NESA number

Chemistry

2022 TRIAL HSC EXAMINATION

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks: 100

Section I – 20 marks (pages 3–10)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks in Booklet A and B (pages 11-30)

- Attempt Questions 21– 32
- Allow about 2 hours and 25 minutes for this section in Booklet A and B

Section I
20 marks

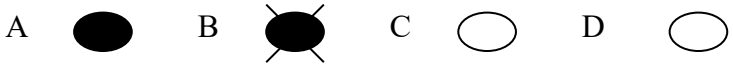
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet.

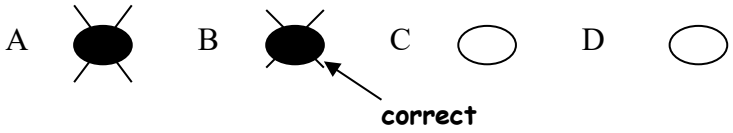
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.



If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



Section I

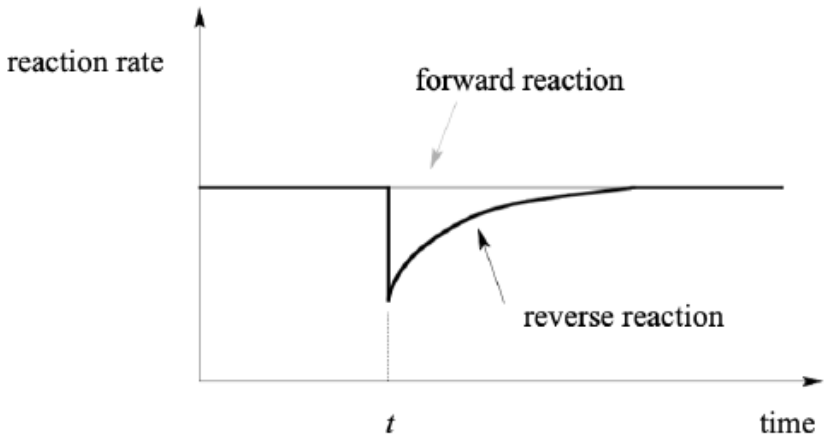
20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

1 A small amount of solid lead iodide was added to a beaker of water, which was stirred. Most of the solid settled on the bottom of the beaker, but a little dissolved, establishing the equilibrium

$$PbI_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2I^-\ (aq)$$

The rates of the forward and reverse reactions were monitored over time, producing the graph shown below:



What happened at time t?

(A) A small amount of solid $Pb(NO_3)_2$ was added to the beaker.
(B) A small amount of solid KI was added to the beaker.
(C) A small amount of solid PbI_2 was removed from the beaker.
(D) A small amount of water was added to the beaker.

2 What is the pH of a 0.010 mol L^{-1} solution of a weak monoprotic acid that is 4.0% ionised?

(A) 2.00
(B) 2.40
(C) 2.80
(D) 3.40

3 Sulfuric acid (H_2SO_4) and nitric acid (HNO_3) are both strong acids. Ethanoic acid (CH_3COOH) is a weak acid.

20.00 mL solutions of 0.10 mol/L concentration of each of these three acids were separately titrated with a 0.10 mol/L solution of sodium hydroxide (NaOH).

In order to react completely

(A) all three acids would require the same amount of NaOH.

(B) HNO_3 would require more NaOH than CH_3COOH but less than H_2SO_4.

(C) H_2SO_4 and HNO_3 would require the same amount of NaOH but CH_3COOH would require less.

(D) CH_3COOH and HNO_3 would require the same amount of NaOH but H_2SO_4 would require more.

4 It is known that carbon monoxide reacts exothermically with hydrogen gas to form methanol at 400°C, in the presence of a catalyst.

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g) \qquad \Delta H = \text{-ve}$$

A mixture of carbon monoxide, hydrogen gas and methanol placed under conditions described above achieves equilibrium in a closed container. If the reaction temperature is changed to 450°C, which of the following statements is correct?

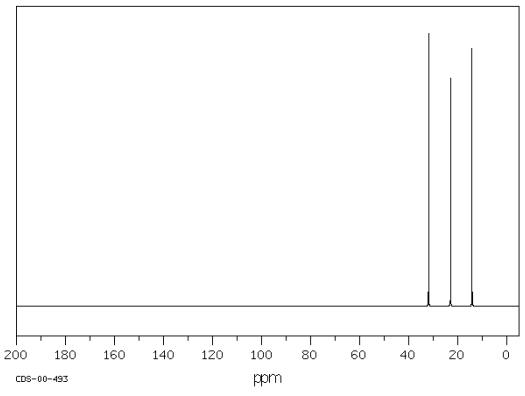
(A) The total number of molecules in the container decreases.

(B) The reaction rates of both the forward and reverse reactions remain constant.

(C) The pressure of the gaseous mixture increases.

(D) Rate of formation of hydrogen decreases while the rate of decomposition of methanol increases.

5 Identify which one of the compounds given below gives the following ^{13}C NMR spectrum:



(A) Prop-1-ene

(B) Hexane

(C) Butanoic acid

(D) Ethanol

6 A student prepares a standard solution in the following way.

i. 2.5 g of pure sodium hydroxide was dissolved into a clear, dry beaker using distilled water
ii. The solution is funnelled into a volumetric flask, and the beaker and funnel set to one side without washing.
iii. The volumetric flask was filled with distilled water, however the student went slightly over the calibration line.
iv. The volumetric flask was shaken to ensure consistency

Despite the errors in the method, the student calculates the concentration of the standard solution. The standard solution is likely to be:

(A) Weaker than calculated.

(B) Stronger than calculated.

(C) Less concentrated than calculated.

(D) More concentrated than calculated.

7 Arrange the following reactions in order of their increasing tendency to reach completion.

I $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $K = 1{\cdot}0 \times 10^{228}$

II $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$ $K = 1{\cdot}0 \times 10^{-13}$

III $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$ $K = 4{\cdot}7 \times 10^{-4}$

IV $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ $K = 5{\cdot}0 \times 10^{-31}$

(NOTE: For each reaction, the equilibrium constant was determined under different conditions.)

(A) I, III, II, IV
(B) III, II, IV, I
(C) IV, II, III, I
(D) I, IV, II, III

8 When acidic potassium permanganate is used to oxidise an alkene, a colour change occurs.

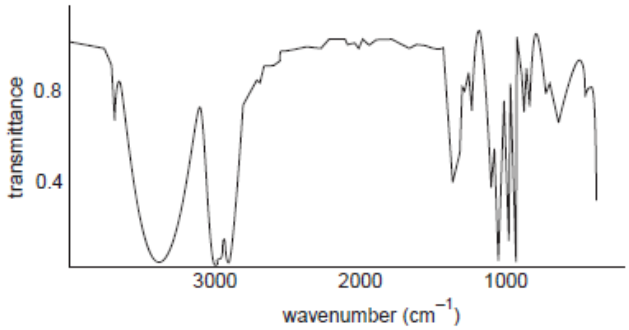
What colour change would be observed?

(A) Colourless to purple
(B) Purple to brown
(C) Brown to colourless
(D) Purple to colourless

9 2-Butanol is heated under reflux with acidified potassium dichromate solution. What is the major organic product?

(A) Butanal
(B) Butyl butanoate
(C) Butanone
(D) Butanoic acid

10 The infrared spectrum of an organic compound is shown below.



The compound could be

(A) Propene
(B) 2-Propanol
(C) Propanoic acid
(C) Propanone

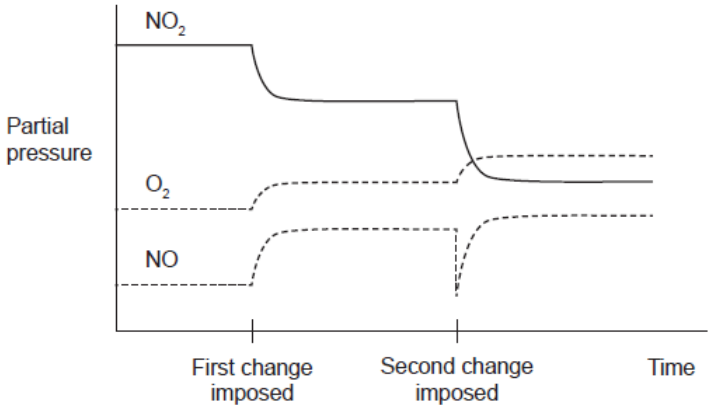
11 When 1.27 g samples of the following substances are all treated with excess dilute hydrochloric acid, all give off carbon dioxide. Which gives off the greatest mass of carbon dioxide?

(A) Lithium carbonate
(B) Beryllium carbonate
(C) Sodium carbonate
(D) Magnesium carbonate

12 Nitrogen dioxide, $NO_2(g)$, is formed when nitrogen monoxide, NO(g), undergoes oxidation as shown below.

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g) \qquad \Delta H = -62\ kJ\ mol$$

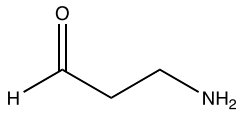
A change was imposed on an equilibrium gas mixture of NO_2, NO and O_2. The mixture returned to equilibrium and another change was imposed. The following graph shows the effects of the two changes.

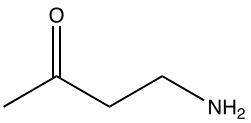


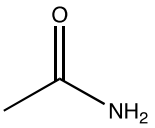
Identify the imposed changes that **best** account for the shape of the graph.

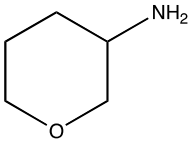
	First change	Second change
(A)	the temperature is decreased	the partial pressure of O_2 is increased
(B)	the temperature is decreased	the partial pressure of NO is decreased
(C)	the temperature is increased	the partial pressure of O_2 is increased
(D)	the temperature is increased	the partial pressure of NO is decreased

13 Which one of the following compounds is both an amine and a ketone?

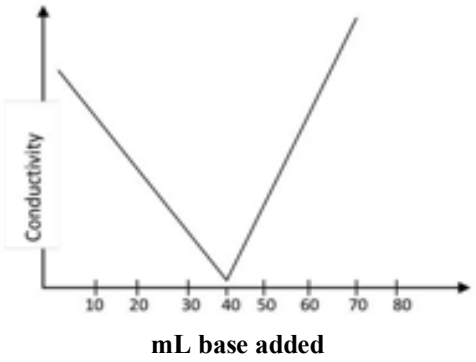
(A) 

(B) 

(C) 

(D) 

14 A conductometric titration was carried out using an acid and a base of similar concentration and the graph below was recorded.



The acid and base used could have been

(A) H_2SO_4 and $Ba(OH)_2$
(B) H_2SO_4 and NH_3
(C) CH_3COOH and NH_3
(D) CH_3COOH and $Ba(OH)_2$

15 A colourless organic liquid compound is tested for the presence of functional groups. 2 mLs of the liquid are poured into three separate tests tubes. A reagent is added to each test tube then shaken.

Test	*Reagent Added*	*Observation made after shaking*
1	2 drops of Bromine water	Yellowish-brown coloured solution
2	3 drops of acidified potassium dichromate	Yellowish-orange coloured solution
3	1 gram of sodium hydrogen carbonate	Colourless solution, small bubbles of colourless gas

What functional group(s) may be present in this compound?

(A) Double bonds
(B) Carboxylic acid
(C) Double bonds and hydroxyl group
(D) Hydroxyl group bonded to a secondary carbon

16 Which row of the table below correctly matches the reaction type with its correct reactants, catalyst and products?

	Reaction Type	Reactants	Catalyst	Products
(A)	Hydration	$H_2C = CH_2 + H_2O$	H_2SO_4	$HOCH_2CH_2OSO_3H$
(B)	Hydration	$H_2C = CH_2$	concentrated H_2SO_4	CH_3CH_2OH
(C)	Addition	$H_2C = CH_2 + H_2O + Br_2$	H_2SO_4	$BrCH_2CH_2Br$
(D)	Addition	$H_2C = CH_2 + H_2$	Nickel	CH_3CH_3

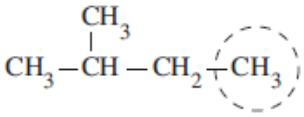
17 Iron(III) forms a variety of coloured complex ions. One such example is that produced by the reaction with salicylic acid ($C_7H_6O_3$):

$$\underset{\text{(pale yellow)}}{Fe^{3+}(aq)} + C_7H_6O_3(s) \rightleftharpoons \underset{\text{(violet)}}{Fe(C_7H_5O_3)^{2+}(aq)} + H^+(aq)$$

The yield of the violet complex, $Fe(C_7H_5O_3)^{2+}$, may be decreased by

(A) adding $C_7H_6O_3(s)$ to the solution.
(B) adding Fe^{3+} ions to the solution.
(C) lowering the pH of the solution.
(D) raising the pH of the solution.

18 The structure of 2-methylbutane is shown. A CH_3 group is circled



Which of the following splitting patterns would be observed in the ^1H NMR spectrum for the CH_3 group circled?

(A) 

(B) 

(C) 

(D) 

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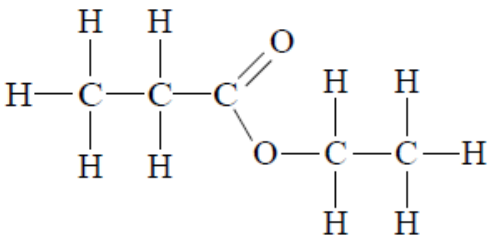


The species that produces the molecular ion peak in the mass spectrum of this compound is

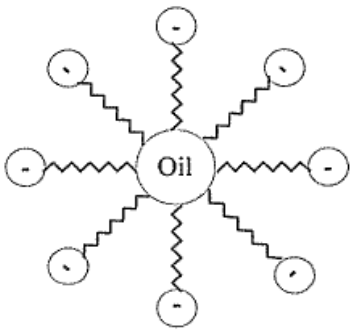
(A) $[CH_3CH_2COOCH_2CH_3]^+$

(B) $[CH_3CH_2COOCH_2CH_3]^{2+}$

(C) $[CH_3CH_2COOCH_2CH_3]^-$

(D) $CH_3CH_2COOCH_2CH_3$

20 Which statement correctly describes the diagram below?



(A) The hydrophilic head of the soap molecule is polar and is attracted to water molecules. The hydrophobic tail is non-polar and forms micelles trapping the oil within the micelle.

(B) The hydrophilic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophobic tail is polar and forms micelles trapping the oil within the micelle.

(C) The hydrophilic head of the soap molecule is polar and is attracted to oil molecules. The hydrophobic tail is non-polar and forms micelles trapping the water within the micelle.

(D) The hydrophobic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophilic tail is non-polar and forms micelles trapping the oil within the micelle.

Chemistry

2022 TRIAL EXAMINATION

Section II
80 marks

Attempt Questions 21- 32
Allow about 2 hour and 25 minutes for this part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.
Section II

Question 21 (3 Marks)

Calculate the minimum concentration of silver nitrate that will cause precipitation of silver bromide when 25.0 mL of the silver nitrate solution is added to 25.0 mL of 0.020 mol/L^{-1} sodium bromide. **3**

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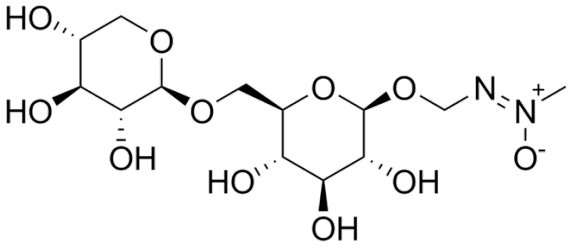
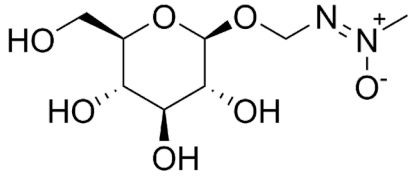
Question 22 (3 marks)

The seeds of cycad plants are used by Aboriginal and Torres Strait Islander peoples to make bread. However, these seeds contain toxins, TWO of which are illustrated below.



macrozamin



cycasin

Explain the process used to remove these toxins with reference to the structure of each molecule. **3**

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Question 23 (7 marks)

High strength aspirin ($C_9H_8O_4$) tablets were purchased overseas by the schools chemistry teacher. Puzzled by the low cost, he encouraged their students to perform a chemical analysis on the concentration of Aspirin in each tablet.

Students were given 6 tablets each and were instructed to use sodium hydroxide solution with an approximate concentration of 0.100 mol/L, which was standardised using oxalic acid $(COOH)_2$.

Four flasks were prepared each containing a mixture of 25.00 mL of water and 10.00 mL of ethanol. 2 aspirin tablets were dissolved in each flask for titration against the sodium hydroxide.

(a) Three 25.00 mL samples of a 0.1034 mol/L solution of oxalic acid were titrated to standardise the NaOH solution according to the following equation:

$$H_2C_2O_4\ (aq) + 2NaOH\ (aq) \rightarrow Na_2C_2O_4\ (aq) + 2H_2O\ (l)$$

The average volume required for neutralisation was 25.75 mL. Calculate the molarity of the NaOH solution. **2**

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(b) What is the endpoint of a titration? **1**

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Question 23 continues on the next page

Question 23 continued

(b) Four flasks were prepared each containing a mixture of 25.00 mL of water and 10.00 mL of ethanol. Two aspirin tablets was dissolved in each flask. The aspirin in each solution was titrated with the standardised NaOH solution according to the following equation:

$$C_9H_8O_4\ (aq) + NaOH\ (aq) \rightarrow C_9H_7O_4Na\ (aq) + H_2O\ (l)$$

The students achieved the following titration results:

Trial	Volume (mL)
1	16.55
2	16.50
3	16.60
4	16.85

The packaging claims the tablets contain 150.0 mg of aspirin per tablet.

Using the information provided, calculate the mass (mg) of aspirin per tablet, and justify whether the claim is true. **4**

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Question 24 (4 marks)

(a) What is the maximum pH which can be obtained by dissolving $Mg(OH)_2$ in pure water? **2**

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(b) How does this compare with the maximum pH which can be obtained with NaOH? **2**
(The solubility of NaOH is 1.20 g/mL at 25°C)

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Question 25 (14 marks)

Nitrogen dioxide is toxic to humans when inhaled and is a significant component of air pollution.

It can be formed by the combustion of nitrogen in the air at high temperatures; firstly forming nitric oxide NO(g) and on further oxidation, forming nitrogen dioxide, $NO_2(g)$.

The overall equation for this process is given here:

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$$

The following questions relate to the equilibrium system represented by this equation.

(a) Write the equilibrium expression for this reaction when it is in equilibrium. **1**

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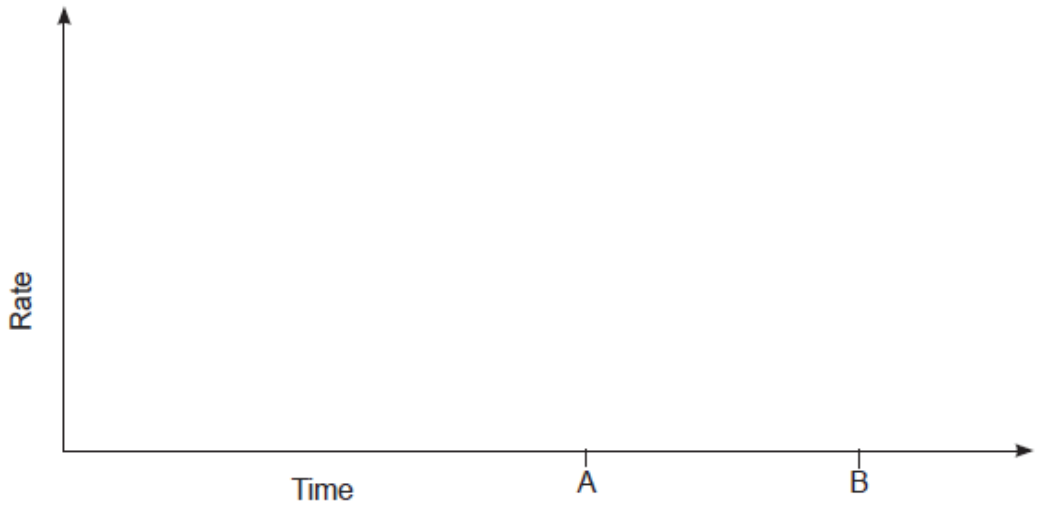
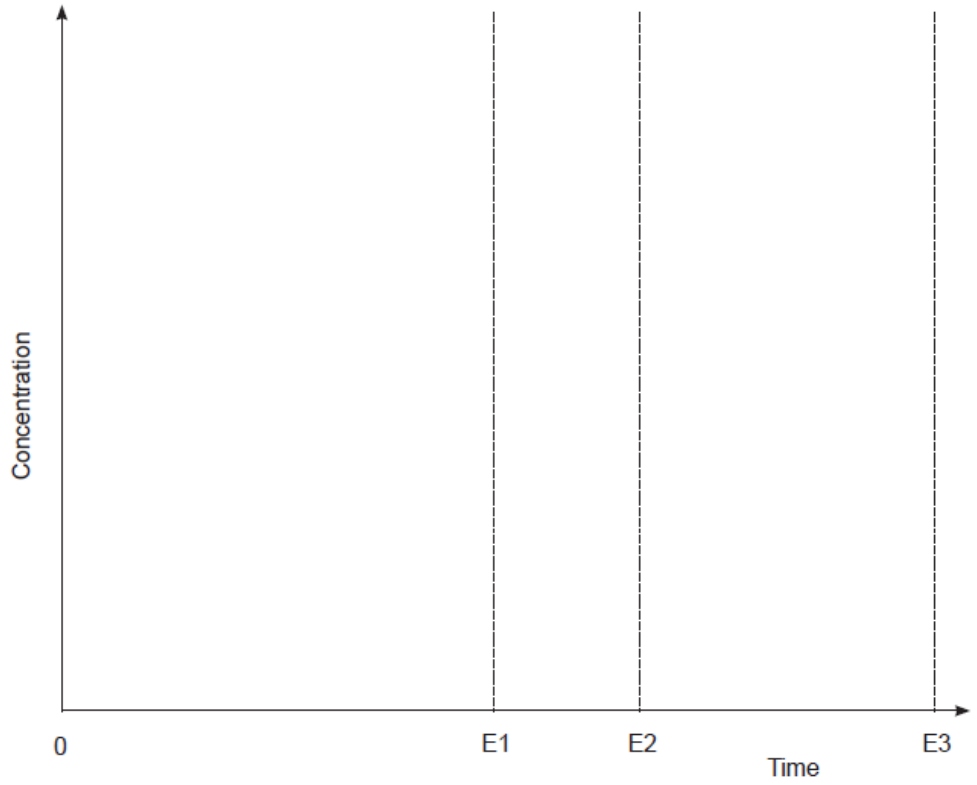
(b) (i) On the axes below, draw the forward (——) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. **3**



(ii) On the same axes above, draw and label clearly the effect of conducting the same reaction at a higher temperature. **2**

(c) On the axes below, draw separate curves to show how the concentrations of the three gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical. **5**

Label clearly the line for each gas.



(d) At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the system is then again allowed to reach equilibrium at Time E3. **3**

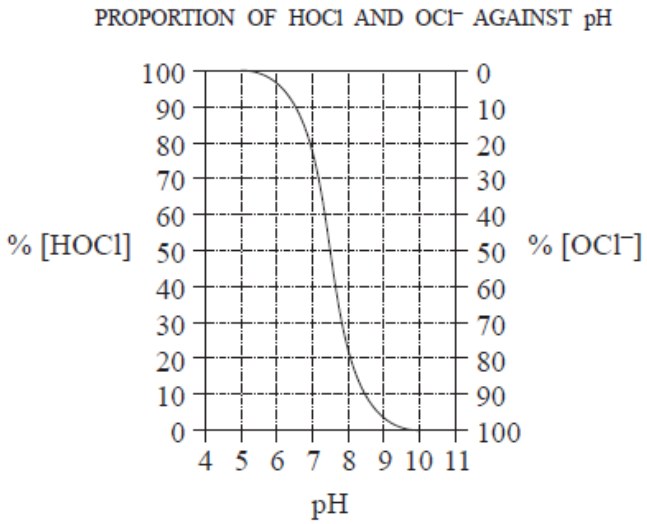
On the same graph above, show how the concentrations of the three gases would change in response to the change in volume, from Time E2 until equilibrium is re-established at Time E3.

Question 26 (5 marks)

Hypochlorous acid (HOCl) is often used in swimming pools as a means of killing bacteria. The HOCl dissociates as shown:

$$HOCl \rightleftharpoons H^+ + OCl^-$$

The curve below shows the distribution of [HOCl] and [OCl^-] in water at 25°C.



(a) What is the effect on pH when OCl^- ions are added to the water? **1**

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(b) At pH = 8·5, what is the ratio of [OCl^-] : [HOCl]? **1**

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(c) Using your answer in part (b), calculate K_a for hypochlorous acid. **3**

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Question 27 (5 marks)

Two neighbouring factories produce large quantities of waste that they need to dispose of safely. One waste is acidic and the other is basic.

25.0 mL of waste A required 29.5 mL of 0.233 mol/L sulfuric acid for exact neutralisation.

25.0 mL of waste B required 32.8 mL of 0.274 mol/L sodium hydroxide for exact neutralisation.

What volume of waste A should be mixed with 100.0 L of waste B in order to produce neutral waste? **5**

Section II extra writing space.

If you use this space indicate clearly which question you are answering.

NESA number

SYDNEY BOYS HIGH SCHOOL

CHEMISTRY
2022 TRIAL HSC EXAMINATION

Section II - Booklet B
Answer questions 30-35

Booklet B Total:

Question 28 (4 marks)

A student has three unlabelled test tubes. They contain three different but apparently identical colourless liquids. One is 1-butanol, another is 2-methyl-2-propanol, and the third is 1-hexene.

Describe the chemical tests the student should carry out to determine which liquid is in each test tube. **4**

In your answer, include expected observations and relevant equations.

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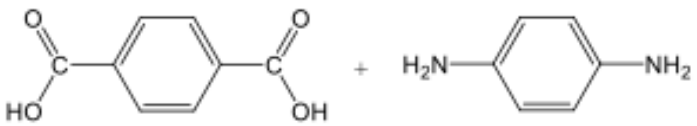
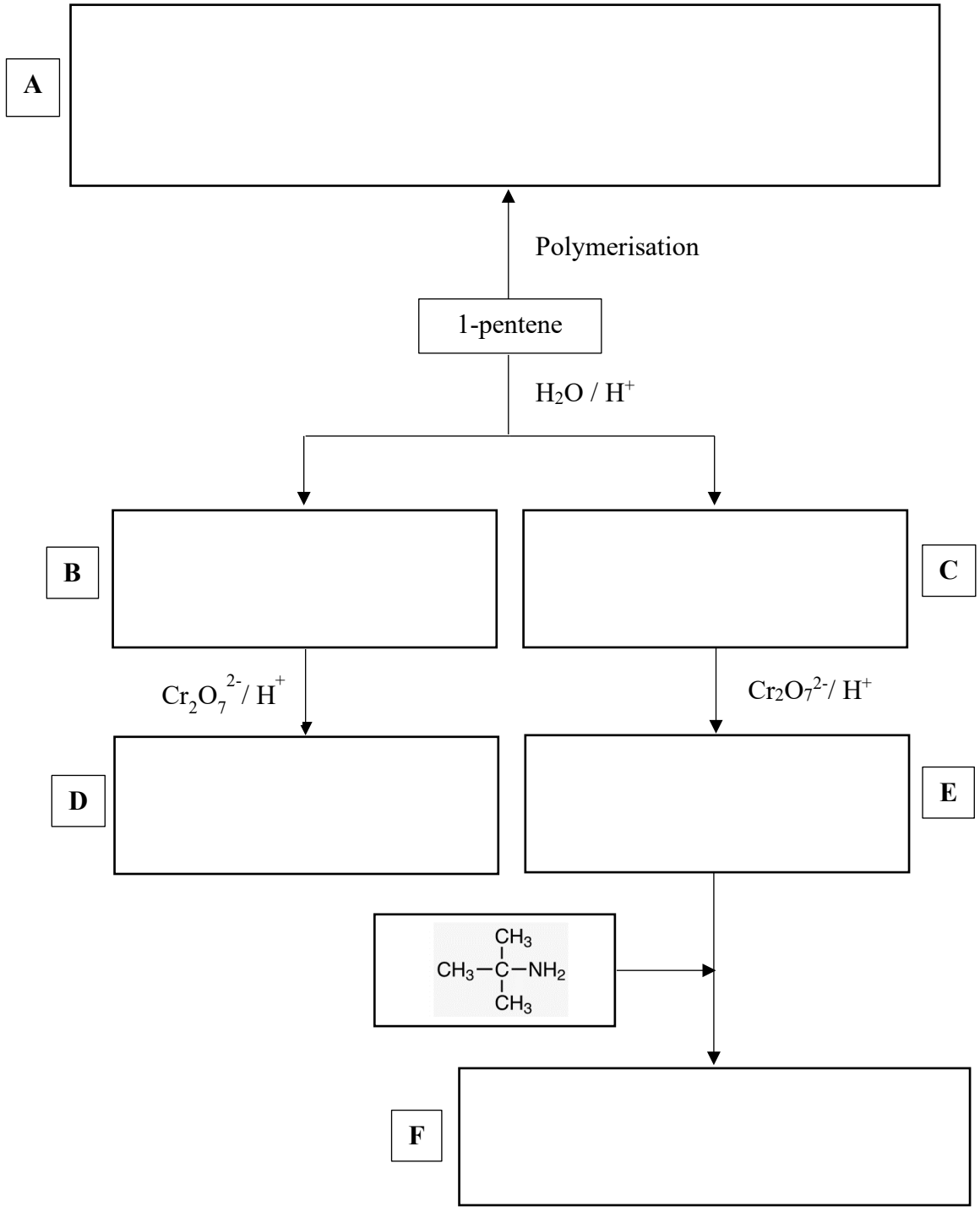
Question 29 (4 marks)

Kevlar is a strong nylon polymer prepared by the reaction shown below. Draw a segment of Kevlar and explain the strength and subsequent uses of the polymer based on its structure. **4**



Question 30 (15 marks)

A student designed and carried out the following synthetic pathway during his studies of chemical reactions on organic compounds. His chosen starting material was 1-pentene.



(a) Draw the structural formulas of compounds B to F in the boxes provided. **5**

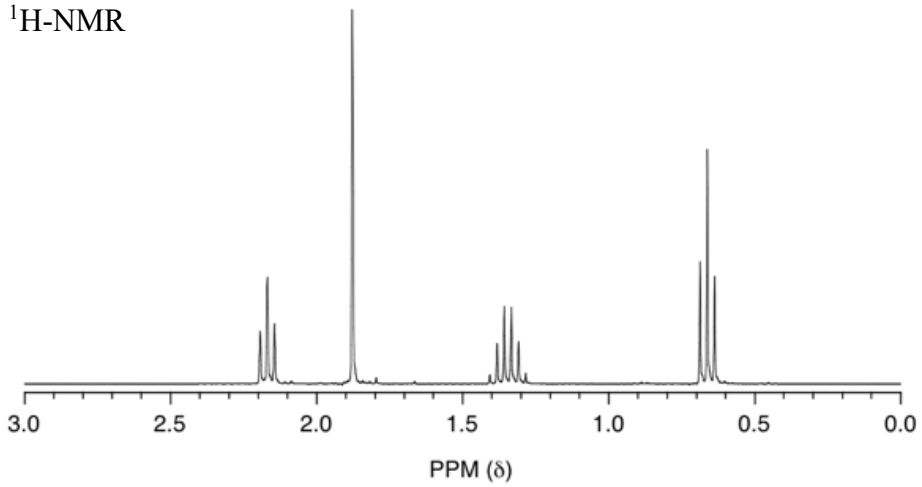
(b) Draw the semi-structural formula, containing 3 monomers, of compound A in the box provided. **1**

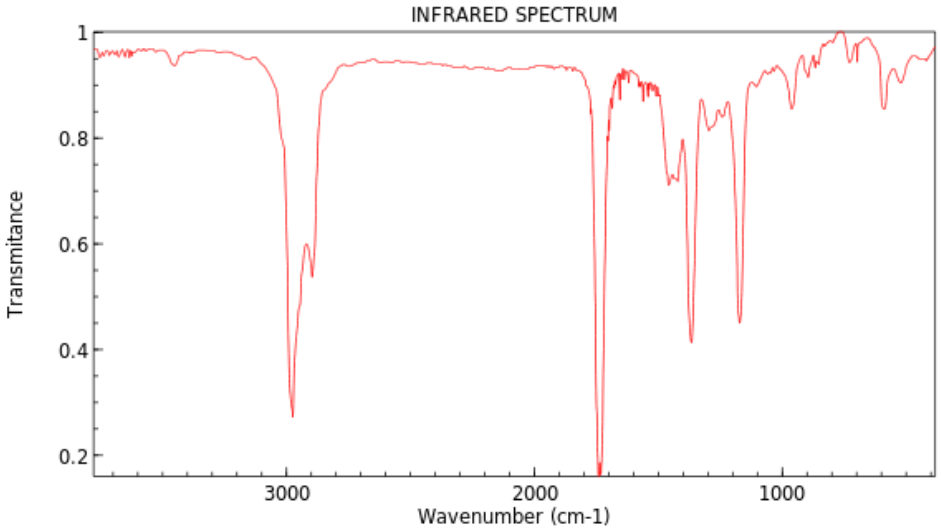
Question 30 continues on the following page.

Question 30 continues.

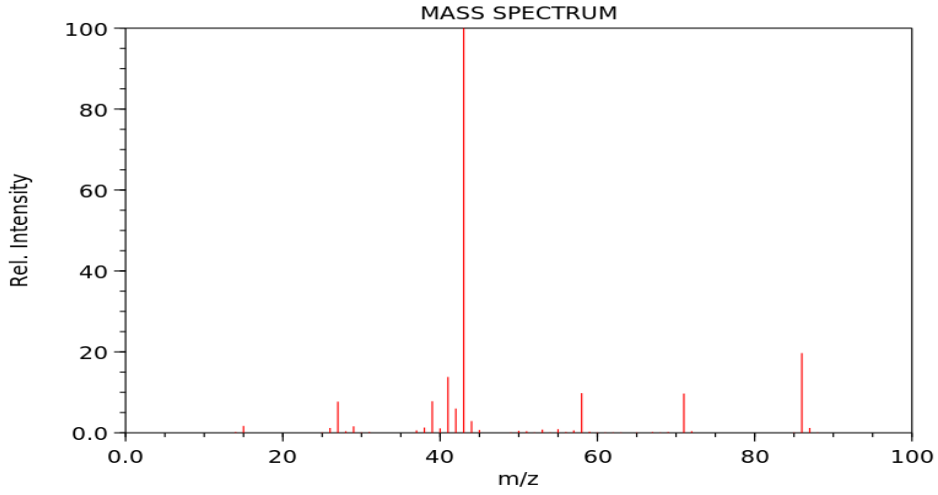
(c) To distinguish between compounds D and E, the student used spectroscopic analysis to determine the structure of the compound produced. He was provided with the following spectra.

^{1}H-NMR





NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)



NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

Question 30 continues on the following page.

Question 30 continues.

Identify which compound from the previous synthetic pathway corresponds to the provided spectra. Justify your choice using the information from each spectrum. **6**

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Question 30 continued on the following page.

Question 30 continued.

^{1}H NMR chemical shift data

Type of proton		δ/ppm
$Si(CH_3)_4$	(TMS)	0
R—CH_3		0.7–1.3
R—CH_2—R		1.2–1.5
R—CHR_2		1.5–2.0
H_3C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—CH—CO—	(aldehydes, ketones or esters)	2.1–2.6
H_3C—O—	(alcohols or esters)	3.2–4.0
—CH—O—	(alcohols or esters)	3.3–5.1
R_2—CH_2—O—	(alcohols or esters)	3.5–5.0
R—OH		1–6
R_2C=CHR	(alkene)	4.5–7.0
R—CHO	(aldehyde)	9.4–10.0
R—COOH		9.0–13.0

1

(d) The IUPAC name for Compound D is:

……

2

(e) In a ^{13}C NMR spectrum of Compound D, how many signals would you expect? Why?

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Question 31 (5 marks)

Some properties of but-1-ene, 1-fluoropropane, propan-1-ol and ethanamide are shown in the table.

Compound	*Molar mass (g mol^{-1})*	*Solubility in water*
but-1-ene	56	insoluble
1-fluoropropane	62	slightly soluble
propan-1-ol	60	soluble
ethanamide	59	soluble

Explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram. **5**

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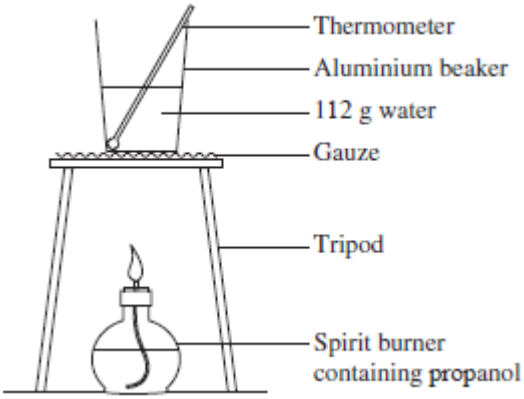
Question 32 (11 marks)

The following apparatus was used in an experiment to determine the molar enthalpy of combustion of propanol.



(a) Calculate the experimental molar enthalpy of combustion $\left(\Delta H_c\right)$ of propanol when 0.543 g propanol was used to raise the water temperature from 19.0°C to37.5°C. **4**
$MM(C_3H_7OH) = 60.10 \text{ g mol}^{-1}$

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(b) Upon replication, the molar enthalpy of combustion obtained in the experiment was consistently much lower than the accepted value. **2**

Explain ONE change that could be made to the experiment that would improve the accuracy of the obtained value.

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Question 32 continues on the following page.

Question 32 continues.

The molar heat of combustion of propan-1-ol, C_3H_7OH, is 2021 kJ mol^{-1}.

(c) Calculate the mass of C_3H_7OH, in tonnes, required to produce 9 605 MJ of energy. **3**

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One way of minimising the greenhouse effect is to minimise the amount of carbon dioxide formed per kilojoule of energy produced. **2**

(d) Using the theoretical ΔH_c, calculate the amount of energy released, in kJ, per mole of carbon dioxide produced during the complete combustion of propan-1-ol.

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End of paper

Section II extra writing space.

If you use this space indicate clearly which question you are answering.

Section II extra writing space.

If you use this space indicate clearly which question you are answering.

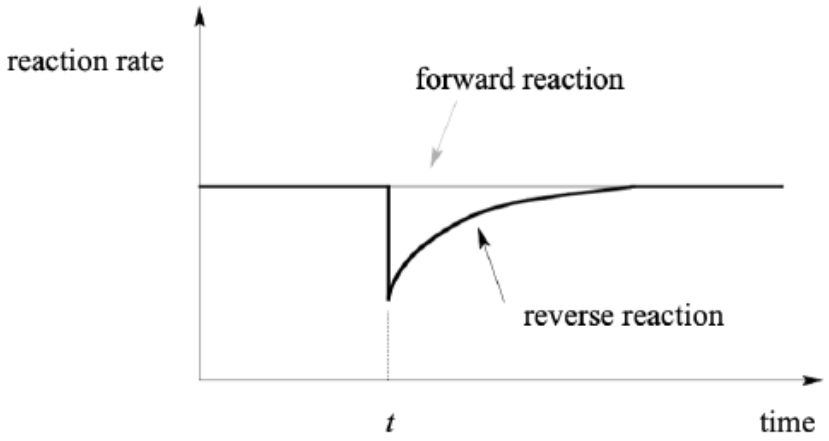
SBHS TRIAL 2022 – MARKING CRITERIA

Use the multiple-choice answer sheet for Questions 1–20.

1 A small amount of solid lead iodide was added to a beaker of water, which was stirred. Most of the solid settled on the bottom of the beaker, but a little dissolved, establishing the equilibrium

$$PbI_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2I^-\ (aq)$$

The rates of the forward and reverse reactions were monitored over time, producing the graph shown below:



What happened at time t?

(A) A small amount of solid $Pb(NO_3)_2$ was added to the beaker.
(B) A small amount of solid KI was added to the beaker.
(C) A small amount of solid PbI_2 was removed from the beaker.
(D) A small amount of water was added to the beaker.

2 What is the pH of a 0.010 mol L^{-1} solution of a weak monoprotic acid that is 4.0% ionised?

(A) 2.00
(B) 2.40
(C) 2.80
(D) 3.40

3 Sulfuric acid (H_2SO_4) and nitric acid (HNO_3) are both strong acids. Ethanoic acid (CH_3COOH) is a weak acid.

20.00 mL solutions of 0.10 mol/L concentration of each of these three acids were separately titrated with a 0.10 mol/L solution of sodium hydroxide (NaOH).

In order to react completely

(A) all three acids would require the same amount of NaOH.

(B) HNO_3 would require more NaOH than CH_3COOH but less than H_2SO_4.

(C) H_2SO_4 and HNO_3 would require the same amount of NaOH but CH_3COOH would require less.

(D) CH_3COOH and HNO_3 would require the same amount of NaOH but H_2SO_4 would require more.

4 It is known that carbon monoxide reacts exothermically with hydrogen gas to form methanol at 400°C, in the presence of a catalyst.

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g) \qquad \Delta H = \text{-ve}$$

A mixture of carbon monoxide, hydrogen gas and methanol placed under conditions described above achieves equilibrium in a closed container. If the reaction temperature is changed to 450°C, which of the following statements is correct?

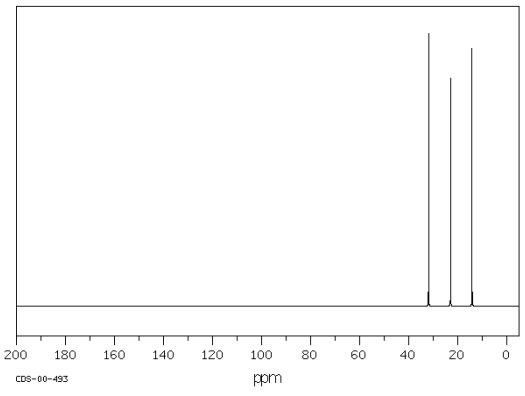
(A) The total number of molecules in the container decreases.

(B) The reaction rates of both the forward and reverse reactions remain constant.

(C) The pressure of the gaseous mixture increases.

(D) Rate of formation of hydrogen decreases while the rate of decomposition of methanol increases.

5 Identify which one of the compounds given below gives the following ^{13}C NMR spectrum:



(A) Prop-1-ene

(B) Hexane

(C) Butanoic acid

(D) Ethanol

6 A student prepares a standard solution in the following way.

i. 2.5 g of pure sodium hydroxide was dissolved into a clear, dry beaker using distilled water
ii. The solution is funnelled into a volumetric flask, and the beaker and funnel set to one side without washing.
iii. The volumetric flask was filled with distilled water, however the student went slightly over the calibration line.
iv. The volumetric flask was shaken to ensure consistency

Despite the errors in the method, the student calculates the concentration of the standard solution. The standard solution is likely to be:

(A) Weaker than calculated.

(B) Stronger than calculated.

(C) Less concentrated than calculated.

(D) More concentrated than calculated.

7 Arrange the following reactions in order of their increasing tendency to reach completion.

I $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $K = 1{\cdot}0 \times 10^{228}$

II $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$ $K = 1{\cdot}0 \times 10^{-13}$

III $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$ $K = 4{\cdot}7 \times 10^{-4}$

IV $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ $K = 5{\cdot}0 \times 10^{-31}$

(NOTE: For each reaction, the equilibrium constant was determined under different conditions.)

(A) I, III, II, IV
(B) III, II, IV, I
(C) IV, II, III, I
(D) I, IV, II, III

8 When acidic potassium permanganate is used to oxidise an alkene, a colour change occurs.

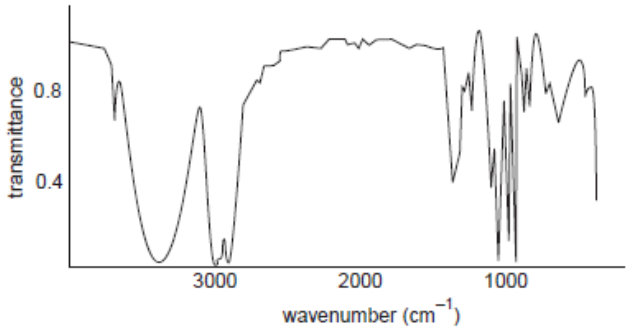
What colour change would be observed?

(A) Colourless to purple
(B) Purple to brown
(C) Brown to colourless
(D) Purple to colourless

9 2-Butanol is heated under reflux with acidified potassium dichromate solution. What is the major organic product?

(A) Butanal
(B) Butyl butanoate
(C) Butanone
(D) Butanoic acid

10 The infrared spectrum of an organic compound is shown below.



The compound could be

(A) Propene
(B) 2-Propanol
(C) Propanoic acid
(C) Propanone

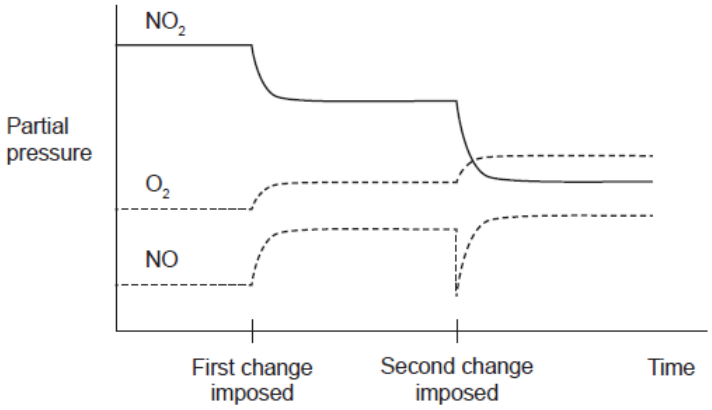
11 When 1.27 g samples of the following substances are all treated with excess dilute hydrochloric acid, all give off carbon dioxide. Which gives off the greatest mass of carbon dioxide?

(A) Lithium carbonate
(B) Beryllium carbonate
(C) Sodium carbonate
(D) Magnesium carbonate

12 Nitrogen dioxide, $NO_2(g)$, is formed when nitrogen monoxide, NO(g), undergoes oxidation as shown below.

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g) \qquad \Delta H = -62\ kJ\ mol$$

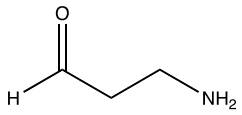
A change was imposed on an equilibrium gas mixture of NO_2, NO and O_2. The mixture returned to equilibrium and another change was imposed. The following graph shows the effects of the two changes.



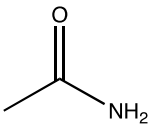
Identify the imposed changes that **best** account for the shape of the graph.

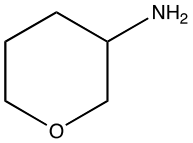
	First change	Second change
(A)	the temperature is decreased	the partial pressure of O_2 is increased
(B)	the temperature is decreased	the partial pressure of NO is decreased
(C)	the temperature is increased	the partial pressure of O_2 is increased
(D)	the temperature is increased	the partial pressure of NO is decreased

13 Which one of the following compounds is both an amine and a ketone?

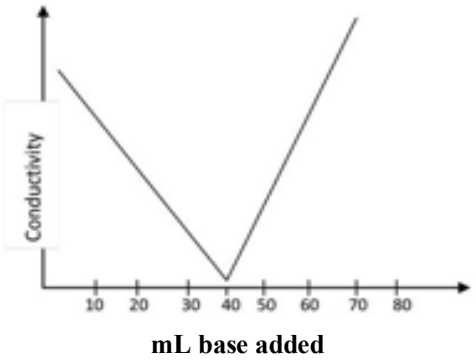
(A) 

(B) 

(C) 

(D) 

14 A conductometric titration was carried out using an acid and a base of similar concentration and the graph below was recorded.



The acid and base used could have been

(A) H_2SO_4 and $Ba(OH)_2$
(B) H_2SO_4 and NH_3
(C) CH_3COOH and NH_3
(D) CH_3COOH and $Ba(OH)_2$

15 A colourless organic liquid compound is tested for the presence of functional groups. 2 mLs of the liquid are poured into three separate tests tubes. A reagent is added to each test tube then shaken.

Test	*Reagent Added*	*Observation made after shaking*
1	2 drops of Bromine water	Yellowish-brown coloured solution
2	3 drops of acidified potassium dichromate	Yellowish-orange coloured solution
3	1 gram of sodium hydrogen carbonate	Colourless solution, small bubbles of colourless gas

What functional group(s) may be present in this compound?

(A) Double bonds
(B) Carboxylic acid
(C) Double bonds and hydroxyl group
(D) Hydroxyl group bonded to a secondary carbon

16 Which row of the table below correctly matches the reaction type with its correct reactants, catalyst and products?

	Reaction Type	Reactants	Catalyst	Products
(A)	Hydration	$H_2C = CH_2 + H_2O$	H_2SO_4	$HOCH_2CH_2OSO_3H$
(B)	Hydration	$H_2C = CH_2$	concentrated H_2SO_4	CH_3CH_2OH
(C)	Addition	$H_2C = CH_2 + H_2O + Br_2$	nil	$BrCH_2CH_2Br$
(D)	Addition	$H_2C = CH_2 + H_2$	Nickel	CH_3CH_3

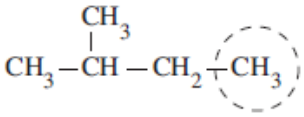
17 Iron(III) forms a variety of coloured complex ions. One such example is that produced by the reaction with salicylic acid ($C_7H_6O_3$):

$$\underset{\text{(pale yellow)}}{Fe^{3+}(aq)} + C_7H_6O_3(s) \rightleftharpoons \underset{\text{(violet)}}{Fe(C_7H_5O_3)^{2+}(aq)} + H^+(aq)$$

The yield of the violet complex, $Fe(C_7H_5O_3)^{2+}$, may be decreased by

(A) adding $C_7H_6O_3(s)$ to the solution.
(B) adding Fe^{3+} ions to the solution.
(C) lowering the pH of the solution.
(D) raising the pH of the solution.

18 The structure of 2-methylbutane is shown. A CH_3 group is circled



Which of the following splitting patterns would be observed in the ^1H NMR spectrum for the CH_3 group circled?

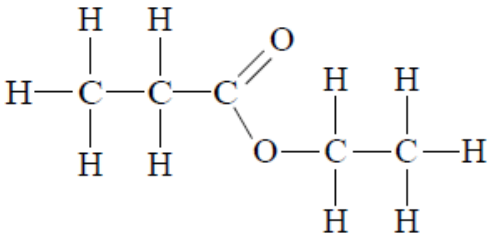
(A) 

(B) 

(C) 

(D) 

19



The species that produces the molecular ion peak in the mass spectrum of this compound is

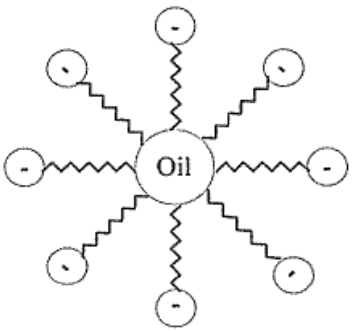
(A) $[CH_3CH_2COOCH_2CH_3]^+$

(B) $[CH_3CH_2COOCH_2CH_3]^{2+}$

(C) $[CH_3CH_2COOCH_2CH_3]^-$

(D) $CH_3CH_2COOCH_2CH_3$

20 Which statement correctly describes the diagram below?



(A) The hydrophilic head of the soap molecule is polar and is attracted to water molecules. The hydrophobic tail is non-polar and forms micelles trapping the oil within the micelle.

(B) The hydrophilic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophobic tail is polar and forms micelles trapping the oil within the micelle.

(C) The hydrophilic head of the soap molecule is polar and is attracted to oil molecules. The hydrophobic tail is non-polar and forms micelles trapping the water within the micelle.

(D) The hydrophobic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophilic tail is non-polar and forms micelles trapping the oil within the micelle.

Chemistry

2022 TRIAL EXAMINATION

Section II
80 marks

Attempt Questions 21- 32
Allow about 2 hour and 25 minutes for this part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.
Section II

Question 21 (3 Marks)

3

$Ag^+(aq) + Br^-(aq) \rightleftharpoons AgBr(s)$ $\quad K_{sp} = 5.35x\ 10^{-13}$

$[Br^-] = 0.02/2 = 0.01$ mol/L (25mL added to 25mL→ conc halved)

$K_{sp} = [Ag^+][Br^-]$
$[Ag^+] = 5.35x\ 10^{-13} / 0.01 = 5.35x\ 10^{-11}$ mol/L (after dilution)

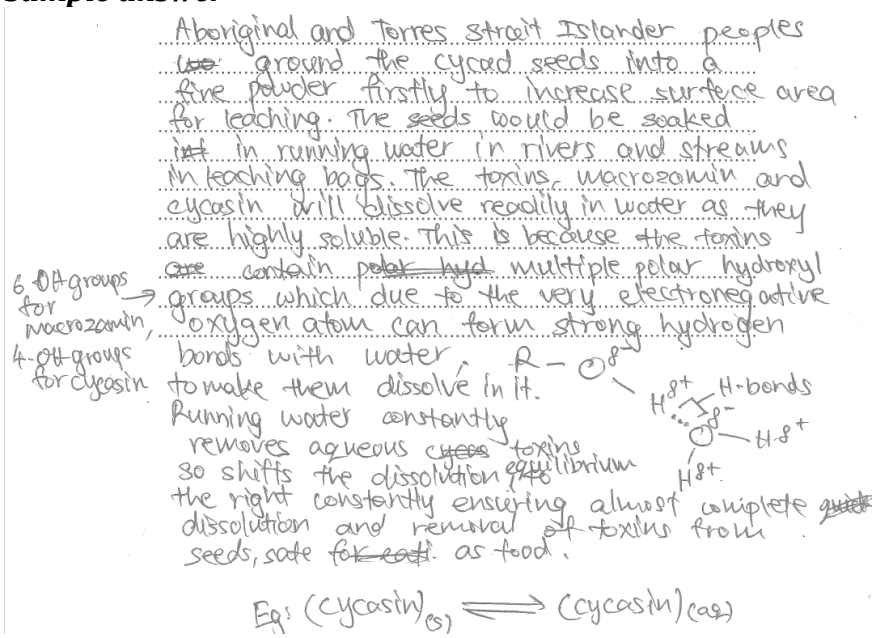
Therefore $[AgNO_3]$ required be added $= 2 \times 5.35x\ 10^{-11}$
$= 1.07 \times 10^{-10}$ mol/L

(2x as initial mixture which is more concentrated)

Question 22 (3 marks)

3

Sample answer



Leaching involves submerging the grounded up powder from the cycad seeds inside a woven bag in running water for up to 4 weeks, depending on the type of seed. Running water is necessary so that the water soluble toxins are washed away and do not reach equilibrium. Each toxin molecule is polar due to the numerus OH functional groups and polar O atoms, hence making them soluble in water which is also polar by forming H- bonding with water molecules

Furthermore, grinding the seeds increases the surface area available for the water to pass through and remove more of the toxin. The remaining carbohydrate is insoluble and can be cooked to make bread.

Question 23 (7 marks)

(a) ***Sample answer*** **2**

$H_2C_2O_4$ (aq) + 2NaOH (aq) → $Na_2C_2O_4$ (aq) + $2H_2O$ (l)

$n(H_2C_2O_4)$ = cv
= 0.1034 x 0.25
= 2.85×10^{-3} mol
= n(NaOH) x 2
n(NaOH) = 0.00517 mol (1:2 ratio)

$$c(NaOH) = \frac{c}{v} = \frac{0.00517}{0.02575}$$
= 0.2008 mol L^{-1}

(b) What is the endpoint of a titration? **1**

Criteria	*Marks*
Correct definition	1

The point during a titration when the indicator first produces a permanent colour change and this indicates that equivalence point has been reached.

NB- With reference to colour change, it is not acceptable to state:

1) the first visible or just visible

2) observable

3) as soon as the indicator changes

4) slight

(c)

Sample answer

Avg. vol. = 16.55 mL (trial 4 is an outlier)
n(NaOH) = cv
= 0.2008 x 0.01655
= 3.323×10^{-3} mol
= $n(C_9H_8O_4)$ (1:1 ratio)
$m(C_9H_8O_4)$ = n x Mm
= 3.323 x 180.154 *(9×12.01+8×1.008+4×16.00)*
= 0.5986 g
= 598.6 mg

$m(C_9H_8O_4) = \frac{598.6}{2}$ Per tablet

$= \mathbf{299.3\ mg}$

The claim about the tablet is not true because the calculated value of 299.3mg is much greater than the stated claim of 150 mg

Question 24 (4 marks)

(a) What is the maximum pH which can be obtained by dissolving $Mg(OH)_2$ in pure water? **2**

Criteria	Mark
Correctly calculates [OH-] and the maximum pH	**2**
Correctly calculates [OH-]	**1**

$Mg(OH)_2(s) \rightleftharpoons Mg^{2+} + 2OH^-$

$K_{sp} = 5.61 \times 10^{-12} = [Mg^{2+}][OH^-]^2$

Let $x = [Mg^{2+}] = 2[OH^-]$

$5.61 \times 10^{-12} = x\,(2x)^2$

$5.61 \times 10^{-12} = 4x^3$

$x = \sqrt[3]{5.61}\ X10^{-12} / 4 = 0.000112$

$[OH^-] = 2 \times 0.000112$

$= 0.000224$ mol/L

$pOH = -\log [OH^-] = -\log(0.000224) = 3.65$

$pH = 14 - pOH$

$= 14 - 3.65$

$= 10.34$

(b) How does this compare with the maximum pH which can be obtained with NaOH? (The solubility of NaOH is 1.20 g/mL at 25°C) **2**

Criteria	Mark
Correctly calculates [OH-] and the maximum pH	**2**
Correctly calculates [OH-]	**1**

$NaOH \rightarrow Na^+ + OH^-$

1.20 g/mL = 1200g/L = 1200g/40 mol/L = 30mol/L

[OH-] = 30 mol/L

$pOH = -\log [OH^-] = -\log(30) = = 1.477$

$pH = 14 - pOH$

$= 14 - -1.477$

= 15.5

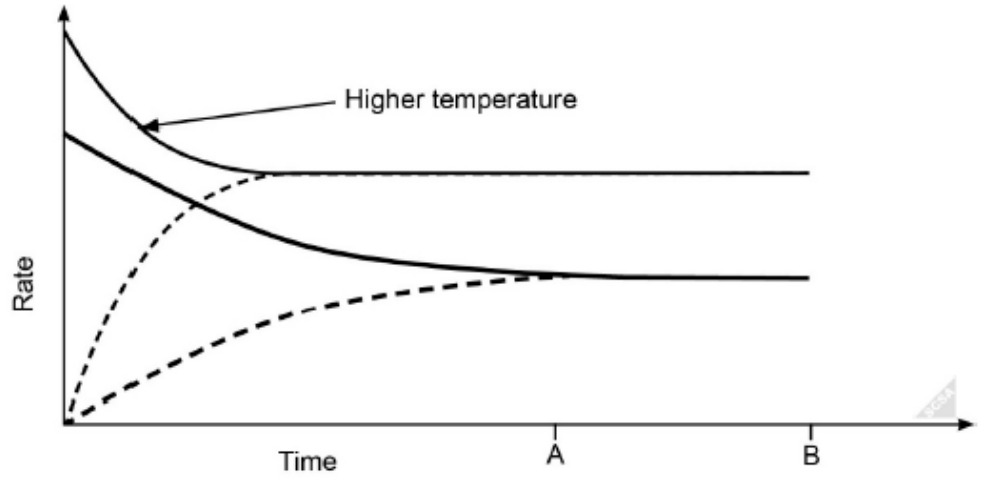
Question 25 (14 marks)

(a)

$K= [NO_2]^2/[N_2][O_2]^2$	1

1

(b)(i)



3

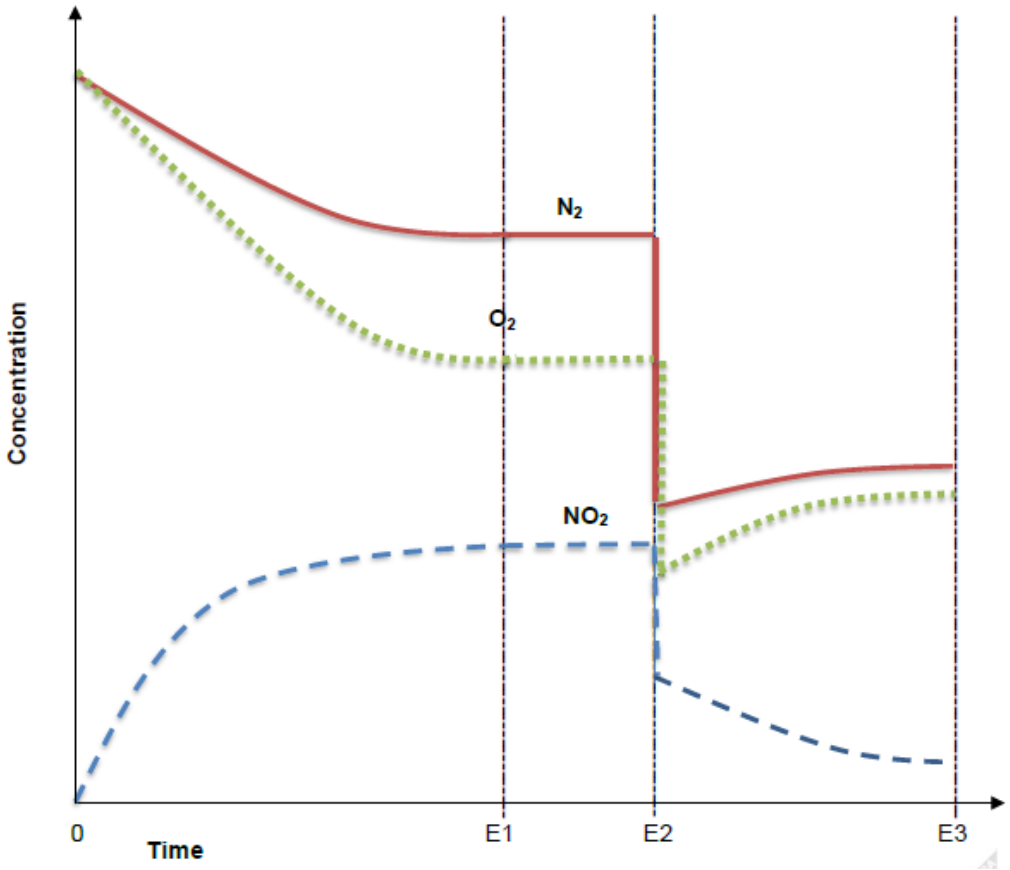
(ii)

2

(iii)

5

(c) Label clearly the line for each gas.



(d) **3**

Question 26 (5 marks)

(a) What is the effect on pH when OCl^- ions are added to the water? **1**

Criteria	Mark
Correctly states the effect on pH	**1**

The increase in the concentration of OCl- causes the pH to increase.

(b) At pH = 8·5, what is the ratio of $[OCl^-]$: [HOCl]? **1**

Criteria	Mark
Correct ratio at pH 8.5 given	**1**

The ratio of $[OCl^-]$: [HOCl] = 9:1 (from graph)

(c) Using your answer in part (b), calculate K_a for hypochlorous acid. **3**

Criteria	**Mark**
Calculates [H+] using pH AND Calculates [HOCl] using ratio from part (b) AND Correctly calculates Ka with all working shown	**3**
Calculates [H+] using pH AND Correct Ka expression OR Correct Ka expression AND Calculates correct Ka value with incomplete working out shown	**2**
Correct Ka expression OR Correctly calculate $[H^+]$ OR Calculates correct Ka value with incomplete working	**1**

$K_a = \dfrac{[H^+][OCl^-]}{[HOCl]}$ $\quad [H^+] = 10^{-8.5} = 3.16 \times 10^{-9}$

$[HOCl] = \% \times [H^+]$

$= 10/90 \times 3.16 \times 10^{-9}$

$= 3.514 \times 10^{-10}\ molL^{-1}$

$Ka = \dfrac{(3.16 \times 10^{-9})^2}{3.514 \times 10^{-10}} = 2.842 \times 10^{-8} = 2.8 \times 10^{-8}$ (2 s.f.)

Question 27 (5 marks)

5

Waste A
H_2SO_4 + 2**A**OH → 2H_2O + **A**$_2SO_4$

n(H_2SO_4) = cV = 0.233 x 29.5/1000 = 0.0068735 mol
n(**A**OH) = 2 x n(H_2SO_4) = 2 x 0.00687 = 0.013747 mol
c(**A**OH) = n/v = 0.013747/0.025 = 0.54988 mol/L

Waste B
NaOH + **B**H → H_2O + Na**B**

n(NaOH) = cV = 0.274 x 32.8/1000 = 0.0089872 mol
n(OH-) = 0.0089872 mol
c(**B**H) = n/V = 0.0089872/0.025 = 0.359488 mol/L

AOH + **B**H → **AB** + H_2O

n(**B**H)[waste B in 100L] = cv = 0.359488 x 100 = 35.9488 mol
n(**A**OH) = cv = 0.54988 x v

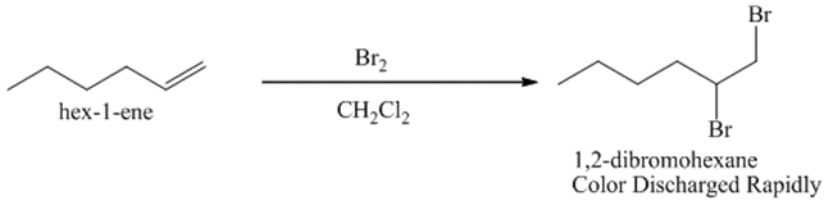
35.9488 mol 35.9488 x v

V= 35.9488 mol/ 35.9488 mol/L = 65. 3757L = **65.4L**

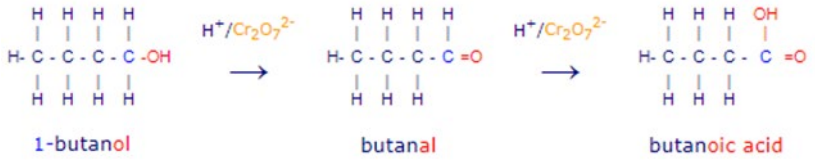
Question 28 (4 marks)

4

Into three separate test-tubes transfer roughly 5 mL of each liquid, and add 5 drops of bromine water then shake. One liquid will turn the orange/brown bromine water colourless, this is 1-hexene. The other two liquids will not show a colour change. The reaction is as such:



For the remaining two liquids, transfer roughly 5mL to two fresh test-tubes and add 5 drops of acidified potassium dichromate solution then shake. The liquid that changes colour from orange to green is 1-butanol. The reaction is as such:



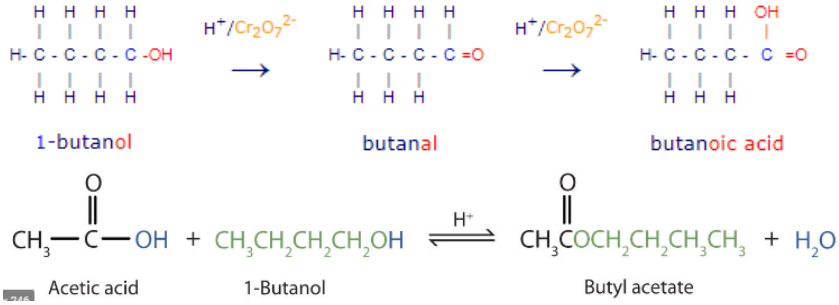
The other liquid will not change colour, which is 2-methyl-2-propanol.

Other chemical tests possible:

1-Butanol – primary alcohol

React with - MnO_4^-/H^+ → purple to colourless solution

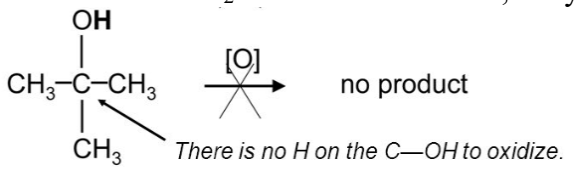
- $Cr_2O_7^{2-}/H^+$ → orange solution changes to green
- a carboxylic acid to form a sweet smelling ester

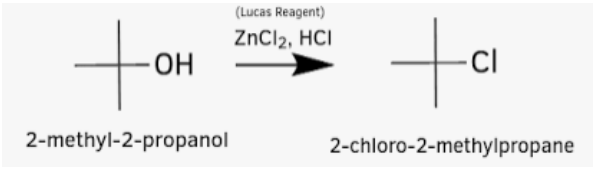


2-methyl – 2- propanol – tertiary alcohol

React with - MnO_4^-/H^+ → purple solution remains unchanged, no reaction

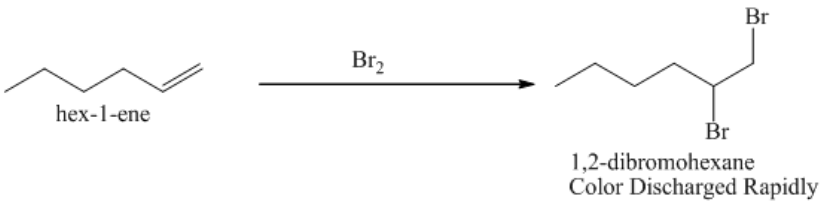
- $Cr_2O_7^{2-}/H^+$ → orange solution remains unchanged, no reaction
- $ZnCl_2/HCl$ → fast reaction, 2 layers form

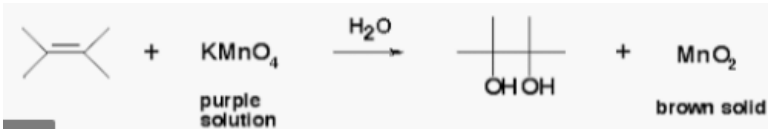




1-hexene -unsaturated hydrocarbon

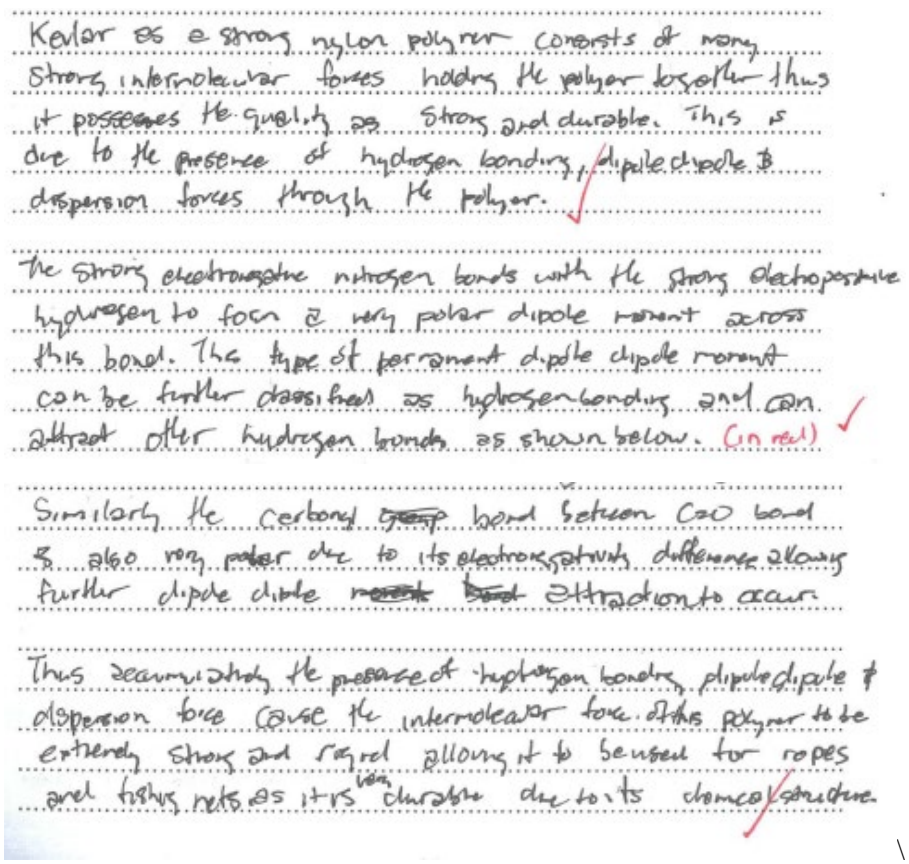
React with - Br_2 or BrOH – orange/brown solutions turns colourless
- MnO_4^-/H^+ - purple colour turns brown





Question 29 (4 marks)

4

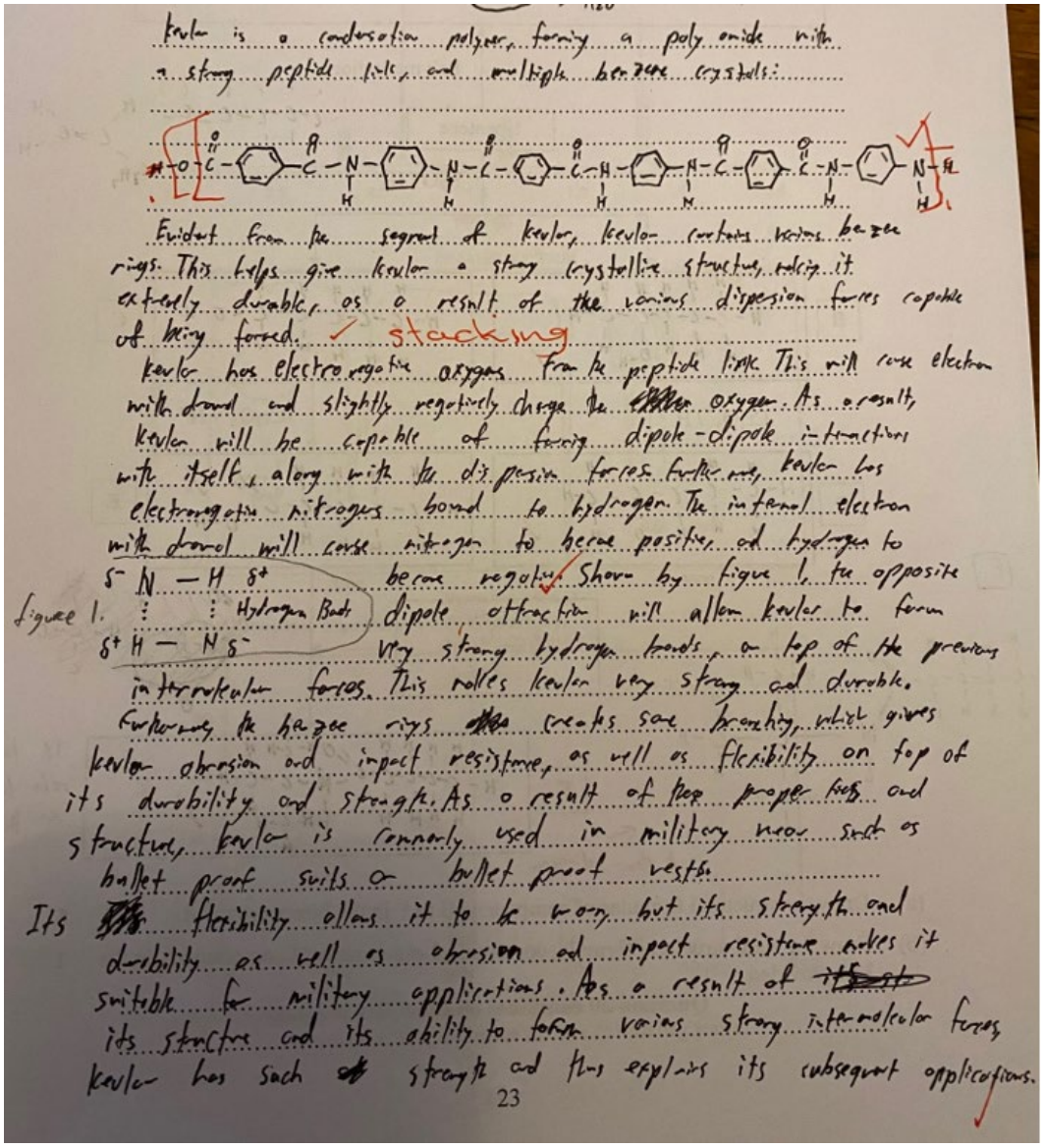

Kevlar as a strong nylon polymer consists of many strong intermolecular forces holding the polymer together thus it possesses the quality as strong and durable. This is due to the presence of hydrogen bonding, dipole dipole & dispersion forces through the polymer. ✓

The strong electronegative nitrogen bonds with the strong electropositive hydrogen to form a very polar dipole moment across this bond. The type of permanent dipole dipole moment can be further classified as hydrogen bonding and can attract other hydrogen bonds as shown below. (in red) ✓

Similarly the carbonyl ~~group~~ bond between C=O bond is also very polar due to its electronegativity difference allowing further dipole dipole ~~moment~~ ~~bond~~ attraction to occur.

Thus accumulatively the presence of hydrogen bonding, dipole dipole & dispersion force cause the intermolecular force of this polymer to be extremely strong and rigid allowing it to be used for ropes and fishing nets as it is idea, durable due to its chemical structure. ✓

Note: this answer doesn't have a segment of polymer



Markers notes:

Be careful when describing H-bonding. Its an intermolecular force between polymer chains not within the molecule.

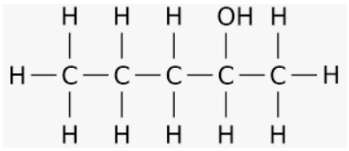
Question was basically about the intermolecular forces present and the stacking ability of the chains that are fairly linear due to the aromatic ring.

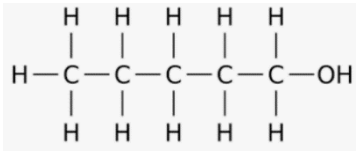
Linking structure to properties to uses.

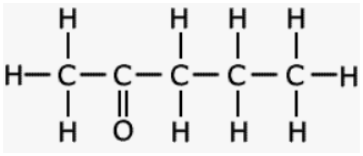
Question 30 (15 marks)

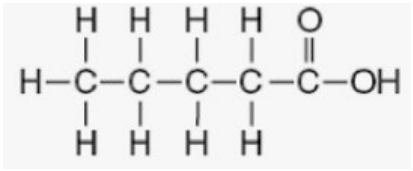
(a) Draw the structural formulas of compounds B to F in the boxes provided. **5**

Criteria	Mark
1 mark for each correct structure	5

B: 

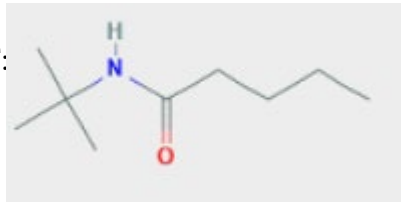
C: 

D: 

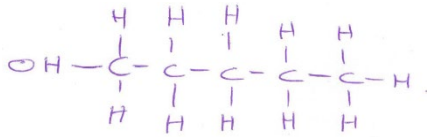
E: 

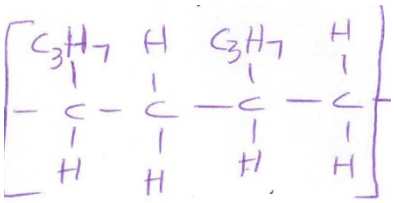
Aldehyde was accepted for E

If F was incorrect

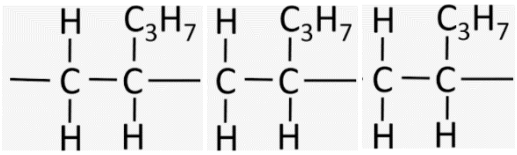
F: 

When drawing structures, ensure atoms have correct number of bonds to them. C-4, H-1, O-2. Don't do:





(b) Draw the semi-structural formula, containing 3 monomers, of compound A in the box provided. **1**



1 mark for correct polymer structure

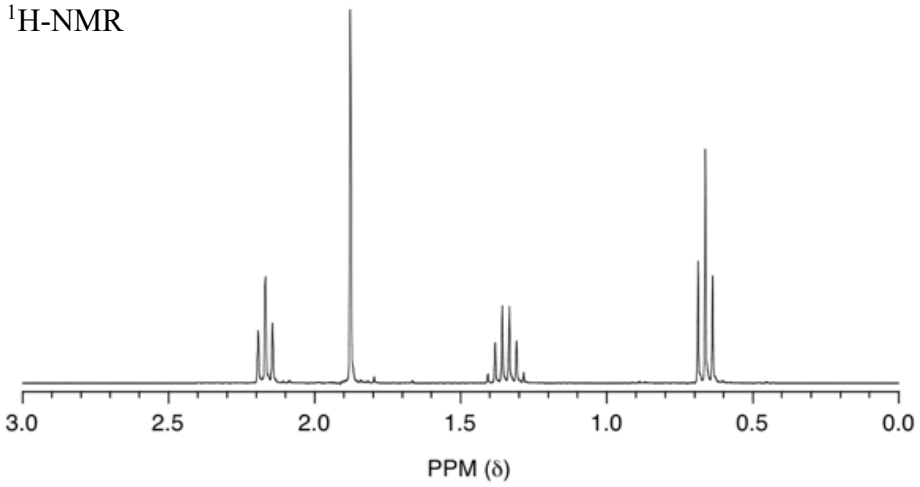
Done REALLY badly. Segment wasn't accepted if H's were missing. Laziness

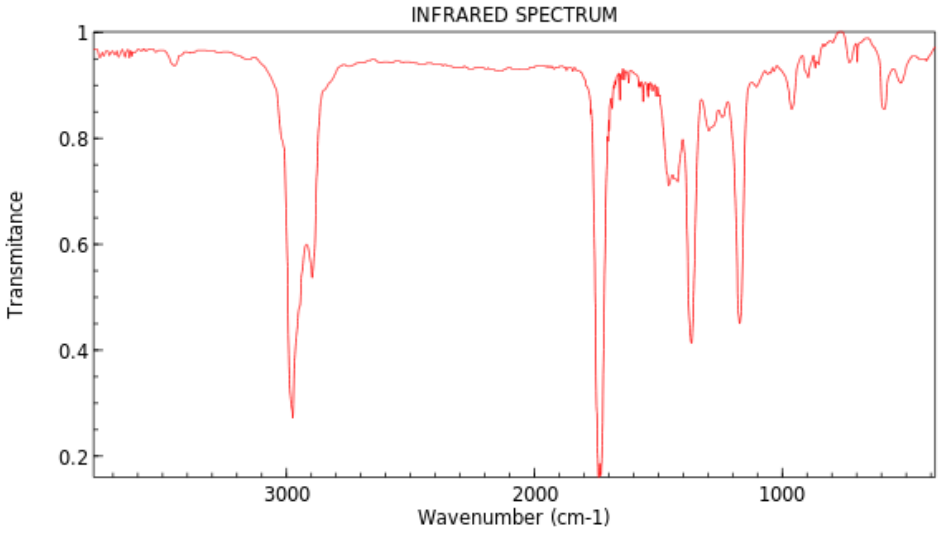
Question 30 continues on the following page.

Question 30 continues.

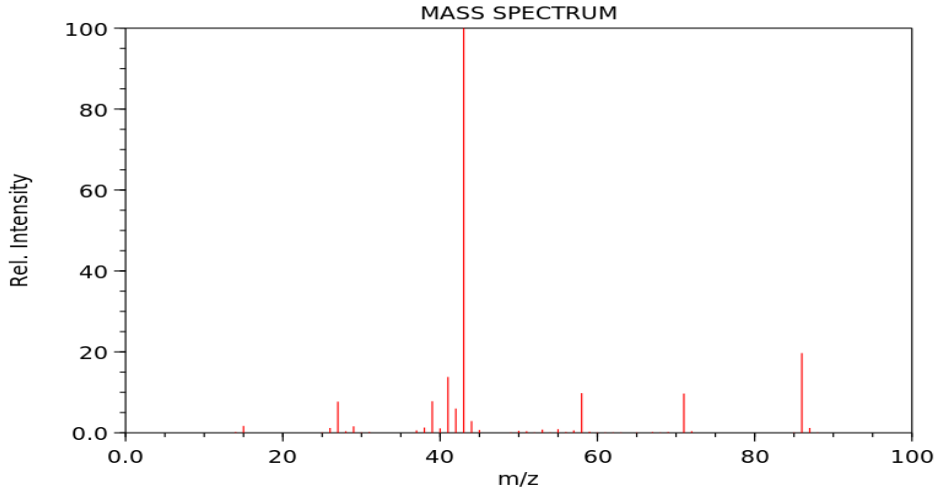
(c) To distinguish between compounds D and E, the student used spectroscopic analysis to determine the structure of the compound produced. He was provided with the following spectra.

^{1}H-NMR





NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

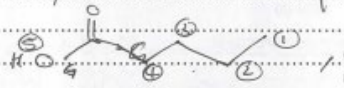


NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

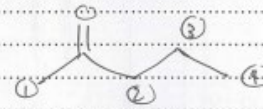
Identify which compound from the previous synthetic pathway corresponds to the provided spectra. Justify your choice using the information from each spectrum. **6**

Compound D. In the IR spectra, there is no acidic -OH broad peak at about 2500 ~ 3000 cm^{-1} which would be expected if the compound was E, due to the carboxyl group. However, it is expected to be absent for D since there are no hydroxyl groups on D (ketone). The presence of C-H sharp peaks at about 3000 cm^{-1} (2850 ~ 3300 cm^{-1}) and a C=O sharp peak at about 1740 cm^{-1} (1650 ~ 1750 cm^{-1}) is consistent with D's C=O group and C-H bonds.

In E, there are 5 unique proton environments:



, yet only 4 peaks in the HNMR (5 is expected instead). However, D has also 4 unique hydrogen environments:

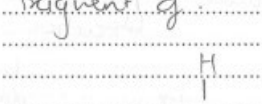


Additionally, the splitting patterns are consistent with D as labelled in the diagram:

- 3H on ① are not split (singlet), as due to no H atoms being <3σ bonds away.
- 2H on ② split into triplet by 2H on ③
- 2H on ③ split into sextet by 2H on ② and 3H on ④
- 3H on ④ split into triplet by 2H on ③.

The chemical shifts are also inconsistent with E. A 9.0 ~ 13.0 ppm δ would be expected for the acidic proton, yet the highest is about 2.18 ppm.

The mass spectrum is consistent with D. The molecular ion peak at about 86 (m/z) is consistent with molar mass of D; MM = 12.01 x 5 + 1.008 x 10 + 16 = 86.13 $g.mol^{-1}$. The base peak can be provided by the possible fragment of:



MM = 12.01 x 2 + 1.008 x 3 + 16.00 = 43.044 $g.mol^{-1}$, consistent with 43 (m/z).

E cannot provided a fragment accounting for this 43 (m/z) base peak. Hence, it is D:

This question was answered really well.

IR - A lot of answered told me what wasn't in the spectra rather than what was in the spectra ie left out analysing the peak that was at 2900cm^{-1}

MS – must refer to both the parent ion (not mother), the base peak and the fragment responsible for it. Both Compounds D and E contain the propyl fragment.
NMR – Needed to assign peaks based on splitting pattern and the chemical shift and state why they were shifted downfield.

Terminology – work on this ie triplet – not 3 splits (this would cause 4 peaks), singlet, triplets and sextet.

The IUPAC name for Compound D is: Pentan-2-one or 2-pentanone

1 mark for correct name

Pentan-2-one or 2-pentanone

Note: pent-2-one incorrect

In a ^{13}C NMR spectrum of Compound D, how many signals would you expect? Why?

Sample Answer:

5 signals as there are five different environments due to the presence of the carbonyl carbon and no symmetry is present.

(d)

1

(e) **2**

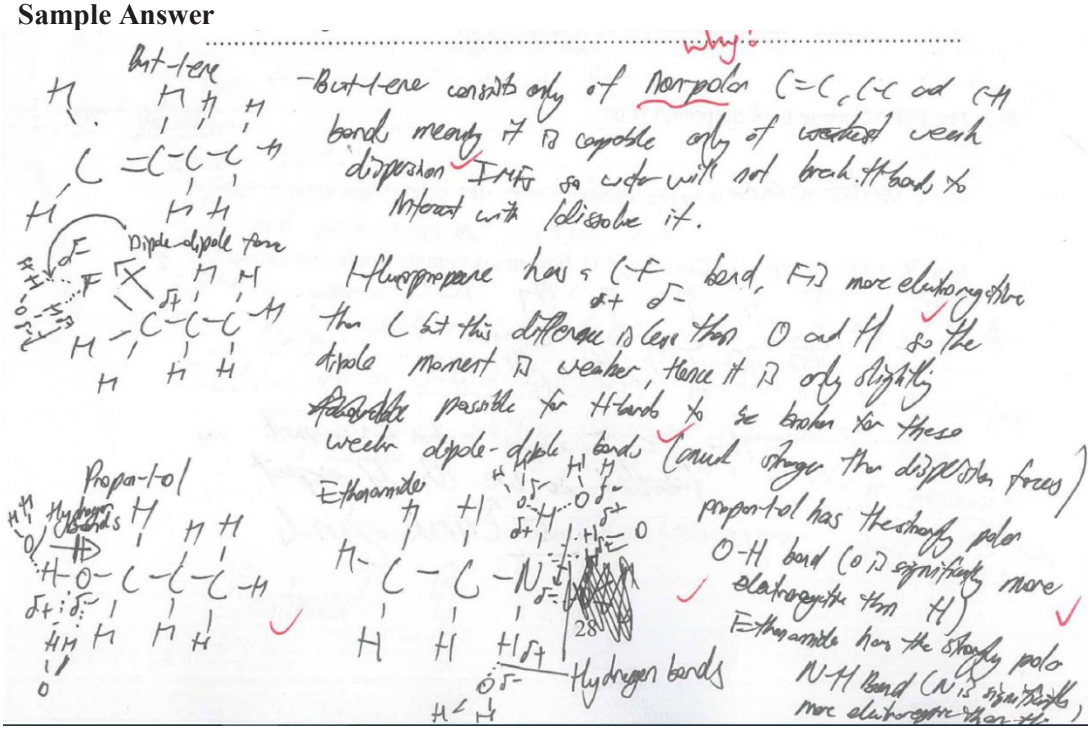
Question 31 (5 marks)

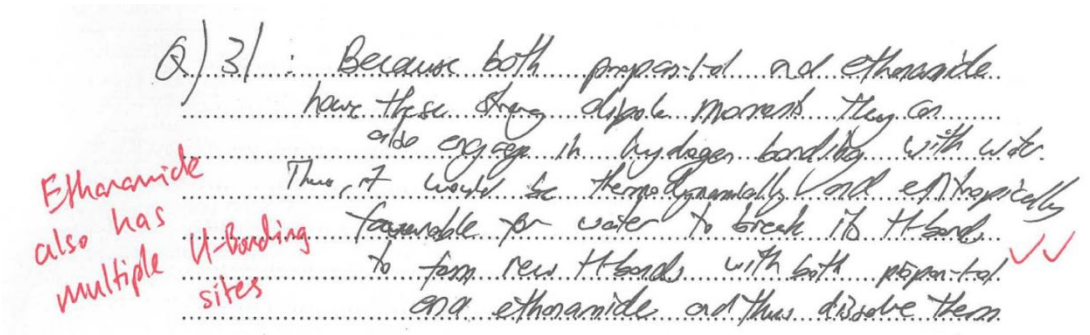
Some properties of but-1-ene, 1-fluoropropane, propan-1-ol and ethanamide are shown in the table.

Compound	*Molar mass (g mol^{-1})*	*Solubility in water*
but-1-ene	56	insoluble
1-fluoropropane	62	slightly soluble
propan-1-ol	60	soluble
ethanamide	59	soluble

Explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram. **5**

Sample Answer





Question 32 (11 marks)

(a) Calculate the experimental molar enthalpy of combustion $\left(\Delta H_c\right)$ of propanol when 0.543 g propanol was used to raise the water temperature from 19.0°C to37.5°C. **4**
MM(C_3H_7OH) = 60.10 g mol^{-1}

Moles(propanol) = 0.543/60.11 = 0.009033 mols
q = mCΔT
= 112 x 4.18 x 18.5
= 8660.96 J

ΔH_C = -q/n = -8660.96/0.009033
= - 958767 J/mol
= -959 kJ/mol (3 s.f.)

Criteria	Marks
• Provides a change that would improve accuracy • Gives a reason for the low molar enthalpy of combustion related to the change	2
• Provides some relevant information	1

Sample answer:

The experimental value for the molar enthalpy of combustion is low, primarily due to heat loss to the environment.

(b) A change that would reduce heat loss and improve accuracy is moving the spirit burner closer to the beaker. **2**

(There are many other possible improvements that are acceptable.)

The molar heat of combustion of propan-1-ol, C_3H_7OH, is 2021 kJ mol^{-1}.

Calculate the mass of C_3H_7OH, in tonnes, required to produce 9 605 MJ of energy.

Answer:
ΔH_C = -q/n
2021 x 10^3 = 9600 x 10^6/n
n = 9600 x 10^6/2021 x 10^3 moles
= 4750.124 mol
m = 4750.124 x 60.10 = 285482.452g
= 0.285 tonnes

(c) One way of minimising the greenhouse effect is to minimise the amount of carbon dioxide formed per kilojoule of energy produced. **3**

Using the theoretical ΔH_c, calculate the amount of energy released, in kJ, per mole of carbon dioxide produced during the complete combustion of propan-1-ol.

Criteria	**Marks**
Balanced chemical equation with states Correct amount of energy calculated	2
Balanced chemical equation OR Correct amount of energy calculated	1

$2C_3H_7OH(l) + 9O_2(g) \rightarrow 8H_2O(l) + 6CO_2(g)$

Energy per mole of CO_2 = 2021/3 = 673.7 kJ per mole of CO_2 released

(d) **2**