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

**Western Australian Certificate of Education
ATAR course examination, 2016**

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.

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: non-programmable calculators approved for use in this 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.

CHE

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	12	12	60	83	35
Section Three Extended answer	5	5	70	85	40
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian Certificate of Education ATAR course examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.

2. 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. 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.

3. 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.

4. 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.

5. Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

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

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. 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. The decomposition of hydrogen peroxide in a closed system is represented by the equation below.

$$2\ H_2O_2(aq) \quad \rightleftharpoons \quad 2\ H_2O(\ell) \quad + \quad O_2(g) \qquad \qquad \Delta H < 0$$

   Which one of the following will increase the equilibrium yield of oxygen?

   (a) decreasing the concentration of hydrogen peroxide
   (b) increasing the total pressure of the system
   (c) decreasing the temperature of the system
   (d) adding an inert gas to the system

2. Sulfur can be obtained from hydrogen sulfide found in natural gas according to the equation below.

$$2\ H_2S(g) \quad + \quad SO_2(g) \quad \rightarrow \quad 2\ H_2O(g) \quad + \quad 3\ S(g) \qquad \qquad \Delta H > 0$$
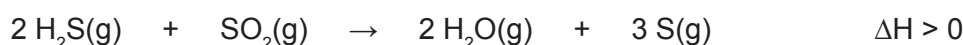
   Which one of the following changes will initially decrease the rate at which sulfur is produced?

   (a) reduce the partial pressure of the hydrogen sulfide ($H_2S(g)$)
   (b) increase the partial pressure of sulfur dioxide ($SO_2(g)$)
   (c) add a metal catalyst to the reaction vessel
   (d) heating the reaction vessel
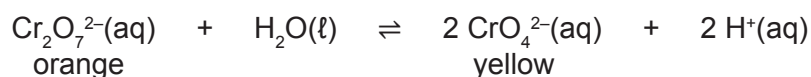
3. Consider the equilibrium system below.

$$N_2(g) \quad + \quad O_2(g) \quad \rightleftharpoons \quad 2\ NO(g)$$
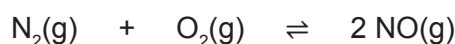
   If the equilibrium constant (K) for this reaction is 4.1×10^{-31}, which one of the following statements is **true** for the system where the initial partial pressures of nitrogen and oxygen were equal to each other?

   (a) Once equilibrium is reached, the reverse reaction rate is much faster than the forward reaction rate.
   (b) The partial pressure of NO(g) is less than the partial pressure of $N_2(g)$.
   (c) The actual ratio of gaseous N_2 particles to NO gaseous particles is 1:2.
   (d) When nitrogen gas is injected into a vessel containing mostly oxygen gas, the partial pressure of oxygen decreases dramatically.

4. A 500 mL solution of dichromate ions and chromate ions at equilibrium is described by the equation below.

$$Cr_2O_7^{2-}(aq) \quad + \quad H_2O(\ell) \quad \rightleftharpoons \quad 2\,CrO_4^{2-}(aq) \quad + \quad 2\,H^+(aq)$$
$$\text{orange} \qquad\qquad\qquad\qquad\qquad \text{yellow}$$

Which of the following **best** describes the effect of adding 10 mL of concentrated potassium hydroxide solution to the system once equilibrium has been re-established.

	Relative change in concentration of $Cr_2O_7^{2-}(aq)$	Relative change in concentration of $CrO_4^{2-}(aq)$	Relative change in concentration of $H^+(aq)$	Colour change of solution
(a)	increase	decrease	decrease	more orange
(b)	decrease	increase	decrease	more yellow
(c)	no change	no change	no change	no change
(d)	decrease	increase	increase	more yellow

5. Which one of the following substances completes the equation illustrating the process of transesterification to produce biodiesel?

Triglyceride   +   [_____]   →   ester (biodiesel)   +   glycerol

(a) sodium hydroxide
(b) methanol
(c) sodium methoxide
(d) lipase

6. Which one of the following sets of titres indicates a systematic error if the actual volume being measured is 85.2 mL?

(a) 85.1 mL, 85.1 mL, 85.3 mL, 85.5 mL
(b) 65.2 mL, 75.2 mL, 85.2 mL, 95.2 mL
(c) 85.2 mL, 85.3 mL, 85.1 mL, 85.1 mL
(d) 87.3 mL, 86.9 mL, 89.1 mL, 88.2 mL

7. In an acid-base titration, which of the following is **least** likely to cause an error in the calculated concentration?

(a) using a funnel in the burette and leaving it in the same place for each titration
(b) measuring the volume at the bottom of the meniscus
(c) each member of the experimental team taking turns to measure the burette
(d) rinsing the burette with distilled water before the titration

8. Which of the following energy profile diagrams **best** represents a spontaneous, exothermic reaction?

(a)

(b)

(c)

(d)
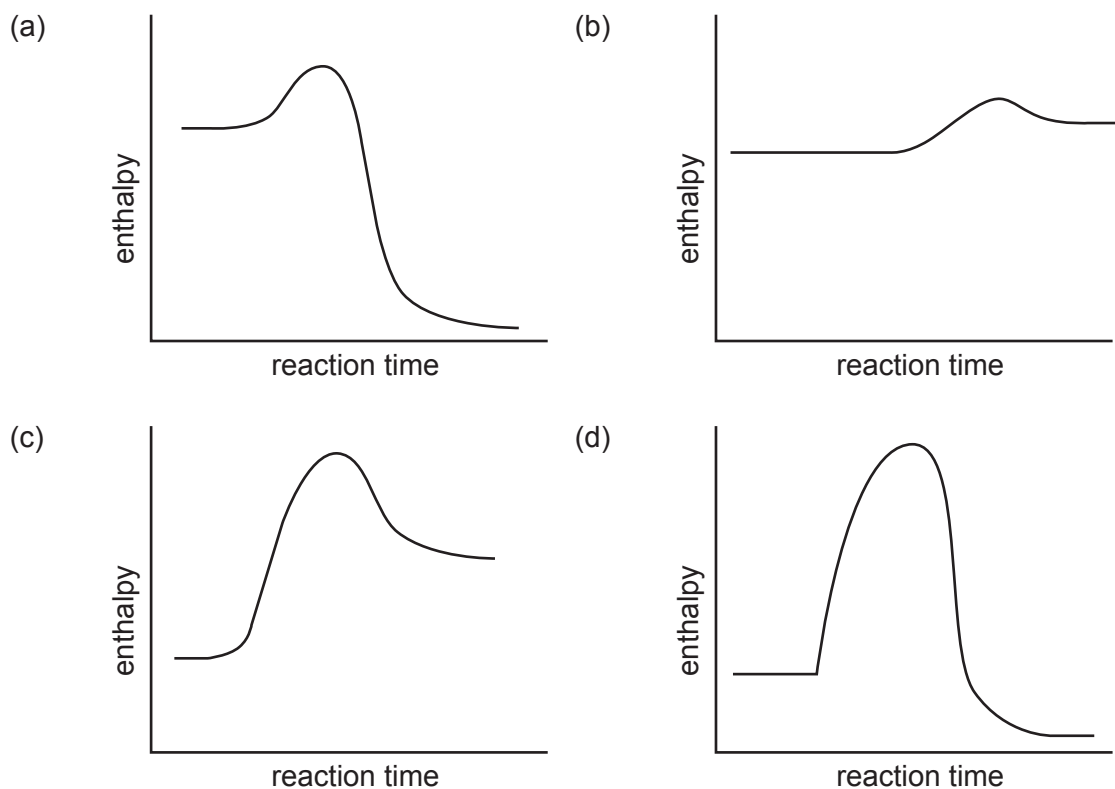
9. How many moles of a diprotic acid would be required to neutralise 1 mole of sodium hydroxide?

(a) 0.5
(b) 1.0
(c) 1.5
(d) 2.0

10. Which one of the following represents a conjugate acid-base pair?

(a) N^{3-}/CN^-
(b) NH_3/NH_2^-
(c) CH_3CH_2OH/CH_3CHO
(d) H_3PO_4/PO_4^{3-}

11. Which of the following equations **best** represents the self-ionisation of water according to the Brønsted-Lowry model?

(a) $H_2O(\ell)$ ⇌ $H^+(aq)$ + $OH^-(aq)$
(b) $H_2O(\ell)$ ⇌ $H_3O^+(aq)$ + $OH^-(aq)$
(c) $2 H_2O(\ell)$ ⇌ $H_3O^+(aq)$ + $2 OH^-(aq)$
(d) $2 H_2O(\ell)$ ⇌ $H_3O^+(aq)$ + $OH^-(aq)$

See next page

12. The **best** definition of the equivalence point in an acid-base titration is the point at which the

    (a) indicator changes colour.
    (b) volume of acid equals the volume of base.
    (c) pH of the solution is 7.
    (d) mole ratio of acid to base is equal to their stoichiometric ratio.

13. Nitric acid can be manufactured from the element nitrogen using the steps below.

Step	1	2	3	4
	$N_2 \rightarrow NH_3$	$NH_3 \rightarrow NO$	$NO \rightarrow NO_2$	$NO_2 \rightarrow HNO_3$

   The smallest change in the oxidation number of nitrogen is found in

    (a) step 1.
    (b) step 2.
    (c) step 3.
    (d) step 4.

14. Which one of the following is **not** a redox reaction?

    (a) $2\ CrO_4^{2-} + 2\ H^+ \rightarrow Cr_2O_7^{2-} + H_2O$
    (b) $2\ Cr^{2+} + 2\ H^+ \rightarrow 2\ Cr^{3+} + H_2$
    (c) $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4\ H_2O + Cr_2O_3$
    (d) $Cr_2O_3 + 3\ C \rightarrow 2\ Cr + 3\ CO$

15. Which one of the following shows the substances listed in order of increasing strength as reducing agents?

    (a) $F^-, A\ell, Zn, Cu, I^-$
    (b) $I^-, F^-, Zn, A\ell, Cu$
    (c) $F^-, I^-, Cu, Zn, A\ell$
    (d) $Zn, A\ell, Cu, I^-, F^-$

16. Which one of the following reactions would **not** produce a current at 25.0 °C, when set up as a galvanic cell?

    (a) $MnO_4^-(aq) + 8\ H^+(aq) + 5\ Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell) + 5\ Fe^{3+}(aq)$
    (b) $Fe(s) + Pb^{2+}(aq) \rightarrow Fe^{2+}(aq) + Pb(s)$
    (c) $Br_2(\ell) + 2\ C\ell^-(aq) \rightarrow 2\ Br^-(aq) + C\ell_2(g)$
    (d) $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

See next page

17. Three metals, A, B and C, were tested to compare their reactivity. Samples of each metal were placed separately into test tubes each containing a nitrate solution of the other metal ions. The following results were obtained.

	A(s)	**B(s)**	**C(s)**
A^{2+}(aq)		No visible reaction	Solid A forms
B^{2+}(aq)	Solid B forms		Solid B forms
C^{2+}(aq)	No visible reaction	No visible reaction	

From these results, the metals arranged in order of decreasing strength as reducing agents can be concluded to be

(a) C > A > B.
(b) B > C > A.
(c) B > A > C.
(d) A > C > B.

18. What is the IUPAC name of the following compound?
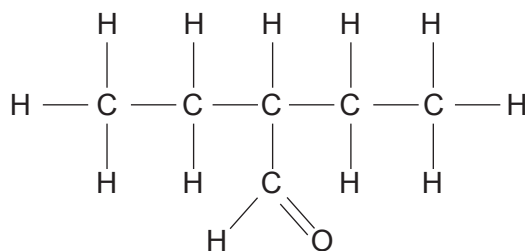
(a) 3-methylpentan-3-al
(b) 2-ethylbutanal
(c) 2,2-diethylethanal
(d) 2-methylbutanal

See next page

19.   Below is a table of reactions involving organic compounds.

Reaction	Product
ethene + hydrogen	1
ethanal + permanganate ion	2
ethanol + acetic (ethanoic) acid	3
acetic (ethanoic) acid + sodium carbonate	4

Which row of the table below identifies a product of each reaction correctly?

	Product 1	Product 2	Product 3	Product 4
(a)	an alkane	a carboxylic acid	an aldehyde	an ester
(b)	an alkene	a carboxylic acid	an ester	carbon dioxide
(c)	an alkane	carbon dioxide	an aldehyde	a carboxylic acid
(d)	an alkane	a carboxylic acid	an ester	carbon dioxide

20.   Which of the following compounds could be used to produce a polymer?

        I CH_2CHCH_3
        II $HOOCCH_2COOH$
        III CH_2CHOH
        IV $HOCH_2CH_3$
        V $H_2NCH_2NH_2$

(a)   I, II, V
(b)   I, II, IV
(c)   I, II, III, V
(d)   II, III, IV, V

See next page

21.　Which of the following **best** represents the generalised structure of α-amino acids?
(Note: R represents a side chain.)

(a)

(b)

(c)

(d)
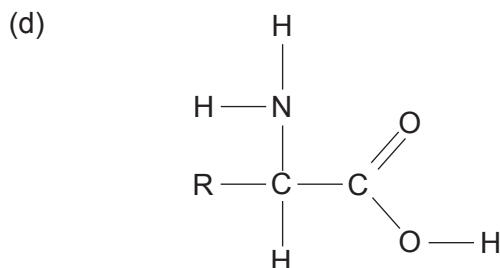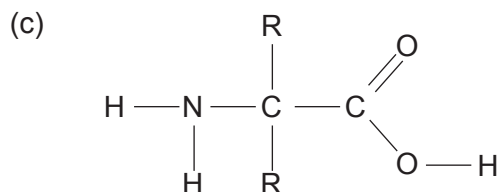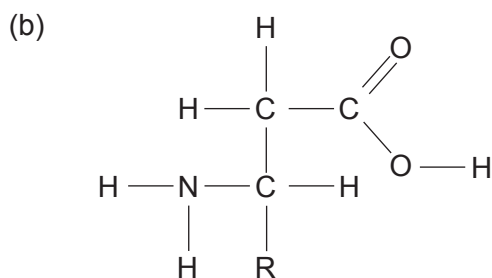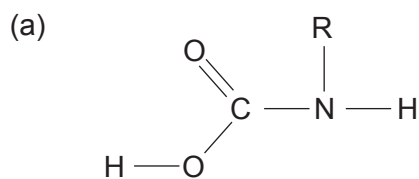
22.　A soap solution can be used to measure the hardness of a water sample. Four 100.0 mL water samples were tested. The table below shows the results of the tests on the four samples.

Sample	Boiling point (°C) at atmospheric pressure	Volume (mL) of soap solution required to form a permanent lather	Mass (g) of precipitate formed when excess silver nitrate solution is added
A	101.7	17.2	1.2
B	100.3	2.1	0.9
C	100.6	4.2	0.6
D	102.4	9.3	1.4

Which of the four samples contained water with the greatest hardness?

(a)　Sample A
(b)　Sample B
(c)　Sample C
(d)　Sample D

Questions 23, 24 and 25 relate to the flow diagram below showing a process for making ethanol.
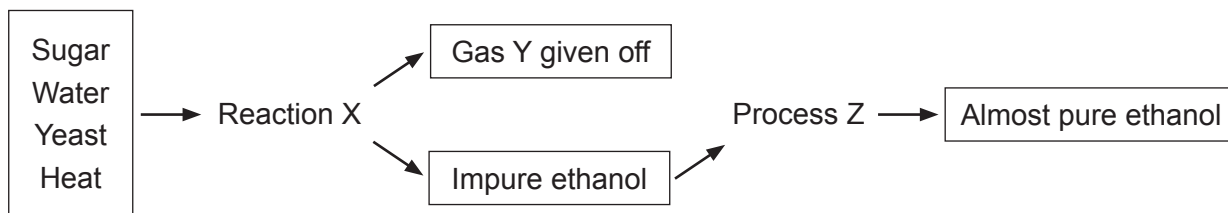
23.   Reaction X is called

(a)   neutralisation.
(b)   fermentation.
(c)   condensation.
(d)   esterification.

24.   Gas Y is

(a)   oxygen.
(b)   hydrogen.
(c)   carbon dioxide.
(d)   carbon monoxide.

25.   Process Z is

(a)   fractional distillation.
(b)   condensation.
(c)   filtration.
(d)   precipitation.

End of Section One

See next page

Section Two: Short answer **35% (83 Marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the spaces provided.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 60 minutes.

Question 26 **(6 marks)**

Galvanic cells and electrolytic cells are often constructed in the laboratory.

(a) List **four** characteristics or components that these two types of cells have in common with each other. (4 marks)

One: _____

_____

Two: _____

_____

Three: _____

_____

Four: _____

_____

(b) List **two** characteristics or components that can be used to distinguish between the two types of cells. State the characteristic or component for each cell. (2 marks)

One: _____

_____

Two: _____

_____

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 27 **(9 marks)**

Write observations for the changes occurring when the substances below are mixed. In your answers include the appearance of the reactants and any product(s) that form.

(a)   (i)   methanol, pentanoic acid and sulfuric acid   (2 marks)

_____

_____

_____

_____

       (ii)   powdered magnesium carbonate and excess methanoic acid   (2 marks)

_____

_____

_____

_____

       (iii) acidified potassium permanganate solution and excess propan-2-ol   (2 marks)

_____

_____

_____

_____

(b)   Name the organic product and write the equation for the reaction when pentanal is added to a solution containing acidified sodium dichromate.   (3 marks)

       Organic product: _____

Question 28 **(6 marks)**

While petroleum diesel and biodiesel are produced differently, they have similar structures to each other.

(a)   The condensed structure of a petroleum diesel is given here.

$$CH_3 - CH_2 - (CH_2)_{12} - CH_2 - CH_3$$
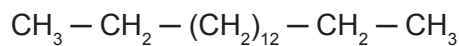
Draw the condensed structure of a biodiesel containing the same number of carbon atoms in the chain.   (3 marks)

(b)   Biodiesel can be synthesised using a base-catalysed method or a lipase-catalysed method. Outline briefly an argument to justify the use of a lipase-catalysed method rather than a base-catalysed method to produce biodiesel.   (3 marks)

Question 29 **(9 marks)**

Addition and condensation polymers are used in industry to produce a vast range of plastics.
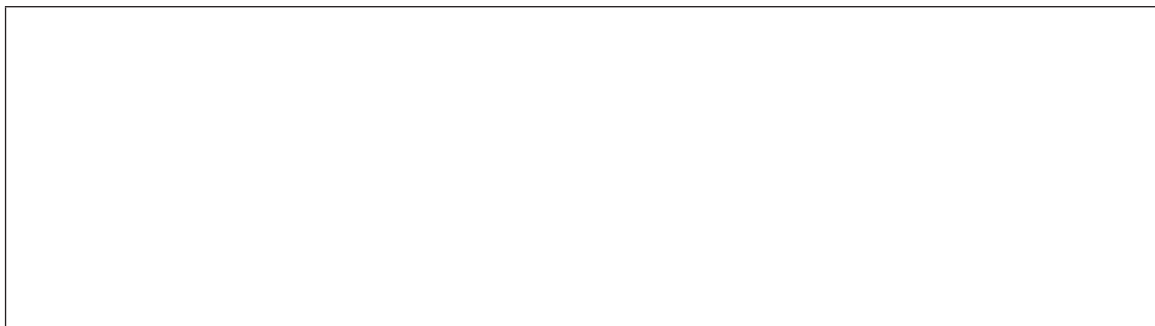
Select **one** addition polymer you have studied and use it to complete parts (a) to (c).

(a)   Draw and name the structure of the monomer used to produce this polymer.   (2 marks)

Name: _____

(b)   Draw and name the polymer, including at least **three** repeating units.   (2 marks)

Name: _____

(c)   State **one** use for this polymer, making reference to its relevant property/ies.   (2 marks)

_____

_____

_____

_____

See next page

Kevlar is a condensation polymer utilised for its high strength. A section of the Kevlar polymer is drawn below.
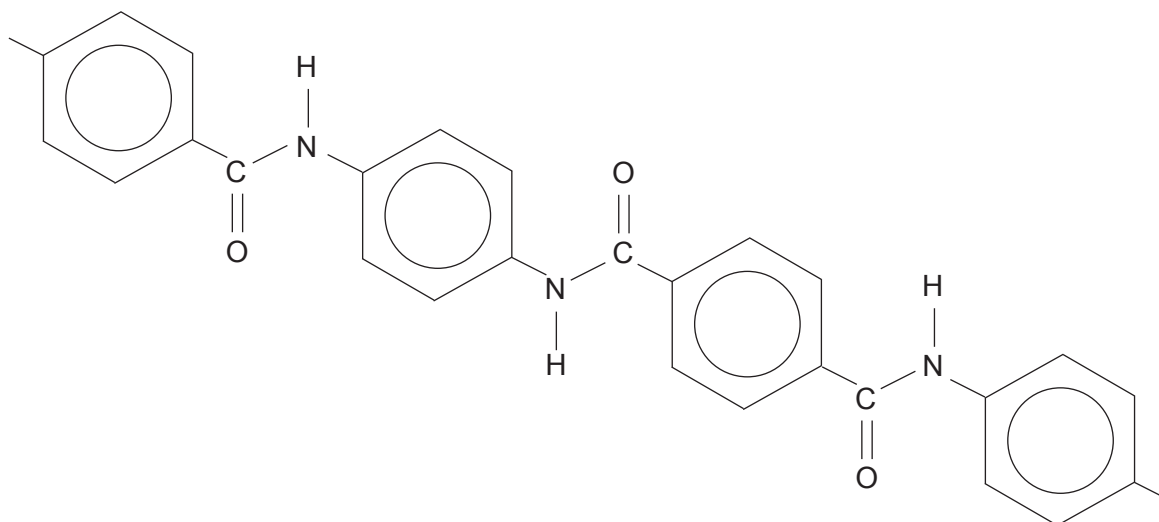
(d)   Draw the **two** monomers from which Kevlar is derived.   (2 marks)
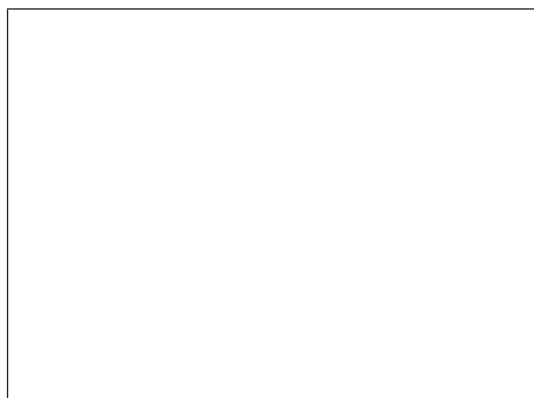
Kevlar's high strength can be attributed in part to the hydrogen bonding that occurs between neighbouring chains. This is similar to a secondary structure of proteins.

(e)   To what secondary structure of proteins does this refer?   (1 mark)

Question 30 **(5 marks)**

The process of chemical synthesis may involve a sequence of reactions.

(a)   Use equations to show how ethyl ethanoate can be produced from ethene through the successive processes of hydrolysis and esterification.   (4 marks)

(b)   Write the overall equation for the process of synthesising ethyl ethanoate from ethene.

(1 mark)

Question 31   **(6 marks)**

(a)   Select **one** basic, **one** acidic and **one** neutral salt from the list below to complete the
        table.   (3 marks)

KCN, NH_4Cl, $Mg_3(PO_4)_2$, $NaNO_3$, $KHCO_3$, $NaCH_3COO$, KCl

Acidic salt	Neutral salt	Basic salt

(b)   Use the Brønsted-Lowry model to explain why the pH of ammonia solution is greater than
        7.0 at 25 °C. Incorporate at least **one** appropriate equation in your answer.   (3 marks)

_____

_____

_____

_____

_____

_____

Question 32 **(6 marks)**

(a) A buffer of carbonic acid (H_2CO_3)/hydrogencarbonate (HCO_3^-) is present in blood plasma to maintain a pH between 7.35 and 7.45. Write an equation to show the relevant species present in a carbonic acid/hydrogencarbonate buffer solution. (2 marks)

(b) Explain why 300.0 mL of 1.00 mol L^{-1} carbonic acid/hydrogencarbonate buffer does **not** change in pH significantly when 3 drops of 1.00 mol L^{-1} HCℓ are added to it, yet when 3 drops of 1.00 mol L^{-1} HCℓ are added to 300.0 mL of distilled water there is a significant change in pH? (4 marks)

Question 33 **(5 marks)**

Citric acid, $C_6H_8O_7$(aq), is a triprotic acid which reacts readily with solid sodium hydroxide, NaOH(s).

(a)   Write a balanced chemical equation for this reaction, showing all state symbols. (2 marks)

The structure of $C_6H_8O_7$ is shown below.
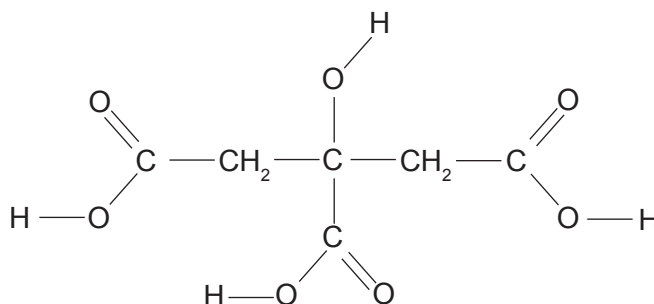
(b)   In the spaces below, complete the structures, showing **each** successive ionisation of the acidic hydrogen atoms. (3 marks)

H⁺ removed	Structure
First	
Second	
Third	

See next page

Question 34 **(6 marks)**

The data below were collected from an acid-base titration.

(a) Label the equivalence point on the titration curve below using an arrow and record the pH value at this point. (2 marks)

Acid-base titration

pH value at equivalence point: _____
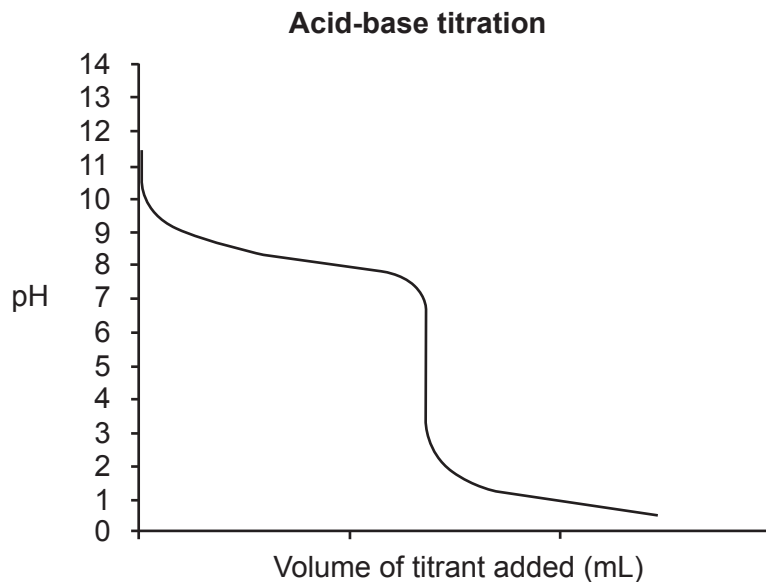
(b) Select an indicator from the table below that would be **best** for this titration and justify your choice. (4 marks)

Indicator	Low pH colour	Transition pH range	High pH colour
Methyl Yellow	red	2.1 – 3.3	yellow
Bromocresol Green	yellow	3.8 – 5.4	blue
Bromothymol Blue	yellow	6.0 – 7.6	blue
Phenolphthalein	colourless	8.3 – 10.0	pink
Alzarine Yellow R	yellow	10.2 – 12.0	red

Indicator: _____

Justification: _____

_____

_____

_____

_____

See next page

Question 35   **(9 marks)**

For each of the three organic compounds identified in the table below:
- use a structural formula to show the arrangement of **all** the atoms and **all** the bonds
- state **all** the intermolecular forces that exist between its molecules.

Organic compound	Full structural formula	All intermolecular forces
hexan-3-one		
1,1-difluoroethane		
butanamide		

Question 36 **(11 marks)**

Condensation reactions will take place between different α-amino acids and results in them being joined by peptide bonds. Structures produced by two α-amino acids are called dipeptides, while those produced by three are called tripeptides.

(a)   Below is the structure of a particular tripeptide.
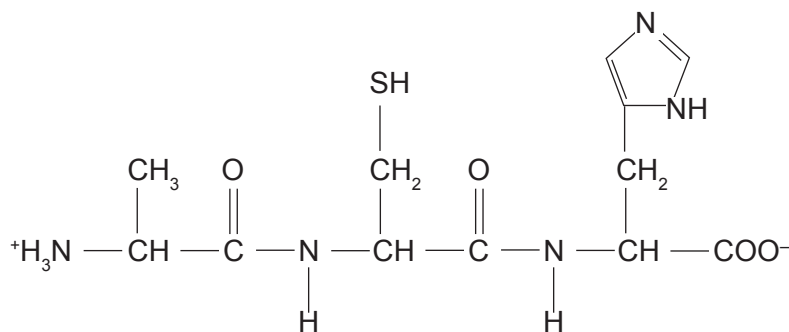
(i)   Circle the peptide bonds on the structure. (2 marks)

(ii)   Name the **three** α-amino acids that reacted to form this tripeptide. (3 marks)

One: _____

Two: _____

Three: _____

(b)   Using the symbols (abbreviations) for these three α-amino acids, give **one** other polypeptide that can be formed from them. (1 mark)

_____

Alanine is one of the simplest examples of the twenty α-amino acids found in the human body. The structure below is an isomer of alanine.

(c)   Circle and name each of the **three** functional groups on the isomer of alanine drawn below.   (3 marks)
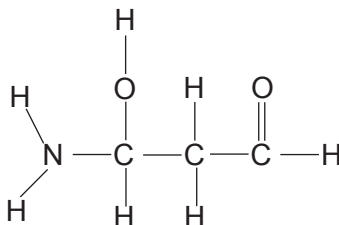
(d)   Draw a different isomer of alanine, showing clearly **all** atoms and **all** bonds.   (2 marks)

Isomer of alanine structure

See next page

Question 37 (5 marks)

Pentane, pentanal and pentanoic acid all contain the same number of carbon atoms but display different physical properties. Their boiling points are given in the table below.

Organic compound	Boiling point (°C)
pentane	36.1
pentanal	102
pentanoic acid	186

Account for the difference in boiling points of the three compounds.

_____

_____

_____

_____

_____

_____

_____

_____

_____

End of Section Two

Section Three: Extended answer **40% (85 Marks)**

This section contains **five (5)** 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.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page

Suggested working time: 70 minutes.

Question 38 **(14 marks)**

A hydrolysis reaction is one that involves water being consumed as a reactant. Hydrolysis reactions can be represented by the following general equation.

$$A—B \ + \ H_2O \ \rightarrow \ A—OH \ + \ H—B$$
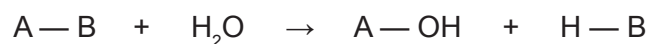
Many processes within the human body involve hydrolysis reactions. These hydrolysis reactions usually require a catalyst; in living organisms that catalyst is an enzyme.

(a) What type of organic compound is an enzyme? (1 mark)

_____

Acetylcholinesterase is an enzyme that is used in the hydrolysis of acetylcholine, a neurotransmitter in the brain.

The structure of acetylcholine is drawn below.

Question 38 (continued)

(b)   Two products are formed when acetylcholine undergoes hydrolysis in the presence of the enzyme acetylcholinesterase; one of these is a charged molecule called choline and the other is a carboxylic acid. Draw structures of these **two** products.   (2 marks)

A catalyst is said to be **active** if it is working to form the desired products. To ensure the acetylcholinesterase is **active** and so catalysing the hydrolysis of acetylcholine, the charged compound found in the reacting vessel is separated and analysed using a combustion reaction to determine its empirical formula.

A 4.270 g sample was combusted in the presence of pure oxygen until no solid remained. 9.020 g of carbon dioxide, 5.169 g of water and 1.886 g of nitrogen dioxide were produced.

(c)   Calculate the empirical formula of the combusted sample.   (9 marks)

See next page

(d)   Use your calculated empirical formula to demonstrate that the enzyme is **active**.

(2 marks)

Question 39 **(16 marks)**

Pentlandite, $Fe_9Ni_9S_8$, is a common nickel sulfide ore that can be used to obtain the materials required to produce sulfuric acid. This metal sulfide ore is combusted in air to form sulfur dioxide according to the following equation.

$$Fe_9Ni_9S_8 \quad + \quad 17\,O_2 \quad \rightarrow \quad 9\,NiO \quad + \quad 9\,FeO \quad + \quad 8\,SO_2$$

(a) What is the volume of sulfur dioxide produced if 2.2 tonne of pentlandite is combusted in air? The process has a yield of 72.0%, and takes place at 300.0 °C and 165.0 kPa. Express your answer to the appropriate number of significant figures.

Molar mass of $Fe_9Ni_9S_8$ = 1287.42 g mol^{-1}. (7 marks)

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This sulfur dioxide is then passed over four beds of a vanadium pentoxide or platinum catalyst at 450 °C to produce sulfur trioxide.

$$2\,SO_2(g) \quad + \quad O_2(g) \quad \rightleftharpoons \quad 2\,SO_3(g) \qquad \qquad \Delta H \quad = \quad -197.78\ kJ$$
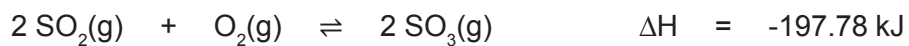
(b)   State **two** justifications for the use of catalysts in this process.   (2 marks)

One: _____

_____

Two: _____

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(c)   State the effect of raising the pressure of the system on both the rate and yield. (2 marks)

Effect on rate: _____

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Effect on yield: _____

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(d)   Use the Collision Theory to explain the effect of raising the total pressure on the yield.
                                                                                    (5 marks)

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Question 40 **(11 marks)**

To be used in wiring, copper must be at least 99.9% pure. To obtain 99.9% pure copper from its most common ore, chalcopyrite ($CuFeS_2$), two processes must take place.

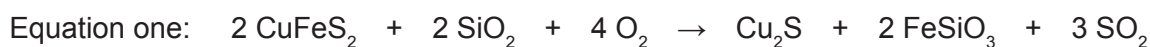(i) The first process occurs in a furnace where the chalcopyrite is converted to 'blister copper', which is approximately 98% pure due to impurities such as sand.

(ii) The second process occurs in an electrolytic cell where the 'blister copper' undergoes electrolysis to produce copper at or above 99.9% purity.

In the furnace, the ore is heated strongly with silica (silicon dioxide), calcium carbonate and air. The furnace reduces the copper(II) in the chalcopyrite first to copper(I) then to copper.

Below are the equations that represent the main processes occurring in the blast furnace.

Equation one: $2\ CuFeS_2\ +\ 2\ SiO_2\ +\ 4\ O_2\ \rightarrow\ Cu_2S\ +\ 2\ FeSiO_3\ +\ 3\ SO_2$

Equation two: $Cu_2S\ +\ O_2\ \rightarrow\ 2\ Cu\ +\ SO_2$

(a) Equation two can be represented as half equations. Write the reduction half equation.

(1 mark)

Reduction: _____

Oxidation: $S^{2-}\ +\ O_2\ \rightarrow\ SO_2\ +\ 2\ e^-$
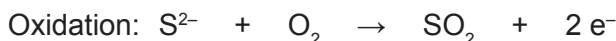
In the electrolytic cell, the copper produced from the blast furnace is purified.

(b) Explain the electrolytic process used to purify copper. Include:
- a brief overview of the process
- a labelled diagram of the electrolytic cell
- the relevant oxidation and reduction half equations
- a discussion of impurities and how they are separated from the copper. (10 marks)

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Question 41 **(18 marks)**

Nitrogen dioxide is toxic to humans when inhaled and is a significant component of air pollution. It can be formed by the combustion of nitrogen in the air at high temperatures; firstly forming nitric oxide NO(g) and on further oxidation, forming nitrogen dioxide, NO_2(g). The overall equation for this process is given here:
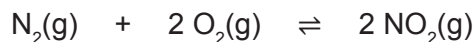
$$N_2(g) \quad + \quad 2\,O_2(g) \quad \rightleftharpoons \quad 2\,NO_2(g)$$

The following questions relate to the equilibrium system represented by this equation.

(a) Write the equilibrium expression for this reaction when it is in equilibrium. (2 marks)

(b) Assuming all other conditions remain constant, what happens to the equilibrium constant after the pressure of the system is lowered and equilibrium is re-established? (1 mark)

(c) (i) On the axes below, draw the forward (——) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. (3 marks)
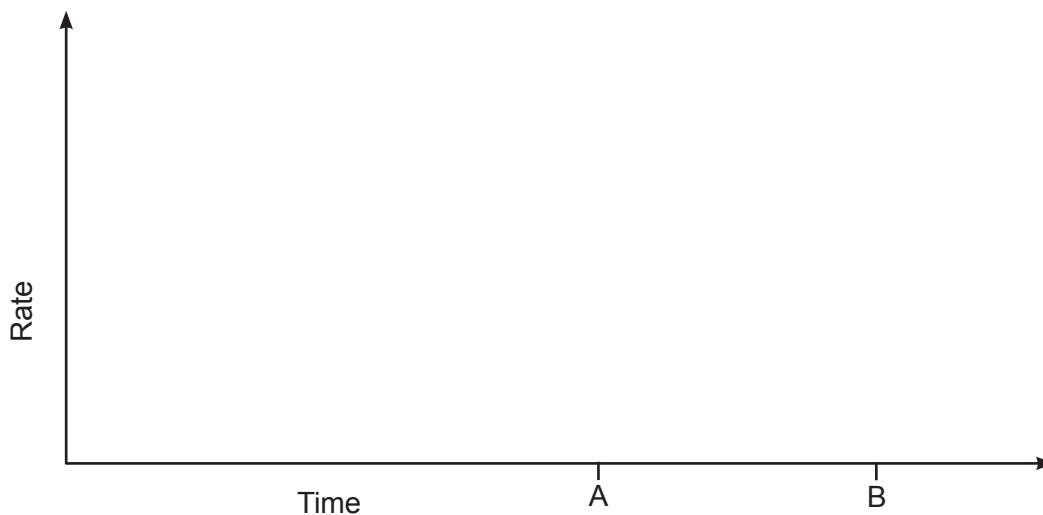
(ii) On the same axes above, draw and label clearly the effect of conducting the same reaction at a higher temperature. (2 marks)

See next page

(d)   On the axes below, draw separate curves to show how the concentrations of the **three** gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical.

Label clearly the line for each gas.   (5 marks)
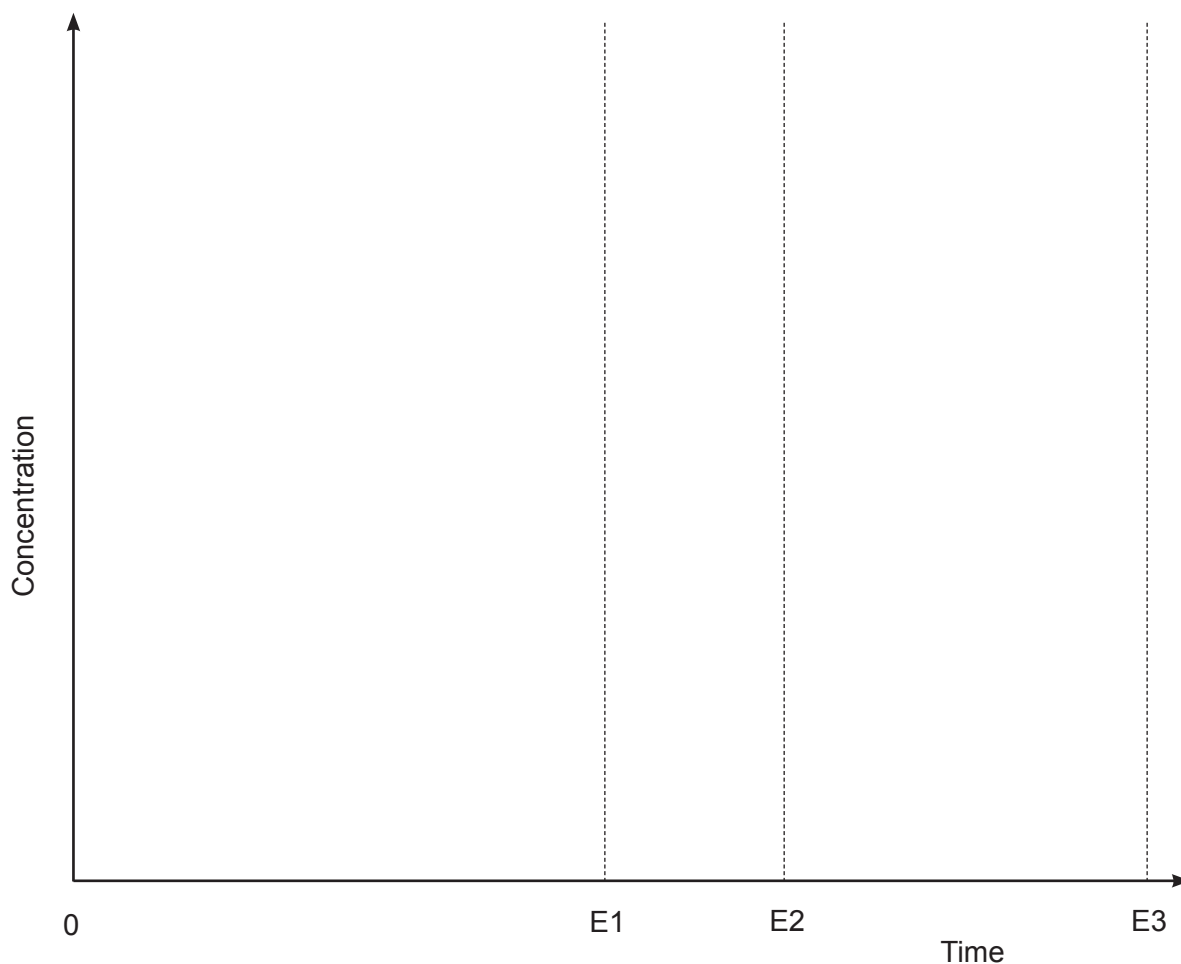
(e)   At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the system is then again allowed to reach equilibrium at Time E3. On the same graph above, show how the concentrations of the three gases would change in response to the change in volume, from Time E2 until equilibrium is re-established at Time E3.   (3 marks)

The reaction between nitrogen gas and oxygen gas occurs at high temperatures such as those found in the combustion engines of cars. The atmosphere is composed of 78% nitrogen and 21% oxygen and has been stable for millions of years.

(f)   What does the stability of this composition indicate about the equilibrium constant and energy requirements of the reaction between nitrogen and oxygen gases?   (2 marks)

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See next page

Question 42 **(26 marks)**

Acid rain is a significant issue in many industrialised areas of the world; particularly around power stations using fossil fuels. Legislation has been developed in Australia to minimise the formation of sulfur dioxide, $SO_2(g)$, such as from the use of low-sulfur fuels in automobiles, which can cause acid rain. Normal rain has a pH of about 5.6; it is slightly acidic because carbon dioxide, $CO_2(g)$ dissolves into it, forming weak carbonic acid. Rain with a pH less than 4.4 is usually classified as acid rain.

Testing was carried out on a rainwater sample taken near a coal-fired power station by titration, using sodium hydroxide solution, $NaOH(aq)$. Standardisation of the sodium hydroxide solution was carried out before it was used in the titration. An anhydrous sodium carbonate, $Na_2CO_3(s)$, primary standard was used to standardise a hydrochloric acid solution, $HC\ell(aq)$ and subsequently used to standardise the $NaOH(aq)$ solution.

Sodium carbonate, $Na_2CO_3(s)$ was heated at 110 °C in a drying oven for 1 hour before 6.08×10^{-4} g was dissolved in distilled water to make 2.00 L of the primary standard. Three 25.0 mL aliquots of $HC\ell(aq)$ were titrated and an average titre of 16.4 mL was required for neutralisation.

(a) Demonstrate, by means of calculation, that the concentration of $HC\ell(aq)$ solution is 3.76×10^{-6} mol L^{-1}. (5 marks)

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(b) Outline **two** reasons why sodium hydroxide, $NaOH(s)$ is **not** a suitable primary standard for this titration. (2 marks)

One: _____

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Two: _____

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See next page

An average titre of 21.3 mL of the standardised (3.76×10^{-6} mol L^{-1}) HCl(aq) solution was required to neutralise 25.0 mL aliquots of NaOH(aq) solution.

(c)   Calculate the concentration of the NaOH(aq) solution.   (3 marks)

The standardised NaOH(aq) solution was then used for the titration of a rainwater sample. A 100.0 mL sample of rain water was collected near a coal-fired power station and diluted to 250.0 mL with distilled water in a volumetric flask. 25.0 mL aliquots of the diluted rainwater were used in the titration.

(d)   Complete the table below to state with what the following pieces of glassware should be rinsed for this titration.   (3 marks)

Glassware	Final rinse
Burette	
Conical flask	
Pipette	

The titre values obtained for the rainwater sample are shown in the table below:

Titre volume of NaOH (mL)				Average titre volume (mL)
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	

(e)   Calculate the average titre volume and record it in the table above.   (1 mark)

See next page

Question 42 (continued)

(f)   Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not. (6 marks)

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(g)   If carbon dioxide, $CO_2(g)$ alone accounts for rain with a pH of 5.60, then calculate the volume of sulfur dioxide, $SO_2(g)$ at 16.0 °C and 97.2 kPa, that would also need to be dissolved to produce 0.100 L of an acid rain sample with a pH of 4.0. Use the equation below.

$$SO_2(g) \quad + \quad H_2O(\ell) \quad \rightleftharpoons \quad H_2SO_3(aq)$$

For this calculation, assume the complete ionisation of $H_2SO_3(aq)$. (6 marks)

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