MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2017

SUBJECT:	CHEMISTRY
PAPER NUMBER:	I
DATE:	4th September 2017
TIME:	9.00 a.m. to 12.05 p.m.

Required Data: Relative atomic masses: H = 1; O = 16; Mg = 24
Avogadro's Number = 6.02×10^{23} mol^{-1}
The molar gas constant, R = 8.314 J K^{-1} mol^{-1}
0 °C = 273 K

Answer **ALL** questions

1. (a) Define the following terms:

(i) Atomic number;

(1)

(ii) Nucleon number;

(1)

(iii) Isotope.

(1)

(b) A glance at the Periodic Table shows that there are a number of elements which have fractional value of the relative atomic mass. Explain how these fractional values arise.

(3)

(c) On vaporisation, 0.100 g of a liquid displaced a volume of 43.1 cm^3 measured at 100 °C and 100 kPa. Find the molar mass of the liquid.

(4)

(Total: 10 marks)

2. (a) What is meant by the term first ionisation energy?

(1)

(b) Write an equation to illustrate the process occurring when the second ionisation energy of magnesium is measured.

(1)

(c) Explain the following observations:

(i) The first ionisation energy of magnesium is higher than that of sodium.

(1)

(ii) The second ionisation energy of magnesium is greater than the first ionisation energy of magnesium.

(1)

(iii) The second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

(2)

(d) State and explain the trend in the first ionisation energy of the elements Mg to Ba in Group 2.

(3)

(e) The ions F^-, Na^+ and Mg^{2+} and all have the same number of electrons.

(i) Give the electronic configuration of the ions.

(1)

(ii) Place the ions in order of increasing ionic radius.

(1)

(Total: 11 marks)

3. Consider the following reactions which take place in the manufacture of sulfuric(VI) acid:

(I) $S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$ $\Delta H^{\ominus} = -297\ kJ\ mol^{-1}$

(II) $SO_2\ (g) + \frac{1}{2}\ O_2\ (g) \rightleftharpoons SO_3\ (g)$ $\Delta H^{\ominus} = -92\ kJ\ mol^{-1}$

(a) Calculate the value of the standard enthalpy of formation of sulfur trioxide (SO_3) (g).

(3)

(b) Explain, with reasons, how the equilibrium in reaction (II) responds to:

(i) an increase in pressure at constant temperature;

(2)

(ii) an increase in temperature at constant pressure.

(2)

(c) Like many industrial processes, the manufacture of sulfuric acid requires a catalyst. In this case, vanadium(V) oxide is used as a heterogeneous catalyst.

(i) State why there is a need for a catalyst in many reactions.

(1)

(ii) Explain what is meant by the term heterogeneous catalyst.

(1)

(iii) Explain what influence, if any, the catalyst will have on the equilibrium in reaction (II).

(2)

(Total: 11 marks)

4. (a) Complete the following table to show information about Period 3 oxides.

	Sodium oxide	Silicon dioxide	Phosphorus(V) oxide	Sulfur dioxide
Physical state at room temperature				
Type of bonding present				

(4)

(b) Different Period 3 oxides behave differently when mixed with water. Answer the following questions

(i) Write an equation for the reaction of sodium oxide with water and state whether the resultant pH is below or above 7.

(2)

(ii) Write an equation for the reaction of sulphur dioxide with water and state whether the resultant pH is below or above 7.

(2)

(iii) Samples of silicon dioxide and phosphorus(V) oxide are added to separate samples of pure water and each mixture is stirred. State whether the resultant pH of the water after stirring is neutral, below 7 or above 7.

pH value with silicon dioxide: _____

pH value with phosphorus(V) oxide: _____

(2)

(c) Aluminium oxide is said to be amphoteric. Describe what this property means and write reactions that show that the oxide exhibits this property.

(3)

(Total: 13 marks)

5. (a) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom and give an approximate bond angle for each.

$BeCl_2$ Cl_2O

Approximate Bond Angle ClBeCl ∠ = _____ ClOCl ∠ = _____

(4)

(b) (i) Write a full balanced equation for the reaction between magnesium hydroxide and hydrochloric acid.

_____

(1)

(ii) Calculate the volume, in cm^3, of 1.50 mol dm^{-3} hydrochloric acid required to react completely with 2.00 g of magnesium hydroxide.

_____

_____

_____

_____

(4)

(c) Suggest a suitable reagent that could be added to separate solutions of $MgCl_2(aq)$ and $BaCl_2(aq)$ in order to distinguish between the two. Describe your observations.

Reagent _____

Observation with $MgCl_2(aq)$ _____

Observation with $BaCl_2(aq)$ _____

(3)

(Total: 12 marks)

6. The following question concerns a number of properties of halogens or their compounds. Refer to the following table of electronegativity values for your answers.

	Fluorine	Chlorine	Bromine	Iodine	Carbon	Hydrogen
Electronegativity	4.0	3.0	2.8	2.5	2.5	2.1

(a) Define the term electronegativity.

(2)

(b) The table below shows the boiling points of fluorine, fluoromethane (CH_3F) and hydrogen fluoride.

	F-F	CH_3F	H- F
Boiling point / K	85	194	293

(i) Name the strongest type of intermolecular force present in:

Liquid F_2 _____

Liquid CH_3F _____

Liquid HF _____

(3)

(ii) Explain how the strongest type of intermolecular force in liquid HF arises.

(3)

(c) The acid dissociation, K_a, constants of the hydrohalic acids HX are given in the table below:

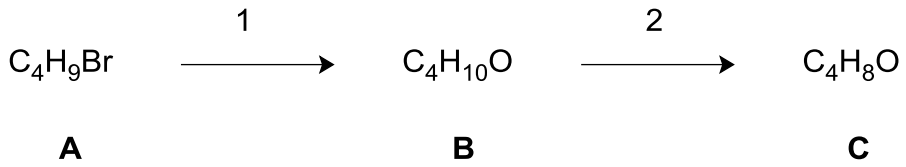
	HF	HCl	HBr	HI
K_a / mol dm^{-3}	5.6×10^{-4}	1.2×10^{8}	2.2×10^{10}	5.0×10^{10}

Explain the trend in the strength of these acids.

(5)

(Total: 13 marks)

7. (a) Compound A reacts in two steps to form compound C.



C reacts with 2,4-dinitrophenylhydrazine to form a yellow precipitate **D**.
C does not react with either Fehling's solution or Tollens' reagent.

(i) Identify **C** and write its structural formula.

(1)

(ii) Name the type or reaction that is taking place in step 1.

(1)

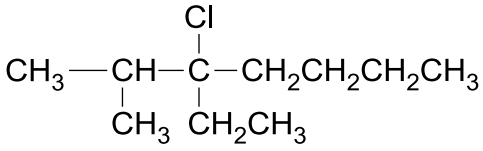
(iii) Suggest a test involving **D** which can confirm the identity of **C**.

(1)

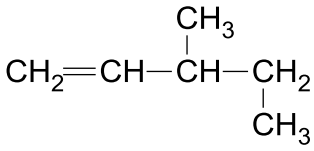
(iv) Draw and name the two geometric isomers arising from the dehydration of **B**.

(2)

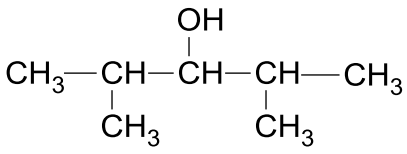
(b) Give systematic names for each of the following compounds:

(i) 

(1)

(ii) 

(1)

(iii) 

(1)

(c) Draw one compound from (i) – (iii) which has a chiral carbon and indicate this chiral carbon.

(2)

(d) Draw the structure of a positional and a functional isomer of compound (iii) in part (b):

Positional isomer: _____

(1)

Functional isomer: _____

(1)

(Total: 12 marks)

8. This question is about the amine $CH_3CH_2CH_2NH_2$.

(a) Give the systematic name of the organic compound.

_____

(1)

(b) Draw the structures of the three isomers of a primary, secondary or tertiary of $CH_3CH_2CH_2NH_2$.

(3)

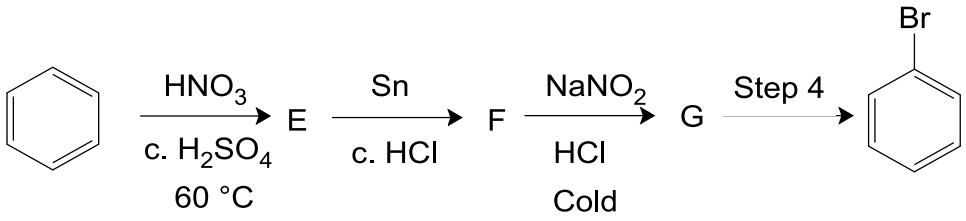
(c) Give an equation of the reaction of the amine $CH_3CH_2CH_2NH_2$ with ethanoyl chloride, CH_3COCl.

(2)

(d) Write a balanced equation for the reaction between the secondary amine from part (b) and ethanoic anhydride.

(3)
(Total: 9 marks)

9. (a) Identify the unknowns E – G in the following scheme:



E: _____
(1)

F: _____
(1)

G: _____
(1)

Reagent or reagents in Step 4: _____
(2)

(b) Compound **F** in part (a) usually needs purification. Name the experimental procedures used to purify **F**.

(1)

(c) Compound **G** can be combined with another organic compound to produce a coloured dye. Suggest an organic compound for this reaction and give the structure of the coloured dye that is produced.

(3)

(Total: 9 marks)

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UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2017

SUBJECT:	CHEMISTRY
PAPER NUMBER:	II
DATE:	5th September 2017
TIME:	9.00 a.m. to 12.05 p.m.

Required Data: Relative atomic masses: H = 1; C = 12; N = 14; O = 16.
Self-ionisation product for water, $K_w = 1 \times 10^{-14}$ mol^2 dm^{-6}.
A Periodic Table is provided.

Answer TWO questions from each section and ANY other question.

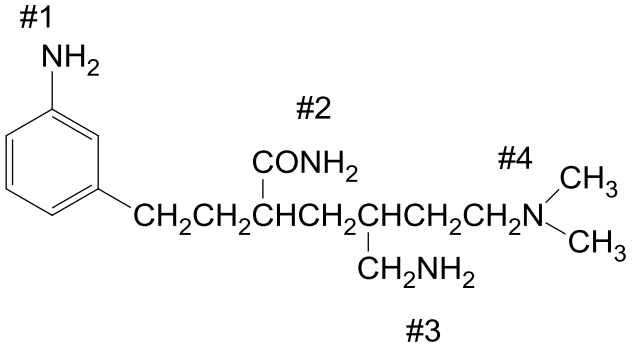
SECTION A

1. (a) Calculate the concentration of H^+ and OH^- ions of a 0.01 mol dm^{-3} solution of ammonia (NH_3) given that K_b for ammonia is 1.8×10^{-5} mol dm^{-3}. (7)

(b) Calculate the K_a of the conjugate acid of ammonia. (3)

(c) To 30 cm^3 of the solution in part (a), 20 cm^3 of a 0.01 mol dm^{-3} solution of hydrochloric acid were added. Calculate the pH of the resultant solution. (6)

(d) Molecule **A** is being screened as an active pharmaceutical ingredient. In order to increase its solubility in water, the molecule is used in its protonated form much like an ammonium ion. Indicate which of the nitrogen atoms, **#1**–**4**, is the most likely to be protonated giving a reason for your choice and reasons why the other nitrogen atoms are less likely to be protonated. (4)



A

(Total: 20 marks)

2. (a) Define the term activation energy for a chemical reaction. (2)

(b) Draw, with labelled axes, a curve to represent the Maxwell–Boltzmann distribution of molecular energies in a gas. Label this curve $\mathbf{T_1}$. On the same axes, draw a second curve to represent the same sample of gas at a lower temperature. Label this curve $\mathbf{T_2}$. Use these curves to explain why a small decrease in temperature can lead to a large decrease in the rate of a reaction. (8)

(c) Give **ONE** reason why most collisions between gas-phase reactants do not lead to a reaction. State and explain **TWO** ways of speeding up a gas-phase reaction other than by changing the temperature. (5)

(d) The rate of oxidation of bromide ions by bromate ions in an acidic aqueous solution,

$$6H^+ + BrO_3^- + 5Br^- \rightarrow 3Br_2 + 3H_2O$$

is found to follow the following rate law:

$$rate = k[Br^-][BrO_3^-][H^+]^2$$

What happens to the rate if, in separate experiments,
(i) $[BrO_3^-]$ is doubled;
(ii) the pH is increased by one unit;
(iii) the solution is diluted to twice its volume, with the pH held constant using a buffer? (5)

(Total: 20 marks)

3. (a) Give chemical reactions for the laboratory preparation of NO_2^-, NO_2, N_2O and NH_3. (4)

(b) Explain the following statements in detail:

(i) Nitrogen monoxide is a pollutant product of the internal combustion engine yet neither petrol nor diesel contain nitrogen. (3)
(ii) Apart from nitrogen monoxide, nitrogen dioxide is also present in the air in traffic zones, yet the standard enthalpy of formation of nitrogen dioxide is endothermic and the standard entropy change of formation is negative. (5)

(c) A sample consisting of 1.00 dm^3 of dinitrogen oxide (N_2O), contaminated by nitrogen monoxide, was drawn through 100 cm^3 of acidified potassium permanganate(VII) solution. The resulting solution oxidised 13.0 cm^3 of iron(II) sulfate solution of concentration 1.0 mol dm^{-3}. It takes 100 cm^3 of a fresh sample of the same potassium permanganate(VII) solution to oxidise 50.0 cm^3 of the iron(II) sulfate solution. Assuming that nitrogen monoxide is oxised to nitrate(V) ions by manganate(VII) ions, and that dinitrogen oxide doesn't react under these conditions, calculate the percentage by volume of nitrogen monoxide in the impure dinitrogen oxide. (Molar volume of a gas under the conditions of experiment is 24.0 dm^3). (8)

(Total: 20 marks)

4. Give a detailed explanation, supported by chemical equations and structures where appropriate, for each of the following observations:

   (a) Different reaction conditions produce different products in the reaction of methylbenzene with chlorine. (5)

   (b) Although they are both aldehydes, propanal and benzaldehyde react with sodium hydroxide in a different manner. (5)

   (c) The reaction of bromine water with ethene produces two products. (5)

   (d) Both phenols and alcohols contain the –OH functional group. However, the conversion of this group into $-O^-$ group requires the use of different reagents for phenols and for alcohols. (5)

(Total: 20 marks)

SECTION B

5. Describe how the following conversions may be carried out. In your answer give the reagents, essential reaction conditions, classification of each reaction where possible and equations to represent reactions taking place.

   (a) **CH_3CH_2Br** to **CH_3CH_2Cl** (5)

   (b) **CH_3CH_2Br** to **$CH_3CH_2CO_2H$** (5)

   (c) **CH_3COCl** to **CH_3NH_2** (5)

   (d) **CH_3CH_2Br** to **CH_3CH_2CHO** (5)

(Total: 20 marks)

6. Write notes about the following, giving examples and equations where necessary:

   (a) H_2O is a liquid at room temperature whereas H_2S is a gas. (4)

   (b) Transition metal ions are often used as catalysts in reactions. (4)

   (c) Lithium and magnesium show similar chemical properties. (4)

   (d) Ionic properties and the trend in thermal stability between the carbonates and nitrates of groups 1 and 2. (4)

   (e) PbO_2 is an oxidising agent while Sn(II) compounds are reducing agents. (4)

(Total: 20 marks)

7. (a) Explain, by referring to electrons, the meaning of the terms reduction and reducing agent. (2)

(b) Iodide ions can reduce sulfuric acid to three different products.
(i) Name each reduction product stating the oxidation state of sulfur in each. (6)
(ii) Describe how you would identify the presence of each reduction product. Your answer should include a simple observation or a simple test. (3)
(iii) Write half-equations showing how each product is formed. (3)

(c) Write an equation for the reaction that occurs when chlorine is added to cold water. State whether or not the water is oxidised and explain your answer. (3)

(d) The standard electrode potential of Br_2/Br^- is +1.07 V whilst that of I_2/I^- is 0.54 V. Deduce which is the strongest reducing agent and describe a simple test tube experiment that can confirm your answer. (3)

(Total: 20 marks)

8. (a) Crude oil is separated into different fractions by fractional distillation. Use a T-X diagram to explain the principle behind the technique. (Assume ideal behaviour.) (5)

(b) Cracking the unbranched compound **A**, C_6H_{14}, generates the saturated compound **B** and the unsaturated compound **C** (RMM = 42 g mol^{-1}). Compound **B** reacts with bromine in UV light to form a monobrominated compound **D** and an acidic gas **E**. Compound **C** reacts with hydrogen bromide to form a mixture of two compounds **F** and **G**. Use the information provided above to identify each of the compounds **A** to **G**. Include names, structural formulae and any relevant equations to explain your answers. (9)

(c) Compound **C** in part (b) can be polymerised. Give the repeating of the polymer formed from **C** and state what type of polymerisation mechanism **C** undergoes. (3)

(d) Oil companies can reform compounds such as **A** in order to produce more valuable products. Suggest **THREE** organic products that can be produced by the reforming of compound **A**. (3)

(Total: 20 marks)

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD
UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
ADVANCED LEVEL
SEPTEMBER 2017

SUBJECT:	CHEMISTRY
PAPER NUMBER:	III – *Practical*
DATE:	30th August 2017
TIME:	3 hours 5 minutes

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

1. In this experiment, you are required to determine the enthalpy change of neutralisation of sodium hydroxide solution with ethanoic acid.

   You are provided with the following solutions:

   (i) a solution of ethanoic acid of concentration 1.50 mol dm^{-3} labelled **A**;

   (ii) a solution of sulfuric acid containing 0.500 mol dm^{-3} labelled **B**;

   (iii) a solution sodium hydroxide $\mathbf{C_n}$, where n is the candidate laboratory number.

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

CANDIDATE LABORATORY NUMBER, n: _____

   (b) **Standardisation of the sodium hydroxide solution $\mathbf{C_n}$,**

   Using a suitably rinsed pipette, transfer 25.0 cm^3 of solution **B** into each of three conical flasks. Titrate each portion with solution $\mathbf{C_n}$ using methyl orange indicator. Record the results of two concordant titrations in the table below.

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

Mean titre: _____cm^3

(20)

(c) Determine the molarity of solution $\mathbf{C_n}$.

(5)

(d) **Determination of the enthalpy change of neutralisation,**

Prepare, 50 cm^3 (**an excess**) of solution **A** in one of the burettes provided. Transfer, by means of the other burette, 50 cm^3 of solution $\mathbf{C_n}$ into a polystyrene cup placed inside an empty beaker. Using the thermometer provided, measure the temperature of solution $\mathbf{C_n}$ at half-minute intervals, stirring continuously and record these temperatures in the table provided on page 3. At 3.0 minutes, skip the temperature reading and transfer at once the 50 cm^3 of solution **A** from the burette into solution $\mathbf{C_n}$ and continue recording the temperature whilst stirring continuously, from minute 4 to minute 15 every 30 seconds.

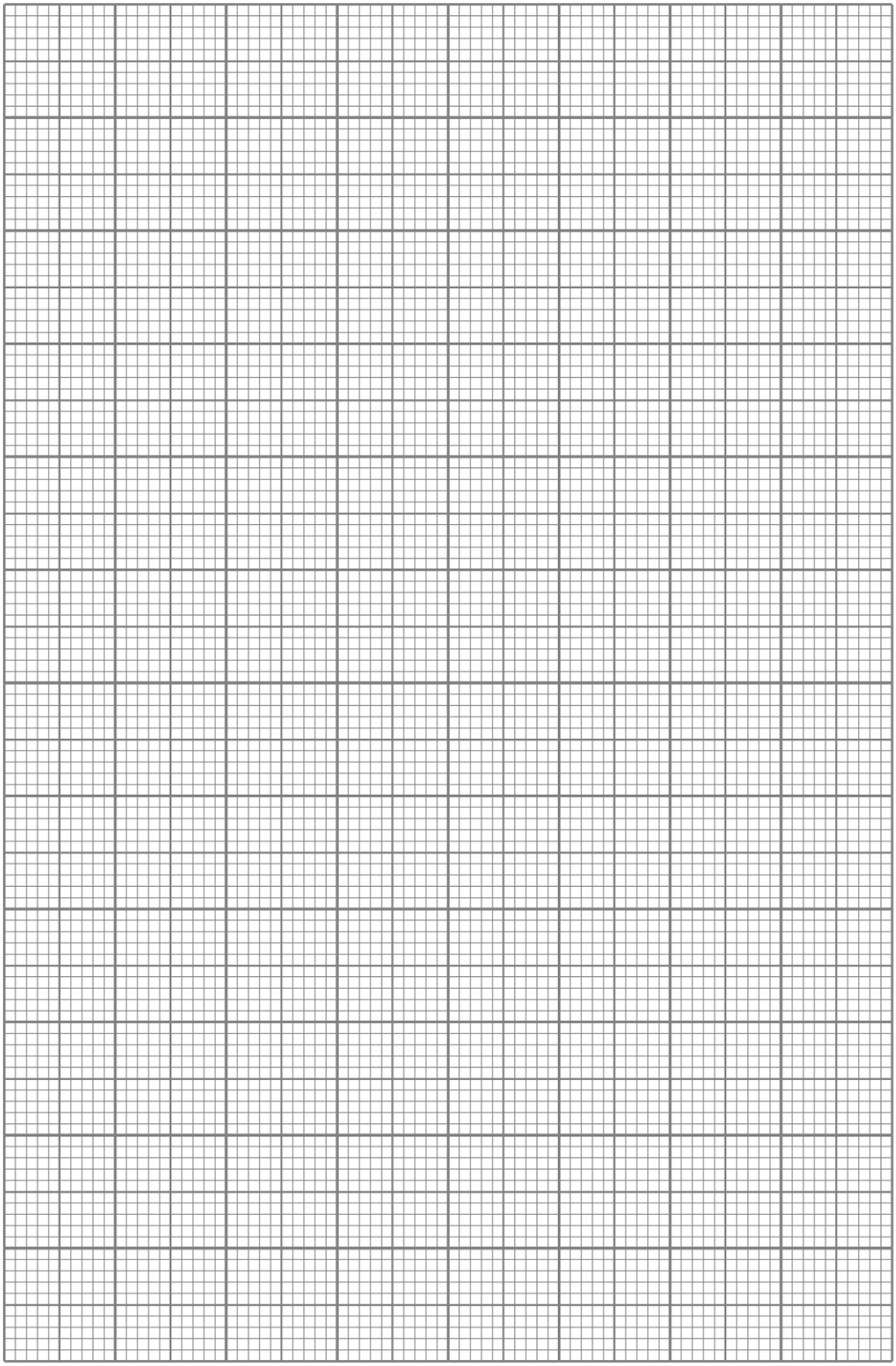
Time (minutes)	0.0	0.5	1.0	1.5	2.0	2.5	3.0
Temperature of solution $\mathbf{C_n}$ (°C)							

Time (minutes)	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
Temperature of mixture (°C)								
Time (minutes)	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5
Temperature of mixture (°C)								
Time (minutes)	12.0	12.5	13.0	13.5	14.0	14.5	15.0	
Temperature of mixture (°C)								

(2)

Question continues on next page

(e) Using the graph below, plot a graph of temperature (y-axis) against time (x-axis). (3)



(f) Using the graph, calculate the maximum temperature rise corrected for heat losses.

Maximum temperature rise = _____ °C. (15)

(g) Assuming that the specific heat capacity of the solution is 4.18 J cm^{-3} $°C^{-1}$, calculate the enthalpy change for the reaction, per mole of water produced.

$$CH_3COOH\ (aq) + NaOH\ (aq) \rightarrow CH_3COONa\ (aq) + H_2O\ (l)$$

_____

_____

_____

_____

_____

_____

_____

_____

_____(5)

(Total: 50 marks)

2. You are provided with a solution of an inorganic salt labelled **E** and a sachet of another inorganic substance labelled **O**. Perform the tests as described below and attempt to identify the compounds. Write your observation from each test as well as your inferences.

Perform tests (a) to (c) on 1 cm^3 portions of solution **E**.

(a) Add drops of aqueous sodium hydroxide followed by an excess.

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

(3)

(b) Add drops of aqueous ammonia followed by an excess.

Observation *Inference*

(3)

(c) Add 5 drops of potassium chromate solution.

Observation *Inference*

(3)

(d) Clean a nichrome loop with concentrated HCl and perform a flame test on solid **O**.

Observation *Inference*

(4)

(e) Dissolve approximately half your sample of **O** in 10 cm^3 of water. **Retain this solution for subsequent tests**.

Observation *Inference*

(3)

(f) Acidify 1 cm^3 of the solution obtained in test (e) with 1 cm^3 of nitric acid and add drops of aqueous silver nitrate followed by excess of aqueous ammonia.

Observation	*Inference*	
		(4)

(g) In a boiling tube, mix 2 cm^3 of the solution obtained in test (e) and 2 mL of solution **E**. Add 5 cm^3 of water and heat carefully. Cool under running water to room temperature. Allow to stand for 1 minute. **Retain for test (h)**.

Observation	*Inference*	
		(4)

(h) Using a pasteur pipette, draw 1 cm^3 of the liquid from test (g). Add 1 cm^3 of iron(II) sulfate solution followed by drops of conc. sulfuric acid (*care!*) down the side of the test tube.

Observation	*Inference*	
		(4)

Conclusion: E is probably a solution of _____ (1)

Conclusion: O is probably: _____ (1)

(Total: 30 marks)

3. You are provided with an organic solid labelled **X**. Perform the tests on this material as described and suggest a plausible identity.

(a) Burn a few crystals of **X** on a crucible lid.

Observation	*Inference*

(3)

(b) Dissolve a few crystals of **X** in about 2 cm^3 of water, and test with litmus paper; warming gently is necessary. Retain this solution for the next test.

Observation	*Inference*

(4)

(c) To about 1 cm^3 of the solution of **X** obtained in test (b), add a few drops of neutral iron(III) chloride.

Observation	*Inference*

(4)

(d) Mix a tip of a spatula of **X** with a tip of a spatula of soda lime in a **DRY boiling tube**. Heat strongly, allow to stand for one minute, and ***carefully*** note any odour evolved. **Note: Allow the boiling tube to cool before washing with water.**

Observation	*Inference*

(4)

(e) Mix a tip of a spatula of **X** with 1 cm^3 of methanol in a test tube and acidify with 1 drop of conc. sulfuric acid. Heat for one minute on a boiling water bath. Carefully add 2 cm^3 of 10% sodium carbonate solution and note any odours.

Observation	*Inference*

(4)

Conclusion: A possible structure for X is: _____ (1)

(Total: 20 marks)

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