Government of **Western Australia**
School Curriculum and Standards Authority

ATAR course examination, 2021

Question/Answer booklet

CHEMISTRY

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of this box.

WA student number: In figures

In words

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Number of additional answer booklets used (if applicable):

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet
Chemistry Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Multiple-choice	25	25	50	25	25
Section Two Short answer	8	8	60	76	35
Section Three Extended answer	6	6	70	90	40
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2021: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

3. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer booklet.

4. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

5. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

6. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

7. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

See next page

Section One: Multiple-choice **25% (25 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice answer sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which of the following statements is/are true for redox reactions?

   (i) Redox reactions involve the transfer of electrons from one species to another.
   (ii) Complete combustion is a redox reaction, but incomplete combustion is not.
   (iii) Oxidation is the gain of electrons while reduction is the loss of electrons.
   (iv) Oxidation and reduction occur simultaneously.

   (a) i only
   (b) i, ii and iv only
   (c) i, iii and iv only
   (d) i and iv only

2. Chlorine gas is bubbled for several minutes through a sample of pent-1-ene. Which of the following statements identifies the type of reaction that occurs and the colour of the solution in the flask after the reaction is complete, assuming the chlorine gas is the limiting reagent?

	Type of reaction	Solution colour after complete reaction
(a)	substitution	colourless
(b)	addition	colourless
(c)	addition	green
(d)	substitution	green

See next page

3. Consider the acids listed in the following table.

Name	Formula	K_a (25 °C)
bromoacetic acid	$CH_2BrCOOH$	1.38×10^{-3}
dibromoacetic acid	$CHBr_2COOH$	3.31×10^{-2}
tribromoacetic acid	CBr_3COOH	1.91×10^{-1}

Which of the following identifies the strongest acid and classifies it correctly as monoprotic, diprotic or triprotic?

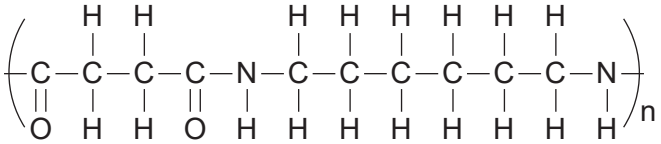
	Strongest acid	Classification
(a)	bromoacetic acid	monoprotic
(b)	dibromoacetic acid	diprotic
(c)	tribromoacetic acid	monoprotic
(d)	tribromoacetic acid	triprotic

4. Which of the following characteristics influence how a particular polymer might be used?

(i) The amount of cross-linking between the hydrogen atoms in the polymer.
(ii) The length of the carbon chains in the polymer.
(iii) The functional groups present in the monomer used to synthesise the polymer.
(iv) The melting point of the polymer.

(a) ii, iii and iv only
(b) i and ii only
(c) ii and iii only
(d) i, ii and iv only

5. Nylon 46 is a polymer that can withstand very large forces without breaking. Its structural formula is shown below.



The intermolecular forces contributing the most to the strength of Nylon 46 is/are

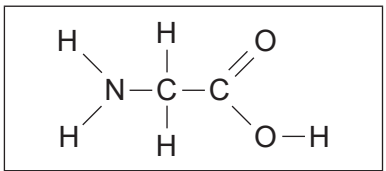
(a) covalent network bonding.
(b) dispersion forces.
(c) hydrogen bonding.
(d) dipole-dipole forces.

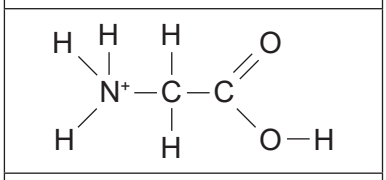
See next page

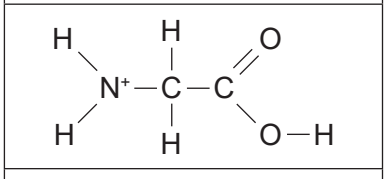
6. Which of the following is **least** likely to be a characteristic of a process classified as green chemistry?

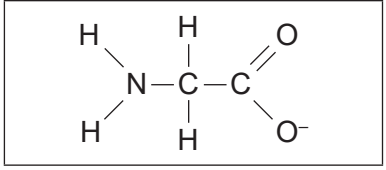
(a) is energy intensive
(b) utilises renewable feedstocks
(c) produces less waste
(d) utilises fewer toxic solvents

7. Which of the following structures represents glycine in acidic conditions?

(a) 

(b) 

(c) 

(d) 

8. Which of the following equation/s demonstrate/s the Arrhenius model of acids and bases?

(i) $HC\ell(aq) \rightarrow H^+(aq) + C\ell^-(aq)$
(ii) $CH_3COOH(aq) + H_2O(\ell) \rightarrow CH_3COO^-(aq) + H_3O^+(aq)$
(iii) $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$
(iv) $H_2PO_3^-(aq) + H_3O^+(aq) \rightarrow H_2O(\ell) + H_3PO_4(aq)$

(a) i, ii, iii and iv
(b) i only
(c) ii and iii only
(d) i and iii only

9. The net ionic equation for the predominant hydrolysis reaction occurring in a 1.00 mol L^{-1} potassium hydrogensulfate solution is:

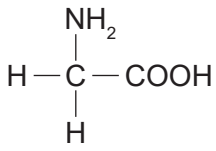
(a) $KHSO_4(aq) + H_2O(\ell) \rightleftharpoons K^+(aq) + H_2SO_4(aq) + OH^-(aq)$
(b) $K^+(aq) + HSO_4^-(aq) \rightleftharpoons K^+(aq) + H^+(aq) + SO_4^{2-}(aq)$
(c) $HSO_4^-(aq) + H_2O(\ell) \rightleftharpoons H_2SO_4(aq) + OH^-(aq)$
(d) $HSO_4^-(aq) + H_2O(\ell) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$

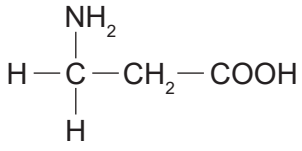
See next page

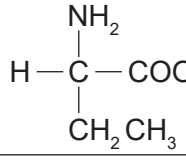
10. Which of the following identifies the recharging ability of a particular type of electrochemical cell and provides an appropriate example?

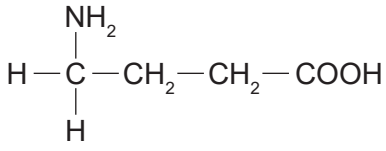
	Electrochemical cell	Rechargeable	Example
(a)	primary	no	Leclanché cell
(b)	secondary	no	lead-acid accumulator
(c)	primary	yes	lead-acid accumulator
(d)	secondary	yes	Leclanché cell

11. Which of the following shows an α-amino acid?

(i)


(ii)


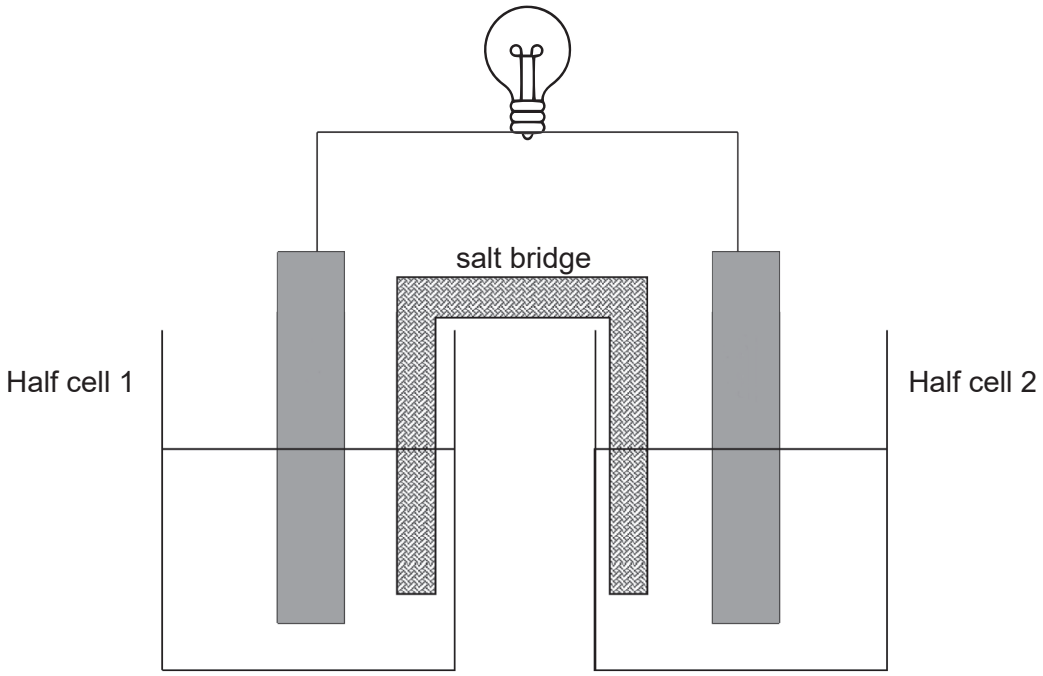
(iii)


(iv)


(a) i and iii only
(b) i only
(c) ii, iii and iv only
(d) i, ii, iii and iv

See next page

Questions 12 and 13 refer to the following electrochemical cell, which contains a light globe.



12. Which combination of electrodes and aqueous electrolytes will result in the possibility of the globe glowing? Assume standard conditions.

	Half cell 1		Half cell 2	
	Electrode	**Electrolyte**	**Electrode**	**Electrolyte**
(a)	graphite	$Ni(NO_3)_2(aq)$	silver	$AgNO_3(aq)$
(b)	silver	$Ni(NO_3)_2(aq)$	graphite	$AgNO_3(aq)$
(c)	nickel	$Ni(NO_3)_2(aq)$	silver	$AgNO_3(aq)$
(d)	nickel	$AgNO_3(aq)$	silver	$Ni(NO_3)_2(aq)$

13. The salt bridge

(a) provides the ions that are oxidised or reduced at the electrodes.
(b) maintains the overall electrical and pH neutrality of the cell by facilitating the transfer of electrons and ions from one half cell to another.
(c) provides the H_3O^+ and OH^- ions needed to maintain the pH neutrality of each half cell, preventing the build-up of electrical charge in the electrolytes.
(d) provides ions and facilitates ion movement between the half cells to complete the electrical circuit.

See next page

14. Consider the following pH values for a range of substances.

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Substance	Battery acid	Stomach acid	Lemon juice	Orange juice	Beer	Black coffee	Milk	Blood	Sea water	Toothpaste	Laundry detergent	Bathroom cleaner	Hair straightener	Oven cleaner	Drain cleaner

Based on these pH values, which one of the following statements about the concentration of hydronium ions is true?

(a) It is 1000 times greater in sea water than in bathroom cleaner.
(b) It is twice as great in beer as it is in lemon juice.
(c) It is three times greater in beer than in hair straightener.
(d) It is 1 000 000 times greater in hair straightener than in milk.

15. Which of the following processes does **not** contribute to the building of weaker seashells through ocean acidification?

(a) $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$
(b) $2\ H^+(aq) + CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_2(aq) + H_2O(\ell)$
(c) $CO_2(g) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)$
(d) $H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

16. Two isomeric forms of a saturated hydrocarbon

(a) contain different types of atoms.
(b) have the same structural formula.
(c) have the same molecular formula.
(d) react vigorously with one another.

17. A chemist performed a series of titrations and published the results in a scientific journal. From the point of view of the chemist, the titration data is

(a) primary.
(b) secondary.
(c) personal.
(d) investigative.

18. An example of a random error in a titration is

(a) reading solution volumes to the bottom of the meniscus.
(b) a gas bubble in the burette tap that comes out during a titration.
(c) calculating the concentration of the primary standard incorrectly.
(d) rinsing down the sides of the conical flasks during titrations.

See next page

19. In which of the following reactions would there be no visible reaction at 25 °C?

(a) A solid iron strip is placed in a solution of 1.00 mol L^{-1} copper(II) sulfate.
(b) Bromine water and 2,3-dimethylbut-2-ene are shaken together.
(c) Chlorine gas is bubbled through a solution of 1.00 mol L^{-1} potassium iodide.
(d) 1.00 mol L^{-1} potassium dichromate and 1.00 mol L^{-1} acetic acid are mixed together.

20. Consider the following reversible reaction:

$$2\ NO(g) + C\ell_2(g) \rightleftharpoons 2\ NOC\ell(g) \qquad K_c = 6.5 \times 10^4 \text{ at } 35\ °C$$

Which of the following statements describes the relative concentrations of reactants and products in this system when equilibrium is established in a closed vessel at 35 °C?

(a) The concentrations of reactants and products will be equal.
(b) There will be a greater concentration of products than reactants.
(c) The reactant concentration will be greater than that of the products.
(d) The concentrations of $NOC\ell$ and NO will be double the concentration of $C\ell_2$.

21. Identify a conjugate acid-base pair in the reaction represented by the following equation:

$$H_2PO_4^-(aq) + CH_3NH_2(aq) \rightleftharpoons CH_3NH_3^+(aq) + HPO_4^{2-}(aq)$$

(a) $H_2PO_4^-(aq)$ and $CH_3NH_2(aq)$
(b) $CH_3NH_3^+(aq)$ and $HPO_4^{2-}(aq)$
(c) $H_2PO_4^-(aq)$ and $HPO_4^{2-}(aq)$
(d) $H_2PO_4^-(aq)$ and $CH_3NH_3^+(aq)$

22. In an electrolytic cell used for plating objects with gold,

(a) the object to be plated is the anode.
(b) there must be a salt bridge connecting the anode and cathode half-cells.
(c) the reaction is spontaneous and so no external potential difference is required.
(d) a piece of pure gold is used as the positively charged electrode.

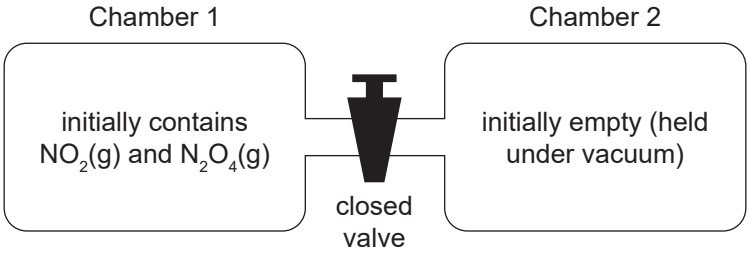
23. The equilibrium position of a system depends on the concentrations of

(a) reactants only.
(b) products only.
(c) reactants and products.
(d) neither reactants nor products.

See next page

Questions 24 and 25 refer to the following information.

Equal moles of nitrogen dioxide gas (NO_2) and dinitrogen tetroxide gas (N_2O_4) are sealed inside one half of a two-chamber reactor as shown below. The temperature inside both chambers is 25 °C.



After a while, the following equilibrium is established inside Chamber 1:

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g) + 58\ kJ\ mol^{-1}$$

reddish brown *colourless*

24. More $N_2O_4(g)$ is added to Chamber 1. What observations would be made about the colour of the gas mixture and its temperature after a new equilibrium is established?

	Gas mixture colour	Temperature
(a)	darker brown	higher
(b)	darker brown	lower
(c)	paler brown	higher
(d)	paler brown	lower

25. The valve between the chambers is opened, allowing the gas mixture in Chamber 1 to fill both chambers. Which statement describes the initial and final observations of the gas mixture's colour as a new equilibrium is established?

	Initial observation when tap is opened	Observation as equilibrium is re-established
(a)	paler brown	became darker
(b)	paler brown	became paler
(c)	darker brown	became darker
(d)	darker brown	became paler

End of Section One

See next page

Section Two: Short answer **35% (76 Marks)**

This section has **eight** questions. Answer **all** questions. Write your answers in the spaces provided.

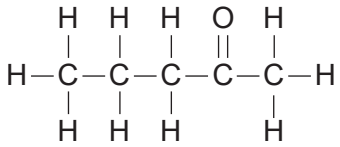
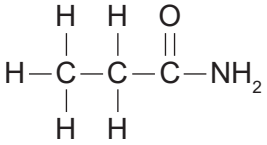
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

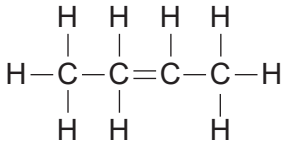
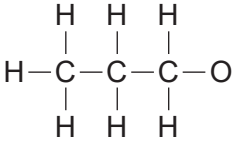
Question 26 **(8 marks)**

A student was given the task of naming and/or drawing the structural formula of some organic compounds. The student, however, made some errors.

(a) For each of the following organic compounds, state why the name given by the student is incorrect and rename it using IUPAC nomenclature. (4 marks)

Structural formula and name given by student	Reason for name being incorrect	IUPAC name
 pentan-4-one		
 1-aminopropanone		

(b) Circle an error in each structural formula and state the reason why it is an error. (4 marks)

Student's structural formula	Reason
	
	

Question 27 **(11 marks)**

Alcohols exhibit a variety of different chemical properties. For example, some alcohols react with acidified permanganate ions while others do not.

(a) The alcohols in the following table were each heated with excess acidified potassium permanganate solution. Name all organic products formed **during** this process. If there is no reaction, indicate this by writing 'no reaction'. (4 marks)

Name of alcohol	Name(s) of organic compound(s) formed
2-methylpentan-2-ol	
pentan-1-ol	
pentan-2-ol	

(b) Write a balanced overall ionic equation showing the formation of **one** of the organic compounds named in part (a). Only the alcohols listed in the table and acidified potassium permanganate solution can be used. Show your working. (4 marks)

See next page

(c) The same type of reaction occurs if alcohols are mixed with acidified potassium dichromate solution.

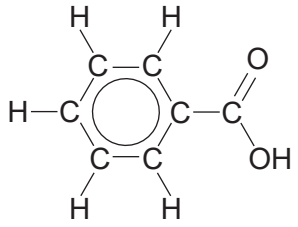
(i) Name this type of reaction. (1 mark)

(ii) State how the reaction observations are different when limited acidified potassium dichromate solution is used instead of limited acidified potassium permanganate solution. (2 marks)

See next page

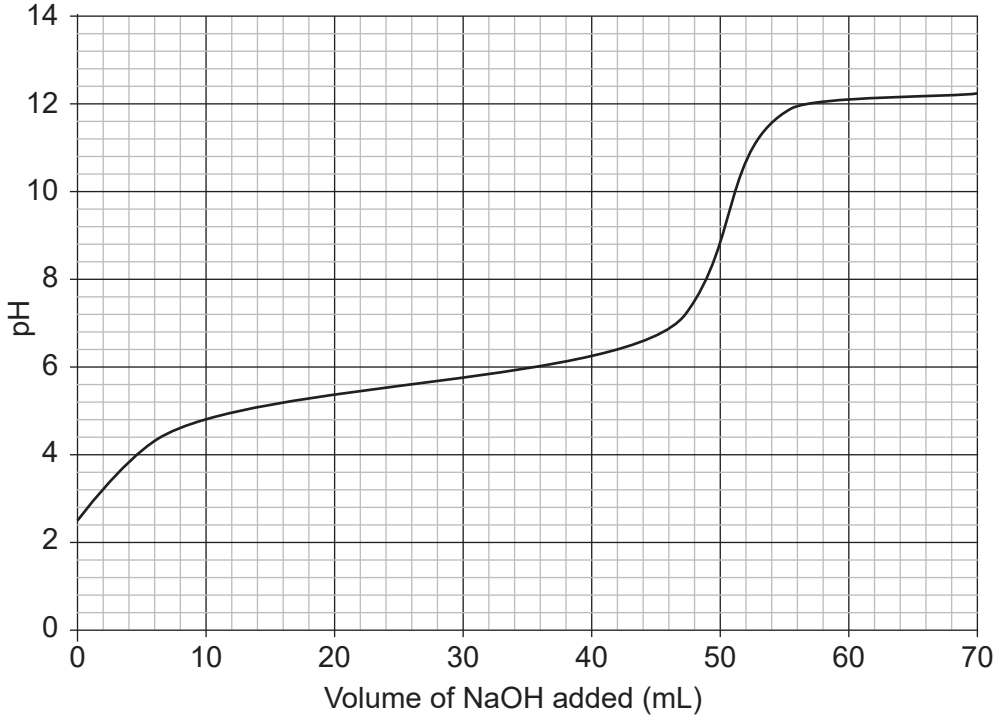
Question 28 **(9 marks)**

Benzoic acid (C_6H_5COOH) is a weak acid. Its structural formula is shown below.



Benzoic acid has a range of uses, including the manufacture of dyes, perfumes and insect repellents. The benzoic acid content of these products can be determined by titration with sodium hydroxide. The salt produced in the titration reaction is sodium benzoate, C_6H_5COONa.

The following graph shows a typical acid-base titration curve for benzoic acid and sodium hydroxide.



(a) Which of the indicators listed in the following table would be most suitable for use in this titration? With reference to the above titration curve, explain your choice. (3 marks)

Name of Indicator	pH Range
Bromocresol green	3.8 – 5.4
Azolitmin	4.5 – 8.3
Cresolphthalein	8.2 – 9.8
Indigo carmine	11.4 – 13.0

See next page

(b) Buffering is observed during this titration.

(i) Circle the region on the titration curve on page 14 to show where the buffering occurs. (1 mark)

(ii) Define the term buffering and explain why it occurs during this titration in the region that you circled in part (b)(i). Include an equation to support your explanation. (5 marks)

Question 29 **(7 marks)**

Water can self-ionise, as shown by the following equation:

$$H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The reaction equilibrium and the pH of water are both affected by changes in temperature. The data in the following table show how changing the temperature affects the pH of pure water.

Temperature (°C)	pH of water
0	7.47
25	7.00
50	6.63
75	6.35

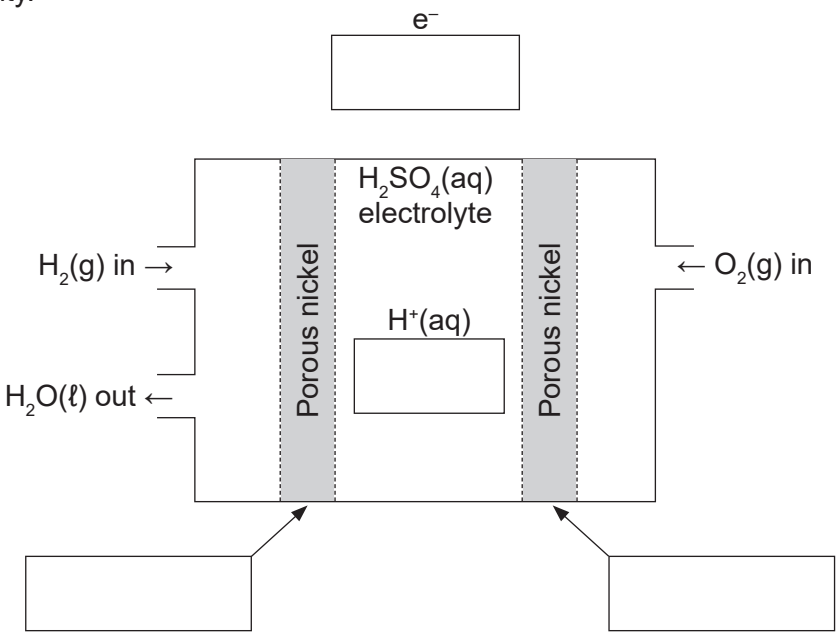
(a) Show how the tabulated data and Le Châtelier's Principle can be used to deduce whether the self-ionisation of water is exothermic or endothermic. Calculations are **not** required. (5 marks)

(b) Calculate the $H^+(aq)$ and $OH^-(aq)$ concentrations of pure water at 100.0 °C given that K_w is equal to 5.13×10^{-15} at that temperature. (2 marks)

See next page

Question 30 **(10 marks)**

Fuel cells, such as the one shown in the diagram below, use gaseous hydrogen and oxygen to produce electricity.



In this particular fuel cell, which uses sulfuric acid as the electrolyte, the hydrogen and oxygen are circulated at very high pressure over porous nickel-platinum electrodes. Operating temperatures range from 25 to 90 °C.

(a) Complete the above diagram by adding labels/arrows to show the:
- anode
- cathode
- direction of electron flow
- direction of hydrogen ion flow. (4 marks)

(b) Write balanced half-equations for the oxidation and reduction reactions and the equation for the overall reaction occurring in this fuel cell. (4 marks)

Oxidation half-reaction	
Reduction half-reaction	
Overall redox reaction	

(c) This fuel cell typically produces 0.7 V, which is significantly less than the predicted value of 1.23 V. State **two** specific conditions of this cell that would account for this observation. (2 marks)

One: _____

_____

Two: _____

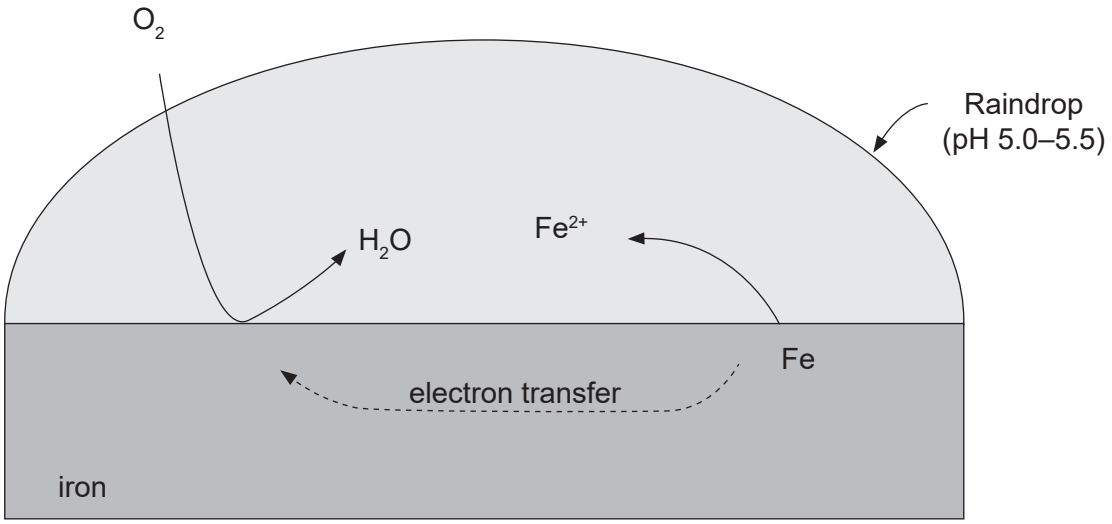
_____

See next page

Question 31 **(9 marks)**

The corrosion of iron is an electrochemical process that results in the formation of a reddish-brown solid commonly known as rust, $Fe_2O_3.H_2O(s)$. Iron objects exposed to rainwater corrode relatively quickly.

Iron corrosion occurs in two stages. During the first stage, an electrochemical cell is established on the iron surface, with electron transfer and Fe^{2+} ion formation occurring. This can be seen in the following diagram.



(a) Write half-equations and the overall balanced equation for the reaction occurring in the above electrochemical cell. State symbols are **not** required. (4 marks)

Oxidation half-equation	
Reduction half-equation	
Redox equation	

(b) During the second stage of iron corrosion, the newly formed Fe^{2+} ions migrate away from the iron surface and react with water and dissolved oxygen to form rust. The balanced equation for this reaction is shown below.

$$4\ Fe^{2+}(aq) + O_2(g) + 6\ H_2O(\ell) \rightarrow 2\ Fe_2O_3.H_2O(s) + 8\ H^+(aq)$$

Use oxidation numbers to show that this reaction is a redox reaction. (2 marks)

See next page

A corrosion chemist inspected an outdoor playground and found that most of the equipment containing iron showed signs of corrosion. The chemist suggested several different methods for protecting the playground equipment from further corrosion, including the use of sacrificial anodes.

(c) State what is a sacrificial anode. (1 mark)

(d) State the name of a metal that can be used as a sacrificial anode to protect the equipment from further corrosion. Use Standard Reduction Potentials to justify your choice. (2 marks)

Question 32 **(14 marks)**

Ammonia is manufactured industrially by the Haber process, the reaction equation being:

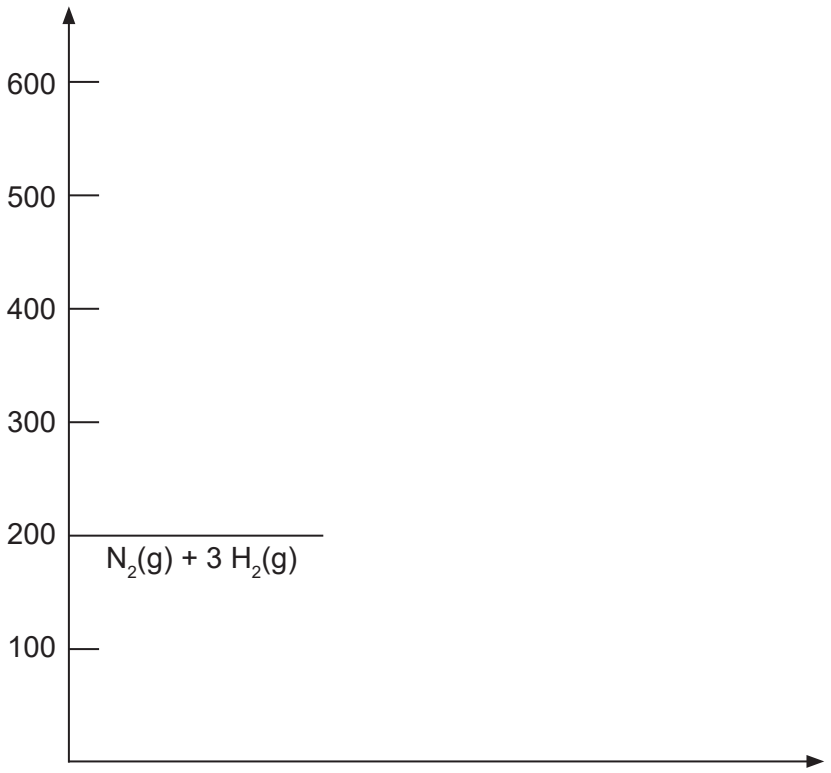
$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g) + 92\ kJ$$

At 400 °C the equilibrium constant of this reaction is equal to 1.60×10^{-4} and the activation energy of the forward reaction is approximately 4.00×10^2 kJ mol^{-1}.

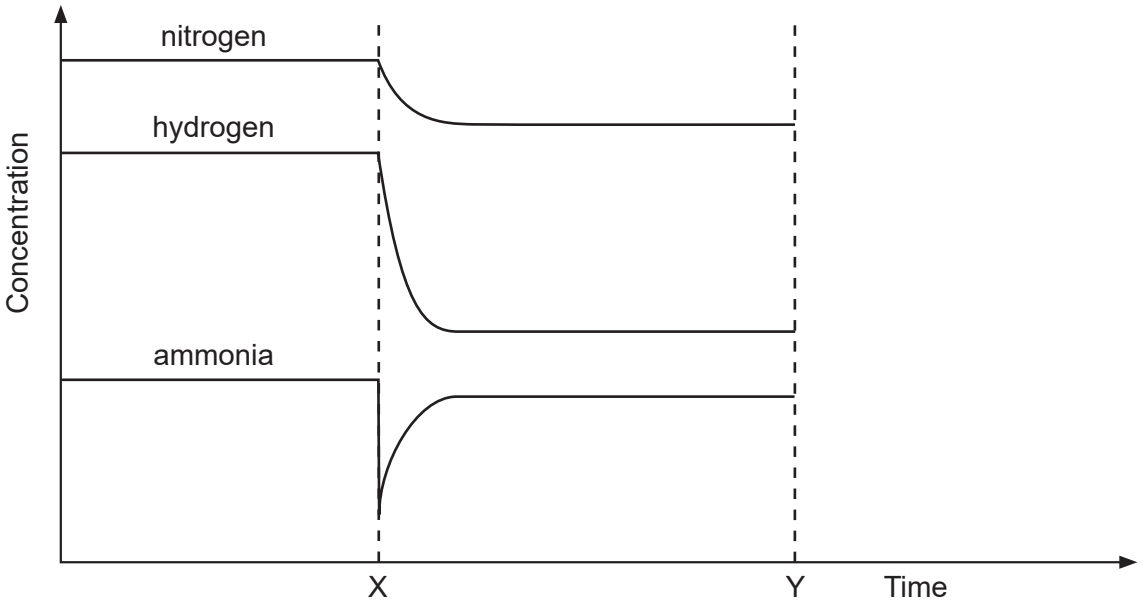
(a) Write the equilibrium constant expression for this reaction. (2 marks)

(b) Use the following axes to sketch an energy profile diagram for the Haber process. Label the:

- axes
- products
- activation energy
- change in enthalpy. (4 marks)



Some hydrogen, nitrogen and ammonia were sealed in a reaction vessel and their concentrations were monitored for a period of time, as shown in the following graph:



(c) A change was made to the reaction system at time X. Identify this change and use collision theory to explain the shapes of the curves in the region X–Y. (5 marks)

(d) The temperature of the reaction system was increased at time Y. Show on the graph how this affected the concentrations of hydrogen, nitrogen and ammonia as the system returned to equilibrium. (3 marks)

See next page

Question 33 **(8 marks)**

Ethanol (C_2H_5OH) dissolves readily in water, while decan-1-ol ($C_{10}H_{21}OH$) has very limited solubility. Explain, with the aid of labelled diagrams, why ethanol is able to dissolve in water and decan-1-ol is not.

End of Section Two

Section Three: Extended answer **40% (90 Marks)**

This section contains **six** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

Question 34 **(13 marks)**

Keratin 86 is a protein found in human fingernails. A small section of the amino acid sequence of Keratin 86 is shown below:

– Asp – Phe – Leu – Arg –

(a) Draw the full structural formula of this small section of Keratin 86. (3 marks)

The amino acid chains in Keratin 86 form α-helices, with two α-helices twisting around each other to form what is called a 'coiled coil' that is held together by disulfide bridges.

(b) Circle the protein structural level represented by an α-helix. (1 mark)

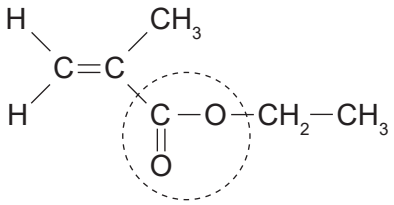
primary secondary tertiary

See next page

Question 34 (continued)

(c) What does the presence of disulfide bridges indicate about the primary structure of Keratin 86? (1 mark)

Synthetic fingernails are a popular fashion accessory. They are made in industrial laboratories from polymers. A monomer that can be used to make a polymer suitable for synthetic fingernails is shown below.



(d) Name the circled functional group in this monomer. (1 mark)

(e) Give the IUPAC name of the alcohol needed to make this monomer. (1 mark)

(f) Draw **three** repeating units of the polymer made from this monomer. (2 marks)

See next page

The protein which makes natural fingernails, Keratin 86, is also a polymer.

(g) What type of polymerisation reaction produces Keratin 86 and what type produces synthetic fingernails? (2 marks)

Polymer	Type of polymerisation reaction
Keratin 86	
Synthetic fingernail polymer	

(h) State **two** differences between the polymerisation reaction types identified in part (g). (2 marks)

One: _____

_____

Two: _____

_____

See next page

Question 35 **(12 marks)**

Smoking is hazardous to a person's health and one option to help quit smoking is the use of nicotine patches. These patches, when placed on the skin, release small amounts of nicotine with the aim of reducing cigarette craving.

The nicotine content of these patches can be determined by titration. The titrating solution is prepared by mixing perchloric acid ($HC\ell O_4$) with glacial acetic acid, resulting in the following equilibrium:

$$HC\ell O_4 + CH_3COOH \rightleftharpoons CH_3COOH_2^+ + C\ell O_4^-$$

The species that reacts with nicotine during the titration is $CH_3COOH_2^+$. 'Glacial' means that the acetic acid does not contain any water.

The perchloric acid/acetic acid solution must be standardised before use and this can be done by titrating it with a solution made from a primary standard.

(a) Other than possessing a relatively high molar mass, state **two** characteristics required of a substance for it to be used as a primary standard. (2 marks)

One: _____

_____

Two: _____

_____

A brand of nicotine patches comes in dose sizes of 7 mg, 14 mg and 21 mg. A manufacturing error produced a batch of unlabelled boxes of patches. A chemist was given the task of identifying the dose size so that the boxes could be accurately labelled and then sold.

The chemist took one of the boxes and extracted all the nicotine from the 14 patches it contained. The nicotine extract was then made up to a total of 100.0 mL using a suitable solvent. Aliquots of the resulting solution (20.0 mL) were then titrated with standardised 0.0483 mol L^{-1} perchloric acid/acetic acid solution, requiring an average of 15.11 mL to reach the end point.

(b) Complete the following table by writing the name of the most suitable piece of equipment to use for each task. (3 marks)

Task	Piece of equipment to use
Making exactly 100.0 mL of nicotine-containing solution	
Measuring a 20.0 mL aliquot of the nicotine-containing solution	
Adding the perchloric acid/acetic acid solution to the nicotine-containing solution	

See next page

(c) Use the chemist's titration data to identify the nicotine dosage of the patches in the unlabelled boxes. Show all of your working.

The molecular formula of nicotine is $C_{10}H_{14}N_2$ and the titration reaction is:

$$C_{10}H_{14}N_2 + 2\ CH_3COOH_2^+ \rightarrow C_{10}H_{16}N_2^{2+} + 2\ CH_3COOH$$ (7 marks)

See next page

Question 36 **(17 marks)**

Glycoluril is an organic compound composed of carbon, hydrogen, nitrogen and oxygen atoms. It is used in paper making and water disinfection. A chemist was given the task of determining the empirical formula and also the molecular formula of glycoluril.

To do this, the chemist combusted 2.30 g of glycoluril in excess air, producing 2.85 g of carbon dioxide and 0.874 g of water.

The chemist then used the Kjeldahl Method to determine the nitrogen content of another 2.30 g sample of the compound. This involved converting all of the nitrogen atoms in the sample into ammonia with the ammonia then distilled into 25.0 mL of 1.35 mol L^{-1} sulfuric acid, which was in excess. The reaction between ammonia and sulfuric acid is:

$$2\ NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

The excess sulfuric acid needed 15.40 mL of 0.186 mol L^{-1} sodium hydroxide for complete reaction. The reaction equation is:

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

(a) Determine the empirical formula of glycoluril. (12 marks)

See next page

(b) Another 2.30 g sample of glycoluril was vapourised at 242.0 kPa and 865.0 °C. The total volume of the resulting gas was 633.0 mL. Determine the molecular formula of glycoluril.
(5 marks)

See next page

Question 37 **(18 marks)**

A chemist was asked to develop a method of recycling used cathodes from a new type of lithium battery. The cathodes were a mixture of lithium cobalt oxide ($LiCoO_2$) and manganese (Mn). Each cathode contained 57.29% cobalt by mass.

Preliminary trials showed that the used cathodes would dissolve completely if enough sulfuric acid was added and if enough time was allowed. The chemist decided to conduct detailed trials to see how the sulfuric acid concentration affected the rate at which the used cathodes dissolved.

Each trial was performed in a sealed, oxygen-free reactor using 5.00 L of sulfuric acid and 0.531 kg of used cathodes. Trials were also performed in the presence of Fe^{2+} ions to see if these ions had a catalytic effect. All trials lasted for 15 minutes with the reactor solutions then analysed for their concentrations of Li^+, Co^{2+}, Mn^{2+} and, where relevant, Fe^{2+}.

The results of the Co^{2+} and Fe^{2+} analyses are summarised in the following table.

Trial	Initial solution composition		Solution composition after 15 minutes	
	H_2SO_4 (mol L^{-1})	Fe^{2+} ($\times 10^{-1}$ mol L^{-1})	Co^{2+} ($\times 10^{-1}$ mol L^{-1})	Fe^{2+} ($\times 10^{-1}$ mol L^{-1})
1	1.37	0.00	4.24	0.00
2	3.01	0.00	4.92	0.00
3	5.91	3.31	7.20	3.29
4	7.40	0.00	5.94	0.00
5	8.80	0.00	6.96	0.00
6	8.80	6.62	9.95	6.61

See next page

(a) (i) Which trial number(s) will allow the chemist to investigate the relationship between the sulfuric acid concentration and the amount of cobalt extracted? (1 mark)

(ii) Use collision theory to explain the effect of acid concentration on the rate at which the used cathodes dissolved. (3 marks)

(b) Do Fe^{2+} ions catalyse the dissolution of cobalt in sulfuric acid? Justify your answer. (3 marks)

See next page

Question 37 (continued)

(c) Would the used cathodes dissolve completely in Trial 2 assuming enough time was allowed? Support your answer with relevant calculations.

The dissolution reaction is:

$2\ LiCoO_2(s) + Mn(s) + 8\ H^+(aq) \rightarrow 2\ Li^+(aq) + 2\ Co^{2+}(aq) + Mn^{2+}(aq) + 4\ H_2O(\ell)$

(7 marks)

See next page

(d) Calculate the percentage, by mass, of lithium in a used cathode. Give your answer to the appropriate number of significant figures. (4 marks)

See next page

Question 38 **(12 marks)**

Sulfuric acid is manufactured by the Contact process, the steps of which are outlined below.

Step One: Molten sulfur is burned in air at approximately 1000 °C:

$$S(\ell) + O_2(g) \rightarrow SO_2(g) + 297 \text{ kJ}$$

Step Two: The resulting sulfur dioxide is converted to sulfur trioxide as shown in the following equilibrium reaction. It is conducted at a temperature of about 450 °C with a V_2O_5 catalyst at a pressure of between 100 and 200 kPa:

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) + 198 \text{ kJ}$$

Step Three: The resulting sulfur trioxide is absorbed into sulfuric acid, producing oleum ($H_2S_2O_7$). Water is added to the oleum, producing 18 mol L^{-1} sulfuric acid:

$$SO_3(g) + H_2SO_4(\ell) \rightarrow H_2S_2O_7(\ell)$$

$$H_2S_2O_7(\ell) + H_2O(\ell) \rightarrow 2\ H_2SO_4(aq)$$

Use your understanding of collision theory and chemical equilibrium to discuss the reaction conditions for Steps 1 and 2 of the Contact process, given that the aim is to produce the greatest yield in the shortest time. In your discussion, also address economic concerns where appropriate.

See next page

See next page

Question 39 **(18 marks)**

The oil extracted from the seeds of a particular Australian tree contains tripalmitin. The presence of tripalmitin, which is a triglyceride, means that this oil can be used to make ethyl palmitate, a type of biodiesel. The condensed structural formulae of tripalmitin and ethyl palmitate are given below.

Tripalmitin (a type of triglyceride)	Ethyl palmitate (a type of biodiesel)
$H_2COOC(CH_2)_{14}CH_3$ | $HCOOC(CH_2)_{14}CH_3$ | $H_2COOC(CH_2)_{14}CH_3$	$CH_3(CH_2)_{14}COOCH_2CH_3$

(a) Demonstrate, by using a series of balanced reaction equations, how ethyl palmitate can be synthesised from tripalmitin. Your synthesis method **must** use ethene and lipase. You can also use water and any common laboratory acids.

Use condensed structural formulae to represent organic compounds. State symbols are only required for inorganic substances. (8 marks)

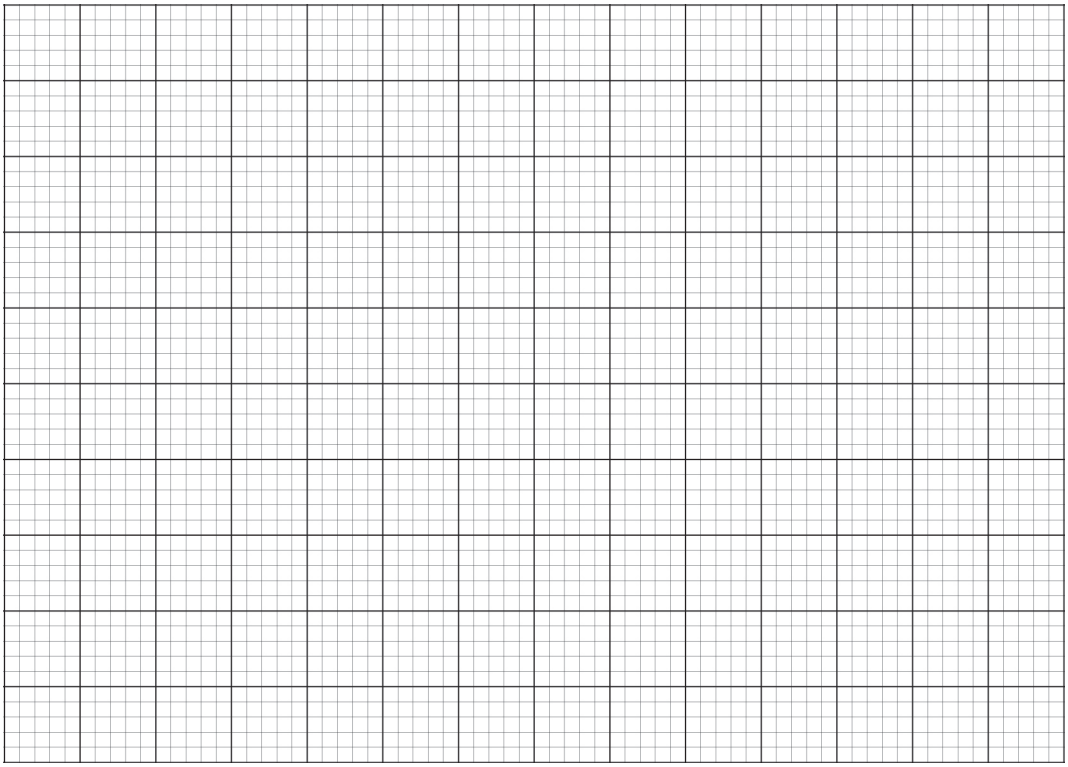
See next page

A chemist investigated the synthesis step involving lipase referred to in part (a). The results obtained by the chemist are shown in the following table.

Temperature of reaction system (°C)	Biodiesel yield (%)
20	65
30	78
35	85
40	88
50	91
55	92
60	85
65	75

(b) Construct a question that the chemist might be trying to answer in this investigation. (1 mark)

(c) Graph the data presented in the table on the following grid. (5 marks)



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

See next page

Question 39 (continued)

(d) Describe the relationship observed in the graph. (2 marks)

(e) Explain how the use of lipase in the synthesis contributes to the relationship described in part (d). (2 marks)

End of questions

Supplementary page

Question number: _____

Supplementary page

Question number: _____

Supplementary page

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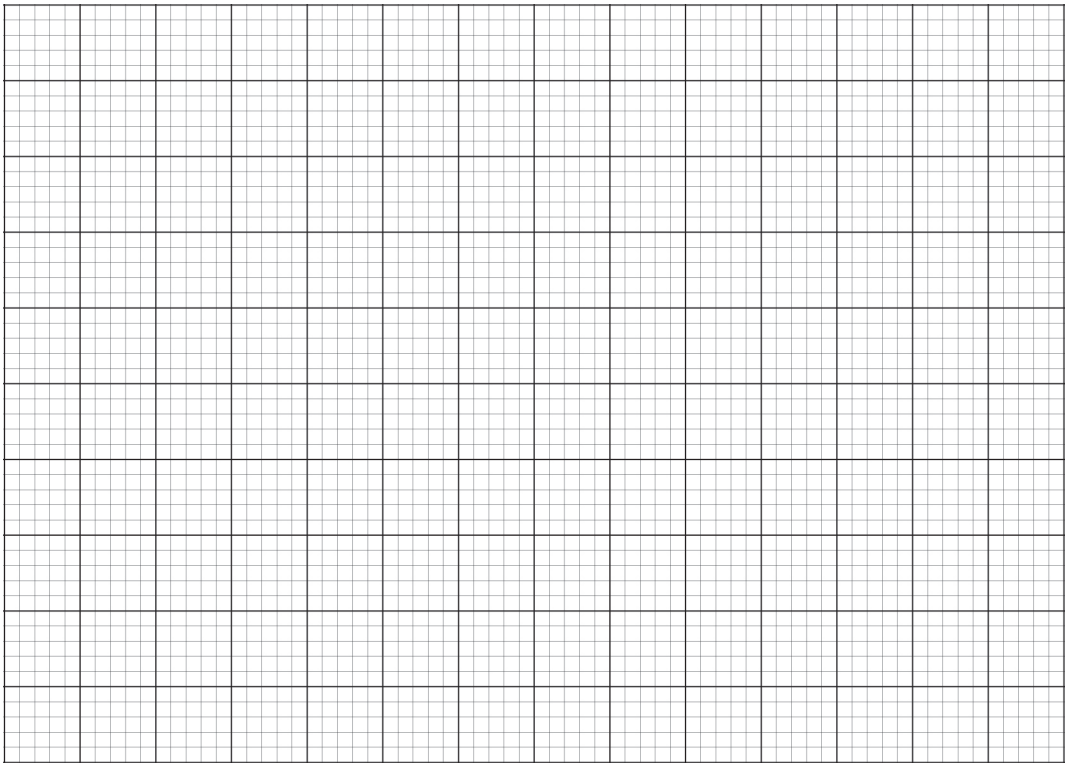
Spare grid



ACKNOWLEDGEMENTS

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