L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE
EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2021 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	I
DATE:	28th June 2021
TIME:	9:00 a.m. to 12:05 p.m.

Required Data: Universal Gas constant (R) = 8.314 J mol^{-1} K^{-1}.

Answer ALL questions

1. This question concerns the energetics of chemical reactions.
   a) State Hess's Law.

_____

_____ (1)

b) Consider the following thermochemical data:

The enthalpy change of formation of liquid carbon disulfide, $CS_2(l)$	+87.9 kJ mol^{-1}
The enthalpy change of combustion of carbon, C(s)	–393.5 kJ mol^{-1}
The enthalpy change of combustion of sulfur, S(s)	–296.8 kJ mol^{-1}

Construct a cycle and calculate the enthalpy change for the following reaction:

$$CS_2(l) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$$

(5)

Question continues on next page

c) The enthalpy change of formation of carbon disulfide is an example of the fact that the sign of ΔH of a reaction is not enough to explain the spontaneity of a reaction. Explain how carbon disulfide can form spontaneously even though its enthalpy of formation is endothermic.

_____

_____

_____ (3)

(Total: 9 marks)

2. a) A sample of gas has a mass of 53.5 g. It occupies a volume of 30.0 dm^3 at a pressure of 101,000 Pa and a temperature of 27 °C. Assuming ideal gas behaviour, determine the molar mass of the gas.

_____

_____

_____

_____

_____ (4)

b) State the assumptions for ideal gas behaviour and explain the conditions under which ideal gas behaviour can be expected.

_____

_____

_____

_____

_____ (4)

c) On the same set of axes, draw distribution diagrams to show the speed of gas molecules at different temperatures. Label the diagrams appropriately to distinguish between the curves at the higher and lower temperature. (3)

(Total: 11 marks)

3. a) Write an equation for the acid dissociation constant, K_a, of a weak acid.

_____

_____

_____ (2)

b) The K_a of ethanoic acid is 1.75×10^{-5} mol dm^{-3} at 298 K. The enthalpy change for the dissociation is –2.1 kJ mol^{-1}. Explain what this implies about the dissociation constant of the acid at temperatures higher than 298 K.

_____

_____

_____ (2)

Question continues on next page

c) A solution contains 0.02 moles of ethanoic acid dissolved in 750 cm^3 of solution. A volume of 250 cm^3 containing 0.01 moles of sodium ethanoate is added to it.

i) The above mixture is known as a buffer solution. Explain what is meant by this term.

_____

_____

_____ (2)

ii) Find the pH of the solution assuming the value of K_a given in part (b).

_____

_____

_____

_____

_____ (5)

(Total: 11 marks)

4. This question is about the transition metal chromium.

a) Explain what is meant by a transition metal.

_____

_____ (1)

b) Give the electronic configuration of the following species in s, p, d, f notation.

Cr _____(1)

Cr(III)_____ (1)

c) Describe how chromium(III) oxide can be prepared.

_____

_____

_____ (2)

d) Describe how hexahydroxochromate(III) is prepared, and comment on the acidity of the ion.

_____

_____

_____ (2)

e) In the space below draw, the structures of the chromate(VI) and dichromate(VI) ions.

(3)

(Total: 10 marks)

5. a) The first ionisation energies of the elements in the period lithium to fluorine are as follows:

Element	Li	Be	B	C	N	O	F
1st IE / kJ mol^{-1}	520	900	801	1086	1503	1314	1681

i) Explain the general increasing trend across the period.

_____

_____

_____ (2)

ii) Explain the decrease in IE between Be and B as well as that between N and O.

_____

_____

_____ (2)

Question continues on next page

b) Using the concepts of bonding and structure, give plausible explanations for LiCl being a solid at room temperature, BCl_3 being a gas and NCl_3 being a liquid.

(4)

c) Explain why the element phosphorus, which is in the same group as nitrogen in the periodic table, can form PCl_3 and PCl_5 whilst nitrogen can only form NCl_3.

(4)

(Total: 12 marks)

6. This question is about nitrogen and its compounds.

a) In the space below, draw the Lewis structure (electron dot structure) for N_2.

(1)

b) Give balanced chemical equations for the preparation of nitrogen dioxide and dinitrogen pentoxide.

_____

_____

_____

_____ (2)

c) Explain why ammonia is a weak Brønsted-Lowry base. In your explanation include an equation for the reaction of ammonia with water.

_____

_____ (2)

d) The oxoacids of nitrogen are nitric(III) acid and nitric(V) acid.

i) Describe the laboratory preparation of nitric(III) acid.

_____

_____ (2)

ii) Nitric(V) acid is both a strong acid and an oxidising agent. By means of appropriate chemical equations give an example of **each**.

_____

_____

_____

_____ (2)

iii) In the space below, draw the structure of nitric(III) acid, including plausible bond angles.

(3)

(Total: 12 marks)

Please turn the page.

7. This question is about haloalkanes.

a) Give the structural formula of the main organic product forming, if at all, from **each** of the following mixtures.

i) 1-bromobutane with aqueous KOH (Reaction 1)

_____ (1)

ii) 1-bromobutane with alcoholic KOH (Reaction 2)

_____ (1)

b) What are the mechanisms involved in **each** of the reactions above?

i) Reaction 1: _____ (1)

ii) Reaction 2: _____ (1)

iii) In the space below, give the mechanism for Reaction 1.

(4)

c) Haloalkanes can also be converted to amines. Give an equation and conditions, if any, for the conversion of 1-bromobutane into an amine.

_____

_____ (2)

(Total: 10 marks)

8. This question is about isomerism.

a) Alprenolol is a beta-blocker that is used to treat angina (heart problems) and exists as two stereoisomers which are optically active. Industrially, alprenolol is produced as a racemic mixture. The structure is shown below.

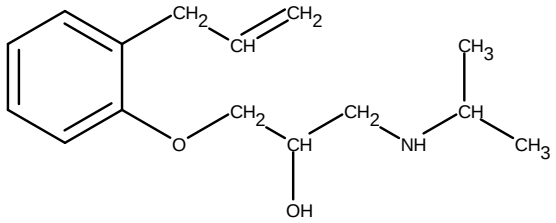

Figure 1: Structure of alprenolol

i) Circle the carbon responsible for the optical activity in alprenolol. Explain your reasoning below.

_____

_____

_____ (2)

ii) What is a racemic mixture?

_____

_____

_____ (2)

iii) What kind of instrument is used to analyse such isomers? Explain briefly how it works.

_____

_____

_____

_____ (2)

Question continues on next page.

b) The structural formula of 2,4-dichloropentane is shown below.

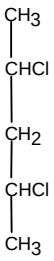

Figure 2

i) This compound also exhibits stereoisomerism but **not** all of the isomers are optically active. Explain this statement.

_____

_____

_____

_____ (3)

c) 1,2-dimethylcyclohexane exhibits another form of stereoisomerism.

i) Draw the structural formulae of the isomers in the space below. Name the compounds using the correct notation.

(2)

ii) Which of the isomers is more stable? Suggest a reason for your answer.

_____

_____

_____ (2)

(Total: 13 marks)

9. This question is about organic qualitative analysis. Give a brief explanation, structural formulae of main organic products and, where necessary, equations, for the following observations.

a) A silver mirror is observed at the bottom of a test-tube when butanal is reacted with ammoniacal silver nitrate.

_____

_____

_____ (2)

b) An orange precipitate is obtained on addition of 2,4-DNPH to propanone.

_____

_____

_____ (2)

c) A colourless vapour which condenses to a colourless liquid is formed when heating crystals of 1,2-benzenedicarboxylic acid.

_____

_____

_____

_____ (2)

d) A negative iodoform test is obtained when treating the product of the reaction between propanoyl chloride and benzene in presence of anhydrous $AlCl_3$.

_____

_____

_____

_____ (3)

e) A cream coloured precipitate forms on addition of aqueous silver nitrate to bromomethyl benzene but **not** when adding the reagent to 1-bromo-2-methylbenzene.

_____

_____

_____

_____ (3)

(Total: 12 marks)

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MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2021 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	II
DATE:	30th June 2021
TIME:	9:00 p.m. to 12:05 p.m.

A Periodic Table is provided.

Answer TWO questions from each section and ANY other question.

SECTION A

1. This question is about sulfur and its oxides.

   Explain **each** of these statements in detail, giving balanced chemical reactions when relevant.

   a) Sulfur dioxide is a toxic gas produced from the burning of fossil fuels, contributing to the formation of acid rain. (4)
   b) Sulfur dioxide can be converted to sulfuric(IV) acid which in turn can be converted to the sulfate(IV) salt. (4)
   c) Concentrated sulfuric acid(VI) has several uses. Describe **TWO** of them. (4)
   d) Hydrogen sulfide is a toxic weak dibasic acid that can also act as a reducing agent. (4)
   e) The sulfate(IV) ions exhibit electron delocalisation. Draw the structure of a sulfate(IV) ion and explain how bond properties can indicate electron delocalisation in the ion. (4)

   (Total: 20 marks)

2. The endothermic decomposition of ammonia occurs at 400 °C. At this temperature, a homogeneous, dynamic equilibrium is established.

   a) i) Explain the terms homogeneous, dynamic and equilibrium. (3)

   ii) Deduce an expression for the equilibrium constant K_p. State the units of K_p. (4)

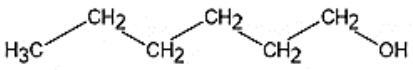
   iii) State, giving explanations, the conditions of pressure and temperature under which a high equilibrium concentration of hydrogen would be obtained. (4)

   iv) Discuss the effect that using a catalyst would have on the equilibrium yield and on the amount of hydrogen which could be produced in a given time. (3)

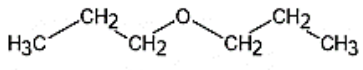
   b) Consider the decomposition of ammonia gas at 400 °C. The total pressure of the equilibrium mixture containing ammonia, hydrogen and nitrogen is 200 atm. At equilibrium, the mixture contains 36% ammonia. Find the value of K_p. (6)

   (Total: 20 marks)

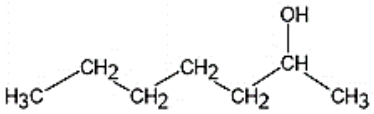
3. This question is about the following compounds.



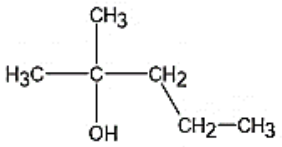
A



B



C



D

a) **A** and **B** can be distinguished by chemical means as well as by using a mass spectrometer. Explain this statement. Your answer should include the IUPAC name of the **TWO** compounds. (5)

b) The same Grignard reagent can be used to synthesize **C** and **D**. Identify the Grignard reagent and explain how you would prepare it from readily available material in the lab. Include any precautions that need to be taken. (5)

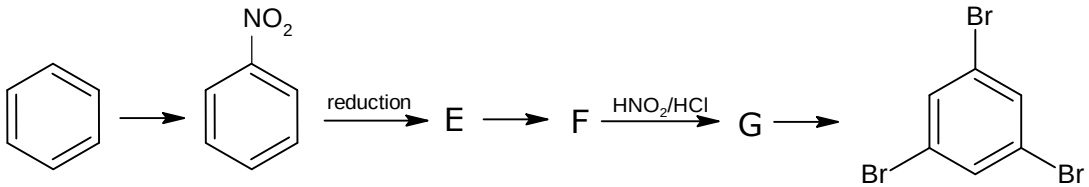
c) If the necessary precautions are **not** taken in the preparation of a Grignard reagent, a hydrocarbon forms. Identify the hydrocarbon that would form from the Grignard reagent identified in part (b), and suggest a mechanism for this reaction. (4)

d) Using the Grignard reagent identified in part (b), write equations for the preparation of **C** and D. In your answer include any other necessary reagents and conditions. (3)

e) Explain, in detail, how you would distinguish between **A**, **C** and **D** via a chemical test. Give the relevant equations and observations where necessary. (3)

(Total: 20 marks)

4. This question is about reactions of benzene and its derivatives.



a) Outline the reagents and experimental conditions needed to convert benzene into nitrobenzene. In your answer, include the reason why this step was necessary to achieve the final product. (5)

b) i) Give a systematic name for the final product of this scheme. (1)
ii) Identify the substances **E**, **F** and **G** by writing their structural formulae. (3)
iii) Explain how each of the following steps, namely nitrobenzene to **E**, **E** to **F**, and **G** to final product, can be brought about in the laboratory. (8)

c) The conversion of **F** to **G** requires specific experimental conditions. Identify these conditions and the possible outcomes if they are **not** followed. (3)

(Total: 20 marks)

SECTION B

5. Hydrogen is the most abundant element in the universe. It is considered as a green fuel and can be produced by several processes.

a) Describe the process by which hydrogen is manufactured from the electrolysis of water. (5)

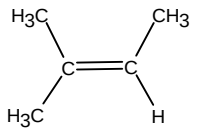
b) There are three known isotopes of hydrogen. The least common isotopes are known as deuterium and tritium. Their atomic mass is twice and three times that of the most abundant respectively. Whilst deuterium is stable, tritium undergoes beta decay. Give the nuclear structure of each of the **THREE** isotopes and write an equation for the decay of tritium. (5)

c) In the laboratory, hydrogen can be prepared by reacting a metal with an acid or by reacting aluminium with an alkali. Give balanced equations for both preparations. (4)

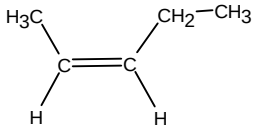
d) Sodium borohydride and lithium tetrahydroaluminate are two reducing agents used extensively in the preparation of several organic compounds.
i) Describe how lithium tetrahydroaluminate can be prepared in the laboratory. (4)
ii) Describe the bonding in lithium tetrahydroaluminate. (2)

(Total: 20 marks)

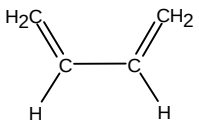
6. This question is about alkenes.



H



I



J

a) Describe in detail, including the relevant equations, how ozonolysis can be used to distinguish between **H** and **I**. (5)

b) On addition of HBr, compound **H**, gives two organic products, **K** and **L**. Identify the **TWO** products and give a detailed account of the mechanism through which they form. (8)

Question continues on next page.

c) When 1 mole of compound **J** is reacted with 1 mole of bromine, two organic products, **M** and **N** are obtained. Deduce the structural formula of the products and give a detailed explanation as to how **each** of them forms. (7)

(Total: 20 marks)

7. a) The following initial rates of reaction were obtained for the hydrolysis of a bromoalkane RBr through the reaction:

$$RBr + OH^- \rightarrow ROH + Br^-$$

Experiment	**Initial [RBr] / mol dm^{-3}**	**Initial [OH$^-$] / mol dm^{-3}**	**Initial rate of formation of ROH / 10^{-3} mol dm^{-3} s^{-1}**
1	0.2	0.01	1.2
2	0.2	0.02	1.2
3	0.4	0.08	2.4

(i) Outline the method of initial rates. (3)
(ii) Find the order of reaction with respect to RBr and the order of reaction with respect to OH^-. Show your reasoning. (4)
(iii) Use your answer to part (ii) and the data in the table to provide the rate expression and calculate the rate constant of the reaction. (4)
(iv) Suggest a possible structure of the bromoalkane and propose a mechanism for the reaction, clearly indicating the rate determining step. (6)

b) Explain what is meant by the half-life of a reaction and explain how the use of half-life can be used to confirm the rate expression obtained in part (a). (3)

(Total: 20 marks)

8. a) Consider the following half-reactions and associated $E^\ominus$ values at 298 K:

Fe^{2+} (aq) $+2e^- \rightarrow$ Fe (s) $\quad E^\ominus = -0.41$ V
Zn^{2+} (aq) $+2e^- \rightarrow$ Zn (s) $\quad E^\ominus = -0.76$ V

(i) Draw a cell diagram for a galvanic cell consisting of the Fe^{2+}/Fe and Zn^{2+}/Zn electrodes using the conventional notation. Explain your reasoning. (5)
(ii) Find the $E^\ominus$ of the cell drawn in part a (i). (3)
(iii) Write the redox reaction of the reaction that takes place in the galvanic cell and state your reasoning. (2)

b) When sodium hydroxide ions are added to aqueous Zn^{2+} in a test tube, a white precipitate appears initially which disappears on further addition of the alkali. When sodium hydroxide is added to aqueous Fe^{2+}, a green precipitate appears which does not dissolve on further addition of alkali. However, the precipitate darkens with time and turns brown at the top of the liquid in the test tube. Describe the chemistry behind these observations, providing chemical equations where possible. (10)

(Total: 20 marks)

Index No.:_____ AM06/III.21m

L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

ADVANCED MATRICULATION LEVEL
2021 FIRST SESSION

SUBJECT:	**Chemistry**
PAPER NUMBER:	III
DATE:	6th July 2021
TIME:	4:00 p.m. to 5:35 p.m.

Directions to Candidates

- Write your index number in the space at the top left-hand corner of this page.
- Answer all questions. Write all your answers in this booklet. Drawings and graphical representations of data are to be made on the appropriate pages within this booklet.
- The marks allotted to parts of question are indicated.
- You are reminded of the necessity for good English and orderly presentation in your answers.
- In calculations you are advised to show all the steps in your working, giving your answer at each stage.
- The use of electronic calculators is permitted.
- A copy of a periodic table is on Page 12.

For examiners' use only:

Question	1	2	3	
Maximum	20	15	15	50
Score				

1. A bottle is labelled "hydrogen peroxide, 0.5 M". It is an old sample and its actual concentration is to be determined by titration with a standard potassium manganate(VII) solution of concentration 0.020 M.

   a) A tenfold dilution is performed. The resulting solution is labelled H(dil), and will be used for the subsequent analysis. Describe in detail how this is carried out, indicating any precautions one should take to ensure accuracy.

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_____

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_____

_____ (4)

b) 25.0 cm^3 aliquots of H(dil) are transferred to each of three conical flasks, whilst the burette is filled with the potassium manganate(VII) solution. The contents of each flask are acidified with 20 cm^3 of 2M sulfuric acid.

Describe how the burette, pipette and the flasks are treated to ensure a correct reading.

(4)

c) Describe and explain the colour changes that are observed as the end point is reached.

(3)

Question continues on next page

d) The following data was obtained. Complete the table with the correct titre readings.

	1	**2**	**3**
Final burette reading / cm^3	21.70	22.80	23.35
Initial burette reading / cm^3	0.00	1.50	2.00
Titre / cm^3			

(3)

e) Hydrogen peroxide and potassium permanganate undergo a redox reaction as follows

$$5H_2O_2 + 6H^+ + 2KMnO_4 \longrightarrow 5O_2 + 2Mn^{2+} + 8H_2O + 2K^+$$

Using appropriate data from the table above, calculate the number of moles of permanganate ions used up in the reaction. Hence, calculate the concentration of H(dil).

(4)

f) Calculate the concentration of the original solution.

(2)

(Total: 20 marks)

Please turn the page

2. The relative molecular mass of a white, crystalline solid known to be a monobasic organic acid, is to be determined with an acid-base titration method.

   a) 5.000 g of the solid are to be quantitatively dissolved in 250.0 cm^3 of distilled water. Describe how this should be performed using an analytical balance and any equipment, including any essential precautions that should be taken to ensure accuracy.

_____

_____

_____

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_____

_____ (4)

b) Three 25 cm^3 aliquots of the solution are transferred to each of three conical flasks and titrated with 0.15 M of sodium hydroxide solution. Phenolphthalein is used as an indicator.

Describe and explain the colour change you would expect to observe as you approach the end-point.

_____

_____

_____

_____

_____

_____

_____ (3)

c) As you titrate, you notice some drops of sodium hydroxide solution on the inner sides of the neck of the conical flask. Describe how you would ensure that these react with the contents of the flask in order to give a reliable titre value.

_____

_____

_____

_____

_____

_____

_____ (2)

Question continues on next page

d) The following data was obtained.

i) Complete the table with the correct titre values.

	1	**2**	**3**
Final burette reading / cm^3	27.80	29.80	28.35
Initial burette reading / cm^3	0.00	2.50	1.00
Titre / cm^3			

(2)

ii) Which values should be accepted and which should be discarded? Explain.

_____

_____

_____

_____

_____

_____ (1)

e) Use the titre values to obtain the relative molecular mass of the acid.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ (3)

(Total: 15 marks)

3. An insulated, polystyrene cup supported in a beaker is used as a simple calorimeter. A burette is used to accurately transfer 50.0 cm^3 of a 0.20 M solution of copper(II) sulfate. The temperature is measured at regular intervals to ensure equilibrium.

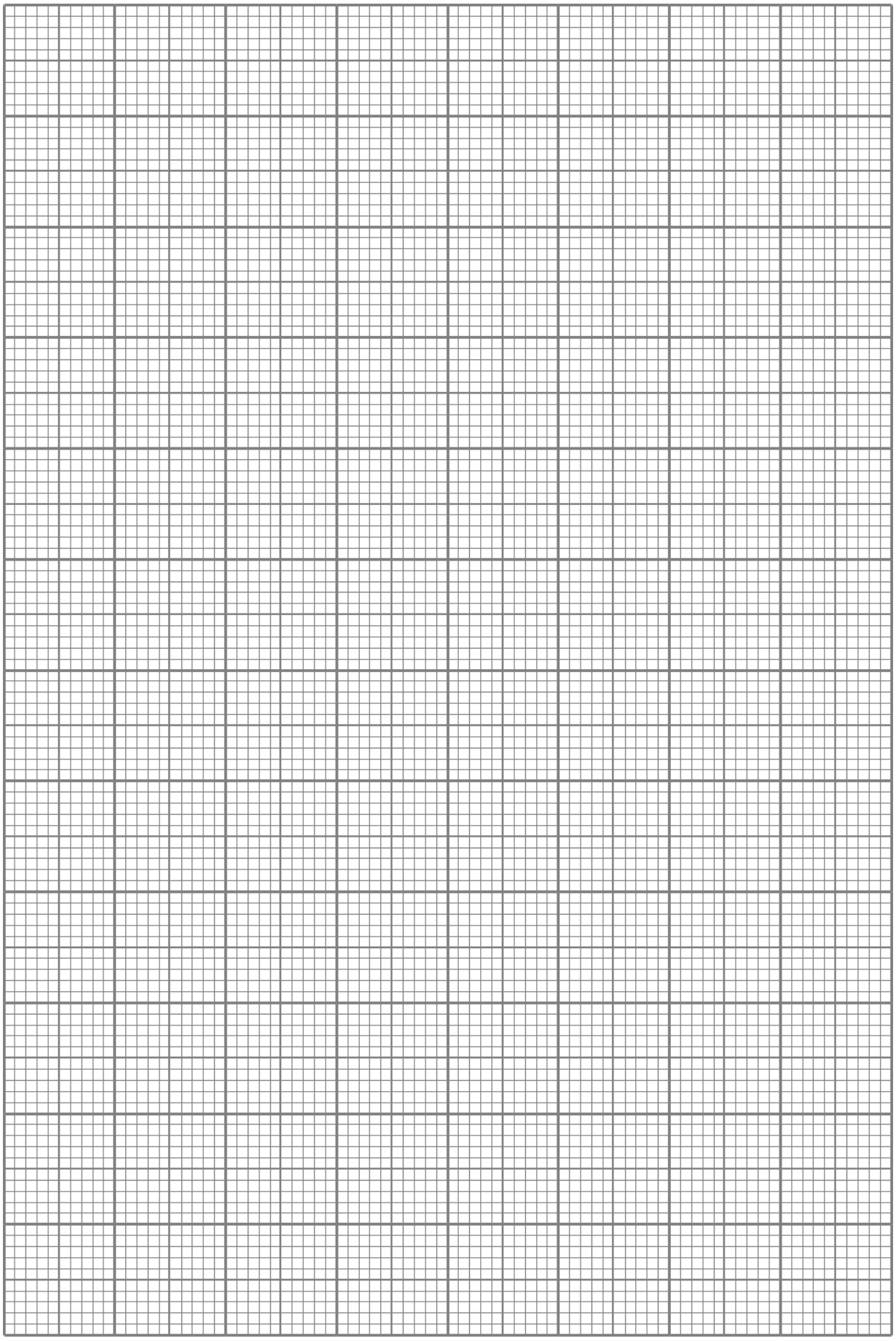
   3 g of zinc (*i.e.* excess) are added to the calorimeter at time = 3 minutes. The reaction mixture is stirred continually with the thermometer. Further temperature readings are taken at 30 second intervals.

   The data obtained is summarised in the table below.

Time (Min)	Temperature (°C)
0.0	21.10
0.5	21.10
1.0	21.15
1.5	21.00
2.0	21.00
2.5	21.15
3.0	
3.5	31.00
4.0	30.95
4.5	30.90
5.0	30.80
5.5	30.65
6.0	30.60
6.5	30.55
7.0	30.40
7.5	30.30
8.0	30.25

a) Plot the data on the graph paper provided on the following page.

Question continues on next page



(7)

b) From your plot, determine the maximum rise in temperature.

(3)

c) Assuming that the reaction mixture has a specific heat capacity of 4.20 $kJkg^{-1}K^{-1}$, calculate the standard enthalpy change in kJ mol^{-1} for the reaction:

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

(5)

(Total: 15 marks)

CHEMISTRY

PERIODIC TABLE: to be used during the MATSEC Examinations at SEC & Intermediate level

I	II											III	IV	V	VI	VII	VIII
																	4 **He** 2
7 **Li** 3	9 **Be** 4											11 **B** 5	12 **C** 6	14 **N** 7	16 **O** 8	19 **F** 9	20 **Ne** 10
23 **Na** 11	24 **Mg** 12											27 **Al** 13	28 **Si** 14	31 **P** 15	32 **S** 16	35.5 **Cl** 17	40 **Ar** 18
39 **K** 19	40 **Ca** 20	45 **Sc** 21	48 **Ti** 22	51 **V** 23	52 **Cr** 24	55 **Mn** 25	56 **Fe** 26	59 **Co** 27	59 **Ni** 28	63.5 **Cu** 29	65 **Zn** 30	70 **Ga** 31	73 **Ge** 32	75 **As** 33	79 **Se** 34	80 **Br** 35	84 **Kr** 36
85 **Rb** 37	88 **Sr** 38	89 **Y** 39	91 **Zr** 40	93 **Nb** 41	96 **Mo** 42	99 **Tc** 43	101 **Ru** 44	103 **Rh** 45	106 **Pd** 46	108 **Ag** 47	112 **Cd** 48	115 **In** 49	119 **Sn** 50	122 **Sb** 51	128 **Te** 52	127 **I** 53	131 **Xe** 54
133 **Cs** 55	137 **Ba** 56	139 **La** 57	178.5 **Hf** 72	181 **Ta** 73	184 **W** 74	186 **Re** 75	190 **Os** 76	192 **Ir** 77	195 **Pt** 78	197 **Au** 79	201 **Hg** 80	204 **Tl** 81	207 **Pb** 82	209 **Bi** 83	209 **Po** 84	210 **At** 85	222 **Rn** 86
223 **Fr** 87	226 **Ra** 88	227 **Ac** 89															

Key

Relative atomic mass — A **X** Z — *Atomic Number*

140 **Ce** 58	141 **Pr** 59	144 **Nd** 60	147 **Pm** 61	150 **Sm** 62	152 **Eu** 63	157 **Gd** 64	159 **Tb** 65	162 **Dy** 66	165 **Ho** 67	167 **Er** 68	169 **Tm** 69	173 **Yb** 70	175 **Lu** 71
232 **Th** 90	231 **Pa** 91	238 **U** 92	237 **Np** 93	244 **Pu** 94	243 **Am** 95	247 **Cm** 96	247 **Bk** 97	251 **Cf** 98	252 **Es** 99	257 **Fm** 100	258 **Md** 101	259 **No** 102	260 **Lr** 103

Useful Information:

Avogadro constant = 6.02×10^{23}
Molar volume of a gas at stp = 22.4 dm^3

Faraday constant = 96 500 $Cmol^{-1}$
Specific heat capacity of water = 4180 $Jkg^{-1}K^{-1}$

$Q = I\,t$
$\Delta H = m\,c\,\Delta\theta$