **two** sections: **A** and **B**.

Section A: Attempt **all** questions. **(70 marks)**

Section B: Attempt any **three** questions. **(30 marks)**

You do not need the Periodic Table.

Silent non-programmable calculators may be used.

SECTION A : Attempt all questions. ***(70 marks)***

01. (a) Give the systematic names of three alcohols whose molecular formula is C_4H_9OH. ***(3 marks)***

(b) One of the alcohols in (a) can be oxidized to form a ketone.

(i) Give the structural formula of the alcohol. ***(1 mark)***

(ii) Give the structural formula of the ketone. ***(1 mark)***

02. 14.8g of magnesium nitrate were heated until there was no further change in the mass.

(a) Write a balanced equation for the reaction. ***(2 marks)***

(b) Calculate the mass of magnesium oxide produced. ***(2 marks)***

03. The atomic number of arsenic (As) is 33.

(a) Using s, p, d notation, give the electronic configuration of arsenic. ***(1 mark)***

(b) Predict the molecular formulae of two chlorides of arsenic. ***(2 marks)***

(c) Deduce the molecular shape and the bond angle of the chloride of arsenic in which arsenic shows a lower oxidation number. ***(2 marks)***

04. Aqueous bromide ions are oxidized by hydrogen peroxide in acidic medium according to the equation below:

$2Br^-_{(aq)} + H_2O_{2(aq)} + 2H^+_{(aq)} \rightleftharpoons Br_{2(aq)} + 2H_2O_{(l)}$ ΔH = negative

Predict and explain the effect on the equilibrium position when:

(a) A small amount of aqueous potassium bromide is added. ***(2 marks)***

(b) A small amount of aqueous sodium hydroxide is added. ***(2 marks)***

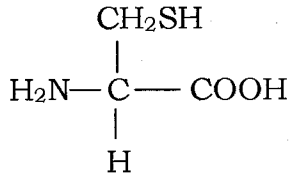
(c) The temperature is increased. ***(2 marks)***

05. (a) What is meant by the term 'electronegativity'? ***(2 marks)***

(b) State and explain the trend in electronegativity across period 3 from Na to Cl. ***(2 marks)***

(c) Explain the trend in polarity of the molecules of Group 7 hydrides from HF to HI. ***(2 marks)***

06. A naturally occurring amino acid cystine has the structure given below:



(a) Give the structural formula of a tripeptide formed from cystine molecules. ***(2 marks)***

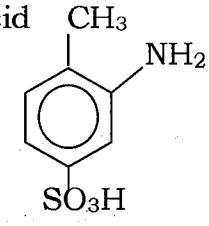
(b) Give the structural formula of the zwitterion formed from cystine. ***(1 mark)***

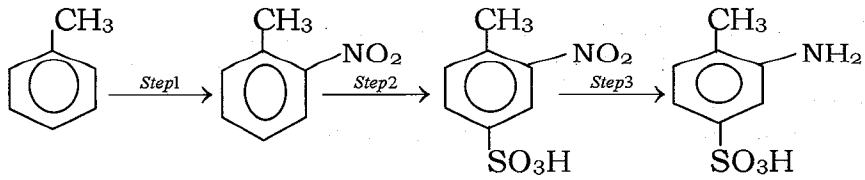
(c) Give the structural formula of the organic product formed when cystine reacts with:

(i) Hydrochloric acid solution. ***(1 mark)***

(ii) Aqueous sodium carbonate. ***(1 mark)***

(iii) Ethanol in the presence of an acid catalyst. ***(1 mark)***

07. A sulphonic acid  can be synthesized from methylbenzene according to the scheme shown below.

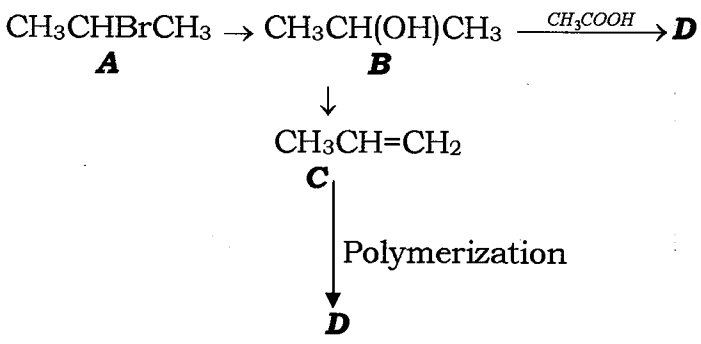


(a) What type of reaction is step 2? ***(1 mark)***

(b) For each of the steps 1 to 3, state the reagents and conditions needed to carry out the reaction. ***(6 marks)***

(c) Outline the mechanism for the reaction in step 2. ***(3 marks)***

08. The scheme below shows a number of reactions starting with 2-bromopropane (***A***).



(a) State the reagent and the type of reaction for converting ***A*** into ***B***. ***(2 marks)***

(b) Give the structural formula of compound ***D***. ***(1 mark)***

(c) Give the reagent and condition for converting ***B*** into ***C***. ***(2 marks)***

(d) Outline the mechanism for the reaction in which ***A*** is converted into ***B***. ***(3 marks)***

09. (a) What is meant by a Bronsted-Lowry acid?
Give one equation to show that ethanoic acid is a Bronsted-Lowry acid. ***(2 marks)***

(b) A buffer solution contains ethanoic acid and sodium ethanoate.
Using equations, explain how this buffer solution resists a change in pH when small amounts of acid or base are added. ***(4 marks)***

(c) Calculate the pH of a buffer solution which consists of 0.200 mol dm^{-3} of ethanoic acid and 0.250 mol dm^{-3} of sodium ethanoate. ***(3 marks)***
(K_a of ethanoic acid = 1.75×10^{-3} mol dm^{-3}).

10. The melting points of oxides of period 3 of the Periodic Table are given in the table below:

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_3
M.P.(°C)	1275	2827	2017	1607	580	33

Explain the following observations in terms of structure and bonding of the relevant oxides:

(a) The melting point of MgO is greater than that of SO_3. ***(2 marks)***

(b) The melting point of SiO_2 is greater than that of P_4O_{10}. ***(2 marks)***

11. Describe all colour changes that are observed when aqueous ammonia is gradually added to a solution of $Cu^{2+}_{(aq)}$.
Write a balanced equation for one of the reactions that occurs. ***(3 marks)***

12. For the elements of period 3 (Na to Ar) of the Periodic Table, state and explain:

(a) The general trend in the first ionization energy. ***(2 marks)***

(b) Why the first ionization energy of sulphur is lower than that of phosphorus. ***(2 marks)***

(Atomic Numbers: P = 15; S = 16)

SECTION B: Attempt any three questions. ***(30 marks)***

13. 7.00g of an impure sample of tin were reacted with dilute hydrochloric acid to convert it to tin (II) (Sn^{2+}) ions in aqueous solution. The solution was made up to 1 dm^3 with distilled water. 25.0 cm^3 of this solution were titrated with 0.02 mol dm^{-3} of acidified potassium manganate (VII) solution. 24.0 cm^3 of the manganate (VII) solution were needed to react completely with 25.0 cm^3 of the $Sn^{2+}_{(aq)}$. The relevant half-equations are:

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

(a) Write a balanced redox equation for the reaction between Sn^{2+} and acidified MnO_4^-. ***(2 marks)***

(b) Calculate the change in oxidation number of manganese in the redox reaction. ***(1 mark)***

(c) Calculate the number of moles of MnO_4^- in 24.0 cm^3 of the solution. ***(1 mark)***

(d) Calculate the number of moles of Sn^{2+} in 25.0 cm^3 of the solution and hence the concentration of Sn^{2+} in mol dm^{-3}. ***(2 marks)***

(e) Calculate the percentage of Sn in the original sample of tin. [A_r(Sn) = 119] ***(2 marks)***

(f) Using examples of CO_2 and SnO_2, briefly explain the trend in the acid-base character of oxides of Group IV in oxidation state +4. ***(2 marks)***

14. The production of ammonia in the Haber process involves the reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

(a) Write an expression for the equilibrium constant, K_c, for the above reaction. ***(1 mark)***

(b) 0.20 mol of $N_{2(g)}$ and 0.20 mol of $H_{2(g)}$ were reacted in a 1 dm^3 closed container until equilibrium was reached. At equilibrium, the concentration of $NH_{3(g)}$ was 0.060 mol dm^{-3}.

(i) Calculate concentrations of $N_{2(g)}$ and $H_{2(g)}$ at equilibrium. ***(2 marks)***

(ii) Calculate the value of K_c and state its units. ***(2 marks)***

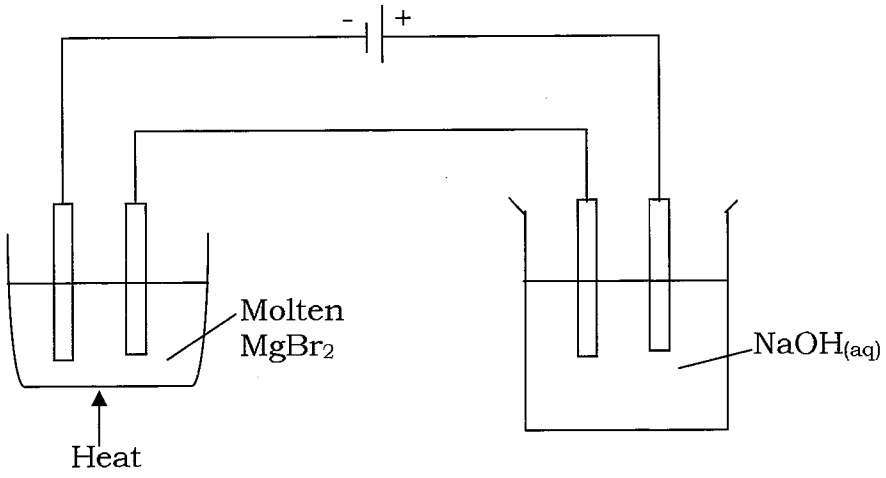
(c) How does an increase in pressure affect the yield of ammonia? Explain your answer. ***(2 marks)***

(d) The actual conditions used in the Haber process are a temperature of 500°C and a pressure of 200 atmospheres. Why are these conditions used instead of the conditions that would give the highest yield? ***(2 marks)***

(e) Give one large scale use of ammonia. ***(1 mark)***

15. (a) With the help of equations of reactions which occur at each electrode, outline what happens during electrolysis of dilute aqueous sodium chloride. What happens to the pH of the solution as electrolysis continues? ***(3 marks)***

(b) Two electrolytic cells containing molten magnesium bromide and dilute sodium hydroxide respectively are connected in series as shown in the diagram below.



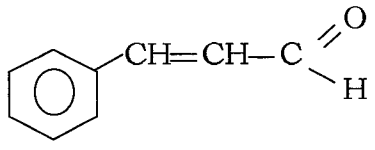
The electrodes in both cells are inert. 6.0 g of magnesium is produced in the first cell.

(i) Identify the products produced in the second cell. ***(2 marks)***

(ii) Calculate the mass of each product in the second cell. ***(3 marks)***
(Mg = 24, Br = 80, Na = 23, H = 1, O = 16)

(c) Briefly outline a method of purifying copper using electrolysis. ***(2 marks)***

16. (a) The organic compound whose structure is shown below can be extracted from some plants:



Give the structural formula of the organic compound formed when the above compound reacts with

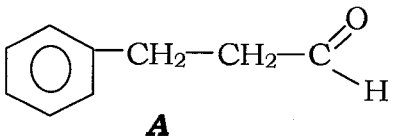
(i) Steam ***(1 mark)***

(ii) Hydrogen cyanide ***(1 mark)***

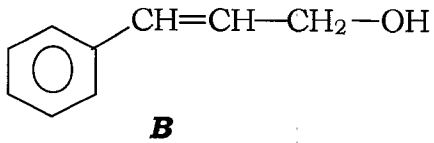
(iii) Acidified $K_2Cr_2O_7$ ***(1 mark)***

(iv) Bromine water or bromine dissolved in an organic solvent. ***(1 mark)***

(b) Describe simple test tube reactions you could use to distinguish between two compounds ***A*** and ***B*** shown below:



A



B

In each test, state the reagents and what you would observe. You need to describe one test in each case. ***(4 marks)***

(c) State two different methods used to produce ethanol on a large scale in industries. ***(2 marks)***

17. (a) By means of equations, outline the steps involved in the manufacture of sulphuric acid from sulphur in the contact process. ***(4 marks)***

(b) Concentrated sulphuric acid can be used to prepare hydrogen chloride from sodium chloride. Briefly explain why a similar method is not suitable for preparing hydrogen bromide from sodium bromide. ***(2 marks)***

(c) Briefly explain why water is a liquid which boils at 100°C at normal atmospheric pressure while hydrogen sulphide is a gas at room temperature and pressure. ***(2 marks)***

(d) Briefly explain the environmental impact of using coal containing sulphur as a source of energy. ***(2 marks)***

Chemistry I

021

13th Nov. 2006 8.30-11.30 a.m

RWANDA NATIONAL EXAMINATIONS COUNCIL

P.O. BOX 3817 KIGALI-TEL/FAX : 586871

ADVANCED LEVEL NATIONAL EXAMINATIONS 2006

SUBJECT : CHEMISTRY I

OPTION : BIOLOGY-CHEMISTRY

DURATION : 3 HOURS

INSTRUCTIONS :

This paper consists of THREE sections : A, B, and C.

SECTION A : Answer ALL questions /55 marks

SECTION B : Answer THREE questions from this section /30marks

SECTION C : Answer ONE question from this section /15marks

Calculators may be used.

SECTION A : Answer ALL questions /55 marks

1. The atomic number of sulphur is 16

(a) In terms of s,p,d electrons, write the electronic configuration of sulphur. **(1mark)**

(b) In which block of the Periodic Table is sulphur located? **(1mark)**

(c) Explain briefly why the first ionisation energy of sulphur is lower than that of phosphorus (atomic number 15) **(2marks)**

2. ${}^{238}_{92}U$ undergoes radioactive decay as shown below:

$$ {}^{238}_{92}U \xrightarrow{\alpha-emission} A \xrightarrow{\beta-emission} B \xrightarrow{\beta-emission} X $$

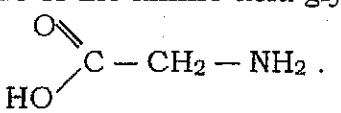
$$ X \xrightarrow{\alpha-emission} Y $$

(a) Calculate the mass number and atomic number of element Y. **(2marks)**

(b) State one medical use of radioactive isotopes. **(1mark)**

(c) A radioactive isotope has a half-life of 15 days. What fraction of the original amount of the isotope would remain after 75 days? **(2marks)**

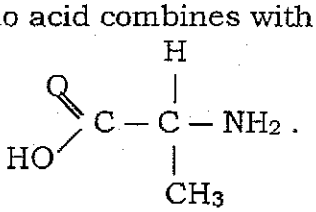
3. The structure of the amino acid glycine is



(1mark)

(a) Write the Zwitterion form of the above amino acid. **(1mark)**

(b) Write the structure of the dipeptide formed when the above amino acid combines with alanine:



(c) Show the structure of the organic product formed when glycine is reacted with nitrous acid. (HNO_2) **(1mark)**

4. Chloroethene, C_2H_3Cl, is the monomer from which the important plastic poly(chloroethene), PVC, is made.

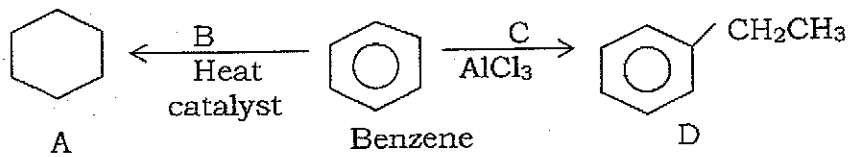
(a) Draw the structural formula of chloroethene. **(1mark)**

(b) Chloroethene can be made in the laboratory using the route below:

$$C_2H_4 \xrightarrow{Step1} C_2H_4Cl_2 \xrightarrow{Step2} C_2H_3Cl$$

i) What reagent is used in step 1? **(1mark)**
ii) State the reagent and conditions used in step 2. **(2marks)**
iii) Give one use of PVC. **(1mark)**

5. Benzene undergoes two reactions shown below:



Give the names of the substances A, B, C and D. **(4marks)**

6. Esters are widely used and some esters occur naturally.

(a) Draw the structural formulae of any three different esters that have the molecular formula $C_5H_{10}O_2$. **(3marks)**

(b) Write an equation for the hydrolysis of one of these esters by hot, aqueous sodium hydroxide. **(1mark)**

7. The standard enthalpy change of the reaction:

$C_2H_{4(g)} + H_2O_{(g)} \longrightarrow C_2H_5OH_{(\ell)}$ can be calculated from standard enthalpy changes of combustion given below:

$C_2H_{4(g)}$ $\quad \Delta H_c^{\theta} = -1411$ kJmol^{-1}

$C_2H_5OH_{(\ell)}$ $\quad \Delta H_c^{\theta} = -1367$ kJmol^{-1}

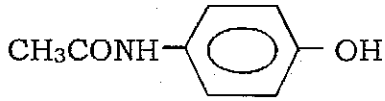
(a) What is meant by standard enthalpy change of combustion? **(2marks)**

(b) Calculate the standard enthalpy change of the above reaction. **(2marks)**

8. (a) Write a balanced equation to show the thermal decomposition of calcium nitrate, $Ca(NO_3)_2$. **(2marks)**

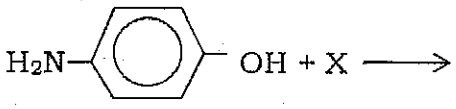
(b) Which one has a higher thermal stability, $Mg(NO_3)_2$ or $Ca(NO_3)_2$. Give a reason for your answer. **(2marks)**

9. A common medicinal drug used as a pain killer has the following structure.



(a) Name two functional groups in the above molecule. **(2marks)**

(b) The medicinal drug can be produced by using the reaction.



i) Suggest the identity of X. **(1mark)**

ii) What reagent would you use to convert ethanoic acid, CH_3COOH, into X. **(1mark)**

10. (a) State and explain the trend of acid strength of the hydrogen halides HCl, HBr and HI. **(2marks)**

(b) A test-tube containing hydrogen chloride gas is inverted in water. Describe what you would observe. **(1mark)**

11. Explain the following observations, clearly showing chemical principles involved.

(a) Ammonia forms complex ions with cobalt(II) ions but methane does not. **(1mark)**

(b) A blue solution of copper(II) sulphate turns green, then yellow when concentrated hydrochloric acid is added. **(2marks)**

12. A reaction between A and B was investigated to determine its rate equation. The results of the investigation are shown in the following table. The temperature was kept constant during the investigation.

[A] (mol dm^{-3})	[B] (mol dm^{-3})	Initial rate (mol $dm^{-3}s^{-1}$)
0.2	0.2	3.2×10^{-4}
0.4	0.2	1.3×10^{-3}
0.4	0.4	1.3×10^{-3}

(a) Deduce the order of the reaction with respect to:
(i) A (ii) B **(2marks)**

(b) Write the rate equation for the reaction **(1mark)**

13. K_a for propanoic acid (CH_3CH_2COOH) is 1.3×10^{-5} mol dm^{-3}.

(a) Write an equation for the dissociation of propanoic acid in aqueous solution **(1mark)**

(b) Calculate the pH of a 0.10 mol dm^{-3} (0.10M) solution of propanoic acid. **(2marks)**

14. The decomposition of dinitrogen tetroxide is represented by the equation.

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)} \quad (\Delta H \text{ is positive})$$

(a) Write an expression for the equilibrium constant, K_p, for this reaction. **(1mark)**

(b) Explain the effect on the equilibrium mixture when the pressure is doubled at a constant temperature. **(2marks)**

15. An electrochemical cell is represented as shown below:

$Mn_{(s)} \mid Mn^{2+}_{(aq)} \parallel Ni^{2+}_{(aq)} \mid Ni_{(s)}$

Use the following data to answer the questions:

$$Mn^{2+}_{(aq)} + 2e^- \rightleftharpoons Mn_{(s)} \qquad E^\theta = -1.18V$$

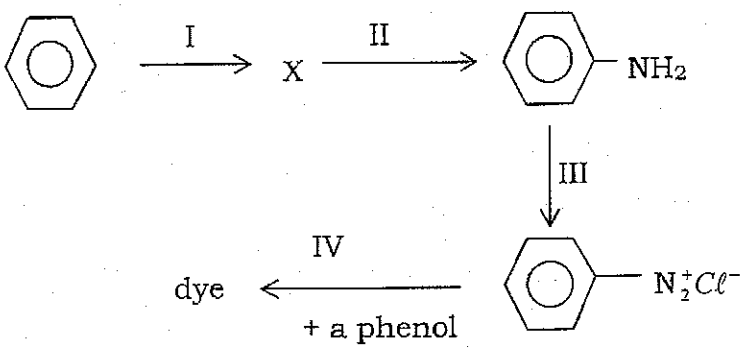
$$Ni^{2+}_{(aq)} + 2e^- \rightleftharpoons Ni_{(s)} \qquad E^\theta = -0.23V$$

(a) Calculate cell e.m.f (E^θ cell). **(1mark)**

(b) State and explain how the cell e.m.f would change if the concentration of $Mn^{2+}_{(aq)}$ is increased in the left hand half-cell. **(2marks)**

SECTION B: Answer THREE questions from this section /30 marks

16. Dyes can be made from aromatic amines and are widely used in textile industries. One synthetic route for making a dye is shown as follows:

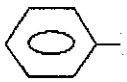


(a) Draw the structural formula of the intermediate compound X. **(1mark)**

(b) State the reagents and conditions for

(i) step I **(2marks)**

(ii) step II **(2marks)**

(c) Phenylamine  is a weak base.

(i) Write an equation to show phenylamine acting as a base. **(1mark)**

(ii) Which one is a stronger base, phenylamine or ammonia? Explain your reasoning. **(2marks)**

(d) State the reagent for step III. **(1mark)**

(e) Give the structural formula of the dye formed when benzene diazonium chloride reacts with phenol. **(1mark)**

17. Zinc is extracted from zinc sulphide in a series of steps. The first step is to roast the sulphide ore in air:

$2\ ZnS_{(s)} + 3O_{2(g)} \rightarrow 2\ ZnO_{(s)} + 2\ SO_{2(g)}$

The final step is to convert ZnO to Zn.

(a) Use the data below to calculate ΔH^{θ} for the above reaction:

$\Delta H_f^{\theta}\ [ZnS_{(s)}] = -200\ kJmol^{-1}$

$\Delta H_f^{\theta}\ [ZnO_{(s)}] = -348\ kJmol^{-1}$

$\Delta H_f^{\theta}\ [SO_{2(g)}] = -297\ kJmol^{-1}$. **(3marks)**

(b) Is the reaction exothermic or endothermic? **(1mark)**

(c) What environmental problem could arise from this process of extraction? **(1mark)**

(d) Suggest one method that can be used to eliminate this environmental problem. **(1mark)**

(e) Suggest a compound or an element which can reduce zinc oxide to zinc. Write an equation for the reaction. **(2marks)**

(f) You are provided with a solution containing zinc ions and lead ions. Suggest a reagent you could use to separate the two ions. Explain the chemical principles involved in this separation. **(2marks)**

18. Two organic compounds X and Y both have the molecular formula C_4H_8O. Both compounds give yellow precipitates when added to 2,4 – dinitrophenylhydrazine (Brady's reagent)

(a) What can you deduce about X and Y? **(1mark)**

(b) Compound X gives a red precipitate when warmed with Fehling's solution but Y shows no reaction when treated this way.

(i) What further deductions can you make about the natures of X and Y? **(1mark)**

(ii) Give the name or the formula of the red precipitate. **(1mark)**

(c) Draw the structural formula of compound Y and give its systematic name. **(2marks)**

(d) The compound $CH_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle OH}{\overset{|}{\underset{|}{C}}}} - CN$ is a product of the reaction between an organic compound and hydrogen cyanide (HCN).

(i) Give the structural formula of the original organic compound. **(1mark)**

(ii) Give the mechanism for the reaction between HCN and the original organic compound. **(3marks)**

(e) Give the structural formula of the organic compound formed when $CH_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle OH}{\overset{|}{\underset{|}{C}}}} - CN$ is reacted with Lithium aluminium hydride ($LiAlH_4$). **(1mark)**

19. (a) What is meant by the term acid according to the Brönsted-Lawry theory of acids and bases? **(1mark)**

(b) Identify two substances acting as acids in the following reaction:

$CH_3NH_2 + H_2O \rightleftharpoons CH_3\overset{+}{N}H_3 + OH^-$ **(2marks)**

(c) Write an expression for the solubility product (K_{sp}) of calcium hydroxide. **(1mark)**

(d) A 20.0cm^3 sample of saturated, aqueous calcium hydroxide required 18.2cm^3 of 0.050 mol dm^{-3} hydrochloric acid for neutralisation. Calculate:

(i) the concentration of OH^- in the saturated solution. **(2marks)**

(ii) A value for the solubility product of calcium hydroxide, stating the units. **(3marks)**

(e) Explain why calcium hydroxide is more soluble in water than potassium hydroxide. **(1mark)**

20. Electrolysis has many applications in industry. One such application is the manufacture of hydrogen, chlorine and sodium hydroxide by electrolysis of brine (concentrated sodium chloride solution)

(a) Briefly outline, using relevant equations how the above products are formed by electrolysis of brine. **(5marks)**

(b) A current of 0.200 A is passed through Copper (II) sulphate solution for 10 hours.

(i) Calculate the mass of copper deposited on the cathode.

(Cu = 63.5, F = 96,500 C mol^{-1}) **(3marks)**

(ii) Calculate the volume of oxygen evolved at the anode (measured at room temperature and pressure). You may use the following data:

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

Molar volume of a gas at r.t.p. = 24 dm^3. **(2marks)**

SECTION C: Answer ONE question from this section /15 marks

21. (a) What mass of potassium iodate (V) (KIO_3) would be required to make 250 cm^3 of a solution containing one-sixtieth (1/60) of a mole per dm^3. (K = 39, I = 127, O = 16) **(2marks)**

(b) When 25 cm^3 of the solution of potassium iodate (V) of the above concentration in (a) was added to excess of acidified potassium iodide solution, the iodine produced reacted with 20 cm^3 of a solution of sodium thiosulphate. Use these equations to answer the questions that follow:

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

(i) Calculate the number of moles of iodate (IO_3^-) ions in 25cm^3 of the solution. **(1mark)**

(ii) Deduce the number of moles of $2S_2O_3^{2-}$ ions in 20 cm^3. **(1mark)**

(iii) Calculate the concentration of the thiosulphate solution in mol dm^{-3}. **(2marks)**

(iv) Give the name of a suitable indicator to use in the titration of iodine solution with the thiosulphate solution. **(1mark)**

(c) Concentrations of chlorine in treated water for domestic use can be monitored by testing water samples. In one such test, excess potassium iodide (KI) was added to a 1000 cm^3 sample of water. The liberated iodine reacted with 14.0 cm^3 of 0.00100 mol dm^{-3} sodium thiosulphate solution (0.00100M)

(i) Calculate the number of moles of sodium thiosulphate, $Na_2S_2O_3$, used in the reaction and hence the number of moles of iodine liberated. **(2marks)**

(ii) Write an equation for the reaction between $Cl_{2(aq)}$ and $I^-_{(aq)}$ ions. Identify the reducing agent in this reaction. **(2marks)**

(iii) Calculate the number of moles of Cl_2 and hence the mass of chlorine molecules in the original sample of water (Cl = 35.5). **(2marks)**

(iv) Write an equation for the reaction between Cl_2 and water and show that this is a disproportionation reaction. **(2marks)**

22. Describe a chemical test to distinguish between each of the pairs of the following compounds. Include in your description the expected observation and give relevant equations for the reactions involved.

(a) NH_4NO_3 and $Mg(NO_3)_2$. **(3marks)**

(b) $CH_3CH_2COCH_2CH_3$ and $CH_3CH_2CH_2CH_2CHO$ **(3marks)**

(c) $CH_3CH_2CH_2Cl$ and $CH_3CH_2\overset{\overset{O}{\|}}{C}-Cl$ **(3marks)**

(d) $CH_3CH = CH_2$ and $CH_3CHBrCH_3$ **(3marks)**

(e) Cu_2O and CuO **(3marks)**

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Chemistry II **023** 13th Nov.2006 8.30-11.30a.m

RWANDA NATIONAL EXAMINATIONS COUNCIL

P.O. BOX 3817 KIGALI-TEL/FAX : 586871

ADVANCED LEVEL NATIONAL EXAMINATIONS 2006

SUBJECT : CHEMISTRY II

OPTION : MATH - PHYSICS

DURATION : 3 HOURS

INSTRUCTIONS :

This paper consists of THREE sections : A, B, and C.

SECTION A : Answer ALL questions /55 marks

SECTION B : Answer THREE questions from this section /30marks

SECTION C : Answer ONE question from this section /15marks

Calculators may be used.

SECTION A : Answer ALL questions /55 marks

1. The atomic number of sulphur is 16

(a) In terms of s,p,d electrons, write the electronic configuration of sulphur. **(1mark)**

(b) In which block of the Periodic Table is sulphur located? **(1mark)**

(c) Explain briefly why the first ionisation energy of sulphur is lower than that of phosphorus (atomic number 15) **(2marks)**

2. $^{238}_{92}U$ undergoes radioactive decay as shown below:

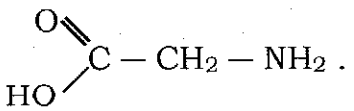
$$^{238}_{92}U \xrightarrow{\alpha-emission} A \xrightarrow{\beta-emission} B \xrightarrow{\beta-emission} X \xrightarrow{\alpha-emission} Y$$

(a) Calculate the mass number and atomic number of element Y. **(2marks)**

(b) State one medical use of radioactive isotopes. **(1mark)**

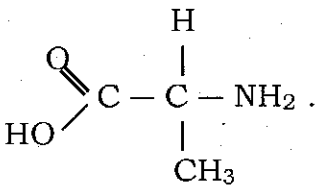
(c) A radioactive isotope has a half-life of 15 days. What fraction of the original amount of the isotope would remain after 75 days? **(2marks)**

3. The structure of the amino acid glycine is



(a) Write the Zwitterion form of the above amino acid. **(1mark)**

(b) Write the structure of the dipeptide formed when the above amino acid combines with alanine:



(1mark)

(c) Show the structure of the organic product formed when glycine is reacted with nitrous acid. (HNO_2) **(1mark)**

4. Chloroethene, C_2H_3Cl, is the monomer from which the important plastic poly(chloroethene), PVC, is made.

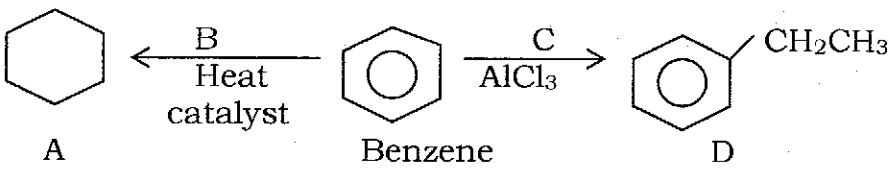
(a) Draw the structural formula of chloroethene. **(1mark)**

(b) Chloroethene can be made in the laboratory using the route below:

$$C_2H_4 \xrightarrow{Step1} C_2H_4Cl_2 \xrightarrow{Step2} C_2H_3Cl$$

i) What reagent is used in step 1? **(1mark)**
ii) State the reagent and conditions used in step 2. **(2marks)**
iii) Give one use of PVC. **(1mark)**

5. Benzene undergoes two reactions shown below:



Give the names of the substances A, B, C and D. **(4marks)**

6. Esters are widely used and some esters occur naturally.

(a) Draw the structural formulae of any three different esters that have the molecular formula $C_5H_{10}O_2$. **(3marks)**

(b) Write an equation for the hydrolysis of one of these esters by hot, aqueous sodium hydroxide. **(1mark)**

7. The standard enthalpy change of the reaction:

$C_2H_{4(g)} + H_2O_{(g)} \longrightarrow C_2H_5OH_{(\ell)}$ can be calculated from standard enthalpy changes of combustion given below:

$C_2H_{4(g)}$ $\quad \Delta H_c^{\theta} = -1411$ kJmol^{-1}

$C_2H_5OH_{(\ell)}$ $\quad \Delta H_c^{\theta} = -1367$ kJmol^{-1}

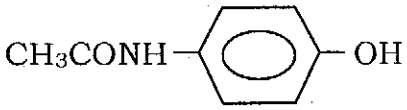
(a) What is meant by standard enthalpy change of combustion? **(2marks)**

(b) Calculate the standard enthalpy change of the above reaction. **(2marks)**

8. (a) Write a balanced equation to show the thermal decomposition of calcium nitrate, $Ca(NO_3)_2$. **(2marks)**

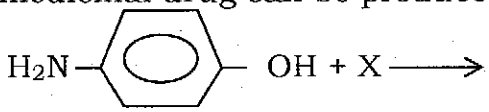
(b) Which one has a higher thermal stability, $Mg(NO_3)_2$ or $Ca(NO_3)_2$. Give a reason for your answer. **(2marks)**

9. A common medicinal drug used as a pain killer has the following structure.



(a) Name two functional groups in the above molecule. **(2marks)**

(b) The medicinal drug can be produced by using the reaction.



i) Suggest the identity of X. **(1mark)**

ii) What reagent would you use to convert ethanoic acid, CH_3COOH, into X. **(1mark)**

10. (a) State and explain the trend of acid strength of the hydrogen halides HCl, HBr and HI. **(2marks)**

(b) A test-tube containing hydrogen chloride gas is inverted in water. Describe what you would observe. **(1mark)**

11. Explain the following observations, clearly showing chemical principles involved.

(a) Ammonia forms complex ions with cobalt(II) ions but methane does not. **(1mark)**

(b) A blue solution of copper(II) sulphate turns green, then yellow when concentrated hydrochloric acid is added. **(2marks)**

12. CCl_4 is unreactive when mixed with water but $SiCl_4$ hydrolyses in water.

(a) Write an equation for the reaction between $SiCl_4$ and water. **(1mark)**

(b) Briefly explain why CCl_4 does not react with water while $SiCl_4$ is hydrolysed readily. **(2marks)**

13. Draw an energy profile (energy against progress of reaction) for a reversible exothermic reaction

$A + B \rightleftharpoons C + D$ **(1mark)**

On the diagram show:

(a) ΔH **(1mark)**

(b) the activation energy, E_a , of the reaction. **(1mark)**

14. The atomic number of Copper (Cu) is 29.

(a) Give the electronic structure (configuration) of Cu and explain why it is unusual. **(2marks)**

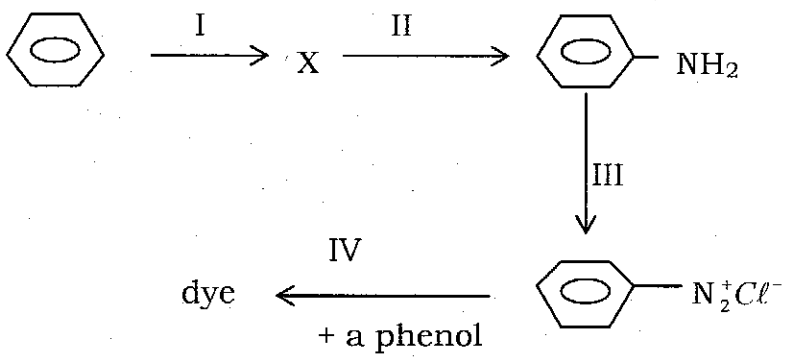
(b) Give the electronic configuration of Cu in the complex ion $[Cu(H_2O)_6]^{2+}$ **(1mark)**

15. A red solid $A(Pb_3O_4)$ on treatment with dulute nitric acid gave a brown solid B and a colourless solution. Solid B when treated with concentrated hydrochloric acid gave a greenish-yellow gas C which bleached damp red litmus paper. The resulting solution, on cooling, gave a white precipitate D. Identify (by the name or the formula):

(a) B (b) C (c) D **(3marks)**

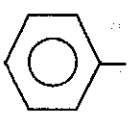
SECTION B: Answer THREE questions from this section. /30marks

16. Dyes can be made from aromatic amines and are widely used in textile industries. One synthetic route for making a dye is shown as follows:



(a) Draw the structural formula of the intermediate compound X. **(1mark)**

(b) State the reagents and conditions for
(i) step I **(2marks)**
(ii) step II **(2marks)**

(c) Phenylamine  is a weak base.
(i) Write an equation to show phenylamine acting as a base. **(1mark)**
(ii) Which one is a stronger base, phenylamine or ammonia? Explain your reasoning. **(2marks)**

(d) State the reagent for step III. **(1mark)**

(e) Give the structural formula of the dye formed when benzene diazonium chloride reacts with phenol. **(1mark)**

17. Zinc is extracted from zinc sulphide in a series of steps. The first step is to roast the sulphide ore in air:

$2\ ZnS_{(s)} + 3O_{2(g)} \rightarrow 2\ ZnO_{(s)} + 2\ SO_{2(g)}$

The final step is to convert ZnO to Zn.

(a) Use the data below to calculate ΔH^{θ} for the above reaction:

$\Delta H_f^{\theta}\ [ZnS_{(s)}] = -200 KJmol^{-1}$

$\Delta H_f^{\theta}\ [ZnO_{(s)}] = -348\ Kjmol^{-1}$

$\Delta H_f^{\theta}\ [SO_{2(g)}] = -\ 297\ Kjmol^{-1}$. **(3marks)**

(b) Is the reaction exothermic or endothermic? **(1mark)**

(c) What environmental problem could arise from this process of extraction? **(1mark)**

(d) Suggest one method that can be used to eliminate this environmental problem. **(1mark)**

(e) Suggest a metal or an element which can reduce zinc oxide to zinc. Write an equation for the reaction. **(2marks)**

(f) You are provided with a solution containing zinc ions and lead ions. Suggest a reagent you could use to separate the two ions. Explain the chemical principles involved in this separation. **(2marks)**

18. Two organic compounds X and Y both have the molecular formula C_4H_8O. Both compounds give yellow precipitates when added to 2,4 – dinitrophenylhydrazine (Brady's reagent)

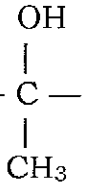
(a) What can you deduce about X and Y? **(1mark)**

(b) Compound X gives a red precipitate when warmed with Fehling's solution but Y shows no reaction when treated this way.

(i) What further deductions can you make about the natures of X and Y? **(1mark)**

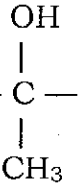
(ii) Give the name or the formula of the red precipitate. **(1mark)**

(c) Draw the structural formula of compound Y and give its systematic name. **(2marks)**

(d) The compound  is a product of the reaction between an organic compound and hydrogen cyanide (HCN).

(i) Give the structural formula of the original organic compound. **(1mark)**

(ii) Give the mechanism for the reaction between HCN and the original organic compound. **(3marks)**

(e) Give the structural formula of the organic compound formed when  is reacted with Lithium aluminium hydride ($LiAlH_4$). **(1mark)**

19. Briefly explain the following observations

(a) The shape of H_2O molecule is bent (V-shaped) while that of H_3O^+ ion is pyramidal. **(3marks)**

(b) Silicon has a high melting point while silicon tetrachloride is a volatile liquid. **(3marks)**

(c) The lattice energy of lithium chloride is more exothermic than that of sodium chloride. **(2marks)**

(d) The melting point of manganese (atomic number 25) is higher than that of potassium (atomic number 19). **(2marks)**

20. (a) With the help of equations, describe the reactions that occur when chlorine is bubbled through

(i) cold aqueous sodium hydroxide. **(2marks)**

(ii) hot aqueous sodium hydroxide. **(2marks)**

(b) (i) Write an equation to show the reaction of propene with bromine vapour (Br_2). **(1mark)**

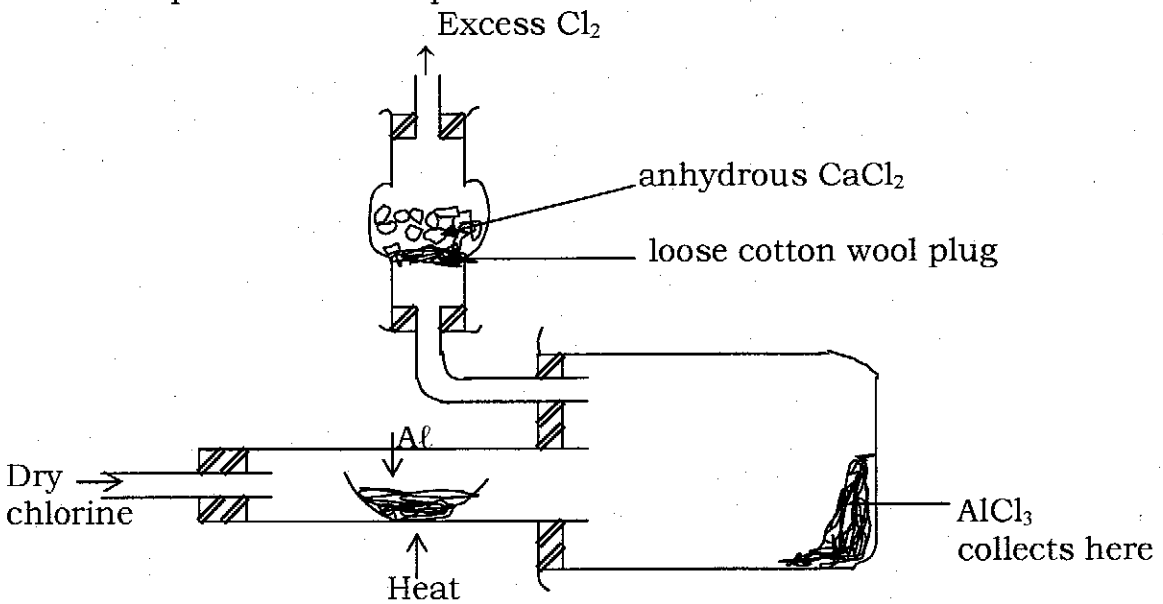
(ii) Describe the mechanism of the reaction, showing clearly the steps involved. **(3marks)**

(c) (i) How does the volatility of halogens (Group VII elements) change down the group? **(1mark)**

(ii) Briefly explain why the volatility changes the way you have described. **(1mark)**

SECTION C: Answer ONE question from this section /15marks

21. Anhydrous aluminium chloride is prepared by passing dry chlorine over hot aluminium under anhydrous conditions. The hot aluminium chloride sublimes and deposits on the cooler part of the apparatus. The experimental set-up is shown below:



(a) Give the reagents you would use to prepare chlorine gas. **(2marks)**

(b) What is the function of anhydrous calcium chloride? **(1mark)**

(c) Why is it necessary to prepare $AlCl_3$ under anhydrous conditions. **(1mark)**

(d) In the vapour phase aluminium chloride exists as Al_2Cl_6. Draw the structure of Al_2cl_6 and show the nature of bonds in the molecule. **(2marks)**

(e) What is a Lewis acid? Using any suitable example, explain how $AlCl_3$ behaves as a Lewis acid. **(3marks)**

(f) Write ionic equations to show the amphoteric nature of Al_2O_3. **(3marks)**

(g) Why does aluminium metal resist corrosion? **(1mark)**

(h) Why does aluminium have a higher electrical conductivity than magnesium? **(2marks)**
(Atomic numbers of Mg and Al are 12 and 13 respectively)

22. Describe a chemical test to distinguish between each of the pairs of the following compounds. Include in your description the expected observation and give relevant equations for the reactions involved.

(a) NH_4NO_3 and $Mg(NO_3)_2$. **(3marks)**

(b) $CH_3CH_2COCH_2CH_3$ and $CH_3CH_2CH_2CH_2CHO$ **(3marks)**

(c) $CH_3CH_2CH_2Cl$ and $CH_3CH_2\overset{\overset{O}{\|}}{C}-Cl$ **(3marks)**

(d) $CH_3CH = CH_2$ and $CH_3CHBrCH_3$ **(3marks)**

(e) Cu_2O and CuO **(3marks)**

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Chemistry I	
021	
22 Nov. 2005	8h30 –11h30 am

RWANDA NATIONAL EXAMINATIONS COUNCIL

P.O. BOX 3817 KIGALI-TEL/FAX : 586871

NATIONAL EXAMINATION 2005

SUBJECT : CHEMISTRY I

OPTION : BIOLOGY - CHEMISTRY

DURATION : 3 HOURS

INSTRUCTIONS :

This paper consists of THREE Sections A, B and C.

- Answer ALL questions in section A.
- Choose THREE questions from section B.
- Choose ONE question from section C.

Calculators may be used.

SECTION A: Answer ALL questions /55 Marks.

1. The percentage abundances of the stable isotopes of chromium are:
$^{50}_{24}Cr$: 4.31%, $^{52}_{24}Cr$: 83.76%, $^{53}_{24}Cr$: 9.55%, $^{54}_{24}Cr$: 2.38%

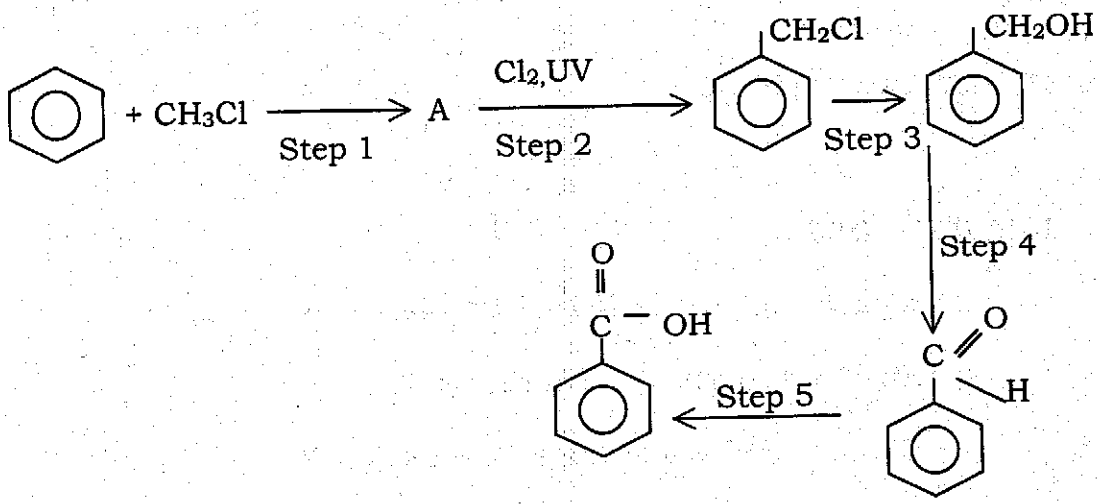
   (a) What is meant by the term "isotopes" and why do isotopes of chromium show similar chemical properties? **(2marks)**

   (b) Calculate the relative atomic mass of chromium, correct to three significant figures. **(1mark)**

   (c) Calculate the number of neutrons in the most abundant isotope of chromium. **(1mark)**

2. This question concerns the following oxides
   Na_2O , MgO , SiO_2 , SO_3 .
   From the list above identify the oxide that best fits the description given:
   (a) An oxide that is insoluble in water. **(1mark)**
   (b) An oxide that has simple molecular structure at room temperature and pressure. **(1mark)**
   (c) An oxide that reacts with water forming a strongly alkaline solution. **(1mark)**
   (d) An oxide that is slightly soluble in water forming a weakly alkaline solution. **(1mark)**

3. A possible synthetic route from benzene to benzoic acid is shown below:



   (a) Give the formulae of a suitable catalyst for step 1 and give the structural formula of compound A. **(2marks)**
   (b) Give the name of the reagent used and the type of reaction in step 3. **(2marks)**
   (c) Name the reagent used in step 4 **(1mark)**

4. Use the bond enthalpies/bond energies in the table below to answer the questions that follow:

Bond	Average bond enthalpy/KJ mol^{-1}
F – F	158
C – H	412
Cl – Cl	242
H – Cl	432
C – Cl	338

(a) Calculate the enthalpy change for the reaction:
$C_3H_8 + Cl_2 \longrightarrow C_3H_7Cl + HCl$. **(2marks)**

(b) By considering the bonds broken and the bonds formed, calculate the average value for the S – F bond energy in the reaction:

$$SF_{4(g)} + F_{2(g)} \longrightarrow SF_{6(g)} \quad \Delta H = -438 \text{ KJmol}^{-1}$$

State any assumption you have made. **(3marks)**

5. (a) (i) Explain what is meant by the standard enthalpy change of formation of a compound. **(1mark)**

(ii) Write a balanced equation which represents the standard enthalpy change of formation of propane. **(1mark)**

(b) Calculate the standard enthalpy change of formation of propane from the standard enthalpy changes of combustion given below:

	ΔH_c^{θ} /KJmol[1]
Carbon	-393
Hydrogen	-286
Propane	-2220

(3marks)

6. This question concerns some reactions of a compound X which has the structure: $CH_3 - CH_2 - CH_2 - CH_2 - OH$

(a) Give the systematic name of compound X. **(1mark)**
(b) Is X a primary, secondary or tertiary alcohol? **(1mark)**
(c) What name is given to the intermolecular forces in compound X? **(1mark)**

(d) Give the structural formulae for two organic compounds which could be obtained by reacting X with a hot mixture of potassium dichromate and sulphuric acid. **(2marks)**

7. Boron, nitrogen and oxygen form fluorides with molecular formulae BF_3 , NF_3 and OF_2

(a) Draw the shape of each molecule and show the position of lone pairs of electrons if any. **(3marks)**

(b) Give the bond angle in each case, explaining your reasons. **(3marks)**

8. (a) Write down the electronic configuration of a calcium atom and of a calcium ion in terms of s.p..... orbitals.
(The atomic number of calcium = 20) **(2marks)**

(b) Why is the atomic radius of calcium significantly greater than the ionic radius of the calcium ion. **(1mark)**

(c) Explain why the hydration energy (enthalpy change of hydration) of Mg^{2+} is more exothermic than that of Ca^{2+}? **(1mark)**

9. Over one million tons of manganese are produced in the world each year.

(a) Write the electronic configuration of manganese (atomic number = 25) and use it to explain why manganese is a transition element. **(2marks)**

(b) State, with specific examples, two properties of manganese or its compounds which are typical of transition elements. **(2marks)**

(c) Calculate the oxidation number of manganese in the ion MnO_4^{2-}. **(1mark)**

10. Explain the following:
(a) The boiling point of water (H_2O) is higher than that of hydrogen sulphide (H_2S). **(1mark)**
(b) The boiling points of ethane, water and sodium hydride increase in the order: $C_2H_6 < H_2O < NaH$. **(2marks)**

11. Consider the following equilibrium reactions:
Reaction I : $3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$
Reaction II: $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

(a) Write expressions for the equilibrium constant, Kp
(i) for reaction I
(ii) for reaction II **(2marks)**

(b) State, giving reasons, how an increase in pressure affects the the position of equilibrium in each reaction above. **(2marks)**

12. A radioactive isotope X decays by emitting beta particles. It was found that only $\frac{1}{32}$ of the original isotope remained after 100 days. Calculate the half-life of the radioactive isotope. **(2marks)**

13. An electric current was passed through two beakers containing aqueous silver nitrate and aqueous copper(II)sulphate connected in series. After 30 minutes 0.100g of silver was deposited in the first beaker

    (a) Write an equation for the deposit of silver. **(1mark)**

    (b) Calculate the current passed(Ag = 108, F = 96500 C mol^{-1}) **(2marks)**

SECTION B: Choose THREE questions from this section /30 Marks.

14. Some foodstuffs contain "acidity regulators" which have a buffering action on the pH. Mixtures of citric acid and its sodium salt are often used for this purpose.

    $C_5H_7O_4COOH \rightleftharpoons C_5H_7O_4COO^- + H^+$

    Citric acid $Ka = 7.4 \times 10^{-4}$ mol dm^{-3}

    (a) The concentration of citric acid in lemon juice is 0.23 mol dm^{-3}. Assuming that no other acid is present, calculate the pH of lemon juice. **(3marks)**

    (b) Write equations to show how citric acid and sodium citrate buffer system regulates the acidity on the addition of:
    (i) H^+ ions
    (ii) OH^- ions **(2marks)**

    (c) Calculate the pH of a solution containing 0.20 mol dm^{-3} citric acid and 0.3 mol dm^{-3} sodium citrate. **(2marks)**

    (d) Define the term K_w and explain why, at 25°C, water has a pH of 7. **(3marks)**

15. (a) Give the formulae of the three structural isomers of C_4H_8 which are non-cyclic. **(3marks)**

    (b) One of these isomers shows a type of stereoisomerism .
    (i) Give the structures of the stereoisomers and name them. **(2marks)**

    (ii) Give a chemical test for the functional group present in the isomers and describe the expected observation. **(2marks)**

(c) One of the isomers of C_4H_8 in (a) reacts with HBr to give two different products, the major one of which is a chiral molecule.

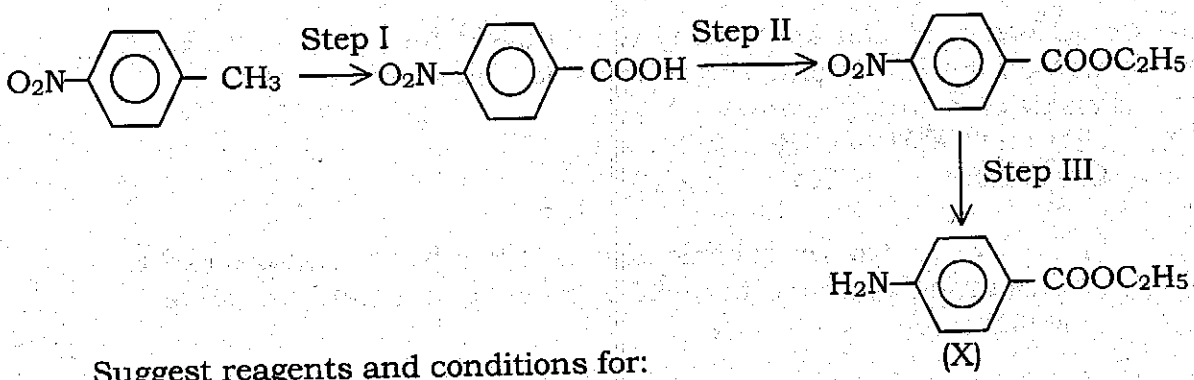
(i) Identify this isomer of C_4H_8. **(1mark)**

(ii) Give the mechanism for the reaction of this isomer with HBr. **(2marks)**

16. (a) What reagents and conditions are used to prepare nitrobenzene from benzene? **(2marks)**

(b) The reaction in (a) is described as electrophilic substitution. Describe the mechanism of this reaction, clearly indicating how the electrophile is formed and its role in all the steps. **(2marks)**

(c) The local pain killer labelled as X below is synthesized from the aromatic compound 4 – nitromethylbenzene as shown in the following steps.



Suggest reagents and conditions for:

Step I

Step II

Step III **(6marks)**

17. The reversible reaction: $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ is used in the Contact process for the manufacture of sulphuric acid, using V_2O_5 catalyst.

(a) (i) Calculate the enthalpy of reaction, ΔH, of the forward reaction, assuming it goes to completion. You are given the enthalpies of formation of $SO_{2(g)}$ and $SO_{3(g)}$ which are -297 and -395 KJ mol^{-1} respectively. **(2marks)**

(ii) State and explain the effect of raising the temperature on the position of equilibrium of this reaction. **(2marks)**

(iii) The optimum temperature used in this industrial process is 450°C. Basing your answers on economics and chemical principles, suggest two reasons which determine the choice of this operating temperature. **(2marks)**

(iv) What is the effect of the catalyst on the position of equilibrium in this reaction? **(1mark)**

(b) (i) Write an expression for the equilibrium constant K_c for the reaction. **(1mark)**

(ii) What is the effect of increasing the concentration of oxygen (at the same temperature) on:
I : the equilibrium constant, K_c.
II : the position of equilibrium. **(2marks)**

18. The following list gives standard electrode potentials for various half-cells:

	E^{θ}/volts
$I_{2(aq)} + 2e^- \leftrightharpoons 2I^-_{(aq)}$	+ 0.54
$Ag^+_{(aq)} + e^- \leftrightharpoons Ag_{(s)}$	+ 0.80
$F_{2(g)} + 2e^- \leftrightharpoons 2F^-_{(aq)}$	+ 2.87
$O_{2(g)} + 4H^+_{(aq)} + 4e^- \leftrightharpoons 2H_2O_{(\ )}$	+ 1.23
$Mg^{2+}_{(aq)} + 2e^- \leftrightharpoons Mg_{(s)}$	- 2.36
$Cu^{2+}_{(aq)} + 2e^- \leftrightharpoons Cu_{(s)}$	+ 0.34

(a) Draw a labeled diagram of a cell which can be used to measure the standard electrode potential of the Cu^{2+}/Cu half-cell. **(4marks)**

(b) From the list above, identify the
(i) Strongest reducing agent
(ii) Strongest oxidizing agent **(2marks)**

(c) Calculate the standard cell e.m.f (E^{θ} cell) corresponding to the cell reaction:
$2Cu^{2+}_{(aq)} + 2H_2O_{(\ )} \rightarrow 2Cu_{(s)} + O_{2(g)} + 4H^+_{(aq)}$ **(1mark)**

(d) When a constant current was passed through an aqueous solution of copper(II) nitrate for one hour the mass of the copper cathode increased by 15.24g.
Calculate the current in amperes which was used.
(F = 96500C mol^{-1}, Cu = 63.5) **(3marks)**

SECTION C: Answer ONE question from this section /15 Marks.

19. For each of the following pairs of compounds identify the chemical test which can be used to distinguish between them. State clearly the expected observations and write relevant equations for the reactions involved.

(a) $CH_3CH_2CH_2CH_2OH$ and $CH_3CH_2CH_2CHO$

(b) $CH_3CH_2CH_2CO_2H$ and $CH_3CH_2CH(OH)CH_3$

(c) $CH_3CH(OH)CH_3$ and $(CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-OH)$ or $(CH_3)_3COH$

(d) $Zn(NO_3)_2$ and $Pb(NO_3)_2$

(e) Na_2SO_3 and Na_2SO_4 **(3marks each)**

20. A 25.0 cm^3 portion of a solution containing Fe^{2+} ions and Fe^{3+} ions was acidified and titrated against potassium manganate(VII) (potassium permanganate) solution. 15.0 cm^3 of a 0.0200 mol dm^{-3} (0.0200M) solution of potassium manganate(VII) were required. In this titration only Fe^{2+} ions react with MnO_4^- ions in an acidic solution. A second 25.0cm^3 portion was reacted with zinc to reduce Fe^{3+} to Fe^{2+}. After the reduction, the sample of 25.0 cm^3 portion was titrated against the same manganate(VII) solution. 19.0 cm^3 of the manganate(VII) solution were required.

(a) Explain why no indicator is required in this titration. **(1mark)**

(b) Use the half-equations below to write the overall redox equation for the reaction between Fe^{2+} and MnO_4^- in an acidic medium:

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

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

(2marks)

(c) Calculate the number of moles of MnO_4^- in 15.0 cm^3 of 0.0200 mol dm^{-3} solution of $KMnO_4$. **(1mark)**

(d) Calculate the concentration in mol dm^{-3} of Fe^{2+} in the original sample of the solution. **(3marks)**

(e) Calculate the number of moles of MnO_4^- in 19.0 cm^3 of 0.0200 mole dm^{-3} (0.0200M) $KmnO_4$. **(1marks)**

(f) Calculate the total concentration of Fe^{2+} in mol dm^{-3} after the reduction of Fe^{3+} in the second portion of the solution. **(3marks)**

(g) Hence calculate the concentration of Fe^{3+} in the original sample of the solution in mol dm^{-3}. **(1mark)**

(h) Calculate the ratio of concentrations of Fe^{3+}: Fe^{2+} in the original sample. **(2marks)**

(i) The final ratio of concentrations of Fe^{3+} : Fe^{2+} is higher after several hours of exposure of the solution to the atmosphere. Suggest an explanation for this. **(1mark)**

Chemistry II

023

12 Oct 2004 8h30 – 11h30

RWANDA NATIONAL EXAMINATIONS COUNCIL

B.P. 3817 KIGALI - TEL/FAX : 586871

NATIONAL EXAMINATION 2003/2004

SUBJECT : CHEMISTRY II

OPTION : MATH - PHYSICS

DURATION : 3 HOURS

INSTRUCTIONS :

This paper consists of THREE sections A, B and C.

Answer ALL questions in section A.

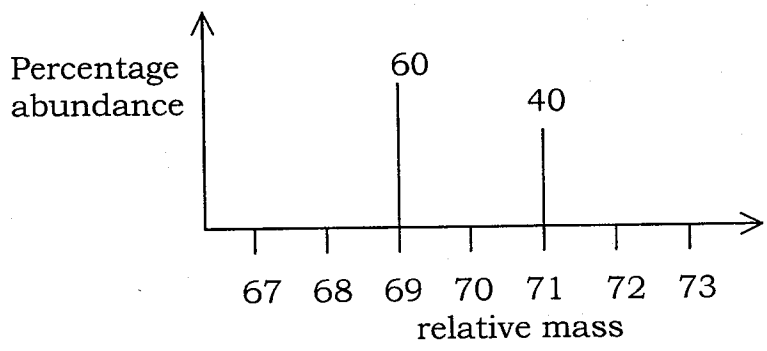
Choose THREE questions from section B.

Choose ONE question from section C.

Calculators may be used.

SECTION A: Answer ALL questions.

1. (a) The diagram below shows the mass spectrum for naturally occurring gallium (Ga).



Calculate the relative atomic mass of naturally occurring gallium. **(2marks)**

(b) Bromine (Br) has two isotopes ^{79}Br and ^{81}Br, if Bromine is used in the mass spectrometer there are three peaks of Br_2^+ at 158, 160 and 162. Show which molecular ions are responsible for these peaks. **(1½marks)**

2. (a) State Hess's Law. **(2marks)**

(b) The standard enthalpy change for the combustion of carbon is $-394\ KJmol^{-1}$, and that of carbonmonoxide is $-111KJmol^{-1}$. Calculate the standard enthalpy change for the reaction $2C_{(s)} + O_2 \rightarrow 2CO_{(g)}$. **(3marks)**

(c) Which of the two reactions below is more likely to take place? Give a reason for your answer.

$2C_{(s)} + O_2 \rightarrow 2CO_{(g)}$

$C_{(s)} + O_2 \rightarrow CO_{2(g)}$ **(1mark)**

3. The compound $C_2H_4Br_{2(\ell)}$ can be made by reacting ethene with bromine.

(a) Show the mechanism for the above reaction. **(2marks)**

(b) What observations would you make at the end of the reaction? **(1mark)**

(c) If $C_2H_4Br_2$ is refluxed with aqueous sodium hydroxide, an organic product B is formed. Write the structural formula of the organic product B and give its systematic name. **(1mark)**

4. An alcohol (Alkanol) has a relative mass of 74 and has the following composition by mass: C, 64.9%; H, 13.5%; O, 21.6%

(a) Show that its empirical formula is the same as its molecular formula. **(3marks)**

(b) Draw the structural formulae of four possible isomers of the alcohol. **(2marks)**

(c) One of the isomers F can be oxidised to form a ketone, G. Show the structural formula of F and G. **(1mark)**

5. The table below gives some data about the chlorides of elements of period 3.

Formula	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	S_2Cl_2	Cl_2
Boiling point °C	1465	1418	423	57	76	136	-34.
P^H of aqueous solution	7	6	2	2	2	1	1

(a) Explain why the boiling point of NaCl is higher than that of $MgCl_2$. **(2marks)**

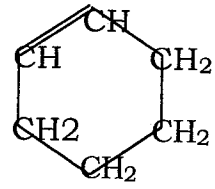
(b) Explain why the P^H of NaCl is 7 and that of $AlCl_3$ is 2. **(2marks)**

6. When dilute sulphuric acid is added to copper I oxide, a pink solid X and a blue solution Y are formed. The pink solid X conducts electricity.

(a) Identify X and Y. **(1mark)**

(b) Write an equation for the reaction. **(1mark)**

(c) Using examples from the reaction above, explain the meaning of disproportionation. **(1½marks)**

7. When1 mole of cyclohexene C_6H_{10} 

is reduced by 1 mole of H_2 to form cyclohexane C_6H_{12}, the enthalpy change of hydrogenation is −119 $KJmol^{-1}$, but when 1 mole of benzene C_6H_6 is reduced by 3 moles of H_2 to cyclohexane, the enthalpy of hydrogenation is not −357 but -207 $KJmol^{-1}$.

(a) Why is benzene reduced by 3 moles of H_2 but cyclohexene is reduced by 1 mole of H_2 ? **(1mark)**

(b) Explain the difference between the theoretical enthalpy of hydrogenation of benzene and the experimentally determined value. **(2marks)**

8. NH_3 reacts with H_2O according to the following reaction

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(a) Which of the species in the above reaction is a Lewis base and which is a Lewis Acid? **(1mark)**

(b) Draw the structures of NH_3, H_2O and NH_4^+ and explain which of the species has the least bond angle. **(2marks)**

9. Butane C_4H_{10} reacts with Cl_2 in the presence of sunlight to form a mixture of products including C_4H_9Cl which is formed as shown in the equation below

$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$.

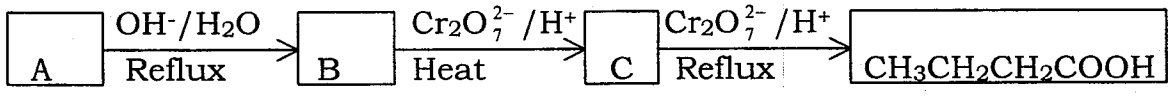
(a) Write equations for the following stages in the mechanism of the reaction.

(i) Equation for the initiation stage.

(ii) Equation for the propagation stage.

(iii) Equation for the termination stage. **(1½marks)**

(b) Compound A which is one of the Isomers of C_4H_9Cl was reacted in sequence as shown below



(i) Write the structural formulae of A, B and C. **(1½marks)**

(ii) What chemical test would you use to show that compound C has formed. **(1½marks)**

10. The table below shows some bond enthalpies. Study the table below and answer the questions that follow.

Bond	Average bond energy/KJmol^{-1}
F – F	+158
Cl - Cl	+244
H – F	+568
H – Cl	+432

Given that the enthalpy change for the reaction $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ is –184 KJmol^{-1}.

(a) Calculate the bond enthalpy of the H – H bond. **(2marks)**

(b) Calculate the enthalpy change for the formation of HF from its elements $H_{2(g)} + F_{2(g)} \rightarrow 2HF_{(g)}$. **(2marks)**

11. Complete the following equation for the decay of bismuth into substance A.

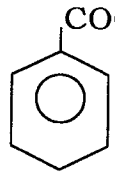
(a) $^{214}_{83}Bi \rightarrow {}^{0}_{-1}\beta + A$. **(1mark)**

(b) The half life of bismuth is 19.7 minutes. Determine the time taken for $1/8$ by mass of bismuth to decay. **(2marks)**

(c) Explain why radio active substances undergo decay. **(1½marks)**

12. Write equations to show how the following compounds can be synthesised.

(a) CH_3COOH from CH_3CH_2Cl. **(2½maks)**

(b)  from benzene. **(2½marks)**

13. Given that atomic numbers of Chromium (Cr) and Copper (Cu) are 24 and 29 respectively.

(a) Write the electronic configuration of Cr and Cu. **(1mark)**

(b) Explain why Cr has an oxidation state of +6. **(2marks)**

(c) State whether anhydrous Copper I chloride is coloured or white. **(1mark)**

SECTION B: Choose THREE questions from this section.

14. Study the table below and answer the questions that follow.

Enthalpy change	$KJmol^{-1}$
Atomisation of Potassium	+90
Atomisation of Iodine	+107
1st Ionization energy of Potassium	+420
1st Electron affinity of Iodine	-314
Formation of Potassium Iodide	-328

(a) Construct a Born Haber's cycle and calculate the lattice energy of Potassium Iodide. **(5marks)**

(b) Given that: $K^+_{(g)} + (aq) \rightarrow K^+_{(aq)}$ $\Delta H = -304$ KJmol^{-1}

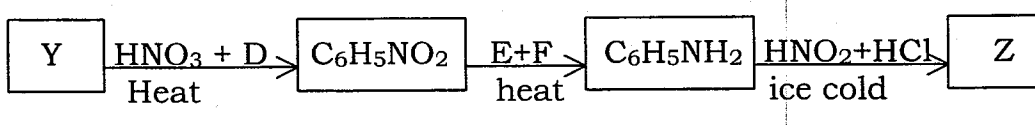
$I^-_{(g)} + (aq) \rightarrow I^-_{(aq)}$ $\Delta H = -306$ KJmol^{-1}

$K^+_{(g)} + I^-_{(g)} \rightarrow KI_{(s)}$ $\Delta H = -631$ KJmol^{-1}

(i) Calculate the enthalpy of solution of potassium Iodide. **(3marks)**

(ii) How would you confirm presence of Iodide ions in aqueous solution? **(2marks)**

15. The flow chart below shows a synthetic route for the preparation of compound Z starting with compound Y.



(a) Name compounds Y, D, E, F and Z. **(5marks)**

(b) Show the reaction mechanism in the formation of compound $C_6H_5NO_2$ from compound Y. **(3marks)**

(a) Explain why compound Y undergoes electrophilic substitution more readily than $C_6H_5NO_2$. **(2marks)**

16. The boiling points of the hydrides of group VII elements are given below.

Compound	HF	HCl	HBr	HI
Boiling point (°C)	+19.9	-85.0	-66.7	-35.4

(a) Explain the trend in the boiling points of the hydrides. **(5marks)**

(b) Suggest why a solution of HCl in methyl benzene doesn't conduct electricity but its solution in water conducts electricity. **(2marks)**

(c) With reasons suggest which of the hydrides above is the strongest acid? **(3marks)**

17. In terms of advantages and disadvantages,

(a) Explain the difference between soap and detergents. **(8marks)**

(b) State two raw materials that can be used in the manufacture of soap. **(2marks)**

18. (a) Draw and name the type of crystal lattice formed by the following.

(i) Iodine
(ii) Sodium chloride
(iii) Silicon dioxide

(4½marks)

(b) Explain how the bonding affects the boiling point in each of the compounds mentioned above. **(5½marks)**

SECTION C: Answer ONE question from this section.

19. For each of the following pairs of compounds identify the chemical test that can be used to distinguish them stating clearly the observations and writing relevant equations where possible.

(a) $CH_3\ CH_2\ \overset{\overset{O}{\|}}{C} - CH_2\ CH_3$ and $CH_3CH_2CH_2CH_2CHO$.

(b) $C_6\ H_5\ CH_2OH$ and C_6H_5OH.

(c) $CH_3CH = CH_2$ and $CH_3\ CH_2\ CH_3$.

(d) $Al(NO_3)_3$ and $Cu(NO_3)_2$.

(e) $FeCl_2$ and $FeCl_3$. **(3marks each)**

20. (a) With the aid of relevant diagrams describe an experiment that can be carried out to dermine the enthalpy of displacement of copper in $CuSO_4$ solution by Zinc. **(10marks)**

(b) Explain how a pure sample of $ZnSO_4$ can be obtained from the mixture mentioned in 20(a). **(5marks)**

21. (a) With the aid of a well labelled diagram, explain how sodium hydroxide can be manufactured from Brine. **(10marks)**

(b) Suggest five different uses of sodium hydroxide. **(5marks)**

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RWANDA NATIONAL EXAMINATIONS COUNCIL

B.P. 3817 KIGALI - TEL/FAX : 586871

Chemistry I

021

12 Oct 2004 8h30 – 11h30

NATIONAL EXAMINATION 2003/2004

SUBJECT : CHEMISTRY I

OPTION : BIOLOGY - CHEMISTRY

DURATION : 3 HOURS

INSTRUCTIONS :

This paper consists of THREE sections A, B and C.

Answer ALL questions in section A.

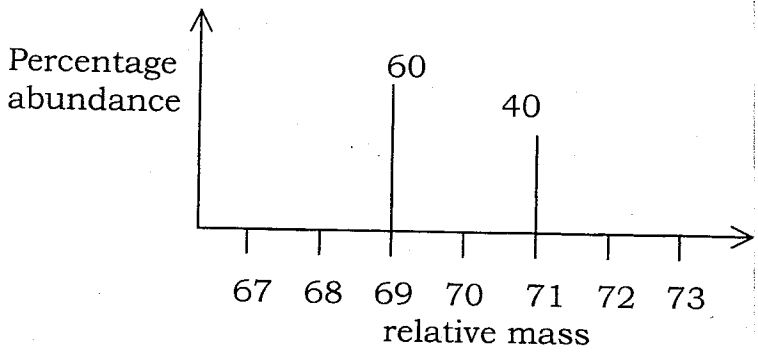
Choose THREE questions from section B.

Choose ONE question from section C.

Calculators may be used.

SECTION A: Answer ALL questions.

1. (a) The diagram below shows the mass spectrum for naturally occurring gallium (Ga).



Calculate the relative atomic mass of naturally occurring gallium. **(2marks)**

(b) Bromine (Br) has two isotopes ^{79}Br and ^{81}Br. If Bromine is used in the mass spectrometer there are three peaks of Br_2^+ at 158, 160 and 162. Show which molecular ions are responsible for these peaks. **(1½marks)**

2. (a) State Hess's Law. **(2marks)**

(b) The standard enthalpy change for the combustion of carbon is $-394\ KJmol^{-1}$, and that of carbonmonoxide is $-111KJmol^{-1}$. Calculate the standard enthalpy change for the reaction $2C_{(s)} + O_2 \rightarrow 2CO_{(g)}$. **(3marks)**

(c) Which of the two reactions below is more likely to take place? Give a reason for your answer.

$2C_{(s)} + O_2 \rightarrow 2CO_{(g)}$

$C_{(s)} + O_2 \rightarrow CO_{2(g)}$ **(1mark)**

3. The compound $C_2H_4Br_{2(\ell)}$ can be made by reacting ethene with bromine.

(a) Show the mechanism for the above reaction. **(2marks)**

(b) What observations would you make at the end of the reaction? **(1mark)**

(c) If $C_2H_4Br_2$ is refluxed with aqueous sodium hydroxide, an organic product B is formed. Write the structural formula of the organic product B and give its systematic name. **(1mark)**

4. An alcohol (Alkanol) has a relative mass of 74 and has the following composition by mass: C, 64.9%; H, 13.5%; O, 21.6%

(a) Show that its empirical formula is the same as its molecular formula. **(3marks)**

(b) Draw the structural formulae of four possible isomers of the alcohol. **(2marks)**

(c) One of the isomers F can be oxidised to form a ketone, G. Show the structural formula of F and G. **(1mark)**

5. The table below gives some data about the chlorides of elements of period 3.

Formula	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	S_2Cl_2	Cl_2
Boiling point °C	1465	1418	423	57	76	136	-34.
PH of aqueous solution	7	6	2	2	2	1	1

(a) Explain why the boiling point of NaCl is higher than that of $MgCl_2$. **(2marks)**

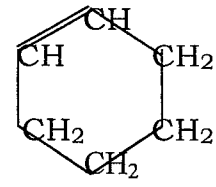
(b) Explain why the PH of NaCl is 7 and that of $AlCl_3$ is 2. **(2marks)**

6. When dilute sulphuric acid is added to copper I oxide, a pink solid X and a blue solution Y are formed. The pink solid X conducts electricity.

(a) Identify X and Y. **(1mark)**

(b) Write an equation for the reaction. **(1mark)**

(c) Using examples from the reaction above, explain the meaning of disproportionation. **(1½marks)**

7. When 1 mole of cyclohexene C_6H_{10}  is reduced by 1 mole of H_2 to form cyclohexane C_6H_{12}, the enthalpy change of hydrogenation is −119 $KJmol^{-1}$, but when 1 mole of benzene C_6H_6 is reduced by 3 moles of H_2 to cyclohexane, the enthalpy of hydrogenation is not −357 but -207 $KJmol^{-1}$.

(a) Why is benzene reduced by 3 moles of H_2 but cyclohexene is reduced by 1 mole of H_2 ? **(1mark)**

(b) Explain the difference between the theoretical enthalpy of hydrogenation of benzene and the experimentally determined value.

(2marks)

8. NH_3 reacts with H_2O according to the following reaction

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(a) Which of the species in the above reaction is a Lewis base and which is a Lewis Acid?

(1mark)

(b) Draw the structures of NH_3, H_2O and NH_4^+ and explain which of the species has the least bond angle.

(2marks)

9. Butane C_4H_{10} reacts with Cl_2 in the presence of sunlight to form a mixture of products including C_4H_9Cl which is formed as shown in the equation below

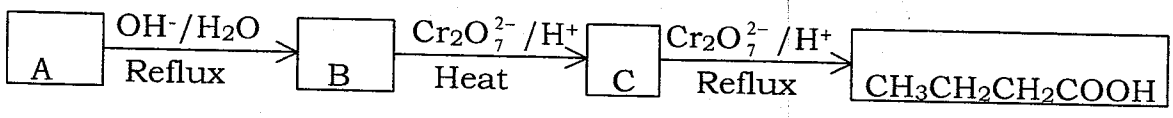
$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$.

(a) Write equations for the following stages in the mechanism of the reaction.

(i) Equation for the initiation stage.
(ii) Equation for the propagation stage.
(iii) Equation for the termination stage.

(1½marks)

(b) Compound A which is one of the Isomers of C_4H_9Cl was reacted in sequence as shown below



(i) Write the structural formulae of A, B and C.

(1½marks)

(ii) What chemical test would you use to show that compound C has formed?

(1½marks)

10. The table below shows some bond enthalpies. Study the table below and answer the questions that follow.

Bond	Average bond energy/KJmol^{-1}
F – F	+158
Cl - Cl	+244
H – F	+568
H – Cl	+432

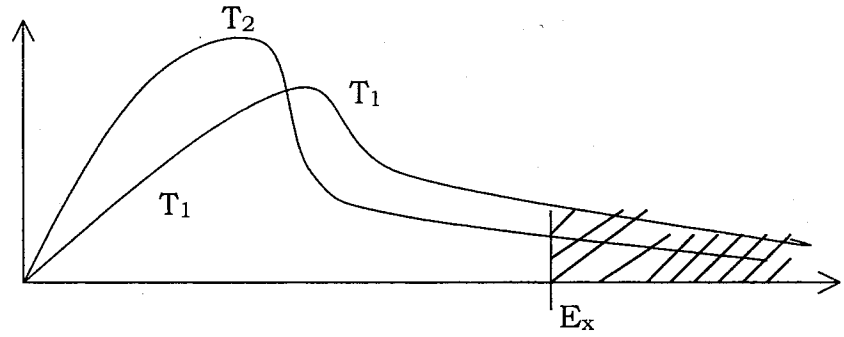
Given that the enthalpy change for the reaction $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ is –184 KJmol^{-1},

(a) Calculate the bond enthalpy of the H – H bond.

(2marks)

(b) Calculate the enthalpy change for the formation of HF from its elements $H_{2(g)} + F_{2(g)} \rightarrow 2HF_{(g)}$. **(2marks)**

11. The graph below shows the Boltzmann distribution curve for the same amount of a gas sample at two different temperatures.



(a) State what you would label on X and Y axis. **(1mark)**
(b) What does the shaded part represent? **(1mark)**
(c) Explain why a small increase in temperature increases the rate of a chemical reaction tremendously. **(1mrk)**

12. The solubility of calcium phosphate $Ca_3(PO_4)_2$ is 0.0011g per 100g of water at 25°C.

(a) Calculate the solubility product of calcium phosphate.
(Ca = 40, P = 31, O = 16) **(4marks)**

(b) What would be the effect on the solubility of calcium phosphate when a solution of sodium phosphate is added to a saturated solution of calcium phosphate? **(2marks)**

13. The table below shows the rates of the reaction between substances A and B at different concentrations.

Experiment	[A] moldm^{-3}	[B] moldm^{-3}	Initial rate of reaction in moldm^{-3}s^{-1}
1	0.50	0.50	2.0×10^{-2}
2	1.00	0.50	8.0×10^{-2}
3	1.00	1.00	16.0×10^{-2}

(a) Determine the overall order of the reaction. **(2½marks)**
(b) Calculate the rate constant for the reaction showing clearly the units. **(2marks)**

SECTION B: Choose THREE questions from this section.

14. Study the table below and answer the questions that follow.

Enthalpy change	$KJmol^{-1}$
Atomisation of Potassium	+90
Atomisation of Iodine	+107
1st Ionization energy of Potassium	+420
1st Electron affinity of Iodine	-314
Formation of Potassium Iodide	-328

(a) Construct a Born Haber's cycle and calculate the lattice energy of Potassium Iodide. **(5marks)**

(b) Given that: $K^+_{(g)} + (aq) \rightarrow K^+_{(aq)}\ \Delta H = -304\ KJmol^{-1}$

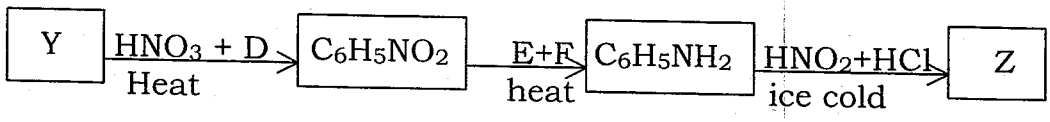
$I^-_{(g)} + (aq) \rightarrow I^-_{(aq)}\ \Delta H = -306\ KJmol^{-1}$

$K^+_{(g)} + I_{(g)} \rightarrow K\ I_{(s)}\ \Delta H = -631\ KJmol^{-1}$

(i) Calculate the enthalpy of solution of Potassium Iodide. **(3marks)**

(ii) How would you confirm presence of Iodide ions in aqueous solution? **(2marks)**

15. The flow chart below shows a synthetic route for the preparation of compound Z starting with compound Y.



(a) Name compounds Y, D, E, F and Z. **(5marks)**

(b) Show the reaction mechanism in the formation of compound $C_6H_5NO_2$ from compound Y. **(3marks)**

(c) Explain why compound Y undergoes electrophilic substitution more readily than $C_6H_5NO_2$. **(2marks)**

16. The boiling points of the hydrides of group VII elements are given below.

Compound	HF	HCl	HBr	HI
Boiling point (°C)	+19.9	-85.0	-66.7	-35.4

(a) Explain the trend in the boiling points of the hydrides. **(5marks)**

(b) Suggest why a solution of HCl in methyl benzene doesn't conduct electricity but its solution in water conducts electricity. **(2marks)**

(c) With reasons suggest which of the hydrides above is the strongest acid? **(3marks)**

17. In Haber's process for manufacturing Ammonia,

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, 46KJ of energy is given out per mole of Ammonia formed.

(a) If 1.02×10^6 kg of ammonia are produced per day, calculate how much heat energy is given out each day. **(2marks)**

(b) An equilibrium mixture in a sealed $2dm^3$ container at 700K and a pressure of 200 KPA contains 0.6 mol of Nitrogen and 2.0 mol of Hydrogen.

(i) Calculate the equilibrium concentration constant K_C including the units. **(3marks)**

(ii) Calculate the pressure equilibrium constant Kp including the units. **(5marks)**

18. Use the data below to answer the questions that follow.

$Cr_2O_7^{2-}{}_{(aq)} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+}_{(aq)} + 7H_2O_{(\ell)}$ $\quad E^\theta = +1.33V$

$Fe^{3+}_{(aq)} + e^- \rightleftharpoons Fe^{2+}_{(aq)}$ $\quad E^\theta = +0.77V$

$MnO^-_{4(aq)} + 8H^+_{(aq)} + 5e^- \rightleftharpoons Mn^{2+}{}_{(aq)} + 4H_2O_{(\ell)}$ $\quad E^\theta = +1.52V$

$FeO_4^{2-}{}_{(aq)} + 8H^+_{(aq)} + 3e^- \rightleftharpoons Fe^{3+}_{(aq)} + 4H_2O_{(\ell)}$ $\quad E^\theta = +2.2V$

$VO^-_{3\,(aq)} + 4H^+_{(aq)} + e^- \rightleftharpoons VO^{2+}_{(aq)} + 2H_2O_{(\ell)}$ $\quad E^\theta = 1.0V$

(a) Which transition metal species (Ions) above is the most powerful oxidising agent and which is the most powerful reducing agent? **(2marks)**

(b) Identify one metal species that can reduce acidified dichromate Ions. **(1mark)**

(c) Write an overall equation to show the reaction between acidified dichromate Ions and the identified species in 18(b). **(2marks)**

(d) Work out the oxidation state of Cr in $Cr_2O_7^{2-}$, and of V in VO_3^-. **(2marks)**

(e) Suggest why acidified FeO_4^{2-} will oxidise Fe^{2+} and write the overall equation. **(3marks)**

SECTION C: Answer ONE question from this section.

19. For each of the following pairs of compounds identify the chemical test that can be used to distinguish them stating clearly the observations and writing relevant equations where possible.

(a) $CH_3\ CH_2\ \overset{\overset{O}{\|}}{C} - CH_2\ CH_3$ and $CH_3CH_2CH_2CH_2CHO$.

(b) $C_6\ H_5\ CH_2OH$ and $C_6\ H_5\ OH$.

(c) $CH_3\ CH = CH_2$ and $CH_3\ CH_2\ CH_3$.

(d) $Al(NO_3)_3$ and $Cu(NO_3)_2$

(e) $FeCl_2$ and $FeCl_3$. **(3marks each)**

20. 0.98 75 g of an impure Potassium manganate(VII) was dissolved in 250cm^3 of water solution. 20 cm^3 of this solution was acidified with dilute sulphuric acid and titrated against sodium ethanedioate (oxalate) solution $Na_2C_2O_4$ and the volume of $Na_2C_2O_4$ required was 24.4cm^3.
Given that 1.675g of $Na_2C_2O_4$ had been dissolved in 250cm^3 of aqueous solution,

(a) Calculate the percentage purity of potassium permanganate (manganate(VII)). **(8marks)**

(b) Given only the solutions of $KMnO_4$, of $Na_2C_2O_4$ and of H_2SO_4 mentioned in this question, a stop watch, Na_2CO_3 solution, conical flasks, a burette and a pipette, how would you determine the order of reaction between $KMnO_4$ and $Na_2C_2O_4$? **(7marks)**

21. Sodium hydroxide solution was added to 25cm^3 of 0.1M ethanoic acid and the PH of the solution was measured at intervals of time. The results are tabled below.

Volume of NaOH(cm^3)	0	4	8	12	16	20	22	22.5	23	24	28
PH of the mixture	2.8	3.5	4.0	4.5	5.1	5.8	7.0	9.0	10.5	11.4	12.3

(a) Plot a graph PH (y axis) against volume of NaOH. **(7½marks)**
(b) Explain the shape of the graph. **(3½marks)**
(c) Using the graph, determine the volume of NaOH required to neutralise the acid and hence calculate the molarity of NaOH. **(3marks)**

RWANDA NATIONAL EXAMINATIONS COUNCIL

021

P.O. BOX 3817 KIGALI.- TEL/FAX 86871

NATIONAL EXAMINATION 2001/2002

SUBJECT : CHEMISTRY I

OPTION : BIOLOGY - CHEMISTRY

DURATION : 3 HOURS

INSTRUCTION :

This paper consists of **three** sections : A, B and C.

Answer **all** questions A.

Choose **three** questions from section B.

Choose **one** question from section C.

Calculators may be used.

SECTION A: ANSWER ALL QUESTIONS IN THIS SECTION

1. Compound A contains the following substances by mass. 22.24% carbon, 3.71% Hydrogen and 74.05% bromine.

(a) Calculate the empirical formula of compound A. **(2 marks)**

(b) If the relative molecular mass of A is 215.8, what is the molecular formula of A? **(1 mark)**

(c) Draw the structural formula for anyone of the branched chain isomers of compound A and give its name. **(1mark)**

2. Draw diagrams to show the shape of one molecule of each of the following compounds and in the each case state the name of the shape.

$BeCl_2$, BCl_3, $SiCl_4$.

You may use the following atomic numbers. **(3 Marks)**
(Be = 4, B = 5 , Si = 14 , Cl = 17)

3. (a) Complete the table below. **(2 Marks)**

	Relative mass	Relative charge
An alpha particle		
A Beta particle		

(b) The decomposition of Hydrogen peroxide $2H_2O_2 \longrightarrow 2H_2O+O_2$ is found to be first order reaction.

(i) Write a rate equation for the reaction. **(1 Mark)**

(ii) Given that the rate constant for the above reaction is $8.25 \times 10^{-4}\ s^{-1}$, calculate the half life $t\frac{1}{2}$ for the reaction. You may use $kt\frac{1}{2} = \ln 2$ where k is the rate constant . **(2 Marks)**

(iii) How long will it take for the concentration of H_2O_2 to reduce to 25% of its original value? **(1 Mark)**

4. (a) What do you understand by the standard enthalpy of formation? **(1½ Mark)**

(b) Use the standard enthalpies of formation in the table below to calculate the standard enthalpy of combustion of Ethane (C_2H_6) . **(1½ Marks)**

Compound	$C_2H_{6(g)}$	$CO_{2(g)}$	$H_2O_{(l)}$
Standard enthalpy of formation in $kJmol^{-1}$ at 298 K	-85	-394	-286

5. (a) Draw & name the structural formula of an isomer of $CH_3CH_2CH = CH_2$ which shows geometrical isomerism . **(1 Mark)**

(b) Draw the structural geometrical isomer of the named isomer in 5(a) **(1 Mark)**

(c) Write a mechanism of the reaction showing the formation of the major product when $CH_3CH_2CH = CH_2$ reacts with HCl gas. **(2 Marks)**

6. The table below shows the relative isotopic abundance of the element titanium Ti.

Isotope	^{46}Ti	^{47}Ti	^{48}Ti	^{49}Ti	^{50}Ti
% abundance	8.02	7.31	73.81	5.54	5.32

(a) Using the information in the table above, calculate the relative atomic mass of titanium. **(2 Marks)**

(b) State any two dangers that can be caused by radio isotopes. **(1 Mark)**

(c) Bromine gas contains the isotopes ^{79}Br and ^{81}Br, state and explain the number of peaks formed in the spectrum of bromine molecular Ion . **(2 Marks)**

7. Explain the following .

(a) Phenylamine ($C_6H_5NH_2$) is a weaker base than ethylamine ($CH_3CH_2NH_2$) **(2 Marks)**

(b) Chloroethanoic acid $CH_2ClCOOH$ is a stronger acid than ethanoic acid CH_3COOH. **(2 Marks)**

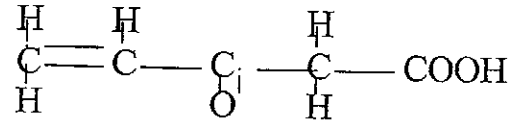
8. The table below shows the melting points of elements of period 3.Use the table to answer the questions that follow.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting point / °C	98	650	660	1407	44	119	-101	-189

(a) Why does magnesium have a higher melting point than sodium? **(2 Marks)**

(b) Explain the trend (variation) in the first Ionization across period 3. **(2 Marks)**

9. Given the organic compound A.



(a) Name any two functional groups present in A. **(1Mark)**

(b) What would you observe when compound A was reacted with :

(i) Sodium carbonate. **(1Mark)**

(ii) Brady's reagent (2,4-dinitrophenylhydrazine). **(1Mark)**

(iii) Fehling's solution. **(1 Mark)**

10. (a) Write the electronic configuration of the following elements .

(i) Chromium **(1 Mark)**
(ii) Copper **(1Mark)**

Atomic numbers of chromium and copper are 24 and 29 respectively.

(b) Why are compounds of copper blue? . **(2 Marks)**

11. Sodium hydride reacts with water according to the following equation:

$$NaH_{(s)} + H_2O_{(l)} \longrightarrow NaOH_{(aq)} + H_{2(g)}$$

1 g of a sample of sodium hydride was added to water and the resulting solution was diluted to a volume of $250cm^3$.

Calculate the concentration in g $/dm^3$ of sodium hydroxide solution formed.
Relative atomic masses are: Na = 23, O = 16, H =1 **(3 Marks)**

12. In an experiment to determine the order of a reaction between substance A and substance B, the following results were obtained.

Experiment	$[A]/moldm^{-3}$	$[B]/moldm^{-3}$	Rate of reaction mol dm^{-3} min^{-1}
1	1.0×10^{-3}	1.0×10^{-3}	$2. \times 10^{-4}$
2	2.0×10^{-3}	1.0×10^{-3}	4.0×10^{-4}
3	2.0×10^{-3}	2.0×10^{-3}	8×10^{-4}

(a) State the order of reaction with respect to A and to B. **(1 Mark)**

(b) Write the rate expression for the reaction. **(1 Mark)**

(c) Calculate the rate constant for the reaction showing clearly the units. **(2 Marks)**

13. Study the following values for standard electrode potentials and answer the questions that follow.

Electrode reaction	Electrode potentials ($E^{\ominus}$/V)
$Mn^{2+}_{(aq)} + 2e \rightleftharpoons Mn_{(s)}$	-1.18
$Fe^{2}_{(aq)} + 2e \rightleftharpoons Fe_{(s)}$	-0.44
$Ni^{2+}_{(aq)} + 2e \rightleftharpoons Ni_{(s)}$	-0.25
$Sn^{2+}_{(aq)} + 2e \rightleftharpoons Sn_{(s)}$	-0.14
$2H^{+}_{(aq)} + 2e \rightleftharpoons H_{2(g)}$	0.00

(a) Using the Electrochemical cell set up below,

$Ni_{(s)} \mid Ni^{2+}_{(aq)} \parallel Sn^{2+}_{(aq)} \mid Sn_{(s)}$

(i) Calculate the e.m.f of this cell **(1 Mark)**

(ii) Write an equation to show the overall reaction in the cell . **(1 Mark)**

(b) Using the standard electrode potentials given, explain whether or not you would expect a reaction to occur if a piece of tin were added to a test tube containing aqueous Iron II sulphate. **(2 Marks)**

14. Ammonia is manufactured by the Haber-Bosch process according to the equation

$N_{2\,(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta H = -92$ kJ mol^{-1}

State and explain the effect of high temperatures on:

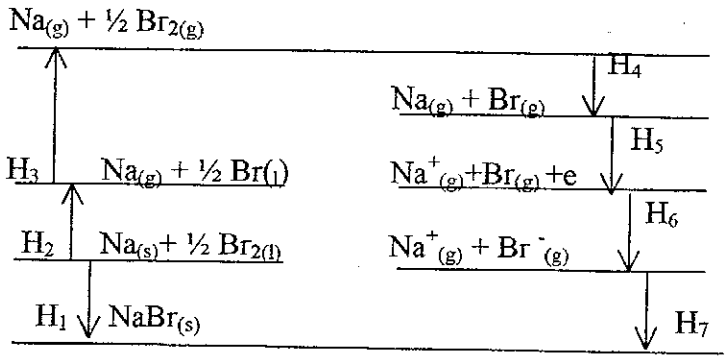
(i) The rate of the above reaction. **(2 Marks)**

(ii) The yield of ammonia. **(2 Marks)**

SECTION B

Answer any three questions from this section .

15. The Born Haber's cycle below represents the formation of sodium bromide from its elements in their natural state.



(a) Name the enthalpy changes H_1 to H_7. **(4 Marks)**

(b) Given that $H_1 = -361$ KJ mol^{-1}, $H_2 = +107$ KJ mol^{-1}
$H_3 = x$ KJ mol^{-1}, $H_4 = +97$ KJ mol^{-1}
$H_5 = +498$ KJ mol^{-1}, $H_6 = -375$ KJ mol^{-1}
$H_7 = -753$ KJ mol^{-1}

Calculate the value of H_3. **(3 Marks)**

(c) Explain why the enthalpy change H7 for Na Br is greater than that of KBr
N.B potassium is below sodium in group I of the periodic table. **(3 Marks)**

16. (a) Suggest the synthesis routes showing conditions and reagents for the following conversion.

(i) Benzene into 2,4, 6- trinitromethyl benzene. **(5 Marks)**

(ii) Methanol into Ethanol **(5 Marks)**

17. Explain the following observation

(a) Reducing power of elements of group VII generally increases down the group. **(2 Marks)**

(b) The solubility of hydroxides of group II elements increases down the group. **(3 Marks)**

(c) The boiling points of Hydrides of group VI generally increase down the group, but H_2O has a higher boiling point than expected . **(3 Marks)**

(d) Lead IV chloride is a covalent compound but lead II chloride is Ionic.**(2 Marks)**

18. Phenolphthalein is an indicator which is a weak acid. Its pKa value is 9.3 and its pH range is 8.3 – 10.0. Methyl orange has pKa value of 3.7 and pH range of 3.1– 4.4.

(a) State and explain which indicator that can be used in the titration of NaOH against HCl. **(3 Marks)**

(b) Sketch a titration graph to show the variation of PH of NaOH against the addition of HCl solution and explain the shape of the graph. **(4 Marks)**

(c) Explain how a mixture of CH_3COONa and CH_3COOH acts as a buffer. **(3 Marks)**

19. $2000cm^3$ of sulphur dioxide was mixed with 1000 cm^3 of oxygen at 300°C and 10 atmospheres pressure in presence of a catalyst. When equilibrium had been attained, it was found that 1333 cm^3 of sulphur dioxide remained.

(a) Write a balanced equation for the reaction between sulphur dioxide and oxygen. **(1 Mark)**

(b) State the name of the catalyst. **(1 Mark)**

(c) Write an expression for the pressure equilibrium constant Kp. **(1 Mark)**

(d) Calculate the partial pressures of each of the gases at equilibrium. **(4 Mark)**

(e) Calculate the equilibrium constant for the reaction. **(3 Marks)**

SECTION C

Answer only one question in this section.

20. With the aid of equations where possible, describe a chemical test you would carry out to distinguish between the following pairs of compounds. In each case, state conditions of the reaction if any and observations that would be made.

(a) $CH_3CH_2NH_2$ and CH_3CONH_2.

(b) CH_3COCH_3 and CH_3CHO.

(c) $Pb^{2+}_{(aq)}$ and $Zn^{2+}_{(aq)}$

(d) $Cu^{2+}_{(aq)}$ and $Al^{3-}_{(aq)}$

(e) Cl_2 gas and HCl gas.

(3 Marks each)

21. A solution of potassium tetraethanedioate has the following formula.
$(K_2C_2O_4)_x (H_2C_2O_4)_y (H_2O)_z$ where x , y and z are whole numbers .
$25cm^3$ of the salt solution of potassium tetraethanedioate were titrated with NaOH solution of concentration 0.1mol dm^{-3}. $23.6cm^3$ of NaOH solution were required for complete neutralization.
25 cm^3 of the same potassium tetraethanedioate were titrated with potassium manganate VII ($KMnO_4$) of concentration 0.02 $moldm^{-3}$ in presence of dilute H_2SO_4.

Given that NaOH only reacts with $H_2C_2O_4$ in the compound and MnO^-_4 reacts with all the $C_2O_4^{2-}$ Ions in the compound,

Given further that the total concentration of the salt is 8 g dm^{-3},

(a) Calculate the number of moles of Ethaneodioate Ions $C_2O_4^{2-}$ present in the salt. **(4 Marks)**

(b) Calculate the number of moles of ethanoic Acid $H_2 C_2O_4$. **(4 Marks)**

You may use the following equations.

$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e$, $MnO^-_4 + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$

(c) Calculate the ratio x: y : z
relative atomic masses are K = 39, C = 12, O = 16, H = 1 **(7 Marks)**

22 In order to determine the rate of a reaction between $CaCO_3$ and HCl, the loss in mass of the reaction mixture was measured at different time intervals. The results obtained were as follows.

Time in seconds	0	10	25	50	100	150	200	250	300
Mass lost in dg	0	0.32	0.6	0.83	1.04	1.13	1.19	1.2	1.2

(a) Sketch a diagram of a complete apparatus that can be used to measure the loss in mass at intervals of time. **(3 Marks)**

(b) Using the results above, plot a graph of loss in mass versus time (time on x-axis). **(7 Marks)**

(c) What causes the loss in mass during the reaction? **(1 Mark)**

(d) Why is the mass lost the same in the last **two** results? **(1 Mark)**

(e) From the graph determine the rate of reaction after 80 seconds. **(2 Marks)**

(f) Deduce the order of the reaction. **(1 Mark)**