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

ATAR course examination, 2019

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: 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.

Ref: 19-011

CHE

2020/1723
Web version of 2019/54771

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	10	10	60	106	35
Section Three Extended answer	6	6	70	109	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 2019*. 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. Boric acid, which is a weak acid, was titrated with standardised sodium hydroxide solution.

   Which one of the indicators listed below would be the **most** suitable to use in this titration?

	Indicator	Range of colour change (pH)
(a)	thymol blue	1 – 3
(b)	bromocresol green	3.8 – 5.4
(c)	cresolphthalein	8 – 10
(d)	alizarin yellow	10 – 12

2. The Haber Process involves the following equilibrium reaction:

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

   A number of closed reaction vessels were set up containing the gases shown in the table below.

Reaction vessel	Gases initially present
i	nitrogen, hydrogen
ii	nitrogen
iii	ammonia
iv	hydrogen, ammonia

   In which of the above closed reaction vessels would equilibrium be established after a period of time?

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

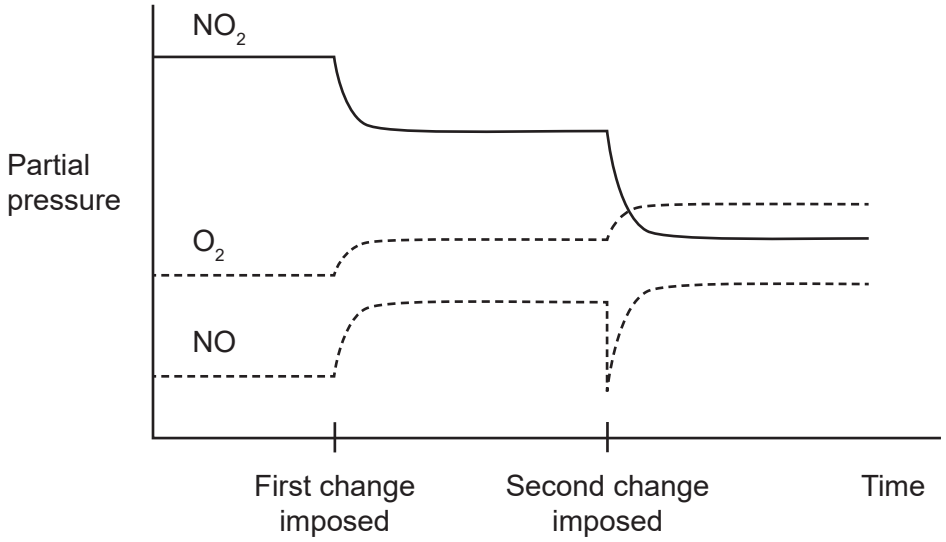
See next page

Questions 3 and 4 refer to the following information.

Nitrogen dioxide, $NO_2(g)$, is formed when nitrogen monoxide, NO(g), undergoes oxidation as shown below.

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g) \qquad \Delta H = -62\ kJ\ mol^{-1}$$

A change was imposed on an equilibrium gas mixture of NO_2, NO and O_2. The mixture returned to equilibrium and another change was imposed. The following graph shows the effects of the two changes.



3. Identify the imposed changes that **best** account for the shape of the graph.

	First change	Second change
(a)	the temperature is decreased	the partial pressure of O_2 is increased
(b)	the temperature is decreased	the partial pressure of NO is decreased
(c)	the temperature is increased	the partial pressure of O_2 is increased
(d)	the temperature is increased	the partial pressure of NO is decreased

4. What do the initial partial pressures of the three gases indicate?

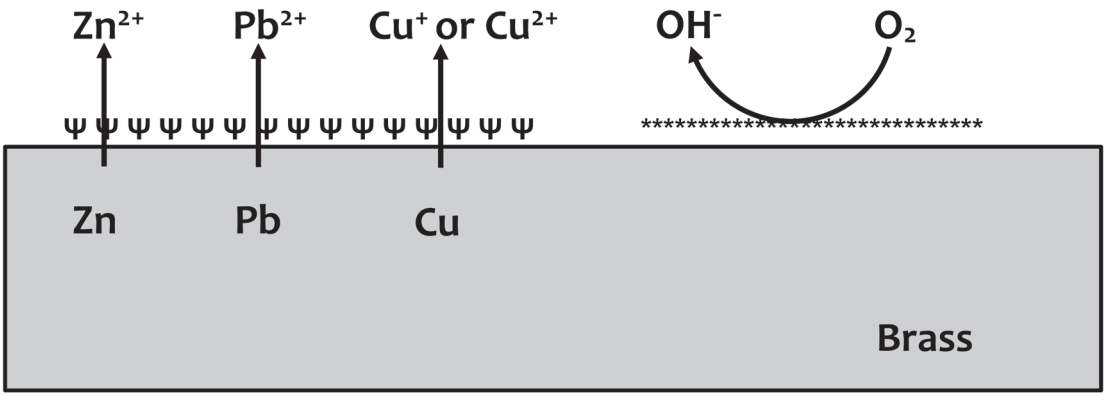
(a) The relative proportions of the gases present at equilibrium.
(b) That there is initially no NO gas present in the system.
(c) That the NO_2 gas reaches equilibrium first.
(d) That the O_2 and NO gases are producing NO_2 at a faster rate than they are being formed.

See next page

Questions 5, 6 and 7 refer to the following information.

The corrosion of brass plumbing fixtures has been identified as a possible cause of the presence of lead in drinking water. Brass is an alloy of copper and zinc but can also contain lead to improve machinability.

The corrosion of brass is a redox process, with an electrochemical cell forming on the surface of the brass as illustrated below.



5. Which one of the following correctly identifies the anodic region, cathodic region and direction of electron flow?

	Anodic region	Cathodic region	Direction of electron flow
(a)	Ψ	*	Ψ → *
(b)	*	Ψ	Ψ → *
(c)	Ψ	*	* → Ψ
(d)	*	Ψ	* → Ψ

6. The overall equation for the reaction of lead with oxygen is as follows:

$$2\ Pb(s) + O_2(g) + 2\ H_2O(\ell) \rightarrow 2\ Pb(OH)_2(s)$$

What is the theoretical E^0 value for the overall Pb/O_2 reaction under standard conditions?

(a) − 0.27 V
(b) + 0.27 V
(c) + 0.53 V
(d) + 0.93 V

7. The composition of brass can be adjusted by adding various metals. Which one of the following metals would **not** undergo corrosion if added to brass?

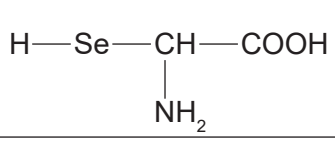
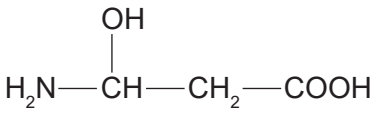
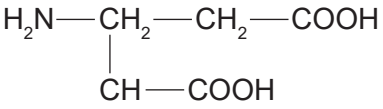
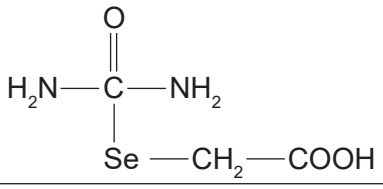
(a) silver
(b) nickel
(c) iron
(d) strontium

See next page

8. A distinguishing feature of strong acids is that they

(a) produce high concentrations of hydronium ions (H_3O^+) in solution.
(b) have high acidity constants.
(c) contain loosely-held hydrogen ions (H^+) in solution.
(d) ionise rather than dissociate in water.

9. Which one of the following is an alpha amino acid?

(a) 	(b) 
(c) 	(d) 

10. Which statement is correct?

(a) Fluorine can be oxidised by potassium bromide solution but not by potassium iodide solution.
(b) Chlorine can be oxidised by potassium fluoride solution but not by potassium iodide solution.
(c) Chlorine can be reduced by potassium bromide solution but not by potassium iodide solution.
(d) Bromine can be reduced by potassium iodide solution but not by potassium chloride solution.

11. Which one of the following statements about catalysis in the production of biodiesel is correct?

(a) Base catalysis generally has a higher reaction rate but, unlike lipase catalysis, can cause saponification, which decreases the biodiesel yield.
(b) The sodium hydroxide and potassium hydroxide used in base catalysis are readily available and relatively cheap, but lipase catalysis produces more toxic waste water.
(c) Base catalysis involves only one step, while lipase catalysis involves many steps in its synthesis sequence, which in turn adds to the cost of the process.
(d) Base catalysis typically has a lower rate and yield of biodiesel but lipase catalysis is sensitive to alcohols, such as methanol, and has higher energy costs.

See next page

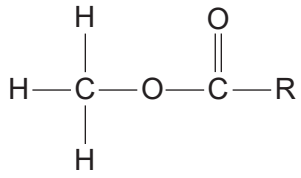
12. The United Nations Kyoto Protocol and the Intergovernmental Panel on Climate Change aim to secure a global commitment to reducing greenhouse gas emissions over the next few decades.

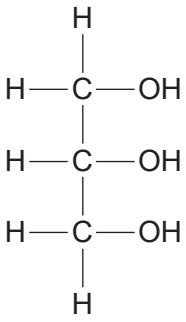
Which of the following equations shows the production of a greenhouse gas?

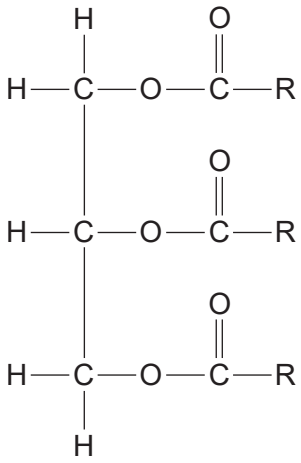
(i) $O_2 + O \rightarrow O_3$
(ii) $C + O_2 \rightarrow CO_2$
(iii) $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$
(iv) $CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O$
(v) $NH_4NO_3 \rightarrow 2\,H_2O + N_2O$

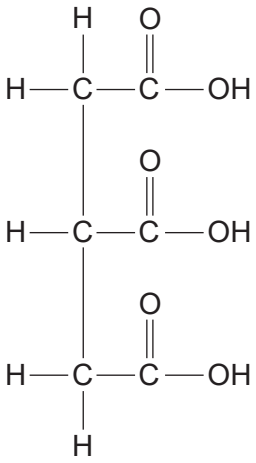
(a) i and ii only
(b) ii and iii only
(c) iii, iv and v only
(d) i, ii, iii, iv and v

13. One method of producing biodiesel is by a transesterification reaction where triglycerides are converted into simpler methyl esters (the biodiesel) of the fatty acids. Which one of the following is a reactant of this transesterification reaction?

(a)


(b)


(c)


(d)


See next page

14. Which one of the following properties exhibited by octanol is **not** related to the dispersion forces between the molecules?

(a) combustibility
(b) melting point
(c) solubility in octane
(d) solubility in water

15. Which one of the following compounds will **not** exhibit geometric (cis-trans) isomerism?

(a) 1,2-difluoro-1-butene
(b) 1,1-difluoro-1-butene
(c) 1,2-difluoro-2-butene
(d) 1,4-difluoro-2-butene

16. Which one of the following statements about an aqueous solution with a pH less than zero at 25.0 °C is true?

(a) Such a solution cannot exist at 25.0 °C.
(b) There are no $OH^-(aq)$ ions present.
(c) The concentration of $H^+(aq)$ ions is much greater than the concentration of $OH^-(aq)$ ions.
(d) There are no $H^+(aq)$ ions present as they have formed water molecules through the process of neutralisation.

17. In which of the following sets do all the **bolded** and underlined atoms have the same oxidation number?

(i) $H_2\mathbf{O}$, $\mathbf{O}_2$, $H_2\mathbf{O}_2$
(ii) $H_2\mathbf{O}_2$, Na**Cℓ**, $Mg\mathbf{H}_2$
(iii) **Na**Cl, $\mathbf{Li}_2CO_3$, **K**OH
(iv) **Fe**O, $\mathbf{Fe}_2O_3$, **Fe**

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

18. Which one of the following could **not** be a product when propan-1-ol is oxidised?

(a) CO_2
(b) CH_3CH_2CHO
(c) CH_3CH_2COOH
(d) CH_3COCH_3

See next page

The following information relates to Questions 19, 20 and 21.

A group of Year 12 Chemistry students wanted to know whether increasing ocean acidity increases the rate at which sea shells, $CaCO_3$, dissolve. They went to a beach to collect seawater and sea shells. In their school laboratory they crushed the sea shells and added 2.00 g of the resulting powder to five clean 250 mL beakers, each of which had been placed on top of its own electronic balance.

They split the seawater into five portions and bubbled carbon dioxide gas into four of the portions for different amounts of time. This gave the students 'natural' seawater plus four seawater samples of different pH. The various seawaters (150 mL portions) were then added to the beakers, with the weight of each beaker and its contents being recorded at timed intervals.

19. Which one of the following proposes a suitable hypothesis for the investigation?

(a) As the seawater becomes more acidic, the sea shell powder will dissolve faster.
(b) The sea shell powder will dissolve fastest in the most acidic seawater.
(c) Adding carbon dioxide to seawater changes the pH of the seawater.
(d) More of the sea shell powder will dissolve as time progresses.

20. Which one of the following pairs of statements on the validity and reliability of the investigation is correct?

	Validity	Reliability
(a)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	It is reliable because the trials were performed in a laboratory.
(b)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is not reliable because only one trial was performed at each different pH value.
(c)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is reliable because trials were performed at five different pH values.
(d)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	Its reliability could be improved by conducting multiple trials at each different pH value.

21. Which of the following reactions is/are likely to be occurring within the beakers during the investigation?

(i) $CaCO_3(s) + 2\,H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3\,H_2O(aq)$
(ii) $CaCO_3(s) + CO_2(aq) + H_2O(\ell) \rightleftharpoons Ca^{2+}(aq) + 2\,HCO_3^-(aq)$
(iii) $Ca(OH)_2(s) + 2\,H_3O^+(aq) \rightleftharpoons Ca^{2+}(aq) + 4\,H_2O(g)$
(iv) $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$

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

See next page

22. Between which of the following pairs of substances can dispersion forces exist?

(i) $CH_3C\ell$ and H_2O
(ii) CH_3CH_2CHO and HBr
(iii) $CH_3CH_2CH_2CH_3$ and $CH_3CH_2CH_2CH_2CH_2CH_3$
(iv) $CH_3CH_2CH_2OH$ and NH_3

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

23. Which one of the following is an isomer of pentanoic acid?

(a) $CH_3CHCH\text{-}O\text{-}CH_2CHO$
(b) $CH_2CHCH_2\text{-}O\text{-}CH_2CH_2OH$
(c) $OHCCH_2CH_2CH_2CHO$
(d) $CH_3CHCHCH_2COOH$

24. Which one of the following underlined species is acting as an acid?

(a) $\underline{CH_3CH_2CH_2CH_2NH_2} + CH_3COOH \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+ + CH_3COO^-$
(b) $HSO_3^- + NH_3 \rightleftharpoons \underline{SO_3}^{2-} + NH_4^+$
(c) $NH_4^+ + CH_3COO^- \rightleftharpoons \underline{NH_3} + CH_3COOH$
(d) $\underline{[Fe(H_2O)_6]}^{3+} + H_2O \rightleftharpoons [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$

25. How many isomers does the compound $C_2H_3Br_3$ have?

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

End of Section One

See next page

Section Two: Short answer **35% (106 Marks)**

This section has **10** 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 **(9 marks)**

Dilute hydrochloric acid, HCℓ(aq), is added to three labelled test tubes.

(I) Excess copper metal, Cu(s), is added to the first test tube.
(II) Excess copper(II) oxide, CuO(s), is added to the second test tube.
(III) Excess copper(II) carbonate, $CuCO_3$(s), is added to the third test tube.

(a) Describe the contents of the first and second test tubes once **any** reactions are complete. (4 marks)

Test Tube	Description
(I)	
(II)	

(b) Write the balanced equation, with appropriate state symbols, for the reaction that takes place between the copper(II) oxide and the hydrochloric acid. (3 marks)

(c) If the labels of test tubes (II) and (III) became smudged, describe **all** the observations that could be used to distinguish between these test tubes once **any** reactions are complete. (2 marks)

Question 27 **(13 marks)**

Calcium hypochlorite, $Ca(OC\ell)_2(s)$, is used for the treatment of water in swimming pools and is sold as 'pool chlorine'.

(a) Explain why a basic solution is produced when 'pool chlorine' is dissolved in the pool water. Include an equation in your answer. (4 marks)

Equation

A pool chemical used to counteract the basicity of the pool water is hydrochloric acid, $HC\ell(aq)$. It is sold as 'pool acid'.

(b) State what happens to the pH of the pool water when 'pool acid' is added to the pool water. Include an equation to illustrate your statement. (3 marks)

Equation

See next page

'Pool chlorine' and 'pool acid' must be stored separately from each other because calcium hypochlorite can react explosively on contact with hydrochloric acid. The equation for this reaction is given below.

$$Ca(OC\ell)_2(s) + 4\ HC\ell(aq) \rightarrow CaC\ell_2(aq) + 2\ H_2O(\ell) + 2\ C\ell_2(g)$$

(c) Sketch a clearly-labelled energy profile diagram illustrating the reaction between the 'pool chlorine' and the 'pool acid'. (6 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 clearly that you have redrawn it on the spare page.

See next page

Question 28 **(7 marks)**

As noted in Question 27, calcium hypochlorite and hydrochloric acid react according to the equation shown below.

$$Ca(OC\ell)_2(s) + 4\ HC\ell(aq) \rightarrow CaC\ell_2(aq) + 2\ H_2O(\ell) + 2\ C\ell_2(g)$$

In this reaction, the chlorine in calcium hypochlorite and the chloride from the hydrochloric acid are both converted to chlorine gas.

(a) What is the oxidation number for the chlorine in:
- calcium hypochlorite, $Ca(OC\ell)_2$
- hydrochloric acid, $HC\ell$? (2 marks)

calcium hypochlorite ☐ hydrochloric acid ☐

Chlorine gas is produced by the oxidation of one of these substances and the reduction of the other.

(b) Write the **two** half-equations showing how chlorine gas is produced from both substances. (5 marks)

Oxidation half-equation

Reduction half-equation

See next page

Question 29 **(8 marks)**

Sulfuric acid is a very useful chemical that is produced industrially by a multi-stepped process. These steps are summarised by the following equations.

Equation 1	$S(\ell)$	+	$O_2(g)$	→	$SO_2(g)$		
Equation 2	$2\ SO_2(g)$	+	$O_2(g)$	⇌	$2\ SO_3(g)$	+	198 kJ
Equation 3	$H_2SO_4(\ell)$	+	$SO_3(g)$	→	$H_2S_2O_7(\ell)$		
Equation 4	$H_2O(\ell)$	+	$H_2S_2O_7(\ell)$	→	$2\ H_2SO_4(\ell)$		

When dihydrogen sulfate, $H_2SO_4(\ell)$, is mixed with water, it produces sulfuric acid, $H_2SO_4(aq)$.

(a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $H_2SO_4(\ell)$, from sulfur dioxide, $SO_2(g)$. (2 marks)

(b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

	Advantage/s	**Disadvantage/s**
High temperature		
High pressure		

See next page

Question 30 **(15 marks)**

Salvarsan is an organic compound that contains the elements: carbon (C), hydrogen (H), arsenic (As), chlorine (Cℓ), nitrogen (N) and oxygen (O). It was one of the first drugs used in chemotherapy and for treating sleeping sickness.

The empirical formula of this compound can be determined in a series of analyses. One process involves the reaction of a known mass of Salvarsan with excess strong acid to convert all the chlorine into aqueous chloride ions.

(a) Describe the laboratory process involved in determining the mass of chlorine in this sample of Salvarsan once it has been treated with the acid. You should reference any chemicals used and include a balanced equation in your answer. (6 marks)

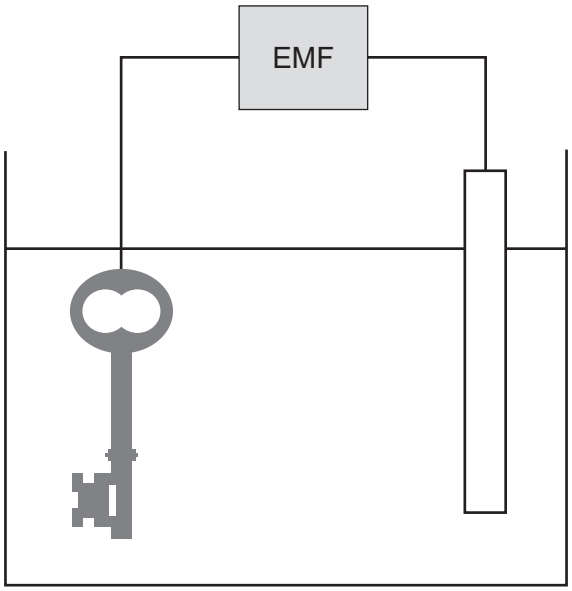
The results of these analyses using 5.22 g samples determined that it contained:

- 32.83% carbon by mass
- 3.21% hydrogen by mass
- 1.78 g of arsenic
- 16.18% of chlorine by mass
- 6.38% of nitrogen by mass.

(b) Use this information to calculate the empirical formula of Salvarsan. Show **all** workings.
(9 marks)

Question 31 **(13 marks)**

A solution that contains silver cyanide, AgCN(aq), is used to plate a key with silver.



(a) Label the above diagram to show the:
- cathode and anode
- direction of electron flow
- direction of ion flow
- polarity (positive/negative) of each electrode. (4 marks)

A salt bridge is required in galvanic cells but is **not** required in the electroplating cell above.

(b) Explain this difference between these two cells. (3 marks)

Use excerpts from the Material Safety Data Sheet for silver cyanide shown below to answer part (c) and part (d).

(c) Explain why action is taken to maintain the pH above 8 as a safety precaution during the electroplating process using silver cyanide. (3 marks)

Question 31 (continued)

(d) Suggest **three** other safety measures that should be taken during the electroplating process and indicate how each addresses a specific potential hazard to either the workers or the environment. (3 marks)

One: _____

_____

_____

Two: _____

_____

_____

Three: _____

_____

_____

See next page

Question 32 **(9 marks)**

From a measuring cylinder, 34.0 mL of 0.114 mol L^{-1} nitric acid, $HNO_3(aq)$, is added to a flask containing 44.5 mL of 0.0556 mol L^{-1} solution of calcium hydroxide, $Ca(OH)_2(aq)$. Determine the pH of the final solution.

See next page

Question 33 **(12 marks)**

Organic molecules have a hydrocarbon skeleton and can contain functional groups that are responsible for the molecules' characteristic chemical properties.

Complete the following tables by

(i) writing the structural formula of each compound listed
(ii) writing the structural formula of the organic product from the reaction
(iii) naming the organic product from the reaction.

When writing the structural formula, show the bonds between carbon atoms and within any functional group e.g. $CH_3—CH_2—\overset{\overset{O}{\|}}{C}—CH_3$

<table>
<tr><th colspan="2">Name of compound</th><th>Structural formula of compound</th></tr>
<tr><td colspan="2">pent-2-ene</td><td></td></tr>
<tr><td rowspan="2">Reacts with $Br_2(aq)$</td><td>Structural formula of organic product</td><td></td></tr>
<tr><td>Name of organic product</td><td></td></tr>
</table>

See next page

Name of compound		Structural formula of compound
ethanal		
Reacts with $KMnO_4(aq) / H^+(aq)$	**Structural formula of organic product**	
	Name of organic product	

Name of compound		Structural formula of compound
butanoic acid		
Reacts with $Na_2CO_3(aq)$	**Structural formula of organic product**	
	Name of organic product	

See next page

Question 34 **(12 marks)**

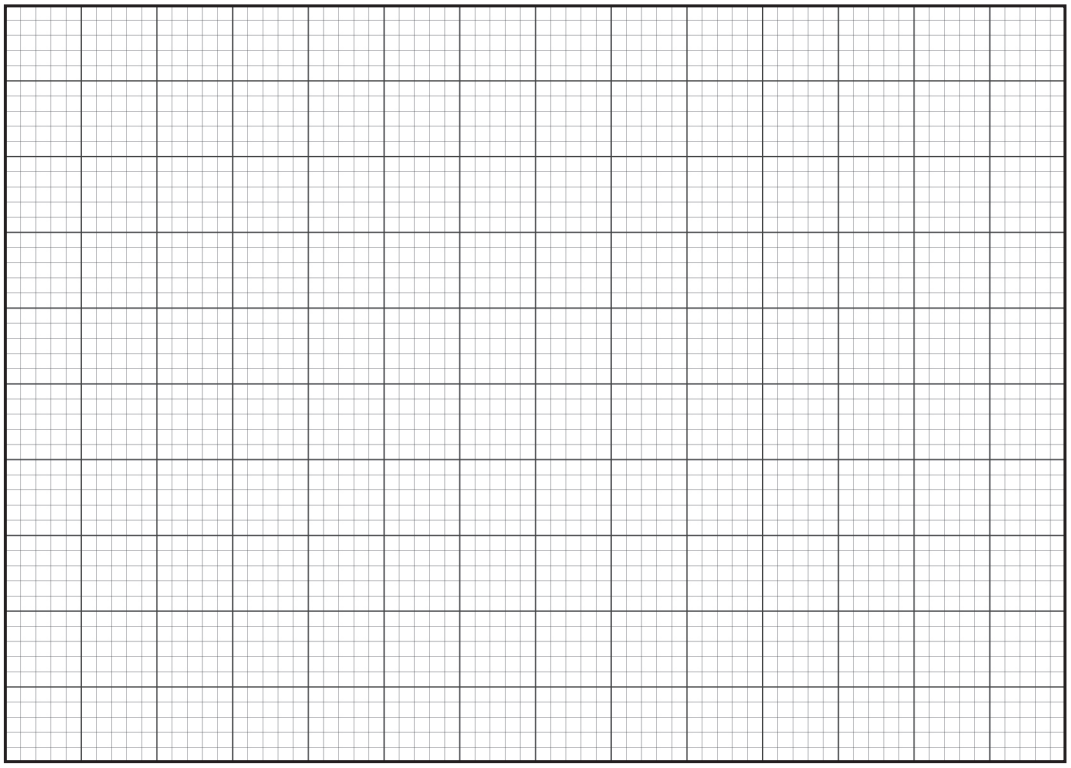
Consider the reaction between magnesium carbonate, $MgCO_3(s)$, and dilute nitric acid, $HNO_3(aq)$.

$$MgCO_3(s) + 2\,H^+(aq) \rightarrow Mg^{2+}(aq) + CO_2(g) + H_2O(\ell)$$

The following data was obtained from the addition of excess 0.500 mol L^{-1} nitric acid to 5.00 g of magnesium carbonate.

Time (min)	0	1.0	2.0	3.0	4.0	5.0	6.0
Volume of gas produced (mL)	0	12	18	25	32	33	33

(a) Draw a labelled graph of the data provided in the grid below. (4 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 clearly that you have redrawn it on the spare page.

See next page

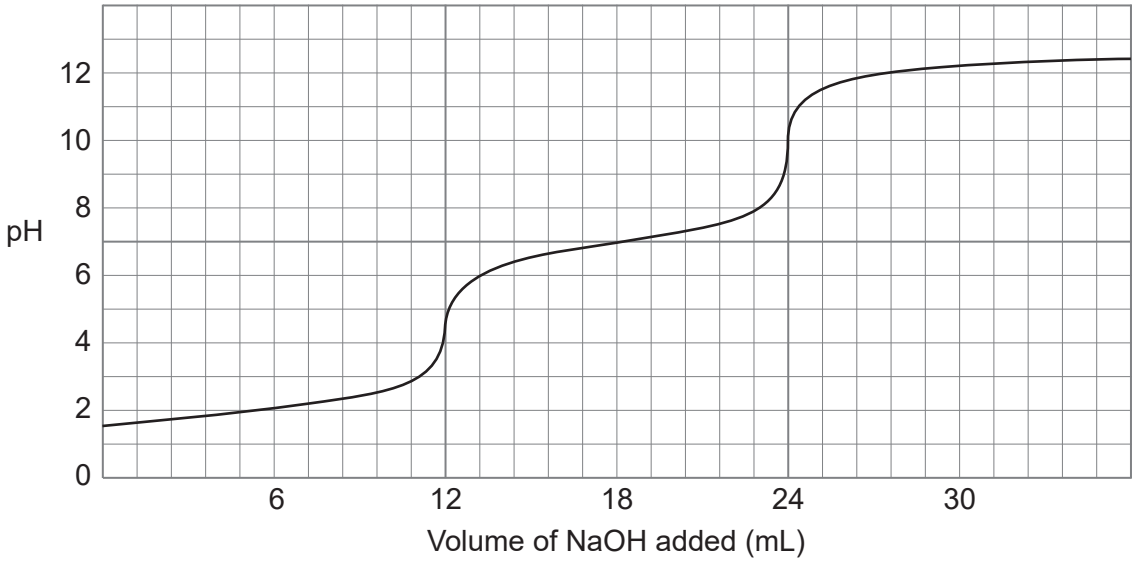
(b) Explain the shape of your graph in part (a) by referring to Collision Theory. (6 marks)

(c) Sketch and label a line on your graph in part (a) that shows the effect of conducting the same experiment at a higher temperature. (2 marks)

See next page

Question 35 **(8 marks)**

Consider the following acid-base titration curve that is produced by the addition of 0.166 mol L^{-1} sodium hydroxide solution to 20.00 mL of an approximately 0.1 mol L^{-1} diprotic acid.



(a) (i) Indicate whether the diprotic acid is most likely to be sulfuric acid, $H_2SO_4(aq)$ or sulfurous acid, $H_2SO_3(aq)$, by **circling** your choice below. (1 mark)

Sulfuric acid Sulfurous acid

(ii) Making reference to the titration curve shown above, give **two** reasons for your answer. (2 marks)

One: _____

_____

_____

Two: _____

_____

_____

See next page

(b) Predict the effect (increase, decrease or no change) on the calculated concentration of the acid for the following two systematic errors that can occur in a titration and justify your choice. (4 marks)

Systematic Error		Effect on calculated concentration of acid (circle)	Justification
I	Only rinsing the pipette with distilled water before use	increase decrease no change	
II	Using an indicator with an end point of pH = 4.5	increase decrease no change	

(c) State **one** reason why these errors are classified as systematic errors rather than random errors. (1 mark)

_____

_____

End of Section Two

See next page

Section Three: Extended answer **40% (109 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 36 **(20 marks)**

The ideal pH of human blood is 7.4. If the pH of a person's blood varies too much from this value, a serious condition can develop. If the pH is too low, it is called acidosis; if the pH is too high, it is called alkalosis. Death may occur if the pH drops below 6.8 or rises above 7.8.

One buffer system for maintaining acid-base balance in blood is the carbonic acid-hydrogencarbonate buffer.

During exercise, the muscles need more oxygen to produce energy. They produce carbon dioxide, CO_2, and hydronium ions, H_3O^+, which move from the muscles to the blood.

The relevant equilibrium equations for the carbonic acid-hydrogencarbonate buffer system are shown as follows.

Equation 1 $H_3O^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(\ell)$

(a) Identify the **two** conjugate acid-base pairs on Equation 1 above, indicating clearly which is the acid and which is the base in each pairing. (2 marks)

See next page

(b) Write the equilibrium constant expression for Equation 1. (2 marks)

Carbonic acid further reacts to form water and carbon dioxide as shown in Equation 2.

Equation 2 $H_2CO_3(aq) \rightleftharpoons H_2O(\ell) + CO_2(aq)$

(c) Combine Equations 1 and 2, to create an overall equation that shows the relationship between $HCO_3^-(aq)$ and $CO_2(aq)$. (2 marks)

(d) Identify the effect on the blood's pH when each of the following components are removed: carbon dioxide and hydrogencarbonate ions. (2 marks)

Component removed	**Effect on pH** (circle your answer)		
carbon dioxide	increase	decrease	no effect
hydrogencarbonate ions	increase	decrease	no effect

Question 36 (continued)

The buffering capacity of the carbonic acid-hydrogencarbonate is greatest when the pH is between 5.1 and 7.1.

(e) State **two** conditions in terms of concentration that are necessary for this buffering capacity to be optimal. (2 marks)

One: _____

_____

_____

Two: _____

_____

_____

When the pH of the blood is too high, the kidneys can remove hydrogencarbonate ions, HCO_3^-, from the blood.

(f) Use Le Châtelier's Principle to demonstrate that the kidneys' action can help to prevent excessively high blood pH. (3 marks)

_____

_____

_____

_____

_____

_____

See next page

When inhaling, oxygen is taken into the lungs and transferred to the blood; when exhaling, carbon dioxide is expelled.

During hyperventilation (very rapid and deep breathing) more carbon dioxide is being expelled from the body than it can produce. This upsets the oxygen/carbon dioxide balance and can cause dizziness and fainting. Hyperventilating results in lowering the carbon dioxide concentration in the blood, which can affect the pH of the blood.

The equation shown below illustrates the formation of hydronium ions within the blood system.

$$2\ H_2O(\ell) \ + \ CO_2(aq) \ \rightleftharpoons \ H_3O^+(aq) \ + \ HCO_3^-(aq)$$

A first-aid treatment for hyperventilation is the 'paper-bag treatment' whereby the patient breathes into a paper bag and so breathes back in the expelled breath, which contains a higher concentration of carbon dioxide.

(g) State the effect of the 'paper-bag treatment' on the pH of the blood and explain why it is an effective treatment for hyperventilation. (3 marks)

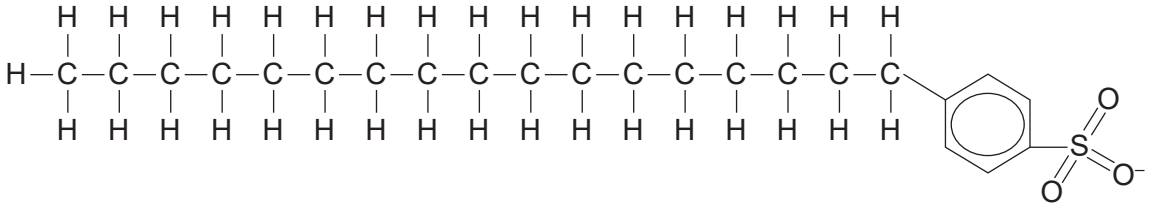
Another contributor to a potential imbalance of blood pH is the formation of lactic acid. The chemical name for lactic acid is 2-hydroxypropanoic acid, $C_3H_6O_3$.

(h) Draw the structural formula for lactic acid with **all** its functional groups circled and labelled. (4 marks)

See next page

Question 37 **(24 marks)**

Detergents and soaps are both used as cleaning agents. The general structure of a detergent is given below.



(a) Explain how detergents are able to remove grease from a surface by referring to the intermolecular forces present. Include a labelled diagram to illustrate your answer.

(7 marks)

See next page

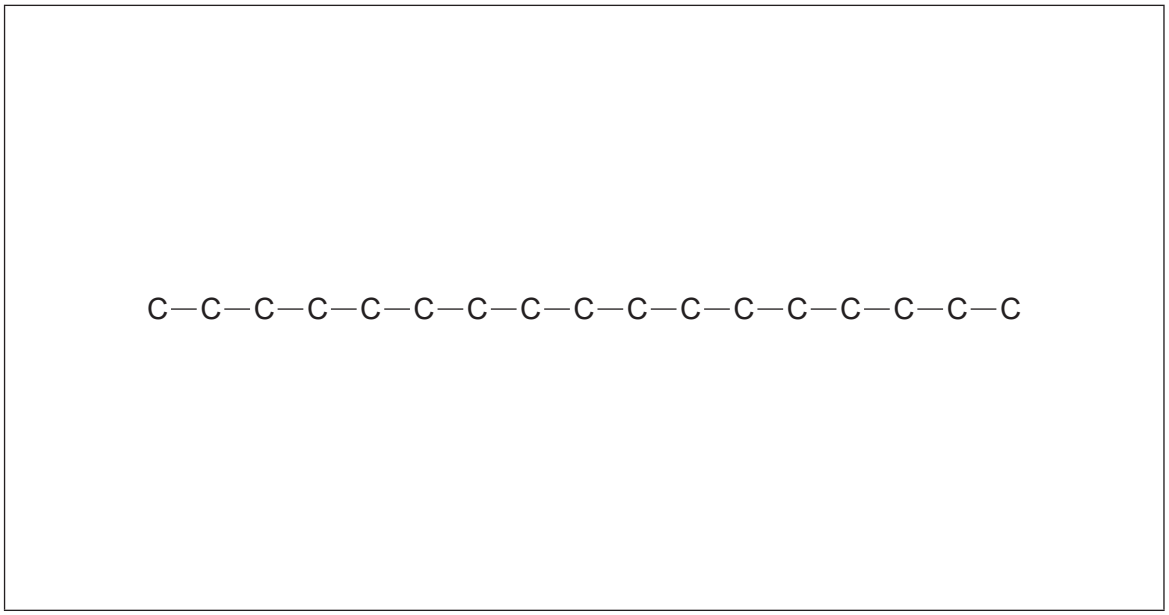
Detergents are considered to be more versatile cleaners than soap.

(b) Explain why soaps are generally less effective than detergents as cleaning agents in hard water. Include a relevant equation in your answer. (4 marks)

Question 37 (continued)

Alkenes can also form soaps.

(c) Draw a structural diagram for the soap ion, $C_{17}H_{31}CO_2^-$ using the incomplete structure below. Show **all** atoms and bonds. (2 marks)



(d) Write an equation showing the formation of this soap from the fat (triglyceride) shown below. (3 marks)

See next page

The formation of soap is both an endothermic and equilibrium reaction.

(e) Predict and explain the conditions that would result in the highest yield of soap in the shortest amount of time. (8 marks)

See next page

Question 38 **(18 marks)**

Polymethyl methacrylate and polycarbonate are two polymers that are used as alternatives to glass. Polymethyl methacrylate is more commonly known as Perspex or plexiglass and is an addition polymer, while polycarbonate is a type of condensation polymer.

Both polymers are transparent to visible light and have other properties as listed below.

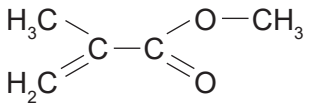
Polymethyl methacrylate	Polycarbonate
lightweight	moderate chemical resistance
moderate UV resistance	high heat resistance
low impact strength	high impact strength
low chemical resistance	low scratch resistance
low heat resistance	low UV resistance

(a) For the following uses as an alternative to glass, identify which polymer would be the more appropriate. Justify your choice of polymer by comparing the effect of **two** relevant properties as listed for both polymers. (4 marks)

Use	Choice of polymer	Justification
Skylight		
Safety glasses		

See next page

The monomer, methyl methacrylate, can be formed from the esterification of methanol and methacrylic acid (2-methylprop-2-enoic acid). The structural formula of methyl methacrylate is shown below.



(b) Write a balanced equation for the esterification of methanol and methacrylic acid. Show the full structural formula of each species in the equation. (4 marks)

Methyl methacrylate can undergo addition polymerisation to form polymethyl methacrylate.

(c) Draw a section of a polymethyl methacrylate showing **all** atoms and at least **three** repeating units of the monomer. (3 marks)

Question 38 (continued)

One method for the production of methacrylic acid is by the following oxidation.

$$\underset{\text{methylpropenol isomer}}{C_4H_8O} \xrightarrow{\text{oxidation}} \underset{\text{methacrylic acid}}{C_4H_6O_2}$$

(d) Suggest an assumption that **must** be made regarding the mole ratios of product to reactant for this reaction and then determine the mass of the methylpropenol isomer required to produce 1.50 tonne of methacrylic acid if the efficiency of this oxidation is 65%. (Note: 1 tonne = 1000 kg.) (5 marks)

Assumption: _____

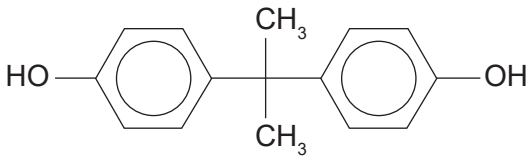
_____

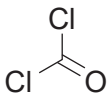
Calculation: _____

See next page

Polycarbonates are condensation-type polymers for which the by-product is hydrogen chloride instead of water.

The two monomers for polycarbonate are shown below.



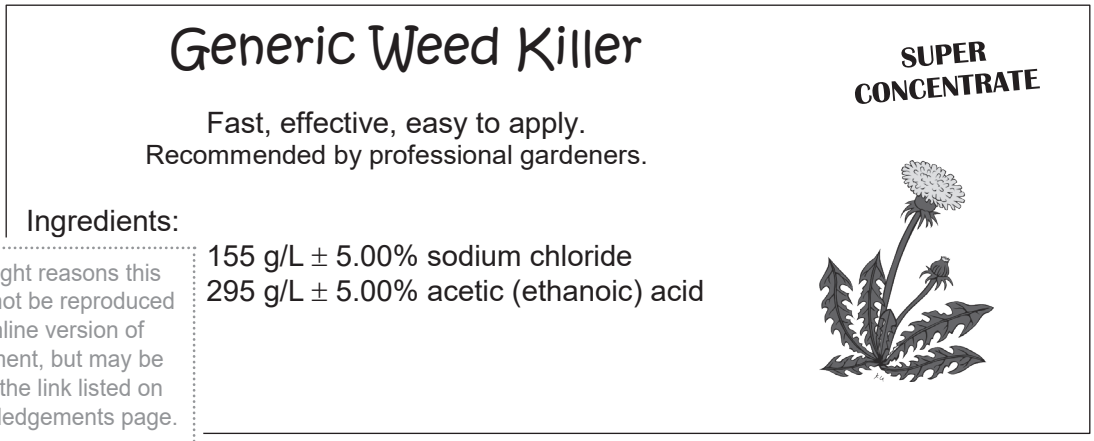


(e) Why is polymethyl methacrylate classified as an addition polymer, while polycarbonate is classified as a condensation polymer? (2 marks)

See next page

Question 39 **(13 marks)**

Herbicides are chemicals that kill plants, including weeds. The label of a commercially-available herbicide concentrate is shown below.



A chemist was given the task of verifying the concentrations of sodium chloride and acetic (ethanoic) acid stated for this herbicide.

The sodium chloride content of the herbicide was analysed. It was found to be consistent within the tolerance of ± 5.00% of the stated concentration. The chemist then performed a series of titrations with sodium hydroxide to measure the acetic (ethanoic) acid concentration.

The herbicide solution used in the titrations was prepared by pipetting 5.00 mL of the concentrate into a 250.0 mL volumetric flask. The solution in the flask was then made up to the mark with distilled water.

A 20.00 mL sample of the diluted herbicide was pipetted into a conical flask and a few drops of a suitable indicator were added. This solution was then titrated with standardised 0.0947 mol L^{-1} NaOH solution.

After an initial 'rough titration', a further four titrations were performed. The results are shown in the following table.

(a) Complete the table and determine the average titre. (2 marks)

Titration number	Burette readings (mL)		
	Initial	Final	Titre
1	1.28	20.75	
2	20.75	40.19	
3	1.48	21.82	
4	21.82	41.21	
		Average titre	

See next page

(b) Identify with what solution each of these pieces of glassware should be rinsed prior to their use in these titrations. (3 marks)

Glassware item	Rinse solution
5.00 mL pipette	
20.00 mL pipette	
250.0 mL volumetric flask	

(c) Demonstrate whether or not the experimentally-determined value of the acetic (ethanoic) acid concentration matches the value given on the herbicide label, bearing in mind that a difference of ± 5.00% is considered acceptable. Show **all** workings and reasoning. (8 marks)

See next page

Question 40 **(22 marks)**

A chemist was developing a new method for extracting lithium metal from ores rich in the mineral lepidolite. The procedure being proposed by the chemist is as follows:

Step 1	crush and grind the ore
Step 2 (Leach)	add sulfuric acid to the crushed ore to dissolve lepidolite (and other soluble ore constituents)
Step 3	add reagents to the leach solution that will precipitate unwanted soluble species
Step 4	recover lithium as lithium carbonate.

In a test of Step 2, performed by the chemist, 5.0 L of sulfuric acid, which was in excess, was added to a crushed and ground sample of a lepidolite-containing ore.

The leach solution was analysed and found to contain sulfate ions and hydrogen ions from the sulfuric acid and the ions stated in the table below.

Ions present	Concentration
Li^+	2.13 g L^{-1}
Rb^+	1.30 g L^{-1}
$A\ell^{3+}$	1.86 g L^{-1}
Fe (as Fe^{2+} and Fe^{3+})	1.27 g L^{-1}

The chemist tried to remove the rubidium and aluminium ions from the leach solution by cooling the solution to 5.00 °C so as to precipitate them as rubidium alum, $RbA\ell(SO_4)_2$. The equation is shown below.

$$Rb^+ (aq) + A\ell^{3+} (aq) + 2\ SO_4^{2-} (aq) \rightarrow RbA\ell(SO_4)_2 (s)$$

The chemist found that, while all of the Rb^+ precipitated, there was a considerable quantity of $A\ell^{3+}$ ions still dissolved in the leach solution.

(a) Calculate the concentration of $A\ell^{3+}$ ions remaining in the 5.0 L of leach solution. Give your answer in grams per litre (g L^{-1}) to the appropriate number of significant figures. (9 marks)

See next page

To remove the remaining $A\ell^{3+}$ ions from the leach solution, the chemist added 2.63 L of a 0.0550 mol L^{-1} K_2SO_4 solution, with the result being the precipitation of potassium alum as shown in the equation below.

$$K^+(aq) + A\ell^{3+}(aq) + 2\ SO_4^{2-}(aq) \rightarrow KA\ell(SO_4)_2(s)$$

The sulfate ions remained in excess due to the initial addition of sulfuric acid.

(b) Was sufficient K_2SO_4 solution added to precipitate all of the $A\ell^{3+}$ ions remaining in the leach solution? Justify your answer with relevant calculations. (4 marks)

See next page

Question 40 (continued)

The final purification step was the removal of iron from the leach solution. To do this the chemist added a suitable oxidant (1.00 mol L^{-1} hydrogen peroxide) to convert all of the Fe^{2+} ions to Fe^{3+} ions. The chemist then added excess sodium hydroxide solution to precipitate all of the iron (now present as Fe^{3+} ions) as $Fe(OH)_3$. This precipitate, and the alum precipitates formed earlier, were removed by filtration.

(c) Write a balanced overall equation to show the conversion of Fe^{2+} to Fe^{3+} by hydrogen peroxide. (3 marks)

The leach solution, now free from rubidium, aluminium and iron, was heated and evaporated to dryness, yielding a lithium-rich residue. The residue was further treated to produce lithium carbonate suitable for use in lithium-ion battery manufacture, with the mass of lithium carbonate recovered being equal to 46.7 g.

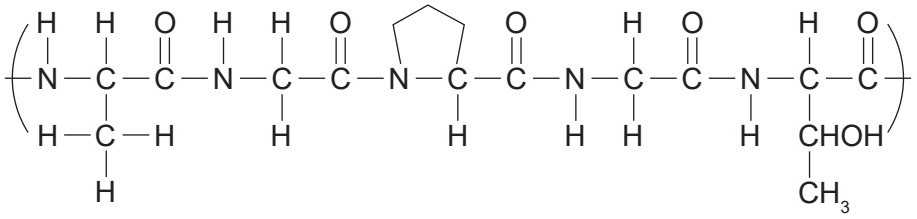
(d) Calculate the percentage yield of lithium carbonate, Li_2CO_3, based on the theoretical amount that should have been recovered. Use the concentration of $Li^+(aq)$ in the table on page 42. (6 marks)

See next page

Question 41 **(12 marks)**

When insects touch a spider's web they become stuck and therefore, easy prey for the spider. The insects become stuck because the web is coated with a glue-like substance produced by the spider. The 'spider glue' consists of water, proteins, ionic salts and polar carbon compounds.

The structural formula given below shows a small section of a spider glue protein.



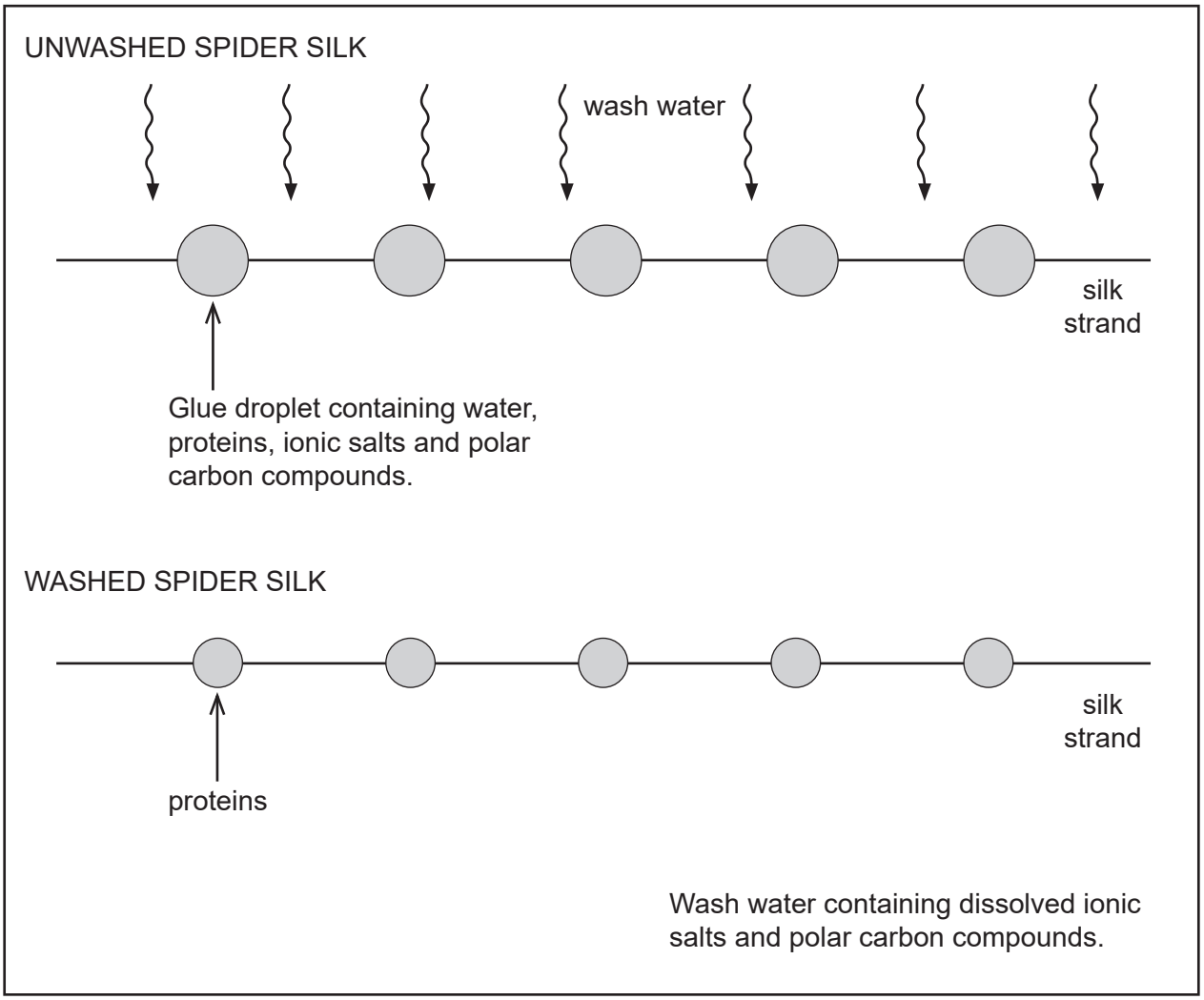
(a) List the names of the amino acids in the order in which they were drawn in the section of the protein given above. Do **not** use abbreviations. (3 marks)

(b) Circle **one** peptide bond in the above structure. (1 mark)

Question 41 (continued)

(c) What is the difference between the primary structure and the secondary structure of a protein? (2 marks)

When spider glue is washed with water, the ionic salts and polar carbon compounds dissolve. The proteins do not dissolve and remain on the silk strand. The following diagram shows what happens.



(d) Explain why the polar carbon compounds dissolve in water but the proteins do not. Illustrate your answer with the aid of a labelled diagram. (6 marks)

End of questions

Supplementary page

Question number: _____

Supplementary page

Question number: _____

Supplementary page

Question number: _____

Supplementary page

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Supplementary page

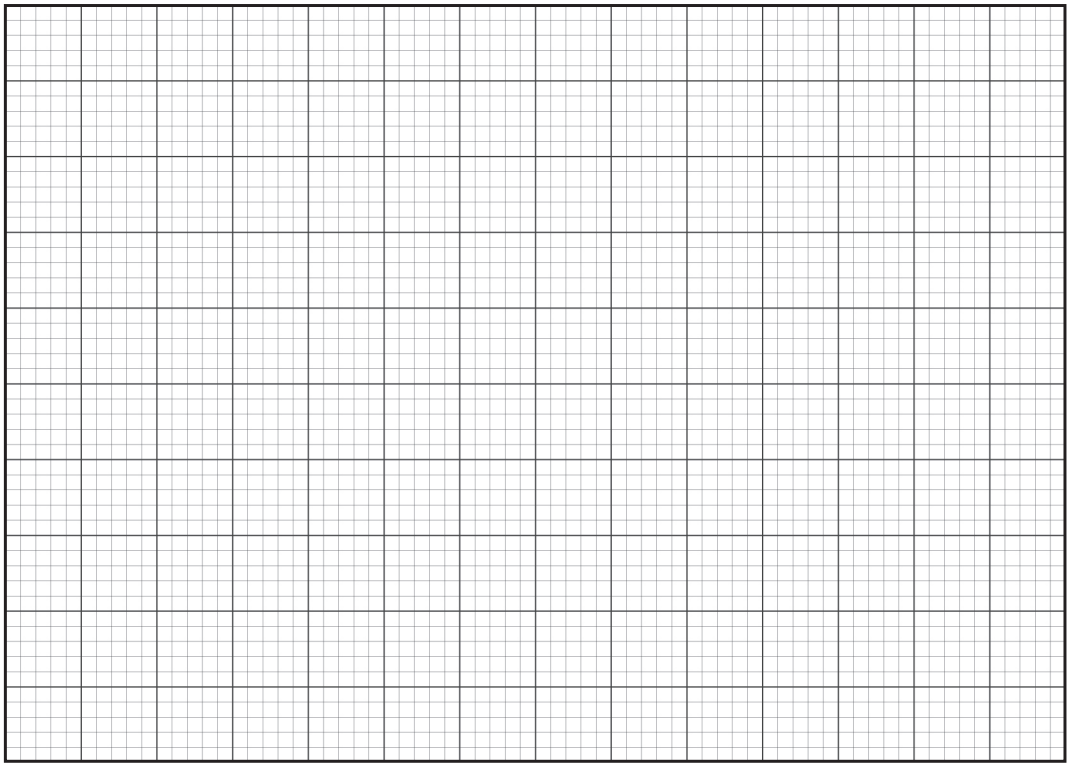
Question number: _____

Supplementary page

Question number: _____

Spare grid

Spare grid



ACKNOWLEDGEMENTS

Question 31

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Question 39

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