Index No.:_____ AM06/I.23s

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	30th August 2023
TIME:	9:00 a.m. to 12:05 p.m.

Required Data: Relative atomic masses (RAM): He = 4, O = 16
Molar Gas Constant, R = 8.31 J mol^{-1} K^{-1}
Faraday's Constant = 96500 C mol^{-1}

Answer ALL questions

1. a) Give the electronic configuration of lithium and chlorine.

_____

_____

_____ (1)

b) Explain how beams of protons, neutrons and electrons behave in an electric field.

_____

_____

_____

_____ (3)

c) Define the relative atomic mass of an element.

_____

_____

_____

_____ (1)

Question continues on next page.

d) The table shows the relative abundances of three isotopes of element **A** identified in a **meteorite sample** by mass spectrometry.

m/z	24.0	25.0	26.0
Relative abundance	64.2	20.3	15.5

i) Calculate the relative atomic mass of element **A**.

_____

_____

_____ (2)

ii) Explain why the relative atomic mass of **A,** as given in the Periodic Table, differs from your answer to part (i).

_____

_____

_____

_____ (2)

(Total: 9 marks)

2. This question is about bonding.

a) Explain the strongest intermolecular forces between urea molecules, $(NH_2)_2C=O$.

_____

_____

_____

_____

_____ (3)

b) Explain why urea is soluble in water.

_____

_____ (1)

c) Caesium chloride and sodium chloride have different lattice structures. Relate how the ratio of the ionic radii influences the type of lattice structure observed.

_____

_____

_____

_____ (2)

d) Use the valence shell electron pair repulsion (VSEPR) theory to draw the shapes of sulfur trioxide and the ammonium ion.

i) Sulfur trioxide.

_____

_____

_____ (2)

ii) Ammonium ion.

_____

_____

_____ (2)

(Total: 10 marks)

Please turn the page.

3. This question is about periodicity.

a) Describe the trend in the melting points of period 3 elements.

_____

_____

_____

_____

_____ (2)

b) Consider the oxides Na_2O and SO_2.

i) Write balanced chemical equations for their reaction with water.

_____

_____ (2)

ii) Describe each resulting solution, using one of the following terms: strongly basic; weakly basic; neutral; weakly acidic; strongly acidic.

_____

_____ (2)

c) Give equations for the reaction, if any, of NaCl and PCl_3 with water.

_____

_____

_____ (2)

d) Aluminium reacts with chlorine gas to form a white solid. Give an equation for this reaction and explain the structure of the dimeric form of this chloride.

_____

_____

_____ (3)

(Total: 11 marks)

4. a) State Dalton's law of partial pressures.

_____

_____

_____ (1)

b) A mixture of gases is made up of 40.0 g of oxygen and 40.0 g of helium. The total pressure of the mixture is 0.900 atm.

i) Calculate the mole fractions of oxygen and helium in the gaseous mixture.

_____

_____

_____

_____

_____

_____

_____ (4)

ii) Calculate the partial pressures of oxygen and helium.

_____

_____

_____ (2)

c) i) Nitrogen is collected over water at 40.0 °C. Given that the vapour pressure of water at 40.0 °C is 7.38 kPa, calculate the partial pressure of nitrogen if the total pressure is measured as 99.42 kPa.

_____

_____

_____

_____ (2)

Question continues on next page.

ii) Given that the total volume of gas at 40.0 °C is 0.113 m^3, calculate the number of moles of nitrogen gas produced.

_____

_____

_____ (2)

(Total: 11 marks)

5. a) The $E^{\ominus}$ value for a Pb electrode is –0.13 V, while the $E^{\ominus}$ value for a Zn electrode is –0.76 V.

i) Indicating your reasoning, deduce the electrode that acts as the anode.

_____

_____

_____ (2)

ii) Indicating your reasoning, deduce the electrode that acts as the cathode.

_____

_____

_____ (2)

iii) Give an equation for the redox reaction taking place.

_____

_____ (1)

b) i) Represent the cell diagram for the galvanic cell composed of a Pb electrode and a Zn electrode.

_____

_____ (2)

ii) Calculate the $E^{\ominus}$ value for the galvanic cell.

_____

_____

_____ (2)

iii) Calculate the standard Gibbs free energy change for the redox reaction.

_____

_____

_____ (3)

(Total: 12 marks)

6. This question is about energetics.
a) Consider the following data:

Enthalpy change	Value (kJ mol^{-1})
Enthalpy change of atomization of silver	+289
Enthalpy change of atomization of fluorine	+79
First ionization energy for silver	+732
First electron affinity of fluorine	–348
Enthalpy change of formation of silver fluoride	-203

i) Construct a Born-Haber cycle for silver fluoride in the space provided.

(6)

ii) Calculate the lattice enthalpy silver fluoride.

_____

_____

_____

_____ (3)

Question continues on next page.

b) The theoretical value for the lattice energy of silver fluoride using a perfectly ionic model is found to be –824 kJ mol^{-1}. Explain why the theoretical value differs from that calculated using the Born-Haber cycle.

_____

_____

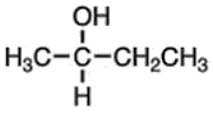
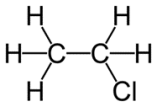
_____

_____ (3)

(Total: 12 marks)

7. This question is about organic chemistry.

a) In the spaces provided below, give the systematic name for each of the following compounds and classify each as primary, secondary, or tertiary.

Compound	Structure	Systematic name	Class
C			
D			

(2)

b) Compound **C** above can be prepared through a Grignard reaction. Give chemical equations for this reaction.

_____

_____

_____ (2)

c) Describe the Lucas test. In your answer, explain how the Lucas test could be used to distinguish between primary and tertiary alcohols.

_____

_____

_____

_____

_____ (2)

d) Explain, giving essential reaction conditions, how one can prepare a compound with a fruity smell that contains four carbon atoms starting from compound **D** as the only available organic substance.

_____

_____

_____

_____

_____

_____

_____ (4)

(Total: 10 marks)

8) This question is about aromatic chemistry

a) Give the structure of each of the following compounds.

Compound	Structure	Systematic name
E		1,4-dimethylbenzene
F		benzenamine

(2)

b) Using canonical forms, describe the delocalization in chlorobenzene. In your answer, explain whether the chlorine atom activates or deactivates the aromatic ring and explain its directing influence towards further substitution.

Question continues on next page.

_____

_____

_____

_____

_____

_____

_____

_____ (7)

c) Draw the structure of the product formed when compound **E** is heated with acidified potassium permanganate.

_____ (1)

d) Give a reaction scheme, including reagents and reaction conditions, for the conversion of compound **F** into chlorobenzene.

_____ (3)

(Total: 13 marks)

9) This question is about spectroscopy. The high-resolution ^1H NMR spectrum of compound **G** is given in Figure 1. The chemical shift data is given in the table below. The same spectrum was obtained when a drop of D_2O was added to compound **G**.

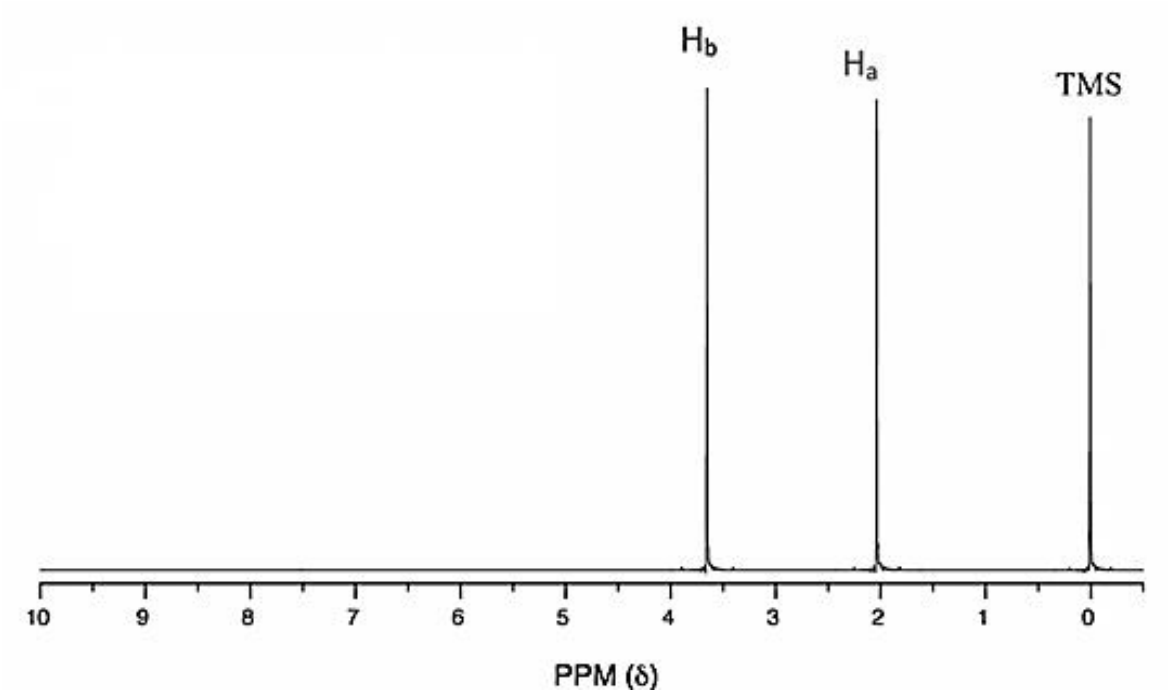


Figure 1**:** High-resolution ^1H NMR spectrum of compound **G**

Type of Proton	**Chemical shift, δ (ppm)**
R-O**H**	0.5 – 5.0
R-C**H₃**	0.7 – 1.4
C**H₃**-COOR	2.0 – 2.2
RCOO-C**H₃**	3.7 – 4.1
R-C**H**O	9.0 – 10.0
R-COO**H**	10.0 – 12.0

a) Explain the use of tetramethylsilane (TMS) in the spectrum.

_____

_____

_____ (2)

Question continues on next page.

b) Use the information provided to interpret the ^{1}H NMR spectrum, identify peaks H_a and H_b and give a plausible structure for compound **G**. Explain your answer.

_____

_____

_____

_____

_____

_____

_____ (4)

c) The IR spectrum of compound **G** is given in Figure 2. The absorption data is also given below.

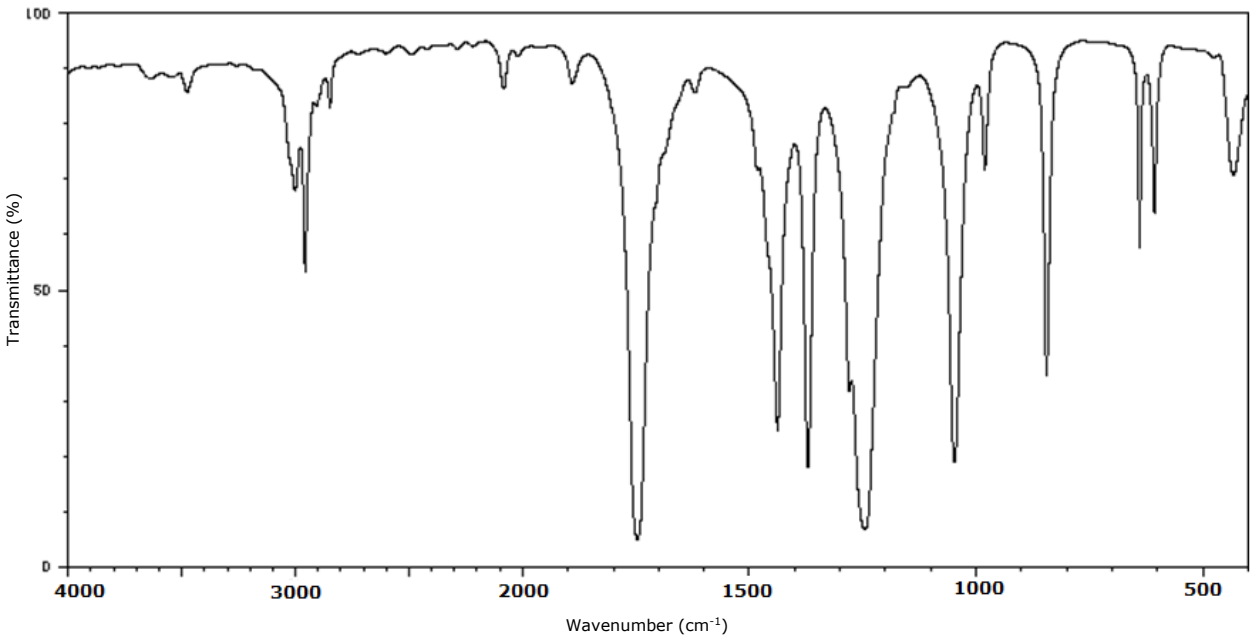


Figure 2**:** IR spectrum of compound **G**

Wavenumber (cm^{-1})	**Bond**	**Compound**
3200 – 3500 (broad)	O–H	alcohols/phenol
2500 – 3500 (very broad)	O–H	carboxylic acid
3300	C–H	aromatic
2845 - 2975	C–H	alkane (aliphatic)
2650 -2880	C–H	aldehyde
1650 - 1750	C=O	aldehyde/ketone/carboxylic acid/ester
1200 - 1250	C–O	ester

Use this data to confirm further the structure of compound **G** deduced in part (b). Explain your answer.

_____

_____

_____

_____

_____

_____

_____ (3)

d) Give equations for the conversion of compound **G** into methanamine. Your answer should include reagents and conditions for each reaction.

_____

_____

_____

_____

_____ (3)

(Total: 12 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	31st August 2023
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 is about the quantity of matter.
   a) In many household bleaches, the chlorate(I) ion (ClO^-) is the active ingredient. A given brand of household bleach was analysed as follows:
      - 10.0 cm^3 of bleach was made up to 250.0 cm^3.
      - 10.0 cm^3 of 1.0 mol dm^{-3} potassium iodide was added to 25.0 cm^3 of the diluted bleach solution, and the mixture was acidified with dilute ethanoic acid.
      - The latter solution was titrated against 0.050 mol dm^{-3} sodium thiosulfate solution.
      - The average titre value was 25.20 cm^3.

      i) Give the reduction and oxidation half equations, and construct the redox equation for the reaction of iodide and chlorate(I) ions. (3)
      ii) Give the ionic equation for the reaction in the titration with sodium thiosulfate solution. (2)
      iii) Calculate the molar concentration of chlorate(I) ions in the household bleach. (7)

   b) A sample of 1.435 g of a dry mixture of calcium carbonate and calcium chloride was dissolved in 25.0 cm^3 of a 0.950 mol dm^{-3} hydrochloric acid solution. This solution was titrated against a 0.093 mol dm^{-3} sodium hydroxide solution giving an average titre value of 21.5 cm^3. Calculate the percentage by mass of calcium chloride in the original mixture. (8)

(Total: 20 marks)

2. This question is about inorganic chemistry.
   a) Lithium shows a diagonal relationship with magnesium. Explain this statement with the help of **TWO** examples that illustrate this relationship. (5)

   b) Describe and explain the trend in thermal stability of the carbonates of Group 2 elements. (5)

   c) Explain the term allotrope, and describe the structure of the three allotropes of carbon. (5)

   d) Hydrogen gas is a potential green energy source. Explain how it can be produced via electrolysis and state **ONE** disadvantage of hydrogen storage. (5)

(Total: 20 marks)

Please turn the page.

3. This question is about chemical equilibria.
   a) Consider the equilibrium reaction, $2HI\ (g) \rightleftharpoons H_2\ (g) + I_2\ (g)$. At a given temperature, at equilibrium, HI is 50% dissociated.
      i) Given that no H_2 and I_2 are present at the beginning of the reaction, give an expression for K_c and find its value, indicating its units. (6)
      ii) Explain any changes in the position of equilibrium and the value of K_c if the total pressure is increased at a constant temperature. (3)
      iii) At the given temperature, the value of the enthalpy change of the forward reaction is 25.9 kJ. Explain what temperature changes must be imposed to increase the yield of hydrogen gas. (3)

   b) A volume of 100 cm^3 of a 0.15 mol dm^{-3} aqueous solution of methylamine was placed in a separating funnel. A volume of 75 cm^3 of an organic solvent at 25 ^oC was added to the separating funnel. The contents were well shaken and eventually left to settle to allow equilibrium to be established. A volume of 50 cm^3 of the aqueous layer was run off and titrated against a 0.225 mol dm^{-3} hydrochloric acid solution giving a titre value of 14.0 cm^3. Calculate the partition coefficient of methylamine between the organic solvent and water. (8)

(Total: 20 marks)

4. This question is about aromatic chemistry.
   a) i) Name and describe the mechanism for the monochlorination of benzene. (6)
      ii) Explain why benzene does **not** undergo an addition reaction with HBr. (3)

   b) i) Starting with benzene, give a reaction scheme for the preparation of phenol. Your answer should include the reagents and conditions for each reaction. (4)
      ii) Account for the difference in acidity between phenol and ethanol. (4)
      iii) Give an equation for the reaction of phenol with benzenediazonium chloride. What can be observed during the reaction? (3)

(Total: 20 marks)

SECTION B

5. This question is about carboxylic acid and their derivatives.
   a) Ethanamide can be prepared in several ways. Give equations for the following preparations of ethanamide.
      i) The thermal decomposition of a carboxylic acid salt. (2)
      ii) The reaction of an ester with ammonia. (2)

   Your answer must include starting reactants, reagents and conditions for each reaction.

   b) Polymerisation is one of the most used reactions in industry and is also very common in biological functions.
      i) Define condensation polymerisation. (2)
      ii) Name **TWO** synthetic polyamides. (2)
      iii) Draw the structure of 2-aminopropanoic acid. (1)
      iv) Using the monomer given in part (iii), give an equation for a condensation reaction and identify the peptide bond. (2)
      v) PET, one of the most used plastics, is a condensation polymer. Outline the formation of this synthetic polymer from its monomers. (3)
      vi) State and explain whether PET is resistant to chemical attack by strong acids and alkalis. (2)

   c) i) Define functional group isomerism. (2)
      ii) Give the structural formula of **TWO** functional group isomers with the molecular formula $C_4H_8O_2$ and state **ONE** chemical property to show how the two isomers are different. (2)

(Total: 20 marks)

6. This question is about ionic equilibria.
   a) A 1.0 L mixture was made up by mixing equal volumes of 0.305 mol dm^{-3} ethanoic acid solution and 0.520 mol dm^{-3} sodium ethanoate solution. Given that the pK_a of ethanoic acid at 25 ^oC is 4.76, find the pH of the buffer solution at this temperature. (9)

   b) Copper(II) oxide is a sparingly soluble salt with a solubility product at 25 ^oC of 5.9×10^{-36} $mol^2\ dm^{-6}$. Calculate the solubility of a saturated copper(II) oxide solution at this temperature. (5)

   c) i) If K_w is the ionic product of water, derive the expression: pK_w = pH + pOH. (3)
      ii) Given that the value of K_w at 25 ^oC is 10^{-14} $mol^2\ dm^{-6}$, use the equation in part (c)(i) to find the pH of a 0.10 mol dm^{-3} NaOH (aq) solution. (3)

(Total: 20 marks)

Please turn the page.

7. This question is about kinetics.
   a) Give the mechanism for the monobromination of methane. (4)

   b) The halogenated product formed in part (a) reacts with aqueous sodium hydroxide.
      i) Write an equation for this reaction. (1)
      ii) What is the order of reaction with respect to aqueous sodium hydroxide (1)
      iii) What is the order of reaction for the overall reaction? Explain your reasoning. (2)
      iv) How will the initial rate of reaction change if the methane concentration is doubled at a constant temperature? (1)
      v) Give the rate equation for this reaction. (1)

   c) The Arrhenius equation is given by the equation $k = Ae^{-\frac{E_A}{RT}}$
      i) Define activation energy. (1)
      ii) Describe the significance of the pre-exponential factor in the Arrhenius equation. (2)
      iii) Use the Arrhenius equation to relate temperature to the rate of a chemical reaction. (3)

   d) Describe the mechanism for the reaction between nitrogen monoxide gas and oxygen gas. Identify the rate-determining step and hence deduce the rate equation for the reaction. (4)

(Total: 20 marks)

8. This question is about transition metals.
   a) Explain why Sc and Zn are **not** classified as transition metals. (4)

   b) Transition elements and their compounds are often used as catalysts for various industrial processes. Use the Haber process as an example to show how a transition metal is employed for such a purpose. (5)

   c) Explain the term coordinate bond. Using haem, explain how transition metal atoms/ions can form multiple coordinate bonds and show how blood haemoglobin carries oxygen. In your answer, explain why carbon monoxide is highly toxic. (7)

   d) The ethanedioate ion forms an octahedral complex with iron(III). Deduce the formula of this complex and draw its structure. (4)

(Total: 20 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2023 SECOND SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	III – *Practical*
DATE:	29th August 2023
TIME:	3 hours 5 minutes

1. You are provided with four solutions as follows:

   i) A solution of sodium thiosulfate of concentration 0.100 mol dm^{-3} labelled **F**;
   ii) A solution of copper sulfate, labelled $\mathbf{C_n}$;
   iii) 10% potassium iodide solution;
   iv) A sachet containing around 2.5 g of zinc powder labelled **M**.

   In this experiment, you are required to determine the concentration of solution **C** by an iodometric method; and, subsequently, determine the standard enthalpy change for the reaction:

$$Cu^{2+}_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

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

CANDIDATE LABORATORY NUMBER, n:.....

Determination of the molar concentration of solution C_n

b) Using a suitably rinsed pipette, transfer 25.0 cm^3 of **C_n** to a 250.0 cm^3 volumetric flask and make up the volume to the mark with distilled water. Label this solution **C_{dil}**.

Fill a burette with solution **F**. Transfer a 25.0 cm^3 aliquot of **C_{dil}** to a conical flask, and add 20 cm^3 of 10% potassium iodide solution. Titrate with solution **F** and add 1 cm^3 starch indicator close to the endpoint. 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 **F**. (20)

c) Copper(II) ions react with iodide as follows, with the formation of iodine:

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Iodine thus generated is reduced back to iodide by thiosulfate as follows:

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

Using the stoichiometry of these reactions and your experimental data, calculate the concentration of **C_{dil}**, and hence the molar concentration of the original undiluted **C_n**.

_____

_____

_____

_____

_____

_____

_____

_____

_____ (5)

Determination of the enthalpy of reaction between copper(II) ions and zinc.

d) Transfer 25.0 cm^3 of the undiluted solution $\mathbf{C_n}$ to the polystyrene cup provided, supported in a 250 cm^3 beaker, for stability.

Use the thermometer provided to stir the contents of the cup. Start the timer and measure the temperature to the nearest 0.1°C, recording these temperatures at half-minute intervals.

Add all of the zinc powder to the cup at exactly three minutes. Keep stirring whilst taking temperature readings for a further ten minutes. Enter your data in the table below.

Time/min	0	1	2	3	4	5	6	7
Temperature /°C				**X**				

Time/min	8	9	10	11	12	13
Temperature /°C						

(2)

e) Plot a graph of temperature against time on the graph paper provided and determine the temperature change (**ΔT**), corrected for heat losses, for the reaction.

ΔT = _____ °C

(23)

f) Determine the molar enthalpy change of the reaction (ΔH) given that the specific heat capacity of the solution is 4.2 kJ kg^{-1} K^{-1}.

_____

_____

_____

_____

_____

_____

_____

_____(5)

(Total: 55 marks)

Please turn the page.

2. You are provided with two solutions **L** and **R,** each of which is a solution of an inorganic salt in water. Carry out the tests described below and attempt to identify the inorganic salts in solutions **L** and **R**.

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

Observation *Inference*

_____ _____

_____ _____

_____ _____

b) To about 5 drops of solution **L**, add a few drops of aqueous ammonia solution, followed by excess.

Observation *Inference*

_____ _____

_____ _____

_____ _____

c) Acidify about 5 drops of solution **L** with two drops of dilute nitric acid, and add a three drops of aqueous silver nitrate. Then add 2 cm^3 of aqueous ammonia solution, and shake.

Observation *Inference*

_____ _____

_____ _____

_____ _____

_____ _____

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

Observation *Inference*

_____ _____

_____ _____

_____ _____

_____ _____

e) Clean the nichrome wire provided with concentrated hydrochloric acid; carry out a flame test on solution **R**.

Observation *Inference*

f) Acidify about 1 cm^3 of solution **R** with dilute nitric acid and add a three drops of aqueous silver nitrate. Then add 2 cm^3 of aqueous ammonia and shake.

Observation *Inference*

g) To about 1 cm^3 of solution **R**, add 1 cm^3 of dilute sulfuric acid followed by three drops of potassium dichromate solution and shake.

Observation *Inference*

Please turn the page.

h) Mix 5 drops each of solutions **L** and **R**, followed by 2 cm^3 of sodium thiosulfate solution.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Conclusion

Suggest a possible identity for substance **L**: _____

Suggest a possible identity for substance **R**: _____

(Total: 30 marks)

3. Substance **Z** is an organic liquid. Carry out tests as described below and suggest a plausible chemical structure for this compound.

a) Note the odour of liquid **Z**.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Please turn the page.

b) Burn one drop of **Z** on a crucible lid.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

c) To about 1 cm^3 of 2,4-DNPH solution, add three drops of **Z**.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

d) Place about 1 cm^3 of potassium dichromate solution in a test tube, followed by 1 cm^3 of concentrated sulfuric acid. To the resulting solution, add a five drops of **Z** and warm in a water-bath.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

e) To about 2 cm^3 of silver nitrate solution in a test tube and add 2 drops of sodium hydroxide solution followed by aqueous ammonia slowly until only a faint trace of precipitate remains. Add two drops of **Z** to the resultant solution and warm in a water bath.

Observation	*Inference*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Conclusion

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

(Total: 15 marks)