Insert School Logo

CHEMISTRY

UNIT 3 & 4

2020

Name: _____

Teacher: _____

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 Booklet

To be provided by the candidate:
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations

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
Section One Multiple-choice	25	25	50	/ 25	/ 25
Section Two Short answer	8	8	60	/ 76	/ 35
Section Three Extended answer	5	5	70	/ 98	/ 40
					/ 100

Instructions to candidates

1. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

2. Answer the questions according to the following instructions.

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

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

3. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answer 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.

4. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

5. 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.

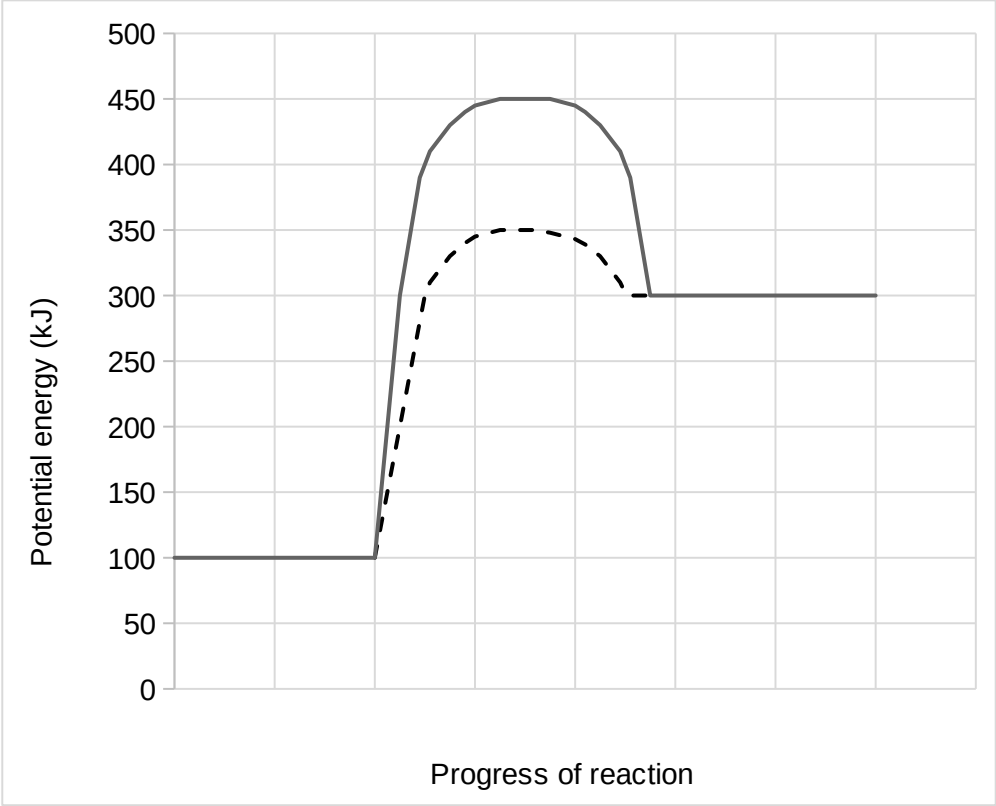
6. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

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.

Questions 1 and 2 refer to the energy profile diagram below.



1. The reaction represented by the **solid** line

   (a) is exothermic.
   (b) has an activation energy of +200 kJ.
   (c) has an enthalpy change of +350 kJ mol^{-1}.
   (d) involves a gain in energy by the system.

2. When compared to the reaction represented by the solid line, which of the following statements is **not** correct regarding the reaction represented by the **dashed** line?

   (a) It would occur at a faster rate.
   (b) It would have a lower enthalpy change.
   (c) It would have a lower activation energy.
   (d) It involves an alternate reaction pathway.

See Next Page

3. Determine the pattern for the oxidation number of **manganese** in the following compounds.

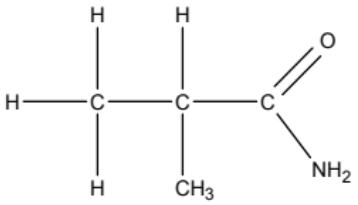
$Mn(s)$, $MnCl_2(aq)$, $MnO_2(s)$, _____

Select the compound that would continue this pattern.

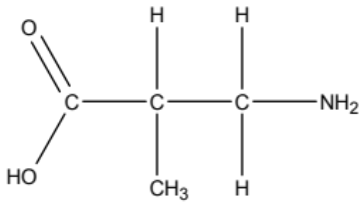
(a) Mn_2O_7
(b) MnF_3
(c) Mn_2O_3
(d) K_2MnO_4

4. Consider the three (3) compounds below.

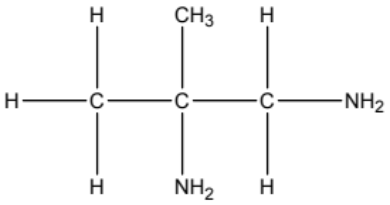
X



Y



Z



Classify each compound correctly, according to functional group.

	Amine	**Amide**	**Amino acid**
(a)	Z	Y	X
(b)	X	Z	Y
(c)	Z	X	Y
(d)	Y	X	Z

5. Which of the following polymers is able to form hydrogen bonds between its chains?

(a) Polyethene
(b) Polytetrafluoroethene
(c) Nylon 6,6
(d) Polyethylene terephthalate

6. A detergent ion does **not** contain

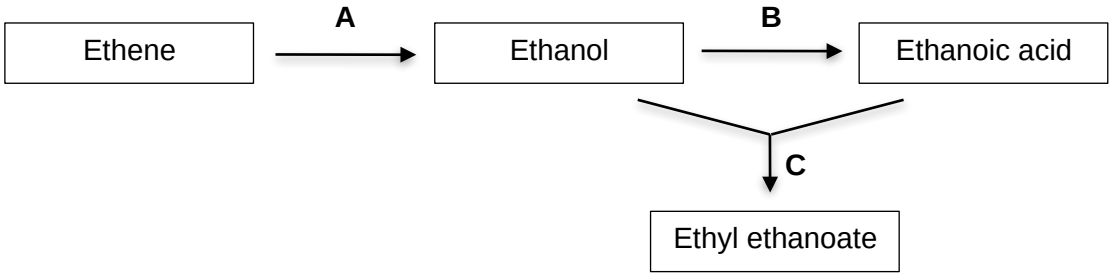
(a) a non-polar hydrocarbon region.
(b) a benzene ring.
(c) a charged COO^- group.
(d) a charged SO_3^- group.

7. Which of the following statements is **not** true for both galvanic and electrolytic cells?

(a) Reduction occurs at the cathode.
(b) Cations migrate towards the positive electrode.
(c) Electrons move from the anode to the cathode.
(d) Electrodes may be inert or reactive.

See Next Page

Questions 8 and 9 refer to the chemical synthesis reaction sequence shown below.



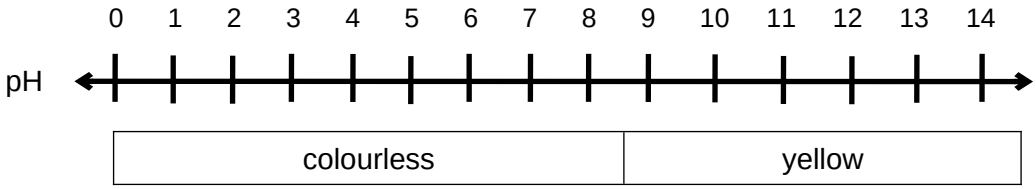
8. Name the processes occurring at A, B and C.

	A	B	C
(a)	hydration	oxidation	esterification
(b)	oxidation	addition	esterification
(c)	addition	hydration	hydrolysis
(d)	hydrogenation	oxidation	dehydration

9. Which catalyst needs to be added at A, B and C for the reactions to proceed as indicated?

(a) H_2SO_4
(b) H_2O
(c) NaOH
(d) H_2O_2

10. The indicator M-Nitrophenol is used for an acid-base titration.



Select the option below that lists the appropriate solution in each flask and the corresponding colour change that would be observed.

	Burette	Conical flask	Colour change
(a)	KOH(aq)	CH_3COOH(aq)	colourless to yellow
(b)	HCl(aq)	NH_3(aq)	yellow to colourless
(c)	HF(aq)	NaOH(aq)	colourless to yellow
(d)	$Ba(OH)_2$(aq)	HNO_3(aq)	yellow to colourless

11. Zwitterions

(a) have an overall positive charge.
(b) have an overall negative charge.
(c) have an overall neutral charge.
(d) are non-polar molecules.

See Next Page

Questions 12 and 13 relate to the Haber process.

The Haber process can be represented by the chemical equation below.

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

12. Periodically, the ammonia is removed from the reaction chamber. What **immediate** effect would this have on the rate of reaction?

(a) The forward reaction rate would increase.
(b) The reverse reaction rate would increase.
(c) The forward reaction rate would decrease.
(d) The reverse reaction rate would decrease.

13. Which of the following conditions will maximise **both** the rate of formation and equilibrium yield of ammonia?

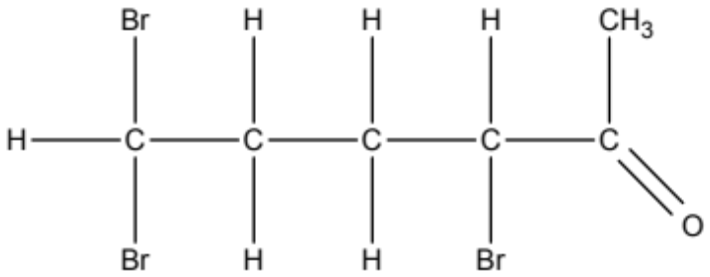
(i) An increased concentration of reactants
(ii) An increased pressure caused by a decrease in volume
(iii) An increased temperature
(iv) Addition of a catalyst

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

14. During the process of electrorefining impure (blister) copper, several different metal impurities are removed. Which statement is **incorrect** regarding the various metal impurities found in blister copper?

(a) Ag would be found in the anode slime.
(b) Zn would be oxidised to $Zn^{2+}(aq)$.
(c) Ni would be found in the anode slime.
(d) Fe would be oxidised to $Fe^{2+}(aq)$.

15. Select the correct IUPAC name for the molecule shown below.



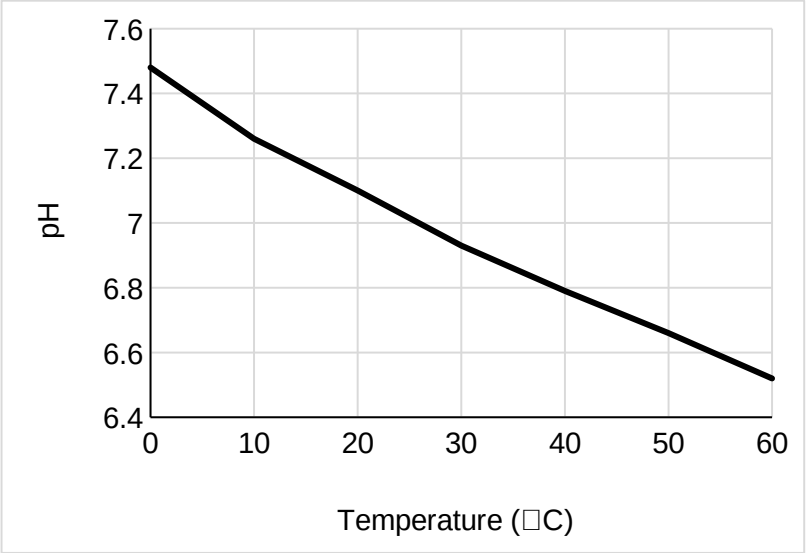
(a) 2,5,5-tribromo-1-methylpentanal.
(b) 1,1,4-tribromohexan-5-one.
(c) 3,6,6-tribromohexan-2-al.
(d) 3,6,6-tribromohexan-2-one.

See Next Page

16. A chemist carried out an experiment to investigate the auto-ionisation of water.

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

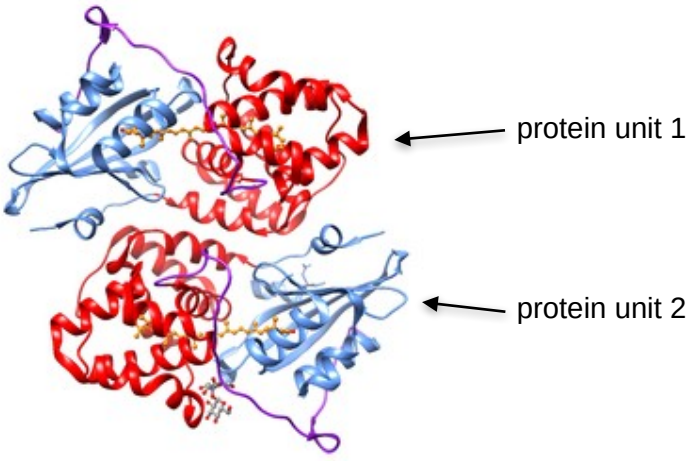
The data collected by the chemist is shown in the graph below.



Which of the following hypotheses is **not** directly related to the data collected in this experiment?

(a) An increase in water temperature will favour the forward reaction.
(b) An increase in water temperature will increase the forward reaction rate.
(c) The auto-ionisation of water is exothermic.
(d) The concentration of $H_3O^+(aq)$ in water is temperature-dependant.

17. The following diagram has been taken from the Protein Data Bank (PDB). It shows the structure of the 'orange carotenoid protein' which is a dimer consisting of two proteins.



This type of 'ribbon structure' provides **least** information about the

(a) primary structure of the protein.
(b) secondary structure of the protein.
(c) tertiary structure of the protein.
(d) protein-protein interactions.

See Next Page

Questions 18 and 19 refer to the information in the table below.

	Boiling point	Solubility in water at 20 ˚C
Butan-1-ol	118 ˚C	7.7 g / 100 mL
Octan-1-ol	195 ˚C	0.1 g / 100 mL

18. The boiling point of octan-1-ol is higher than butan-1-ol because octan-1-ol has

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

19. The aqueous solubility of butan-1-ol is greater than octan-1-ol because butan-1-ol has

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

20. The following reaction represents the oxidation of thiosulfate ($S_2O_3^{2-}$) to tetrathionate ($S_4O_6^{2-}$) by iodine.

$$I_2(aq) + 2\ S_2O_3^{2-}(aq) \rightarrow 2\ I^-(aq) + S_4O_6^{2-}(aq)$$

This redox reaction was used as the basis for a galvanic cell and the EMF was measured to be +0.46 V under standard conditions.

What is the value of the standard reduction potential (E^0) for the conversion of tetrathionate ($S_4O_6^{2-}$) to thiosulfate ($S_2O_3^{2-}$)?

(a) - 0.08 V
(b) + 0.08 V
(c) - 1.00 V
(d) + 1.00 V

21. Soaps are less effective than detergents in hard water, because the soap ion

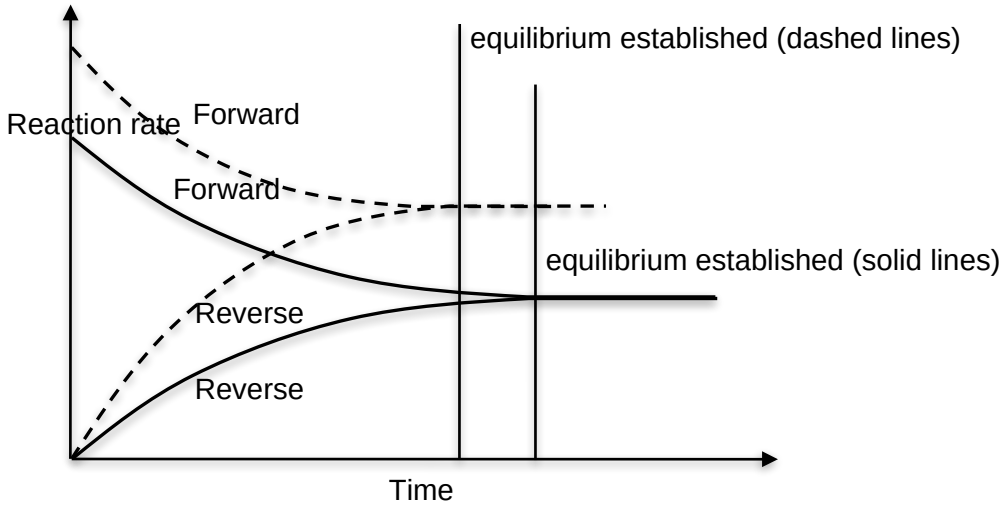
(a) does not contain a charged group.
(b) only contains a short non-polar region.
(c) neutralises hard water.
(d) precipitates $Ca^{2+}(aq)$ ions in hard water.

See Next Page

22. Consider the following gaseous equilibrium system;

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$$

The **solid** lines on the following graph represent the establishment of equilibrium under a particular set of conditions for this system.



Which of the following changes to this system would **not** result in the establishment of a new equilibrium as indicated by the **dashed** lines?

(a) An increase in the temperature of the system.
(b) A decrease in the volume of the system.
(c) The addition of helium gas to the system.
(d) The addition of an appropriate catalyst.

23. The secondary structures of proteins are stabilised by

(a) dipole-dipole forces.
(b) hydrogen bonds.
(c) disulfide bridges.
(d) ionic bonds.

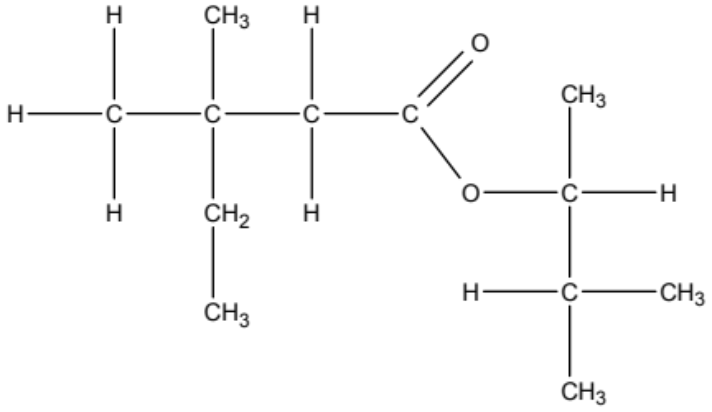
24. The wet corrosion of iron (Fe) occurs in the presence of oxygen gas (O_2) and water (H_2O). The iron reacts to become iron(II) ions, $Fe^{2+}(aq)$, whilst the water and oxygen gas form hydroxide ions, $OH^-(aq)$. The iron(II) ions and hydroxide ions then precipitate to form iron(II) hydroxide, $Fe(OH)_2(s)$. Over time, this precipitate forms iron(III) hydroxide, $Fe(OH)_3(s)$ which then dehydrates to form iron(III) oxide, $Fe_2O_3(s)$, which is commonly called rust.

Which of the following statements is **not** correct, regarding the corrosion process described?

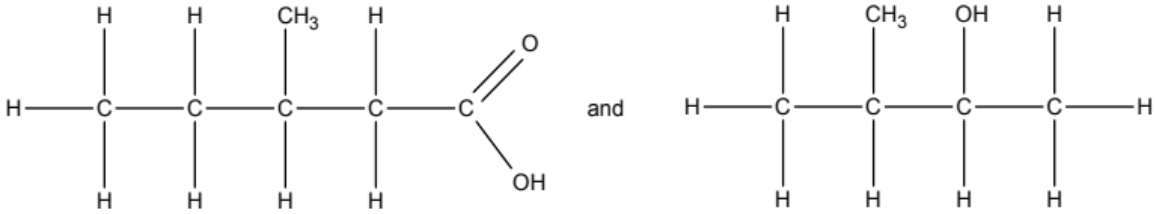
(a) The oxidation number of O_2 is decreased.
(b) The solid Fe loses electrons.
(c) The H_2O acts as the oxidising agent.
(d) The precipitation of $Fe(OH)_2$ is not a redox process.

See Next Page

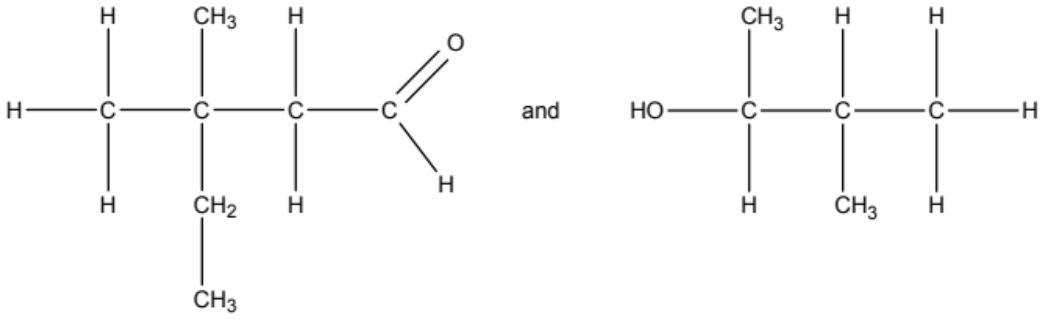
25. Which pair of substances could react, in the presence of an appropriate catalyst, to form the compound below?



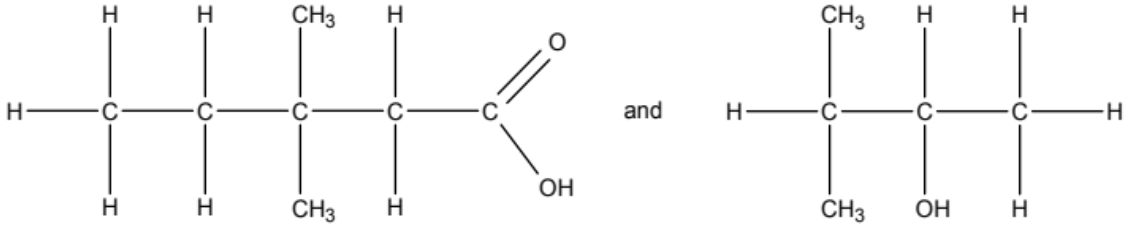
(a)



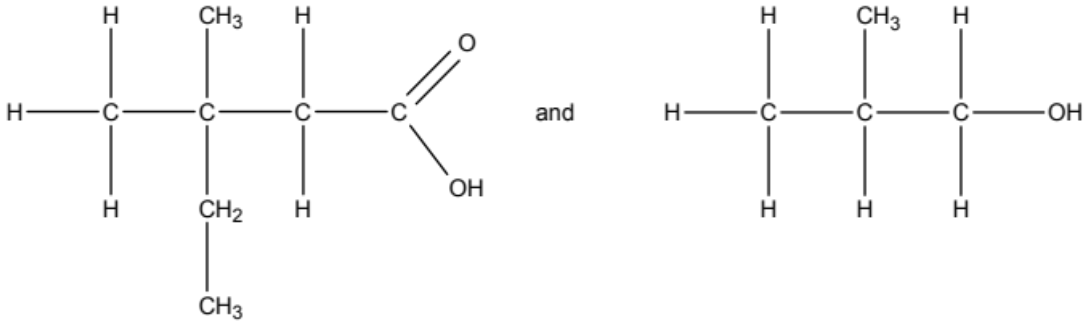
(b)



(c)



(d)



End of Section One

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Section Two: Short answer **35% (76 marks)**

This section has **8** 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 **(12 marks)**

Consider 0.05 mol L^{-1} solutions of sodium hydrogencarbonate, potassium hydrogensulfate and lithium phosphate. The table below lists these salts, along with K_c values for the corresponding hydrolysis reactions.

0.05 mol L^{-1} solution	Hydrolysis equation	K_c of hydrolysis reaction
$NaHCO_3(aq)$		2.4×10^{-8}
$KHSO_4(aq)$		1.2×10^{-2}
$Li_3PO_4(aq)$		2.3×10^{-2}

(a) Complete the table above, by writing the hydrolysis equation that would take place in each solution. (3 marks)

(b) Rank these solutions in order from lowest to highest pH. (3 marks)

Lowest pH		Highest pH

The pH of a lithium carbonate solution, $Li_2CO_3(aq)$, was tested with a pH meter and determined to be 10.3.

A chemistry student had 8.50 mL of 0.0500 mol L^{-1} barium hydroxide solution, $Ba(OH)_2(aq)$. They wanted to dilute the barium hydroxide so that it would have the same pH as the lithium carbonate solution.

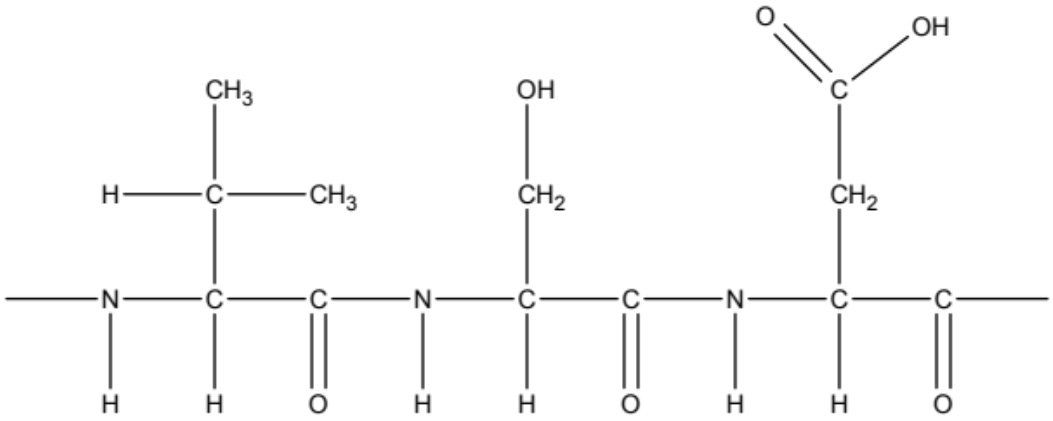
(c) Calculate the volume of water the student would need to add to the barium hydroxide solution, to produce the same pH as the lithium carbonate. (6 marks)

See Next Page

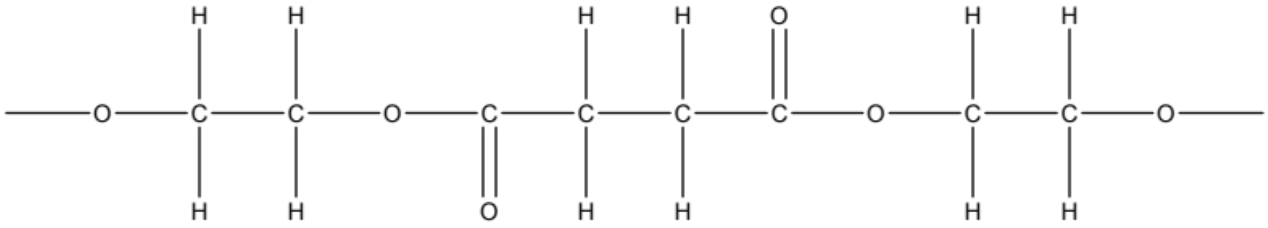
Question 27 **(9 marks)**

Consider the three (3) different polymer fragments shown below.

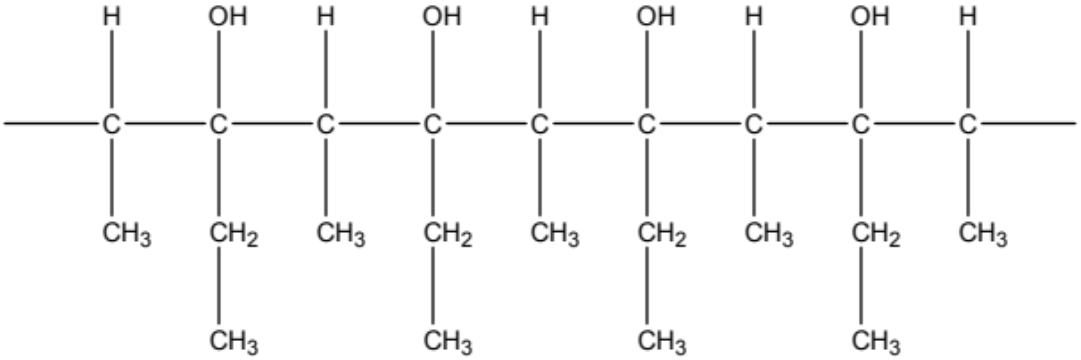
A



B



C



(a) Classify the polymers as having been formed by addition or condensation polymerisation by writing the letters A, B and C in the appropriate column in the table. (3 marks)

Addition polymerisation	Condensation polymerisation

(b) Draw the monomer(s) used to form each of these polymers. (6 marks)

A	
B	
C	

Question 28 **(10 marks)**

Consider the two redox reactions below.

Reaction A $Sn^{2+}(aq) + 2\,I^{-}(aq) \rightarrow Sn(s) + I_2(aq)$

Reaction B $Sn^{2+}(aq) + Co(s) \rightarrow Sn(s) + Co^{2+}(aq)$

(a) Which reaction relates to a galvanic cell and which relates to an electrolytic cell? Justify your answer. (3 marks)

Reaction _____ relates to a galvanic cell.

Reaction _____ relates to an electrolytic cell.

Using the appropriate reaction (A or B) from above;

(b) Draw a diagram of the experimental set up that could be used to produce a **galvanic cell**. Your diagram should label the equipment and chemicals required to set up the cell. (Note that labels of electrodes, polarity, ion and electron flow are **not** required.) (4 marks)

(c) Calculate the EMF produced by this galvanic cell, assuming standard conditions. (1 mark)

Using the appropriate reaction (A or B) on the previous page;

(d) State the observations for each electrode, if this process was occurring in an **electrolytic cell**. Assume the electrodes are made from graphite. (2 marks)

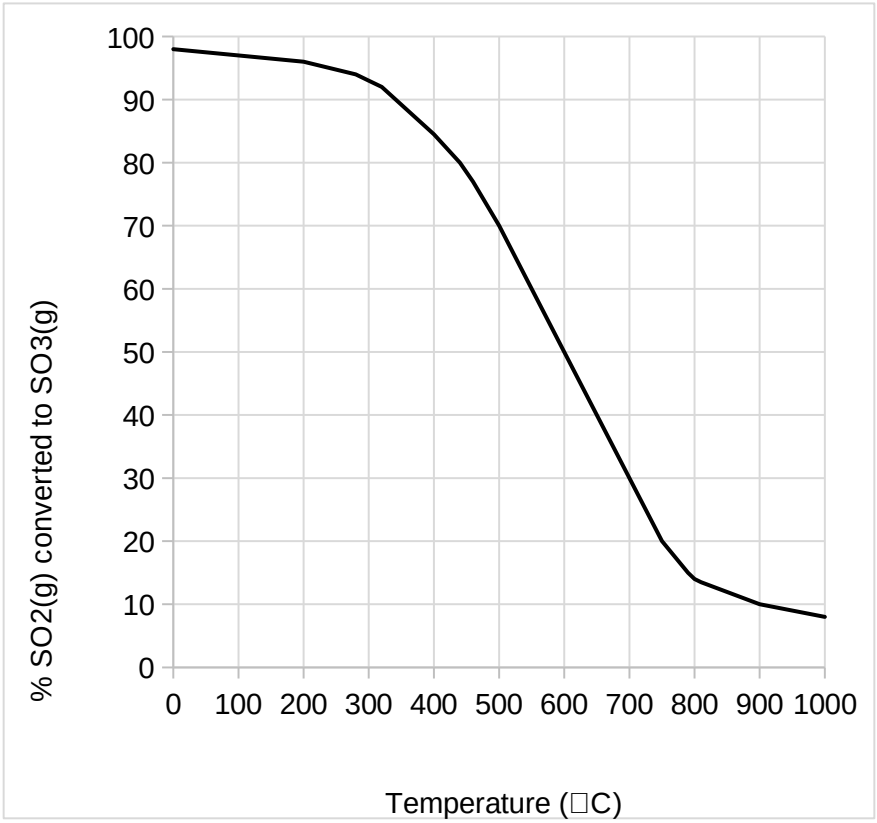
positive electrode	
negative electrode	

Question 29 **(9 marks)**

A key reaction in the Contact process involves the conversion of sulfur dioxide gas to sulfur trioxide gas. This reversible process can be represented by the equation below.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$

The following graph shows the relationship between temperature and percentage conversion of $SO_2(g)$ to $SO_3(g)$ for this process.



(a) Use the information in the graph provided to determine if this reaction is endothermic or exothermic as written. Justify your answer. (3 marks)

(b) Complete the following table, by stating the **pressure** conditions of the system (high or low) that would result in;
(i) the fastest rate, and
(ii) the highest yield.
Give a brief justification for each of your choices. (5 marks)

(i) fastest rate	(circle your choice)	high	OR	low
	Justification			
(ii) highest yield	(circle your choice)	high	OR	low
	Justification			

When this process is carried out industrially, a low pressure of 1-2 atm is used.

(c) Suggest a reason for this. (1 mark)

_____

_____

_____

Question 30 **(9 marks)**

Telluric acid has the formula H_6TeO_6. In solid form, it is found as white crystals. These crystals dissolve in water to produce hydronium ions, $H_3O^+(aq)$. The K_a values for telluric acid at 18 °C are given below.

$K_{a1} = 2.09 \times 10^{-8}$ $K_{a2} = 1.00 \times 10^{-11}$

(a) Classify telluric acid as strong or weak (circle your choice). Justify your answer. (2 marks)

strong OR weak

(b) Classify telluric acid as monoprotic or polyprotic (circle your choice). Justify your answer. (2 marks)

monoprotic OR polyprotic

(c) Label and link the conjugate acid-base pairs in the following equation. (2 marks)

$$H_6TeO_6(aq) + HPO_4^{2-}(aq) \rightleftharpoons H_2PO_4^-(aq) + H_5TeO_6^-(aq)$$

Telluric acid can be produced by the oxidation of solid tellurium dioxide, $TeO_2(s)$, by hydrogen peroxide solution. In this reaction, hydrogen peroxide forms water.

(d) Write the oxidation and reduction half-equations and the overall redox equation for this reaction, assuming acidic conditions. (3 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

See Next Page

Question 31 **(8 marks)**

(a) Give the IUPAC names for isomers of $C_3H_6O_2$ matching each description below. (2 marks)

	IUPAC Name
A sweet or fruity smelling liquid	
A weak electrolyte with a pH below 7	

(b) Give the IUPAC names for isomers of $C_5H_{12}O$ matching each description below. (2 marks)

	IUPAC Name
A primary alcohol	
A tertiary alcohol	

(c) Draw full structural diagrams for isomers of $C_2H_2F_2$ matching each description below. Include **all** bonds and **all** atoms. (2 marks)

The *cis* geometric isomer	The *trans* geometric isomer

(d) Draw full structural diagrams for isomers of C_4H_8O matching each description below. Include **all** bonds and **all** atoms. (2 marks)

A compound that can be oxidised by acidified $KMnO_4$ solution	A compound that cannot be oxidised by acidified $KMnO_4$ solution

See Next Page

Question 32 **(13 marks)**

The following equilibrium system exists in ocean water and shows the relationship between several of the carbon-species present.

$$Ca^{2+}(aq) + 2\,HCO_3^-(aq) + \text{heat} \rightleftharpoons CaCO_3(s) + H_2O(l) + CO_2(g)$$

The forward reaction represents the process of '**calcification'**, where solid $CaCO_3$ forms. The reverse process represents the '**dissolution'** of solid $CaCO_3$.

(a) Write the equilibrium constant (K) expression for this system. (1 mark)

The large quantity of $CO_2(g)$ produced and released into our atmosphere by human activity is having an effect on the carbon equilibria in our oceans.

(b) Explain, in terms of the collision theory and reaction rates, how this increase in the partial pressure of atmospheric $CO_2(g)$ affects the calcification process. Your answer should refer to the equation above. (4 marks)

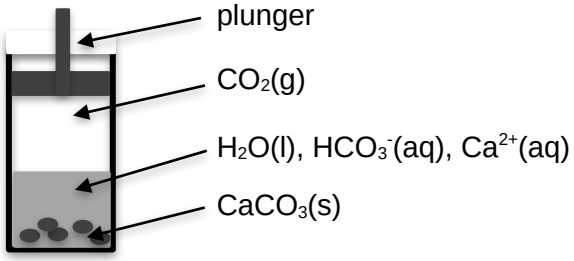
See Next Page

(c) State two (2) consequences for calcifying species that may result from this increase in the partial pressure of atmospheric $CO_2(g)$. (2 marks)

(d) Write a three-step reaction sequence, showing how an increased partial pressure of atmospheric $CO_2(g)$ leads to a decrease in ocean pH. (3 marks)

Step 1	
Step 2	
Step 3	

An artificial replica of this equilibrium system was set up in a closed container, which was sealed with a moveable plunger, allowing for variable gas volume and pressure to be achieved. The set up is illustrated in the diagram to the right.



(e) Consider the effect of imposing the following changes on the system. Complete the table below by stating whether the process of calcification or dissolution, or neither, is favoured. (3 marks)

	Favoured process (calcification / dissolution / neither)
The volume of the system is decreased by pushing the plunger down	
Additional $CaCO_3(s)$ is added to the system	
The temperature of the system is increased	

Question 33 **(6 marks)**

Consider the distinguishing chemical tests described below.

(a) Write **observations** for the following test, which can be used to distinguish between solutions of sodium chloride and sodium iodide. (2 marks)

	Bromine water, $Br_2(aq)$, is added to each
NaCl(aq)	
NaI(aq)	

(b) Write an **ionic equation**, or state 'no reaction', for the following test which can be used to distinguish between solutions of silver nitrate and zinc sulfate. (3 marks)

	A piece of nickel metal, Ni(s), is added to each
$AgNO_3(aq)$	
$ZnSO_4(aq)$	

(c) Name or give the formula of a substance that could be added to each solution, to produce the observations given for the following distinguishing test. (1 mark)

	Substance added:
HCHO(aq)	White powder mixed with colourless solution. No changes are observed.
HCOOH(aq)	White powder mixed with colourless solution. White powder dissolves and colourless, odourless gas is produced.

End of Section Two

See Next Page

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Section Three: Extended answer **40% (98 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 34 **(20 marks)**

The following reversible reaction between chromate (CrO_4^{2-}) and dichromate ($Cr_2O_7^{2-}$) was set up in a beaker and allowed to establish equilibrium. The initial colour of the equilibrium system was a light orange. The equilibrium can be represented by the following equation;

$$\underset{\textit{yellow}}{2\ CrO_4^{2-}(aq)} + 2\ H^+(aq) \rightleftharpoons \underset{\textit{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

This equilibrium system is 'pH dependent'.

(a) Complete the following table, by writing the colour this equilibrium system would appear at both a low and a high pH. (2 marks)

Colour at low pH	Colour at high pH

The equilibrium mixture was then divided equally into 2 smaller beakers. The separate beakers, Beaker 1 and Beaker 2, were treated as described below.

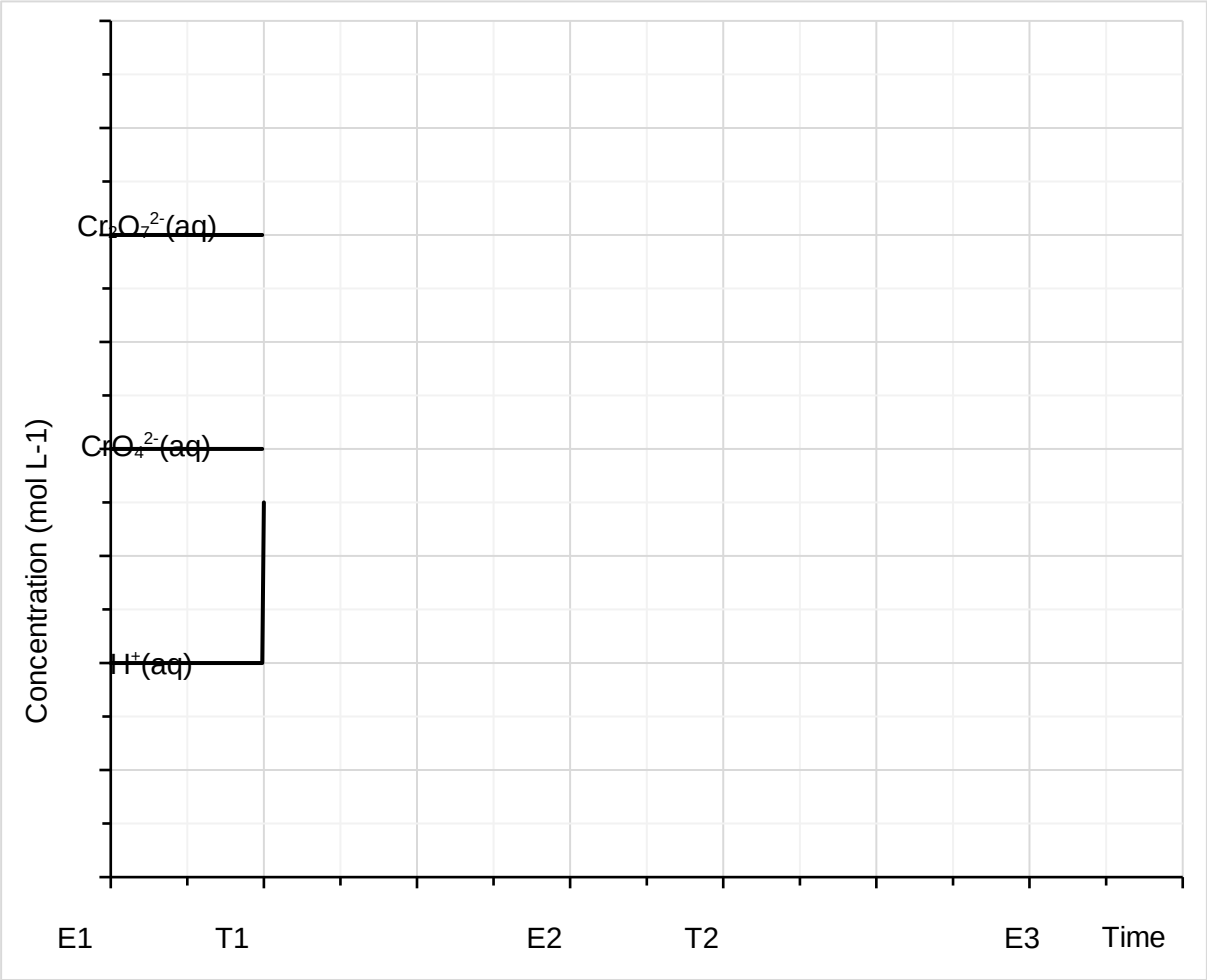
Beaker 1

- Firstly, 10 drops of 2 mol L^{-1} HCl(aq) were added at Time T1, and equilibrium was re-established at Time E2.
- Next, 10 drops of 2 mol L^{-1} NaOH(aq) were added at Time T2, and equilibrium was once again re-established at Time E3.

You may assume the increase in volume due to the added HCl(aq) and NaOH(aq) are negligible.

The following graph represents the equilibrium in Beaker 1.

$$2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$



(b) Plot the concentration for each of the ions shown on the graph, from Time T1 to Time E3. (8 marks)

(c) Why isn't a curve for water concentration plotted on the graph? (1 mark)

_____

_____

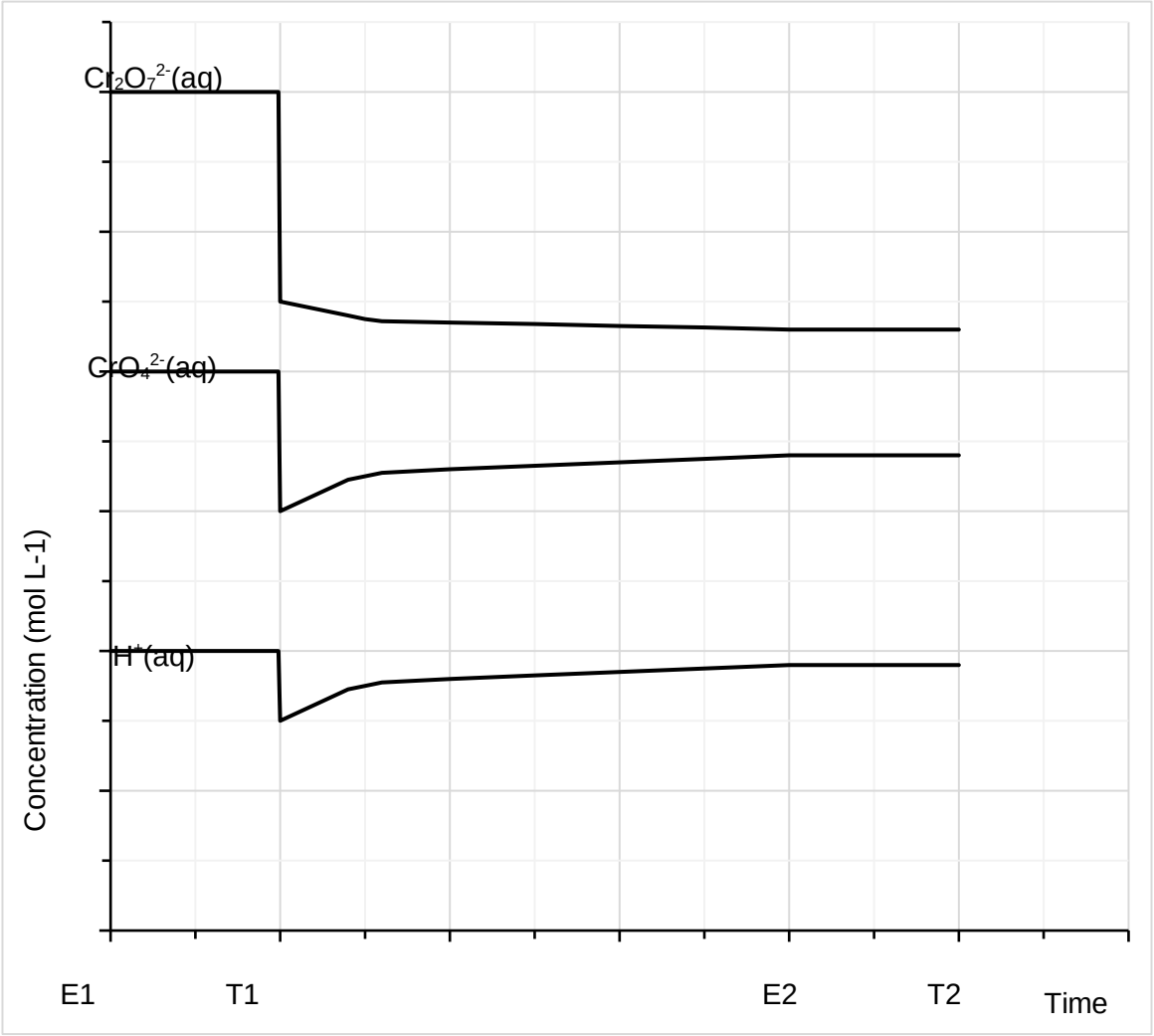
_____

See Next Page

Beaker 2

The following graph represents the equilibrium in Beaker 2.

$$2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$



(d) State the change imposed at Time T1. Justify the subsequent equilibrium shift using Le Chatelier's Principle. (3 marks)

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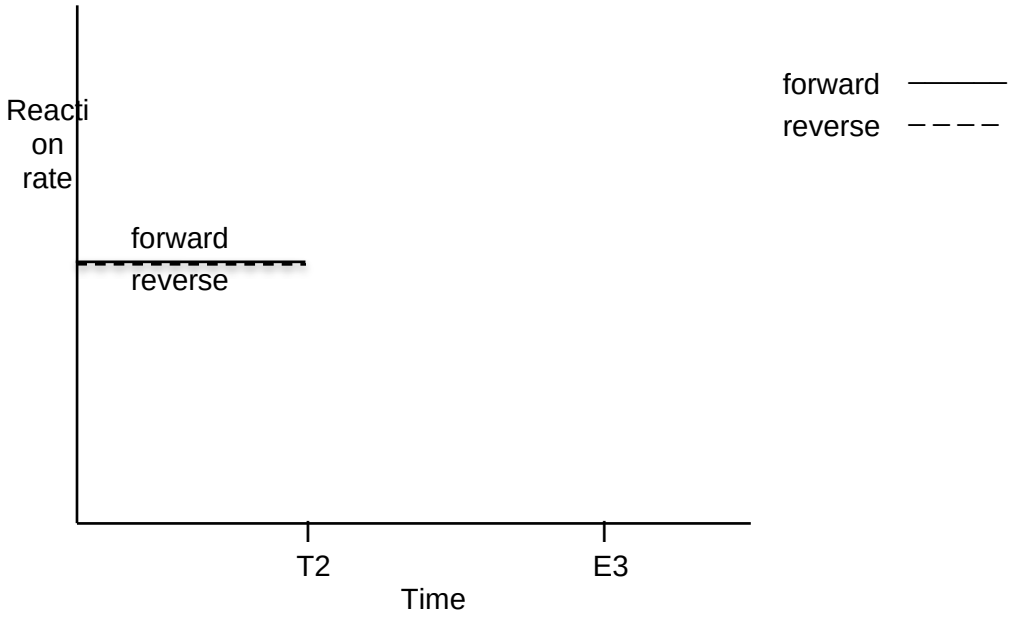
At Time T2, Beaker 2 was placed into an ice bath. Over several minutes, the equilibrium became a more yellow colour.

(e) Explain what information this provides about the heat of reaction (H) for this equilibrium system. (3 marks)

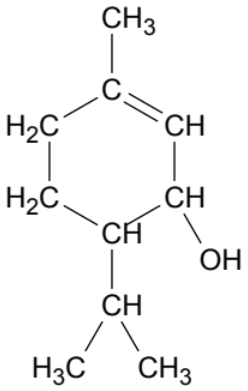
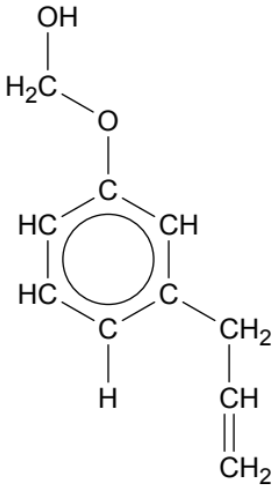
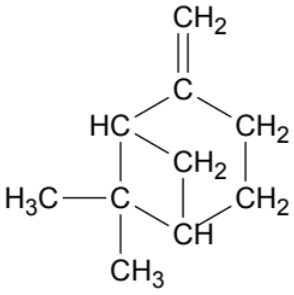
(f) Complete the reaction rate graph below, for both the forward and reverse reaction rates, from Time T2 until the re-establishment of equilibrium at Time E3. (3 marks)



Question 35 **(16 marks)**

In traditional Aboriginal culture, native plants have been used for many generations to treat or heal those who are sick or injured. Research is now being carried out on many of the various plants that were used by Aboriginal peoples and has found that they often contain well known anti-bacterial or anti-inflammatory compounds.

The table below gives information on three (3) compounds that have been identified in native Australian plants which were used by Aboriginal peoples to treat various medical conditions.

Name of compound	Terpinenol	Eugenol	Pinene
Extracted from	Tea tree oil	Australian lemongrass	Eucalyptus oil
Aboriginal medicinal use	treating wounds and throat ailments	treating headaches, colds and muscle pain	treating body pain, fever and chills
Structure			

A chemist was given a pure sample of each of these 3 compounds for analysis. However, the samples were not labelled.

(a) Explain why the addition of bromine water to each of these samples would **not** be a useful distinguishing test. (2 marks)

See Next Page

The compound ‘pinene’ could quickly be distinguished from the other two compounds by adding a few drops of acidified sodium dichromate solution to each.

(b) Justify how this test would allow for the identification of pinene, including relevant observations in your answer. (Note that equations are **not** required.) (3 marks)

The chemist then used combustion analysis to distinguish ‘terpinenol’ and ‘eugenol’. A 7.58 g sample of one of the compounds was taken for analysis. Upon combustion, 20.33 g of carbon dioxide and 4.99 g of water vapour was produced.

(c) Determine the empirical formula of this sample and identify which compound was being analysed. (9 marks)

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The chemist then carried out two further chemical tests with the compound identified by combustion analysis in part (c).

(d) Draw structural diagrams for the resulting organic compound formed when the substance identified in (c) reacts
(i) with bromine water
(ii) with acidified sodium dichromate. (2 marks)

	bromine water, $Br_2(aq)$	chemical test described in part (b)
Organic product formed		

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Question 36 **(14 marks)**

A beaker contained 135 mL of 0.273 mol L^{-1} hydrochloric acid, HCl(aq). A group of chemistry students were given some 0.198 mol L^{-1} ammonia solution, $NH_3(aq)$, and asked to neutralise the acid.

They measured 344 mL of the ammonia solution and poured it into the beaker containing the hydrochloric acid. The equation for the reaction that took place is given below.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

(a) Determine, by calculation, whether all the hydrochloric acid was neutralised upon addition of the ammonia. (4 marks)

(b) Calculate the final concentration, in mol L^{-1}, of any excess reagent present. (2 marks)

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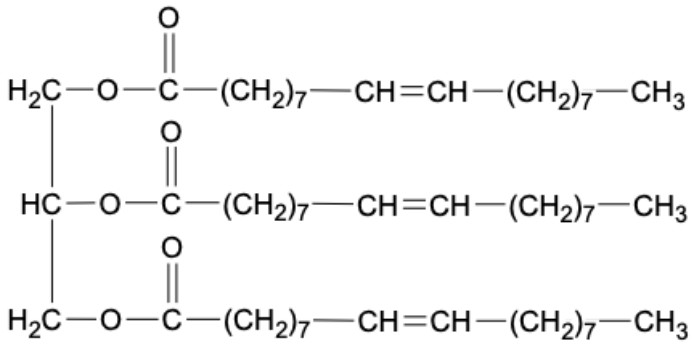
(c) Calculate the final concentration, in mol L^{-1}, of ammonium chloride product. (2 marks)

One of the chemistry students in the group, proposed that the final mixture in the beaker would act as a buffer solution.

(d) Was this student correct? Justify your answer using relevant chemical theory. Include a brief description of how the student's hypothesis could be tested experimentally. (6 marks)

Question 37 **(25 marks)**

An ongoing area of chemical research relates to the optimisation of biodiesel production from the triglycerides in waste vegetable oil. The chemical process involves converting waste vegetable oil into biodiesel, in a reaction catalysed by sodium hydroxide (NaOH). A common component found in waste vegetable oil is the triglyceride 'triolein'. The structure of triolein is shown below.



(a) What is biodiesel? Describe how triolein can be converted into biodiesel, by naming the chemical reaction and stating the additional reactant required. (4 marks)

One of the problems associated with converting waste vegetable oil into biodiesel, is that the vegetable oil can often contain a high levels of free fatty acids (FFAs). In the case of triolein, when heated for use in cooking it can produce 'oleic acid', $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$.

The 'percent free fatty acid' (% FFA) of vegetable oil is calculated as the grams of FFA present per 100 g of oil. The concentration of FFA in any oil, is generally calculated and stated in terms of 'oleic acid', as this is a common fatty acid of average molecular weight.

$$\text{i.e.} \quad \%\ \text{FFA} = \frac{m(\text{oleic acid})}{m(\text{oil})} \times 100$$

When making biodiesel, if the waste vegetable oil contains greater than 1% FFA by mass, extra sodium hydroxide must be added to the reaction mix. This ensures that the FFAs are completely neutralised, and that there is still enough sodium hydroxide left over to act as a catalyst in the formation of biodiesel.

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(b) Write the equation for the reaction of oleic acid with sodium hydroxide. (1 mark)

(c) Give the **general** name for the type of organic substance produced in (b). (1 mark)

A particular batch of waste vegetable oil from a restaurant was being analysed for FFA content, before being converted into biodiesel. The amount of sodium hydroxide required to neutralise the FFAs present in a sample of waste vegetable oil is determined by titration.

A 10.00 mL sample of the waste vegetable oil was taken and mixed with 100.0 mL of propan-2-ol. Then 15.00 mL aliquots of the diluted oil were titrated against 0.01180 mol L^{-1} NaOH(aq). This required an average titre of 10.66 mL. The density of the waste vegetable oil was 0.895 g mL^{-1}.

(d) Calculate the % FFA in this batch of waste vegetable oil. (6 marks)
(The molecular mass of oleic acid is 282.452 g mol^{-1}.)

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(e) State two (2) reasons for performing repeat trials in a titration, in order to obtain an average titre. (2 marks)

(f) If the burette had been rinsed with water before use in this titration, state the effect this would have had on the calculated % FFA content. Justify your answer. (2 marks)

The standard amount of solid sodium hydroxide catalyst, NaOH(s), added to the reaction mix during biodiesel production, is 3.5 g per litre of vegetable oil, **plus** any extra NaOH that is required to neutralise the FFAs present.

A 2500 L batch of the waste oil from the restaurant was to be converted to biodiesel.

(g) Calculate the total mass of NaOH needed for this reaction mixture. (5 marks)

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An alternate catalyst for the production of biodiesel by this method, is the enzyme lipase.

(h) State two (2) similarities and two (2) differences in the way the NaOH and lipase catalysts **function** in this process. (4 marks)

Similarities	
1	
2	
Differences	
1	
2	

Question 38 **(23 marks)**

With an emphasis on the principles of green chemistry becoming essential in our modern world, this has led to many new areas of research. One particular type of fuel cell, the 'high temperature carbonate fuel cell' has been designed so that it can be powered by biogas (a mixture of methane and carbon dioxide gases).

High temperature carbonate fuel cells are often built at landfill sites, where biogas is already being produced. As microbes digest organic waste, they produce methane in a process called 'methanogenesis'. This is performed by bacteria called methanogens, which convert the glucose found in landfill into biogas.

Step 1: $C_6H_{12}O_6(s) \rightarrow 3\ CO_2(g) + 3\ CH_4(g)$

The carbon dioxide is removed from the biogas and the methane is then used in the carbonate fuel cell, where it reacts with water to produce hydrogen gas.

Step 2: $CH_4(g) + H_2O(g) \rightarrow 3\ H_2(g) + CO(g)$

The hydrogen gas is then reacted with oxygen gas in the fuel cell to produce electrical energy.

Step 3: $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$

The process of methanogenesis (i.e. Step 1) is catalysed by various enzymes (proteins) present in the bacteria. These enzymes are sensitive to both temperature and pH.

(a) With reference to **tertiary structure**, explain why enzymes generally only function within a narrow temperature and pH range. (5 marks)

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One of the principles of green chemistry involves maximising atom economy. Atom economy is a measure of the proportion of reactant atoms that are converted into the desired product in the chemical reaction.

(b) Calculate the percent atom economy of Step 1. (2 marks)

$$\% \text{ atom economy} = \frac{\text{total molar mass of atoms in desired product}}{\text{total molar mass of atoms in all reactants}} \times 100$$

High temperature carbonate fuel cells produce 135 kg of hydrogen gas per day using this method. The yield of Step 1 is 94.2% and the yield of Step 2 is 86.8%.

(c) Calculate the mass of glucose required **each day** to produce this hydrogen. State your answer to the appropriate number of significant figures. (6 marks)

(d) Calculate the volume of air, collected at 15.0 ˚C and 97.6 kPa, that would be required **each day** to supply sufficient oxygen to react with this hydrogen. Assume air is composed of 21.0% oxygen gas by volume. (3 marks)

(e) Complete the following table by providing an example of how the 'high temperature carbonate fuel cell' supports the following principles of green chemistry. (3 marks)

Waste prevention	
Use of renewable feedstocks	
Design less hazardous chemical syntheses	

See Next Page

(f) Write separate half-equations for the oxidation and reduction processes taking place in Step 3 (assuming acidic conditions). (2 marks)

Oxidation half-equation	
Reduction half-equation	

(g) Is a fuel cell classified as a ‘galvanic’ or ‘electrolytic’ cell? Justify your answer. (2 marks)

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End of questions

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Acknowledgements

Q 17 Orange carotenoid protein
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