Perth Modern School examination, Semester 2, 2020

Question/Answer booklet

CHEMISTRY ANSWERS

Student Name: _____

Student Number: In figures | | | | | | | | |

In words

Teacher Name: _____

Time allowed for this paper

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

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet
Chemistry Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including colours), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in this examination

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

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

Instructions to candidates

1. The rules for the conduct of ATAR course examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
3. Answer the questions according to the following instructions.

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

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

4. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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

6. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

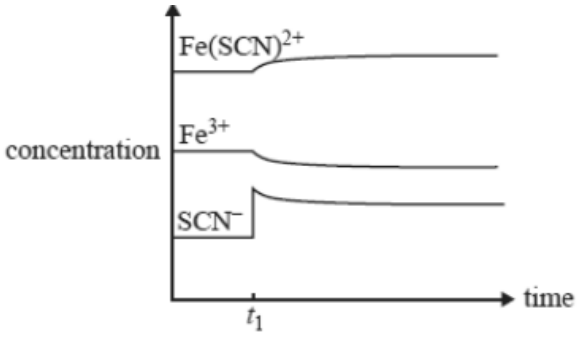
7. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

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

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

Suggested working time: 50 minutes

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



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

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

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

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

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

See next page

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

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

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

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

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

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

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

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

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

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

a) CH_3COOH and $NaCH_3COO$
b) HCl and NaCl.
c) NH_3 and $(NH_4)_2SO_4$
d) NH_3 and NH_4Br

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

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

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

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

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

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

See next page

10. Which of the following statements is false?

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

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

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

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

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

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

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

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

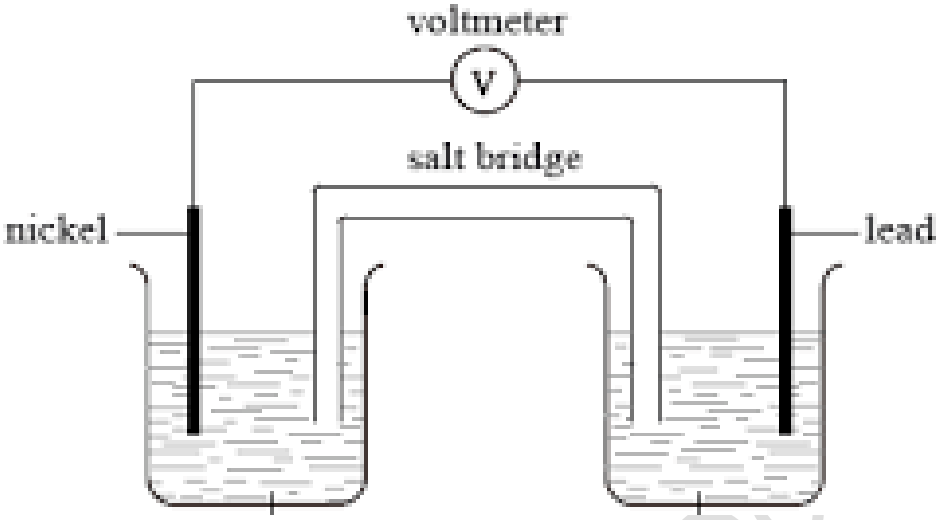
14. For a voltaic (or galvanic) cell using Ag, Ag^+ (1.0 mol L^{-1}) and Zn, Zn^{2+} (1.0 mol L^{-1}) half-cells, which of the following statements is incorrect?

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

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

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

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



Which of the following statements is false?

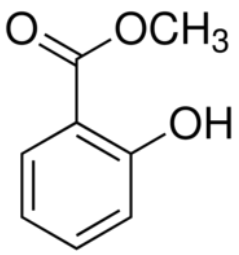
a) No reaction would occur if the contents of the two beakers were mixed.
b) The overall reaction is Ni (s) + Pb^{2+} (aq) ⇌ Ni^{2+}(aq) + Pb (s)
c) Lead (II) ions are reduced to lead.
d) Electrons flow from the lead electrode to the nickel electrode.

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

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

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

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



oil of wintergreen

The functionality of the carbonyl group it contains is:

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

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

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

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

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

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

See next page

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

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

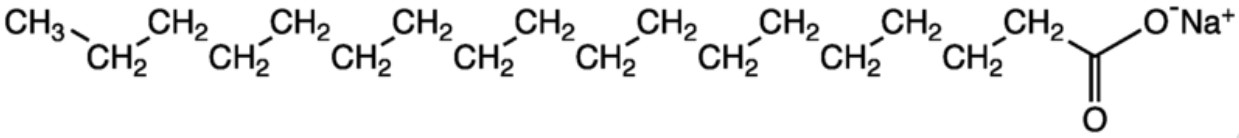
22. Which one of the following pairs of compounds would produce biodiesel if reacted together?

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

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

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

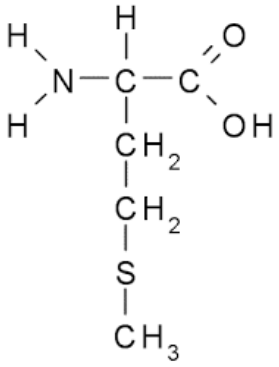
24. The following formula represents the structure of a chemical compound.



Which of the following statements about this molecule is false?

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

25. Consider the amino acid methionine:



Which one of the following is false?

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

End of Section 1

See next page

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

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

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

Suggested working time: 60 minutes.

Question 26 **(9 marks)**

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

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

Description	**Marks**
Silvery solid is consumed	1
Bubbling / fizzing / effervescence	1
Other appropriate observation (i.e. heat evolved)	
Total	**2**

Observations needed to be for the reaction taken place not for the before -> after. Observations must not state the name of reactant or product. A number of people said Sodium was white which was not paid.

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

Description	**Marks**
$2Na\ (s) + 2CH_3CH(OH)CH_2CH_3\ (aq) \rightarrow 2Na^+\ (aq) + 2CH_3CH(O)CH_2CH_3^-\ (aq) + H_{2\ (g)}$ OR: $2Na\ (s) + 2C_4H_9(OH)\ (aq) \rightarrow 2Na^+\ (aq) + 2C_4H_9(O)^-\ (aq) + H_{2\ (g)}$ OR: $2Na\ (s) + 2C_4H_{10}O\ (aq) \rightarrow 2Na^+\ (aq) + 2C_4H_9(O)^-\ (aq) + H_{2\ (g)}$	2
NOTE: accept structural / condensed / molecular formula	
Minor error (i.e. state symbols)	-1
Total	**2**

Needed to be an ionic equation with sodium and ethoxide ion separate. Lots did not get the correct formula for ethoxide or missed hydrogen gas or correct balancing

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

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

Description	Marks
CH_3COOH (aq) + H_2O (l) ⇌ CH_3COO^- (aq) + H_3O^+ (aq)	2
NOTE: accept structural / condensed / molecular formulae	
Minor error (i.e. state symbols / not equilibrium arrows)	-1
Total	**2**

Question answered well. Minor mistake of not including equilibrium arrow as weak acid.

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

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

Description	Marks
1. Right 2. No change 3. right	3
Total	**3**

Lots of people did not get the 3rd mark. Most got the first mark.

See next page

Question 27 **(13 marks)**

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

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

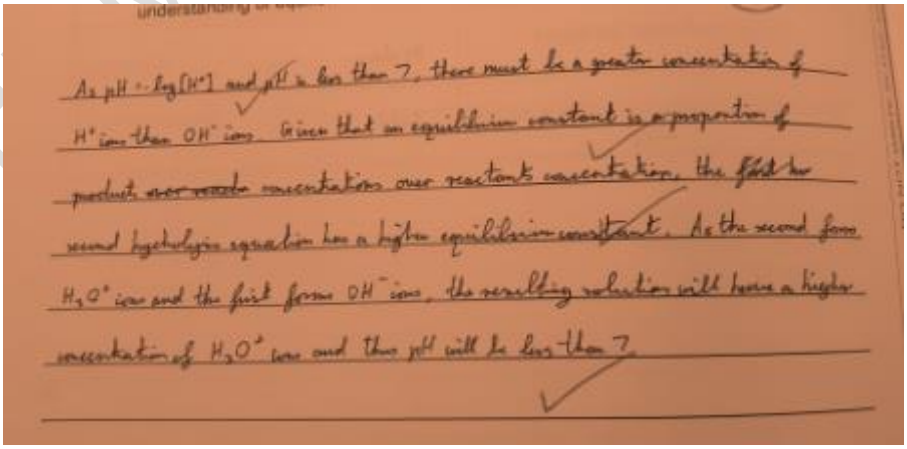
Description	Marks
$HC_2O_4^-$ (aq) + H_2O (l) ⇌ $C_2O_4^{2-}$ (aq) + H_3O^+ (aq)	1
$HC_2O_4^-$ (aq) + H_2O (l) ⇌ $H_2C_2O_4$ (aq) + OH^- (aq)	1
Use of equilibrium arrows and balanced (state symbols not required)	1
If sodium was present in both and "made sense"	-1
Total	**3**

Lots of variations on answers here. Marks not awarded for not including equilibrium, arrow. Lots of people where including sodium and trying to balance as complex ions.

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

Description	Marks
If solution has pH < 7, the concentration of [H3O+] > [OH–]	1
K is ratio of products to reactants	1
H3O+ producing equation has the higher K value	1
Thus, H3O+ producing equation moves forward to a greater extent than the OH– producing equation – FAVOURS MORE	1
Total	**4**

Lots of people got 3 out of 4. Where they did not get marks awarded was acknowledging [H3O+] > [OH–] as assuming only equation for [H_3O^+] is working or which equation is favoured more.



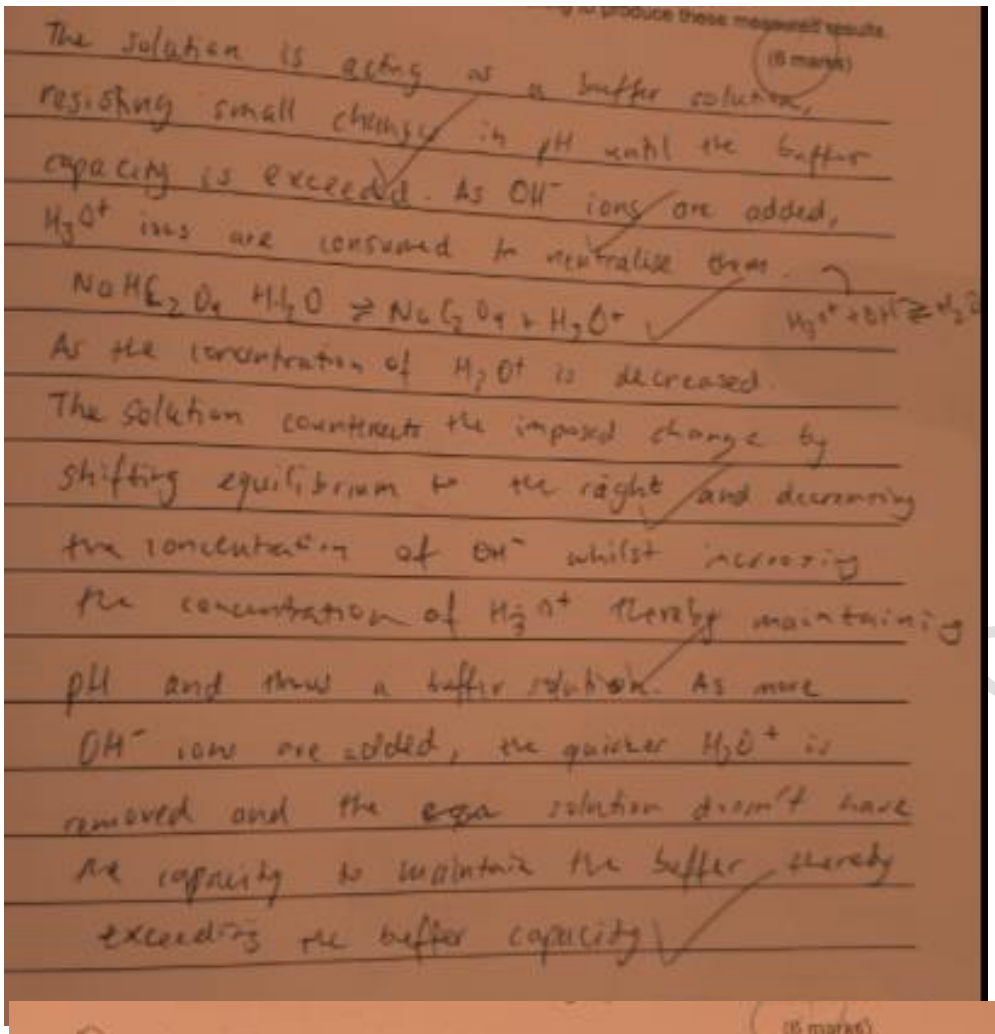
Successive 0.1 mL volumes of dilute sodium hydroxide solution are added to the sodium hydrogen oxalate solution and the pH was measured after each small addition. It was noticed that for the first few additions, the pH hardly changed. After the fourth addition, the pH changed significantly and for every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

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

(6 marks)

Description	**Marks**
Buffering capacity exceed	1 mark
$HC_2O_4^-$(aq) + $H_2O(\ell)$ ⇌ $C_2O_4^{2-}$(aq) + H_3O^+(aq)	1 mark
Neutralization reduces concentration of H_3O^+ ions / Addition of OH^- reacts with H_3O^+ to produce water	1 mark
Equilibrium of the hydrolysis of **$HC_2O_4^-$(aq) moves to the right**	1 mark
Increasing **concentration of H_3O^+, prevents pH** from rising	1 mark
Used up reactants, greater change in pH explained.	1 mark
Total	**6 marks**

If students did not use the correct equation and explained it in term of addition of hydroxide and how it effects the equation $HC_2O_4^-$ (aq) + H_2O (l) ⇌ $H_2C_2O_4$ (aq) + OH^- (aq) with no mention of [H_3O^+] changed they did not answer the question as they needed to discuss pH and pH is a measure of the – log [H^+]. If they did discuss buffer capacity and how that works they could receive a maximum of 2 marks.



The solution is acting as a buffer solution, resisting small changes in pH until the buffer capacity is exceeded. As OH^- ions are added, H_3O^+ ions are consumed to neutralise them. $NaHC_2O_4 + H_2O \rightleftharpoons NaC_2O_4 + H_3O^+$ $H_3O^+ + OH^- \rightleftharpoons 2H_2O$

As the concentration of H_3O^+ is decreased. The solution counteracts the imposed change by shifting equilibrium to the right and decreasing the concentration of OH^- whilst increasing the concentration of H_3O^+ thereby maintaining pH and thus a buffer solution. As more OH^- ions are added, the quicker H_3O^+ is removed and the ~~eqn~~ solution doesn't have the capacity to maintain the buffer, thereby exceeding the buffer capacity.

(5 marks)

① $HC_2O_4^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2O_4^{2-}{}_{(aq)}$

The solution acts as a buffer according to eq. ①.

When a small amount NaOH is added, it neutralises the $H_3O^+_{(aq)}$ and reduces $[H_3O^+_{(aq)})$, causing equilibrium shift to the right and partially restore the pH as (H_3O^+), hence preventing the large pH change. This occurs when more drops are added until the concentration of $HC_2O_4^-{}_{(aq)}$ becomes too low. (as when equilibrium shifts right, $HC_2O_4^-$ is consumed to produce $(C_2O_4^{2-})$, and hence the buffering capacity is ~~corrected~~ exceeded, and then pH would change drastically with each addition of NaOH, as the change in $[H_3O^+]$ would not be counteracted by the buffer system ① Anymore.

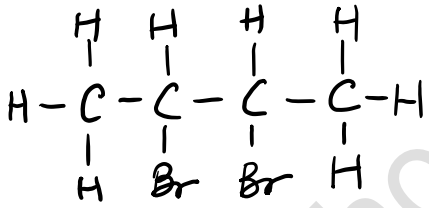
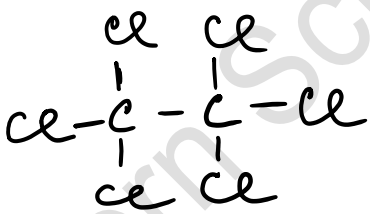
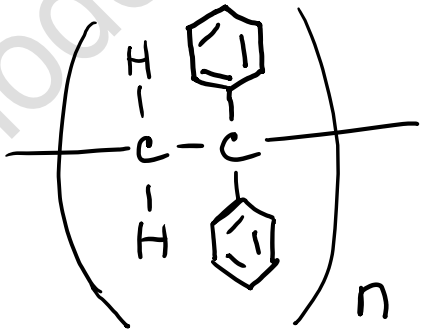
Question 28 **(6 marks)**

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

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

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

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

Description	**Marks**
Structure - with all bonds and all atoms shown a)  b)  c)  For structure of polymer: Bonds extending outside of brackets and **n** must be present for a mark.	0-3 marks

See next page

IUPAC Name: 2,3-dibromopentane Hexachloroethane (**not** 1,1,1,2,2,2-hexachloroethane) polydiphenyllethene **Note:** The name of the compound is written out with the substituents in alphabetical order followed by the base name (derived from the number of carbons in the parent chain). Commas are used between numbers and dashes are used between letters and numbers. There are **no** spaces in the name.	0-3 marks
Total	**6 marks**

Question 29 **(11 marks)**

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

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

Description	**Marks**
Statement: Enzymes are a catalyst (or definition of catalyst)	1 mark
Graph indicating Energy Profile:	
Catalyst lower activation energy than non-catalysed	1 mark
Exothermic reaction	1 mark
Activation energy **and** enthalpy	1 mark
Total	**4 marks**

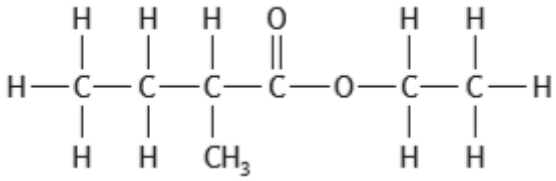
Some of the ethanol that is supplied by the fermentation process can oxidise to form two water soluble organic molecules that can spoil the flavour of the cider.

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

Description	**Marks**
Ethanal Ethanoic acid	0-2 marks
$CH_3CH_2OH \rightarrow CH_3CHO + 2\ H^+ + 2\ e^-$ $CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4\ H^+ + 4\ e^-$	0-2 marks
Minor error	-1 mark
Total	**4 marks**

See next page

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



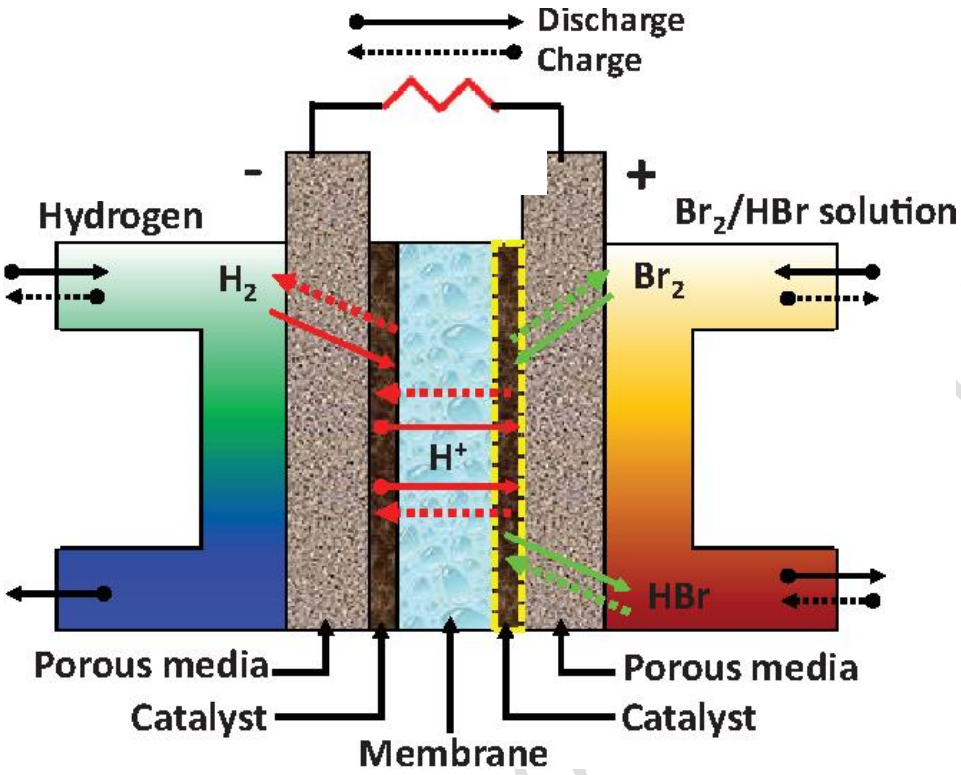
c) State the IUPAC name for this molecule. (1 mark)

Description	**Marks**
Ethyl 2-methylbutanoate	1 mark
Total	**1 mark**

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

Description	**Marks**
Ethanol + 2-methylbutanoic acid → ethyl 2-methylbutanoate + water	0-2 marks
Note: Correct structure of 2-methylbutanoic acid and ethanol (1 mark) Water as product (1mark)	
Total	**2 marks**

Question 30 **(7 marks)**



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

a) Write the equations representing the redox processes occuring at each electrode of the cell when <u>discharging</u> its potential. (2 marks)

Description	**Marks**
Anode: $H_2 \rightarrow 2\ H^+ + e^-$	1
Cathode: $Br_2 + 2\ e^- \rightarrow 2\ Br^-$	1
Total	**2**

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

Description	**Marks**
1.08 V	1
Total	**1**

See next page

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

Description	Marks
Any two from: Concentration not at 1.0 mol L-1 Temperature not at 25 C Pressure not at 100 kPa	2
NOTE: no marks for "not at STP" Many students grouping answers in 1 section then writing something irrelevant in the second…… 1 mark	0
Total	**2**

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

Description	Marks
E cell = E red + E ox 4.12 = 1.08 + E ox E ox = 4.12 – 1.08 = 3.04 V	1
Std reduction of Li is -3.04 V	1
Total	**2**

Question 31 **(15 marks)**

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

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

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

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

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

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

Description	Marks
$H_4IO_6^-$ $H_3IO_6^{2-}$	0-2
Total	**2**
N.B. Water is not shown acting amphoteric but no penalty if mentioned.	

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

(5 marks)

Description	Marks
all favor LHS as all K values significantly < 1	1
Thus weak as a low level of ionization/dissociation	1
Triprotic: able to donate three protons/H+	1
Triprotic: Discussion of Ka 3 and inability to further ionise despite having protons available	0-2
Total	**5**

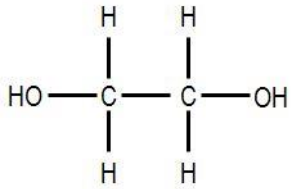
See next page

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

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

Description	Marks
Determining ON of iodine is +7	1
Evidence of proving ON is same in both species…. H_5IO_6 $(+1)_5$**(+7)**$(-2)_6$ HIO_4 $(+1)$**(+7)**$(-2)_4$	1
Total	**2**

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



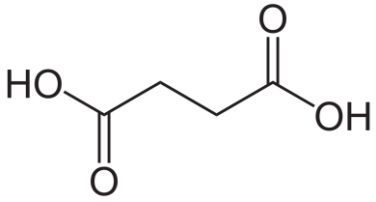
Ethylene glycol

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

(3 marks)

Description	**Marks**
Ox: $C_2H_6O_2 \rightarrow 2\ CH_2O + 2\ H^+ + 2\ e^-$	1 mark
Red: $H_5IO_6 + H^+ + 2\ e^- \rightarrow H_2IO_4^- + 2\ H_2O$	1 mark
$H_5IO_6 + C_2H_6O_2 \rightarrow H_2IO_4^- + 2\ CH_2O + 2\ H_2O + 2\ H^+$	1 mark
Total	**3 marks**

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



Succinic acid

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

Description	**Marks**
Ester linkages and in correct sequence	1 mark
Two repeating units	1 mark
All bonds	1 mark
Total	**3 marks**

See next page

Question 32 **(15 marks)**

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

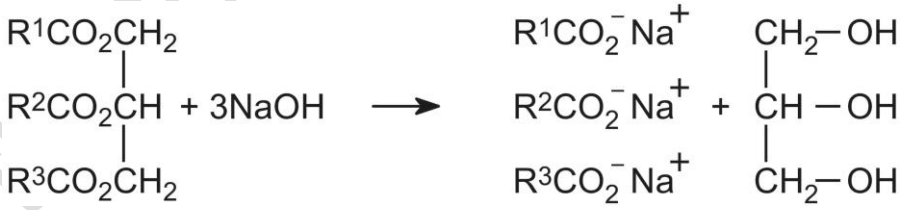
a) From the condensed formulae only, deduce the major difference in the two straight-chained C-18 acids. (1 mark)

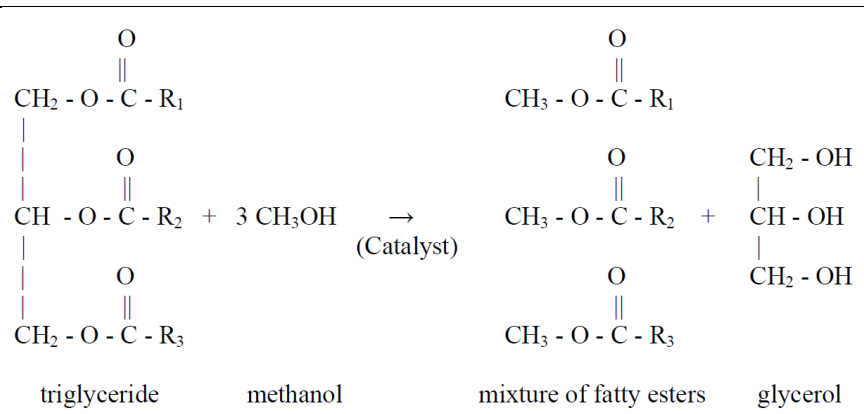
Description	Marks
While Both contain C=C double bonds in chain and are considered unsaturated Linoleic acid is **more** unsaturated Comments that indicate oleic acid is saturated were not awarded	
Linoleic acid is more unsaturated	1
Total	**1**

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

Description	Marks
Identifying two oleic and one linoleic chains	1
Correct triglyceride structure	1
Total	**2**

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

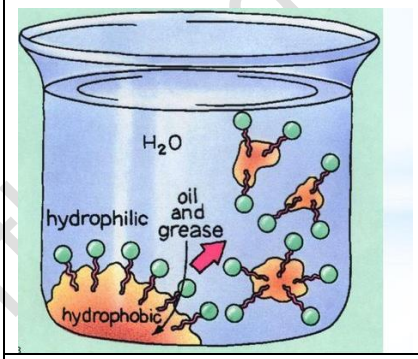
Description	Marks
Soap – triglyceride and 3 NaOH to produce 2 sodium oleate and sodium linoleate and glycerol  ECF from triglyceride in (b) allowed, 1 mark for 3 NaOH and glycerol, 2nd mark for soaps	0 – 2
BioD - triglyceride and 3 methanol to produce 3 methyl esters and glycerol. ECF from triglyceride in (b) allowed, 1 mark for 3 alcohols and glycerol, 2nd mark for esters	0 – 2

 triglyceride methanol mixture of fatty esters glycerol	
Total	**4**

d) Explain why this biofuel could be considered a "Green" source of fuel. (1 mark)

Description	**Marks**
Any of: • From a renewable resource (plants) • Not from non-renewable resource (crude oil) • Carbon neutral (with explanation – must be qualified) Sustainable alone is insufficient	1 mark
Total	**1 mark**

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

Description	**Marks**
Diagram  1 mark for features of soap molecule shown in diagram (hydrophilic head, hydrophobic tail) 1 mark for micelle shown with grease droplet inside (phases must be made explicit)	0-2
IMF - **Ion dipole** interaction between polar water and ionic end of molecule	1
IMF – **Dispersion** forces between grease and alkyl chain of soap molecule	1
Micelle formation allows grease lifted from fabric to be miscible / suspended in water – must clearly link to micelle not grease alone	1
Total	**5**

See next page

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

Description	Marks
Detergents do not produce ppts with Ca^{2+} or Mg^{2+}	1
Cleaning more effective as more molecules available for interaction with grease Or Detergents have greater charge densities – stronger ionic forces with water increases effectiveness of cleaning. Must link to use	1
Total	**2**

End of Section Two

Section Three: Extended Answer **42% (92 Marks)**

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

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original question where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes

Question 33 **(12 marks)**

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

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

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

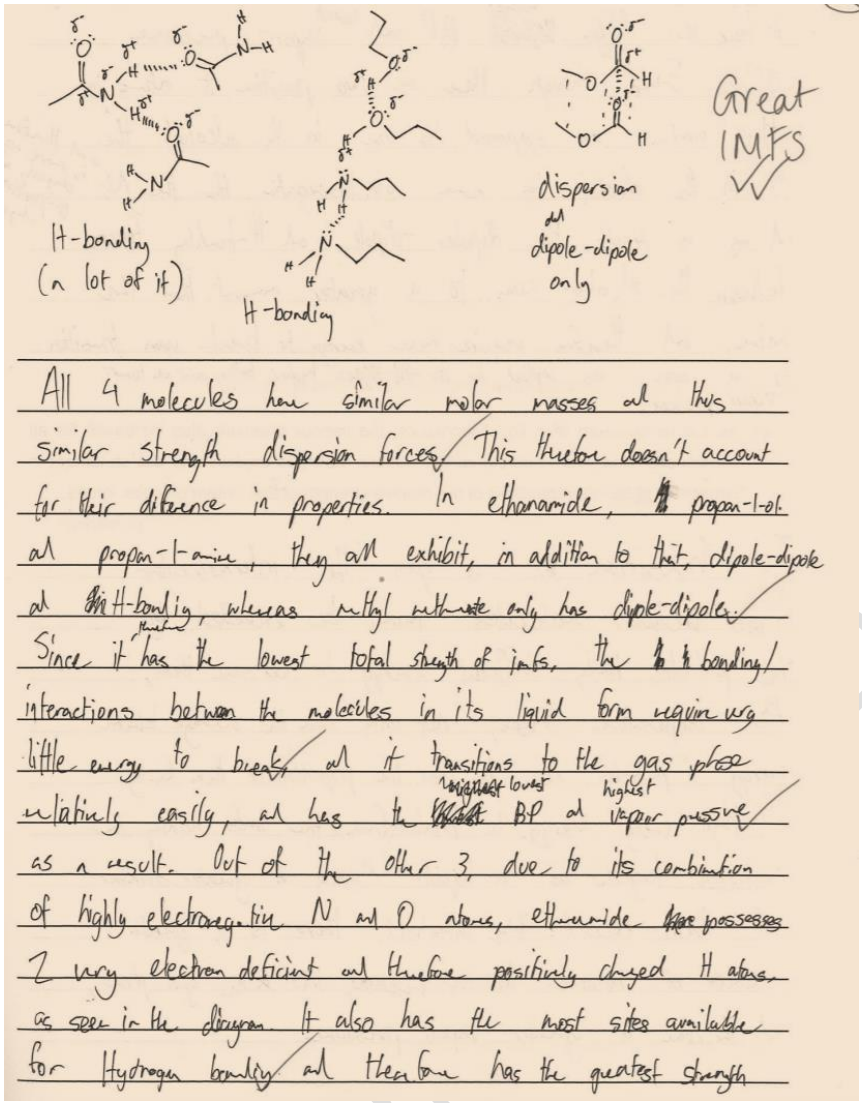
See next page

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

Description	**Marks**
Stronger intermolecular forces require more **energy** to break	1 mark
Stronger IMFs means **lower VP** and **higher Bpts** – clear link to data	1 mark
IMFs correctly identified: All have dipole-dipole, all but ester have H-bonds	1 mark
Propan-1-ol vs propan-1-amine: comparison of **strength** of H bonding The O-H dipole on alcohol is stronger than N-H dipole on the amine.	1 mark
Ethanmide has **two sites for H-bonding** between N-H and C=O on neighboring molecules. (The C=O site is also referred to as site for dipole -dipole interaction.) No sufficient just to state: H-bonding stronger between amides	1 mark
All have similar dispersion forces due to similar molecular weight.	1 mark
Diagrams Clear diagrams supporting justification (2) Inaccurate / lack of detail in diagram (1) No diagrams or very poor diagrams (0)	0-2 marks
Total	**8 marks**

See next page for model answer!

Model answer:



All 4 molecules have similar molar masses and thus similar strength dispersion forces. This therefore doesn't account for their difference in properties. In ethanamide, propan-1-ol and propan-1-amine, they all exhibit, in addition to that, dipole-dipole and H-bonding, whereas methyl methanoate only has dipole-dipoles. Since it has the lowest total strength of imfs, the H bonding/ interactions between the molecules in its liquid form require very little energy to break and it transitions to the gas phase relatively easily, and has the lowest BP and highest vapour pressure as a result. Out of the other 3, due to its combination of highly electronegative N and O atoms, ethanamide possesses 2 very electron deficient and therefore positively charged H atoms, as seen in the diagram. It also has the most sites available for Hydrogen bonding and therefore has the greatest strength

of H-bonds, and dipole-dipole interactions, and therefore requires the most energy to break the total imfs between molecules, therefore it has the highest BP and lowest vapour pressure. Even though there are two positive H atoms in the amine as opposed to one in the alcohol, the O in the alcohol is more electronegative than the N, and therefore is more negatively charged and its H positively charged as a result the dipole-dipole, and H-bonding forces between the alcohol sum to a greater amount than the amine, and therefore require more energy to break upon transition to a gas, as implied by its higher boiling point and lower vapour pressure.

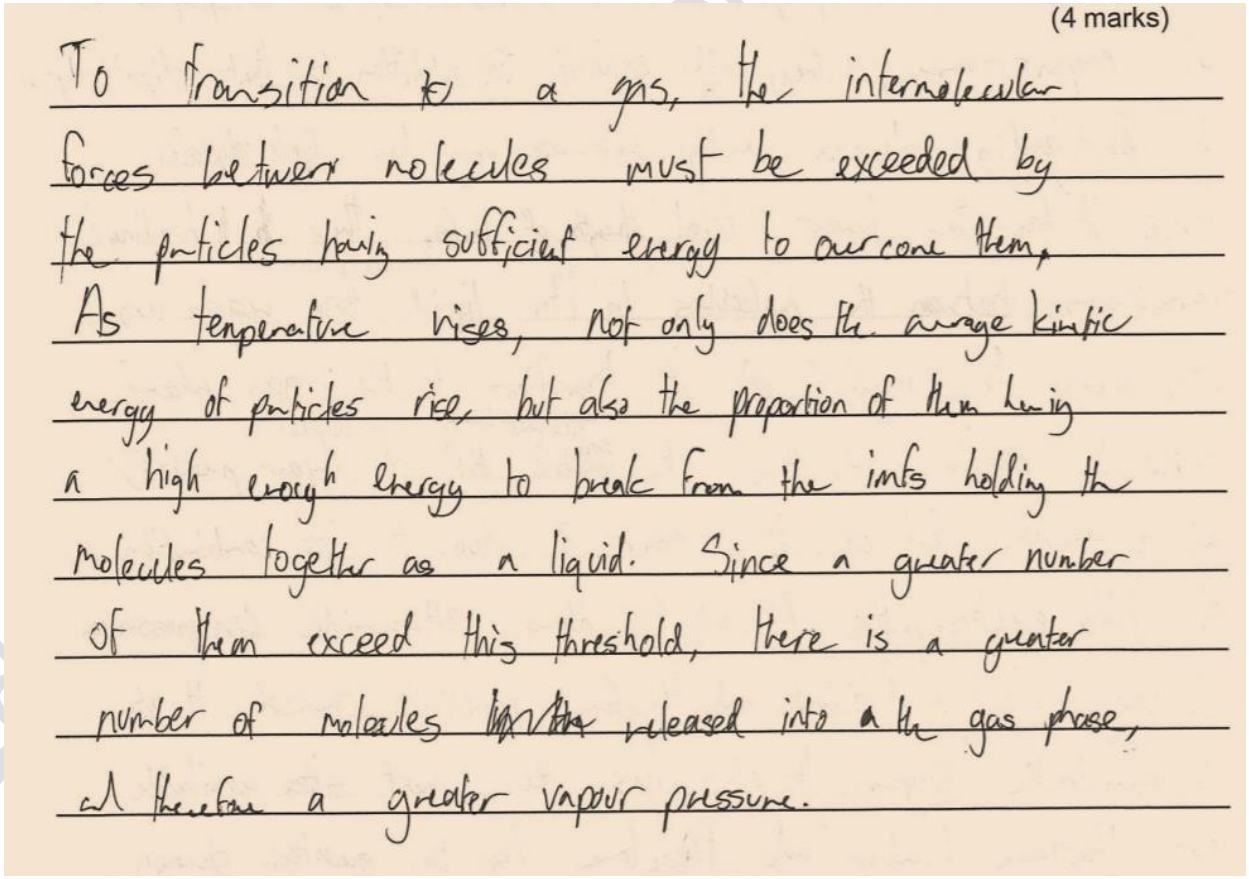
See next page

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

(4 marks)

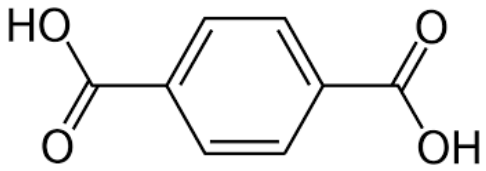
Description	**Marks**
Increase temp increase KE of molecules	1 mark
Greater <u>proportion of molecules</u> with sufficient energy to overcome <u>IMF</u> and enter gas phase	0-2 mark
More molecules in gas phase produces greater pressure	1 mark
Discussion of activation energy / reaction / collision theory not kinetic theory not sufficient, did not receive full credit in any cases	
Total	**4 marks**

Model answer:



Question 34 **(15 marks)**

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



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

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

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

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

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

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

Description	Marks
Statement indicating it is an average of values excluding outlier (20.25), understanding of selection of titres shown	1
Total	**1**

See next page

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

Description	Marks
n(HCl) = 0.01016 x 0.02065 = 2.09804 x 10^{-4} mol n(NaOH in xs) = 2.09804 x 10^{-4} mol	1
In 250 mL solution there is c(NaOH in aliquot) = 2.09804 x 10^{-4} / 0.02 = 0.01049 mol L^{-1} n(NaOH in 250 mL) = 0.01049 x 0.25 = 0.00262255 mol NaOH or 0.00209804 x 0.25 / 0.02 = 0.00262255 mol NoOH	1
n(NaOH added) = 0.8982 x 0.065 = 0.058383 mol	1
n(NaOH consumed) = 0.058383 – 0.00262255 = 0.0557605 mol	1
n(terephthalic acid) = 1/2 x n(OH consumed) = 0.0278802 mol	1
m(terephthalic acid) = 0.00278802 x 166.13 = 4.63169 g	
% purity = 4.6317 / 5.012 = 92.41 %	1
Correct sig figs = 92.41 %	1
Total	**7 marks**

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

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

Description	Marks
Reaction between NaOH and HCl, so large change in pH, equivalence around 7	1
Methyl red has end point / colour change within this large change in pH so suitable	1
Total	**2**

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

Description	Marks
Reaction with between terephthalic acid and sodium hydroxide is slow / discussion of low solubility of terephthalic acid that shows understanding	1
Total	**1**

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

Description	Marks
Systematic: increase difference between reported and true value	1
Random: No effect	1
Total	**2**

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

Description	Marks
Systematic: No effect	1
Random: increase potential for outliers to effect result	1
Total	**2**

See next page

Question 35 **(22 marks)**

Western Australia accounts for almost 70% of the national gold production. Gold is often found in elemental form in its ores and the refining of such gold can be achieved via a leaching of the metal with cyanide ions in a two-step process before an electrowinning process to recover purified gold metal. The two-step leaching process begins with the Elsner Equation (Eq 1 below). Metallic gold that is trapped in pulverized ore is be treated with aerated potassium cyanide solution.

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

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

Description	**Marks**
$[H+] = 10^{-8.90} = 1.26 \times 10^{-9}$ mol L^{-1}	1 mark
$[OH-] = 10^{-14} / [H+] = 7.94 \times 10^{-6}$ mol L^{-1} or $10^{-5.1}$	1 mark
m(Au) = 32 x 1.5 = 48 g	1 mark
n(Au) = 48 g / 196.97 = 0.244 mol	1 mark
Yield: n(OH-) = 0.244 x 0.923 = 0.225 mol	1 mark
$V = n / C = 0.225 / 7.94 \times 10^{-6} = 2.83 \times 10^4$ L (sig figs not req.)	1 mark
Total	**6 marks**
NOTE: candidates must show all working for e.c.f.	

b) If 10.0 moles of cyanide ions were introduced to the leaching of the 1.50 tonnes of the gold ore in Equation 1, justify that gold was the limiting reagent. (2 marks)

Description	**Marks**
Use ratio 1:2 n(CN)required = 0.244 mol x 2 = 0.488 mol OR n(Au)required = 10 mol / 2 = 5 mol	1 mark
Compare moles available n(CN) > n(CN) required OR n(Au) < n(Au)required	1 mark
Total	**2 marks**
NOTE: logic which does not include the ratio 1:2, receives a 0 mark	

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

$4\ [Au(CN)_2]^-\ (aq) + 2\ H_2O\ (l) \rightleftharpoons 4\ Au\ (s) + 8\ CN^-\ (aq) + 4\ H^+\ (aq) + O_2\ (g)$ Eq 2

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

Description	**Marks**
Au in $[Au(CN)_2]^-$ has ON of **+1** reduced to Au (s) where ON is **zero**	1 mark
Oxygen (accept water) is oxidised	1 mark
Require evidence for third mark: Oxygen in water has an ON of **-2** and is oxidised to O_2 (ON: **zero**)	1 mark
Total	**3 marks**

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

Description	**Marks**
Oxidation: $2\ H_2O\ (l) \rightarrow O_2\ (g) + 4\ H^+\ (aq) + 4\ e^-$	1 mark
Reduction: $[Au(CN)_2]^-\ (aq) + e^- \rightarrow Au\ (s) + 2\ CN^-\ (aq)$	1 mark
State symbols not required.	
NOTE: do not accept Au^+ in lieu of $[Au(CN)_2]^-\ (aq)$	
Total	**2 marks**

See next page

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

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

(7 marks)

Description	Marks
Electrodes: Anode LHS, Cathode RHS	1
Anode (+), Cathode (-) (polarity must be shown next to electrode or name)	1
Electrons moving from anode to cathode (e^- must be labelled)	1
Equations and observations: Correct half equations at each electrode (e.c.f. from part d)	1
yellow solid coating on cathode	1
Gas evolution / bubbles / effervescence at anode NOTE: zero mark if "anode loses mass"	1
Reactants: Show electrode where $\underline{[Au(CN)_2]^-}$ will react (cathode) NOTE: electrode where water reacts, not required. Do not allow gold ions as e.c.f.; $[Au(CN)_2]^-$ is the reactant in equation 2.	1
Total	**7**

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

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

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

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

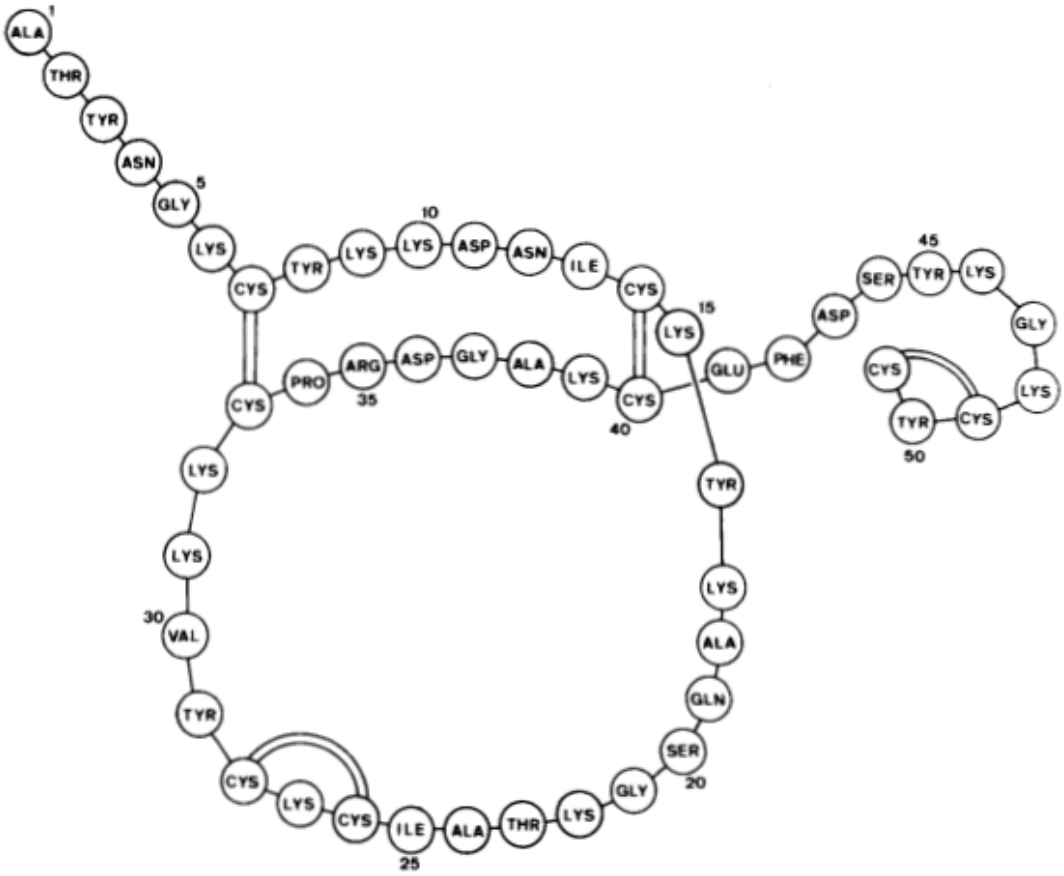
f) To determine the effectiveness of the cyanide recovery, the plant needs to be aware of the overall equation outlining their process. Write the combined equation for the conversion of cyanide ions to ammonium ions using equations 3-5. (2 marks)

Description	**Marks**
Correct: $2\ CN^-\ (aq) + O_2\ (g) + 6\ H_2O\ (l) \rightarrow 2\ OH^-\ (aq) + 2\ HCO_3^-\ (aq) + 2\ NH_4^+(aq)$	2
Minor error: $2\ CN^-\ (aq) + O_2\ (g) +$ **$4\ H_2O\ (l)$** $\rightarrow 2\ OH^-\ (aq) + 2\ HCO_3^-\ (aq) + 2\ NH_4^+(aq)$ OR $2\ CN^-\ (aq) + O_2\ (g) + 6\ H_2O\ (l) \rightarrow$ **$OH^-\ (aq)$** $+ 2\ HCO_3^-\ (aq) +$ **$NH_4^+(aq)$** OR $2\ CN^-\ (aq) + O_2\ (g) + 6\ H_2O\ (l) \rightarrow 2\ OH^-\ (aq) +$ **$HCO_3^-\ (aq)$** $+ 2\ NH_4^+(aq)$	1
Other combinations contain major error or missing/added chemical species.	0
Total	**2 marks**

See next page

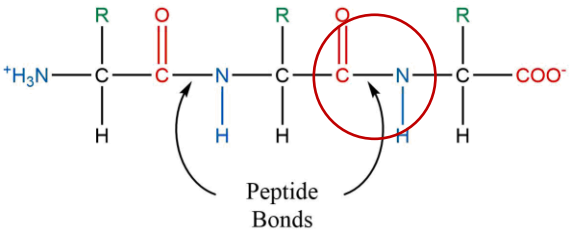
Question 36 **(22 marks)**

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



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

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

Description	Marks
Structure correct for each amino acid Correct order of amino acids All peptide bonds indicated correctly Note: peptide bonds including CONH are not accepted Structure must be shown as a tripeptide not part of a protein  Peptide in alkaline condition with R-COO^- and R-NH_2 - not a zwitterion as shown above	0-4 marks
Order of amino acids correct	1
Peptide bonds identified – (both of them) Note - Only the C-N bond as the peptide bond accepted	1
C terminal end is anionic N-terminal is neutral -NH_2 S-H on must be on Cysteine (no disulfide bridge)	0-2
Total	**4 marks**

See next page

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

Description	**Marks**
Primary structure - due to the sequence of amino acids	1
Secondary structure due to H-bonding between amide and carbonyl groups of from the main amino acid chain i.e. C=O and N-H groups	1
Naming secondary structure as alpha helix or beta sheets	1
Tertiary structure due to IMF between side chains of amino Acids • Statement indicating tertiary structure is caused by IMFs between side chains • All possible IMFs types must be identified: disulfide bridging, ionic (or ion-dipole), H-bonding, dipole-dipole, dispersion,	0-2
Total	**5 marks**

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

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

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

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

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

Description	**Marks**
$n(CO_2) = 75.60 / 44 = 1.7178$ mmol $n(C) = 1.7178$ mmol $m(C) = (1.7178 \times 12.01) = 20.631$ mg $\%(C) = (20.631 / 50.46) \times 100 = 40.894\%$	1 mark
$n(H_2O) = 30.95 / 18.016 = 1.7178$ mmol $n(H) = 2 \times n(H_2O) = 3.4356$ mmol $m(H) = (3.4356 \times 1.008) = 3.4633$ mg $\%(H) = (3.4633 / 50.46) \times 100 = 6.863\%$	1 mark
$n(NH_3) = PV / RT = 220.6 \times 9.794 / (8.314 \times 301.17) = 0.86287$ mmol $n(N) = n(NH_3) = 0.86287$ mmol $m(N) = 0.86287 \times 14.01 = 12.089$ mg $\%(N) = (12.089 / 76.04) \times 100 = 15.898\%$	1 mark
$n(S) = n(BaSO_4) = m/Mw = 44.03 / 233.37 = 0.18866$ mmol $m(S) = 0.18866 \times 32 = 6.0502$ mg $\%S = 6.0502 / 33.25 = 18.196\ \%$	1 mark
$\%(O) = 100 - 40.894 - 6.863 - 15.898 - 18.196 = 18.156\ \%$	1 mark

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	C	H	S	N	O	
% (or in 100g)	40.886`	6.8631	18.196	15.898	18.156	2 marks
n = m / M_w	40.886 / 12	6.8631 / 1.008	18.196 / 32	15.898 / 14	18.156 / 16	
n =	3.41	6.809	0.5674	1.1348	1.1348	
Ratio (divide 0.0.5674)	5.99	11.99	1	2	2	
Ratio	6	12	1	2	2	

State Empirical Formula as $C_6H_{12}SN_2O_2$	1 mark
Mw of EF is176.246 Ratio MF/EF = 352.5 / 176.246 = 2	1 mark
State confirmation that Molecular Formula is $C_{12}H_{24}S_2N_4O_4$.	1 mark
Note: This is a proof hence evidence of logic steps MUST clearly be shown.	
Total	**10 marks**

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

Low pH: Protonated amine group shown by +ve charge on nitrogen atom (H_3N^+-CH) AND neutral COOH group	1
Moderate pH: +ve charge on amino nitrogen AND Deprotonated carboxylate group shown by -ve charge on the acidic oxygen <accepted neutral molecules terminating in H_2N and COOH>	1
High pH: -ve charge on the acidic oxygen AND neutral NH_2 group	1
Deduction for minor error across all parts for minor error including: - Positive charge is not localized on N (i.e. on H instead) - incorrect amino acid structure Note – condensed structures accepted but candidates should note this may not be the case in the ATAR exam	
Total	**3 marks**

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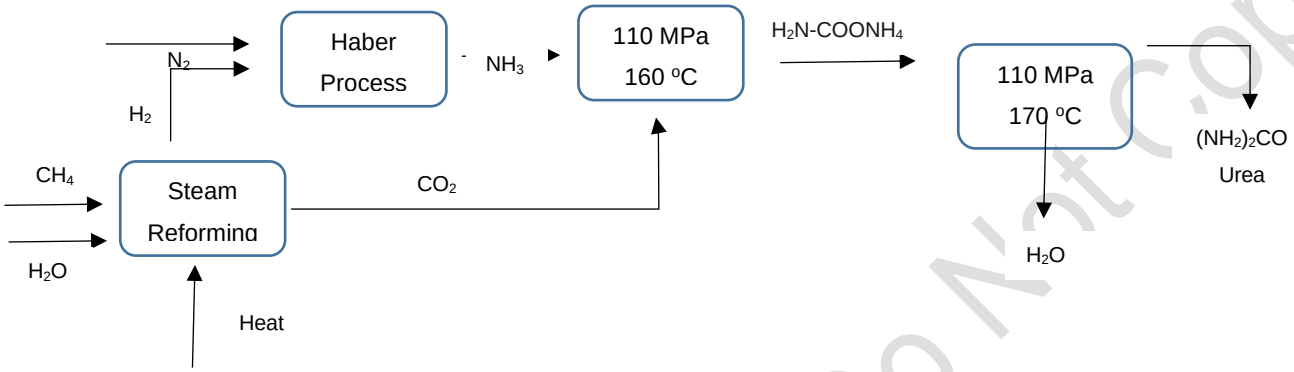
Question 37 **(21 Marks)**

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



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

Steam Reformation:

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

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

Haber Process:

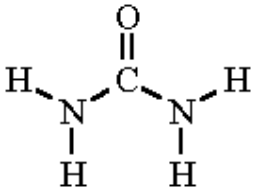
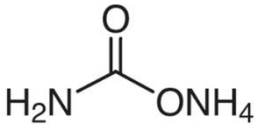
Eqn 3: 2 N_2 (g) + 3 H_2 (g) ⇌ 2 NH_3 (g) (yield 95.6%)

Urea production:

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

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

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

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

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

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

Description	Marks
Temperature: - Raising temperature increases energy cost - Raised Temp increases reaction rates of both eqn 1 and eqn 2 - Greater number of molecules with greater energy to successfully react - Discussion that heat will shift position of equilibrium with respect to either exothermic/endothermic constraints	0-4
Pressure: - High pressures increase cost of equipment etc. - Eqn 1 at high pressure favors RHS increasing yield - Eqn 2 pressure no effect on yield	0-3
Total	**7**
Note Schematic shows heat being applied, and all reactants/products are in the gas phase. Hence the MOST obvious considerations were the effects of Temperature and Pressure. *However, the use of catalysts and control of concentration are also valid and were awarded if included as below:*	
Catalyst: - Increases rate NOT yield - Economic consideration needed- eg: addition cost to use but can be reused	0-2
Concentration considerations: - Removing CO_2 and H_2 for downstream uses moves equilibrium of both eqn 1 & eqn 2 to RHS. - Comment regarding economic advantage of using product elsewhere.	0-2

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

Description	Marks
71.1 = 0.857 x 0.956 x 0.984 x 0.882 x 100	1
Must show calculation steps	
Total	**1 marks**

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

Description	Marks
n(urea) = 1 x 10^6 / 60.056 = 16651 mol	1
n(Methane) = n(urea) = 16651 mol x 100 / 71.1 = 23419 mol	1
m(Methane) = 23419 x 16.04 = 375643 g (375.6 kg)	1
m(LNG) = 100 / 90 x 375.6 = 417 kg	1
Volume of LNG = 417 / 0.41 = 1018 L	1
Total	**5**
Note: Using mass not moles; V = 3812 L (4 marks)	

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

Description	Marks
There were many valid options Any two valid and well-articulated ideas	0-2
Examples included - Hydrogen gas produced by steam reformation used in Haber process. - CO_2 gas produced by steam reformation used in Urea production step. - Heat used in first step of urea production used to heat second. - Only water produced as waste - Minimal waste through high yield or high atom economy - Moderate temperatures used	
Note: methane is not “renewable”	
Total	**2**

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

Description	Marks
Both rates are greater t2 that they were before t1	1
Fwd rate increases to meet rev rate at t2.	1
Rev rate decreases to meet fwd rate at t2)	1
Total	**3**

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

Description	**Marks**
Statement indicating relationship of <u>number (or frequency)</u> of collisions and <u>energy</u> of colliding particle with change the reaction rate. Eg: rates depend on the number of collisions and energy in which particle collide – an increase in both causes increase in rate.	0-2
Indicating both rates increase	1
Total	**3 marks**

End of Questions

Supplementary page

Question number:_____

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Supplementary page

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