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

ATAR course examination, 2018

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.

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Ref: 18-012
CHE

2019/3359
Web version of 2018/52173

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	9	9	60	79	35
Section Three Extended answer	6	6	70	94	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 2018*. 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.

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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. An acid-base indicator is red in acid, green in base and yellow in neutral solutions. The indicator was originally in sodium hydroxide solution and excess nitric acid was added dropwise. Which of the following shows the order of colour that would be shown by the indicator?

   (a) red only
   (b) yellow, green, red
   (c) green, yellow, red
   (d) yellow, red

2. Consider the following reaction systems at equilibrium.

   System 1: $2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$ $K = 6.4 \times 10^{-2}$

   System 2: $2\ NO(g) + 2\ H_2(g) \rightleftharpoons N_2(g) + 2\ H_2O(g)$ $K = 1.3 \times 10^{2}$

   Which of these statements regarding these systems is/are true?

   (i) System 2 reaches equilibrium faster than System 1.
   (ii) The greatest ratio of products to reactants occurs in System 2.
   (iii) Equilibrium in System 1 favours the reactants more than it does in System 2.

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

3. Which of the following solutions has the **greatest** electrical conductivity?

   (a) 0.010 mol L^{-1} methanoic acid, HCOOH(aq) ($K_a = 1.8 \times 10^{-4}$)
   (b) 0.100 mol L^{-1} methanoic acid, HCOOH(aq) ($K_a = 1.8 \times 10^{-4}$)
   (c) 0.010 mol L^{-1} hypochlorous acid, HCℓO(aq) ($K_a = 3.5 \times 10^{-8}$)
   (d) 0.100 mol L^{-1} hypochlorous acid, HCℓO(aq) ($K_a = 3.5 \times 10^{-8}$)

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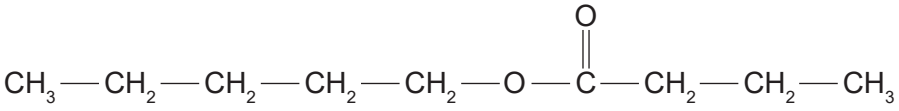
4. The compound with the structural formula shown below smells like apricots:



Which of the following is true for this compound?

	Name of compound	Organic reactants required to synthesise this compound
(a)	pentyl butanoate	pentanol and butanoic acid
(b)	butyl pentanoate	butanol and pentanoic acid
(c)	pentyl butanoate	butanol and pentanoic acid
(d)	butyl pentanoate	pentanol and butanoic acid

Questions 5 and 6 refer to the following information.

When a piece of indium metal, In(s), is placed in some acidified dichromate solution, $Cr_2O_7^{2-}(aq)$, a reaction occurs resulting in $In^{3+}(aq)$ ions being produced. The equation for this reaction is shown below.

$$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 2\ In(s) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(\ell) + 2\ In^{3+}(aq)$$

The EMF for this reaction at 25.0 °C was found to be +1.70 V.

5. What is the calculated E^o value for the In^{3+}/In half-equation?

(a) – 0.34 V
(b) 0.34 V
(c) 1.36 V
(d) 3.06 V

6. According to the Standard Reduction Potential Table, which of the following sets of metals **cannot** be oxidised by indium ion, In^{3+}, under standard conditions.

(a) Sn, Cd, Fe, Cr
(b) Mg, Na, Ca, Sr
(c) Mn, Ni, Sn, Cu
(d) Ni, Sn, Cu, Ag

7. Molybdenum, Mo, is present in each of the following species: MoO_2 $Mo_2O_7^{2-}$ $HMoO_4^{2-}$
Which of the following lists these species in order of **increasing** oxidation number of molybdenum?

(a)	$HMoO_4^{2-}$	MoO_2	$Mo_2O_7^{2-}$
(b)	$Mo_2O_7^{2-}$	$HMoO_4^{2-}$	MoO_2
(c)	$Mo_2O_7^{2-}$	MoO_2	$HMoO_4^{2-}$
(d)	MoO_2	$HMoO_4^{2-}$	$Mo_2O_7^{2-}$

See next page

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8. Consider the hydrolysis equation below.

$$CH_3NH_2(aq) + H_2O(\ell) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Which of the following are conjugate acid-base pairs?

(i) CH_3NH_2 and H_2O
(ii) CH_3NH_2 and $CH_3NH_3^+$
(iii) H_2O and OH^-
(iv) $CH_3NH_3^+$ and OH^-

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

9. Which of the following statements about the Protein Databank (PDB) is/are correct?

(i) The PDB allows users to select a protein and then view its structure.
(ii) The PDB is updated regularly and access by scientists worldwide is free.
(iii) The PDB is a worldwide repository of information on all chemical substances listed in chronological order of discovery.

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

10. Which of the following is **not** a use of polytetrafluorethene?

(a) windscreen wiper blades
(b) parachute canopies
(c) fabric and carpet protection
(d) cookware coating

11. Which of the following molecules is capable of demonstrating cis-trans isomerisation?

(a) $CH_2CHCHBrCH_3$
(b) $CH_3CHCHCH_3$
(c) $CBr_2CHCH_2CH_2Br$
(d) $CH_2BrCBr_2CH_2CH_3$

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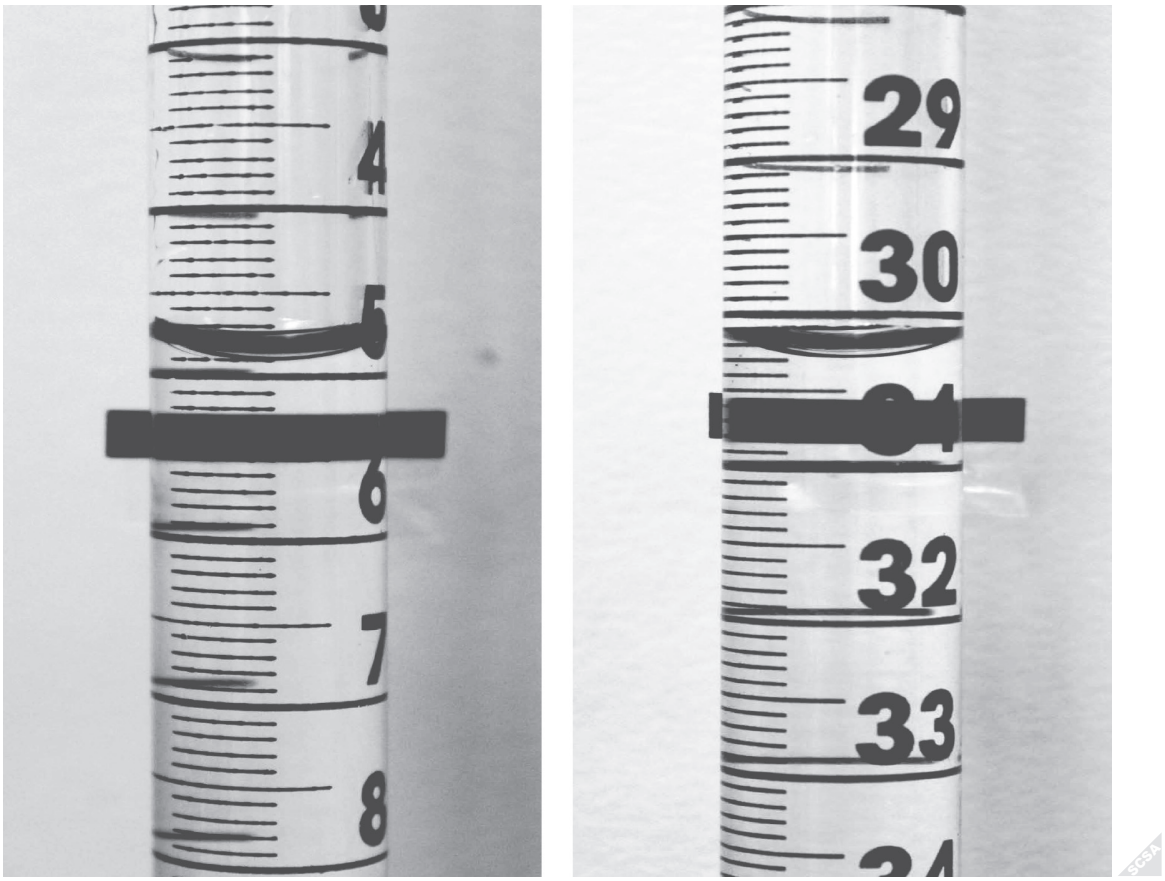

12. The photographs above show a Class A burette before (left) and after (right) a titration. Use these photographs to determine the titre volume used in this titration.

(a) 25.3 ± 0.05 mL
(b) 25.33 ± 0.05 mL
(c) 25.39 ± 0.10 mL
(d) 26.6 ± 0.1 mL

13. The table below shows the volumes added from a burette during a titration.

Titre (mL)					
1	**2**	**3**	**4**	**5**	**6**
19.23	19.94	19.98	19.94	20.02	19.94

What value should be used in the titration calculations?

(a) 19.84 mL
(b) 19.94 mL
(c) 19.95 mL
(d) 19.96 mL

See next page

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Questions 14 and 15 refer to the following information.

A group of students decided to investigate the reactivity of four different transition metals; rhenium, vanadium, zirconium and tantalum. They did this by placing small pieces of each metal in separate test tubes with the appropriate test solutions. The 1.00 mol L^{-1} test solutions were prepared by dissolving the nitrate salt of each metal in distilled water. Their results are summarised in the table below.

Metal	Metal Ions			
	$Re^{3+}(aq)$	$V^{2+}(aq)$	$Zr^{4+}(aq)$	$Ta^{3+}(aq)$
Rhenium		no reaction	no reaction	no reaction
Vanadium	reaction occurs		no reaction	reaction occurs
Zirconium	reaction occurs	reaction occurs		reaction occurs
Tantalum	reaction occurs	no reaction	no reaction	

14. Which of these metals is the **most** easily oxidised?

(a) rhenium
(b) vanadium
(c) zirconium
(d) tantalum

15. Which of these metals is the **weakest** reducing agent?

(a) rhenium
(b) vanadium
(c) zirconium
(d) tantalum

16. Chemists must act ethically when conducting research. Which of the following statements relate to **ethical** behaviour?

(i) Chemists calibrate all of their instruments with primary standards.
(ii) Chemists give due credit to all contributors to an investigation in their written reports.
(iii) Chemists record their experimental results accurately and without alteration to fit their prediction.
(iv) Chemists dispose of their waste materials carefully, especially those containing heavy metals.
(v) Chemists ensure that there is only one independent variable in every experiment they perform.
(vi) Chemists declare any conflict of interest relevant to their investigation.

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

See next page

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17. Proteins can contain α-helices and/or β-pleated sheets. The intermolecular forces holding these structures in their shapes are

(a) dispersion forces.
(b) dipole-dipole forces.
(c) hydrogen bonds.
(d) ion-dipole attractions.

18. Which of the following sets of equations corresponds correctly to the acid-base theory of the chemist/s who proposed it?

	Chemist/s	Equations
(a)	Johannes Brønsted and Thomas Lowry	$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
	Humphry Davy	$HNO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$
	Svante Arrhenius	$HC_2H_3O_2(aq) + H_2O(\ell) \rightleftharpoons C_2H_3O_2^-(aq) + H_3O^+(aq)$
(b)	Johannes Brønsted and Thomas Lowry	$HC_2H_3O_2(aq) + CH_3OH(aq) \rightleftharpoons CH_3OH_2^+(aq) + C_2H_3O_2^-(aq)$
	Humphry Davy	$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
	Svante Arrhenius	$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
(c)	Johannes Brønsted and Thomas Lowry	$HC\ell(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + C\ell^-(aq)$
	Humphry Davy	$H_3O^+(aq) + OH^-(aq) \rightarrow 2\,H_2O(\ell)$
	Svante Arrhenius	$HNO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$
(d)	Johannes Brønsted and Thomas Lowry	$NH_3(aq) + CH_3OH(aq) \rightleftharpoons CH_3O^-(aq) + NH_4^+(aq)$
	Humphry Davy	$2\,HC\ell(aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+}(aq) + 2C\ell^-(aq)$
	Svante Arrhenius	$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

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Questions 19 and 20 refer to two different methods of synthesising ethanol.

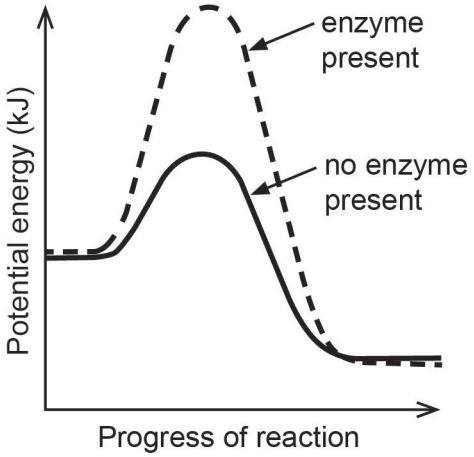
19. Ethanol can be synthesised by combining sugar, a suitable enzyme and water. The equation for this is shown below.

$$C_6H_{12}O_6(aq) \rightleftharpoons 2\,CH_3CH_2OH(aq) + 2\,CO_2(g) + \text{energy}$$

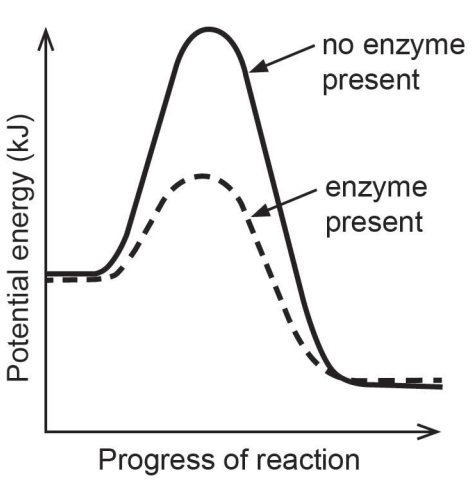
This process is known as 'fermentation'.

Which of these energy profile diagrams shows the effect of an enzyme on this reaction? All other conditions are constant.

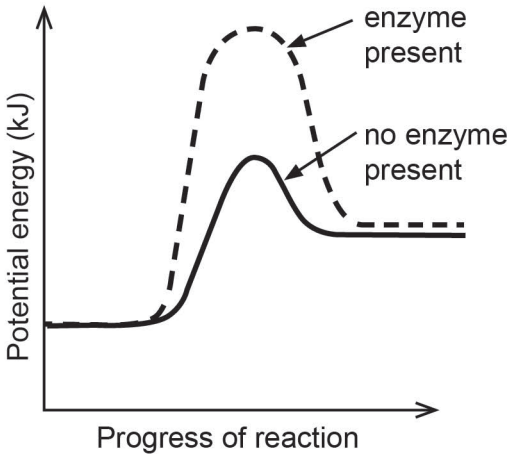
(a)



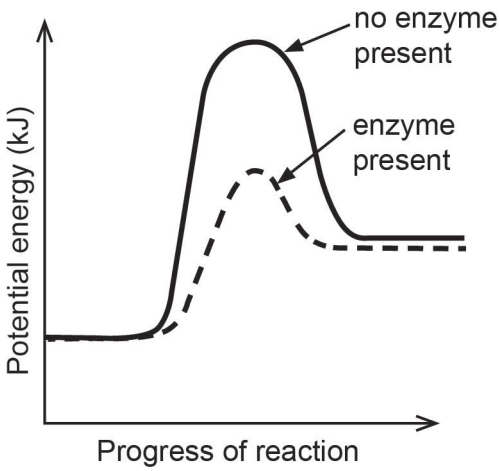
(b)



(c)



(d)



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20. Ethanol can also be produced by reacting ethene with steam. The equation for this reaction, which is known as hydration, is shown below.

$$CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

Which statement about this reaction is **incorrect**?

(a) The hydration reaction requires higher pressures than fermentation to achieve an economically-viable rate.
(b) The hydration of ethene is an addition reaction.
(c) Enzymes decrease the activation energies of both the hydration and fermentation reactions.
(d) The hydration reaction requires higher temperatures than fermentation to achieve an economically-viable rate.

Questions 21, 22 and 23 relate to the following information.

Ammonia, NH_3, is an industrially-important chemical. It is produced on an industrial scale by the Haber process. The reaction for the Haber process is shown below.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) + 92 \text{ kJ mol}^{-1}$$

21. What is the immediate effect of increasing the temperature on the rates of the forward and reverse reactions in the Haber process?

(a) The rates of the forward and reverse reactions increase equally.
(b) The rates of both reactions increase while the rate of the reverse reaction increases more than the rate of the forward reaction.
(c) The rates of both reactions increase while the rate of the forward reaction increases more than the rate of the reverse reaction.
(d) The rate of the forward reaction remains unchanged while the rate of the reverse reaction increases.

22. What combination of temperature and pressure should be used to maximise the yield of ammonia, NH_3?

	Temperature for maximum NH_3 yield	**Pressure for maximum NH_3 yield**
(a)	high temperature	low pressure
(b)	high temperature	high pressure
(c)	low temperature	low pressure
(d)	low temperature	high pressure

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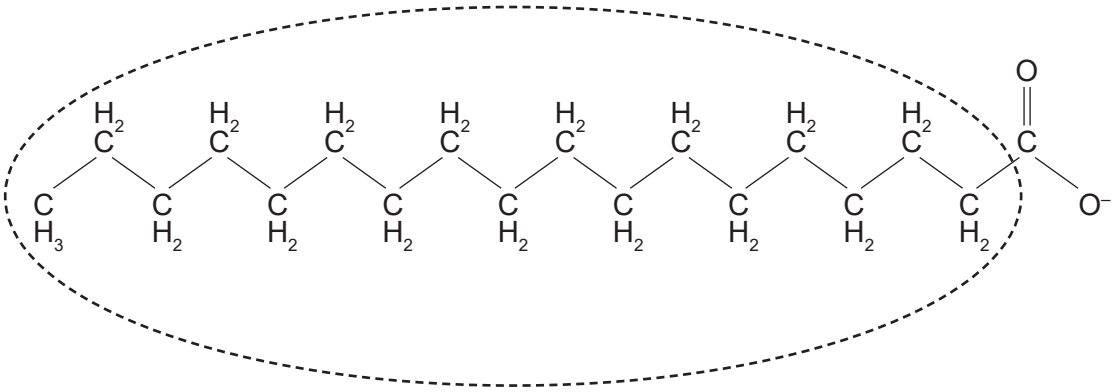
23. The Contact process, which is used to produce sulfuric acid, is another industrially-important process. The process contains several steps, one of which is the production of sulfur trioxide, SO_3, as shown below.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -196\ kJ\ mol^{-1}$$

Which statement regarding both the Haber and Contact processes is correct?

(a) Both are exothermic and both need a suitable catalyst to occur at a satisfactory rate.
(b) Both are endothermic and both need a suitable catalyst to occur at a satisfactory rate.
(c) Both need a suitable catalyst so that the yield of their respective products is maximised.
(d) Both can achieve high rates and high yields without the need for a catalyst.

24. Soap and water can be used to remove oil and grease from human skin. The following diagram represents an anion of soap.



Which of the following correctly describes the orientation of the circled section and the attractive force it forms?

	Orientation	Attractive force
(a)	toward oil and grease	dispersion forces
(b)	toward oil and grease	dipole-dipole forces
(c)	toward water	hydrogen bonds
(d)	toward water	ion-dipole forces

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25. Which of the following statement pairs can be used to distinguish between an electrolytic cell and a galvanic cell?

	Electrolytic cell	Galvanic cell
(a)	an electric current flows from an external electrical power source	the chemical reaction produces an electric current
(b)	oxidation occurs at the cathode	oxidation occurs at the anode
(c)	ions do not migrate through an electrolyte	ions migrate through an electrolyte
(d)	can be used to power a battery	can be used to electroplate metals such as copper and silver

End of Section One

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Section Two: Short answer **35% (79 Marks)**

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

Solid copper(II) hydroxide is added to excess 0.100 mol L^{-1} carbonic acid solution.

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

(b) Predict **all** visible changes that would be observed, if any, while the reactants are mixed together and afterwards. (3 marks)

(c) Predict **two** observations that would be different if excess 0.100 mol L^{-1} hydrochloric acid was used instead of the 0.100 mol L^{-1} carbonic acid. (2 marks)

One: _____

Two: _____

(d) State **two** personal safety measures the experimenter should take when conducting these experiments. (2 marks)

One: _____

Two: _____

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Question 27 **(12 marks)**

Phosphoric acid, $H_3PO_4(aq)$, is a weak, triprotic acid.

(a) Write the ionisation equation for phosphoric acid in water which shows the **second** proton of the acid being released into solution. (2 marks)

Magnesium carbonate, $MgCO_3(s)$, is an ingredient of a commonly-used antacid.

(b) Other than water, list **three** species (elements, compounds, ions) that would be found in the reacting vessel open to the atmosphere at the completion of the reaction between excess solid magnesium carbonate and an aqueous solution of phosphoric acid. (3 marks)

One: _____

Two: _____

Three: _____

Sodium hydroxide solution, NaOH(aq), was used in a titration to determine the concentration of phosphoric acid.

(c) Other than it having too low a molar mass, state **two** reasons why the concentration of the sodium hydroxide solution cannot be reliably determined by weighing out an amount of solid sodium hydroxide and dissolving it in a known volume of distilled water. (2 marks)

One: _____

Two: _____

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The table below lists some acid-base indicators and the colour that each appears over a pH range.

Indicator	Colour		pH range
	Acid	Base	
Universal indicator	red	violet	1.0 – 14.0
Methyl orange	red	yellow	3.2 – 4.4
Bromocresol green	yellow	blue	3.8 – 5.4
Litmus	red	blue	4.5 – 8.3
Methyl red	yellow	red	4.8 – 6.0
Bromothymol blue	yellow	blue	6.0 – 7.6
Phenol red	yellow	red	6.8 – 8.4
Phenolphthalein	colourless	magenta	8.2 – 10.0

(d) Select the acid-base indicator from the table above that would be most suitable for the titration between phosphoric acid, $H_3PO_4(aq)$, and sodium hydroxide solution, NaOH(aq). Justify your choice of indicator, including **one** relevant equation. (5 marks)

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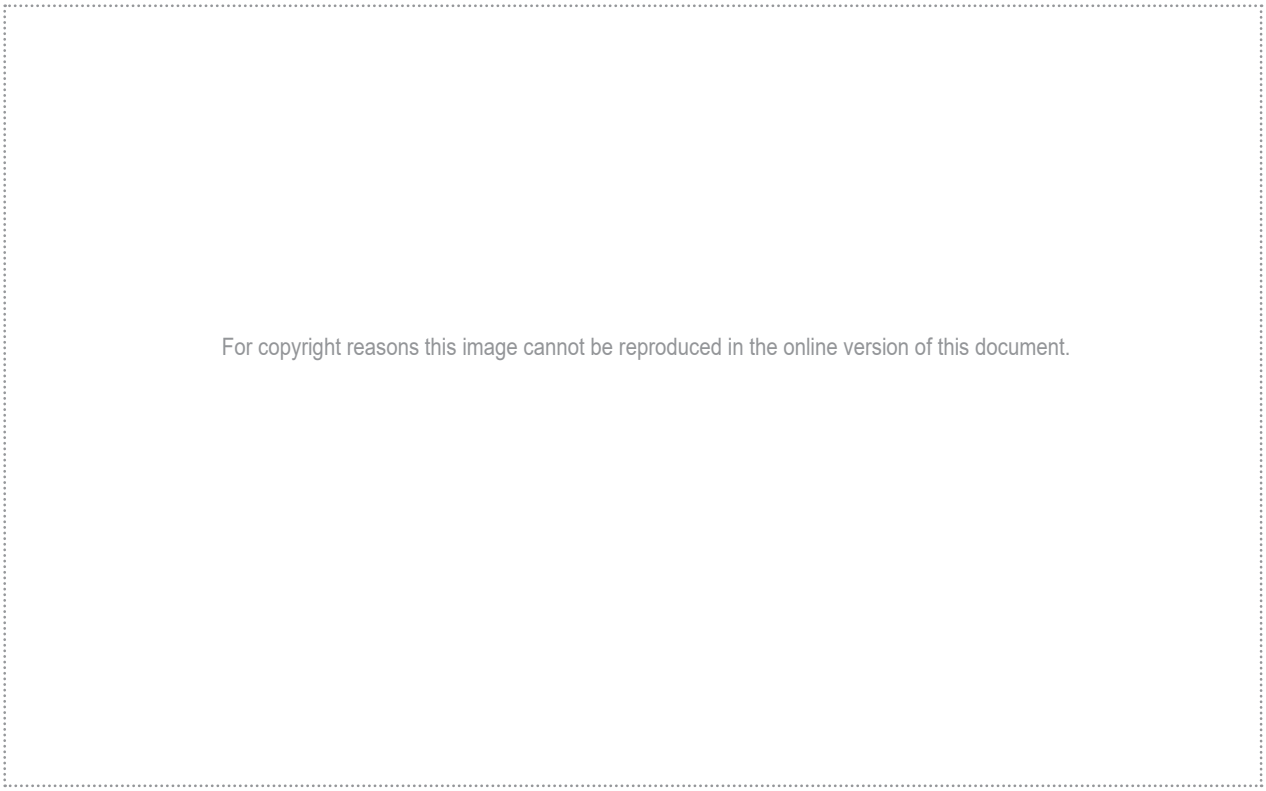
Question 28 **(8 marks)**

An example of a galvanic cell is the molten carbonate fuel cell, represented in the diagram below. As this cell operates, hydrogen gas is reacted with the carbonate ion at the anode, while oxygen gas reacts with carbon dioxide gas at the cathode. The carbon dioxide gas is re-used.



(a) Write the half-equation to show the reaction at the electrode at which oxidation occurs. (3 marks)

(b) Write the overall equation for the current-producing reaction. (3 marks)

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(c) State **two** reasons why this fuel cell is a more environmentally-friendly alternative to the internal combustion engine. (2 marks)

One: _____

_____

Two: _____

_____

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Question 29 **(15 marks)**

Wines and other alcoholic drinks can spoil when the alcohol (ethanol) they contain oxidises to acetic acid (ethanoic acid). An acidity regulator, monosodium citrate, is often added to drinks to prevent the formation of acetic acid. The monosodium citrate does this by acting as a buffer.

A citric acid/dihydrogen citrate ion buffer can be prepared from citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$.

(a) Write an equation for the buffer system ($H_3C_6H_5O_7$ / $H_2C_6H_5O_7^-$) containing citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$. (2 marks)

Buffers that contain equal concentrations of both components are most effective. This buffer solution is prepared by mixing 100.0 mL of citric acid solution with 100.0 mL of monosodium citrate solution. The citric acid solution, $H_3C_6H_5O_7(aq)$, has a concentration of 0.200 mol L^{-1}.

(b) Calculate the mass of sodium citrate, $NaH_2C_6H_5O_7$, that would need to be dissolved in 100.0 mL of distilled water to make the most effective buffer solution. (3 marks)

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(c) If a citric acid buffer was prepared to a pH of 3.5, what would be the concentration of the hydroxide ion at 25.0 °C? (3 marks)

(d) Explain why only a small change in pH is observed in this buffer solution when a small amount of sodium hydroxide solution is added, compared to adding a similar amount of sodium hydroxide solution to a system that is not a buffer solution. Your answer should refer to the buffer equilibrium in part (a). (4 marks)

(e) Increasing the concentration of this buffer solution will increase its buffering capacity. Explain this statement. (3 marks)

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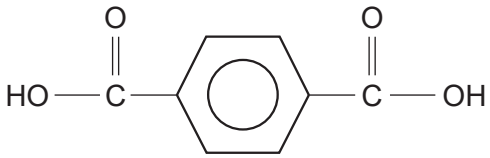
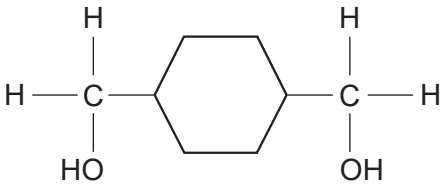
Question 30 **(7 marks)**

Polycyclohexanedimethyl terephthalate glycol, (PCTG), is a strong, chemically-resistant polymer that is food-safe. The monomers needed to synthesise PCTG are terephthalic acid and 1,4-cyclohexanedimethanol, as shown below.



terephthalic acid



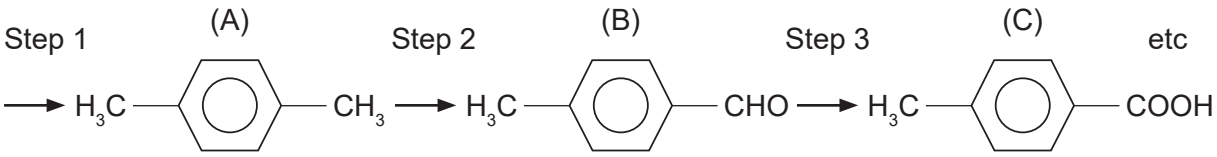
1,4-cyclohexanedimethanol

(a) In the space below, draw the structural formula of PCTG, showing **two** repeating units. (2 marks)

(b) State the name or give the formula of the by-product of this polymerisation process. (1 mark)

_____

The following flow diagram shows some of the steps needed to synthesise terephthalic acid.



(c) Name **two** reagents that could be used to synthesise (C) from (B) in Step 3. (2 marks)

One: _____

Two: _____

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(d) Write a balanced half-equation to show (B) reacting to form (C). (2 marks)

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Question 31 **(6 marks)**

Arsenic acid, $H_3AsO_4(aq)$, is a weak, triprotic acid that can be produced from the element directly through the reaction with water and ozone, $O_3(g)$. This reaction can be represented by the equation below.

$$2\,As(s) + 3\,H_2O(\ell) + 5\,O_3(g) \rightleftharpoons 2\,H_3AsO_4(aq) + 5\,O_2(g)$$

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

(b) The arsenate ion, $HAsO_4^{2-}(aq)$, is amphoteric, meaning it can act as an acid and as a base.

(i) With the aid of equations, describe the amphoteric nature of $HAsO_4^{2-}$ in this aqueous solution. (3 marks)

(ii) State why an aqueous solution containing $HAsO_4^{2-}$ is found to have a pH>7 at 25 °C. (1 mark)

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Question 32 **(4 marks)**

Many marine animals have shells that consist mainly of calcium carbonate. These shells are built from dissolved calcium and carbonate ions.

As the amount of atmospheric carbon dioxide increases, more carbon dioxide dissolves in the ocean. There is increasing concern that as more carbon dioxide dissolves, it will be more difficult for calcium carbonate to form.

Use the following equations to explain why an increasing concentration of atmospheric carbon dioxide will decrease the formation of calcium carbonate.

$$CO_2(g) \rightleftharpoons CO_2(aq) \qquad \text{Equation 1}$$

$$CO_2(aq) + H_2O(\ell) + CO_3^{2-}(aq) \rightleftharpoons 2\,HCO_3^{-}(aq) \qquad \text{Equation 2}$$

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s) \qquad \text{Equation 3}$$

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Question 33 **(11 marks)**

Consider the compounds and their properties listed in the table below.

Compound	Boiling point (°C)	Solubility in water (g L^{-1})
Butane C_4H_{10}	-0.5	0.061
Butan-1-ol $C_4H_{10}O$	117	73.0
Butanone C_4H_8O	79.6	27.5

(a) Given that the molecular formulas indicate that the compounds contain the same number of carbon atoms and differ only in the number of one or two hydrogen or oxygen atoms, propose an hypothesis for why there is a variation in the boiling points of these compounds. (2 marks)

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(b) Explain why these organic compounds have very different solubilities in water. (6 marks)

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Question 33 (continued)

Butanoic acid, $C_4H_8O_2$, is another organic compound that contains four carbon atoms in each molecule and, like butan-1-ol, it is a colourless liquid.

(c) Complete the table below to describe a chemical test that could be used to distinguish between butan-1-ol and butanoic acid by stating the reagent/s used and the distinguishing observations. (3 marks)

Reagent/s used		
Substance being tested	Butan-1-ol	Butanoic acid
Observations		

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Question 34 **(6 marks)**

For the molecular formula $C_6H_{12}O$ draw **two** different structural isomers, one which can be readily oxidised by acidified dichromate solution and one which cannot be readily oxidised by acidified dichromate solution. Show all atoms.

Isomer that **can** be readily oxidised by acidified dichromate solution.

Isomer that **cannot** be readily oxidised by acidified dichromate solution.

End of Section Two

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Section Three: Extended answer **40% (94 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.

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 35 **(16 marks)**

A chemical, commonly called iopromide (IOP), is used to enhance the images produced by a medical procedure called a CT scan. It contains carbon, hydrogen, iodine, nitrogen and oxygen, $C_vH_wI_xN_yO_z$.

Use the following information to determine the molecular formula of IOP.

- The molar mass of IOP is 791.102 g mol^{-1}.
- A 5.62 g sample of IOP contained 0.2986 g of nitrogen, N.
- A 3.54 g sample of IOP is fully combusted to produce;
  - 1.72 L of carbon dioxide gas, $CO_2(g)$, at 125 °C and 155.3 kPa.
  - 0.967 g of water vapour, $H_2O(g)$.
- All of the iodine contained in a 2.523 g sample of IOP is converted to iodide, I^-. This sample is then dissolved in water and excess lead(II) nitrate solution, $Pb(NO_3)_2(aq)$, is added to precipitate the iodine as lead(II) iodide, $PbI_2(s)$. This produced 2.21 g of lead(II) iodide.

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Question 36 **(17 marks)**

A scientist was given the task of investigating the concentration of dissolved heavy metals in abandoned open-cut mines that had filled with water to create small freshwater dams.

Using a map, the scientist identified 180 locations containing abandoned open-cut mines that had become freshwater dams. The scientist decided to randomly select locations to take water samples. The procedure for water sampling at each location was as follows:

1. Take two samples using separate 100.0 mL bottles at a water depth of 0.50 m.
2. Acidify each sample with a few drops of nitric acid solution to minimise heavy metal precipitation.
3. Wait eight hours before measuring heavy metal concentration.
4. Calculate the average concentration of a range of heavy metals, using two samples per location.

(a) Outline the difference between random and systematic errors. Give an example of each that might be encountered in this investigation. (4 marks)

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Water samples were collected from 59 of the 180 possible locations.

(b) (i) Calculate the sample size as a percentage of the testable locations. (1 mark)

(ii) Propose **two** reasons why samples were not collected from all locations. (2 marks)

One:

Two:

(iii) Predict the effect of using a smaller sample size on the reliability of the overall results. Justify your answer. (2 marks)

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Question 36 (continued)

Once the samples had been analysed, the scientist found that a particular sampling location had a high concentration of cadmium(II) ions. The dam from which the sample came is now used as a water source for leisure activities and irrigation of surrounding food crops.

Cadmium is known to be harmful to human health. Authorities are concerned that the cadmium could be consumed accidentally by humans at that water source or they could be exposed to cadmium from crops irrigated by the dam.

After further investigation, the scientist determined that the freshwater dam had:

- a volume of 1.123×10^9 L
- an average cadmium(II) ion concentration of 0.5310 mg L^{-1} with an error margin of ±0.09100 mg L^{-1}.

To remove the cadmium(II) ions, phosphate ions can be added to immobilise the cadmium as an insoluble precipitate. The scientist proposes that sodium phosphate, $Na_3PO_4(s)$, be used to remove the cadmium(II) ions.

(c) Calculate the minimum mass of sodium phosphate needed to remove all the cadmium(II) ions from the water. Give your final answer to the appropriate number of significant figures. Assume that there are no species other than cadmium(II) ions present in the dam that will react with the phosphate ions. (8 marks)

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Question 37 **(12 marks)**

Gallium is present as gallium(III) oxide, Ga_2O_3, in the red mud waste from the processing of bauxite. The first step in its recovery from the red mud is the addition of hydrochloric acid, HCℓ (aq). This is represented by the equation below.

$$Ga_2O_3(s) + 6\ H^+(aq) \rightarrow 2\ Ga^{3+}(aq) + 3\ H_2O(\ell)$$

The results in the table below show the effect of temperature on the rate of gallium extraction from a red mud sample. Note that all of the other reaction conditions were constant.

Temperature (°C)	Reaction rate (as percentage of gallium extracted after four hours)
40	77
55	88
70	95
85	96
100	97

(a) Explain the effect of temperature on reaction rate by applying collision theory. Support your explanation with an appropriate and clearly-labelled diagram. (7 marks)

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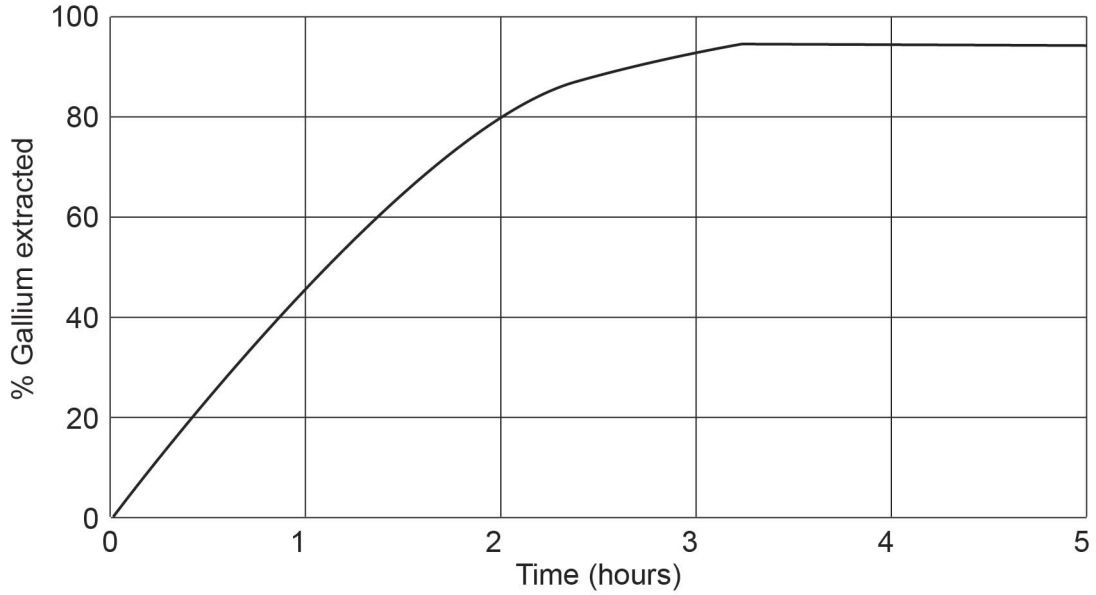
Question 37 (continued)

This graph shows how the amount of gallium extracted from red mud varies over time at a hydrochloric acid concentration of 1.00 mol L^{-1}.



(b) Sketch on the graph above the result that would be obtained if the hydrochloric acid concentration was changed to 2.00 mol L^{-1}. (2 marks)

(c) Use collision theory to justify the position and shape of the graph you sketched in part (b). Assume that all other reaction conditions were kept constant. (2 marks)

In a laboratory analysis, the red mud containing gallium(III) oxide, was mixed with excess hydrochloric acid solution. The concentration of gallium(III) ions, $Ga^{3+}(aq)$, in the resulting solution was analysed and the percentage of gallium in the red mud was determined.

(d) State **one** reason why the hydrochloric acid used in this analysis needed to be in excess. (1 mark)

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Question 38 **(18 marks)**

SpaceX is an American company that wants to send humans to Mars to explore the planet and establish a colony. One of the challenges of such a mission is finding reliable fuel sources away from Earth.

SpaceX plans to solve this problem by using the Sabatier reaction. The equation for the reaction is:

$$CO_2(g) + 4\ H_2(g) \rightleftharpoons CH_4(g) + 2\ H_2O(g) \qquad \Delta H = -165\ kJ\ mol^{-1}$$

The optimal conditions for this reaction are:
- temperature of 300 – 400 °C
- pressure of 200 – 300 kPa
- nickel catalyst.

The carbon dioxide would be obtained from the Martian atmosphere and the hydrogen from the hydrolysis of water extracted from either the Martian subsoil or atmosphere. The resulting methane could be used as rocket fuel while the water could be electrolysed to produce hydrogen and oxygen. The hydrogen could be fed back into the reaction vessel and the oxygen used for breathing apparatus.

(a) With reference to rates of reaction, equilibrium and economic considerations, explain why the above conditions are considered optimal for the Sabatier reaction. In your response, address any compromises in conditions. (7 marks)

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Question 38 (continued)

(b) Predict the effect of each of the following changes on the methane yield in the Sabatier reaction. (5 marks)

Imposed change	**Effect on methane yield** (circle your answer)		
a suitable catalyst is added	increase	decrease	no effect
the volume of the reaction vessel is increased	increase	decrease	no effect
the temperature is increased	increase	decrease	no effect
methane is removed through a special valve as soon as it forms	increase	decrease	no effect
the partial pressure of carbon dioxide is decreased	increase	decrease	no effect

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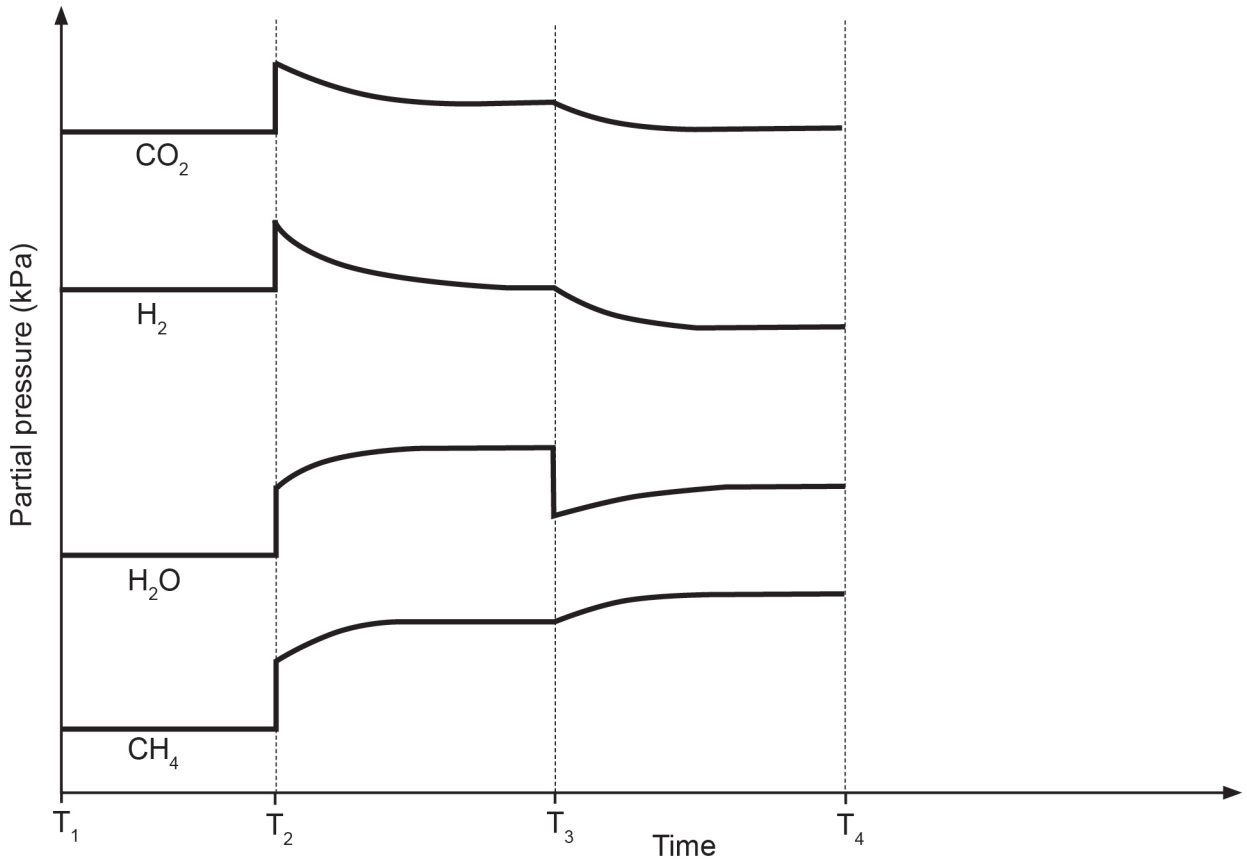
Graphs can be drawn to show the effects of imposed changes on equilibrium systems. The graph below shows the effects of some changes that might be made to the reacting system in a flexible vessel.

$$CO_2(g) + 4\,H_2(g) \rightleftharpoons CH_4(g) + 2\,H_2O(g) \qquad \Delta H = -165 \text{ kJ mol}^{-1}$$



With reference to the above graph, answer the following questions.

(c) (i) What happened at T_1? (1 mark)

(ii) Identify the change imposed at each time in the table below. (2 marks)

Time	Change imposed on the system
T_2	
T_3	

(iii) The temperature of the reaction vessel was decreased at T_4. Sketch on the graph above to show how this affected the partial pressures of all species present. Include any changes to scale and continue until a new equilibrium is established. (3 marks)

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Question 39 **(14 marks)**

The Atlantic longfin inshore squid is able to blend into its surroundings and seemingly disappear. It does this by reflecting light using specialised cells. The squid tunes and adapts the reflection of light from these cells by using a class of proteins called reflectins.

The amino acid sequences of some reflectins from this squid have been characterised. A small sequence from one of the reflectins is shown below.

– Tyr – Val – Asn –

(a) Draw the full structural formula of this section of the reflectin. Show all hydrogen atoms. (3 marks)

(b) Circle **one** peptide bond in the structure that you drew in part (a). (1 mark)

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The amino acid leucine is also found in reflectin.

(c) Draw the full structural formula of leucine, Leu, in each of the conditions specified below. Show all hydrogen atoms. (4 marks)

Low pH (acidic)

High pH (basic)

(d) Explain why the structure of Leu is pH dependent. (3 marks)

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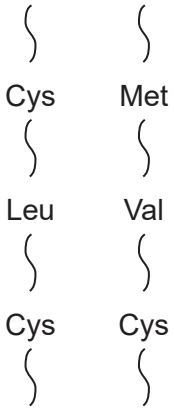
Question 39 (continued)

Consider the following amino acids found on neighbouring protein chains as they come into proximity to each other.



(e) Identify the pair **most** strongly attracted to each other. Justify your choice. (3 marks)

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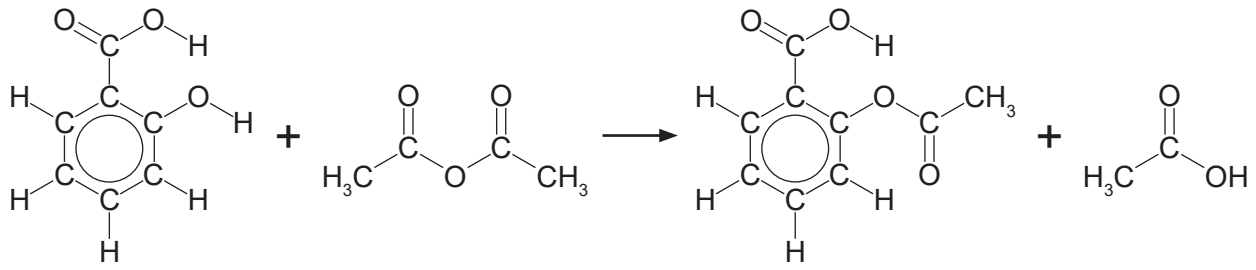
Question 40 **(17 marks)**

Acetylsalicylic acid is better known as aspirin. It is used to treat pain and inflammation. Aspirin can be synthesised from salicylic acid and acetic anhydride ($C_4H_6O_3$). This process can be represented by the equation below.



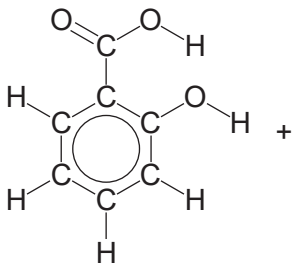
salicylic acid acetic anhydride aspirin acetic acid

The molar mass of salicylic acid is 138.121 g mol^{-1}.
The molar mass of aspirin is 180.158 g mol^{-1}.
This reaction is an equilibrium reaction with a K value of approximately 5.

(a) In the synthesis of aspirin, 45.0 g of salicylic acid was reacted with excess acetic anhydride. This produced 50.2 g of aspirin. What was the percentage yield of this reaction? (4 marks)

A student conducts a titration to determine the percentage purity of a sample of salicylic acid that was to be used in the synthesis of aspirin.

(b) Complete the equation for the reaction between salicylic acid and sodium hydroxide solution. (2 marks)



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Question 40 (continued)

An amount of 3.55 g of salicylic acid was dissolved in distilled water and added to a 250.0 mL volumetric flask, which was filled to the calibration line with additional distilled water. 20.00 mL aliquots of the acid solution were titrated against 0.0966 mol L^{-1} sodium hydroxide solution. The average titre obtained was 18.45 mL.

(c) Calculate the mass of salicylic acid in the sample and therefore the percentage purity of the sample. (5 marks)

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During the titration, the student used the following procedure.

Number	Procedure
1	Swirl the conical flasks while adding sodium hydroxide solution from the burette.
2	Use the same number of drops of indicator for each titration.
3	Stop the titration at the first sign of the indicator showing a colour change.
4	Wash the pipette with distilled water before filling with salicylic acid solution.
5	Slow down the addition of sodium hydroxide solution as the end point is approached.
6	Rinse down the sides of the conical flask during the titration.

(d) Identify **two** incorrect procedures from the list above, select the effect on the calculated concentration of salicylic acid and give the reason for the effect. (6 marks)

Number	**Effect on calculated concentration** (circle your answer)	**Reason**
	increase decrease no change	
	increase decrease no change	

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End of questions

Supplementary page

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Supplementary page

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ACKNOWLEDGEMENTS

Question 27(d) Table data source: Stark, J. G., & Wallace, H. G. (Eds) (SI ed.). (1975). *Chemistry data book*. London: John Murray.

Question 28 Diagram adapted from: Li, X. (2005). *Principles of fuel cells*. New York: Taylor & Francis.

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