



ATAR Chemistry

Units 3 & 4

Semester Two

Examination 2023

Question/Answer booklet

Name: _____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

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 notes or other items of a non-personal nature in the examination room. 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 exam	
Section One: Multiple-choice	25	25	50	25	25	
Section Two: Short answer	9	9	60	80	35	
Section Three: Extended answer	5	5	70	86	40	
Total					100	
Final percentage					$\frac{\quad}{25} \times 25 + \frac{\quad}{80} \times 35 + \frac{\quad}{86} \times 40 =$	%

Instructions to candidates

1. Answer the questions according to the following instructions.

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

Sections Two and Three: Write your answers in this Question/Answer Booklet.

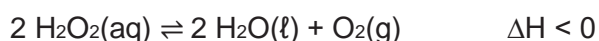
2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.
3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.
5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

Section One: Multiple-choice**25% (25 marks)**

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

Suggested working time: 50 minutes.

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

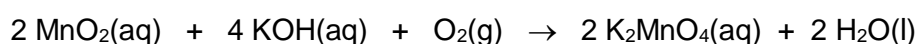


Which one of the following will increase the equilibrium yield of oxygen?

- (a) Decreasing the concentration of hydrogen peroxide.
 - (b) Increasing the total pressure of the system.
 - (c) Decreasing the temperature of the system.
 - (d) Adding an inert gas to the system.
2. Consider a 0.5 mol L^{-1} solution of sodium ethanoate, $\text{NaCH}_3\text{COO}(\text{aq})$. After water, the species present in the highest concentration would be

- (a) $\text{Na}^+(\text{aq})$.
- (b) $\text{CH}_3\text{COO}^-(\text{aq})$.
- (c) $\text{H}_3\text{O}^+(\text{aq})$.
- (d) $\text{OH}^-(\text{aq})$.

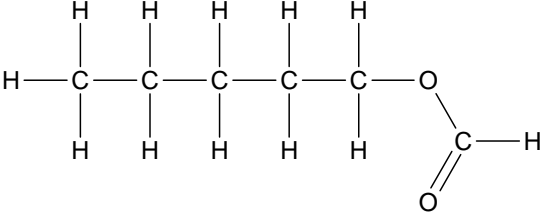
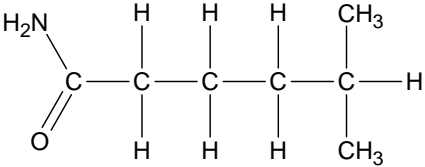
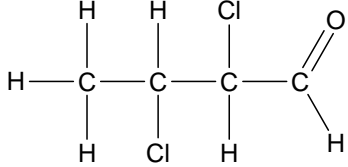
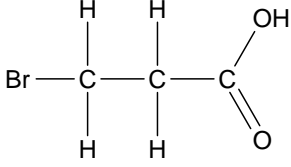
3. Consider the following chemical reaction.



Identify the oxidant and reductant in this reaction.

	Oxidant	Reductant
(a)	O_2	MnO_2
(b)	O_2	KOH
(c)	KOH	MnO_2
(d)	MnO_2	O_2

4. In which of the following does the structural diagram correctly match the IUPAC name given?

<p>(a) methyl pentanoate</p> 	<p>(b) 5-methylhexanamide</p> 
<p>(c) 2,3-dichlorobutan-1-al</p> 	<p>(d) 1-bromopropanoic acid</p> 

5. The function of a catalyst is to

- (i) increase the yield of the reaction.
- (ii) increase the rate of the reaction.
- (iii) increase the activation energy of the reaction.
- (iv) increase the kinetic energy of the reacting particles

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

6. In which of the following compounds is carbon in its highest oxidation state?

- (a)** Methane.
- (b)** Methanal.
- (c)** Methanoic acid.
- (d)** Difluoromethane.

7. The balanced chemical equation representing the complete combustion of propan-1-ol in excess oxygen can be written as;

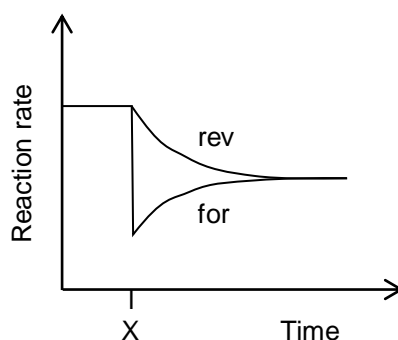
- (a)** $\text{C}_3\text{H}_7\text{OH}(\text{l}) + 3 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}(\text{g}) + 4 \text{H}_2\text{O}(\text{g})$
- (b)** $\text{C}_3\text{H}_7\text{OH}(\text{l}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g})$
- (c)** $2 \text{C}_3\text{H}_7\text{OH}(\text{l}) + 9 \text{O}_2(\text{g}) \rightarrow 6 \text{CO}_2(\text{g}) + 8 \text{H}_2\text{O}(\text{g})$
- (d)** $2 \text{C}_3\text{H}_7\text{OH}(\text{l}) + 10 \text{O}_2(\text{g}) \rightarrow 6 \text{CO}_2(\text{g}) + 8 \text{H}_2\text{O}(\text{g})$

Questions 8 and 9 refer to the following information.

The acid ionisation constants of three monoprotic acids are listed in the table below.

Name	Formula	K_a value
Chlorous acid	HClO_2	1.1×10^{-2}
Hydrofluoric acid	HF	7.2×10^{-4}
Nitrous acid	HNO_2	4.0×10^{-4}

8. When titrating 20.00 mL aliquots of $0.1000 \text{ mol L}^{-1}$ solutions of these acids, which would require the greatest volume of $0.2500 \text{ mol L}^{-1} \text{ NaOH(aq)}$ to reach the equivalence point?
- (a) Chlorous acid.
 (b) Hydrofluoric acid.
 (c) Nitrous acid.
 (d) The acids above would all require the same volume.
9. Which of the following solutions would have the lowest pH?
- (a) $\text{NaClO}_2(\text{aq})$.
 (b) NaF(aq) .
 (c) $\text{NaNO}_2(\text{aq})$.
 (d) The solutions above would all have the same pH.
10. Consider the following reaction rate versus time graph, which illustrates the effect of an imposed change on an equilibrium system.

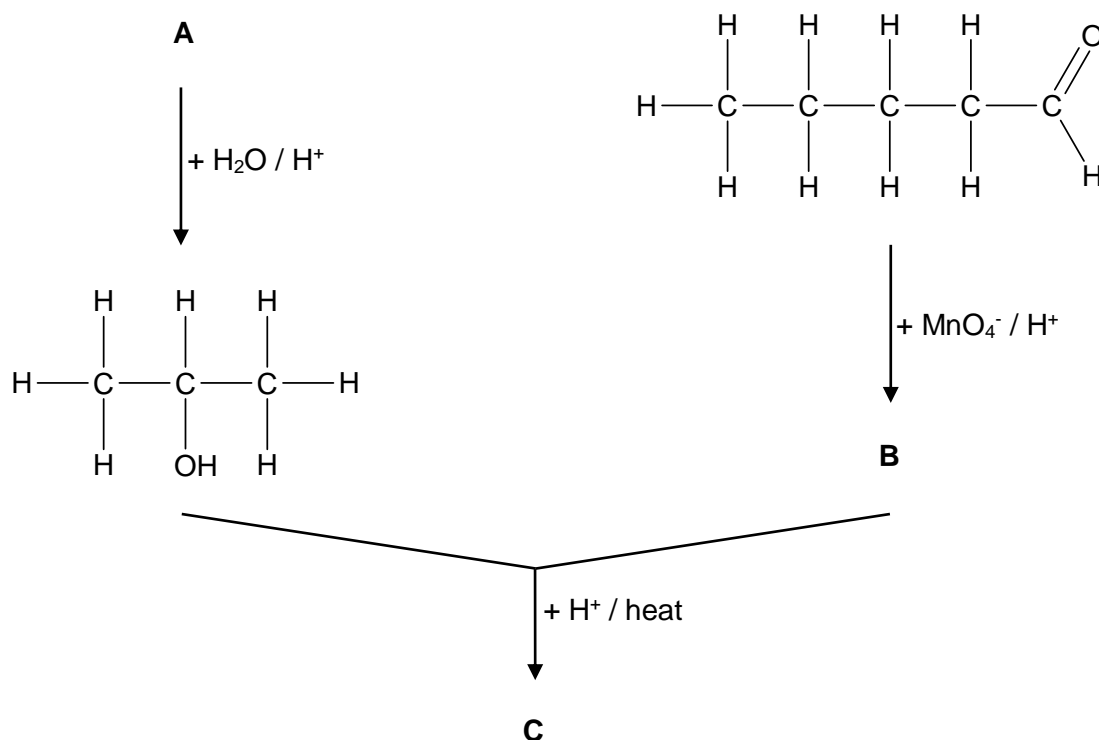


Based on the information in this graph, it can be determined that at Time X, the concentration of a

- (a) reactant was increased.
 (b) reactant was decreased.
 (c) product was increased.
 (d) product was decreased.

Questions 11 and 12 refer to the following chemical synthesis process.

The following reaction sequence has been designed to produce a particular organic compound.



11. Identify the IUPAC name of organic compounds A and B.

A	B
(a) propene	pentan-1-ol
(b) propene	pentanoic acid
(c) propane	pentanoic acid
(d) propane	pentan-1-ol

12. The semi-structural formula of compound C is;

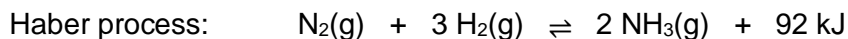
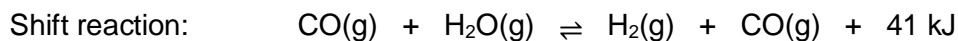
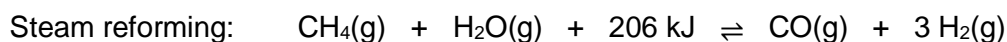
- (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3$
 (b) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COCH}_2\text{CH}_2\text{CH}_3$
 (c) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}(\text{CH}_3)_2$
 (d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COCH}(\text{CH}_3)\text{CH}_3$

13. Hypochlorite ions (ClO^-) can undergo self-redox, which results in the formation of both chloride ions (Cl^-) and chlorate ions (ClO_3^-). The correct coefficient for H^+ in the balanced oxidation half-equation for this process would be

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

Questions 14 and 15 refer to the industrial production of ammonia.

The chemical equations below represent the three steps involved in the production of ammonia.

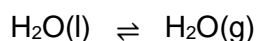


14. A condition of high temperature would best be utilised to optimise the equilibrium yield of
- (a) the steam reforming.
 - (b) the Shift reaction.
 - (c) the Haber process.
 - (d) both the Shift reaction and the Haber process.
15. A condition of high pressure would best be utilised to optimise the equilibrium yield of
- (a) the steam reforming.
 - (b) the Shift reaction.
 - (c) the Haber process.
 - (d) both the Shift reaction and the Haber process.
16. A protein structure contains (amongst others) the α -amino acids cysteine and methionine. Which of the following interactions can take place between the side chains of these two α -amino acids?
- (a) Ionic bonding.
 - (b) Dipole-dipole forces.
 - (c) Disulfide bridge.
 - (d) Hydrogen bonding.

17. Which of the following is **not** an isomer of butanoic acid?

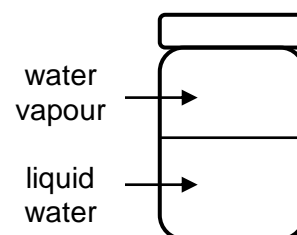
- (a) Methyl propanoate
- (b) 2-hydroxybutanal
- (c) 3-hydroxybutan-2-one
- (d) 1-hydroxy-3-methylbutan-2-one

18. A sealed jar containing distilled water was left on a bench top, and the following equilibrium was established.



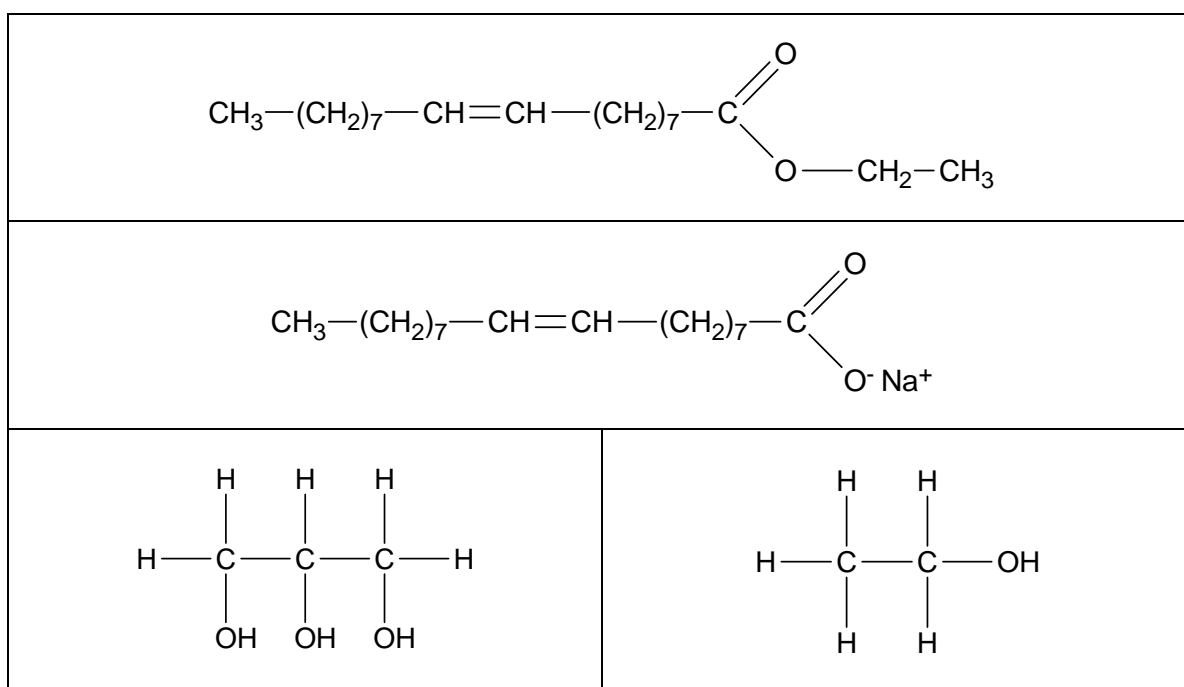
If the temperature of the surroundings was increased, this would

- (a) decrease the rate of condensation.
- (b) increase the liquid water level.
- (c) decrease the mass of water vapour.
- (d) increase the value of K_c .



Questions 19 and 20 refer to the production of biodiesel.

A particular batch of biodiesel had just been made, when a sample was taken from the reaction chamber. Upon analysis, the final reaction mixture was found to contain the following organic substances;

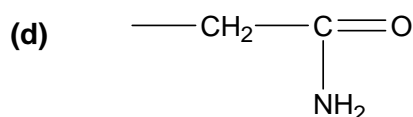
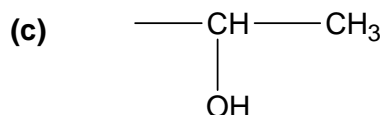
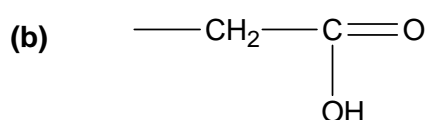
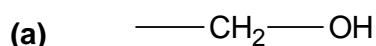


19. Which of the following reagents is **least** likely to have been used in the production of this batch of biodiesel?

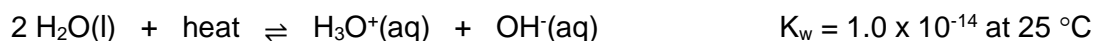
- (a) Triglyceride.
- (b) Ethanol.
- (c) Lipase.
- (d) Sodium hydroxide.

See next page

20. A major advantage of biodiesel, compared to petrodiesel, is that
- (a) it is produced from renewable resources.
 - (b) its production does not require the use of any unsafe chemicals.
 - (c) it does not produce carbon emissions when combusted.
 - (d) its production does not have any negative environmental impacts.
21. Octanoic acid has a higher boiling point than propanoic acid because
- (a) octanoic acid is considered to be more polar.
 - (b) octanoic acid exhibits stronger hydrogen bonding between molecules.
 - (c) the non-polar region in octanoic acid is larger.
 - (d) the dispersion forces between octanoic acid molecules are stronger.
22. An α -amino acid has the molecular formula $C_4H_9NO_3$. The arrangement of the side chain (R group) on this amino acid is most likely;



23. The following chemical equation represents the autoionisation of pure water.



For which temperature range is liquid water considered to be neutral under atmospheric pressures?

- (a) Between $0 \text{ }^\circ\text{C}$ and $25 \text{ }^\circ\text{C}$.
- (b) At $25 \text{ }^\circ\text{C}$ only.
- (c) Between $25 \text{ }^\circ\text{C}$ and $100 \text{ }^\circ\text{C}$.
- (d) Between $0 \text{ }^\circ\text{C}$ and $100 \text{ }^\circ\text{C}$.

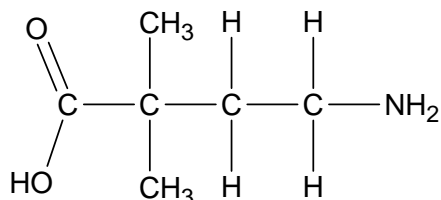
24. A group of chemistry students set up a small-scale cell to replicate the process of copper electrorefining.

The initial mass of the anode and cathode were each recorded as 45.0 g. The cell was then connected to a power source and run for a period of 2 hours.

Assuming the cell had been set up correctly, which of the following is most likely to represent the final mass of each electrode?

	Anode	Cathode
(a)	42.8 g	46.2 g
(b)	43.2 g	47.1 g
(c)	47.3 g	42.9 g
(d)	46.6 g	43.1 g

25. The monomer below was used to produce a polyamide.



Which of the following correctly shows the structure of this polyamide?

- (a) $\text{---O---C(=O)---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---O---C(=O)---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---O---C(=O)---C(CH}_3\text{)}_2\text{---}$
- (b) $\text{---C(=O)---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---C(=O)---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---C(=O)---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---}$
- (c) $\text{---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---CH}_2\text{---N---}$
- (d) $\text{---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---N---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---N---C---C(CH}_3\text{)}_2\text{---CH}_2\text{---N---C---C(CH}_3\text{)}_2\text{---}$

End of Section One

See next page

Section Two: Short answer

35% (80 marks)

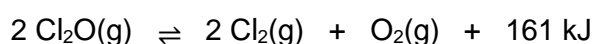
This section has 9 questions. Answer **all** questions. Write your answers in the spaces provided. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

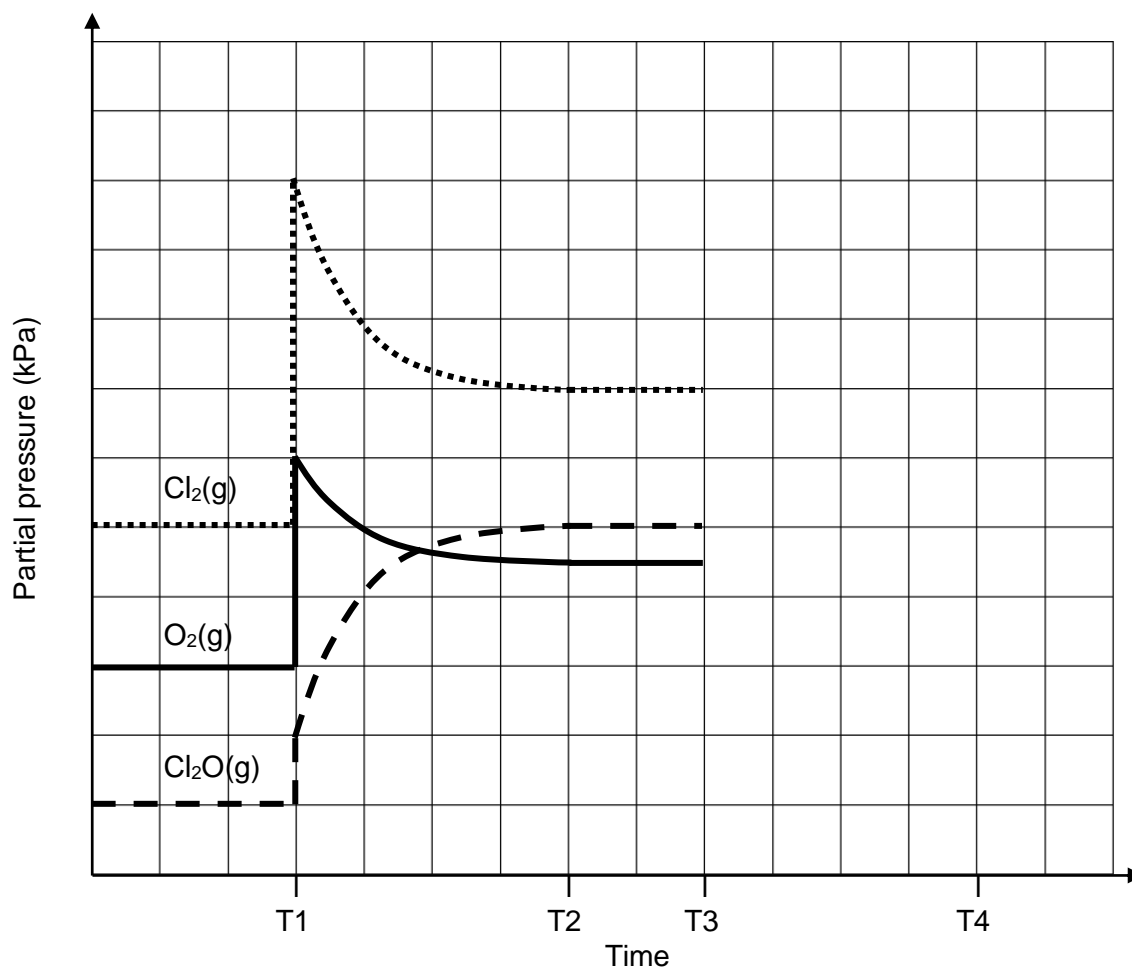
Question 26

(11 marks)

A sample of dichlorine monoxide was placed into an empty chamber, and allowed to establish equilibrium according to the chemical equation below.



Some changes were then imposed on the system and the associated changes in partial pressure were recorded on the graph below.



- (a) Identify the change that was imposed on the system at Time T1. (1 mark)

(b) State and explain what happened to the **forward** reaction rate during each of the following time periods;

(i) instantaneously, at Time T1. (3 marks)

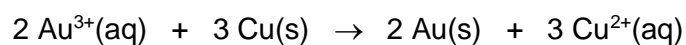
(ii) between Time T1 and T2. (4 marks)

At Time T3, the temperature of the system was increased.

(c) On the graph on the previous page, continue the curves from Time T3 until equilibrium was re-established at Time T4. (3 marks)

Question 27**(6 marks)**

Consider the chemical reaction given below.



- (a)** Identify the type of redox reaction occurring. (1 mark)

- (b)** Justify this is a redox reaction, by describing the process of electron transfer taking place. (1 mark)

- (c)** Justify this is a spontaneous redox reaction. (2 marks)

- (d)** Describe the observations that would be associated with this reaction. (2 marks)

Question 28**(9 marks)**

A 1.074 g piece of magnesium was placed in a beaker containing 175 mL of hydrochloric acid. The reaction was allowed to proceed until all the magnesium had dissolved. The final pH of the solution was measured using a pH meter and found to be 3.03.

- (a)** Write a balanced ionic equation for the reaction that would take place. Include state symbols in your answer. (2 marks)

- (b)** Calculate the original pH of the hydrochloric acid solution. (7 marks)

Question 29

(9 marks)

(a) Complete the following table by;

- drawing structural diagrams for the organic substances named, and
- stating the expected observations for the distinguishing test described. (6 marks)

IUPAC name: 2-methylpropanoic acid	IUPAC name: 3,3,4-trifluorobutanal
Structural diagram:	Structural diagram:
A small amount of $\text{MgCO}_3(\text{s})$ powder is added.	
Distinguishing observation:	Distinguishing observation:

(b) Complete the following table by;

- stating the correct IUPAC name for the organic substances drawn, and
- identifying the chemical(s) which could be used to produce the distinguishing observations given.

(3 marks)

IUPAC name:	IUPAC name:
Structural diagram: $ \begin{array}{ccccccc} & & \text{H} & & & & \\ & & & & & & \\ & \text{H} & - \text{C} & - \text{H} & & & \\ & & & & & & \\ & \text{H} & - \text{C} & - \text{H} & & & \\ & & & & \text{Br} & & \text{H} \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{C} & - \text{C} & - \text{H} \\ & & & & & & \\ & \text{H} & \text{H} & \text{O} & \text{H} & \text{H} & \\ \end{array} $	Structural diagram: $ \begin{array}{ccccccccc} & & \text{H} & & \text{OH} & & \text{H} & & \text{H} & & \text{H} & & \\ & & & & & & & & & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & & & & & & \\ & & \text{H} & & \text{H} & & \text{Cl} & & \text{H} & & \text{Cl} & & \\ \end{array} $
<p style="text-align: center;">A few drops of</p> <p style="text-align: center;">_____</p> <p style="text-align: center;">is added and warmed.</p>	
Distinguishing observation: <p style="text-align: center;">Final colour of solution remains orange.</p>	Distinguishing observation: <p style="text-align: center;">Orange solution becomes deep green.</p>

Question 30

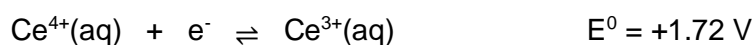
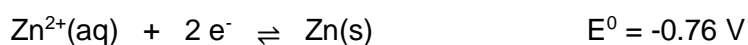
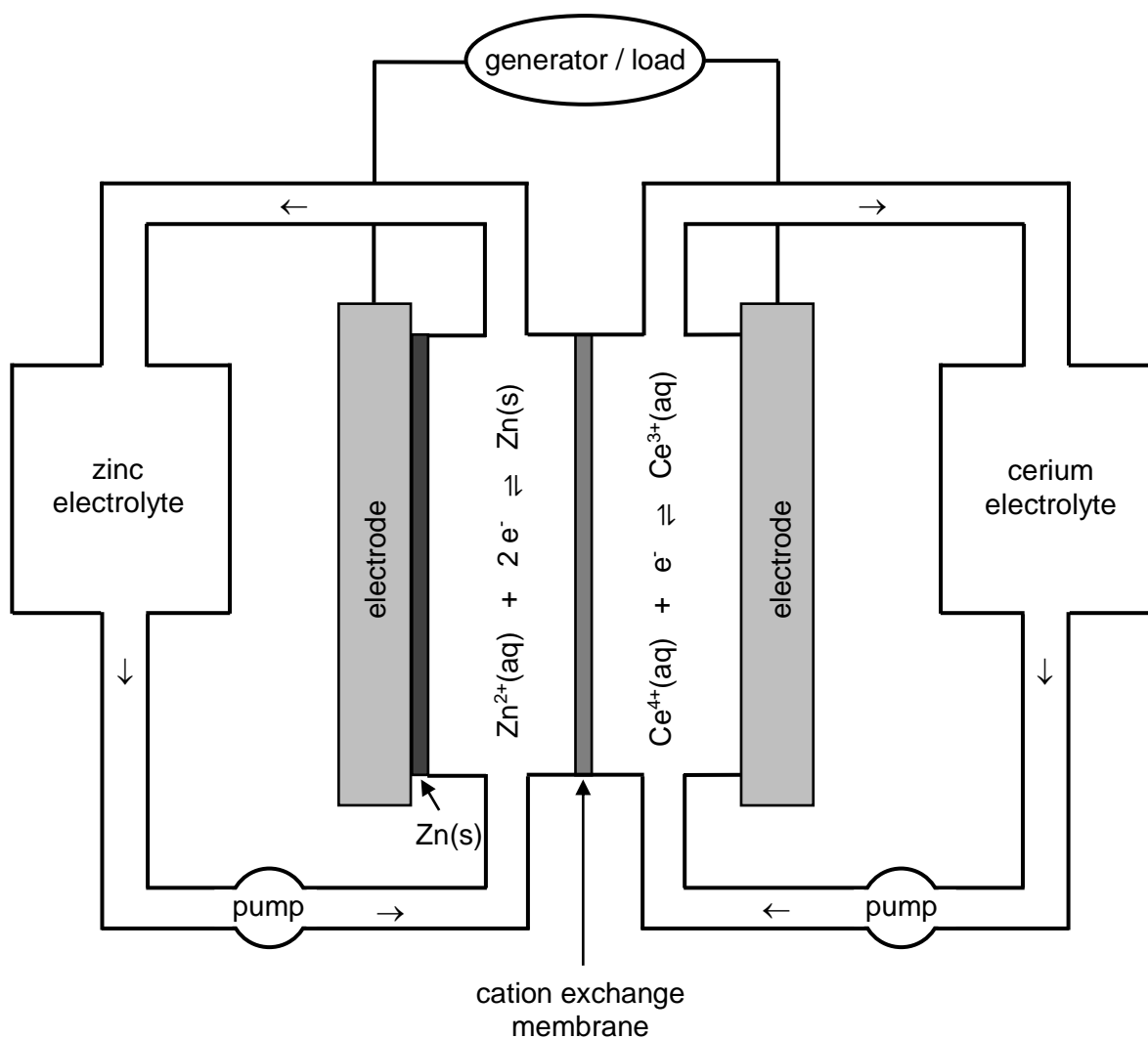
(8 marks)

The zinc-cerium battery is a type of 'redox flow battery'. These batteries are so named, because in each half-cell the electrolyte is continually circulated.

An electrolyte containing zinc ions circulates in one half-cell, whilst an electrolyte containing cerium ions circulates in the other. Both electrolytes are acidified using methanesulfonic acid, and a cation exchange membrane ensure the electrolytes do not mix.

Zinc-cerium batteries are rechargeable, since the half-cell reactions can be reversed.

A diagram of the zinc-cerium battery is shown below, as well as the relevant half-equations and standard reduction potential data.



See next page

- (a) Suggest a reason that 'redox flow batteries' are classified as a type of fuel cell. (1 mark)

- (b) Classify the zinc-cerium battery as a primary or secondary cell. (1 mark)

- (c) Consider the chemical processes occurring at the electrode in the zinc half-cell during **discharge**, and complete the following table. (3 marks)

Classify this electrode as the 'anode' or 'cathode'.	
Classify the polarity of this electrode as 'positive' or 'negative'.	
Identify whether cations would move 'toward' or 'away from' this electrode.	

- (d) Calculate the maximum voltage produced by the zinc-cerium cell, under standard conditions. (1 mark)

- (e) Write a balanced chemical equation for the overall reaction that occurs during **recharge** of the zinc-cerium battery. (2 marks)

Question 31**(10 marks)**

An organic substance known to contain only carbon, hydrogen and nitrogen was analysed.

A 1.839 g sample of the compound was found to contain 0.857 g of nitrogen. The percentage by mass of carbon in the compound was known to be 39.9%.

(a) Determine the empirical formula of the compound.

(4 marks)

A separate 0.633 g sample of the same compound was placed in a conical flask containing 25.00 mL of distilled water and swirled until all the solid dissolved. It was also known that this compound was a diprotic base (i.e. capable of accepting two protons).

Volumetric analysis determined that 28.44 mL of 0.7406 mol L⁻¹ HNO₃(aq) was required to reach the equivalence point.

(b) Determine the molecular formula of the compound. (4 marks)

(c) Draw a possible structural diagram for this compound. (2 marks)

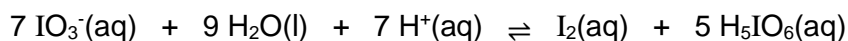
Structural diagram	
--------------------	--

Question 32

(9 marks)

When iodine (I_2) and starch are mixed, they form a dark blue coloured complex. This occurs because the iodine becomes bound within the helices found in starch, effectively removing it from solution.

Consider the following chemical reaction involving iodine.



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

The chemical reaction above was set up in a beaker and allowed to establish equilibrium. The colour of the equilibrium mixture was pale brown due to the presence of iodine.

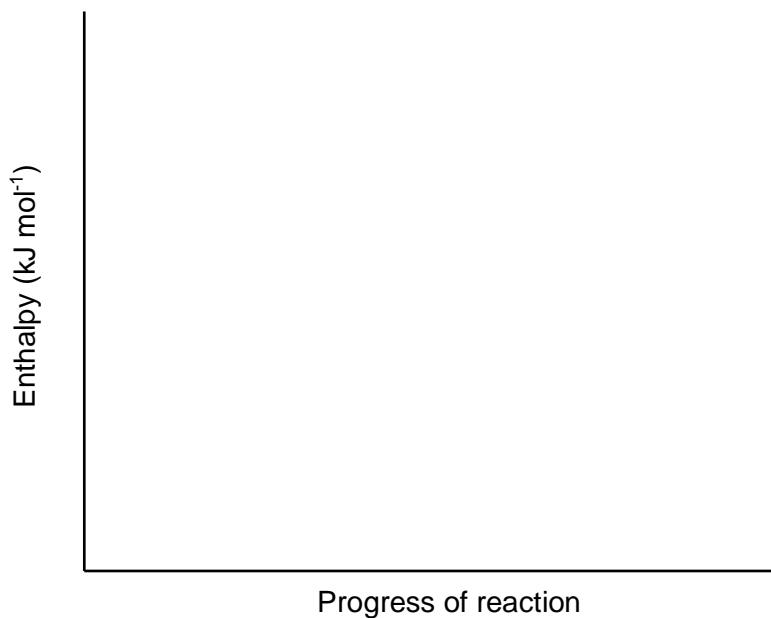
The mixture was then divided into three separate beakers. The table below summarises the tests conducted on the first two beakers.

- (b) Complete this table by stating how each of the changes would affect;
- (i) the rate of the forward reaction once equilibrium is re-established, and
 - (ii) the position of equilibrium. (4 marks)

	Rate of forward reaction (state 'increased', 'decreased', or 'no change')	Position of equilibrium (state 'shift left', 'shift right', or 'no change')
A few drops of starch solution was added.		
A 100 mL aliquot of distilled water was added.		

The final beaker containing the equilibrium mixture was placed in the fridge for an hour. The colour of the solution was subsequently noted to be a darker brown.

- (c) On the axes below, sketch an energy profile diagram for this reaction. Label the activation energy and enthalpy change. (3 marks)



This page is intentionally blank.

See next page

Question 33

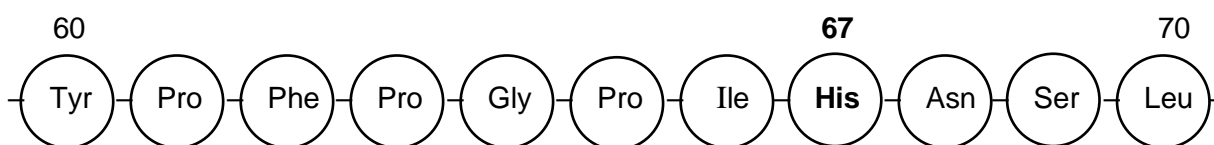
(8 marks)

A2 cow's milk has become popular on supermarket shelves in recent years. This milk is named for the type of 'beta casein' protein it contains.

The beta casein protein has two common variants named A1 and A2. Both these variants are comprised of 209 amino acids.

The sequence of amino acids in the A1 and A2 protein is identical, except for the amino acid at position 67. In the A1 variant, the 67th amino acid is histidine, whilst in the A2 variant it is proline.

The diagram below gives the sequence of amino acids in the A1 protein from position 60 to 70, with position 67 shown in **bold**.



- (a) Identify the number of peptide bonds that would be formed during synthesis of the entire beta casein protein. (1 mark)

- (b) Identify whether the diagram above represents the primary, secondary or tertiary structure of the beta casein protein. (1 mark)

- (c) Draw a full structural diagram of the **A2 variant** of the beta casein protein, showing only the amino acid residues from position 66 to 68. (3 marks)

When we drink milk, the proteins in it are broken down by our digestive system. The difference in the 67th amino acid of beta casein changes the shape of the protein, and results in the formation of different digestion by-products. This has led to reports by some people that they find A2 milk easier to digest.

(d) Explain how an amino acid change can result in alteration of the shape of a protein.

(3 marks)

-
- (b) Explain why a much lower temperature of 25-35 °C is used for the production of ethanol by the fermentation method. (2 marks)

End of Section Two

See next page

Section Three: Extended answer**40% (86 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

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.

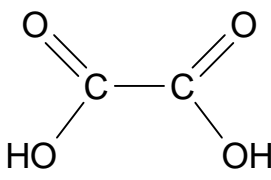
Suggested working time: 70 minutes.

Question 35**(21 marks)**

The rhubarb plant has been used for thousands of years, as both a food source and in traditional medicines. Whilst the red-pink stalks are edible, rhubarb leaves are poisonous. This is thought to be due to the high levels of oxalic acid present in the leaves.

When consumed in large amounts, oxalic acid can cause kidney failure. A lethal dose of oxalic acid is considered to be **375 mg per kilogram of body weight**.

Some information regarding oxalic acid is provided in the table below.

Name	oxalic acid
Molecular formula	$\text{H}_2\text{C}_2\text{O}_4$
Structural diagram	
Molar mass	$90.036 \text{ g mol}^{-1}$

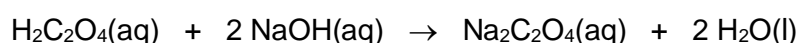
- (a) Explain why oxalic acid is highly soluble in water. (4 marks)

A chemistry student harvested a rhubarb plant from the school vegetable garden and performed a titration to determine the oxalic acid concentration in rhubarb leaves.

A sample of rhubarb leaves weighing 73.82 g was taken, and to it was added a small amount of distilled water. The mixture was then blended until a smooth liquid was produced. The liquid was filtered to remove any solid particles.

The filtered liquid was placed in a 100.0 mL volumetric flask, made up to the mark with distilled water, and inverted several times. The dilute solution was then poured into a burette.

This solution was titrated against a 20.00 mL aliquot of standard 0.1014 mol L⁻¹ sodium hydroxide solution, according to the chemical equation below. A titre of 19.54 mL was required to reach the equivalence point.



- (b) Explain why phenolphthalein, which has an end point of approximately pH 8.3 - 10, is an appropriate indicator choice for this titration. Use a chemical equation to support your answer. (3 marks)

- (c) Calculate the percentage by mass of oxalic acid in the rhubarb leaves. State your answer to the appropriate number of significant figures. (7 marks)

- (d) Calculate the mass of rhubarb leaves that would need to be ingested by an average 70 kg person, to result in a lethal dose of oxalic acid being consumed. (2 marks)

The student considered possible improvements to their investigation.

- (e) Identify if the suggested improvement would increase the accuracy, reliability, or validity of the investigation. (2 marks)

	Which is increased? (state 'accuracy,' 'reliability,' or 'validity')
Sampling leaves from different rhubarb plants grown in different geographical regions.	
Repeating the volumetric analysis several times to obtain an average titre.	

Consider the impact of incorrectly rinsing the burette with water in this titration.

- (f) State and explain the effect of this error on the calculated percentage by mass of oxalic acid in the rhubarb leaves. (3 marks)

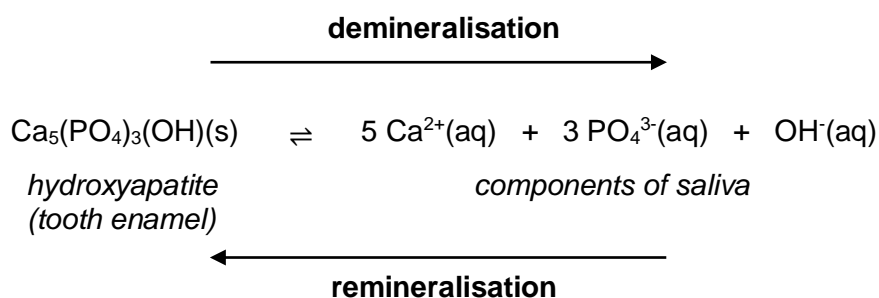
Question 36

(17 marks)

The hardest substance in the human body is enamel – the white outer layer of the tooth. About 96% of enamel is comprised of the mineral hydroxyapatite, $\text{Ca}_5(\text{PO}_4)_3(\text{OH})(\text{s})$.

Small amounts of hydroxyapatite dissolve in the saliva in your mouth, in a process called demineralisation. The calcium and phosphate ions in your saliva are also remineralised back into hydroxyapatite. Saliva has a pH range of about 6.2 to 7.4, in order to maintain a healthy mouth environment.

The equation below represents this reversible process.



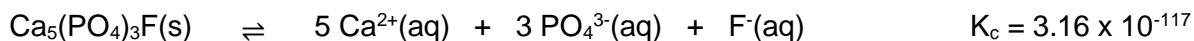
- (a) Explain how the total mass of hydroxyapatite in teeth can remain constant, despite the processes of demineralisation and mineralisation continually occurring. (2 marks)

Brushing your teeth helps minimise tooth decay by removing leftover food and acids from your teeth. Toothpaste also contains fluoride which helps to strengthen teeth by converting some of the hydroxyapatite into fluorapatite.

The chemical equations below compare the demineralisation and remineralisation processes associated with both hydroxyapatite and fluorapatite.



hydroxyapatite



fluorapatite

- (f) By referring to the K_c values provided, justify why the presence of fluorapatite in teeth protects against tooth decay. (2 marks)

Question 37**(15 marks)**

Hard water is water with a high mineral content. A sample of hard water, thought to contain reasonably high concentrations of both $\text{Ca}^{2+}(\text{aq})$ and $\text{Mg}^{2+}(\text{aq})$ ions, was analysed to determine its chemical composition.

During the initial analysis, the concentration of $\text{Ca}^{2+}(\text{aq})$ ions in the hard water was determined using atomic absorption spectroscopy. This was recorded as $0.004117 \text{ mol L}^{-1}$.

The next stage of the analysis investigated the behaviour of the hard water with soap. A 385 mL sample of the hard water was mixed with excess sodium palmitate, $\text{C}_{15}\text{H}_{31}\text{COONa}(\text{s})$. The mixture was thoroughly shaken and then left to settle. The scum formed was collected and dried, and its total mass was determined to be 1.636 g.

You may assume the scum was composed entirely of;

- calcium palmitate, $\text{Ca}(\text{C}_{15}\text{H}_{31}\text{COO})_2(\text{s})$ ($M = 550.896 \text{ g mol}^{-1}$), and
- magnesium palmitate, $\text{Mg}(\text{C}_{15}\text{H}_{31}\text{COO})_2(\text{s})$ ($M = 535.126 \text{ g mol}^{-1}$).

(a) Calculate the concentration of $\text{Mg}^{2+}(\text{aq})$, in mg L^{-1} , in the hard water sample. (7 marks)

- (b) Calculate the minimum mass of sodium palmitate, $C_{15}H_{31}COONa(s)$ ($M = 278.398 \text{ g mol}^{-1}$), required to ensure precipitation of all the $Ca^{2+}(aq)$ and $Mg^{2+}(aq)$ ions. (3 marks)

Sodium palmitate is a soap, as well as a common ingredient in many skincare and cosmetic products.

- (c) Write a balanced chemical equation showing how the soap sodium palmitate can be produced. (3 marks)

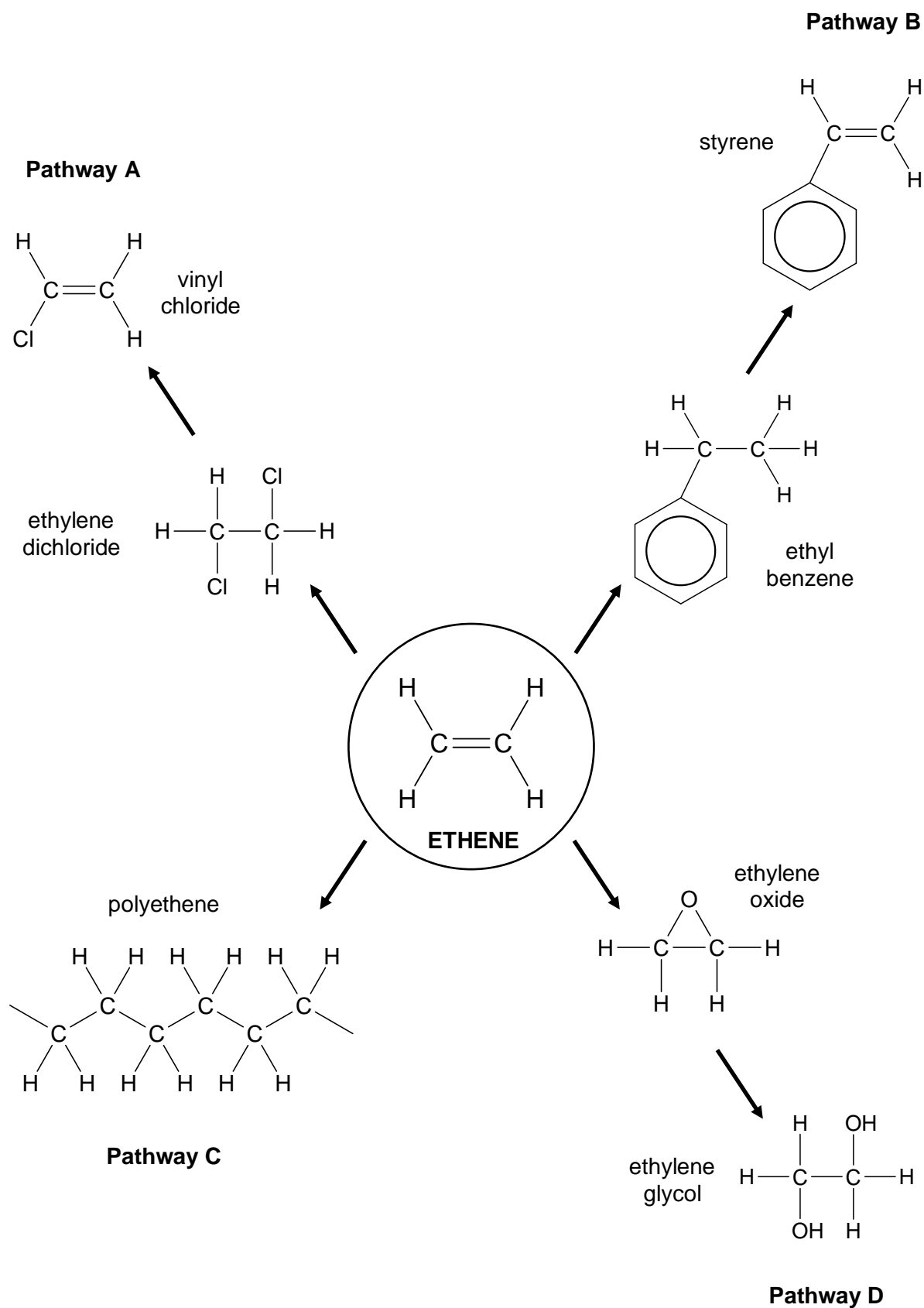
If an item of clothing needed to be washed in this hard water, a detergent would likely be used, instead of sodium palmitate.

- (d) Explain why the detergent would be a more effective choice. (2 marks)

Question 38

(19 marks)

Ethene (CH_2CH_2) is an extremely important chemical and has a wide variety of uses. The vast majority of ethene is used in one of the four reaction pathways shown in the diagram below.



See next page

Consider the reaction sequence summarised by **Pathway A**. The first step in this pathway involves the conversion of ethene to ethylene dichloride.

- (a) Complete the table below by;
- (i) identifying the other reactant required to convert ethene to ethylene dichloride, and
 - (ii) naming the type of reaction occurring in this step. (2 marks)

Identity of other reactant required	
Type of reaction occurring	

The vinyl chloride produced by this pathway can then be polymerised to form polyvinylchloride (PVC).

- (b) Identify the type(s) of intermolecular force(s) that would exist within a sample of PVC. (1 mark)

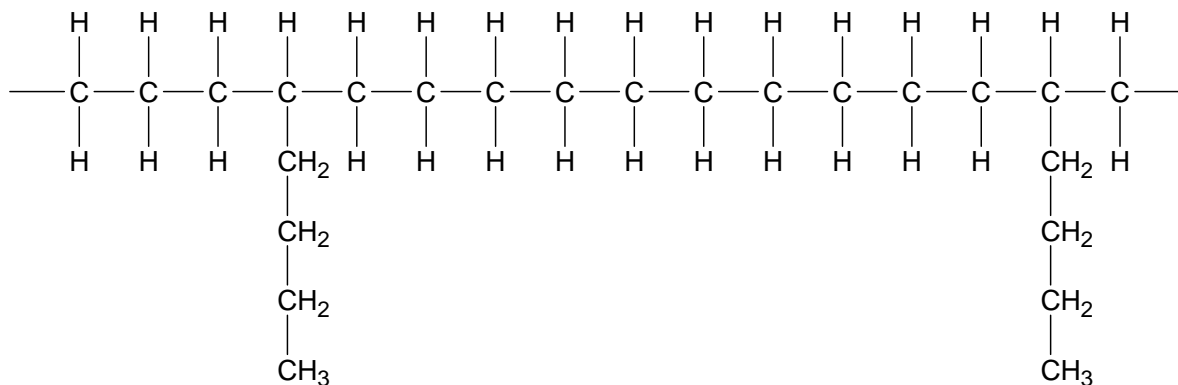
Consider **Pathway B** which illustrates the formation of styrene. Styrene can be polymerised to form polystyrene.

- (c) Draw a structural diagram showing three (3) repeating units of polystyrene. (2 marks)

Over half the global supply of ethene is converted to polyethene, as shown in **Pathway C**.

Several different forms of polyethene exist, and these generally vary in terms of the chain length and degree of branching. One such form is 'linear low density polyethene' (LLDPE), which is produced by the polymerisation of ethene with hex-1-ene.

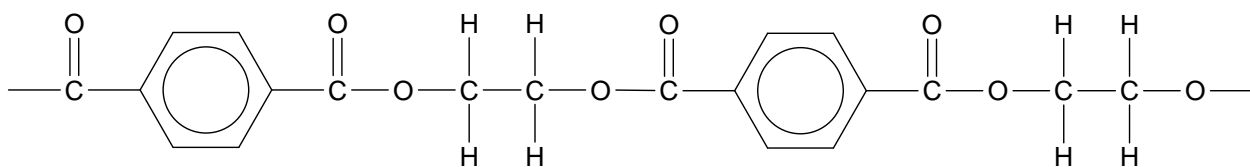
A diagram showing the structure of LLDPE is given below.



Consider the effect of incorporating a greater amount of hex-1-ene into the polymer.

- (d) State the effect this would have on the melting point of the LLDPE, and justify your answer by referring to the role of intermolecular forces present in the polymer. (3 marks)

Pathway D represents the production of ethylene glycol, which is used in the production of polyethylene terephthalate (PET). The following diagram illustrates the structure of PET.

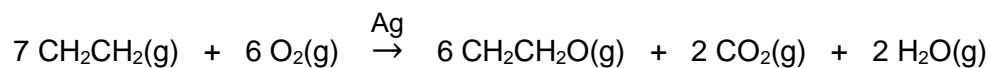


- (e) Complete the table below by;
- (i) drawing the structure of the other monomer required, and
 - (ii) naming the type of polymerisation reaction occurring to produce PET. (2 marks)

Structural diagram of other monomer required	
Type of polymerisation reaction occurring	

As shown in this pathway, the manufacture of ethylene glycol first requires production of the intermediate ethylene oxide, $\text{CH}_2\text{CH}_2\text{O}(\text{g})$.

This process involves reacting ethene gas with 'enriched oxygen', which is a gaseous solution containing 95.0% $\text{O}_2(\text{g})$. This reaction takes place in the presence of silver, as shown in the chemical equation below.



A particular reaction chamber contained 13.6 kL of 'enriched oxygen'. The temperature and pressure within the chamber were 260 °C and 2500 kPa respectively.

A 228 kg quantity of ethene was then added to the chamber, and the reaction allowed to proceed.

- (f) Determine the limiting reagent. Show all workings. (6 marks)

Upon completion of the reaction, 279 kg of ethylene oxide was recovered.

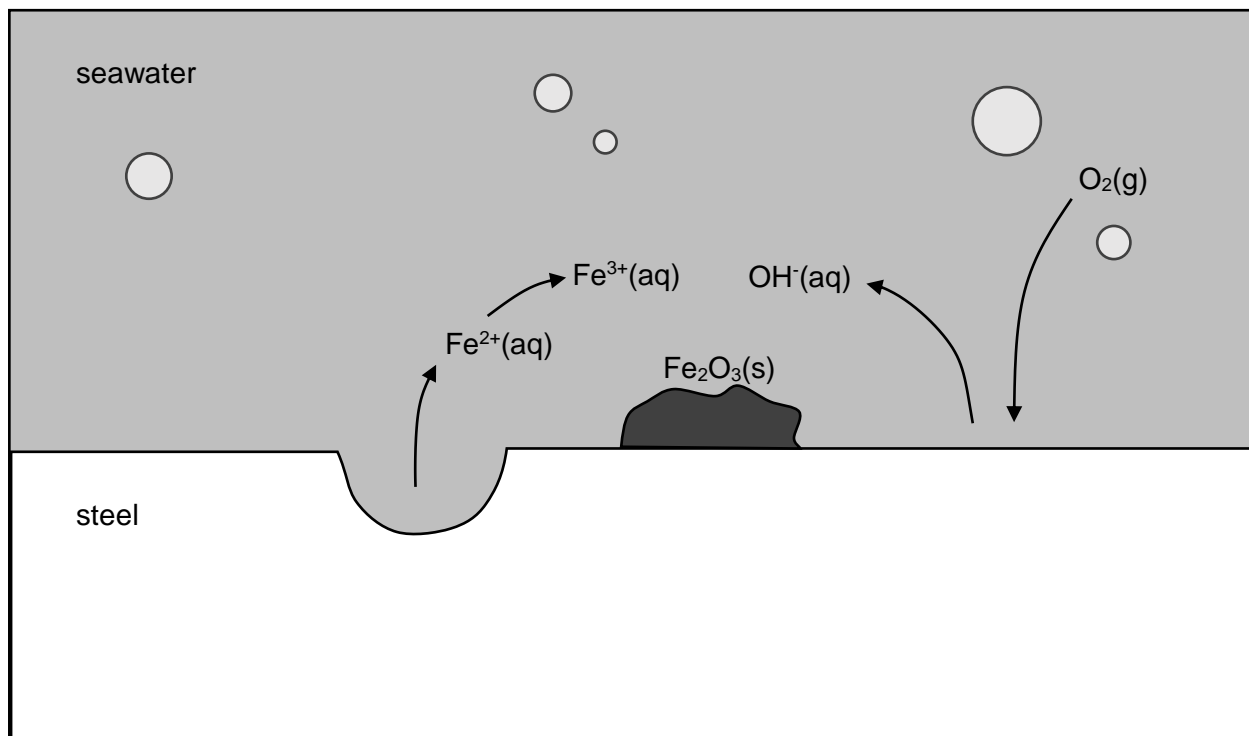
- (g) Calculate the percent yield of this process. (3 marks)

Question 39

(14 marks)

Corrosion is a major issue that affects any iron-based structure submerged in seawater. Ships, offshore drilling rigs, subsea equipment and harbours are all highly susceptible to corrosion.

The diagram below illustrates the formation of rust, $\text{Fe}_2\text{O}_3(\text{s})$, on submerged steel.



- (a) Write balanced half-equations for the **initial** reactions that occur during the electrochemical process of corrosion. (3 marks)

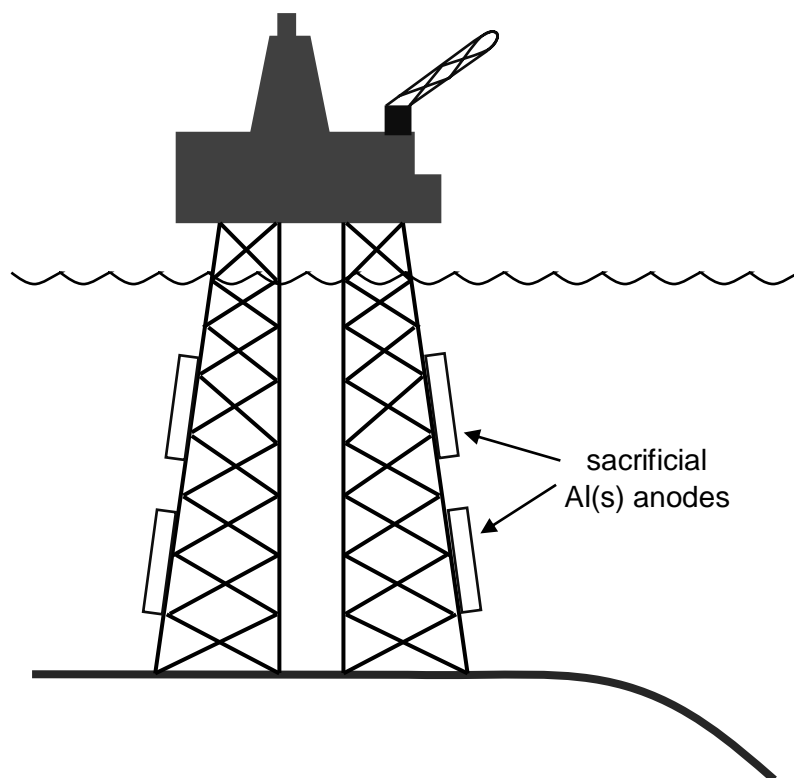
anodic region	
cathodic region	

- (b) On the diagram above, label the direction of electron flow. (1 mark)

Cathodic protection is commonly used to prevent the corrosion of submerged steel structures such as fixed offshore platforms. There are two types of cathodic protection;

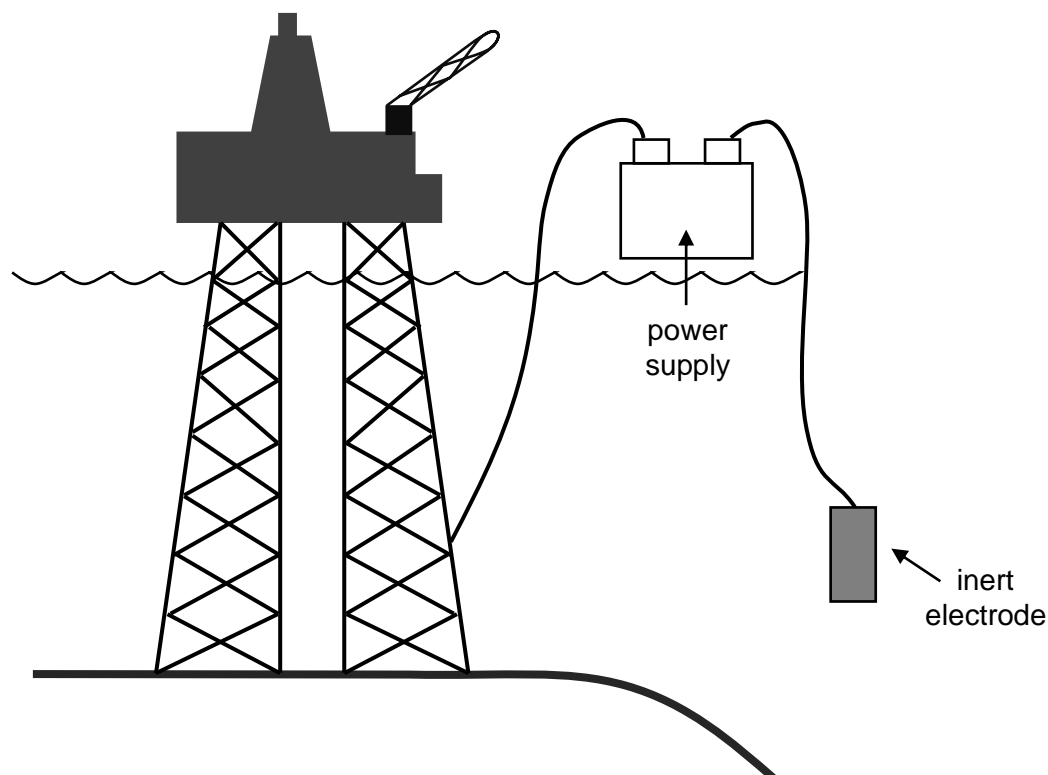
1. sacrificial anode cathodic protection
2. impressed current cathodic protection

The diagram below shows how sacrificial anodes made of aluminium have been bolted to the platform, in order to prevent corrosion.



- (c) Explain how these aluminium blocks are able to reduce the rate of corrosion. Support your answer with an appropriate half-equation. (3 marks)

In the following diagram, the platform, as well as some specially designed inert electrodes, are connected to a DC power supply.



- (d) On the diagram above, label the polarity (sign) of the power supply terminals. (1 mark)

When the power source is switched on, the flow of current protects the platform from corrosion.

The inert electrodes are often made by incorporating a mixed metal oxide catalyst onto a titanium structure. There are two possible reactions that can take place at this electrode. In regular seawater, the chloride ions present in the salt water are converted to chlorine gas. In low saline conditions, it is the water itself that reacts, forming oxygen gas.

- (e) Write balanced half-equations representing each of the possible reactions that could occur at the inert electrode. (2 marks)

regular seawater	
low saline seawater	

- (f) Describe why 'sacrificial anode cathodic protection' is considered a galvanic process, but 'impressed current cathodic protection' is considered an electrolytic process. (2 marks)

- (g) Aside from sacrificial anode cathodic protection and impressed current cathodic protection give one other method of rusting prevention and briefly describe how it works. (2 marks)

End of Questions



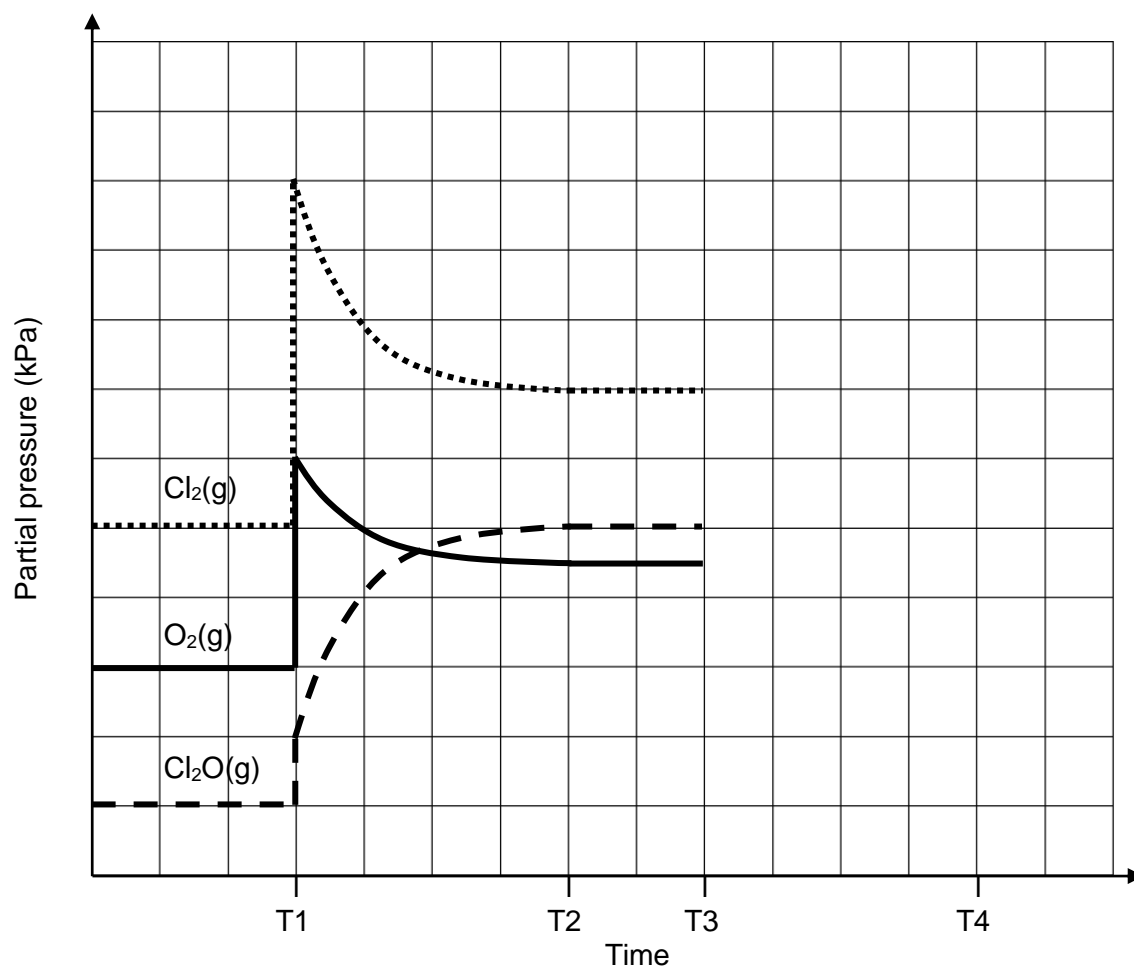
(Puneet, 2014)

Bibliography

Puneet. (2014, February 2). *The Joys of Calvin and Hobbes*. Retrieved from The Blue Surreal: <https://thebluesurreal.wordpress.com/2014/02/02/the-joys-of-calvin-and-hobbes/>

Additional working space

Spare grid Q26(c)



Spare axes Q32(c)



Additional working space

Question number(s):

Additional working space

Question number(s):

Additional working space

Question number(s):