SEMESTER TWO EXAMINATION 2023
Question/Answer Booklet

ATAR CHEMISTRY UNITS 3 & 4

Mark Ingkey

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.

26 – 30c), 37 a)+b)-39
30d) – 36, 37 c) + d)

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

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

1	a ☐ b ☐ c ■ d ☐		6	a ☐ b ☐ c ■ d ☐		11	a ☐ b ■ c ☐ d ☐	
2	a ■ b ☐ c ☐ d ☐		7	a ☐ b ☐ c ■ d ☐		12	a ☐ b ☐ c ■ d ☐	
3	a ■ b ☐ c ☐ d ☐		8	a ☐ b ☐ c ☐ d ■		13	a ☐ b ☐ c ☐ d ■	
4	a ☐ b ■ c ☐ d ☐		9	a ■ b ☐ c ☐ d ☐		14	a ■ b ☐ c ☐ d ☐	
5	a ☐ b ■ c ☐ d ☐		10	a ☐ b ■ c ☐ d ☐		15	a ☐ b ☐ c ■ d ☐	
c, a, a, b, b			**c, c, d, a, b**			**b, c, d, a, c**		

16	a ☐ b ■ c ☐ d ☐		21	a ☐ b ☐ c ☐ d ■				
17	a ☐ b ☐ c ☐ d ■		22	a ☐ b ☐ c ■ d ☐				
18	a ☐ b ☐ c ☐ d ■		23	a ☐ b ☐ c ☐ d ■				
19	a ☐ b ☐ c ■ d ☐		24	a ■ b ☐ c ☐ d ☐				
20	a ■ b ☐ c ☐ d ☐		25	a ☐ b ■ c ☐ d ☐				
b, d, d, c, a			**d, c, d, a, b**					

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.

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

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

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

(a) Decreasing the concentration of hydrogen peroxide.
(b) Increasing the total pressure of the system.
(c) Decreasing the temperature of the system.
(d) Adding an inert gas to the system.

2. Consider a 0.5 mol L^{-1} solution of sodium ethanoate, $NaCH_3COO(aq)$. After water, the species present in the highest concentration would be

(a) $Na^+(aq)$.
(b) $CH_3COO^-(aq)$.
(c) $H_3O^+(aq)$.
(d) $OH^-(aq)$.

3. Consider the following chemical reaction.

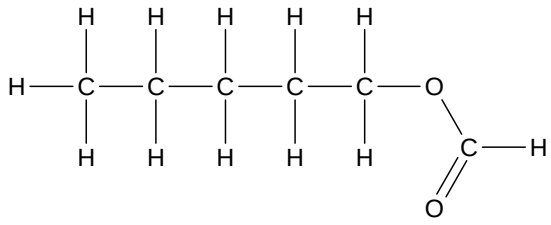
$$2\ MnO_2(aq) + 4\ KOH(aq) + O_2(g) \rightarrow 2\ K_2MnO_4(aq) + 2\ H_2O(l)$$

Identify the oxidant and reductant in this reaction.

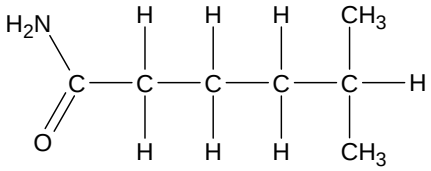
	Oxidant	**Reductant**
(a)	O_2	MnO_2
(b)	O_2	KOH
(c)	KOH	MnO_2
(d)	MnO_2	O_2

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

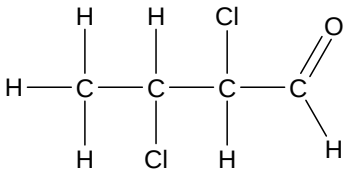
(a) methyl pentanoate



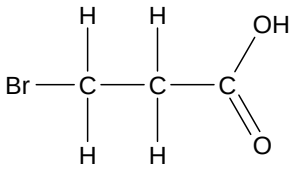
(b) 5-methylhexanamide



(c) 2,3-dichlorobutan-1-al



(d) 1-bromopropanoic acid



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) $C_3H_7OH(l) + 3\ O_2(g) \rightarrow 3\ CO(g) + 4\ H_2O(g)$
(b) $C_3H_7OH(l) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$
(c) $2\ C_3H_7OH(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$
(d) $2\ C_3H_7OH(l) + 10\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$

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}

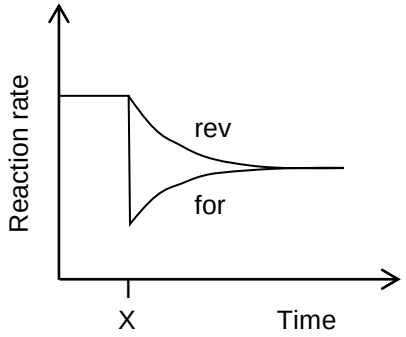
8. When titrating 20.00 mL aliquots of 0.1000 mol L^{-1} solutions of these acids, which would require the greatest volume of 0.2500 mol L^{-1} NaOH(aq) to reach the equivalence point?

(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) $NaClO_2$(aq).
(b) NaF(aq).
(c) $NaNO_2$(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.

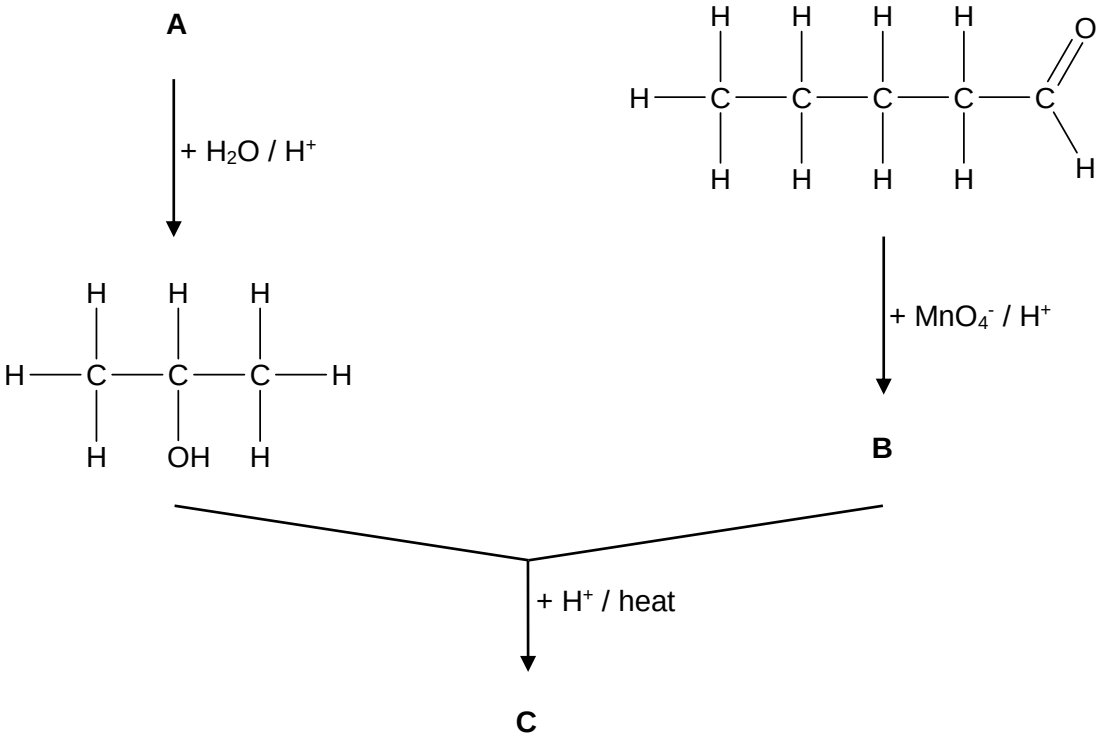


Based on the information in this graph, it can be determined that at Time X, the concentration of a

(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) $CH_3CH_2CH_2CH_2COOCH_2CH_2CH_3$
(b) $CH_3CH_2CH_2CH_2COCH_2CH_2CH_3$
(c) $CH_3CH_2CH_2CH_2COOCH(CH_3)_2$
(d) $CH_3CH_2CH_2CH_2COCH(CH_3)CH_3$

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.

Steam reforming: $CH_4(g) + H_2O(g) + 206\ kJ \rightleftharpoons CO(g) + 3\ H_2(g)$

Shift reaction: $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) + 41\ kJ$

Haber process: $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g) + 92\ kJ$

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.

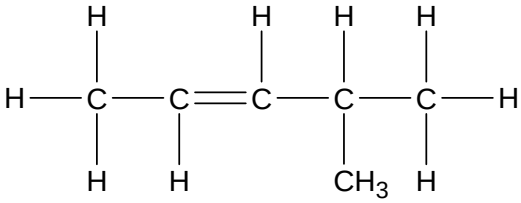
15. A condition of high pressure would best be utilised to optimise the equilibrium yield of

(a) the steam reforming.
(b) the Shift reaction.
(c) the Haber process.
(d) both the Shift reaction and the Haber process.

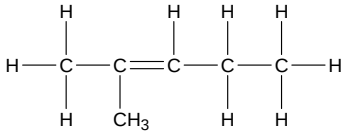
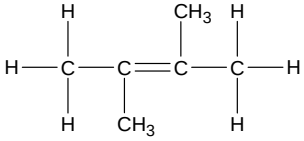
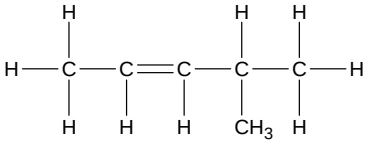
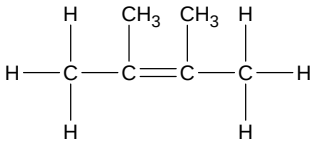
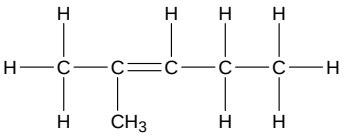
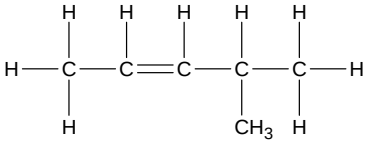
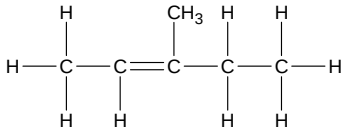
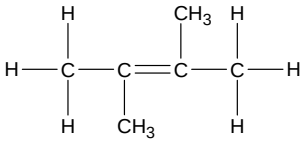
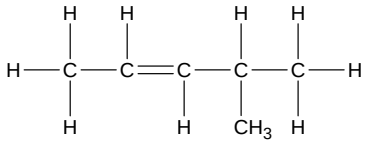
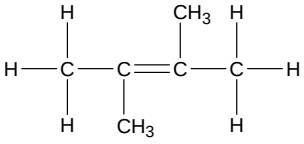
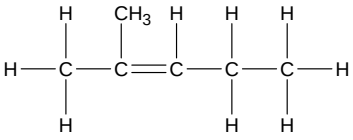
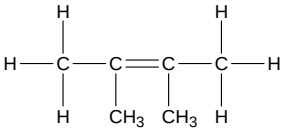
16. A protein structure contains (amongst others) the α-amino acids cysteine and methionine. Which of the following interactions can take place between the side chains of these two α-amino acids?

(a) Ionic bonding.
(b) Dipole-dipole forces.
(c) Disulfide bridge.
(d) Hydrogen bonding.

17. Consider the molecule below.

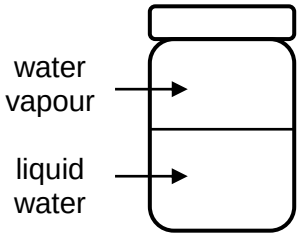


Which of the following correctly shows a chain structural, position structural and geometric isomer of this molecule?

	Chain	Position	Geometric
(a)			
(b)			
(c)			
(d)			

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

$$H_2O(l) \rightleftharpoons H_2O(g)$$

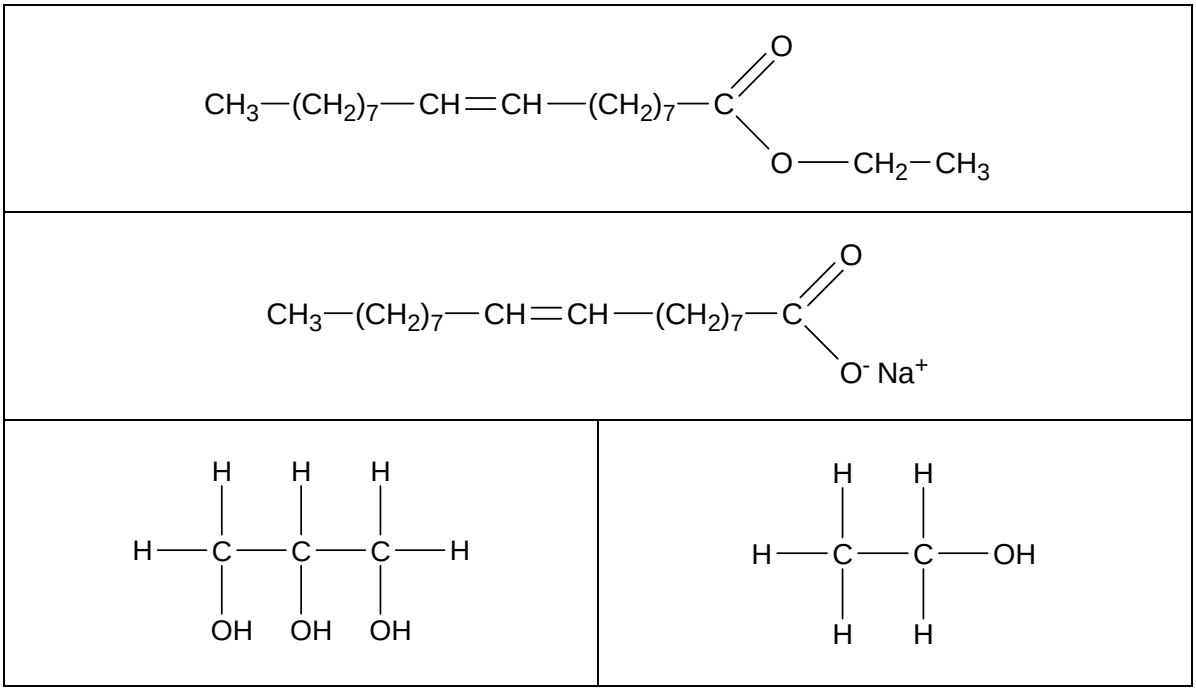


If the temperature of the surroundings was increased, this would

(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.

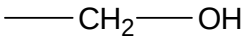
20. A major advantage of biodiesel, compared to petrodiesel, is that

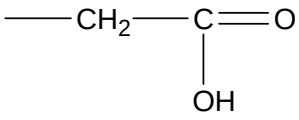
(a) it is produced from renewable resources.
(b) its production does not require the use of any unsafe chemicals.
(c) it does not produce carbon emissions when combusted.
(d) its production does not have any negative environmental impacts.

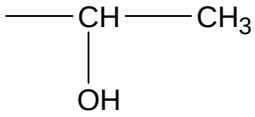
21. Octanoic acid has a higher boiling point than propanoic acid because

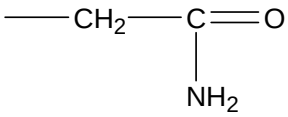
(a) octanoic acid is considered to be more polar.
(b) octanoic acid exhibits stronger hydrogen bonding between molecules.
(c) the non-polar region in octanoic acid is larger.
(d) the dispersion forces between octanoic acid molecules are stronger.

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;

(a) 

(b) 

(c) 

(d) 

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

$2\ H_2O(l) + \text{heat} \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ $\quad K_w = 1.0 \times 10^{-14}$ at 25 °C

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

(a) Between 0 °C and 25 °C.
(b) At 25 °C only.
(c) Between 25 °C and 100 °C.
(d) Between 0 °C and 100 °C.

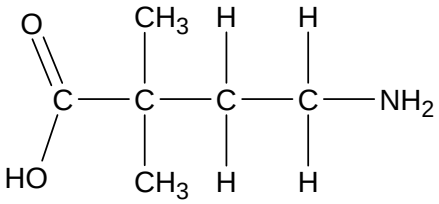
24. A group of chemistry students set up a small-scale cell to replicate the process of copper electrorefining.

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?

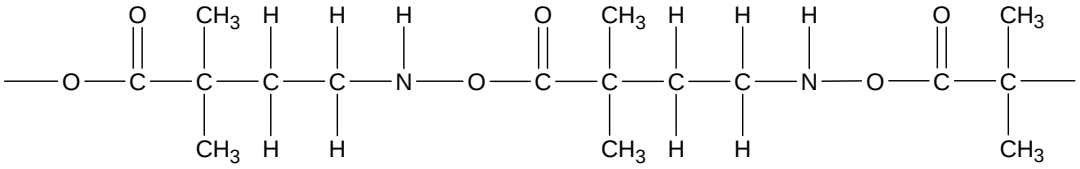
	Anode	**Cathode**
(a)	42.8 g	46.2 g
(b)	43.2 g	47.1 g
(c)	47.3 g	42.9 g
(d)	46.6 g	43.1 g

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

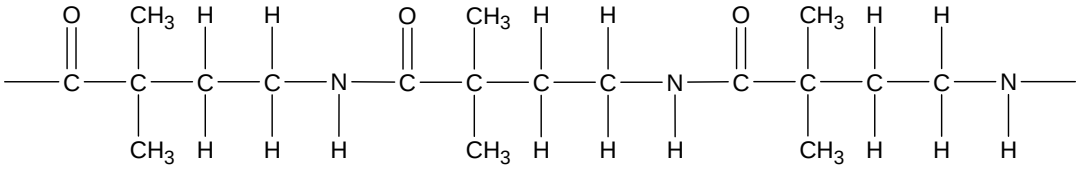


Which of the following correctly shows the structure of this polyamide?

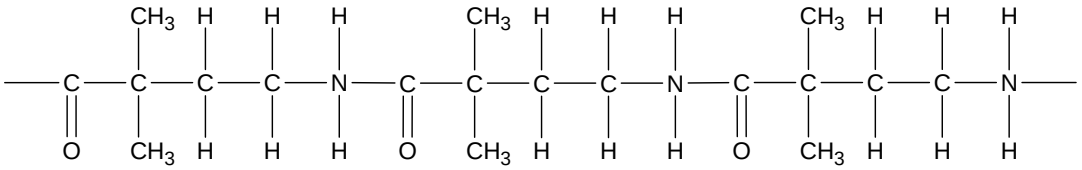
(a)



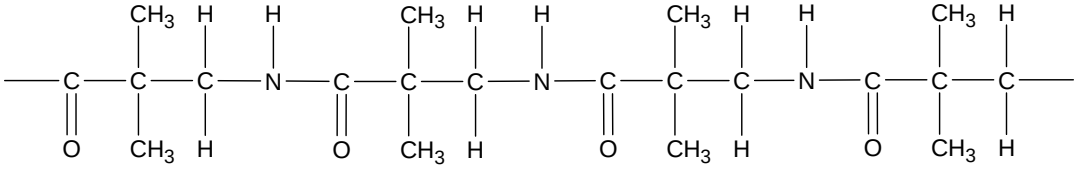
(b)



(c)



(d)



End of Section One

Section Two: Short answer **35% (80 marks)**

Question 26 **(11 marks)**

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

Description	Marks
Decrease in volume. **or** Volume of system was halved.	1
Total	**1**
Note: accept 'an additional amount of each gas was injected simultaneously' Do not accept pressure was increased	

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

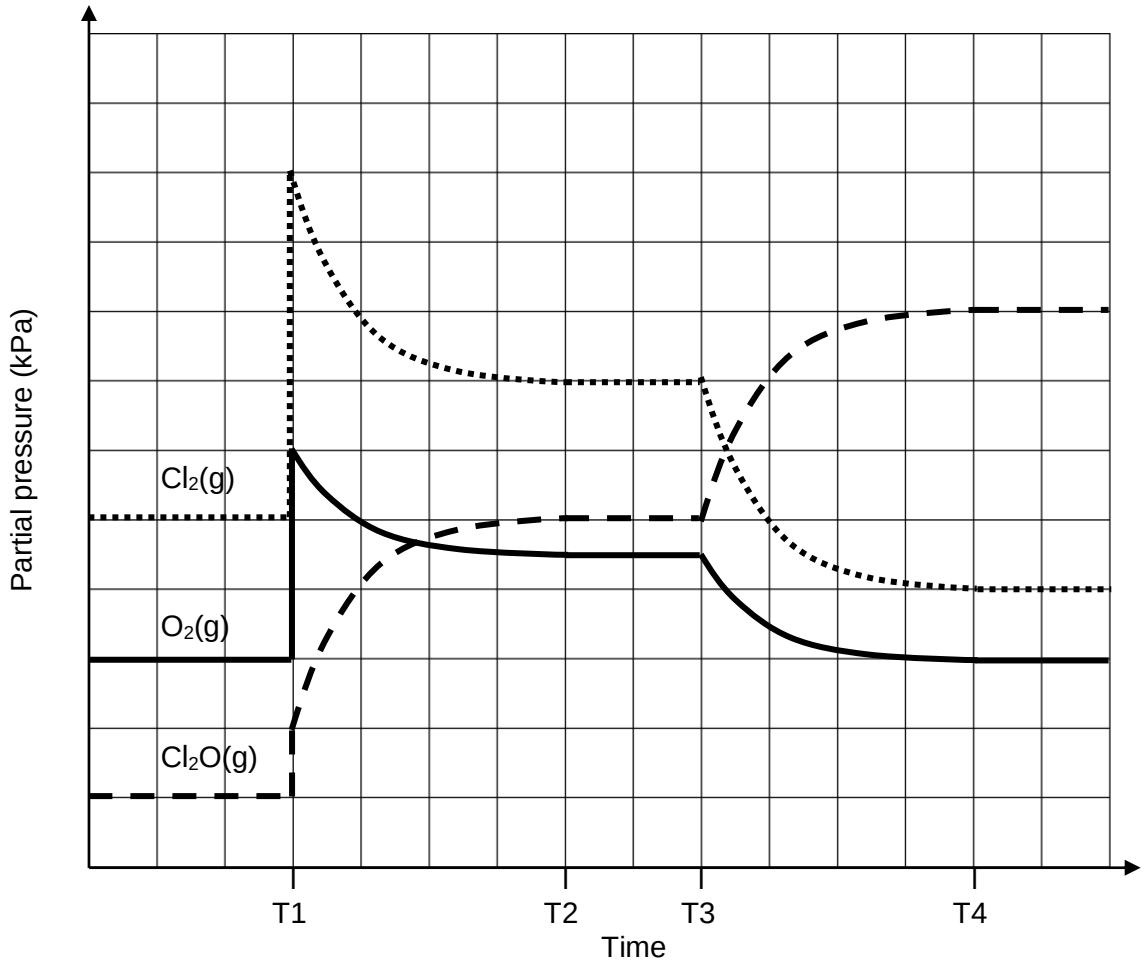
(i) instantaneously, at Time T1. (3 marks)

Description	Marks
The forward reaction rate increased.	1
The distance between the particles decreased **or** There are a greater number of gas particles per unit volume.	1
Therefore, the frequency/rate of successful (reactant) collisions would increase.	1
Total	**3**

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

Description	Marks
The forward reaction rate increased.	1
As there are a greater number of product particles (3:2), initially the reverse reaction rate is greater than the forward reaction rate.	1
This means over time the concentration of reactants increases.	1
Therefore, the frequency/rate of successful (reactant) collisions would increase.	1
Total	**4**

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

Description	Marks
	
Correct 'direction' (i.e. increase or decrease) of curves	1
Correct stoichiometric ratio shown in gradient of curves	1
Horizontal lines at T4 and beyond (q asked for until T4 so pay if lines stop at T4)	1
Total	**3**

Question 27 **(6 marks)**

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

Description	Marks
(Metal) displacement.	1
Total	**1**

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

Description	Marks
Electrons are transferred from copper metal to gold ions.	1
Total	**1**

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

Description	Marks
$Au^{3+}(aq) + 3\ e^- \rightarrow Au(s)$ +1.50 V $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$ - 0.34 V +1.16 V	1
Since EMF > 0 reaction is spontaneous.	1
Total	**2**
Note: accept written answers that refer specifically to standard reduction potential data. e.g. 'For a reaction to be spontaneous, the EMF must be a positive value. (1) Thus because the reduction potential for $Au^{3+}(aq)$ to Au(s) is +1.50 V, the oxidation potential of Cu(s) to $Cu^{2+}(aq)$ would have to be greater than -1.50 V. Since the oxidation potential of Cu(s) to $Cu^{2+}(aq)$ is -0.34 V, the reaction is spontaneous.' (1)	

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

Description	Marks
A salmon pink metal is placed in a colourless solution forming a yellow solid in a blue solution.	2
Any two of the following: • salmon pink metal dissolves • colourless solution becomes blue • yellow solid formed	1
Total	**2**

Question 28 **(9 marks)**

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

Description	Marks
$Mg(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$	
Correct species and correctly balanced equation	1
Correct state symbols (can get this mark if not ionic)	1
Total	**2**

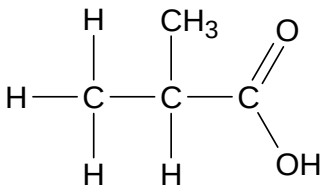
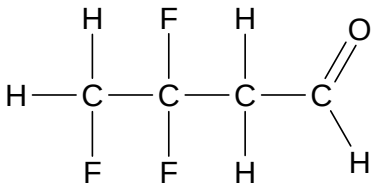
(b) Calculate the original pH of the hydrochloric acid solution. (7 marks)

Description			Marks
$[H^+$ final$]$	=	$10^{-3.03}$	1
	=	0.00093325 mol L^{-1}	
$n(H^+$ final$)$	=	0.00093325 x 0.175	1
	=	0.00016332 mol	
n(Mg)	=	1.074 / 24.31	1
	=	0.044179 mol	
$n(H^+$ reacted$)$	=	2 x n(Mg)	1
	=	0.088359 mol	
$n(H^+$ initial$)$	=	0.088359 + 0.00016332	1
	=	0.088522 mol	
$[H^+]$	=	0.088522 / 0.175	1
	=	0.50584 mol L^{-1}	
pH	=	-log(0.50584)	1
	=	0.296	
Total			**7**

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)

Description	Marks
Structural diagram:  Distinguishing observation: **white solid dissolves, colourless (odourless) gas produced**	
Structural diagram:  Distinguishing observation: **no observable change**	
Correct structural diagram of 2-methylpropanoic acid	2
Correct structural diagram of 3,3,4-trifluorobutanal	2
Correct distinguishing observation for 2-methylpropanoic acid	1
Correct distinguishing observation for 3,3,4-trifluorobutanal	1
Total	**6**
Note: one mark may be allocated per structural diagram for a minor error such as a 'missing H atom' etc.	

(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)

Description	**Marks**
IUPAC name: **2-bromo-4-methylhexan-3-one** / IUPAC name: **3,5-dichloropentan-2-ol**	
A few drops of **acidified sodium dichromate solution OR $H^+/Na_2Cr_2O_7(aq)$** is added and warmed.	
Correct IUPAC name of 2-bromo-4-methylhexan-3-one	1
Correct IUPAC name of 3,5-dichloropentan-2-ol	1
Correct identification of distinguishing reagent	1
Total	**3**
Note: reagent must be acidified salt solution.	

Question 30 **(8 marks)**

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

Description	Marks
There is a continual flow of reactants through the cell.	1
Total	**1**

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

Description	Marks
Secondary	1
Total	**1**

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

Description		Marks
Classify this electrode as the 'anode' or 'cathode'.	anode	1
Classify the polarity of this electrode as 'positive' or 'negative'.	negative	1
Identify whether cations would move 'toward' or 'away from' this electrode.	away from	1
Total		**3**

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

Description	Marks
+2.48 V	1
Total	**1**

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

Description	Marks
$2\ Ce^{3+}(aq) + Zn^{2+}(aq) \rightarrow 2\ Ce^{4+}(aq) + Zn(s)$	
Correct species	1
Correct balancing	1
Total	**2**
Note: state symbols are not required for full marks	

Question 31 **(10 marks)**

(a) Determine the empirical formula of the compound. (4 marks)

Description	Marks

	C	H	N
mass (g)	(39.9/100) x 1.839 = 0.73376	1.839 – (0.857 + 0.73376) = 0.24824	0.857
moles (mol)	0.73376 / 12.01 = 0.061096	0.24824 / 1.008 = 0.24627	0.857 / 14.01 = 0.061171
ratio	0.061096 / 0.061096 = 1.00 = 1	0.24627 / 0.061096 ≈ 4.03 = 4	0.061171 / 0.061096 ≈ 1.00 = 1

or

	C	H	N
Mass in 100g (g)	39.9	100 – (39.9 + 46.60) = 13.50	(0.857/1.839) x 100 = 46.60
moles (mol)	39.9 / 12.01 = 3.32	13.50 / 1.008 = 13.39	46.60 / 14.01 = 3.33
ratio	3.32/ 3.32 = 1.00 = 1	13.39/ 3.32 ≈ 4.06 = 4	3.33/ 3.32 ≈ 1.00 = 1

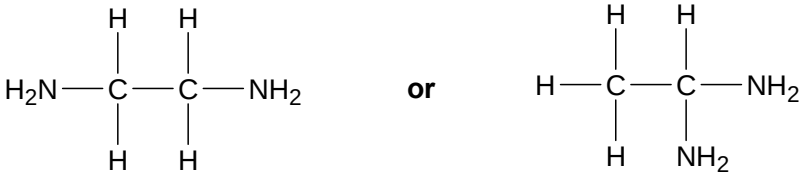
Empirical formula is CH_4N

Calculating % of N or mass of C	1
Calculating mass of H	1
Calculating moles of C/H/N	1
Determining simplest ratio and writing empirical formula as CH_4N	1
Total	**4**

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

Description	Marks
$n(HNO_3)$ = 0.7406 x 0.02844 = 0.021063 mol	1
n(base) = ½ x $n(HNO_3)$ = 0.010531 mol	1
M(base) = 0.633 / 0.010531 = 60.1063 g mol^{-1}	1
M / M(EF) = 60.1063 / 30.052 = 2 Therefore molecular formula is $C_2H_8N_2$	1
Total	**4**

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

Description	Marks
 **or**	1
Both N atoms bonded to C atoms	1
Total	**2**

Question 32 **(9 marks)**

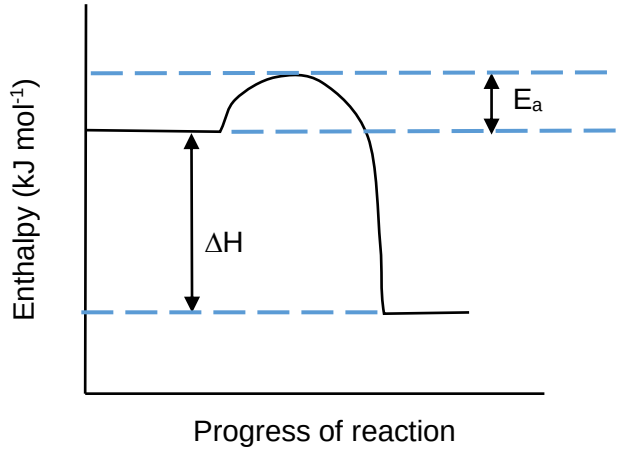
(a) Write the equilibrium constant expression (K) for this reaction. (2 marks)

Description	Marks
$K = \dfrac{[I_2][H_5IO_6]^5}{[IO_3^-]^7[H^+]^7}$	
Products over reactants	1
Correct indices	1
Total	**2**
Note: no K = -½ mark.	

(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)

Description			Marks
A few drops of starch solution was added.	decreased	right	2
A 100 mL aliquot of distilled water was added.	decreased	left	2
		Total	**4**
Note: No follow through allowed in this question.			

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

Description	Marks
	
Exothermic shape of curve	1
Correctly labelled activation energy	1
Correctly labelled enthalpy change	1
Total	**3**

Question 33 **(8 marks)**

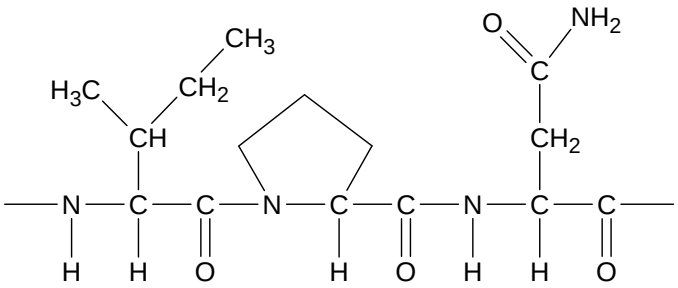
(a) Identify the number of peptide bonds that would be formed during synthesis of the entire beta casein protein. (1 mark)

Description	Marks
208	1
Total	**1**

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

Description	Marks
Primary	1
Total	**1**

(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)

Description	Marks
	
Three amino acids (Ile – Pro – Asn) drawn correctly	1
Both peptide links drawn correctly	1
Non-terminating ends	1
Total	**3**
Note: accept if each individual amino acid is reversed, causing left terminating side to be carbonyl end and right terminating side is amino end (Ile-Pro-Asn order is maintained).	

(d) Explain how an amino acid change can result in alteration of the shape of a protein. (3 marks)

Description	Marks
Changes to amino acids (in the primary structure) will incorporate different side chains.	1
Side chain interactions determine the tertiary structures of a protein.	1
Tertiary (and secondary) structures determine the shape of a protein.	1
Total	**3**

Question 34 **(10 marks)**

(a) Explain, in terms of collision theory and reaction rates, why a 'compromise' temperature of around 300 °C is used for this industrial process. (8 marks)

Description	Marks
Explanation of effect of temperature on rate, for example: • A high temperature will increase the average kinetic energy of particles. • This increases the proportion of collisions with sufficient kinetic energy to meet the required activation energy. • This will increase the frequency of successful collisions. • This results in a faster reaction rate. **or** • A low temperature will decrease the average kinetic energy of particles. • This decreases the proportion of collisions with sufficient kinetic energy to meet the required activation energy. • This will decrease the frequency of successful collisions. • This results in a slower reaction rate.	4
Explanation of effect of temperature on yield, for example: • A high temperature will increase the rate of both the forward and reverse reaction. • The reverse, endothermic reaction rate will be increased more relative to the forward reaction rate. • This will result in a lower yield. **or** • A low temperature will decrease the rate of both the forward and reverse reaction. • The reverse, endothermic reaction rate will be decreased more relative to the forward reaction rate. • This will result in a higher yield.	3
Statement addressing 'compromise', for example: • A compromise temperature achieves a reasonable yield at an acceptable reaction rate. **or** • a compromise temperature aims to simultaneously address the opposing requirements for high rate and yield.	1
Total	**8**

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

Description	Marks
The fermentation method uses an enzyme catalyst.	1
A higher temperature would denature/destroy the shape (secondary and tertiary structures) of a protein/enzyme. **or** The shape of an enzyme is maintained within an optimal temperature range.	1
Total	**2**

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

Question 35 **(21 marks)**

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

Description	Marks
Water possesses dispersion forces, dipole-dipole forces and hydrogen bonding.	1
Oxalic acid possesses dispersion forces, dipole-dipole forces and hydrogen bonding.	1
When these substances are mixed, new hydrogen bonds (and dipole-dipole and dispersion forces) are able to form between water and oxalic acid.	1
The strength of these new forces between water and oxalic acid are sufficient to overcome the original intermolecular forces within water and within oxalic acid. **or** The formation of these new forces between water and oxalic acid releases sufficient energy to overcome the original intermolecular forces within water and within oxalic acid.	1
Total	**4**

(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)

Description	Marks
$C_2O_4^{2-}(aq) + H_2O(l) \rightleftharpoons HC_2O_4^-(aq) + OH^-(aq)$	1
The oxalate ions formed in this titration (hydrolyse with water to produce an excess of hydroxide ions) result in $[OH^-] > [H_3O^+]$.	1
Phenolphthalein has a basic end point which is chosen to coincide with the basic equivalence point in the titration.	1
Total	**3**
Note: if equilibrium arrow not used in equation -½ mark	

(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)

Description			Marks
n(NaOH initial)	= =	0.1014 x 0.02000 0.002028 mol	1
n(oxalic in 19.54 mL)	= =	½ x n(NaOH) 0.001014 mol	1
n(oxalic in 100.0 mL)	= =	0.001014 x (100/19.54) 0.005189 mol	1
n(oxalic in leaves)	=	0.005189 mol	1
m(oxalic)	= =	0.005189 x 90.036 0.467229 g	1
% oxalic in leaves	= =	(0.467229 / 73.82) x 100 0.63293 %	1
	=	0.6329 % (4SF)	1
		Total	**7**

(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)

Description			Marks
m(oxalic required for lethal dose)	= =	(375/1000) x 70 26.25 g	1
m(leaves required for lethal dose)	= =	26.25 x (100/0.6329) 4148 g	1
		Total	**2**

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

Description		Marks
Sampling leaves from different rhubarb plants grown in different geographical regions.	validity	1
Repeating the volumetric analysis several times to obtain an average titre.	reliability	1
	Total	**2**

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

Description	Marks
This error would dilute the rhubarb extract.	1
This means an increased titre volume is required.	1
Thus the calculated oxalic acid concentration would be lower.	1
Total	**3**

Question 36 **(17 marks)**

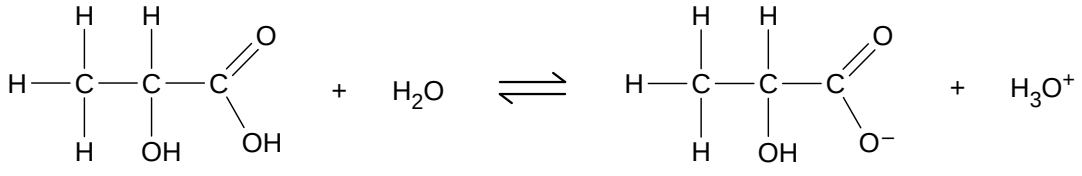
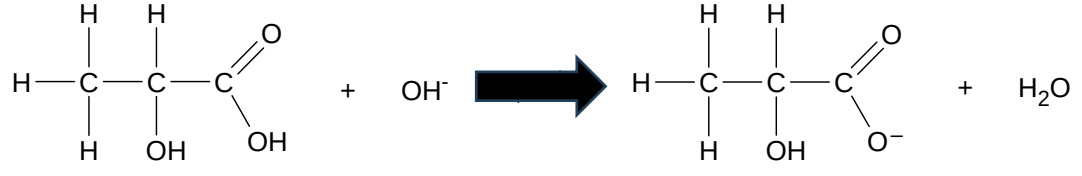
(a) Explain how the total mass of hydroxyapatite in teeth can remain constant, despite the processes of demineralisation and mineralisation continually occurring. (2 marks)

Description	Marks
Equilibrium has been established in this system.	1
The rate of demineralisation is equal to the rate of remineralisation. **or** The rate of dissolving/dissolution (forward reaction) is equal to the rate of crystallisation/solidification (reverse reaction).	1
Total	**2**

(b) Justify, with reference to Le Chatelier's principle, how consuming acidic foods can result in tooth decay. (4 marks)

Description	Marks
Acidic foods will (increase the concentration of H_3O^+ which will) decrease the concentration of OH^- in the mouth.	1
(Le Chatelier's principle predicts that) the system will therefore act to increase the concentration of OH^-.	1
This will result in the equilibrium shifting right.	1
Thus the mass of hydroxyapatite/tooth enamel is decreased (leading to tooth decay). **or** Thus demineralisation of the teeth occurs faster than remineralisation (leading to tooth decay).	1
Total	**4**

(c) Write a balanced chemical equation, illustrating how lactic acid lowers the pH inside the mouth. (2 marks)

Description	Marks
 **or** 	
Correct species	1
Correct arrow	1
Total	**2**

(d) Explain, in terms of reaction rates, how this buffer system counteracts the lowered pH associated with consuming food. Include an appropriate equation in your answer. (4 marks)

Description	Marks
A decrease in the pH will increase the concentration of H_3O^+/H^+.	1
An increase in the concentration of H_3O^+/H^+ will increase the rate of the reverse reaction relative to the forward reaction rate (due to an increased frequency of collisions) according to the equation:	1
$HCO_3^-(aq) + H_3O^+(aq) \rightarrow H_2CO_3(aq) + H_2O(l)$	1
This lowers the concentration of H_3O^+/H^+ and maintains the pH in the mouth.	1
Total	**4**
Note: equation must have full arrow	

(e) State and explain the effect this has on the buffering capacity of saliva. (3 marks)

Description	Marks
Increased buffering capacity.	1
The concentration of the conjugate base species/component of the buffer has been increased.	1
Therefore a greater amount of H_3O^+/H^+/acidic food can be neutralised ($HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2O(l) + H_2CO_3(aq)$)	1
Total	**3**

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

Description	Marks
The lower K_c value shows that fluorapatite is less soluble / less likely to undergo demineralisation.	1
Thus the tooth enamel is stronger / won't be broken down as easily (conferring protection against tooth decay).	1
Total	**2**

Question 37 **(15 marks)**

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

Description			Marks
$n(Ca^{2+})$	=	0.004117 x 0.385 = 0.001585 mol	1
$n(Ca(C_{15}H_{31}COO)_2)$	=	0.001585 mol	1
$m(Ca(C_{15}H_{31}COO)_2)$	=	0.001585 x 550.896 = 0.87319 g	1
$m(Mg(C_{15}H_{31}COO)_2)$	=	1.636 – 0.87319 = 0.76281 g	1
$n(Mg(C_{15}H_{31}COO)_2)$	=	0.76281 / 535.126 = 0.0014255 mol = $n(Mg^{2+})$	1
$m(Mg^{2+})$	=	0.0014255 x 24.31 x 1000 = 34.653 mg	1
$c(Mg^{2+})$	=	34.653 / 0.385 = 90.0 mg L^{-1}	1
		Total	**7**

Alternate working (for final three marks):

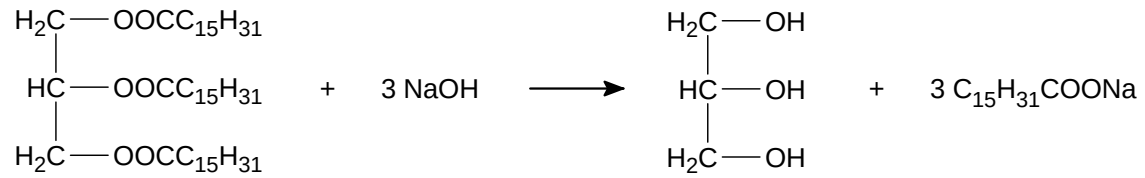
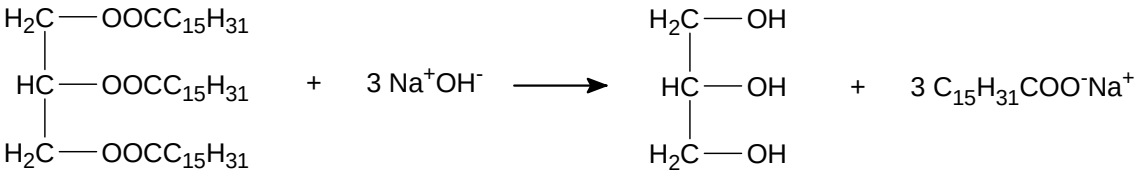
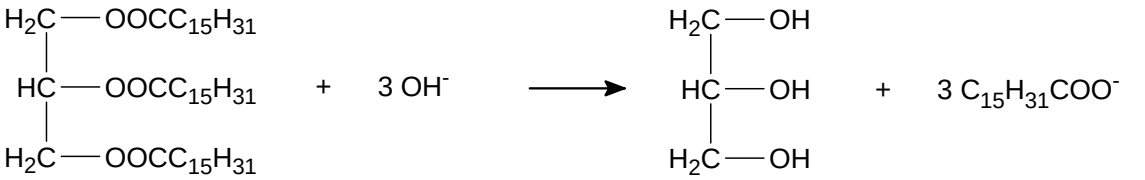
$m(Mg^{2+})$ = (24.31/535.126) x 0.76281
= 0.034653 g
= 34.653 mg

$c(Mg^{2+})$ = 34.653 / 0.385
= 90.01 mg L^{-1}

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

Description			Marks
$n(C_{15}H_{31}COO^-$ required)	=	2 x $n(Ca^{2+})$ + 2 x $n(Mg^{2+})$ = 2 x 0.001585 + 2 x 0.0014255 = 0.0060209 mol	1
$n(C_{15}H_{31}COONa)$	=	0.0060209 mol	1
$m(C_{15}H_{31}COONa)$	=	0.0060209 x 278.398 = 1.676 g	1
		Total	**3**

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

Description	Marks
 **or**  **or** 	
Correct reactants	1
Correct products	1
Correct balancing	1
Total	**3**

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

Description	Marks
No scum would be formed when using detergent. **or** The detergent surfactant won't precipitate in hard water.	1
Therefore the surfactant ion remains dissolved/suspended/in a micelle and is able to clean (more effectively than soap).	1
Total	**2**

Question 38 **(19 marks)**

(a) Complete the table below by;

(i) identifying the other reactant required to convert ethene to ethylene dichloride, and

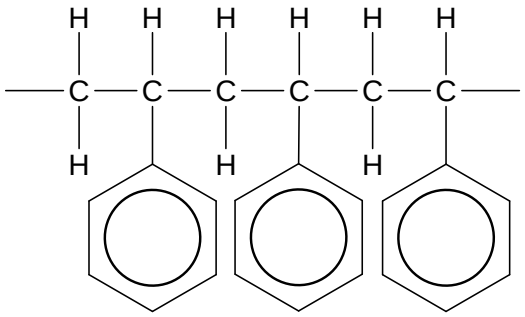
(ii) naming the type of reaction occurring in this step. (2 marks)

Description		Marks
Identity of other reactant required	chlorine / Cl_2	1
Type of reaction occurring	addition / halogenation	1
	Total	**2**

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

Description	Marks
Dipole-dipole and dispersion forces.	1
Total	**1**

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

Description	Marks
	
Correct structure of repeating unit shown	1
Three repeating units shown	1
Total	**2**

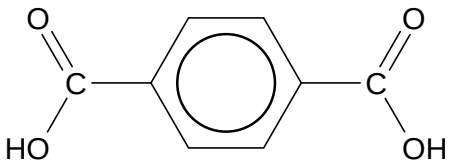
(d) State the effect this would have on the melting point of the LLDPE, and justify your answer by referring to the role of intermolecular forces present in the polymer. (3 marks)

Description	Marks
The melting point would decrease.	1
More branches on the polymer would disrupt the ability of the polymer chains to pack together / decrease the contact surface area between adjacent polymer chains.	1
This would result in weaker dispersion forces.	1
Total	**3**

(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)

Description		Marks
Structural diagram of other monomer required		1
Type of polymerisation reaction occurring	condensation	1
	Total	**2**

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

Description			Marks
$V(O_2)$	=	(95/100) x (13.6 $x10^3$) x 1000	1
	=	12920 L	
Temperature	=	260 + 273.15	1
	=	533.15 K	
$n(O_2)$	=	(2500 x 12920) / (8.314 x 533.15)	1
	=	7286.9 mol	
$n(CH_2CH_2)$	=	($228x10^3$) / 28.052	1
	=	8127.8 mol	
Mole comparison			1
$n(O_2)$	=	7286.9 / 6	
	=	1.21 $x10^3$ mol	
$n(CH_2CH_2)$	=	8127.8 / 7	
	=	1.16 $x10^3$ mol	
Ethene is the limiting reagent as there is less present on a mole-to-mole basis.			1
		Total	**6**
Note: other methods acceptable as long as chemically sound.			

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

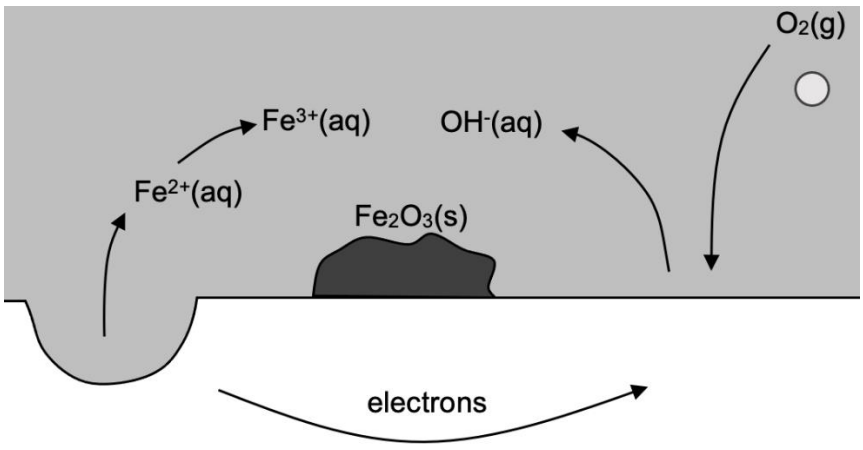
Description			Marks
n(theoretical CH_2CH_2O)	=	(6/7) x $n(CH_2CH_2)$	1
	=	6966.7 mol	
m(theoretical CH_2CH_2O)	=	6966.7 x 44.052	1
	=	306895 g	
	=	306.895 kg	
% yield	=	(279 / 306.895) x 100	1
	=	90.91 %	
		Total	**3**

Question 39 **(14 marks)**

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

Description	Marks
anodic region: $Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^-$ cathodic region: $O_2(g) + 2\ H_2O(l) + 4\ e^- \rightarrow 4\ OH^-(aq)$	
Correct oxidation half-equation	1
Correct reduction half-equation	1
Half-equations assigned to correct electrode region	1
Total	**3**

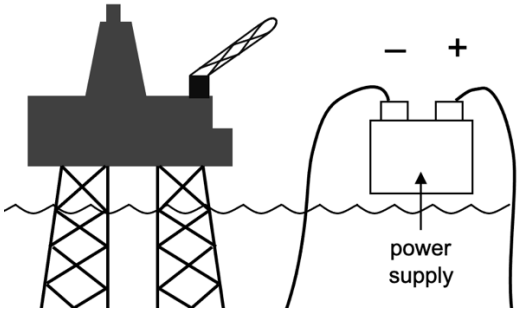
(b) On the diagram above, label the direction of electron flow. (1 mark)

Description	Marks
	
Labelled arrow shown correctly on diagram	1
Total	**1**

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

Description	Marks
The aluminium is preferentially oxidised in place of the iron.	1
$Al(s) \rightarrow Al^{3+}(aq) + 3\ e^-$	1
This is because it has a higher oxidation potential than iron / is more easily oxidised than iron / has an oxidation potential greater than +0.44 V / has an oxidation potential of +1.68 V.	1
Total	**3**

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

Description	Marks
	
Polarities shown correctly on diagram	1
Total	**1**

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

Description	Marks
regular seawater: $2\ Cl^-(aq) \rightarrow Cl_2(g) + 2\ e^-$	
Correct equation	1
low saline seawater: $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4\ e^-$	
Correct equation	1
Total	**2**

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

Description	Marks
Sacrificial anode cathodic protection is a **spontaneous** redox reaction.	1
Impressed current cathodic protection is a **non-spontaneous** redox reaction.	1
Total	**2**

(f) 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)

Description	Marks
Any one of the following: • Inert, non-metallic coating (e.g. painting, coating with plastic, etc). • Inert, metallic coating (e.g. coating with copper, tin, lead, etc). • Galvanising (coating with zinc).	1
Prevents oxygen and water coming into contact with the iron.	1
Total	**2**