L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	20th May 2026
TIME:	9:00 a.m. to 12:05 p.m.

Required Data: Relative atomic masses (RAM): H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Co = 58.9, Br = 80, I = 127, Ba = 137.3

Answer ALL questions

1. This question is about chemical bonding.

   a) Explain why the boiling point of Br_2 is 59 °C while that of iodine monochloride, ICl, is 97 °C.

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_____

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_____

_____ (3)

   b) Draw the Lewis structure for the following chemical species.

   i) $SO_3(g)$

(1)

   ii) NH_4^+ ion

(1)

Question continues on the next page.

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c) The bonding in the carbonate ion exhibits delocalisation of electrons.

i) Explain 'delocalisation of electrons'.

_____

_____

_____ (1)

ii) Illustrate delocalisation of electrons in the carbonate ion with the aid of resonance structures (canonical forms) of the ion.

(2)

iii) The C-O bond is 143 pm long while the C=O bond is 123 pm long. Explain, with the aid of a diagram, why all three carbon-to-oxygen bonds in the carbonate ion are 136 pm in length.

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_____

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_____

_____ (3)

d) Explain, in terms of bonding and structure, why graphite can be used as a lubricant.

_____

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_____

_____

_____ (2)

(Total: 13 marks)

2. This question is about inorganic chemistry

a) The first electron affinity of oxygen is exothermic, whereas the second electron affinity of oxygen is endothermic. Explain these observations.

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_____ (2)

b) Consider the following half-equation.

$$X_2(g) + 2e^- \rightleftharpoons 2X^-(aq)$$

The $E^\ominus$ values for this half-reaction with fluorine and chlorine gas are 2.87 V and 1.36 V, respectively.

i) Use these $E^\ominus$ values to determine which oxidising agent is stronger.

_____

_____

_____ (1)

ii) By considering the energy cycle for the formation of aqueous halide ions, explain why chlorine is a stronger oxidising agent than bromine. Your answer must account for the relative contributions of bond dissociation enthalpy, first electron affinity, and hydration enthalpy.

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Question continues on the next page.

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_____

_____ (4)

c) Relate the physical state of NaH and HCl at room temperature to their structure and bonding.

_____

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_____ (3)

(Total: 10 marks)

3. A hydrated ammonium cobalt sulfate(VI) compound has the general formula $Co_a(NH_4)_b(SO_4)c{\cdot}dH_2O$. The values of a, b, c, and d were determined by performing the following experiments on separate 2.50 g samples of the compound.

   a) Aqueous Na_2CO_3 was added in excess to one of the samples, resulting in the precipitation of $CoCO_3$. After filtration and heating under inert conditions, 0.481 g of CoO was obtained. Calculate the percentage by mass of cobalt in the original sample.

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_____

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_____ (2)

b) Another sample was treated with excess NaOH and heated, releasing ammonia gas. The NH_3 was absorbed in water and neutralised using 28.9 cm^3 of 0.443 mol dm^{-3} HCl(aq). Determine the percentage by mass of ammonium ions in the sample.

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_____

_____

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_____

_____ (2)

c) The third sample reacted with excess $BaCl_2$ solution to form a precipitate of $BaSO_4$. After filtration, 2.94 g of $BaSO_4$ were collected. Calculate the percentage by mass of sulfate(VI) ions in the sample.

_____

_____

_____

_____

_____ (2)

d) Using your results from parts (a), (b), and (c), deduce the values of a, b, c, and d in the empirical formula of the compound, $Co_a(NH_4)_b(SO_4)c{\cdot}dH_2O$.

_____

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_____

_____ (3)

(Total: 9 marks)

Please turn the page.

4. This question is about transition elements.

a) Give the electronic configurations (in terms of s, p, d orbitals) of the following transition metal ions: (1)

i) Mn^{2+} _____

ii) Cu^{2+} _____

b) Give a chemical formula for **each** of the following species: (3)

i) An optically active complex ion of Fe^{3+}.

_____

ii) A Cr^{3+} complex ion with water and chloride ligands, which exhibits cis/trans isomerism.

_____

iii) A tetrahedral complex of Cu^{2+}.

_____

iv) The brown complex of $Fe^{2+,}$ which is produced in the chemical test for nitrate(V) ion.

_____

v) The blood-red complex produced in the chemical test for Fe^{3+}.

_____

vi) A colourless complex of Cu^{+}.

_____

c) State **TWO** factors which determine the colour of transition metal complexes. For **each** factor, provide **TWO** specific examples of complex ions, stating their chemical formulae and the resulting colour change to illustrate the effect of the factor.

_____

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_____ (3)

d) A reddish-brown precipitate of Cu_2O is produced in the Fehling's test for aldehydes. With the aid of two half reactions and the full redox equation, describe how this precipitate is formed.

_____

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_____ (2)

e) Manganate(VII) ions under alkaline conditions oxidise methylbenzene to benzoate ions. Give the equations of the two half reactions and the full redox equation.

_____

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_____

_____ (2)

f) In blood haemoglobin, Fe^{2+} transfers oxygen from the lungs to the rest of the body. Explain why CO is so toxic when inhaled.

_____

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_____ (1)

(Total: 12 marks)

5. This question is about chemical equilibria.

a) Describe how the magnitude of the numerical value of the equilibrium constant (K_c or K_p) of a reaction relates to the extent of a reversible reaction at equilibrium.

_____

_____

_____ (1)

Question continues on the next page.

b) The industrial preparation of ethanol involves the reaction of ethene with steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

i) At 500 K, ethene and steam are introduced in a closed vessel at initial partial pressures of 10.0 atm and 8.0 atm, respectively. They are allowed to reach equilibrium, where 75% of ethene is converted to ethanol. Calculate K_p at this temperature.

_____

_____

_____

_____

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_____

_____ (3)

ii) Describe what happens to K_p when the pressures of both ethene and steam are increased at constant temperature.

_____

_____

_____ (1)

iii) Describe what happens to K_p when the temperature is decreased at the same pressure.

_____

_____

_____ (1)

c) The following reaction represents the synthesis of HI gas.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

Determine whether this reaction is endothermic or exothermic, given that K_c increases with increasing temperature. Explain your answer.

_____

_____

_____

_____ (2)

d) To reduce greenhouse gas emissions, ammonia can potentially be used to replace fossil fuels in gas turbines since it produces hydrogen as a clean fuel. State the ideal conditions of temperature and pressure that have to be used to produce a high equilibrium concentration of hydrogen gas, given that the decomposition of ammonia into nitrogen and hydrogen is endothermic. Explain your answer.

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_____ (3)

(Total: 11 marks)

6. This question is about reaction kinetics.

a) In a reaction between A and B, the rate of reaction quadruples when the concentration of A is doubled while that of B is kept constant. The rate increases by a factor of 8 when the concentrations of both A and B are doubled.

i) Derive the rate equation.

_____

_____

_____

_____

_____

_____ (3)

Question continues on the next page.

ii) Deduce the overall order of the reaction.

_____ (1)

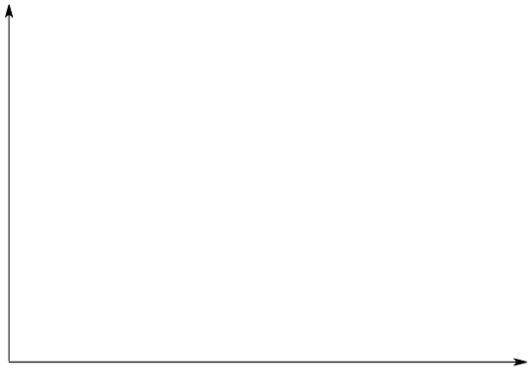
iii) Deduce the units of the rate constant.

_____

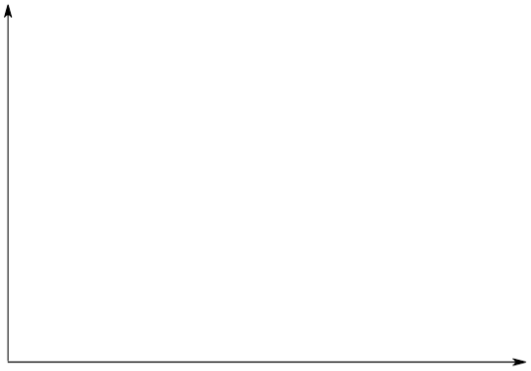
_____ (1)

b) The decomposition of hydrogen peroxide into water and oxygen is a first-order reaction. On the axes provided below, sketch a graph for the following. (2)

i) $[H_2O_2]$ against time.



ii) rate of reaction of H_2O_2 against $[H_2O_2]$.



c) The reaction of NO with O_2 to give NO_2 is second order with respect to NO and first order with respect to O_2. Suggest a mechanism for the reaction and indicate the rate-determining step.

_____

_____

_____

_____ (2)

d) State **TWO** reasons why it is highly improbable for a three-particle collision to result in a reaction.

_____

_____

_____

_____

_____ (2)

(Total: 11 marks)

7. a) Fill in the following table, giving the structural formula of the organic product of the following reactions.

Reaction	Structural formula of the product
1-bromopropane refluxed with KCN in aqueous ethanol.	
Heating 2-iodopropane and sodium metal in dry ether.	
1-bromopropane refluxed with magnesium in dry ether.	
PCl_5(s) added to 4-hydroxybutanal.	
2-iodobutane refluxed with sodium propanoate.	

(3)

b) Give the name of a halogenoalkane that can be used to prepare but-1-ene as the only alkene product.

_____ (1)

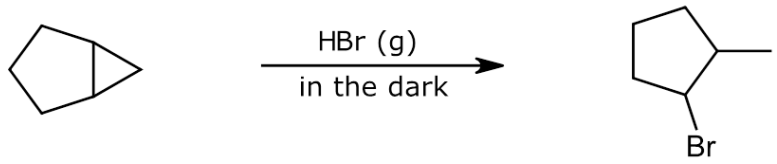
c) Give a balanced equation, including reagent(s) and conditions to prepare but-1-ene from the halogenoalkane given in part (b).

_____

_____ (2)

Question continues on the next page.

d) Bicyclo[3.1.0]hexane is a cycloalkane composed of two hydrocarbon rings fused together. It reacts with HBr(g) in the dark to form 1-bromo-2-methylcyclopentane.



bicyclo[3.1.0]hexane

1-bromo-2-methylcyclopentane

i) Use your knowledge of the reactivity of cycloalkanes to explain why the reaction of bicyclo[3.1.0]hexane with HBr(g) in the dark stops at 1-bromo-2-methylcyclopentane, and no further reaction is observed.

_____

_____

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_____

_____

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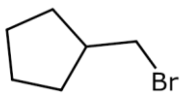
_____

_____ (3)

ii) The reaction shown in part (d) proceeds via electrophilic addition, and a secondary product, shown below, can form in minor quantities. Use your knowledge of the electrophilic addition mechanism to suggest an explanation for the formation of the minor and major products in terms of the stability of carbocations.



1-(bromomethyl)cyclopentane

_____

_____

_____

_____

_____

_____

_____

_____

_____ (3)

iii) Give the structure of a positional isomer of 1-bromo-2-methylcyclopentane.

_____ (1)

(Total: 13 marks)

8. Consider the following two compounds.

$CH_3CH_2CH(OH)CH_3$ $CH_3CH_2CH_2OCH_3$

a) Give the systematic name of **each** compound.

$CH_3CH_2CH(OH)CH_3$ _____

$CH_3CH_2CH_2OCH_3$ _____(1)

b) What specific type of isomerism do they show?

_____ (1)

c) Both compounds can react with concentrated HI. Give equations for both reactions.

_____

_____ (2)

d) $CH_3CH_2CH(OH)CH_3$ has a positional isomer. They both react when warmed with acidified potassium manganate(VII).

i) Give structural formulae of the products of the reaction of both isomers with acidified potassium manganate(VII).

_____

_____ (2)

ii) Describe any visible change during these reactions.

_____ (1)

(Total: 7 marks)

Please turn the page.

9. Ethanal can be prepared from ethanol using a distillation apparatus with a dropping funnel.

a) Explain why distillation rather than the reflux setup is used in this preparation.

_____

_____

_____ (2)

b) State the reagents that are placed in the dropping funnel.

_____ (2)

c) The ethanal formed can be purified by preparing a solid derivative with sodium hydrogensulfate(IV). Give the structural formula of the solid derivative formed.

_____ (1)

d) Aldehydes like ethanal can be converted to alcohols.

i) State the type of reaction.

_____ (1)

ii) Suggest a suitable reagent for this reaction.

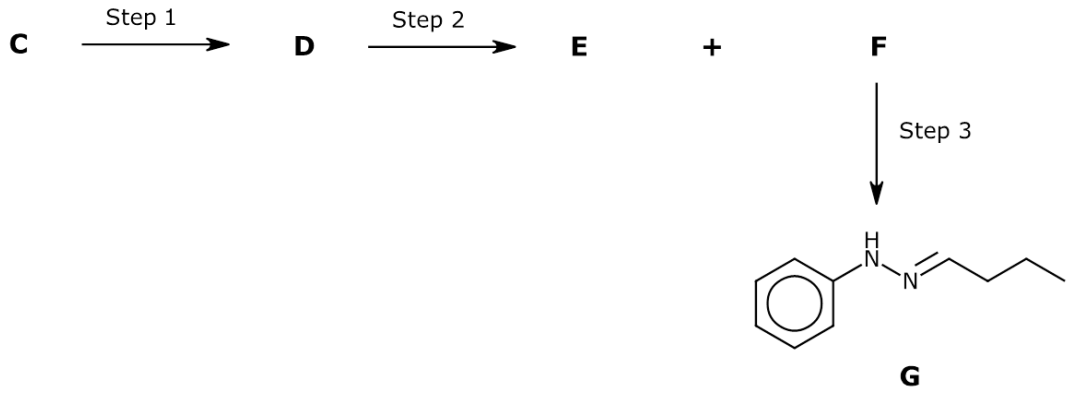
_____ (1)

iii) Describe a simple test to distinguish between ethanol and ethanal, which gives a positive result for ethanal.

_____

_____ (1)

e) In the following scheme, compounds **C** to **G** are organic compounds. Compound **C** is a hydrocarbon with an RMM of 70. Compound **F** reacts to form compound **G** in step 3. Compound **E** disproportionates in the presence of cold, concentrated sodium hydroxide.



i) Give the structures of the organic compounds **C**, **D**, and **F**.

_____

_____

_____ (3)

ii) State the reagents used in steps 1 and 3.

_____

_____ (2)

iii) Give the equation for the disproportionation of compound **E**.

_____ (1)

(Total: 14 marks)

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ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	21st May 2026
TIME:	9:00 a.m. to 12:05 p.m.

A Periodic Table is provided.
Ionic product of water, K_w = 1.00 x 10^{-14} mol^2 dm^{-6}

Answer TWO questions from each section and ANY other question.

SECTION A

1. This question deals with ionic equilibria.
   a) Although $CuCO_3$ is regarded as insoluble in water, a small amount actually dissolves.
      i) Relate the solubility product, K_{sp}, to the molar solubility of $CuCO_3$. (1)
      ii) Given that 0.30 mg of $CuCO_3$ dissolves in 200 mL of aqueous solution at 25 °C, calculate K_{sp} of $CuCO_3$ at this temperature and give its unit. (3)
      iii) Explain how the presence of sodium carbonate in the aqueous solution will influence, if at all, the solubility of $CuCO_3$. (1)
      iv) Explain how the addition of aqueous ammonia affects the aqueous solubility of $CuCO_3$. (2)

   b) Explain the following statements.
      i) $AlCl_3$ is a Lewis acid. (1)
      ii) The hydrogencarbonate ion is amphoteric. (1)
      iii) Ammonium chloride solution is acidic. (2)

   c) Lidocaine (Lid) is a common local anaesthetic that acts by blocking sodium channels inside nerve cells. Its protonated form ($LidH^+$) has a pK_a of 7.90 at 25 °C.
      i) Write the equilibrium equation for lidocaine (using Lid for the free base) reacting with water. (1)
      ii) Calculate K_b for lidocaine. (3)
      iii) If a doctor uses a lidocaine solution that has a pH of 6.9, use the expression of K_b to calculate the ratio of the protonated form ($LidH^+$) to the free base in this solution. (3)
      iv) Given that the fat-soluble free base is required to enter the nerve cell, explain whether a lidocaine solution at pH 7.9 would be more effective as a painkiller. (2)

(Total: 20 marks)

Please turn the page.

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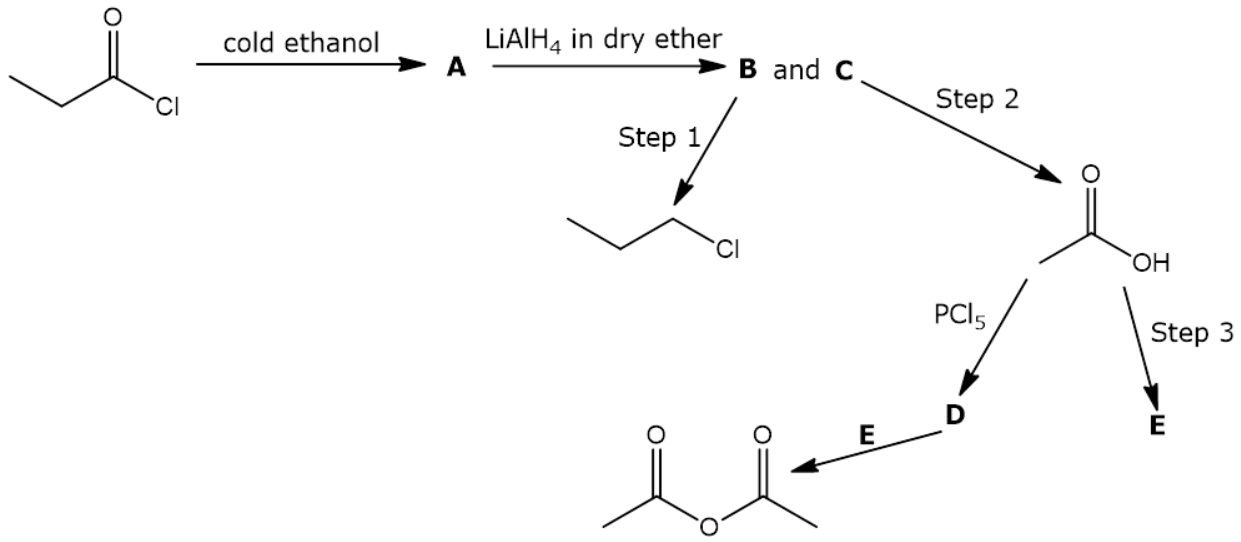
2. This question is about aliphatic organic chemistry and kinetics.
Consider the following scheme. Compounds **A** to **E** are organic molecules.



a) Give the systematic name of compound **A**. (1)
b) Complete the reaction scheme above by giving the structure of compounds **B**, **C**, **D**, and **E**. (4)
c) Give the reagents and conditions for steps 1, 2 and 3 in the scheme above. (3)
d) $(CH_3CO)_2O$ can be converted to ethanamine. Give balanced equations to show this conversion. (4)
e) CH_3CH_2COOH and CH_3COOCH_3 are isomers, yet have different boiling points. Explain. (3)
f) Ethanoic anhydride decomposes in the gas phase at 600 K to produce ethenone and ethanoic acid according to the following equation. The table below gives the decomposition data.

$$(CH_3CO)_2O\ (g) \xrightarrow{heat} CH_2{=}CO\ (g) + CH_3COOH\ (g)$$

Time elapsed (s)	**$[(CH_3CO)_2O]$ mol dm^{-3}**
0	0.1000
46	0.0500
92	0.0250
138	0.0125

i) Derive the rate equation from the given data. Explain your answer. (2)
ii) Calculate the elapsed time to reach the final concentration of 0.0125 mol dm^{-3} had the initial concentration been 0.200 mol dm^{-3}. (1)
iii) Sketch on the same pair of axes a graph showing the distribution of energies at 600 K and 610 K. Label the graphs. (2)

(Total: 20 marks)

3. This question is about aromatic organic chemistry.
   a) Benzene can be converted to nitrobenzene.
      i) State the reagents and conditions to bring about this change. (1)
      ii) Describe the mechanism for this reaction. (4)
   b) Nitrobenzene can be converted to phenylmethanamine ($C_6H_5CH_2NH_2$). Give a scheme clearly showing reagents, conditions and any intermediate compounds formed in this conversion. (8)
   c) Benzeneamine and phenylmethanamine have different basic strengths. Explain. (3)
   d) An isomer of phenylmethanamine can be oxidised to an amino acid that can show intramolecular hydrogen bonding.
      i) Identify this isomer by giving the structure. (1)
      ii) Under the right conditions, this isomer can be oxidised to an amino acid. Give the structure of the amino acid. (1)
      iii) Explain the absence of optical activity in the amino acid described in part (ii). (2)

(Total: 20 marks)

4. This question is about phase and redox equilibria.
   a) The table below gives the compositions of two solutions, S and P and their experimental saturated vapour pressure (P_{exp}).

	Compositon (moles)			
Solution	**Liquid A**	**Liquid B**	**Liquid C**	P_{exp} **(kPa)**
S	0.72	0.48	0	9.2
P	0.40	0	0.93	8.5

   The saturated vapour pressures of liquids A, B, and C when pure are 12.8 kPa, 3.8 kPa, and 5.0 kPa, respectively. Evaluate whether solutions S and P exhibit ideal or non-ideal behaviour. (4)

   b) Nitric(V) acid and water form a non-ideal solution, and their boiling points when pure are 78.2 °C and 100 °C, respectively, with an azeotrope forming at a composition of 68 % by mass nitric(V) acid.
      i) Sketch a temperature-composition diagram for solutions of the two liquids and explain its shape. (4)
      ii) Describe the fractional distillation of a 50 % by mass nitric acid solution. (4)

   c) Explain why the electrode potential of a redox reaction must be positive for the reaction to be thermodynamically feasible. (3)

   d) In the presence of water and oxygen, iron rusts.
      i) Explain the electrochemical process by which iron corrodes. (3)
      ii) To prevent corrosion, iron is usually galvanised by coating it with a layer of zinc. Explain why galvanised iron does **not** corrode when a small part of the zinc layer is scratched off. (2)

(Total: 20 marks)

Please turn the page.

SECTION B

5. This question is about s-block and group 4 chemistry.
   a) Describe the trend in the melting points of the Group 1 elements lithium, sodium and potassium and explain this trend in terms of metallic bonding. (3)

   b) Describe the reactions of Group 2 metals with water, highlighting the trend in reactivity down the group. (3)

   c) Explain the trend in thermal stability of Group 2 carbonates down the group. In your answer, include chemical equations. (4)

   d) Identify the principal oxidation states of tin and lead, and provide examples of the redox behaviour of simple compounds of these elements. Discuss the relative stabilities of these states within Group 4, providing an explanation of the inert pair effect to account for the observed trends. (7)

   e) Explain why carbon tetrachloride does **not** hydrolyse in water, whereas silicon tetrachloride hydrolyses readily. (3)

(Total: 20 marks)

6. This question concerns the chemistry of oxygen, sulfur, and group 7 elements.
   a) Superoxides are unstable, highly reactive species.
      i) Illustrate the structure and bonding of the superoxide ion, indicating any unpaired electrons. (1)
      ii) Potassium superoxide is used in rebreathers. Explain briefly why and write chemical equations to back up your answer. (3)

   b) Explain the trend in acid strength of the hydrogen halides HF, HCl, HBr and HI in aqueous solution. (4)

   c) Hydrogen peroxide can act as both an oxidising and a reducing agent.
      i) Describe the preparation of hydrogen peroxide in the laboratory. (4)
      ii) Using ionic equations, show how hydrogen peroxide can act both as an oxidising agent and as a reducing agent. Indicate any changes in the oxidation states of chemical species. (3)

   d) Sulfuric(VI) acid is a highly corrosive acid widely used in both small-scale reactions and industrial applications.
      i) Describe **THREE** of the properties of sulfuric(VI) acid, besides its acidicity, that make it such an important reagent. (3)
      ii) Account for the presence of sulfuric(VI) acid in the atmosphere and list two environmental impacts. (2)

(Total: 20 marks)

7. This question is on the chemistry of amines.

a) A series of spectroscopic and chemical tests was performed to determine the structure of aliphatic amine **Q**.

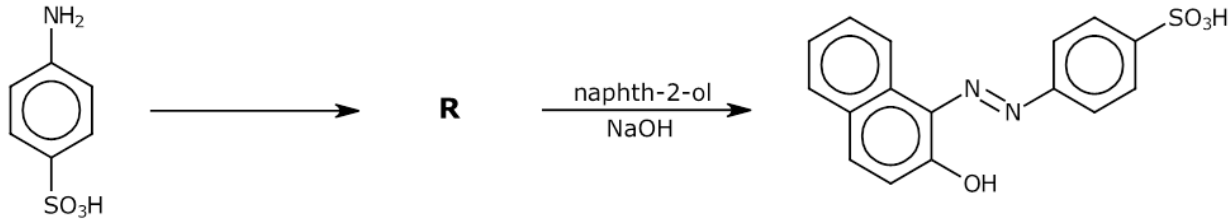
i) Compound **Q** shows a molecular ion peak at *m/z* = 59 and a peak at *m/z* = 15. Draw the structures of **FOUR** isomeric amines that would give such mass spectral peaks. (2)

ii) Amines react with nitric(III) acid. Write a fully balanced equation, with state symbols, for the reaction of one of the isomeric amines from part (i) with nitric(III) acid, and state what would be observed in this reaction. (2)

iii) Compound **Q** does not show a visible reaction with nitric(III) acid. Spectroscopic analysis showed that the IR spectrum of **Q** contained a C–N stretching absorption but no N–H stretching vibration, and that its ^{1}H NMR spectrum consisted of a single peak. A second ^{1}H NMR spectrum, obtained after treating **Q** with deuterium oxide, was identical to the first. Identify the structure of **Q** and justify your answer using all this information. (3)

iv) Write an equation for the reaction of **Q** with iodomethane and name the organic product formed. (2)

b) The following scheme shows part of the process which leads to the formation of Acid Orange 7, a brightly coloured compound used in the textile dyeing industry.



4-aminobenzenesulfonic acid

Acid Orange 7

i) Name the reagents and conditions which are required to produce **R** in the above scheme and draw the structure of **R**. (2)

ii) Explain the importance of maintaining the required conditions for the formation of **R** and describe the outcomes if these conditions are **not** kept. (2)

iii) Explain why an aryl diazonium ion is significantly more stable than an aliphatic diazonium ion. In your answer, include appropriate resonance structures. (4)

iv) In the above scheme, naphth-2-ol (a phenol) and aqueous sodium hydroxide are added to convert compound **R** to the final product, Acid Orange 7. Describe this reaction. In your answer, explain the role of sodium hydroxide and identify the electrophile. (3)

(Total: 20 marks)

Please turn the page.

8. This question focuses on energetics.

a) Hydrazine is a hypergolic fuel that combusts spontaneously upon contact with oxygen, forming nitrogen gas and water. The standard enthalpy of formation of a hydrazine liquid (H_2N-NH_2) can be calculated in two ways, either from standard enthalpies of combustion or from the bond enthalpies. Explain the principle behind each method and state whether experimental or theoretical data are used in each case. (4)

b) Methylpropanal and butanone are structural isomers of butanal. For **each** isomer, state whether its enthalpy of formation would be the same, slightly different or significantly different to that of butanal. (1)

c) Construct a fully annotated Born-Haber cycle for the formation of magnesium chloride. Your diagram must explicitly label **each** enthalpy change and include the appropriate state symbols for **all** species involved. (7)

d) Butanal exists as a liquid at room temperature but vaporises under suitable conditions. The following thermodynamic data are available for butanal.

Property	Symbol	Value
Standard enthalpy of vaporisation	$\Delta H°_{vap}$	33.0 kJ mol^{-1}
Standard molar entropy (liquid)	S° (l)	200 J mol^{-1} K^{-1}
Standard molar entropy (gas)	S° (g)	295 J mol^{-1} K^{-1}

i) Explain the relationship between enthalpy change and entropy change in governing the thermodynamic feasibility of physical and chemical processes. (3)

ii) Butanal undergoes vaporisation at 298 K.

$$CH_3CH_2CH_2CHO\ (l) \rightarrow CH_3CH_2CH_2CHO\ (g)$$

Calculate the standard entropy change for the system, ΔS°_{sys}, for this process at 298 K and justify your answer by referring to what is happening at the molecular level during the process. (3)

iii) The Gibbs free energy equation can be used to determine the boiling point of butanal. Given that, in a closed system, the liquid and vapour phases are at equilibrium at the boiling point, use the provided data to calculate the boiling point of butanal. (2)

(Total: 20 marks)

Index No.:_____ AM06/III.26m

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2026 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	III – *Practical*
DATE:	11th June 2026
TIME:	3 hours 5 minutes

1. You are provided with three solutions as follows:

   i) A solution of sodium hydroxide of unknown concentration, labelled **L_n**;
   ii) A solution of sulfuric(VI) acid of concentration 0.0400 mol dm^{-3}, labelled **Z**;
   iii) A solution of an unknown acid of concentration 0.350 mol dm^{-3}, labelled **M**.

   In this experiment, you are required to:

   - titrate solution **Z** with solution **L_n** to calculate the molar concentration of solution **L_n**;
   - dilute the solution of the unknown acid **M**;
   - titrate the diluted acid solution **dM** with solution **L_n** and calculate the basicity of the unknown acid **M**.

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

CANDIDATE LABORATORY NUMBER, n:.....

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Determination of the molar concentration of the solution L_n

b) Fill the burette with solution **L_n**. Using a suitably rinsed pipette and a pipette filler, transfer 25.0 cm^3 aliquots of solution **Z** to conical flasks and add three drops of bromocresol green indicator. Titrate to a green endpoint and record the 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 **L_n**.

(18)

c) Sulfuric(VI) acid and sodium hydroxide react as follows:

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Calculate the concentration of solution **L_n** using the stoichiometry of this reaction and the data from part (b).

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_____

(3)

Determination of the basicity of acid M

d) Transfer 25.0 cm^3 of solution **M** into a 250 cm^3 volumetric flask, using a suitably rinsed pipette and pipette filler. Make up the volume to the mark with distilled water and shake the volumetric flask to homogenise the solution. Label the diluted solution, **dM**.

Fill the burette with solution $\mathbf{L_n}$. Using a suitably rinsed pipette and pipette filler, transfer 25.0 cm^3 aliquots of solution **dM** into conical flasks and add three drops of phenolphthalein indicator. Titrate with solution $\mathbf{L_n}$ and record the 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 $\mathbf{L_n}$.

(25)

e) Acid **M** and sodium hydroxide react according to the equation:

$$H_nX(aq) + nNaOH(aq) \rightarrow Na_nX(aq) + nH_2O(l)$$

Calculate the basicity of acid **M**.

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(4)

(Total: 50 marks)

Please turn the page.

2. You are provided with a solution of compound **P** and a solid **Q**. Carry out the tests described below and attempt to identify the salts **P** and **Q**. In your inferences, include the identity of any precipitates or gases which are produced.

a) To about 1 cm^3 of solution **P**, add a few drops of sodium hydroxide solution, followed by excess.

Observation *Inference*

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

(3)

b) To about 1 cm^3 of solution **P**, add a few drops of potassium thiocyanate solution.

Observation *Inference*

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

(3)

c) To about 1 cm^3 of solution **P**, add 2 cm^3 of aqueous tin(II) chloride. Shake the resulting solution, then add three drops of potassium thiocyanate solution.

Observation *Inference*

_____ _____

_____ _____

_____ _____

_____ _____

(3)

d) To about 1 cm^3 of solution **P**, add four drops of aqueous silver nitrate, followed by excess aqueous ammonia.

Observation *Inference*

(6)

e) Dissolve about half of the sample of solid **Q** in 10 cm^3 of distilled water in a boiling tube. Use this solution of **Q** for tests 2(e) and 2(f).

To about 1 cm^3 of solution **Q**, add a few drops of sodium hydroxide solution, followed by excess. Warm the resulting mixture.

Observation *Inference*

(3)

Question continues on the next page.

f) To about 1 cm^3 of solution **Q**, add an equal volume of sodium carbonate solution.

Observation *Inference*

(3)

g) Carry out a flame test on solid **Q**.

Observation *Inference*

(2)

h) Dissolve a full spatula tip of iron(II) sulfate in 5 cm^3 of water in a boiling tube. Dissolve around a quarter of your sample of solid **Q** in the freshly prepared iron(II) sulfate solution. Incline the test-tube slightly and, using a dropping pipette, carefully add 3 cm^3 of concentrated sulfuric(VI) acid down the side of the test-tube, so that it forms a separate layer beneath the aqueous solution. Do **not** shake or mix the contents of the test tube.

NOTE: Once the test is finished, dilute the solution with water and rinse the boiling tube several times with tap water.

Observation *Inference*

(5)

Conclusion

Suggest a possible identity for substance **P**: _____ (1)

Suggest a possible identity for substance **Q**: _____ (1)

(Total: 30 marks)

3. Substance **T** is an organic solid. Carry out the following tests and suggest a chemical structure for this compound.

a) Place a full spatula tip (approximately a quarter of your sample) of compound **T** in a test tube and add about 2 cm^3 of distilled water. Shake the mixture, then add 2 cm^3 of aqueous hydrochloric acid. Shake the mixture again.

Observation *Inference*

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_____ _____

(4)

b) Place a spatula tip of compound **T** in a test tube and add 4 cm^3 of distilled water, followed by 10 drops of dilute sodium hydroxide solution. Shake the mixture. **Retain this mixture for the test (c).**

Observation *Inference*

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_____ _____

(5)

Question continues on the next page.

c) To about 2 cm^3 of the mixture from test (b), add a few drops of neutral iron(III) chloride.

Observation *Inference*

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(3)

d) Place a full spatula tip (approximately a quarter of your sample) of compound **T** in a boiling tube and add about 3 cm^3 of aqueous hydrochloric acid. Cool the contents in an ice bath.

In a small test tube, dissolve a spatula tip of sodium nitrate(III) crystals in 3 cm^3 of water. Cool the contents in an ice bath.

In another small test tube, dissolve a spatula tip of naphthol in 2 cm^3 of methanol. Cool the contents in an ice bath.

Add the cold sodium nitrate(III) solution to the solution in the boiling tube and shake the contents. Finally, add the cold naphthol solution to the resulting mixture in the boiling tube.

Observation *Inference*

_____ _____

_____ _____

_____ _____

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(5)

Conclusion

Suggest a structure for compound **T** is: _____(3)

(Total: 20 marks)