Perth Modern School examination, Semester 2, 2020

Question/Answer booklet

CHEMISTRY

Student Name: _____

Student Number:	In figures							
	In words							

Teacher Name: _____

Time allowed for this paper
Reading time before commencing work: 10 minutes
Working time for paper: 3 hours

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 colours), 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.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination	Your mark
Section One Multiple-choice	25	25	50	50	23	
Section Two Short answer	7	7	60	76	35	
Section Three Extended answer	5	5	70	92	42	
				Total	100	

Instructions to candidates

1. The rules for the conduct of ATAR course 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 the 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 responses 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.

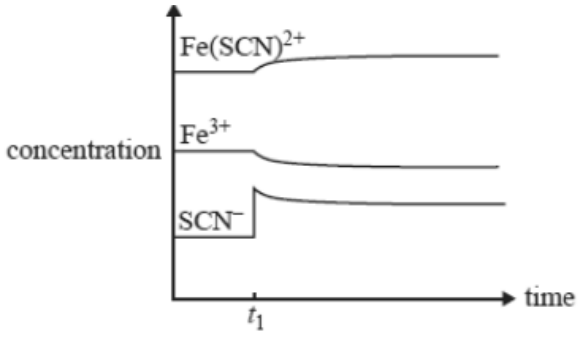
7. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Multiple-choice **23% (50 Marks)**

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

Suggested working time: 50 minutes

1. Solutions of KSCN and $FeCl_3$ are mixed, producing a red solution due to formation of the aqueous $FeSCN^{2+}$ ion. The concentration profile below represents a change to the following equilibrium system at time t_1. $Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$



Which one of the following would account for the changes in concentration at time t_1?

a) the addition of SCN
b) the removal of $Fe(SCN)^{2+}$
c) an increase in temperature
d) a decrease in temperature

2. Ethene may be produced from ethane by heating in the presence of a catalyst, according to the following equation: $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$ $\Delta H = +138$ kJ mol^{-1}

At 425°C, and in presence of 'Speedicrak' patent catalyst, equilibrium is rapidly achieved. The proportion of ethane converted to ethene at equilibrium would be increased by:

a) reducing the volume of the reaction vessel.
b) replacing 'Speedicrak' with a more effective catalyst.
c) lowering the temperature.
d) raising the temperature.

See next page

Questions 3, 4, and 5 refer to the following reaction between hydrogen gas and bromine to form hydrogen bromide:

$$H_2\,(g) + Br_2\,(g) \rightleftharpoons 2\,HBr\,(g) \qquad \Delta H < 0$$

3. If hydrogen gas and bromine were placed in a sealed insulated vessel together with a catalyst, which of the following would not cause an increase in the rate at which equilibrium would be attained?

a) Increasing the volume of the vessel
b) Increasing the temperature
c) The addition of bromine to the reaction mixture
d) Increasing the state of sub-division of the catalyst

4. Which of the following statements is/are **true** when the system is at equilibrium?

(i) Reactants are no longer turning into products.
(ii) The concentration of bromine in the vessel is constant.
(iii) Adding a catalyst would not affect the proportions of reactants and products.

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

5. Which of the following changes would not be observed once equilibrium is re-established if a little hydrogen gas were added at constant temperature to an equilibrium mixture containing the three gases in the equation?

a) The forward and reverse reaction rates would be equal.
b) The concentration of hydrogen gas would increase.
c) The mass of bromine in the vessel would decrease.
d) The value of the equilibrium constant, K, would decrease.

6. When in solution, which of the following combinations cannot produce a buffered solution?

a) CH_3COOH and $NaCH_3COO$
b) $HC\ell$ and $NaC\ell$
c) NH_3 and $(NH_4)_2SO_4$
d) NH_3 and NH_4Br

7. Which of the following equations represents a reaction in which water acts as an acid?

a) $CH_3COOH + H_2O \rightleftharpoons CH_3CO_2^- + H_3O^+$
b) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
c) $Zn^{2+} + 4H_2O \rightleftharpoons Zn(H_2O)_4^{2+}$
d) $NaOH(s) \rightleftharpoons Na^+(aq) + OH^-(aq)$

8. Each of the following substances was dissolved in water. Which one of the following answers correctly classifies the resulting solutions?

	$NaHCO_3(aq)$	**$KC\ell(aq)$**	**$NaHSO_4(aq)$**	**$NH_4NO_3(aq)$**
a)	acidic	basic	acidic	neutral
b)	basic	neutral	acidic	acidic
c)	basic	neutral	basic	neutral
d)	neutral	neutral	acidic	acidic

9. A basic buffer solution can be prepared by mixing equal number of moles of:

a) ammonium chloride and hydrochloric acid
b) sodium chloride and sodium hydroxide
c) sodium carbonate and sodium hydrogen carbonate
d) phosphoric acid and potassium phosphate

See next page

10. Which of the following statements is false?

a) The pH of a solution of a strong acid is less than the pH of an equimolar solution of a weak acid.
b) The pH of a solution of a strong base is greater than the pH of an equimolar solution of a weak base.
c) Weak acids and weak bases do not react with each other.
d) It is possible for water to act either as an acid or as a base.

11. Consider a solution which is 0.10 mol L^{-1} in CH_3COOH and 0.20 mol L^{-1} in $NaCH_3COO$. Which of the following statements is true?

a) If a small amount of NaOH is added, the pH decreases very slightly.
b) If NaOH is added, the OH^- ions react with the CH_3COO^- ions.
c) If a small amount of $HC\ell$ is added, the pH decreases very slightly.
d) If more CH_3COOH is added, the pH increases.

12. Which indicator (identified by a letter) would be the best option to be used to titrate aqueous NH_3 with $HC\ell$ solution?

Indicator	Acid Range Colour	Colour-Change pH	Basic Range Colour
a)	pink	1.2 - 2.8	yellow
b)	blue	3.4 - 4.6	yellow
c)	yellow	6.5 - 7.8	purple
d)	colourless	8.3 - 9.9	red

13. What is the ratio of **a to b to c** in the following equation, after it is balanced?

$$\underline{\mathbf{a}}\ Cr_2O_7^{2-} + \underline{\mathbf{b}}\ Sn^{2+} + \underline{\mathbf{c}}\ H^+ \rightleftharpoons \underline{\mathbf{d}}\ Cr^{3+} + \underline{\mathbf{e}}\ Sn^{4+} + \underline{\mathbf{f}}\ H_2O$$

a) 3 to 1 to 14
b) 1 to 2 to 14
c) 1 to 3 to 14
d) 1 to 3 to 16

14. For a voltaic (or galvanic) cell using Ag, Ag^+ (1.0 mol L^{-1}) and Zn, Zn^{2+} (1.0 mol L^{-1}) half-cells, which of the following statements is <u>incorrect</u>?

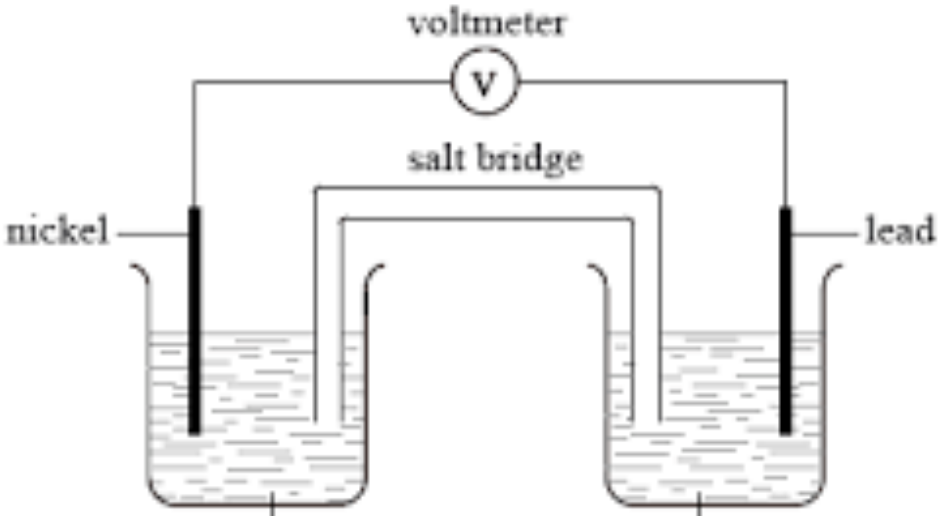
a) The zinc electrode is the anode.
b) Electrons will flow through the external circuit from the zinc electrode to the silver electrode.
c) Reduction occurs at the zinc electrode as the cell operates.
d) The mass of the zinc electrode will decrease as the cell operates.

15. What would happen if you tried to store 1.0 mol L^{-1} $Fe_2(CO_3)_3$ in a container made of Ni metal?

a) The 1.0 mol L^{-1} $Fe_2(CO_3)_3$ could be stored quite safely.
b) The nickel of the container would dissolve, and Fe metal would be formed.
c) The nickel of the container would dissolve, and Fe^{2+} ions would be formed.
d) The nickel of the container would dissolve, and H_2 gas would be evolved.

See next page

16. Consider the electrochemical cell shown below with a nickel electrode in a solution of nickel (II) sulfate and a lead electrode in a solution of lead (II) nitrate.



Which of the following statements is false?

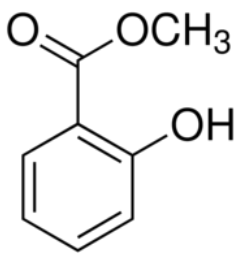
a) No reaction would occur if the contents of the two beakers were mixed.
b) The overall reaction is Ni (s) + Pb^{2+} (aq) ⇌ Ni^{2+}(aq) + Pb (s)
c) Lead (II) ions are reduced to lead.
d) Electrons flow from the lead electrode to the nickel electrode.

17. Steel motorcycle fittings are often electroplated with nickel and then plated with chromium to improve their appearance and resistance to corrosion (the nickel is used to help the chromium adhere to the object). An experiment is set up to electroplate a motorcycle headlight with nickel.

Which one of the following statements describes how the experiment should be set up?

a) The cathode is made of nickel and the headlight is the anode.
b) The headlight is the anode and the electrolyte is a solution of nickel sulfate.
c) The headlight is the cathode and the electrolyte is a solution of nickel nitrate.
d) The headlight is the cathode; the anode is made of steel and the electrolyte is nickel carbonate.

18. Consider the following molecule, commonly known as oil of wintergreen:



oil of wintergreen

The functionality of the carbonyl group it contains is:

a) an alcohol.
b) an ester.
c) an acid.
d) an ester and an alcohol.

19. Which of the following molecules would react with acidified dichromate to produce a ketone?

(i) 2-methylpropan-2-ol
(ii) 3-methylbutan-2-ol
(iii) CH_3CHO
(iv) CH_3CH_2OH

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

20. When hydrogen bromide gas reacts with propene it produces bromopropane. How many isomers are in the product mixture?

a) only 1 form is made, there are no isomers
b) 2
c) 3
d) 4

See next page

21. Which one of the following statements about soaps is correct?

a) Soaps are typically the sodium or potassium salts of fatty acids.
b) Soaps act as surfactants because they contain ions with a positively charged end and a negatively charged end.
c) Soaps are manufactured by using an esterification reaction.
d) Glycerol is used as a reactant in the manufacture of soaps.

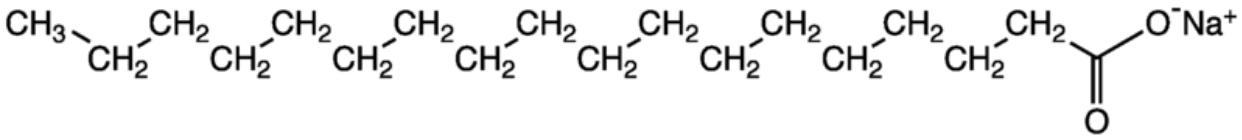
22. Which one of the following pairs of compounds would produce biodiesel if reacted together?

a) a triglyceride and a strong alkali
b) a carboxylic acid and a strong oxidising agent
c) an alcohol and a triglyceride
d) a fatty acid and an ester

23. Which one of the following statements regarding ß-pleated sheets in proteins is <u>true</u>?

a) The ß-pleated sheets form part of the tertiary structure of proteins.
b) Hydrogen bonds are responsible for the formation of the ß-pleated sheets.
c) The ß-pleated sheet structure is created when side chains on the protein interact.
d) A protein that contains ß-pleated sheets cannot also contain the α-helix structure.

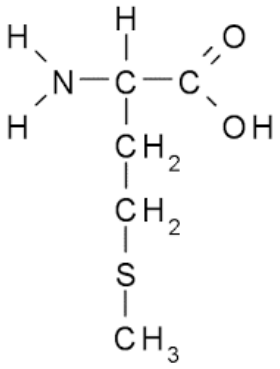
24. The following formula represents the structure of a chemical compound.



Which of the following statements about this molecule is false?

a) It is preferred as it is unlikely to form scum with hard water.
b) The molecule is water-soluble.
c) They are produced by the saponification of triglycerides.
d) The molecules contain large non-polar regions that can form strong intermolecular forces with fats.

25. Consider the amino acid methionine:



Which one of the following is false?

a) A solution of the amino acid can act as a buffer.
b) The amino acid can contribute to the tertiary structure of a protein via disulfide bridges.
c) The amino acid can form a dipeptide with alanine via a condensation reaction.
d) The amino acid can contribute to primary structure of a protein by forming peptide linkages as a part of a sequence with other amino acids.

End of Section 1

See next page

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

This section has **seven (7)** 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)**

Three small cubes of sodium metal were added to a beaker containing butan-2-ol.

a) Provide two observations for this reaction. (2 marks)

Observation 1:

Observation 2:

b) Write the net ionic equation for the reaction involving both sodium metal and aqueous butan-2-ol. (2 marks)

Ethanoic acid hydrolyses in water in a reaction that forms an equilibrium between reactants and products.

c) Write a balanced equation for the hydrolysis of ethanoic acid, including equilibrium arrows (2 marks)

_____

_____

d) Complete the following table by using the words 'left', 'right' and 'no change' to describe how each of the following changes to this equilibrium system will affect the position of equilibrium following Le Châtelier's principle. (3 marks)

Imposed change	Position of equilibrium shifts:
Additional ethanoic acid added	
Two drops of water are added	
Solid sodium hydrogen carbonate is added	

See next page

Question 27 **(13 marks)**

An aqueous solution is prepared by dissolving a mass of the ionic salt, sodium hydrogen oxalate ($NaHC_2O_4$), in sufficient water to form a 0.1 mol L^{-1} solution.

a) Write the two hydrolysis reactions that are possible within a solution containing this salt. (3 marks)

<u>One:</u>

<u>Two:</u>

b) The pH of the solution was measured to be less than seven. Based on this observation, state which of the hydrolysis equations has the higher equilibrium constant. Use your understanding of equilibrium concepts to explain your choice fully. (4 marks)

Successive 0.1 mL volumes of dilute sodium hydroxide solution are added to the sodium hydrogen oxalate solution and the pH was measured after each small addition. It was noticed that for the first few additions, the pH hardly changed. After the fourth addition, the pH changed significantly and for every successive addition thereafter the pH changed drastically in the same direction.

c) Identify the property of the solution that is being displayed and use appropriate equations to explain how the solution is behaving to produce these measured results.

(6 marks)

See next page

Question 28 **(6 marks)**

Draw the structure and name the organic product(s) for each of the following reactions in the boxes provided.

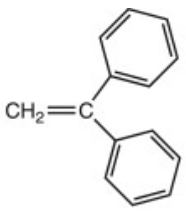
a) $CH_3CHCHCH_3 + Br_2 \rightarrow$ (2 marks)

Name:

b) Ethane is added to excess chlorine water in the presence of UV light. (2 marks)

Name:

c) Diphenyl ethene (DPE), shown below, is reacted to form a polymer. (2 marks)



DPE

Name:

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See next page

Question 29 **(11 marks)**

Cider is made in a process that involves crushing and pressing apples, converting the sugars to alcohols. Brewers add yeast, that contains a mixture of enzymes, to convert the sugars in the apples into alcohol and carbon dioxide. While this process does produce heat, the enzyme allows the reaction to occur at a temperature that does not combust the alcohol.

a) State the function of the enzyme and sketch a graph to illustrate how the enzyme affects progress of this reaction as the sugar (fructose, $C_6H_{12}O_6$) is converted to alcohol (primarily ethanol) and carbon dioxide. (4 marks)

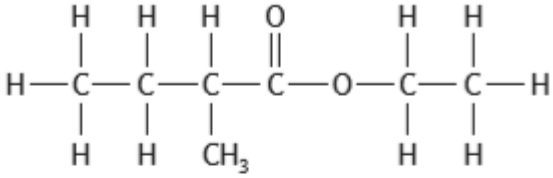
Some of the ethanol that is supplied by the fermentation process can oxidise to form two water soluble organic molecules that can spoil the flavour of the cider.

b) State the name of the two organic products of the oxidation of ethanol and provide the oxidation half equations that demonstrate their formation. (4 marks)

One:

Two:

Cider contains many naturally occurring compounds that affect taste and aroma. It was determined that the apple aroma for cider was due to the molecule shown below.

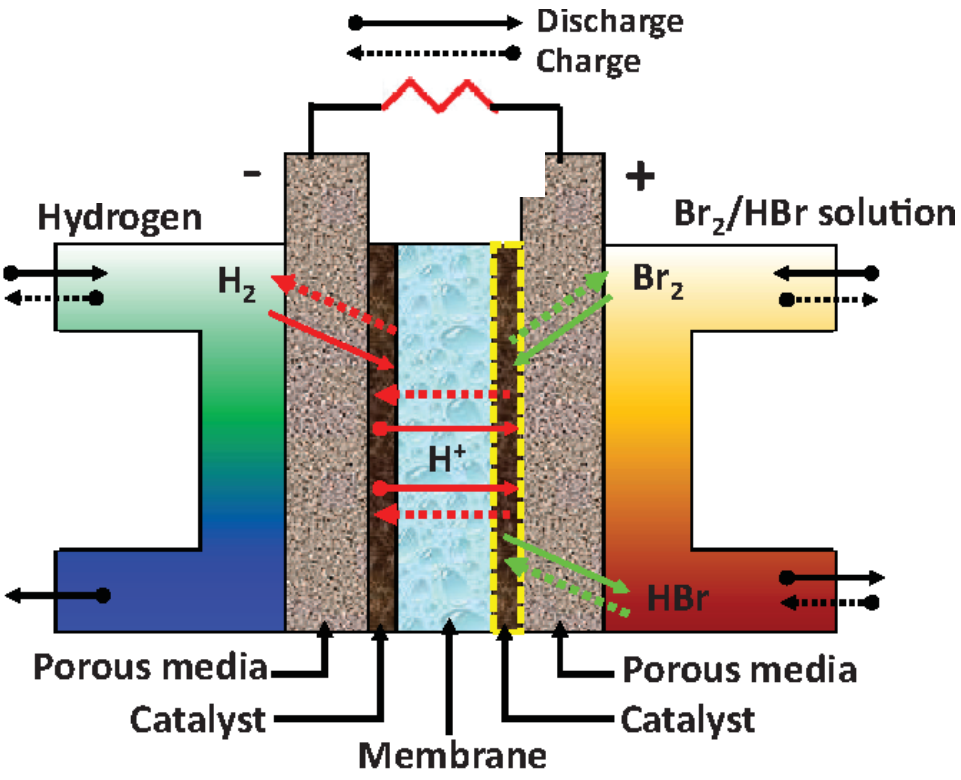


c) State the IUPAC name for this molecule. (1 mark)

d) Write the formula equation (condensed or structural) that outlines how this molecule could be synthesised in the laboratory using an alcohol and a carboxylic acid. (2 marks)

See next page

Question 30 **(7 marks)**



A bromine fuel cell, like the one pictured above, is a rechargeable cell that has application for storing potential generated from renewable sources (such as solar or tidal).

a) Write the equations representing the redox processes occurring at each electrode of the cell when discharging its potential. (2 marks)

Anode:

_____

Cathode:

_____

b) Determine the potential at standard conditions that this cell could produce. (1 mark)

_____

c) Provide two reasons that account for a measured cell potential to be 0.2 V less than the predicted value from part (b). (2 marks)

One:

Two:

d) Battery engineers replaced hydrogen for lithium metal. They constructed the cell and at STP measured the potential to be 4.12 V. Use this information and that in the standard reduction table to predict the standard reduction potential for lithium. (2 marks)

See next page

Question 31 **(15 marks)**

Orthoperiodic acid (H_5IO_6) has the capacity to behave as a Bronsted-Lowry acid as well as an oxidising agent. It is a white solid at room temperature (m.p. = 128 ^oC) and is very soluble in water.

Below are the K values of orthoperiodic acid donating protons when in water

$H_5IO_6 + H_2O \rightleftharpoons H_4IO_6^- + H_3O^+$ $K_a = 1.20 \times 10^{-4}$

$H_4IO_6^- + H_2O \rightleftharpoons H_3IO_6^{2-} + H_3O^+$ $K_a = 4.90 \times 10^{-9}$

$H_3IO_6^{2-} + H_2O \rightleftharpoons H_2IO_6^{3-} + H_3O^+$ $K_a = 2.51 \times 10^{-12}$

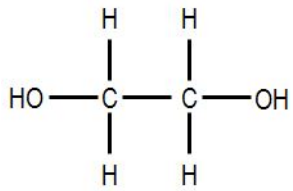
a) List all the species that are demonstrating amphoteric characteristics. (2 marks)

b) Use the K values to justify orthoperiodic acid being classified as a weak triprotic acid. (5 marks)

Periodic acid has two forms – orthoperiodic acid (H_5IO_6) and metaperiodic acid (HIO_4). In both forms, iodine has the same oxidation state.

c) Determine the oxidation state of iodine in both forms of this acid and provide evidence that it is the same. (2 marks)

Vicinal diols such as ethylene glycol (below) can be oxidised and cleaved by orthoperiodic acid to form aldehydes via the Malaprade oxidation reaction. Ethylene glycol ($C_2H_6O_2$) can be oxidised to methanal (CH_2O) while orthoperiodic acid is reduced to the ion $H_2IO_4^-$.



Ethylene glycol

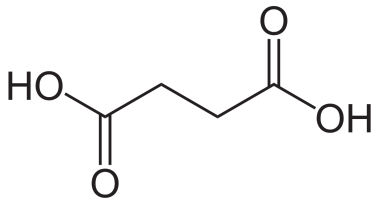
d) Write the balanced half equations and the overall equation for this reaction.

(3 marks)

Oxidation	
Reduction	
Overall	

See next page

Ethylene glycol is made to react with succinic acid to form a polymer.



Succinic acid

e) Draw two repeating structures of the polymer formed. (3 marks)

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See next page

Question 32 **(15 marks)**

Canola oil contains about 65% oleic acid ($C_{17}H_{33}COOH$) and 35% linoleic acid ($C_{17}H_{31}COOH$).

a) From the condensed formulae only, deduce the major difference in the two straight-chained C-18 acids. (1 mark)

b) Draw a condensed formula for the triglyceride that you could expect to find in abundance in canola oil. (2 marks)

c) Write chemical equations to show how canola oil can be used to form soap and biodiesel. (4 marks)

Soap:
Biodiesel:

d) Explain why this biofuel could be considered a “green” source of fuel. (1 mark)

e) Soaps and detergents both form micelles to remove grease and oils from surfaces. With reference to an appropriate diagram and the intermolecular forces present, explain how soaps remove grease from a surface in an aqueous solution. (5 marks)

See next page

f) Hard water is comprised of elevated magnesium and calcium ion concentrations. Describe how detergents are more effective than soaps in hard water (2 marks)

End of Section Two

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See next page

Section Three: Extended Answer **42% (92 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.

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 question where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes

Question 33 **(12 marks)**

Vapour pressure is an indication of a liquid's evaporation rate. It relates to the tendency of particles to escape from the liquid phase. The pressure exhibited by vapour present above a liquid surface is known as vapour pressure.

Amides have a significantly lower vapour pressure than amines, alcohols or esters that have similar molar masses. This is illustrated in the table below.

Compound name	Molar mass ($g\ mol^{-1}$)	Boiling point (ºC)	Vapour pressure at 20°C
Ethanamide	59	221	1.3 Pa
Propan-1-ol	60	97	1.99 kPa
Propan-1-amine	59	51	33.1 kPa
Methyl methanoate	60	32	63.4 kPa

a) Use the data in the table and appropriate diagrams to describe the type of intermolecular forces and justify the relative strength of the intermolecular forces that occur in these substances. (8 marks)

See next page

b) As the temperature of a liquid increases, the vapour pressure also increases for all substances. Use your understanding of kinetic theory to explain why this statement is correct for <u>all</u> liquids regardless of the relative strength of their intermolecular forces.

(4 marks)

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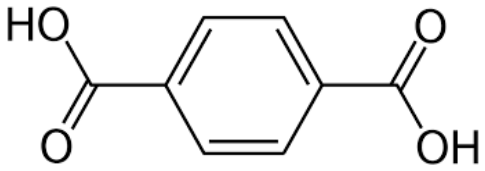
See next page

Question 34 **(15 marks)**

Terephthalic acid is a white solid at room temperature that is a monomer used to make several polymers. It has a chemical structure shown below.



Terephthalic Acid - molecular mass 166.13 g mol^{-1}

A laboratory has been given 100 g of a white solid claiming to be entirely terephthalic acid. The laboratory, which is an expert in titrimetric methods, sets about determining the purity of the acid.

The laboratory accurately weighed 5.012 g of the sample that contained the acid and combined it with approximately 80 mL of distilled water to produce an opaque or turbid solution. To this was added 65.00 mL of a standardised 0.8982 mol L^{-1} sodium hydroxide solution. The mixture was heated until there was no solid evident, before being cooled back to room temperature where the clear and colourless solution was diluted to exactly 250.0 mL with distilled water.

Four 20.00 mL aliquots were taken and each titrated with standardised 0.01016 mol L^{-1} hydrochloric acid until a suitable end point was observed using methyl red indicator.

	1	**2**	**3**	**4**
Final volume (mL)	31.10	32.95	31.90	42.60
Initial volume (mL)	10.85	12.30	11.30	21.90
Titre used (mL)	20.25	20.65	20.60	20.70

a) Justify the reliability for reporting the average titre value to be 20.65 mL. (1 mark)

b) Assuming the only acid in the sample was terephthalic acid, determine the purity of the sample to the appropriate number of significant figures. (7 marks)

See next page

c) Given the laboratory had the option to use any of the indicators listed below justify the use of methyl red as a valid indicator for this titration. (2 marks)

Indicator	End point range	Colour change
Phenolphthalein	8.3 – 9.8	Colourless (acidic) – Purple (basic)
Methyl Red	4.4 – 6.2	Red (acidic) – Yellow (basic)
Phenol Red	6.4 – 8.0	Yellow (acidic) – Red (basic)

d) Explain why the sample was not titrated directly with the standardised sodium hydroxide. (1 mark)

e) The sodium hydroxide concentration was incorrectly calculated as 0.4452 mol L^{-1} after being standardised against a hydrochloric acid secondary standard. Consider the impact on the magnitude of systematic and random error on this action. (2 marks)

Random:

Systematic:

f) To save time the laboratory is considering only titrating one aliquot. Consider the impact on the magnitude of systematic and random error on this action. (2 marks)

Random:

Systematic:

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Question 35 **(22 marks)**

Western Australia accounts for almost 70% of the national gold production. Gold is often found in elemental form in its ores and the refining of such gold can be achieved via a leaching of the metal with cyanide ions in a two-step process before an electrowinning process to recover purified gold metal.

The two-step leaching process begins with the Elsner Equation (Eq 1 below). Metallic gold that is trapped in pulverized ore is be treated with aerated potassium cyanide solution.

$$4\ Au\ (s) + 8\ CN^-\ (aq) + O_2\ (g) + 2\ H_2O\ (\ell) \rightleftharpoons 4\ [Au(CN)_2]^-\ (aq) + 4\ OH^-\ (aq) \qquad \text{Eq 1}$$

a) A gold ore that has been analysed by spectrometry contains 32 grams of gold metal per tonne. A consignment of 1.50 tonnes of ore is passed through the facility and the outflow of liquids are contained in a storage dam at 25 ^oC . The process in Eq 1 allows for a remarkable 92.3% conversion of gold to gold cyanide ions. Calculate the volume of liquid in the dam if the measured pH of the dam after processing is 8.90 (6 marks)

b) Ten moles (10.0 mol) of cyanide ions were introduced to the leaching of 1.50 tonnes of the same gold ore used in part (a). Use Eq 1 to justify that gold was the limiting reagent. (2 marks)

The liquor containing $[Au(CN)_2]^-$ ions is then passed an electrowinning cell containing two inert platinum electrodes and a potassium hydroxide containing electrolyte. The overall equation for the electrowinning process is shown in equation 2 below:

$$4\ [Au(CN)_2]^-\ (aq) + 2\ H_2O\ (\ell) \rightleftharpoons 4\ Au\ (s) + 8\ CN^-\ (aq) + 4\ H^+\ (aq) + O_2\ (g) \qquad \text{Eq 2}$$

c) Equation 2 is a redox system. Use oxidation numbers to provide evidence that the gold cyanide is reduced and identify the species that is being oxidised (3 marks)

d) Write the oxidation and reduction half equations that combine to produce Equation 2. (2 marks)

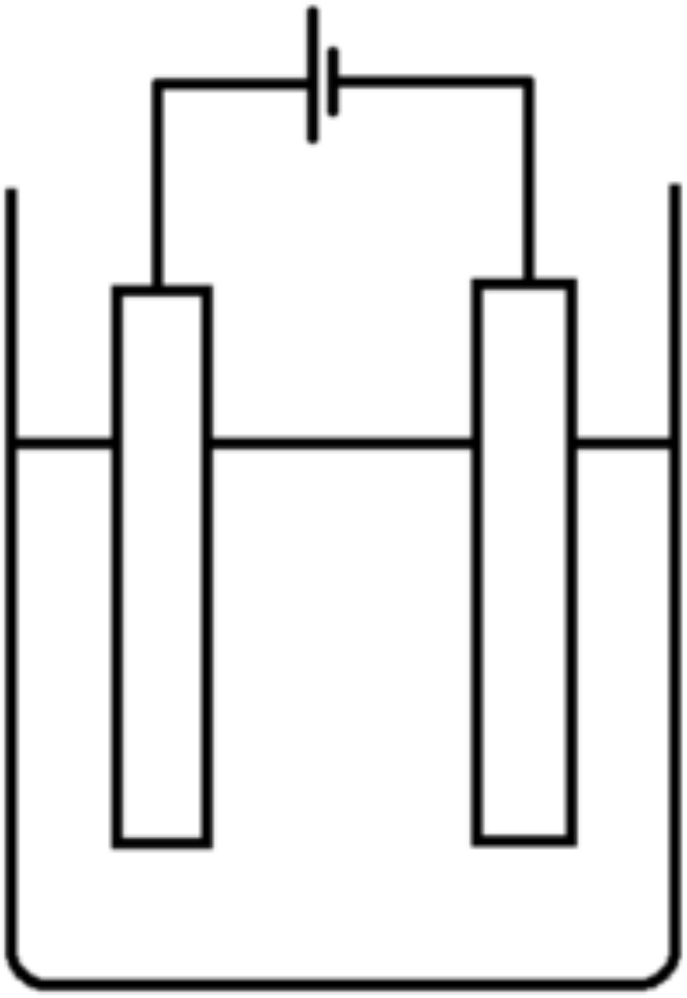
Oxidation	
Reduction	

See next page

e) Label the electrolytic cell diagram provided to illustrate the cell configuration used for the electrowinning of gold in equation 2. Label the diagram clearly showing how the cell would appear after several hours of constant operation with sufficient voltage applied to produce gold metal at the electrode on the right. Both electrodes often used are made of platinum. Be sure to show all details pertaining to:

- Migration of reacting species
- Movement of electrons
- Location of the correct half equations
- Polarity of anode and cathode
- Observations at each electrode

(7 marks)



A resourceful mine site has constructed a processing plant to recycle all cyanide ions present in the dam to a safer alternative in ammonium ions. The recycling process is summarised in equations 3 to 5 below:

$2\ CN^-\ (aq) + O_2\ (g) \rightarrow 2\ OCN^-\ (aq)$ **Eq 3**

$OCN^-\ (aq) + 2\ H_2O\ (\ell) \rightarrow HCO_3^-\ (aq) + NH_3\ (aq)$ **Eq 4**

$NH_3\ (aq) + H_2O\ (\ell) \rightarrow NH_4^+\ (aq) + OH^-\ (aq)$ **Eq 5**

f) To determine the effectiveness of the cyanide recovery, the plant needs to be aware of the overall equation outlining their process. Write the combined equation for the conversion of cyanide ions to ammonium ions using equations 3-5. (2 marks)

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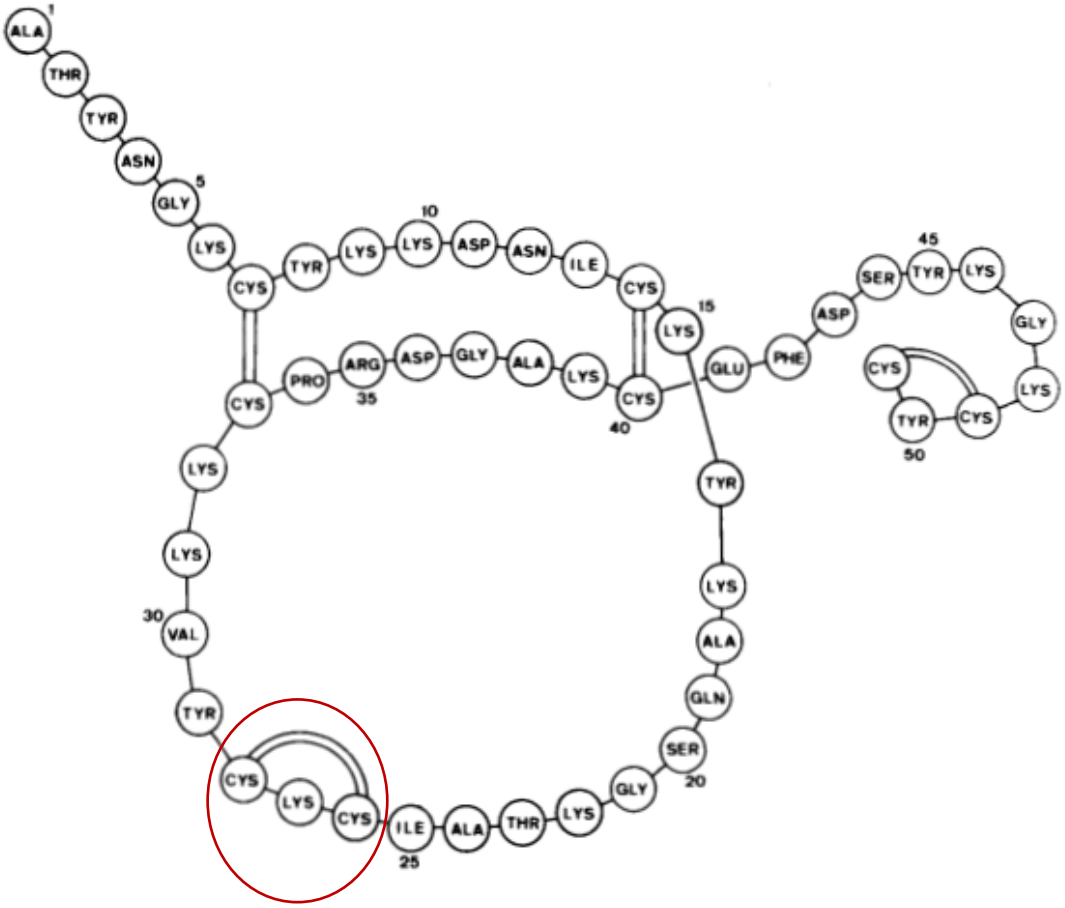
Question 36 **(22 marks)**

A secreted protein which displays antifungal activity was isolated from the medium of the mould, *Aspergillus giganteus*. The protein consists of 51 amino acid residues; and its sequence was determined as displayed below.



A sequence of the peptide containing three amino acids that was to be studied further was isolated. It was supposed that the sequence comprised of the peptide Cys-Lys-Cys. This fragment was isolated for further analysis.

a) Draw the structure of the tripeptide fragment (Cys-Lys-Cys) in alkaline conditions clearly indicating the peptide bonds (4 marks)

b) The protein consists of 51 amino acids and has a complex shape. Describe in detail how this large molecule can maintain its shape. In your response consider the primary, secondary and tertiary structure and what properties of the molecule is responsible for those structural shapes. (5 marks)

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The tripeptide Cys-Lys-Cys was synthesised in the laboratory and analysed as outlined below: Combustion analysis was performed in excess oxygen on a 50.46 mg sample of the peptide, yielded 75.60 mg of carbon dioxide and 30.95 mg of water.

Nitrogen analysis was performed on a separate 76.04 mg sample of the peptide that converts all of the nitrogen in the molecule to ammonia gas (in a 1:1 ratio). This analysis recorded a volume of 9.794 mL of ammonia gas at 28.02 ^{o}C and 220.6 kPa.

All the sulfur in a 33.25 mg sample of the peptide was converted to 44.03 mg of barium sulfate.

Mass spectral analysis confirmed that the molecular mass of the synthetic peptide was 352.5 g mol^{-1} .

c) Use this information to <u>determine the empirical formula</u> of the synthetic peptide and <u>confirm that the molecular formula</u> is $C_{12}H_{24}S_2N_4O_4$. (10 marks)

d) Solutions of the amino acid cysteine (Cys) can migrate to electrically charged plates depending on the pH. Show the structure of cysteine at the following pH when the movement of the amino acid was observed as described below. (3 marks)

Very Low pH	Moderate pH	Very High pH
Migration observed towards negatively charged plate	No migration observed	Migration observed towards positively charged plate

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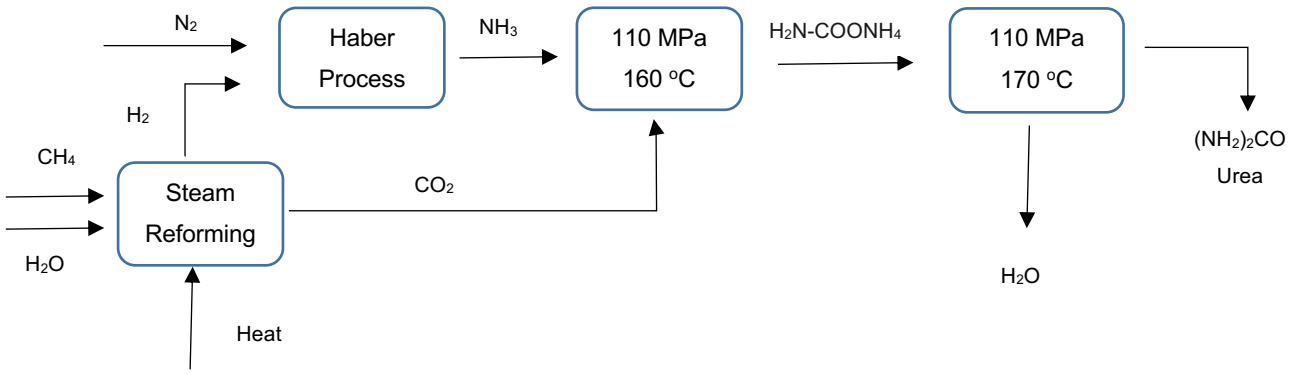
Question 37 **(21 Marks)**

Urea is used extensively as a fertilizer and in the production of polyurethanes. The industrial manufacturing process to obtain urea comprises several chemical processes that are outlined in the schematic and equations below:



The facility uses conditions that provide the following yields which were measured:

Steam Reformation:

Eqn 1: CH_4 (g) + H_2O (g) ⇌ CO (g) + 3 H_2 (g)

Eqn2 : CO (g) + H_2O (g) ⇌ CO_2 (g) + H_2 (g) (yield of CO_2 from methane: 85.7%)

Haber Process:

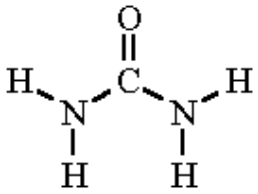
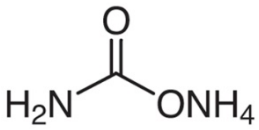
Eqn 3: 2 N_2 (g) + 3 H_2 (g) ⇌ 2 NH_3 (g) (yield 95.6%)

Urea production:

Eqn 4: 2 NH_3 (g) + CO_2 (g) ⇌ H_2N-$COONH_4$ (ℓ) (yield 98.4%)

Eqn5: H_2N-$COONH_4$ (ℓ) ⇌ $(NH_2)_2CO$ (s) + H_2O (g) (yield 88.2%)

The urea production consists sists of two main equilibrium reactions where the product from the equation 4 is fed it equation 5. Equation 4 where carbamate is formed is a a fast reaction of liquid ammonia with gaseous carbon dioxide (CO_2) at high temperature and pressure to form ammonium carbamate (H_2N - $COONH_4$): (ΔH= -117kJ mol^{-1} at 110 MPa and 160°C) The reaction heat from equation 4 is used to drive equation 5. The conditions used by this industrial plant appear to favor carbamate formation and have an unfavorable effect on the urea conversion equilibrium system. The adopted conditions are therefore a compromise.

	
Urea A white solid at room temperature. (Mw = 60.056 g mol^{-1} and Mp = 130 ^oC)	**Ammonium Carbamate** A white ionic solid that decomposes at 60 ^oC. (Mw = 78.07 g mol^{-1})

a) *Consider only the two-step steam reformation process for part (a).*

Use your understanding of equilibria to explain how the conditions of the steam reformation processes can be labelled a compromise. Ensure you consider the impact of the conditions on the equilibria of <u>each</u> of the reactions as well as the economic implications to produce carbon dioxide and hydrogen gases from methane. (7 marks)

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b) Justify that the yield of urea from methane is 71.1%. (1 mark)

c) If the Plant uses liquefied natural gas (LNG) for the source of methane, calculate the volume of LNG needed to produce each tonne of urea if the LNG used contains 90% (by weight) methane and has a density of 0.41 kg L^{-1}. (5 marks)

d) Using only the details above outline two features of this processing plant that enable it to claim that it supports Green Chemistry concepts. (2 marks)

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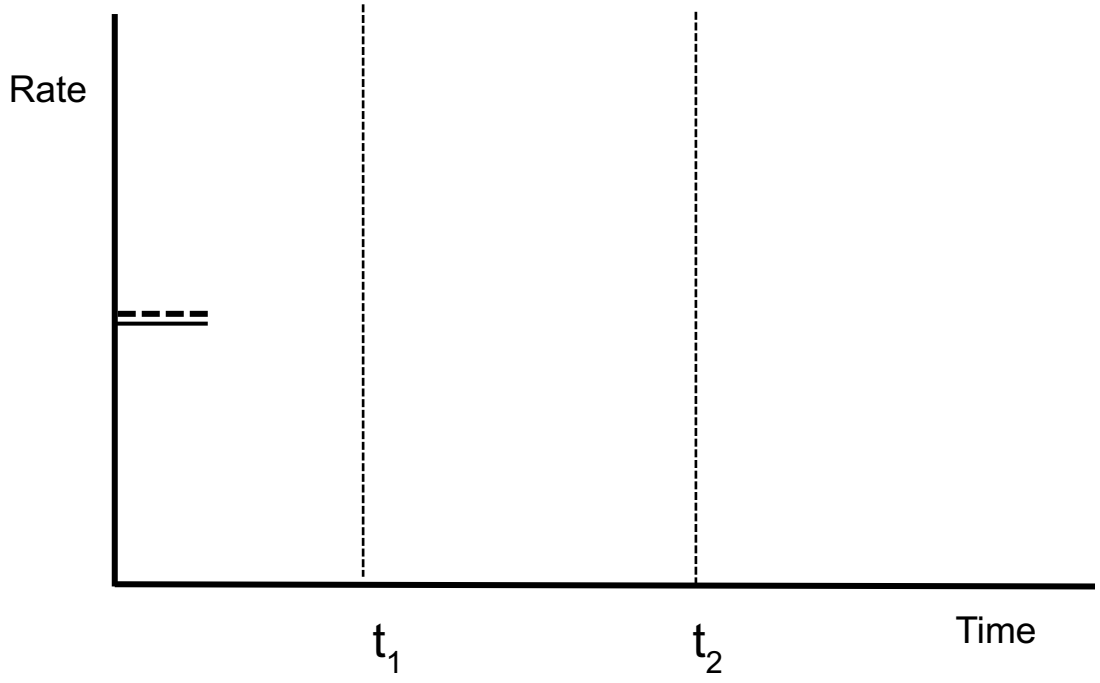
e) A suggestion by an Engineer in the Haber Process facility was to increase the temperature of the reaction chamber. The Haber process is known to have an enthalpy change of – 92 kJ mol $^{-1}$. Show on the graph below how increasing the temperature of the reaction chamber will affect the forward and reverse reaction rates. Assume the system is at equilibrium before the temperature is increased at t_1 and then new equilibrium is re-established at t_2. (3 marks)



f) Account for the changes in rates for the forward and reverse reactions. (3 marks)

End of Questions

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