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) $CH_3COOH_{(l)} + 2O_{2(g)} \rightarrow 2H_2O_{(l)} + 2CO_{2(g)}$ ΔH_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

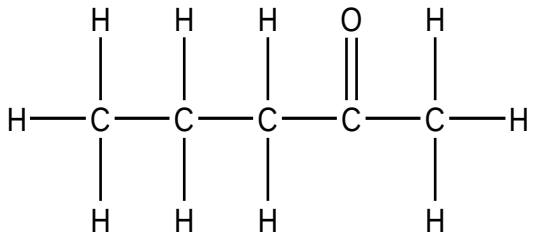
Figure 1

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

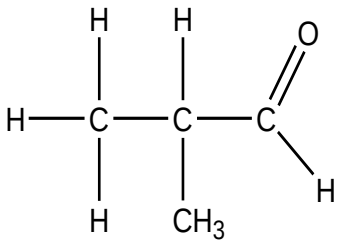
b) State and explain the general trend in variation of first electron affinity across the period and down the group of the Periodic Table. **(2 marks)**

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

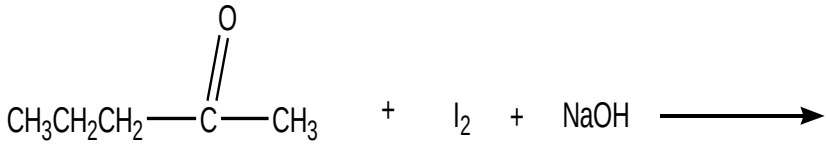


Compound Y

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}).

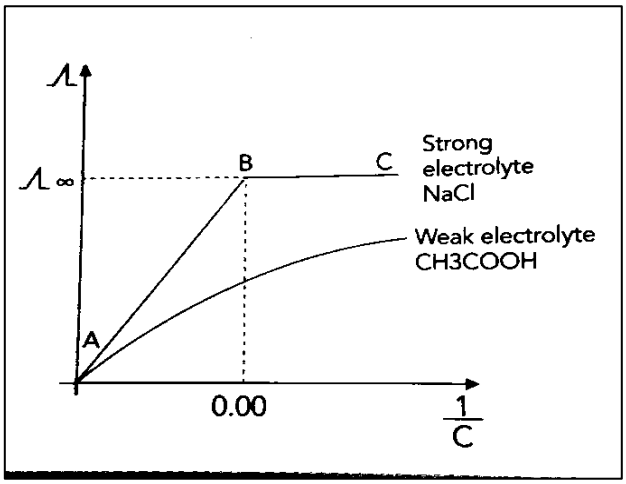


Figure 2

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)**

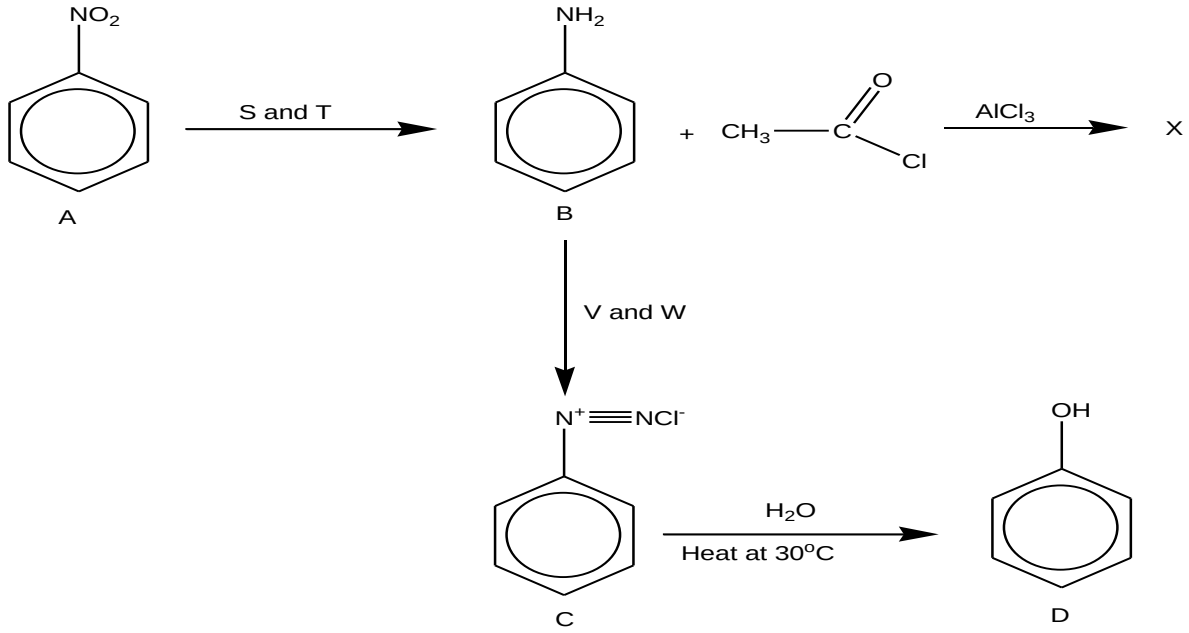
b) Iron (III) oxide was found to be contaminated with copper (II) sulphate. Describe how a sample of iron (III) oxide, free of copper (II) sulphate, can be obtained. **(2 marks)**

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)**

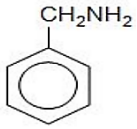
b) Draw the structure of the major product **X**. **(1 mark)**

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.

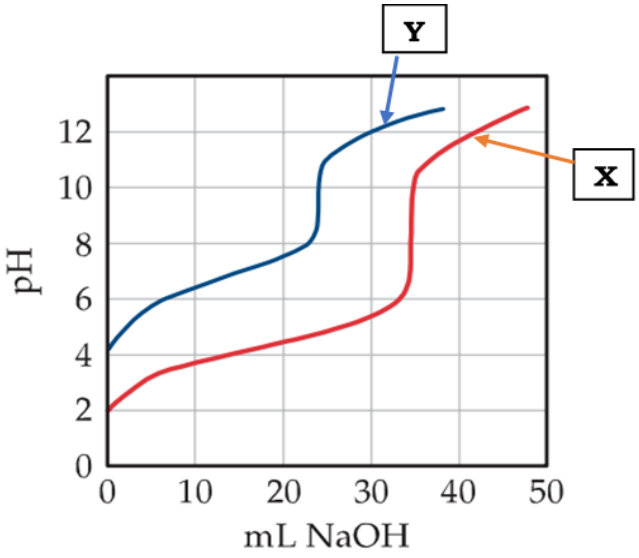


Figure 3

(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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