



ATAR course examination, 2022

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

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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	71	35
Section Three Extended answer	6	6	70	90	40
Total					100

Instructions to candidates

- The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2022: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.
- 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 preferably using a blue/black pen. Do not use erasable or gel pens.
- 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.
- 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.
- 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.
- 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.

1. Consider the following statements about acid-base indicators. Acid-base indicators

- (i) change colour as the concentration of hydrogen ions changes.
- (ii) are weak acids or bases.
- (iii) must not react with the reactants or products in a titration.
- (iv) must be used in large volumes for the best results.

Which of the above statements is/are correct?

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

2. Which of the following pairs represents the **greatest** difference in oxidation state of the underlined element?

- (a) Mn²⁺ and KMnO₄
- (b) CrO₄²⁻ and Cr₂O₇²⁻
- (c) Cl⁻ and HClO₄
- (d) S²⁻ and SO₃²⁻

3. Which of the following may occur in a closed chemical system?

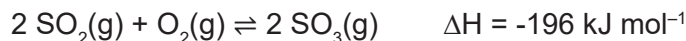
- (a) Energy and matter are exchanged with the surroundings.
- (b) Energy, but not matter, is exchanged with the surroundings.
- (c) Matter, but not energy, is exchanged with the surroundings.
- (d) Neither energy nor matter are exchanged with the surroundings.

4. Which of the following is a saponification reaction?

- (a) condensation of α -amino acids
- (b) oxidation of primary alcohols
- (c) acid-catalysed reaction of alcohols and carboxylic acids
- (d) base hydrolysis of fats

5. Which of the following pairs, in equimolar amounts, would result in an acidic buffer solution?
- (i) $\text{CH}_3\text{COOH}/\text{CH}_3\text{COO}^-$
 - (ii) $\text{H}_2\text{CO}_3/\text{HCO}_3^-$
 - (iii) $\text{NH}_3/\text{NH}_4^+$
 - (iv) $\text{H}_2\text{SO}_4/\text{HSO}_4^-$
 - (v) $\text{CH}_3\text{NH}_2/\text{CH}_3\text{NH}_3^+$
- (a) i, ii and iv
 - (b) iii and v
 - (c) ii, iii and v
 - (d) i and ii

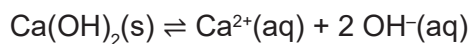
Questions 6 to 8 refer to the following reaction at equilibrium in a closed reaction vessel.



6. The equilibrium constant for this reaction at 298 K is 4.0×10^{-24} . What information does this provide about the reaction mixture at this temperature? The partial
- (a) pressure of the products is greater than that of the reactants.
 - (b) pressures of all species are the same.
 - (c) pressures of the reactants are greater than that of the products.
 - (d) pressures of both sulfur oxides are greater than that of oxygen.
7. Which of the following changes will initially decrease the rate at which $\text{SO}_2(\text{g})$ is consumed?
- (a) decrease the volume of the reaction vessel
 - (b) decrease the partial pressure of $\text{O}_2(\text{g})$
 - (c) heat the reaction vessel
 - (d) add an appropriate catalyst
8. Which of the following changes will increase the yield of $\text{SO}_3(\text{g})$ in the reaction?
- (a) remove $\text{O}_2(\text{g})$ from the reaction vessel
 - (b) add an inert gas to the reaction vessel
 - (c) increase the volume of the reaction vessel
 - (d) decrease the temperature of the reaction vessel
9. Consider an acid-base titration between hydrochloric acid solution and ammonia solution. Which of the following actions is **least** likely to cause an error when calculating the concentration of hydrochloric acid?
- (a) cleaning the pipette with distilled water before each titration
 - (b) rinsing the sides of the conical flask with distilled water during the titration
 - (c) measuring the ammonia solution in a 20 mL measuring cylinder
 - (d) leaving the funnel in the burette for each titration

See next page

10. Which of the following is the correct equilibrium constant expression for the dissolution of calcium hydroxide, represented by the following equation?

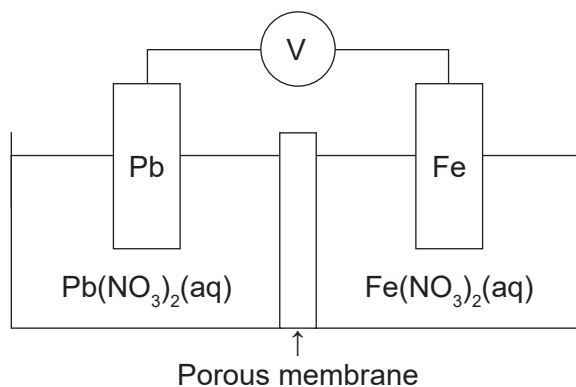


- (a) $K = \frac{[\text{Ca}^{2+}] [\text{OH}^{-}]^2}{[\text{Ca(OH)}_2]}$
- (b) $K = \frac{[\text{Ca(OH)}_2]}{[\text{Ca}^{2+}] [\text{OH}^{-}]^2}$
- (c) $K = [\text{Ca}^{2+}] [\text{OH}^{-}]^2$
- (d) $K = \frac{1}{[\text{Ca}^{2+}] [\text{OH}^{-}]^2}$
11. Select the **best** reason why the Brønsted-Lowry model is preferred over the Arrhenius model of acids and bases. The Brønsted-Lowry model
- (a) includes a wider range of substances and can be used more broadly.
- (b) demonstrates when hydrogen atoms are replaced by metals.
- (c) easily identifies that acids produce hydrogen ions and bases produce hydroxide ions.
- (d) demonstrates that non-metal oxides dissolve in water to produce acidic solutions.
12. A student tested an acid with a pH meter. When dipped into the acid the pH was shown to be 4. What is the concentration of hydrogen ions in this solution?
- (a) 0.0004 mol L⁻¹
- (b) 0.00001 mol L⁻¹
- (c) 0.0001 mol L⁻¹
- (d) 0.004 mol L⁻¹
13. Identify the **weakest** acid in the following series.

	Name	Formula	K _a (25 °C)
(a)	acetic acid	CH ₃ COOH	1.8 × 10 ⁻⁵
(b)	chloroacetic acid	ClCH ₂ COOH	1.3 × 10 ⁻³
(c)	dichloroacetic acid	Cl ₂ CHCOOH	4.5 × 10 ⁻²
(d)	trichloroacetic acid	CCl ₃ COOH	2.2 × 10 ⁻¹

14. Which of the following equations represents the HPO_4^{2-} ion acting as a Brønsted-Lowry acid?
- (a) $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\ell)$
 (b) $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$
 (c) $\text{HPO}_4^{2-}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$
 (d) $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{PO}_4^{3-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$

Questions 15 to 17 refer to the electrochemical cell below.



15. Which of the following series of labels **best** represents the cell above?

	Anode	Cathode	Direction of electron flow	Direction of anion flow
(a)	lead	iron	←	→
(b)	lead	iron	→	←
(c)	iron	lead	→	→
(d)	iron	lead	←	→

16. Using the standard reduction potentials, determine the theoretical value that the voltmeter would show for this electrochemical cell?

- (a) +0.31 V
 (b) +0.57 V
 (c) +0.64 V
 (d) +0.90 V

17. Which of the following reasons would cause the voltmeter to show a different value to the theoretical voltage?

- (i) the cell is at 100 kPa
 (ii) the cell is at 20 °C
 (iii) the $\text{Pb}(\text{NO}_3)_2$ solution is 0.1 mol L⁻¹ and the $\text{Fe}(\text{NO}_3)_2$ solution is 0.2 mol L⁻¹
 (iv) the lead and iron electrodes are in the opposite solution to that shown in the diagram above

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

See next page

18. The presence of a carboxylic acid functional group in an unknown organic compound may be identified by observing a reaction with which of the following?

- (a) $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$
- (b) $\text{Br}_2(\text{aq})$
- (c) $\text{Na}_2\text{SO}_4(\text{s})$
- (d) $\text{Na}_2\text{CO}_3(\text{s})$

19. The following compounds have similar molar masses and polar functional groups. Which compound is expected to have the highest melting point?

(a)	$\text{NH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$	88 g mol^{-1}
(b)	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$	89 g mol^{-1}
(c)	$\begin{array}{c} \text{O} \\ \\ \text{HO}-\text{C}-\text{CH}_2\text{CH}_2\text{OH} \end{array}$	90 g mol^{-1}
(d)	$\begin{array}{c} \text{O} \quad \text{O} \\ \quad \\ \text{HO}-\text{C}-\text{C}-\text{OH} \end{array}$	90 g mol^{-1}

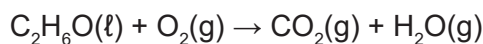
20. Which of the following is the dominant form of serine in acidic conditions?

(a)	$\begin{array}{c} \text{CH}_2-\text{OH} \\ \\ \text{H}_3\text{N}^+-\text{CH}-\text{COOH} \end{array}$
(b)	$\begin{array}{c} \text{CH}_2-\text{OH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
(c)	$\begin{array}{c} \text{CH}_2-\text{OH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COO}^- \end{array}$
(d)	$\begin{array}{c} \text{CH}_2-\text{OH} \\ \\ \text{H}_3\text{N}^+-\text{CH}-\text{COO}^- \end{array}$

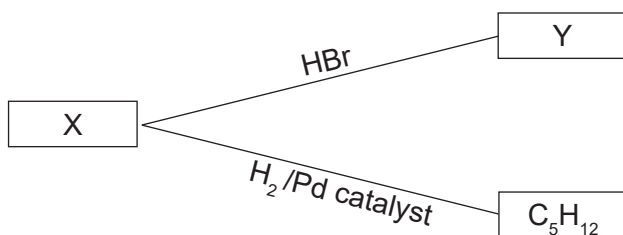
21. How many isomers are there for a molecule with the formula $\text{C}_3\text{H}_6\text{Cl}_2$?

- (a) 5
- (b) 4
- (c) 3
- (d) 2

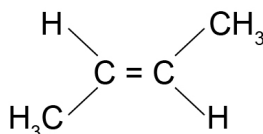
22. How many moles of oxygen will be consumed in the complete combustion of 1 mole of ethanol? The unbalanced equation for this reaction is shown below.



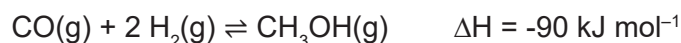
- (a) 1 mol
 (b) 2 mol
 (c) 3 mol
 (d) 4 mol
23. In the following diagram, determine the molecular formulae of substances X and Y.



- | | X | Y |
|-----|--------------------------------|--|
| (a) | C ₅ H ₁₂ | C ₅ H ₁₃ Br |
| (b) | C ₅ H ₁₀ | C ₅ H ₁₁ Br |
| (c) | C ₅ H ₁₀ | C ₅ H ₁₀ Br ₂ |
| (d) | C ₅ H ₈ | C ₅ H ₉ Br |
24. Which of the following is the correct IUPAC name for the molecule below?



- (a) *trans*-but-2-ene
 (b) 1,4-dimethylbutene
 (c) *cis*-but-2-ene
 (d) methylprop-1-ene
25. Which set of conditions below would optimise the yield of methanol in the following industrial process?



- (a) low pressure, high temperature
 (b) high pressure, high temperature, catalyst
 (c) low pressure, low temperature, catalyst
 (d) high pressure, low temperature

End of Section One

See next page

Section Two: Short answer**35% (71 Marks)**

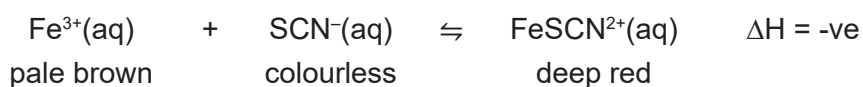
This section has **eight** questions. Answer **all** questions. Write your answers in the spaces provided.

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**(12 marks)**

Consider the following system at equilibrium:



For each of the applied changes after equilibrium is re-established, predict the:

- shift in equilibrium position (left, right or no change)
- rate of the forward reaction compared to the original rate (increase, decrease or no change)
- colour of the reaction mixture.

Change	Shift in equilibrium position (left, right or no change)	Rate of the forward reaction compared to original rate (increase, decrease or no change)	Colour of reaction mixture
The reaction mixture is heated			
A few crystals of FeCl_3 are added			
Water is added to the reaction mixture			
A few drops of concentrated Na_3PO_4 are added			

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Question 27

(12 marks)

The information in the table below shows the boiling temperature for a range of primary amines.

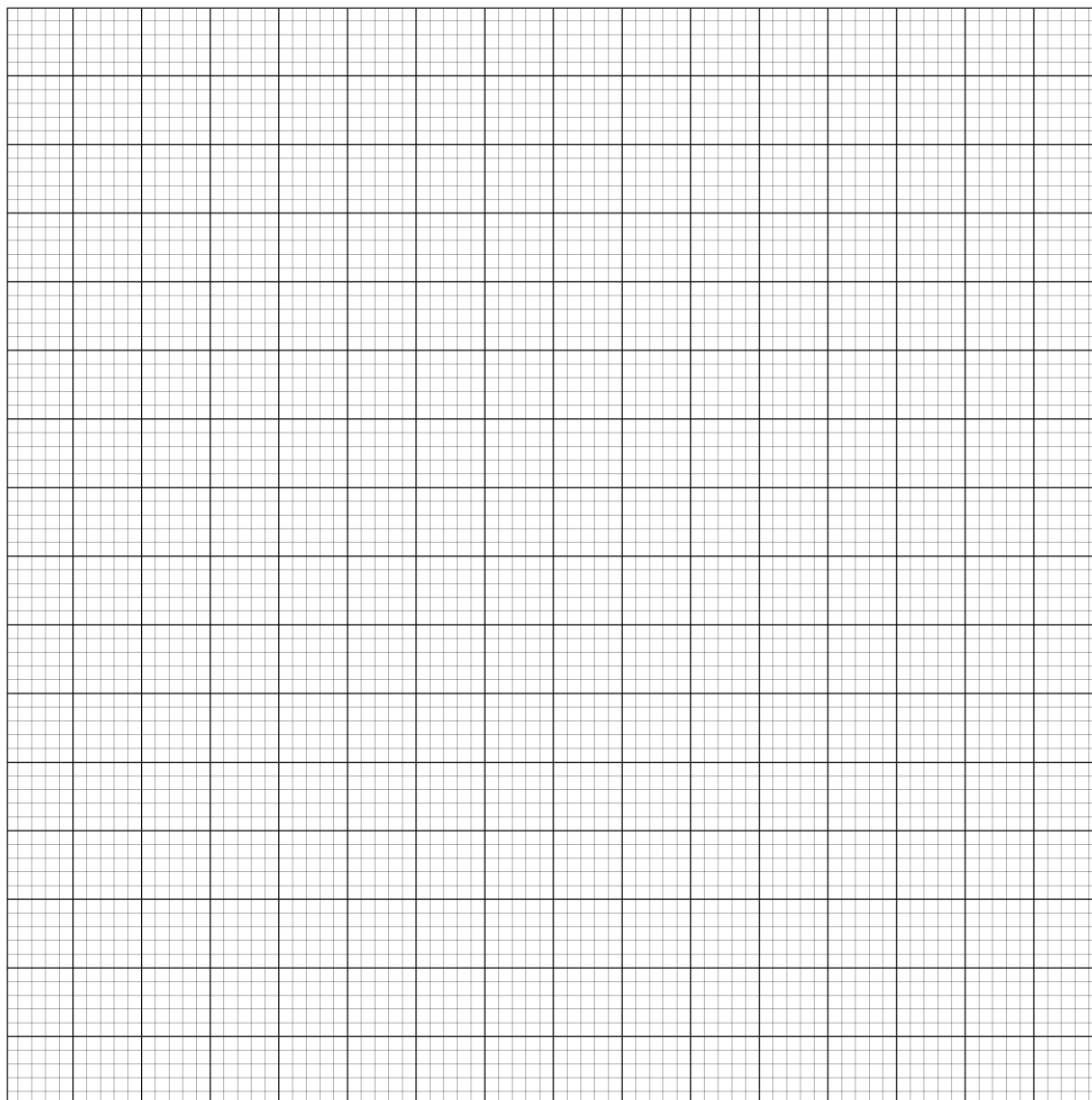
Amine	Boiling temperature (°C)
Ethanamine	16.6
Propan-1-amine	47.8
Butan-1-amine	78.0
Hexan-1-amine	131
Heptan-1-amine	155

- (a) Draw the structure of butan-1-amine showing all atoms and bonds. (2 marks)



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- (b) Use the data in the table on the previous page to graph the boiling temperature of amines versus the number of carbons in the amines on the grid below. The x-axis has been labelled for you. (5 marks)



Number of carbons in amine

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.

- (c) Use your graph to predict the boiling temperature of pentan-1-amine. (1 mark)

See next page

Question 29

(11 marks)

Keratin is a substance made up of several different proteins that form the structure of various anatomical features such as human hair and nails.

- (a) Keratins are known to contain relatively large amounts of the α -amino acid valine. A property of α -amino acids is that they can form zwitterions.

- (i) Draw the structure of valine as a zwitterion. (2 marks)



- (ii) State the condition that is required for zwitterions of α -amino acids to form in aqueous solution. (1 mark)

- (b) The strength of hair keratin is attributed to a relatively high content of the α -amino acid cysteine.

- (i) State which interaction is possible in proteins due to the presence of cysteine. (1 mark)

- (ii) Define 'protein tertiary structure' and describe how it is formed. (3 marks)

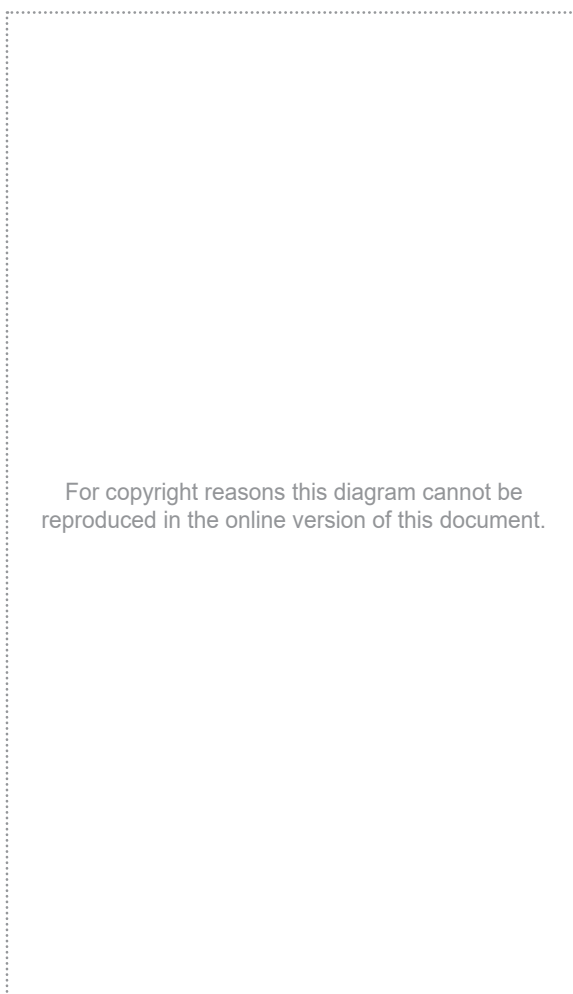
Definition: _____

Description: _____

- (c) Proteins are distinguished at the level of the primary structure. Describe this level of protein structure. (2 marks)

The α -helix is a common secondary structure observed in keratins.

- (d) Draw dotted lines (.....) on the diagram below to show the position of at least **two** hydrogen bond interactions that stabilise the helical shape. (1 mark)



The nature of the α -amino acid side chain or R-group in the helical part of keratins is critical to the overall structure. In certain positions the side chains are non-polar.

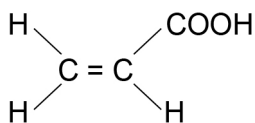
- (e) Identify **one** α -amino acid from the Data booklet with a non-polar side chain. (1 mark)

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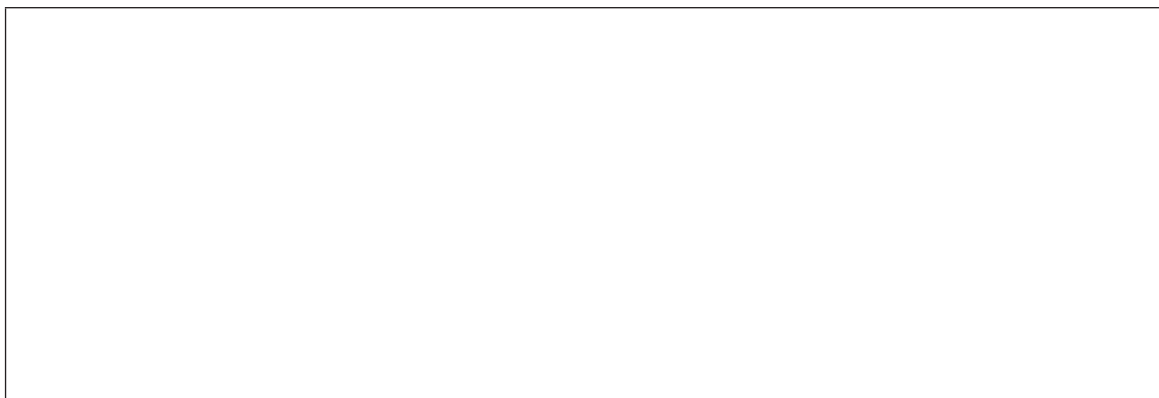
Question 31

(7 marks)

Polyacrylic acid is a polymer that is formed from the monomer propenoic acid (also known as acrylic acid). The monomer propenoic acid is shown below.



- (a) Draw the structure of the polymer polyacrylic acid showing at least **three** repeating units. (2 marks)

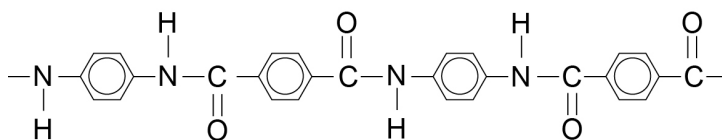


When reacted with sodium hydroxide, polyacrylic acid becomes polyacrylate. Polyacrylate is a powder that swells when water is added and can absorb up to 180 times its weight in water. It is used for applications such as disposable nappies.

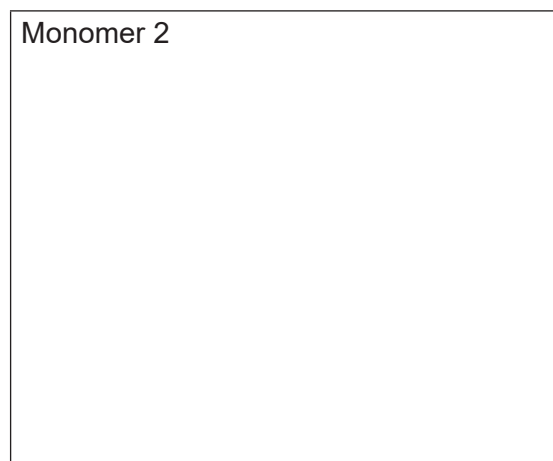
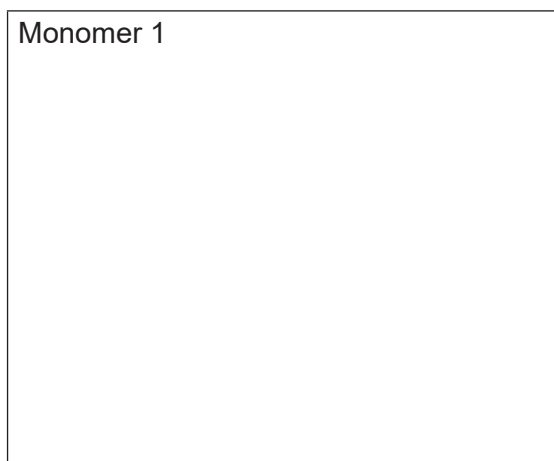
- (b) A child's nappy contains approximately 3.97 g of polyacrylate, and a particular company state that their nappies are at least 97.4% efficient at absorbing water. After thorough testing it was demonstrated that this brand of nappies could absorb 691 g of water. Use a calculation to determine whether the claims of the company that manufacture the nappies are true. (3 marks)

Question 31 (continued)

Kevlar is a polymer that is formed through a condensation reaction that releases water during the polymerisation of its monomers. A section of the Kevlar polymer is shown below.



- (c) Draw the structure of the **two** monomers from which Kevlar is made. (2 marks)

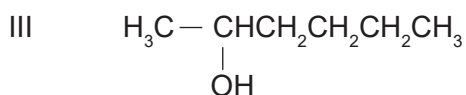
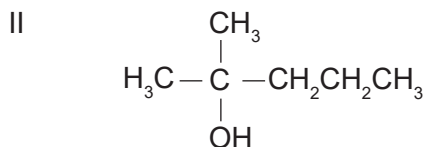


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Question 32

(6 marks)

Consider the following three isomers of $C_6H_{14}O$:



- (a) State the IUPAC name for each isomer. (3 marks)

Isomer	IUPAC name
I	
II	
III	

- (b) Propose a chemical test and state the expected observations for each isomer that could be used to distinguish between isomer I and isomer II. (3 marks)

Chemical test: _____

Isomer I: _____

Isomer II: _____

Question 33

(11 marks)

Esters are chemical compounds derived from a carboxylic acid and an alcohol during esterification. An ethyl ester is synthesised using ethanol as the alcohol.

- (a) Two methods of producing ethanol industrially include fermentation of glucose and hydrolysis of ethene. Write a chemical equation for each process and state any conditions that are required. (8 marks)

Chemical formula for glucose: $C_6H_{12}O_6$

Fermentation of glucose:

Conditions:

Hydrolysis of ethene:

Conditions:

- (b) The ethanol produced was added to pentanoic acid along with a few drops of concentrated sulfuric acid. This mixture was then heated. Draw the structure and state the IUPAC name of the ester that is formed in this reaction. Include **all** atoms. (3 marks)

Structure:

IUPAC name: _____

End of Section Two

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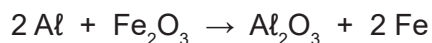
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Question 35

(17 marks)

Thermite is a mixture of aluminium and iron(III) oxide that, when ignited, rapidly produces a large amount of heat as it burns. The reaction is represented by the equation:



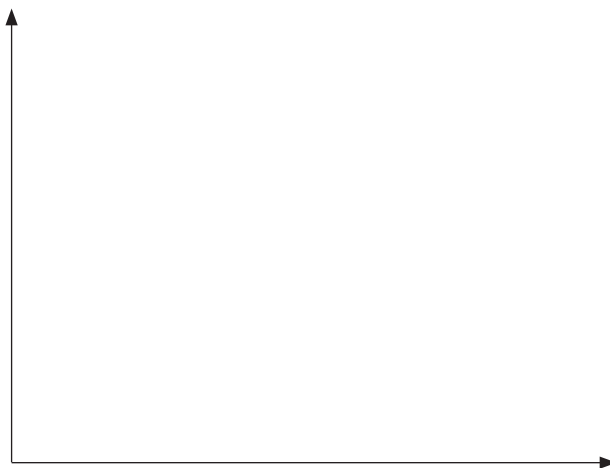
The heat produced in the reaction is sufficient to melt iron, which is why the reaction is used to weld iron railway tracks.

(a) Use the following axes to sketch an energy profile diagram for the thermite reaction.

Label the:

- axes
- reactants and products
- activation energy
- change in enthalpy.

(4 marks)

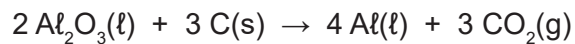


(b) In order for the reaction to occur, the iron(III) oxide and aluminium are mixed as powders and a heat source, such as burning magnesium, is used to ignite the mixture. Using your understanding of collision theory, explain these observations. (4 marks)

See next page

Question 35 (continued)

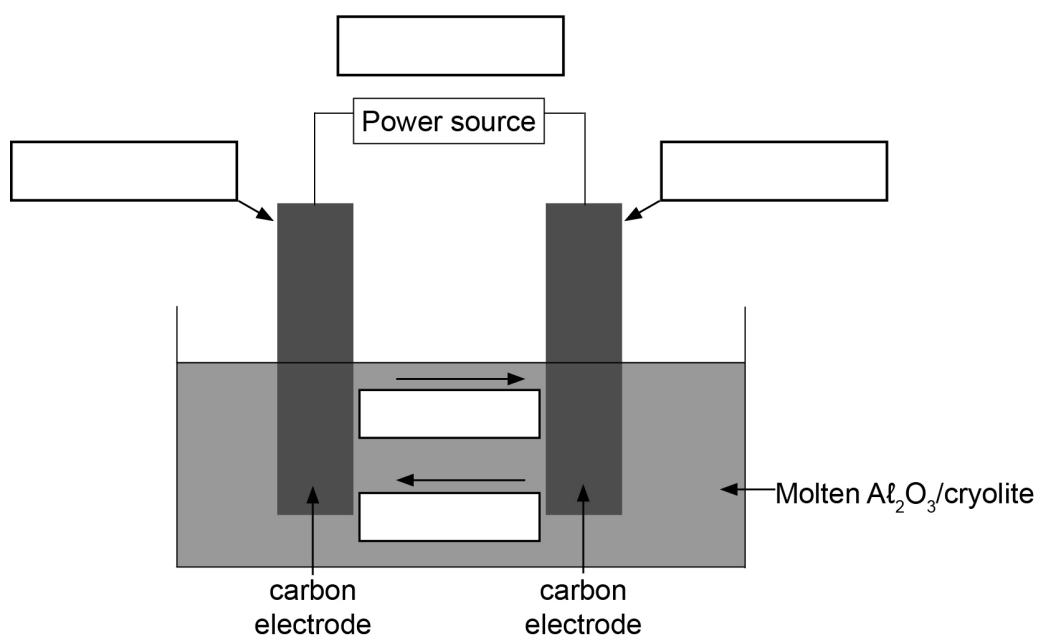
Aluminium can be refined through electrolysis. Molten aluminium oxide, which is mixed with a substance called cryolite to reduce the melting point, is electrolysed to produce aluminium and carbon dioxide, which is represented by the following equation:



(d) On the diagram below, correctly place the following in the boxes:

- anode
- cathode
- direction of cation flow and direction of anion flow
- direction of electron flow.

(3 marks)



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Question 37

(18 marks)

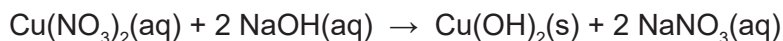
The copper cycle is a series of reactions involving copper.

Step 1: 2.54 g of copper is added to excess concentrated nitric acid to produce copper(II) nitrate, nitrogen dioxide and water.

- (a) Write balanced half-equations for the oxidation and reduction reactions and a balanced overall redox equation for the reaction in Step 1. (5 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Step 2: Copper(II) nitrate is added to excess sodium hydroxide solution, according to the following equation:



- (b) Describe all the observations for this reaction, including colour changes. (2 marks)

Step 3: Copper(II) hydroxide is heated to produce copper(II) oxide and water vapour.

- (c) Write an equation for Step 3, including state symbols. (3 marks)

Step 4: Copper(II) oxide is added to excess dilute sulfuric acid solution.

- (d) Write an equation for this reaction. (2 marks)

See next page

- (b) Hydrochloric acid must be standardised against a primary standard before it can be used in titrations such as the one described in part (a). List **three** properties of substances suitable for use as primary standards. (3 marks)

One: _____

Two: _____

Three: _____

- (c) Methyl orange, which changes colour between a pH of 3.1 and a pH of 4.4, was chosen as the indicator for this reaction. Justify, with the aid of an equation, the selection of this indicator for the titration. (4 marks)

Question 39

(16 marks)

A student wanted to investigate how changing temperature would influence how rapidly oxalic acid solution would decolourise an acidified potassium permanganate solution.

The student was provided with the following chemicals and equipment:

- 0.1 mol L⁻¹ acidified potassium permanganate solution
- 0.1 mol L⁻¹ oxalic acid solution
- 250 mL conical flasks
- Bunsen burner
- tripod and gauze mat
- thermometer
- stop watches
- 5.00 mL, 10.00 mL, 20.00 mL and 25.00 mL pipettes
- distilled water
- 25.0 mL measuring cylinders.

- (a) State a hypothesis for this investigation. (2 marks)

- (b) Identify the independent and dependent variables. (2 marks)

Independent variable: _____

Dependent variable: _____

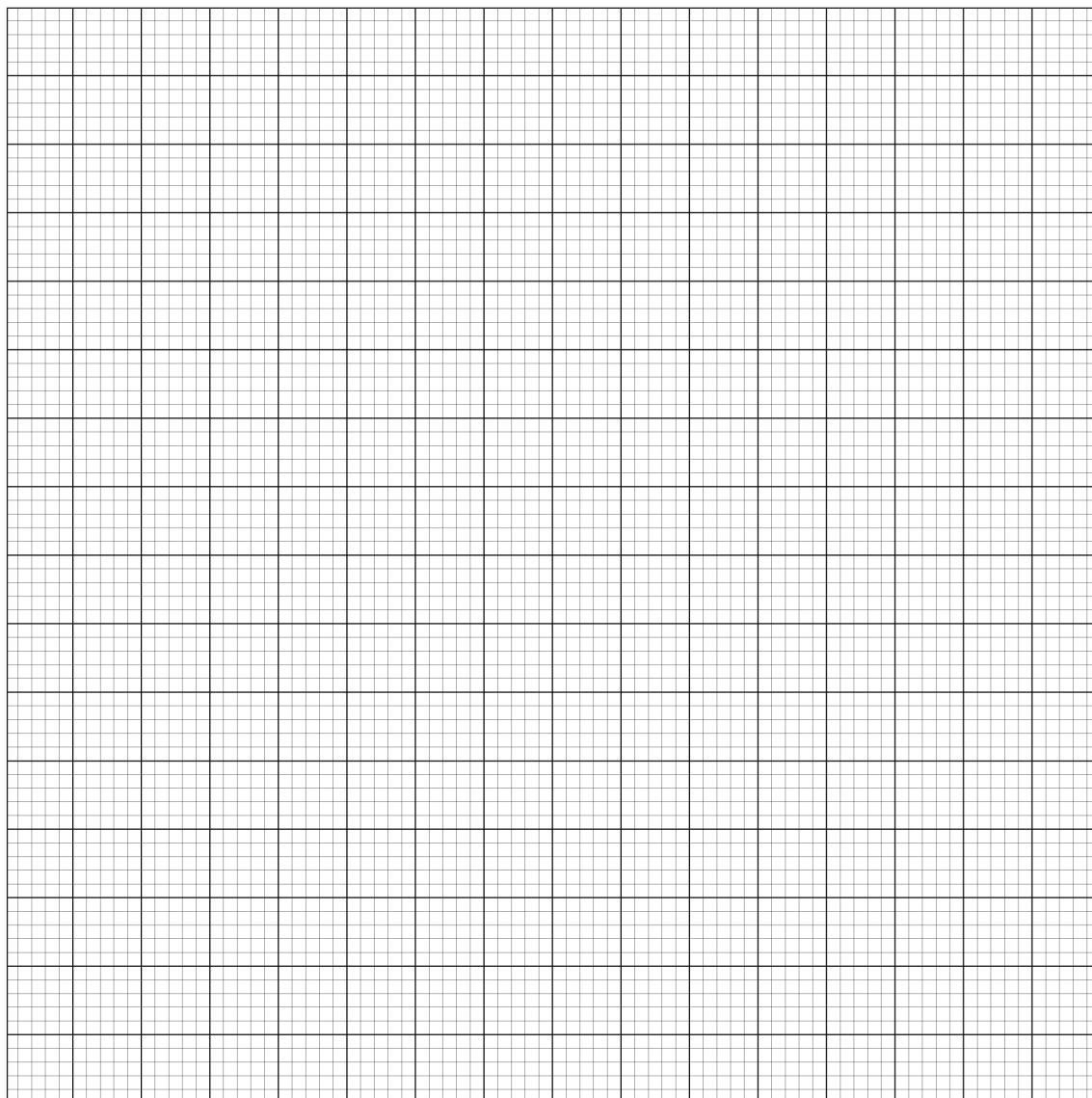
- (c) Identify **two** control variables. (2 marks)

One: _____

Two: _____

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Spare grid for Question 27(b)



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Number of carbons in amine

ACKNOWLEDGEMENTS

Question 29(d) Image adapted from: Morganti, P., & Li, H. Y. (2015). Innovation in cosmetic and medical science. The role of chitin nanofibrils composites (Fig. 2) [Diagram]. *Journal of Applied Cosmetology*, 33(1–2). Retrieved May 2022, from https://www.researchgate.net/figure/The-alpha-helix-structure-of-keratins_fig3_282148893

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