Index No:_____ **AM 06/I.16m**

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	I
DATE:	23rd May 2016
TIME:	9.00 a.m. to 12.05 p.m.

Answer all questions

1. Explain briefly each of the following statements.

(a) The intramolecular bonding in ammonia and ammonium ion is not identical.

_____

_____

_____

_____

(2 marks)

(b) The bonding electrons in hydrogen fluoride are not shared equally.

_____

_____

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(2 marks)

(c) The molecules PH_3 and BH_3 have three hydrogen atoms covalently bonded to the central atom, but the molecules do not have the same shape.

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(3 marks)

(d) The two molecules CCl_4 and CH_2Cl_2 have different polarity.

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(3 marks)
(Total = 10 marks)

2. The properties of elements exhibit **periodic** behaviour.

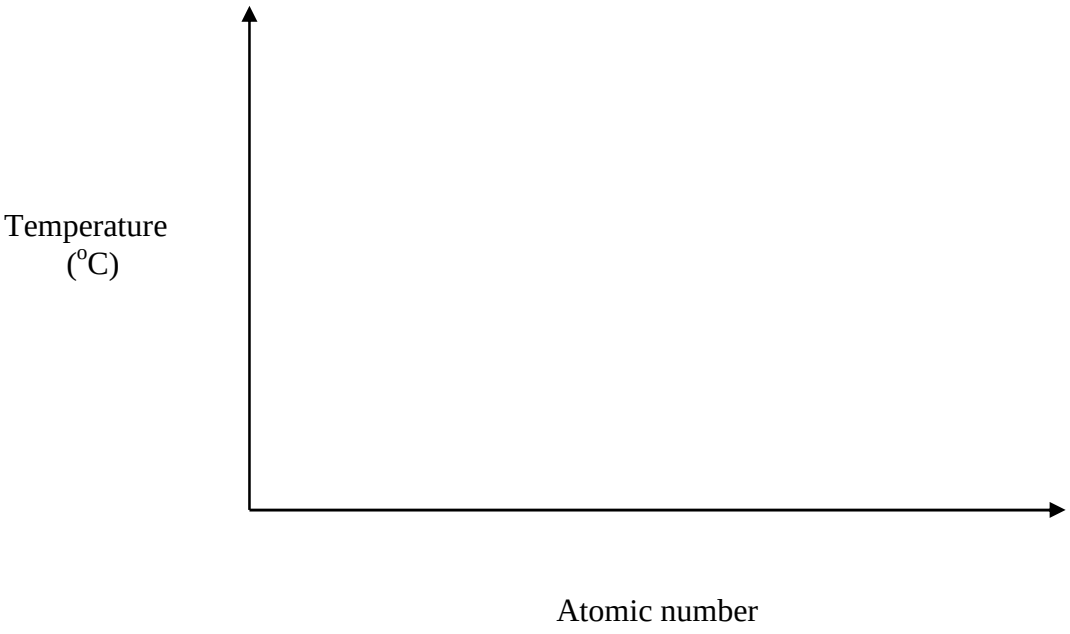
(a) Explain the term **periodic**.

_____

_____

(1 mark)

(b) (i) Sketch a graph showing the general periodic behaviour of the melting points of the elements in period 3.



(ii) Explain in detail the graph sketched in part (b) (i) based on the bonding properties of the elements.

(6 marks)

(c) The table below reports the formulae and acid-base character of the oxides of period 3 of the Periodic table. Fill in the blanks in the table below.

Group	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Oxide	Na_2O	MgO			P_4O_{10}	SO_2	
Acid-base character	basic			acidic		acidic	acidic

(3 marks)
(Total = 10 marks)

3. (a) Distinguish between the terms **transition element** and **d-block element**.

(2 marks)

(b) (i) Write the electronic configuration of iron.

(ii) Explain why transition metals such as manganese and iron have more than one oxidation state.

(iii) Give the electronic configuration for the ions Fe^{2+} and Fe^{3+} and, using these, suggest why iron(II) is easily oxidised to iron(III).

(5 marks)

(c) Explain the following terms:

complex ion:

ligand:

coordination number:

(3 marks)
(Total = 10 marks)

4. (a) What is meant by the term **dynamic equilibrium**?

(1 mark)

(b) The value of Kp for the reversible reaction between dinitrogen tetroxide and nitrogen dioxide, both in the gaseous state, is **0.660 atm at 45 ^{o}C**.

(i) Write the chemical equation representing this reversible reaction and the corresponding equation for Kp. Explain your reasoning for your choice of the chemical equation.

(ii) Give an expression for Kp in terms of α, the degree of dissociation, of dinitrogen tetroxide and the total pressure at equilibrium, P.

(7 marks)

(c) (i) Calculate Kp at **25 ^{o}C** for the equilibrium reaction in part (b) (i), given that α for dinitrogen tetroxide is 0.186 at a total equilibrium pressure of 1.00 atm.

(ii) Deduce whether the reaction in part (b) (i) is endothermic or exothermic. Explain how you arrived at your answer.

(4 marks)
(Total = 12 marks)

5. (a) Consider the reaction and the set of corresponding kinetic data carried out at constant temperature in the table below.

$$NO_{2\,(g)} + CO_{(g)} \longrightarrow NO_{(g)} + CO_{2\,(g)}$$

Trial	**Rate of formation of CO_2 (mol L^{-1} min^{-1})**	**Initial Concentration of NO_2 (mol L^{-1})**	**Initial Concentration of CO (mol L^{-1})**
1	2.73	0.100	0.100
2	2.73	0.100	0.200
3	10.92	0.200	0.100

(i) Name a method that can be used to follow the rate of the reaction in part (a).

(ii) Deduce the order with respect to NO_2. Explain your reasoning.

(iii) Deduce the order with respect to CO. Explain your reasoning.

(iv) Deduce the rate equation for the reaction and the overall order of reaction.

(v) Calculate the rate constant for the reaction.

(8 marks)

(b) Considering the results obtained in part (a), suggest a mechanism for this reaction. Indicate the rate-determining step. Explain your reasoning.

(4 marks)
(Total = 12 marks)

6. Reaction **A** is **spontaneous** at room temperature, whilst reaction **B** is **not**.

A $NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

B $NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)} \longrightarrow NH_4NO_{3(s)}$

(a) What is understood by the term spontaneous?

_____

_____

_____

(1 mark)

(b) At what temperature does reaction **B** become just spontaneous, knowing that $\Delta H^o = -28.05$ kJ mol^{-1} and $\Delta S^o = -108.7$ J K^{-1} mol^{-1}.

_____

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_____

_____

(3 mark)

(c) Reaction **A** is a neutralization reaction, and its enthalpy change may be described by the '*standard enthalpy change of neutralization*'. Define this term.

_____

_____

_____

(1 mark)

(d) 50 mL of 2.0 mol dm^{-3} CH_3COOH were mixed with 50 mL of 2.0 mol dm^{-3} NaOH in an insulated container. The initial temperature of both reagents at mixing was equal at 23.3 °C. After mixing, the temperature of the solution was measured at regular intervals as shown in the table below.

Time (min)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Temperature (^{o}C)	23.3	23.3	23.3		36.3	36.2	36.0	35.9	35.7	35.6

(i) **Plot a graph** and calculate the temperature change of the reaction.

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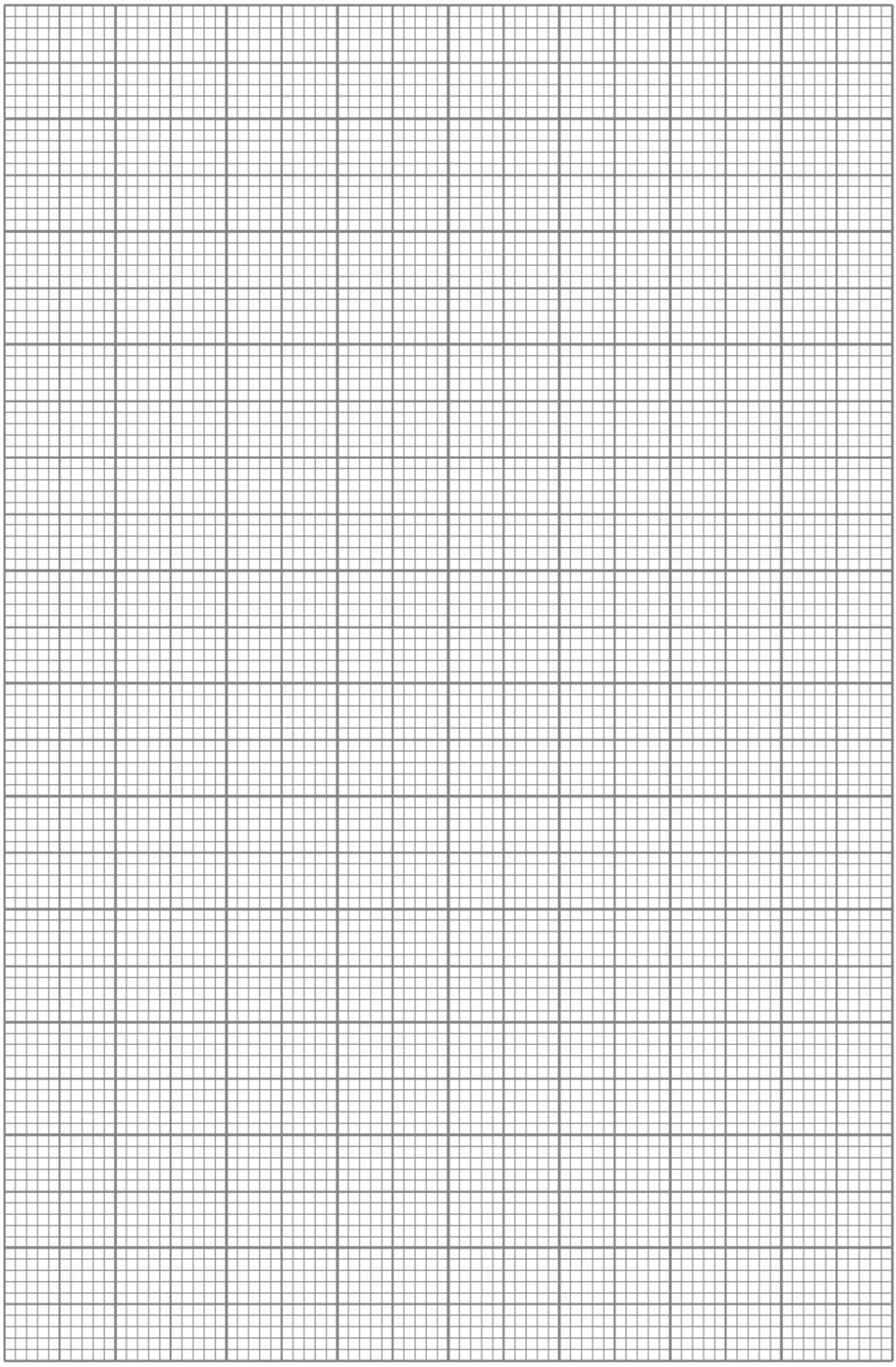


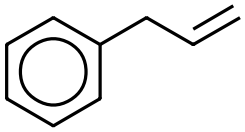
(ii) Assuming that the solution has a specific heat capacity of 4.18 kJ kg^{-1} K^{-1}, calculate the standard enthalpy change of neutralization for the reaction.
Note that the density of NaOH and CH_3COOH solutions may be assumed to be equal to 1.0 kg dm^{-3}.

(7 marks)

(e) Assuming that there were no heat losses during the experiment, explain why the value obtained in part (d) (ii) is lower from the expected value for the standard enthalpy change of neutralization.

(1 mark)
(Total = 13 marks)

7. This question is about organic molecule **A**, shown below.

A: 

(a) Give the systematic name of molecule **A**.

_____

(1 mark)

(b) The reaction of **A** with HBr in the dark can hypothetically produce two products, however, the reaction results in one major product.

(i) Give the structure of the major product from this reaction.

_____

(1 mark)

(ii) Give the mechanism for this reaction.

_____

_____

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(4 marks)

(iii) Explain why this reaction results in one major product.

_____

_____

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_____

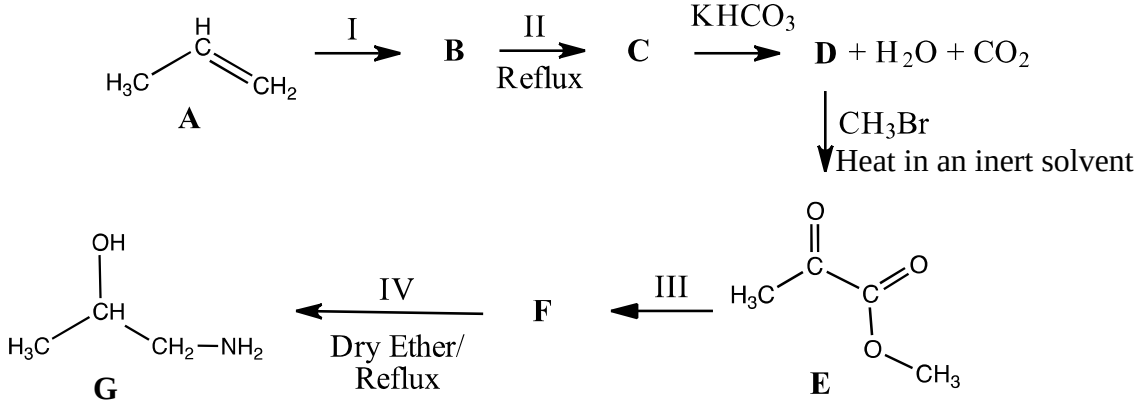
(3 marks)

(c) Give the structure of the product from the reaction of **A** with aqueous **acidified** MnO_4^- .

_____

(1 mark)
(Total = 10 marks)

8. Amino alcohols are important precursors of a number of pharmaceutical compounds. The scheme below shows a possible route for the production of a particular amino alcohol **G** from propene (**A**), where **B**, **C**, **D**, **E** and **F** refer to intermediate organic substances and **I**, **II**, **III** and **IV** are the reagents involved in specific steps as shown.



(a) Give the systematic name of compound **G**.

_____

(1 mark)

(b) Give the structural formulae of substances **B**, **C, D** and **F.**

_____ _____

B **C**

_____ _____

D **F**

(4 marks)

(c) Identify reagents I to IV.

_____

_____

_____

_____

(4 marks)

(d) Compound **G** can be found in more than one form.

(i) What are the isomers of **G** called?

_____

(ii) Discuss why **G** has different isomers.

_____

_____

_____

(iii) Explain how the different isomers of **G** can be distinguished from each other.

_____

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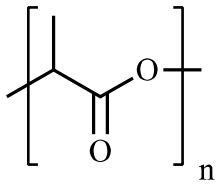
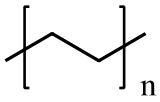
_____

(3 marks)
(Total = 12 marks)

9. **A** and **B**, shown below, are two polymers.

A: 

B: 

(a) Give the molecular structure of the monomers of polymers **A** and **B**.

(2 marks)

(b) Give the mechanism for the production of polymer **B** from its monomer.

(4 marks)

(c) One of the above polymers has an environmental advantage over the other. Identify which polymer has this advantage. Explain your answer.

_____

_____

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(3 mark)

(d) Proteins are biological polymers, having amino acids as their monomers. Give chemical equations showing how the amino acid glycine ($C_2H_5O_2N$) can be produced from ethanoic acid?

_____

_____

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(2 marks)
(Total = 11 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	II
DATE:	23rd May 2016
TIME:	4.00 p.m. to 7.05 p.m.

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

Answer two questions from each section and any other question.

Section A

1. (a) (i) Explain how hydrogen is produced in industry from methane gas giving chemical equations where appropriate.

(ii) Describe the bonding of the hydrides of period 3 of the Periodic Table and relate it to their physical state.

(9 marks)

(b) Explain the role of transition metals as heterogeneous catalysts in hydrogenation reactions of alkenes.

(4 marks)

(c) Solid **A** reacts completely with liquid **B** to produce gas **C** as one of the products.

(i) Calculate the molar mass of gas **C,** given that the gas has a density of 1.060 kg m^{-3} at 25 ^{o}C and 101 kPa and the universal gas constant has a value of 8.314 J K^{-1} mol^{-1}.

(ii) Identify gas **C**, knowing that when passed through a red hot metal tube it produced a volatile aromatic liquid compound. Explain your answer.

(iii) Identify solid **A** and liquid **B**.

(7 marks)
(Total: 20 marks)

2. Explain each of the following statements.

(a) Al_4C_3 and CO are not examples of carbon with an oxidation state of +4.

(2 marks)

(b) Lead can form two types of chlorides. The two chlorides have different physical and chemical properties.

(4 marks)

(c) (i) When elemental sulfur is boiled in the presence of an oxoanion of the same element, a compound is formed in which sulfur atoms have different oxidation states.

(ii) The compound formed in part (c) (i) is not stable under acidic conditions and it reacts with halogens, but does so differently with iodine and chlorine.

(9 marks)

(d) Nitrogen monoxide does not follow the octet rule and the molecule can be considered as a free radical. Illustrate your answer with an appropriate dot-and-cross diagram.

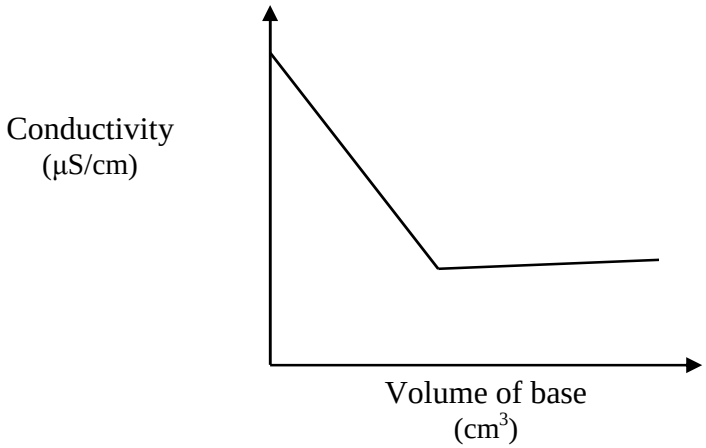
(2 marks)

(e) Nitric(V) acid can be prepared by the reaction of an involatile acid on nitrate(V) salts.

(3 marks)

(Total: 20 marks)

3. (a) Identify the type of conductimetric titration given in the graph below and explain in detail the shape of the graph.



(3 marks)

(b) Give the pH curve for a titration between aqueous ammonia and hydrochloric acid where the acid is the titrant. Explain the pH curve in detail and choose an appropriate indicator for the titration giving reasons for your choice.

(6 marks)

(c) Consider the following equilibria in sea water at 25 ^{o}C:

$$CO_{2\,(aq)} + H_2O_{\,(l)} \overset{Ka_1}{\rightleftharpoons} HCO_{3\,(aq)}^{-} + H^{+}_{(aq)}$$

$$HCO_{3\,(aq)}^{-} \overset{Ka_2}{\rightleftharpoons} CO_{3\,(aq)}^{2-} + H^{+}_{(aq)}$$

(i) Write down equations for the equilibrium constants, Ka_1 and Ka_2 for the above reactions, and state their units.

(ii) Considering that at 25 ^{o}C, the concentration of CO_2 (aq) in sea water is 5.05×10^{-4} g dm^{-3}, Ka_1 is 4.47×10^{-7} mol dm^{-3} and Ka_2 is 3.98×10^{-11} mol dm^{-3}, calculate the molar concentration of carbonate ions in sea water at pH 8.

(iii) Use the above equilibria to explain how the pH of sea water is not significantly affected by acid rain.

(11 marks)
(Total: 20 marks)

4. Explain the following statements, giving equations and/or diagrams where appropriate.

(a) The positional isomers of butyne can be distinguished through one chemical test.

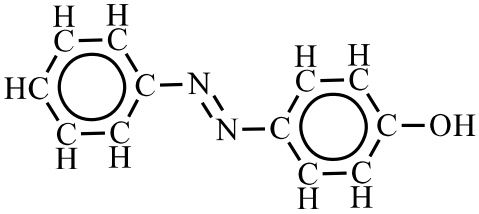
(5 marks)

(b) **B** is an organic compound composed of carbon, hydrogen and oxygen. **B** does not appear to react with either PCl_5 or 2,4-dinitrophenylhydrazine. Reaction of **B** with HI yields one organic product, **C**. If **C** has a molar mass of 142 g mol^{-1}, identify compound **B**. Explain your reasoning.

(5 marks)

(c) Starting from phenylamine as the **only organic reagent**, describe by giving relevant chemical equations how organic compound **D** can be prepared**.**

D



(5 marks)

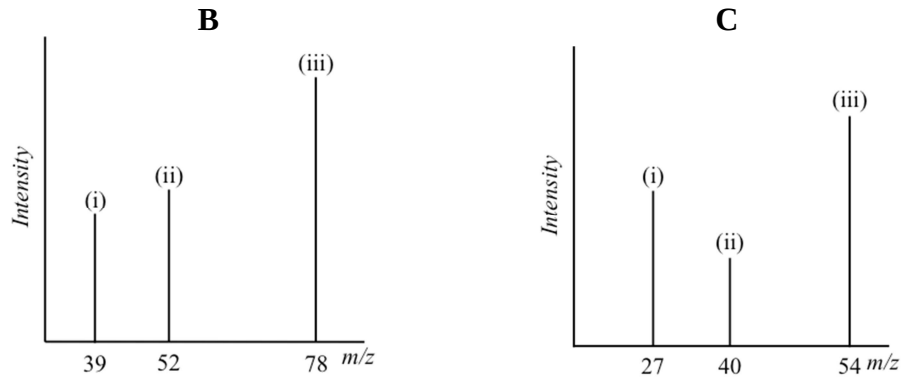
(d) Iodoethane reacts with a metal to form a compound that upon reaction with carbonyl compounds produces primary, secondary and tertiary alcohols.

(5 marks)
(Total: 20 marks)

Please turn the page.

Section B

5. This question is about two **unsaturated** hydrocarbons **B** and **C**. The mass spectra for these two compounds are shown below.



Acidified manganate(VII) solution is decolorised by **C**, but it is not decolorised by **B**. Furthermore, **C** decolorizes bromine water in the dark. Complete reaction occurs when 0.33 moles of **C** are added to 0.66 moles of liquid bromine.

(a) Identify hydrocarbons **B** and **C**. Explain your reasoning.

(8 marks)

(b) Calculate the standard enthalpy of combustion of **B** and **C** using the following standard mean bond enthalpies (all values are given in kJ mol^{-1}).

C-C	348	C=C	612	C≡C	837
C-H	412	O-H	463	C=O in CO_2	805
O=O	496				

(7 marks)

(c) The experimentally derived enthalpies of combustion for **B** and **C** are −3207 kJ mol^{-1} and −2422 kJ mol^{-1} respectively. Account for any differences between the experimental values and the values you obtained in question (b).

(3 marks)

(d) Suggest a reason why **B** and **C** react very differently.

(2 marks)
(Total: 20 marks)

6. Paracetamol is an important pharmaceutical compound. It can be prepared in the laboratory as follows.

Reagent **I** is first treated with $NaNO_3$ in the presence of dilute H_2SO_4, forming two isomers, **J** and **K**. **J** then reacts with sodium borohydride to form **L**, which in turn reacts in a 1:1 ratio with **M** to produce paracetamol ($C_8H_9O_2N$) as the major product and $C_{10}H_{11}O_3N$ as a minor product.

Note that:

- Reagent **I** is a slightly acidic organic compound which forms a purple solution with neutral iron(III) chloride.
- **J** has a higher boiling point than **K**.
- Reagent **M** is a symmetrical organic compound. The **product of hydrolysis** of **M** releases CO_2 with sodium carbonate and turns blue litmus red (these two reactions **do not** take place if **M** is **not** hydrolysed).
  Adding an aqueous solution of $AgNO_3$ to **M** after hydrolysis yields no apparent product.
  However, addition of an aqueous solution of neutral iron(III) chloride, to the products of hydrolysis of **M,** gives a brown/red solution, which forms a brown precipitate on boiling.

(a) Give the systematic names of compound **I** to **M**, explaining your reasoning. Give chemical equations when required.

(14 marks)

(b) Give the reaction of **L** with **M**, showing the formation of paracetamol.

(2 marks)

(c) The reaction of reagent **I** with $NaNO_3$ in the presence of dilute H_2SO_4 can theoretically produce three isomers, however, only two are produced in large amounts. Explain.

(4 marks)

(Total: 20 marks)

Please turn the page.

7. (a) (i) Steam distillation is an important purification technique. Explain how it works and state where this technique is most useful.

(ii) Quinoline, C_9H_7N, can be steam distilled at 760 mmHg. At a distillation temperature of 99 ^oC the saturated vapour pressure of quinoline is 10 mmHg. Calculate the mass of quinoline obtained in 100 g of distillate.

(8 marks)

(b) A mixture is composed of 4.0 moles of liquid A and 2.0 moles of liquid B at 25 ^oC. The saturated vapour pressures at 25 ^oC of pure liquid A and pure liquid B are 75 kPa and 45 kPa respectively.

(i) Explain what is meant by ideal mixtures.
(ii) Identify the more volatile of the two liquids A and B. Explain your answer.
(iii) Find the percentage composition of A and B in the vapour phase at 25 ^oC. Comment on the results of your answer.
(iv) Suggest two liquids that would form an ideal mixture.

(8 marks)

(c) A technician was asked to prepare an intravenous glucose, $C_6H_{12}O_6$, solution that matches the osmotic pressure of blood. The technician was given the following data:
- Osmotic pressure of blood at 37 ^oC is 7.65 atm;
- Molar gas constant, R, is 0.08206 **L.atm/mol.K**.

Calculate the molarity of the intravenous glucose solution that must be prepared by the technician.

(4 marks)
(Total: 20 marks)

8. (a) MnO_2 can be oxidised to a green solid that easily disproportionates under neutral or acidic conditions. Explain giving appropriate balanced chemical equations.

(4 marks)

(b) Addition of sodium carbonate solution to chromium(III) nitrate solution forms a precipitate which is not the carbonate. Explain giving appropriate balanced chemical equations.

(4 marks)

(c) Identify compounds **D** to **L** giving the systematic name of each compound. Give all the relevant balanced chemical equations where necessary.

Compound **D**, containing iron, oxygen and carbon was heated giving a black solid **E** and two colourless odourless gases, **F** and **G**. Gas **F** burns with a clean blue flame. Addition of dilute sulfuric(VI) acid to **E** forms a pale green solution **H.**

When a solution of sodium nitrate(V) is added to solution **H** followed by the slow addition of concentrated sulfuric(VI) acid, a brown coloured solution, **I** is formed at the interface of the two layers. On warming the solution in the presence of air, a brown gas **J** is given off.

Addition of an orange solution **K** to **H,** decolourises solution **K** and produces a light brown solution **L.**

(12 marks)
(Total: 20 marks)

Index No.:_____ **AM 06/III.16m**

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UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
MAY 2016

SUBJECT:	CHEMISTRY
PAPER NUMBER:	III – *Practical*
DATE:	10th June 2016
TIME:	3 hours 5 minutes

There are three questions in this paper. Answer all questions.

1. In this experiment you are required to identify the metal cation of an ethanedioate salt.

You are supplied with the following chemicals:
(i) 125 cm^3 solution of ammonium iron(II) sulfate hexahydrate, $(NH_4)_2Fe(SO_4)_2.6H_2O$, of concentration **0.100 mol dm^{-3}** labelled **S**.
(ii) 250 cm^3 of a solution of potassium manganate(VII) labelled $\mathbf{T_n}$ where **n** is the candidate laboratory number.
(iii) 125 cm^3 of **7.08 g dm^{-3}** ethanedioate monohydrate solution labelled **E**.
(iv) 2 M sulfuric acid.

(a) Enter the value of your laboratory number, **n**, in the following box.

CANDIDATE LABORATORY NUMBER, n:.....

Standardisation of potassium manganate(VII) solution, T_n.

(b) Pipette 25.0 cm^3 of solution **S** into a conical flask. Using a measuring cylinder add approximately 20 cm^3 of 2 M sulfuric acid and titrate with $\mathbf{T_n}$ from the burette. Enter your titration results in the table below.

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

Mean titre$_1$: _____ cm^3 of $\mathbf{T_n}$

(20 marks)

(c) Calculate the concentration of potassium manganate(VII) solution, $\mathbf{T_n}$.

$$8H^+_{(aq)} + MnO^-_{4\,(aq)} + 5Fe^{2+}_{(aq)} \longrightarrow 5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$$

(3 marks)

Identification of the metal ion in the ethanedioate salt.

(d) Pipette 25.0 cm^3 of solution **E** into a conical flask followed by approximately 20 cm^3 of 2 M sulfuric acid using a measuring cylinder. Place the thermometer in the conical flask and heat the solution to about 60 ^oC on a tripod and gauze using a bunsen burner.

Carefully transfer the hot solution in the conical flask under the burette and titrate slowly with $\mathbf{T_n}$ from the burette. Enter your titration results in the table below.

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

Mean titre$_2$: _____ cm^3 of $\mathbf{T_n}$

(20 marks)

(e) Given that the redox reaction is:

$$16H^{+}_{(aq)} + 2MnO^{-}_{4\,(aq)} + 5C_2O^{2-}_{4\,(aq)} \longrightarrow 10CO_{2\,(g)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$$

calculate the molar concentration, to three significant figures, of the ethanedioate salt solution **E**.

(3 marks)

(f) Given that solution **E** has a concentration of **7.08 g dm^{-3}**, identify the metal cation, M, of the ethanedioate salt, $M_2C_2O_4.H_2O$.
(Relative atomic masses: H = 1; C = 12, O = 16).

(4 marks)

Please turn the page.

2. You are provided with a solid inorganic substance labelled **X** which contains more than one cation. Carry out the tests as described below, record your observations carefully and attempt to identify the compounds.

(a) Dissolve your sample of substance **X** in approximately 20 cm^3 of water. ***Retain this solution for tests (b) to (h)***.

Observation	*Inference*

(b) To about 1 cm^3 of the solution from (a), add aqueous ammonia solution slowly until in excess.

Observation	*Inference*

(c) To about 2 cm^3 of the solution from (a), add dilute sodium hydroxide solution slowly until in excess and then heat the mixture gently.

Observation	*Inference*

(d) To about 1 cm^3 of the solution from (a), add 1 cm^3 concentrated hydrochloric acid.

Observation	*Inference*

(e) To about 1 cm^3 of the solution from (a), add an equal amount of potassium hexacyanoferrate(II) solution.

Observation	*Inference*

(f) To about 1 cm^3 of the solution from (a), add an equal amount of potassium thiocyanate solution.

Observation	*Inference*

Please turn the page.

(g) To about 1 cm^3 of the solution from (a), add 5 cm^3 of $SnCl_2$ solution followed by 5 drops of potassium thiocyanate solution.

Observation *Inference*

(h) To about 1 cm^3 of the solution from (a), add an equal amount of barium chloride solution followed by 1 cm^3 of dilute nitric acid.

Observation *Inference*

Conclusion

Substance **X** is probably: _____

(30 marks)

3. You are provided with an organic solid, substance **Z**, containing more than one functional group. Perform the following tests on **Z** and record your observations and inferences in the spaces provided.

(a) Burn a **small quantity (tip of a spatula)** of **Z** on a crucible lid. Do not allow the flame to burn longer than you need to make a good observation.

Observation	*Inference*

(b) Transfer a small quantity (on a tip of a spatula) of **Z** to a boiling tube and add 10 cm^3 of distilled water. Heat the resulting mixture slowly to boiling. Stop heating and test the contents of the boiling tube with litmus paper. **Retain the contents for the boiling tube for tests (c) and (d)**. **Tests (c) and (d) must be carried out immediately.**

Observation	*Inference*

Please turn the page.

(c) To 1 cm^3 of the contents of test (b) add 1 cm^3 of bromine water.

Observation *Inference*

(d) To 1 cm^3 of the contents of test (b) add few drops of neutral iron(III) chloride.

Observation *Inference*

(e) Transfer the remaining quantity of **Z** to a boiling tube and add 2 cm^3 of methanol followed by 10 drops of concentrated sulfuric acid (CARE! CORROSIVE). Heat the mixture in a boiling water bath for 1 minute. Cool and add the mixture slowly to 10 cm^3 of sodium carbonate solution.

Observation *Inference*

Conclusion: A possible structure for **Z** is: _____

(20 marks)