Index No.:_____ AM06/I.22s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2022 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	29th August 2022
TIME:	9:00 a.m. to 12:05 p.m.

Required Data: Universal Gas constant (R) = 8.314 J mol^{-1} K^{-1}.
RAM: H = 1; C = 12; O = 16; Cl = 35.5

Answer ALL questions

1. This question is about atomic structure.

   a) i) Identify and write the electronic configuration using the s and p notation of the element with an atomic number of 11.

   _____ (1)

   ii) Write the electronic configuration of Zn^{2+}.

   _____ (1)

   b) The first ionisation energy of carbon is 1086 kJ mol^{-1}. Would you expect the first ionisation energy of silicon to be greater or less than this amount? Explain.

   _____

   _____

   _____

   _____

   _____

   _____ (3)

   c) Complete the following table.

Hybridisation	Molecular geometry
sp^3	
	trigonal planar

(1)

d) Using the electron box notation, describe the hybridisation of the carbon atoms in ethyne.

_____

_____

_____ (2)

e) Give the systematic name of the hydrocarbon shown below and state the hybridisation of the carbon atoms labelled **a** and **b**.

CH_3-CH=CH-CH=CH_2
a **b**

_____

_____

_____

_____ (2)

(Total: 10 marks)

2. This question is about bonding.

a) Use the valence shell electron pair repulsion (VSEPR) theory to draw the structure of the I_3^+ ion. Show your working.

_____

_____

_____ (3)

b) Solid sodium sulfate, which has a melting point of 884 °C, does not conduct electricity, but molten sodium sulfate and aqueous solutions of sodium sulfate conduct electricity. Explain.

_____

_____

_____

_____ (3)

c) With the aid of a diagram, use HF to explain intermolecular hydrogen bonding.

_____

_____

_____ (2)

d) Ice melts upon increasing pressure at a constant temperature. Explain this in terms of the structure of solid water.

_____

_____

_____

_____

_____

_____

_____ (3)

(Total: 11 marks)

Please turn the page.

3. This question is about periodicity.
   a) Consider the elements of period 3.
      i) Explain why the electrical conductivity increases from Na to Al.

_____

_____

_____

_____

_____ (2)

      ii) Explain why silicon has a high melting point.

_____

_____ (2)

   b) Consider the hydrides formed by elements lithium to fluorine.
      i) Give an example of a hydride having the following structures:

Ionic _____

Polymeric covalent _____

Simple covalent _____ (3)

      ii) Give the equation for the reaction (if any) of the hydrides of the elements with atomic numbers 6, 7 and 9, with water.

_____

_____

_____ (3)

(Total: 10 marks)

4. a) In a mixture of gases, each component exerts its partial pressure.
   i) Explain what is meant by partial pressure.

_____

_____

_____

_____ (2)

   ii) State Dalton's law of partial pressures.

_____

_____ (1)

   iii) Gases can undergo diffusion and effusion. Distinguish between the two processes.

_____

_____

_____

_____ (2)

   iv) State which states of matter can undergo diffusion and effusion.

_____

_____ (2)

b) A mixture of neon and argon in a 0.20 dm^3 container had a pressure of 760 kPa. The mixture was transferred to a 1.0 dm^3 container at a constant temperature. Calculate the partial pressure of neon in the 1.0 dm^3 container if the mole fraction of argon is 0.34.

_____

_____

_____

_____

_____

_____

_____ (4)

(Total: 11 marks)

Please turn the page.

5. a) Calculate the osmotic pressure (in kPa) of a solution containing 13.6 g of sucrose ($C_{12}H_{22}O_{11}$) in 250 cm^3 of solution at 25 ^oC.

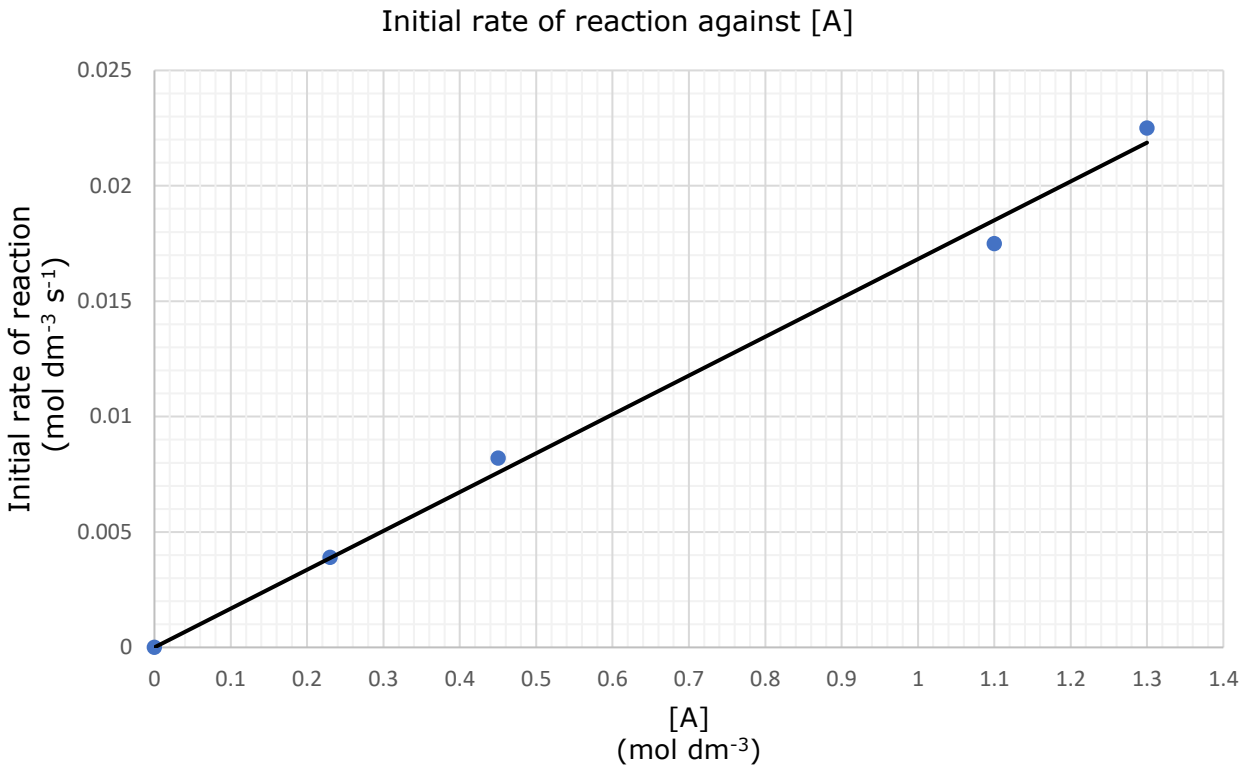
(4)

b) The vapour pressure of trichloromethane and dichloromethane at 298 K is 200 mm Hg and 415 mm Hg, respectively. Calculate the vapour pressure of the ideal mixture prepared by mixing 25.5 g of trichloromethane and 40.0 g of dichloromethane at 298 K.

(5)

(Total: 9 marks)

6. a) The plot below gives the experimental values for the initial rate of reaction against the molar concentration of A, for a reaction A → B + C.



i) Use the graph to determine the order of reaction with respect to A.

_____

_____

_____

_____ (3)

ii) Give the rate expression and calculate the rate constant.

_____

_____

_____

_____

_____ (2)

Please turn the page.

iii) Comment on the half-life of the reaction.

_____

_____

_____

_____ (2)

b) Consider the following reaction mechanism:

Step 1: $A_2 + B_2 \rightarrow R + C$ (slow step)

Step 2: $A_2 + R \rightarrow C$ (fast step)

i) Write the overall equation for this chemical reaction.

_____

_____ (1)

ii) Identify any intermediates in the reaction mechanism.

_____ (1)

iii) What is the order with respect to each reactant? Explain your answer.

_____

_____

_____

_____ (2)

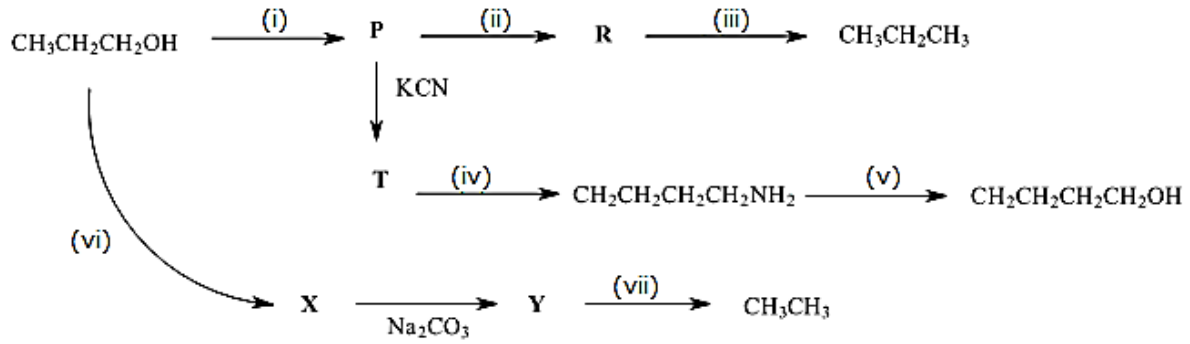
iv) Write the rate law for this reaction.

_____

_____ (1)

(Total: 12 marks)

7) Consider the following reaction scheme involving propan-1-ol.



a) Give the reagent/s and conditions for reactions:

(i) _____

(ii) _____

(iii) _____

(iv) _____

(v) _____

(vi) _____

(vii) _____ (7)

b) Give the structural formula for the organic compounds **P**, **R**, **T, X** and **Y**.

P	**R**
T	**X**
Y	

(5)

(Total: 12 marks)

Please turn the page.

8) This question is about alcohols and carbonyl compounds.

a) Figure 1 presents a laboratory set-up for the preparation of butanal, starting with butan-1-ol. The boiling point of butanal is 75 °C, while that of butan-1-ol is 118 °C.

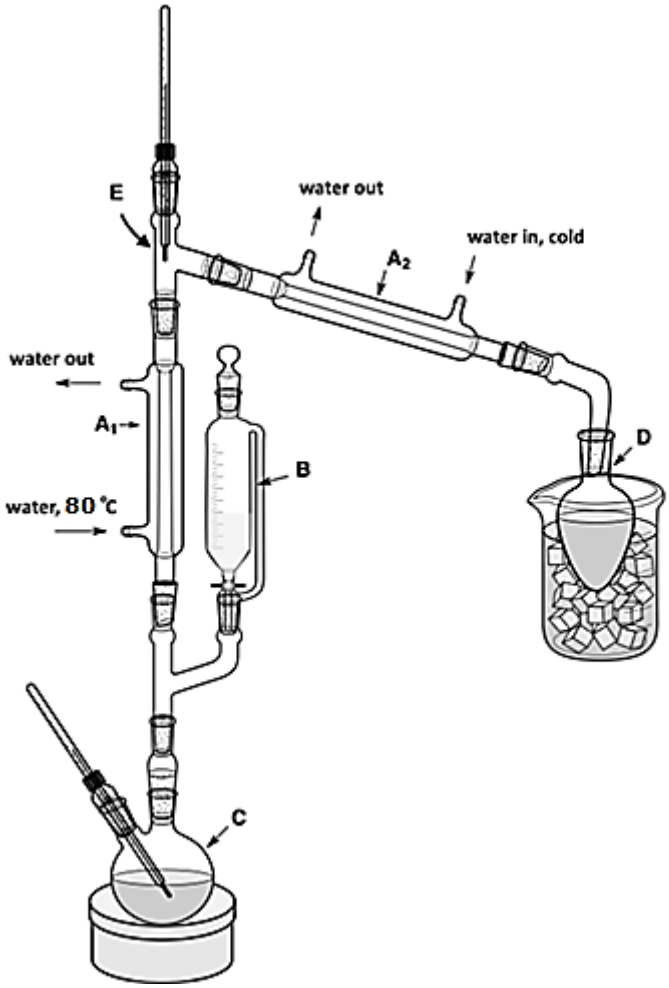


Figure 1

i) Continue the following sentence by filling in the blanks:

A1 and **A2** are both _____ but **A1** is set to carry out the process of _____ while **A2** is set to carry out the process of _____ (3)

ii) Name the apparatus labelled **B**, **C**, **D**.

B _____

C _____

D _____ (3)

iii) Give the contents of vessels **B** and **C** before the reaction starts.

B _____

C _____ (2)

iv) In Figure 1, the inlet water temperature of **A1** is set at 80 °C, while the inlet water temperature of **A2** is set to cold (<5 °C). Suggest why the water inlet temperatures of **A1** and **A2** are set in this way.

_____

_____

_____

_____

_____

_____ (3)

v) Why is it important to closely monitor the temperature inside the still head labelled **E**?

_____

_____ (1)

b) After the reaction is over, a few grams of anhydrous calcium chloride are added to the butanal collected in **D**. The calcium chloride is then filtered out, and the butanal is re-distilled. Suggest **ONE** reason for:

i) the addition of anhydrous calcium chloride;

_____

_____ (1)

ii) the re-distillation of the aldehyde.

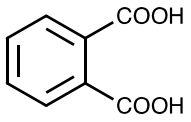
_____

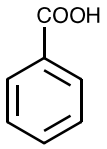
_____ (1)

(Total: 14 marks)

Please turn the page.

9) Complete the following table by writing suitable structural formulae of organic compounds or properties of the organic compound in the spaces provided as required.

	Organic substance	**Product of reaction or property of the organic compound**
a)		Draw the molecular structure of the sublimed product that is collected after heating this substance. (2)
b)	But-2-ene-1,4-dioic acid	Draw and name the structure of **each** of the two geometrical isomers of this substance. (3)
c)	$CH_3CH_2CH_2COOH$	Give the structural formula of the product of reaction obtained when an equimolar amount of Cl_2 is bubbled through the boiling substance in the presence of trace quantities of red phosphorus. (2)
d)	$CH_3CH(OH)CH_2OCH_2COOH$	Give the structural formula of the ester formed by this substance when it reacts with ethanoic acid. (2)

e)		Draw the molecular structure of the organic product of the mononitration of this substance. (2)

(Total: 11 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2022 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	30th August 2022
TIME:	9:00 a.m. to 12:05 p.m.

A Periodic Table is provided.
$K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}

Answer TWO questions from each section and ANY other question.

SECTION A

1. This question is about transition metals.

   a) i) Write the electronic configurations for Cu and Cu^{2+}. (1)

   ii) Explain why copper is considered a transition metal but zinc is not. (2)

   iii) Give an example of a complex ion of copper which clearly shows a typical property of transition metals. (1½)

   iv) Identify and give the electronic configuration of another d-block element in period 4 that is **not** considered a transition element. (1½)

   b) Define the following terms: ligand, complex ion and chelate. Give suitable examples for **each** term. (6)

   c) Explain how potassium thiocyanate, KSCN, can be used to test for the presence of iron(III) ions. (4)

   d) Chromate and dichromate ions exist in equilibrium in an aqueous solution. Write an equation for this equilibrium and comment on the effect of adding acid or alkali on the equilibrium. (4)

   (Total: 20 marks)

2. This question is about elements in group 7.

   a) Explain, with the help of a labelled diagram, how you would safely prepare chlorine in the laboratory. Give the chemical equation for the reaction involved, including the state symbols. State and explain how you would test for chlorine. (6)

   b) Explain why bromine can be easily prepared in the laboratory by oxidation of bromide ions by a halogen. Include a chemical equation to support your answer. (2)

c) Freon-12, CCl_2F_2, is prepared by reaction of CCl_4 with HF. The other product of this reaction is HCl. Determine the percentage yield if 12.5 g CCl_2F_2 is produced from 32.9 g CCl_4. (4)

d) An iodimetric titration was carried out to determine the amount of copper in an unknown copper(II) salt. A 0.10 g sample of the salt was weighed out and treated with excess potassium iodide solution. The liberated iodine was titrated against 0.0120 mol dm^{-3} sodium thiosulfate solution. A volume of 32.50 cm^3 of sodium thiosulfate solution was needed to react with the iodine. Calculate the percentage by mass of copper in the unknown copper(II) salt. State any assumptions made. (5)

e) Explain why aqueous HF is a weak acid. (3)

(Total: 20 marks)

3. This question is about chemical equilibria.

a) An aliquot of 100 cm^3 of 0.150 mol dm^{-3} solution of aqueous propan-1-amine was shaken in a separating funnel with 50.0 cm^3 of an organic solvent at 25 ^oC. The system was allowed to reach equilibrium. At this point, 50.0 cm^3 of the aqueous layer was run off, and on titration, it needed 14.1 cm^3 of 0.225 mol dm^{-3} hydrochloric acid for complete neutralisation.

i) Calculate the partition coefficient of propan-1-amine between the organic solvent and water. (8)

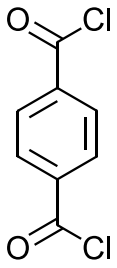
ii) Use your answer to part (a) (i) to explain in which phase, water or the organic solvent, is propan-1-amine more soluble. (2)

iii) Primary amines can be converted into alcohols. Give an equation including reagents and conditions for the conversion of propan-1-amine into an alcohol. (2)

b) Calculate how much propan-1-amine is extracted from the same volume of 0.150 mol dm^{-3} solution if two consecutive extractions using 25.0 cm^3 aliquots of organic solvent at 25 ^oC are employed. Which of the two techniques provides the higher yield of amine, and by how much? Quote your answer in moles of amine. (8)

(Total: 20 marks)

4. Kevlar^R is a man-made fibre material used in the manufacture of bullet-proof vests and other shock-resistant materials. The fibres may be formed by the poly-condensation of the monomers **X** and **Y**. The structure of monomer **Y** is given below, while that of monomer **X** is given in part (c).

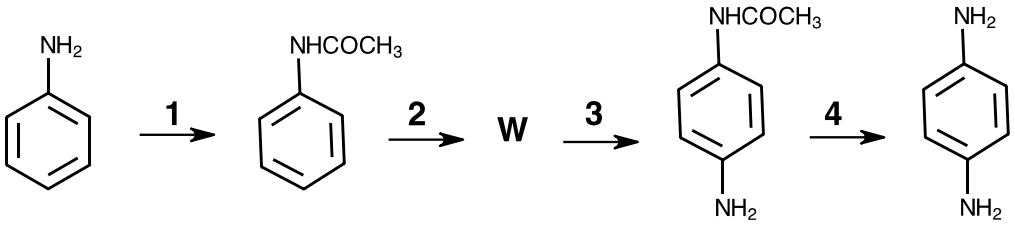


Monomer **Y**

a) Give an equation to show how molecules **X** and **Y** polymerise to produce Kevlar^R. (3)

b) Suggest the main type of intermolecular forces acting between the polymer chains of Kevlar^R and identify the functional group responsible for such interactions. (2)

c) A synthetic route for monomer **X** starting with phenylamine is given below.



(V) **(X)**

i) Identify the reagents and reaction conditions in steps **1**, **2**, **3** and **4**, and give the structure of the intermediate **W**. (10)

ii) In what way does intermediate **V** aid in the preparation of monomer **X**? (2)

d) Give a reaction scheme to show how monomer **Y** presented above can be synthesised from 1,4-dimethylbenzene. (3)

(Total: 20 marks)

Please turn the page.

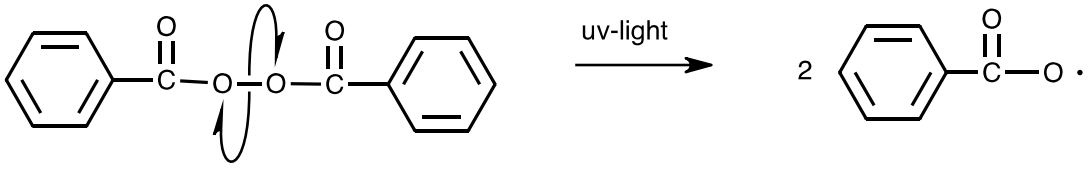
SECTION B

5. The addition of hydrogen bromide to ethene proceeds by electrophilic addition across the double bond and the formation of a carbocation. The polymerisation of ethene occurs by a free radical addition process.

   a) Show the mechanism of the reaction of hydrogen bromide with ethene, identifying clearly the electrophile and the intermediate involved. Suggest a step in the mechanism that likely serves as the rate-determining step and give a reason for your answer. (6)

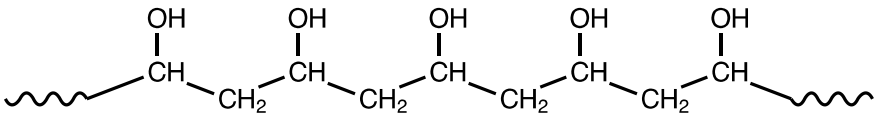
   b) The addition of hydrogen bromide to propene gives rise to two products, a major product and a minor one. Identify these two products, giving their respective structural formulae and stating which of them forms in major amount. Explain why the formation of the major product is preferred in terms of carbocation stability. (5)

   c) The high-pressure polymerisation of ethene occurs in three steps, a chain initiation process that leads to chain propagation and growth. The growth of the polymer chain ends with a chain termination step. Describe the mechanism of polymerisation of ethene when the chain initiation step involves use of benzoyl peroxide, which breaks down into free radicals as follows:



(4)

   d) The following represents a segment of an addition-type water-soluble polymer:



   i) Deduce the structural formula of the monomer. (1)

   ii) Suggest a reason for the good water-solubility of the polymer. (2)

   iii) Explain why the polymer **cannot** be made directly from its monomer. (2)

(Total: 20 marks)

6. This question is about energetics.

a) Consider the following thermochemical information:

Enthalpy change of atomisation of Mg	+148 kJ mol^{-1}
First electron affinity for O	–141 kJ mol^{-1}
First ionisation energy for Mg	+738 kJ mol^{-1}
Second ionisation energy for Mg	+1450 kJ mol^{-1}
Bond dissociation enthalpy for O_2	+498 kJ mol^{-1}
Second electron affinity for O	+798 kJ mol^{-1}
Lattice enthalpy for MgO (s)	–3845 kJ mol^{-1}

Given the above information for magnesium, oxygen, and magnesium oxide, construct a Born-Haber cycle and calculate the enthalpy change of formation of magnesium oxide. (10)

b) i) Consider the following reaction:

$$4NH_3\ (g) + 7O_2\ (g) \rightarrow 4NO_2\ (g) + 6H_2O\ (g)$$

The enthalpy change for the reaction is -1135 kJ. Given that the bond enthalpy terms for N-H, O=O and O-H are 389 kJ mol^{-1}, 498 kJ $mol^{-1}$and 464 kJ mol^{-1}, respectively, find the bond enthalpy term for the nitrogen-oxygen bonds in NO_2. (7)

ii) Given that the bond enthalpy terms for N-O and N=O are 222 kJ mol^{-1} and 590 kJ mol^{-1}, respectively and considering the result of part (b) (i), what can you conclude about the bonding between nitrogen and oxygen in the NO_2 molecule? (3)

(Total: 20 marks)

7. This question is about ionic equilibria.

a) Given that the pK_a of ethanoic acid is 4.76 at 25 °C, what is the pH of a solution prepared by dissolving 5.0 x 10^{-3} moles of ethanoic acid in water to give 250 cm^3 of solution at this temperature. (7)

b) Give an expression for the equilibrium constant, K_b, for the equilibrium reaction between the ethanoate ion and water, in terms of the K_a of ethanoic acid and K_w. (5)

c) Find the pH of the solution prepared in part (a) if 5.0 x 10^{-3} moles of sodium hydroxide are added to the solution. Ignore any changes in volume due to the addition of sodium hydroxide. (8)

(Total: 20 marks)

Please turn the page.

8. Explain the following observations as fully as you can, giving relevant chemical equations and chemical structures where appropriate.

   a) Primary, secondary and tertiary alcohols can be distinguished on the basis of their reaction with oxidising agents. (8)

   b) A substance with molecular formula C_6H_{10} reacts with ozone at low temperature in tetrachloromethane solvent to produce an oily product. Mild acid hydrolysis in the presence of Zn dust produces a single product. (5)

   c) Alkenes are most effectively hydrogenated in the presence of finely divided metallic powders such as Ni, Pt or Pd. With the aid of a labelled diagram, describe the mechanism of heterogeneous catalysis of alkenes. Explain why these catalysts are used as finely divided powders. (7)

(Total: 20 marks)

Index No.:_____ AM06/III.22s

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2022 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	III – *Practical*
DATE:	26th August 2022
TIME:	9:00 a.m. to 11:05 a.m.

1. You are provided with three solutions as follows:

   i) Potassium manganate(VII), labeled $\mathbf{N_n}$;
   ii) ethanedioic acid, of concentration 0.0500 mol dm^{-3}, labelled **A**;
   iii) A solution of iron(II) sulfate-7-water, labelled **U**, made by dissolving 30.0 g of a low-grade sample of the iron(II) salt in 1.00 dm^3 water.
   iv) Dilute sulfuric acid.

   In this experiment, you are required to:

   i) determine the molar concentration of solution $\mathbf{N_n}$;
   ii) determine the concentration of the iron(II) solution, **U**.
   iii) determine the percentage purity of the solid used to make solution **U**.

a) Record the value of your laboratory number, **n** (found on solution **N**), on your answer book in the following box.

CANDIDATE LABORATORY NUMBER, n:.....

Determination of the molar concentration of solution N_n

b) Fill your burette with solution $\mathbf{N_n}$. Into each of three conical flasks, pipette a 25.0 cm^3 aliquot of solution **A**. Add 20 cm^3 of dilute sulfuric acid. Heat each flask to approximately 60 °C and titrate with solution $\mathbf{N_n}$ to the first permanent pink end-point. Record your results in the table below.

	1st Titration	2nd Titration	3rd Titration
Final burette reading			
Initial burette reading			
Titre (cm^3)			

Mean titre: _____ cm^3 of solution $\mathbf{N_n}$. (22)

c) Oxalic acid and manganate(VII) react according to the equation

$$2MnO_4^- (aq) + 5(COOH)_2 (aq) + 6H^+(aq) \rightarrow 2Mn^{2+} (aq) + 10CO_2 (g) + 8H_2O (l)$$

Using the data obtained above, determine the molar concentration of solution $\mathbf{N_n}$.

_____

_____

_____

_____

_____

_____

_____

_____

_____ (3)

Determination of the percentage purity of the iron(II) solution.

d) Transfer a 25.0 cm^3 aliquot of solution **U** into each of 3 conical flasks and acidify with 20 cm^3 dilute sulfuric acid. Titrate each flask with solution $\mathbf{N_n}$ to the first permanent pink end-point, and record your data in the table below.

	1st Titration	2nd Titration	3rd Titration
Final burette reading			
Initial burette reading			
Titre			

Mean titre: _____ cm^3 of solution $\mathbf{N_n}$. (20)

e) Iron(II) ions and manganate(VII) react according to the equation

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

Use the data above to calculate the concentration of solution **U** in g dm^{-3}.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____(4)

DO NOT WRITE ABOVE THIS LINE

f) Determine the percentage purity of the solid used to make solution **U**.

(1)

(Total: 50 marks)