James Ruse Agricultural High School

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2025

HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION

Chemistry

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 formula sheet and data sheet and Periodic Table are provided.
- For questions in Section II, **show all relevant working** in questions involving calculations.

Total marks 100

Section I -20 marks (pages 2-12)
- Attempt Questions 1– 20
- Allow about 35 minutes for this part

Section II -80 marks (pages 13-32)
- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this part

This paper MUST NOT be removed from the examination room.

Section I

20 marks
Attempt Questions 1-20
Allow about 35 minutes for this section.
Mark your answers on the ANSWER grid in the Answer booklet on page 13.

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

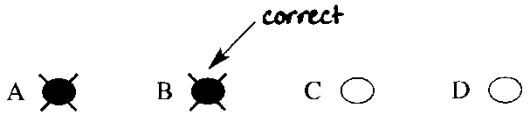
Sample: $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

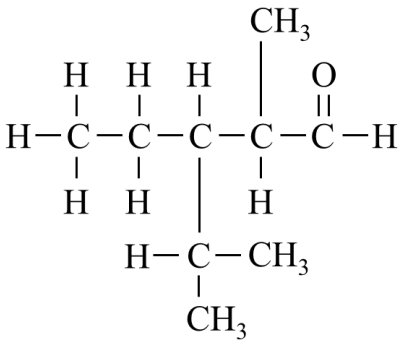
If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

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.



1. What is the systematic name of the following compound?



A. 3-ethyl-2,4-dimethylpentanal

B. 2,4-dimethyl-3-ethylpentanal

C. 3-ethyl-2,4-dimethylpentan-1-one

D. 2,4-dimethyl-3-ethylpentan-1-one

2. Determine the titre from the first and second burette readings

A. 14.30

B. 14.50

C. 15.00

D. 15.50

3. A flame test experiment was carried out on a cation in solution. It was found that a brick red flame colour was observed.

Which metal ion could be responsible for this?

A. Ag^{+}

B. Ca^{2+}

C. Pb^{2+}

D. Fe^{3+}

4. What is an important safety precaution required when adding bromine water to an alkene in a school laboratory?

A. Ensure the absence of UV light.

B. Include a dye in the bromine water so that it is visible.

C. Perform the reaction under reflux.

D. Carry out the reaction in a fume cupboard.

5. How many isomers are there with the formula C_4H_9Cl?

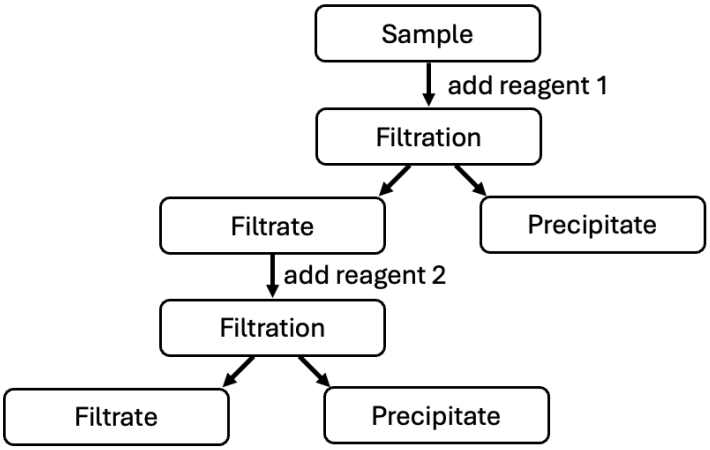
A. 2

B. 3

C. 4

D. 6

6. A chemist was trying to separate a mixture of barium, copper, and lead ions from a sample solution. The plan for their investigation is outlined in the flowchart shown.



What is reagent 2?

A. Na_2SO_4

B. NaOH

C. NaCl

D. Na_2CO_3

7. What is the major product when hydrogen chloride is added to hex-3-ene?

A. hexane

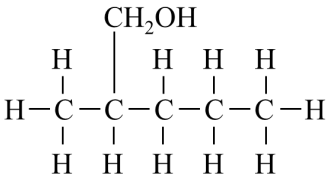
B. 4-chlorohexane

C. 3-chlorohexane

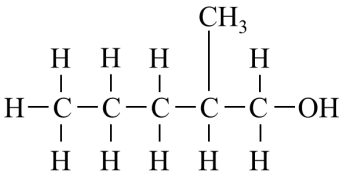
D. 3,4-dichlorohexane

8. Which of the following is a positional isomer of 2-methylpentan-1-ol?

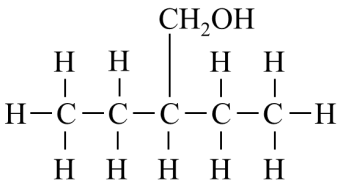
A.



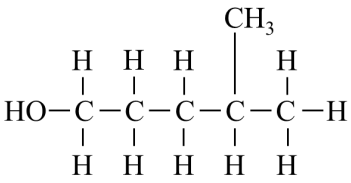
B.



C.



D.



9. Five solutions labelled A-E were tested using a range of indicators.
The solutions are 0.10 $molL^{-1}$ solutions of sodium hydroxide, hydrochloric acid, sodium chloride, sodium hydrogen carbonate or ammonium chloride.

	Indicators colours		
Solutions	Bromothymol Blue	Methyl Orange	Phenolpthalein
A	green	yellow	colourless
B	yellow	yellow	colourless
C	blue	yellow	pink
D	blue	yellow	pale pink
E	yellow	red	colourless
pH range	6.0 – 7.6	3.1 – 4.4	8.3 – 10

Which option correctly identifies solutions A-E?

	A	*B*	*C*	*D*	*E*
A.	$NaHCO_3$	NaCl	NaOH	HCl	NH_4Cl
B.	NaCl	HCl	$NaHCO_3$	NH_4Cl	NaOH
C.	NaCl	NH_4Cl	NaOH	$NaHCO_3$	HCl
D.	$NaHCO_3$	NH_4Cl	NaCl	NaOH	HCl

10. 7.80 g of chromium metal reacts with excess hydrochloric acid to give 11.16 L of hydrogen gas at 25° C and 100 kPa, and a salt.

What is the formula of the salt produced?

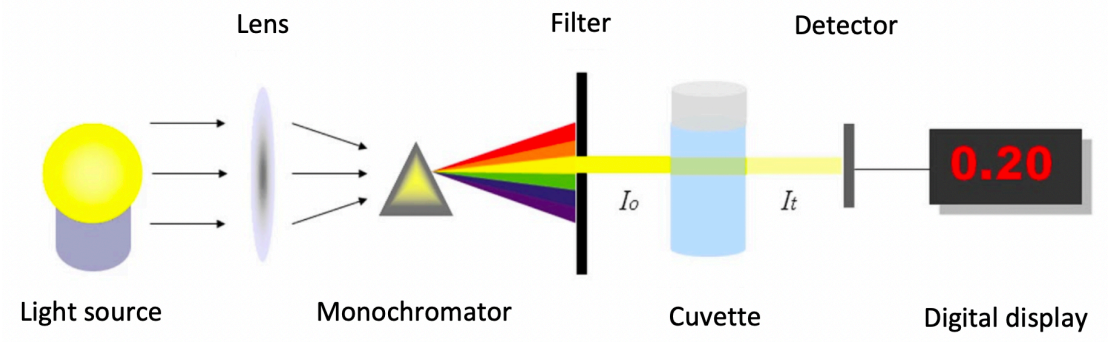
A. $CrCl_2$

B. $CrCl_3$

C. $CrCl_4$

D. $CrCl_6$

11. The diagram shows the components of a colorimeter.



Which of the following correctly matches the component to the function?

	Component	*Function*
A.	Lens	Selects a particular wavelength of light that travels through the sample.
B.	Detector	Measures the intensity ratio between the absorbed and unabsorbed wavelength of light.
C.	Light source	An element specific light globe used to match the absorbance of the species tested.
D.	Monochromator	Focuses the wavelengths of light to pass through the filter into the sample.

12. Which oxygen containing functional group is consistent with the information provided?

Source	*Observations*
Chemical test	No reaction with small piece of magnesium metal
Infrared spectrum	Strong signal at 1710 cm^{-1} Sharp signal at 1100 cm^{-1}
^{13}C NMR spectrum	Peak at 182 ppm

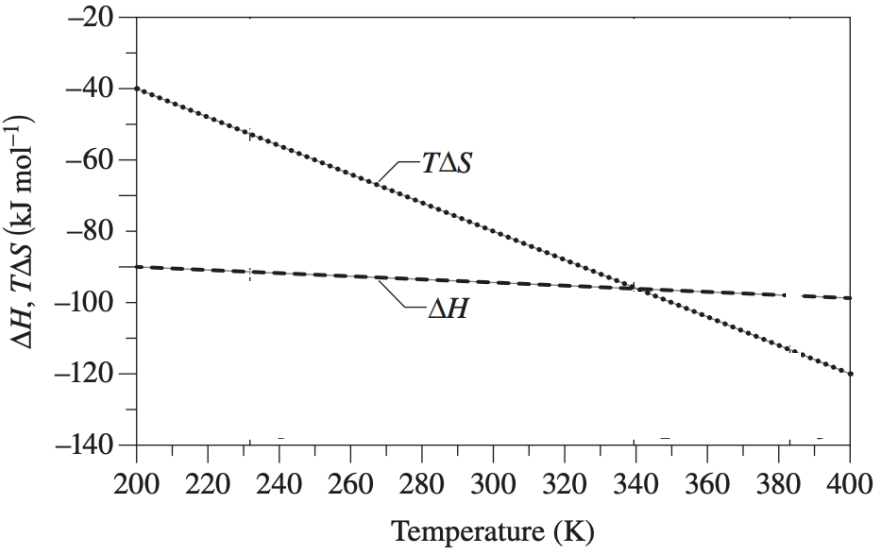
A. ester

B. ketone

C. alcohol

D. carboxylic acid

13. Use the data in the graph to determine what can be deduced about the system at 240 K.



A. ΔG is negative, and the reaction is spontaneous.

B. ΔG is positive, and the reaction is spontaneous.

C. ΔG is negative, and the reaction is non-spontaneous.

D. ΔG is positive, and the reaction is at equilibrium.

14. Consider the molecules CH_2CHCH_3, CH_3COCH_3 and $CHCCH_3$.
How many of these have a bond angle of approximately 120° around the central carbon atom?

A. 0

B. 1

C. 2

D. 3

15. Which chemical test and instrumental technique could be used to confirm that the hydration of an unsaturated hydrocarbon molecule has gone to completion?

A. sodium metal and ^{1}H NMR spectroscopy

B. bromine water and infrared spectroscopy

C. lucas reagent and ^{13}C NMR spectroscopy

D. potassium permanganate and mass spectrometry

16. Which of the following would produce the greatest mass of precipitate when mixed with 10 mL of a 0.1 mol L^{-1} solution of silver nitrate?

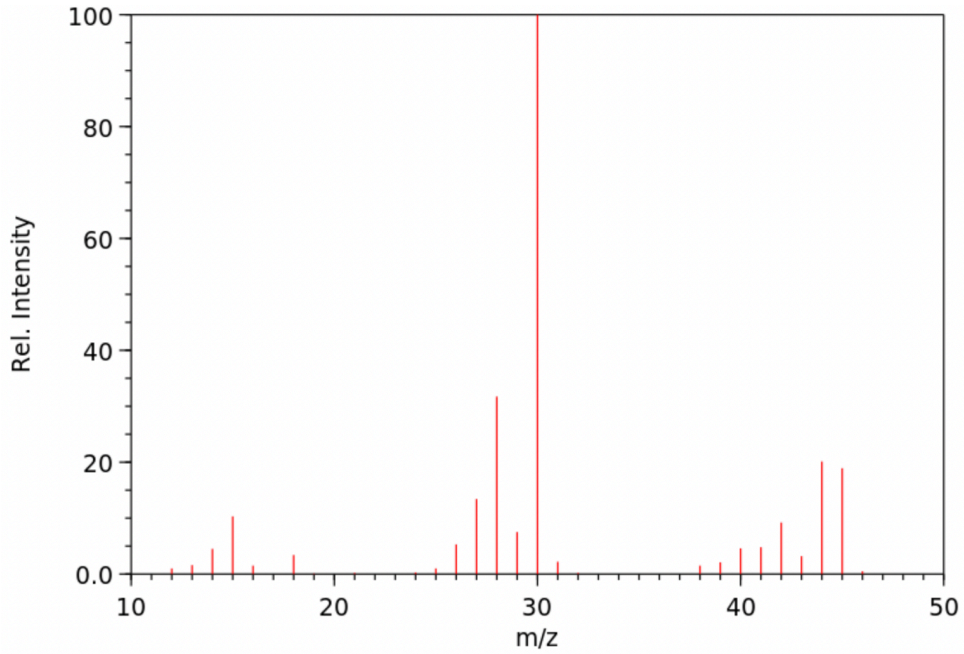
A. 10 mL of 0.1 mol L^{-1} sodium hydroxide

B. 10 mL of 0.1 mol L^{-1} sodium chloride

C. 10 mL of 0.1 mol L^{-1} sodium carbonate

D. 10 mL of 0.1 mol L^{-1} sodium phosphate

17. An organic molecule with the chemical formula C_2H_7N is given in the mass spectrum.



What is a possible identity for the base peak?

A. $[CH_3]^+$

B. $[CH_3CH_2]^+$

C. $[CH_2NH_2]^+$

D. $[CH_3CH_2NH_2]^+$

18. What mass of glucose must be fermented to fill a 5.0 L gas bottle with CO_2 to a pressure of 4100 kPa on an 18 °C, day?

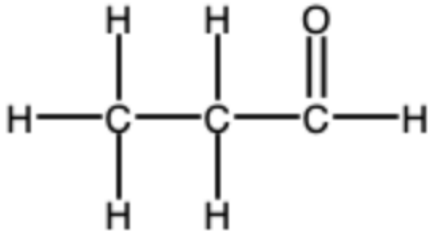
A. 4.2 g

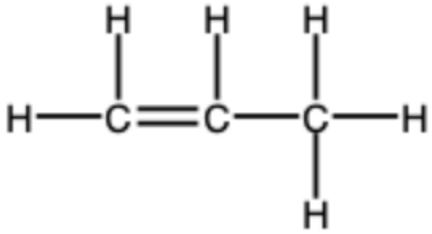
B. 760 g

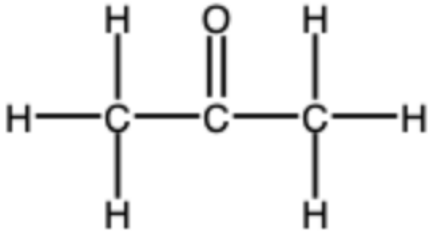
C. 1500 g

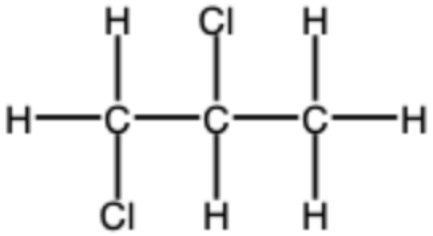
D. 12 000 g

19. Which of the following organic compounds would have a peak splitting pattern with a multiplicity of 5 in their ^{1}H NMR spectrum?

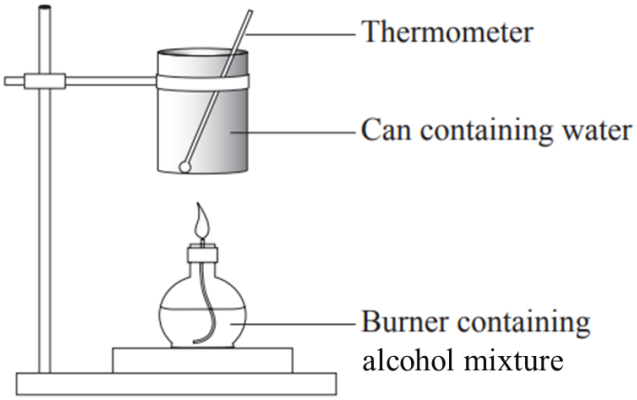
A. 

B. 

C. 

D. 

20. A student sets up the following apparatus in the school laboratory:



Instead of using a pure alcohol, the student burns a mixture of two alcohols.
The following results were obtained by the student:

Mass of water: 186.2 g
Initial temperature of water: 22.3 °C
Final temperature of water: 83.6 °C
Mass of alcohol burnt: 1.8 g

The heat of combustion for two alcohols is shown below:
Methanol 22.7 kJ g^{-1}
Ethanol 29.7 kJ g^{-1}

Assuming that the two alcohols do not react with one another and that all the heat released from the combustion is absorbed by the water, which of the following conclusions is consistent with this data?

A. The mixture is nearly pure methanol.

B. The mixture is nearly pure ethanol.

C. The mixture is a fairly equal mix of methanol and ethanol.

D. It is not a mixture of methanol and ethanol.

James Ruse Agricultural High School

Starting from the left, please write your student number NEATLY in the boxes.

Mark

JRAHS Chemistry Trial 2025

Section I Multiple Choice Answers

1.	A ○	B ○	C ○	D ○
2.	A ○	B ○	C ○	D ○
3.	A ○	B ○	C ○	D ○
4.	A ○	B ○	C ○	D ○
5.	A ○	B ○	C ○	D ○
6.	A ○	B ○	C ○	D ○
7.	A ○	B ○	C ○	D ○
8.	A ○	B ○	C ○	D ○
9.	A ○	B ○	C ○	D ○
10.	A ○	B ○	C ○	D ○
11.	A ○	B ○	C ○	D ○
12.	A ○	B ○	C ○	D ○
13	A ○	B ○	C ○	D ○
14.	A ○	B ○	C ○	D ○
15.	A ○	B ○	C ○	D ○
16.	A ○	B ○	C ○	D ○
17.	A ○	B ○	C ○	D ○
18.	A ○	B ○	C ○	D ○
19.	A ○	B ○	C ○	D ○
20.	A ○	B ○	C ○	D ○

Section II

80 marks
Attempt Questions 21-36
Allow about 2 hours and 25 minutes for this section.

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (3 marks)

Use an example to explain how Aboriginal and Torres Strait Islanders used the principles of solubility equilibria to detoxify compounds from food. **3**

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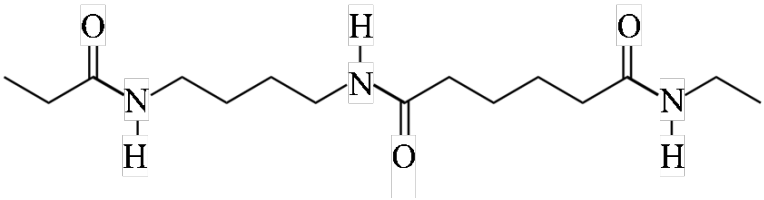
Question 22 (3 marks)

Examine part of a nylon polymer shown below:



(a) Identify the name of the functional group in this polymer. **1**

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(b) Draw the formula of ONE monomer used to make this polymer. **2**

Question 23 (4 marks)

The acid ionisation constants for three acids are given below.

Acid	*Acid ionisation constant, Ka*
Hydrofluoric	7.2×10^{-4}
Methanoic acid	1.77×10^{-4}
Ammonium ion	5.6×10^{-10}

(a) Write an equation showing the ammonium ion acting as an acid in water. **2**

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(b) List the conjugate bases for these three acids in correct order of increasing base strength. **2**

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Question 24 (5 marks)

Colourless nitrogen monoxide reacts with oxygen to form brown nitrogen dioxide according to the following reaction:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \quad \Delta H < 0$$

(a) Use Le Chatelier's principle to explain any observed colour change when the temperature is decreased. **2**

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(b) A 2.0 L reaction vessel initially contained 0.50 mole nitrogen monoxide and 0.24 mole of oxygen. At equilibrium there was 0.10 mole of nitrogen monoxide. Calculate the equilibrium constant for this reaction. **3**

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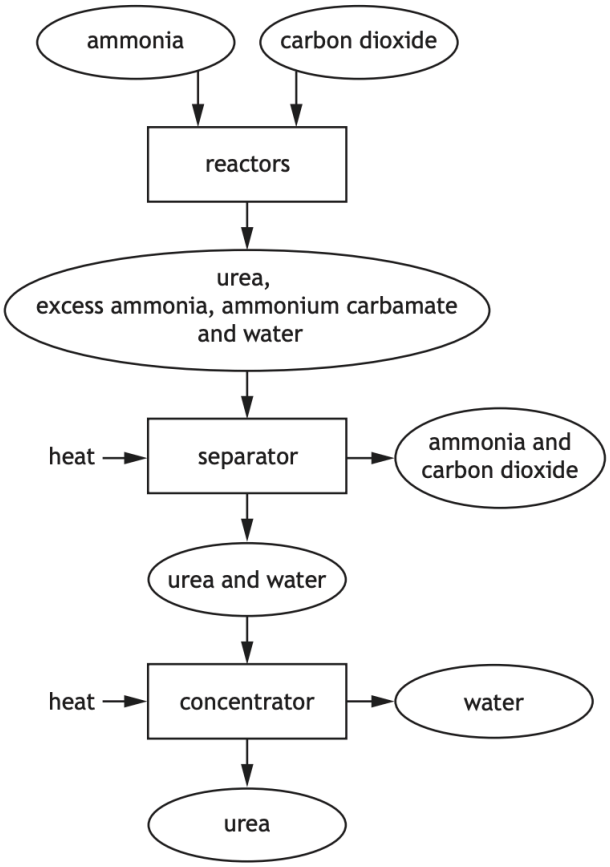
Question 25 (2 marks)

Urea is an important chemical reagent used in the agricultural industry for fertilisers and animal food supplements. The industrial means of producing urea is shown in the flowchart below.



Explain ONE improvement that could be made to the industrial process shown. **2**

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Question 26 (8 marks)

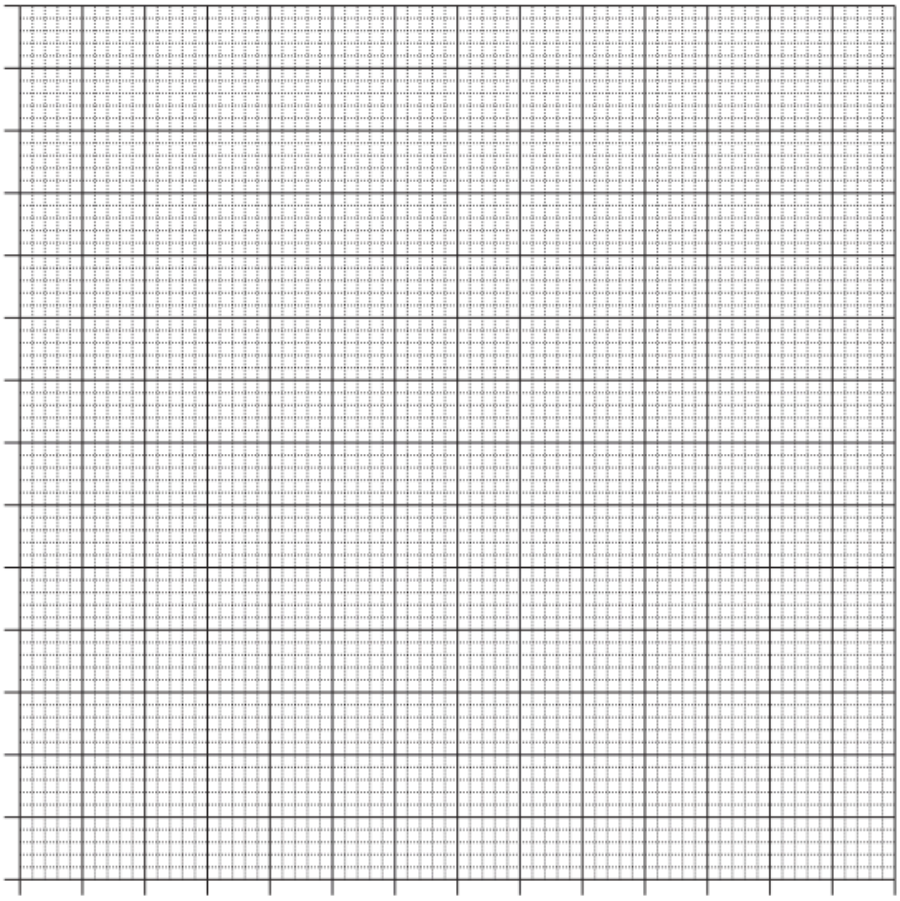
Hydrochloric acid can be neutralised by using sodium carbonate.

A range of volumes of 1.00 mol L^{-1} hydrochloric acid solutions were mixed with 10.0 mL of a sodium carbonate solution of unknown concentration and the volume of the solution made up to 20.0 mL.

The change in temperature for each solution was measured and recorded in a table.

Volume of hydrochloric acid added (mL)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0
Temperature increase (^{o} C)	0.0	1.4	2.8	4.3	5.2	6.2	6.2	6.2

Graph the data in the table and use the graph and relevant calculations to determine the initial concentration of the sodium carbonate solution. **8**



Question 26 continued on page 19

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Question 27 (6 marks)

(a) Calculate the molar solubility of silver carbonate at 25 ºC. **2**

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(b) Determine whether a precipitate will form when 100.0 mL of a 3.0×10^{-3} mol L^{-1} solution of silver nitrate is mixed with 100.0 mL of a 1.0×10^{-2} mol L^{-1} solution of sodium carbonate. **4**

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Question 28 (4 marks)

In a reaction, 30.0mL of a 0.106 mol L^{-1} NaOH solution is added to 25.0 mL of 0.100 mol L^{-1} HCl solution.

What will be the pH of the final solution? **4**

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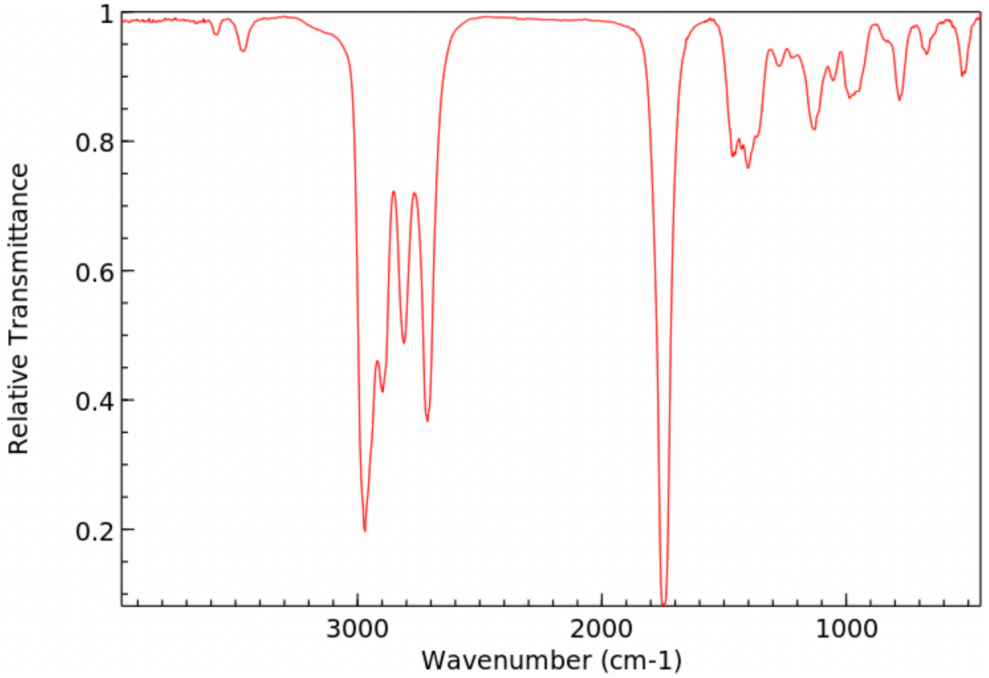
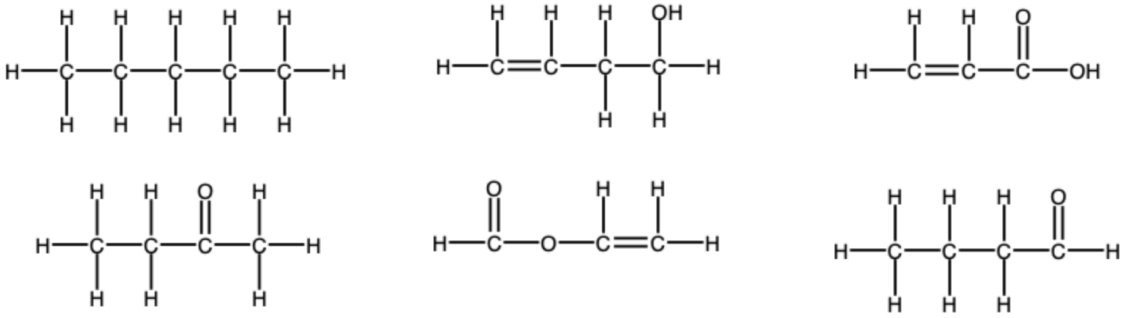
Question 29 (4 marks)

The infrared spectrum has been provided for an unknown organic compound that contains a single functional group. This spectrum is misleading since that data can be used to deduce a variety of different possible functional groups for this compound.



(a) Circle the TWO possible structures for this spectrum. **2**



(b) Select another spectroscopic technique and explain how it could be used to decide between the different possible functional groups you identified above. **2**

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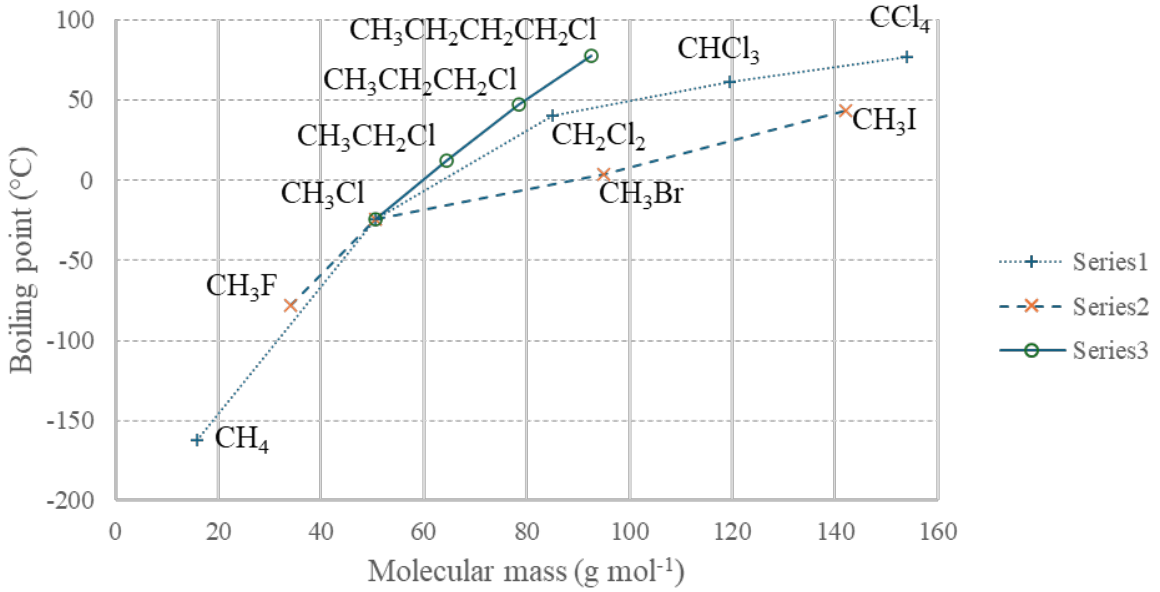
Question 30 (5 marks)

Ethyl acetate, $CH_3COOC_2H_5$, is produced in large quantities for use as a solvent. It can be synthesised using ethanol as the only organic reagent.

Draw a flowchart to show how ethanol can be used to produce ethyl acetate, including the inorganic chemicals required and the reaction conditions for each step. Your response should identify any intermediate organic molecules but does not need to include any purification steps. **5**

Question 31 (8 marks)

Chloromethane is a compound produced both naturally and industrially. It can be grouped in a number of series of compounds, with three such series shown in the graph below.



(a) Identify the homologous series **1**

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(b) Use your knowledge of intermolecular and intramolecular bonds to account for the trends in boiling points within each of these series. **7**

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Question 31 continued on page 25

Question 32 (5 marks)

Oct-3-yne is a hydrophobic liquid at room temperature.

(a) Draw the structural formula for oct-3-yne. **1**

(b) Explain, with the use of a diagram, how a soap could be used to remove oct-3-yne from a surface. **4**

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Question 33 (6 marks)

A standardised solution of 0.10 mol L^{-1} sodium hydroxide solution was titrated against 25.00 mL of a solution of ethanoic acid by 4 different students. The results are recorded in the table below

	Titre volumes (mL)				
Student	Trial 1	Trial 2	Trial 3	Trial 4	Average titre
A	16.70	16.10	16.00	16.20	16.25
B	15.75	15.30	15.40	15.25	15.35
C	17.85	17.50	16.80	17.45	17.25
D	17.00	16.40	17.00	17.45	16.95

(a) Assess which student(s) have calculated reliable average titres. **3**

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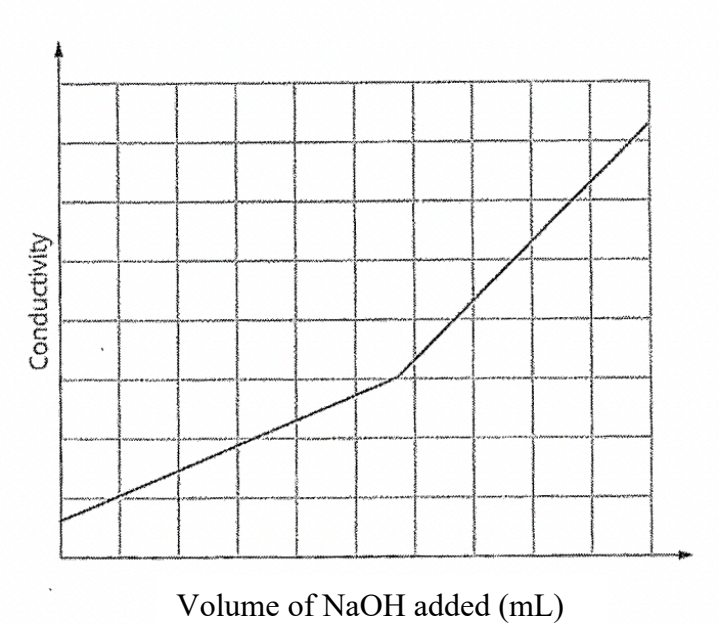
Question 33 continued on page 28

(b) Explain the shape of the conductometric graph for this titration. Include a relevant equation in your answer **3**



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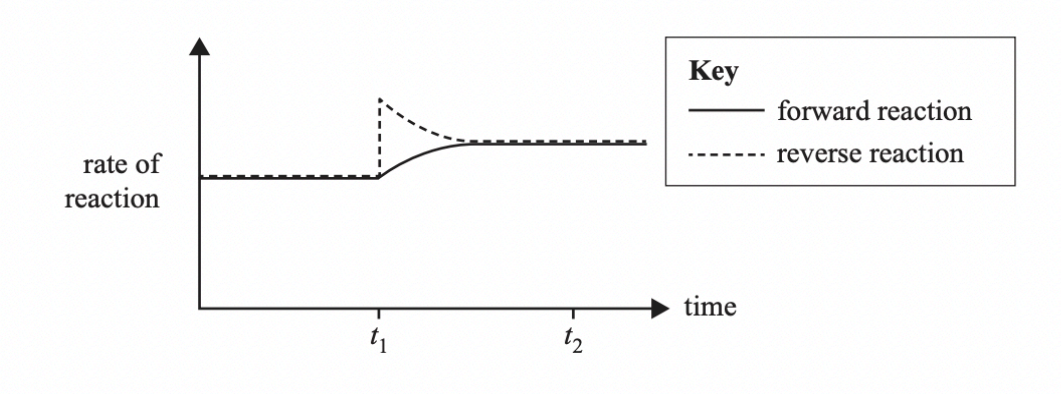
Question 34 (4 marks)

An equilibrium of four gases is represented by the following equation.

$$A\ (g) + 2B\ (g) \rightleftharpoons C\ (g) + D\ (g) \quad \Delta H > 0$$

The graph below shows the rate of the forward and reverse reactions versus time.

A single change is made to the equilibrium mixture at time t_1 and equilibrium is re-established at t_2.



Use the graph and collision theory to explain a change that may have occurred at t_1. **4**

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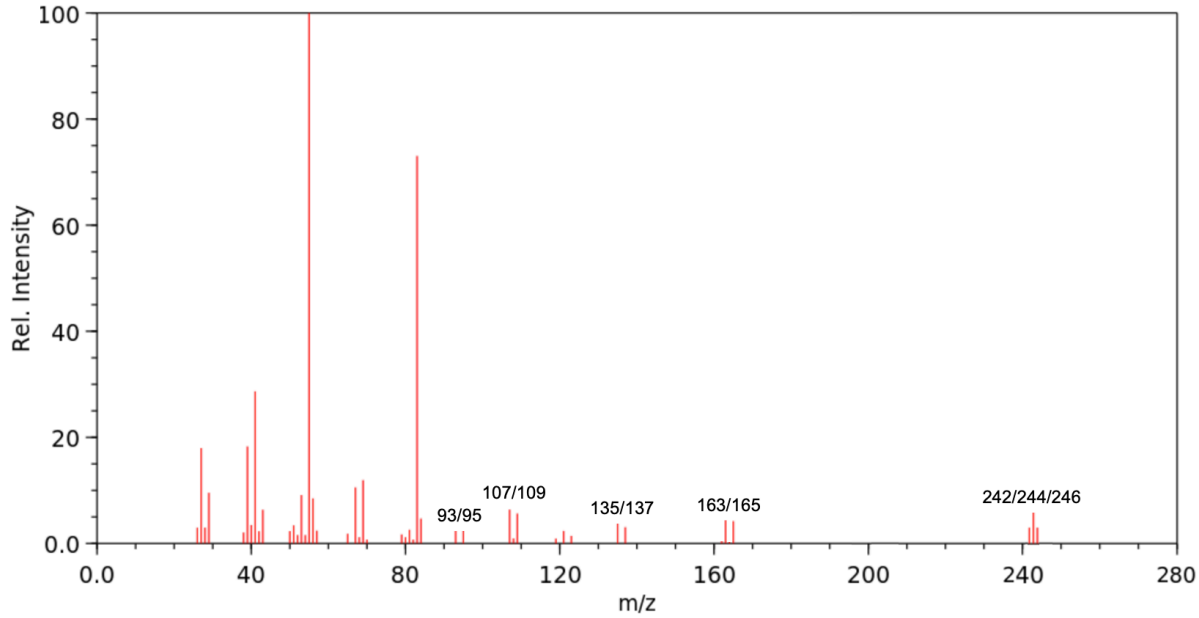
Question 35 (8 marks)

A chemist performed organic synthesis using compounds E, F and G according to the reaction pathway shown.

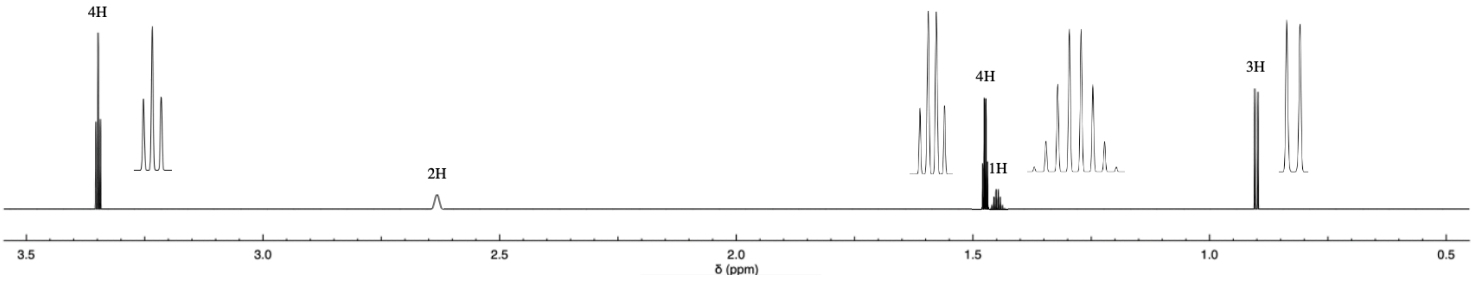
The molecular formula for the final product, compound G was partially derived as $C_6H_{10}O_X$.

Spectral data for these compounds is given below.

Mass Spectrum of Compound E



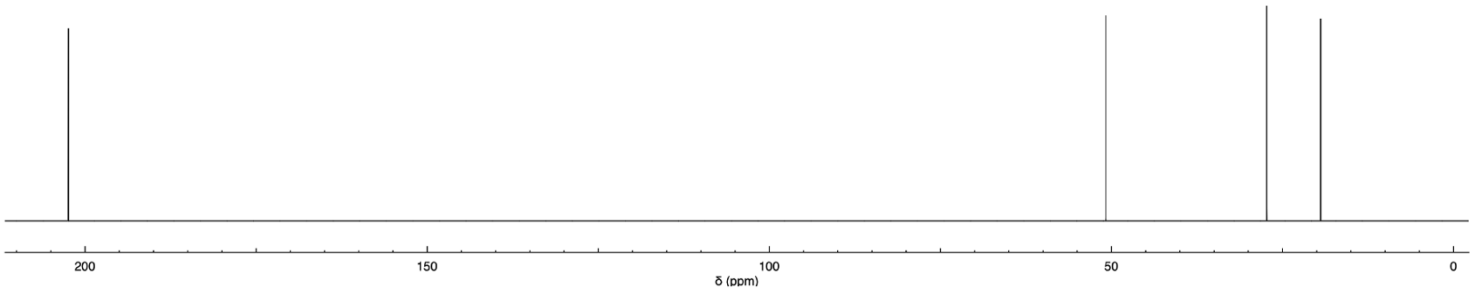
^{1}H NMR Spectrum of Compound F



^{1}H NMR Spectrum Data for Compound F

Chemical shift (ppm)	*Integration*	*Peak splitting*
0.90	3	Doublet
1.44	1	Multiplet (8)
1.47	4	Quartet
2.63	2	Singlet
3.35	4	Triplet

^{13}C NMR Spectrum of Compound G



Draw the structure of compounds E, F, and G. Justify your answer with reference to the information provided.

Compound E
Compound F
Compound G

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Question 35 continued on page 32

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Question 36 (5 marks)

Hawaiian sea salt is a variation of table salt (sodium chloride) which has a unique flavour and colour due to a range of impurities, including calcium chloride, magnesium chloride, and magnesium sulfate.

A chemist carried out a series of precipitation titrations to determine the composition of the impurities present in a 100 g packet of Hawaiian sea salt which was dissolved in 200 mL of demineralised water.
To determine the calcium chloride content, 28.71 mL of a 2.40 mol L^{-1} solution of sodium hydroxide was required for complete precipitation.

$$CaCl_2\ (aq) + 2NaOH\ (aq) \longrightarrow Ca(OH)_2\ (s) + 2NaCl\ (aq)$$

Once the precipitate was filtered out of the solution, 31.61 mL of a 1.51 mol L^{-1} sodium carbonate solution was added to precipitate all the magnesium ions, which was also removed.

$$MgCl_2\ (aq) + Na_2CO_3\ (aq) \longrightarrow MgCO_3\ (s) + 2NaCl\ (aq)$$
$$MgSO_4\ (aq) + Na_2CO_3\ (aq) \longrightarrow MgCO_3\ (s) + Na_2SO_4\ (aq)$$

The resultant solution was reacted with 23.19 mL of a 0.672 mol L^{-1} solution of barium nitrate.

$$Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq) \longrightarrow BaSO_4\ (s) + 2NaNO_3\ (aq)$$

Calculate the masses of the calcium chloride, magnesium chloride and magnesium sulfate impurities. **5**

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Question 36 continued on page 34

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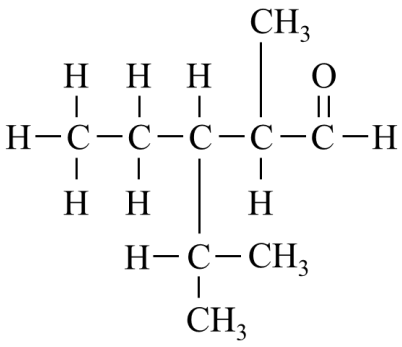
If you use this space, clearly indicate which question you are answering here AND on your question.

Part B extra writing space
If you use this space, clearly indicate which question you are answering here AND on your paper.

Trial 2025 answers S

1. What is the systematic name of the following compound?



A. 3-ethyl-2,4-dimethylpentanal

B. 2,4-dimethyl-3-ethylpentanal

C. 3-ethyl-2,4-dimethylpentan-1-one

D. 2,4-dimethyl-3-ethylpentan-1-one

2. Determine the titre from the first and second burette readings

A. 14.30

B. 14.50

C. 15.00

D. 15.50

3. A flame test experiment was carried out on a cation in solution. It was found that a brick red flame colour was observed.

Which metal ion could be responsible for this?

A. Ag^{+}

B. Ca^{2+}

C. Pb^{2+}

D. Fe^{3+}

4. What is an important safety precaution required when adding bromine water to an alkene in a school laboratory?

A. Ensure the absence of UV light.

B. Include a dye in the bromine water so that it is visible.

C. Perform the reaction under reflux.

D. Carry out the reaction in a fume cupboard.

5. How many isomers are there with the formula C_4H_9Cl?

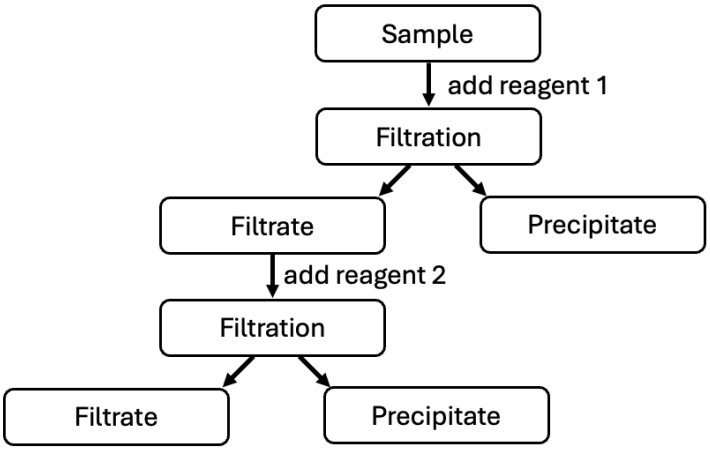
A. 2

B. 3

C. 4

D. 6

6. A chemist was trying to separate a mixture of barium, copper, and lead ions from a sample solution. The plan for their investigation is outlined in the flowchart shown.



What is reagent 2?

A. **Na_2SO_4**

B. NaOH

C. NaCl

D. Na_2CO_3

7. What is the major product when hydrogen chloride is added to hex-3-ene?

A. hexane

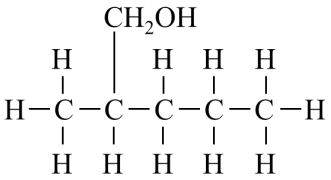
B. 4-chlorohexane

C. **3-chlorohexane**

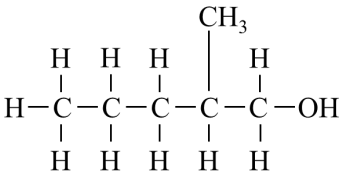
D. 3,4-dichlorohexane

8. Which of the following is a positional isomer of 2-methylpentan-1-ol?

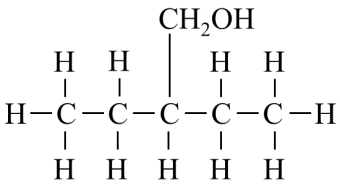
A.



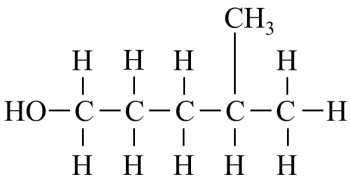
B.



C.



D.



9. Five solutions labelled A-E were tested using a range of indicators.
The solutions are 0.10 $molL^{-1}$ solutions of sodium hydroxide, hydrochloric acid, sodium chloride, sodium hydrogen carbonate or ammonium chloride.

	Indicators colours		
Solutions	Bromothymol Blue	Methyl Orange	Phenolpthalein
A	green	yellow	colourless
B	yellow	yellow	colourless
C	blue	yellow	pink
D	blue	yellow	pale pink
E	yellow	red	colourless
pH range	6.0 – 7.6	3.1 – 4.4	8.3 – 10

Which option correctly identifies solutions A-E?

	A	*B*	*C*	*D*	*E*
A.	$NaHCO_3$	NaCl	NaOH	HCl	NH_4Cl
B.	NaCl	HCl	$NaHCO_3$	NH_4Cl	NaOH
C.	**NaCl**	**NH_4Cl**	**NaOH**	**$NaHCO_3$**	**HCl**
D.	$NaHCO_3$	NH_4Cl	NaCl	NaOH	HCl

10. 7.80 g of chromium metal reacts with excess hydrochloric acid to give 11.16 L of hydrogen gas at 25° C and 100kPa, and a salt.

What is the formula of the salt produced?

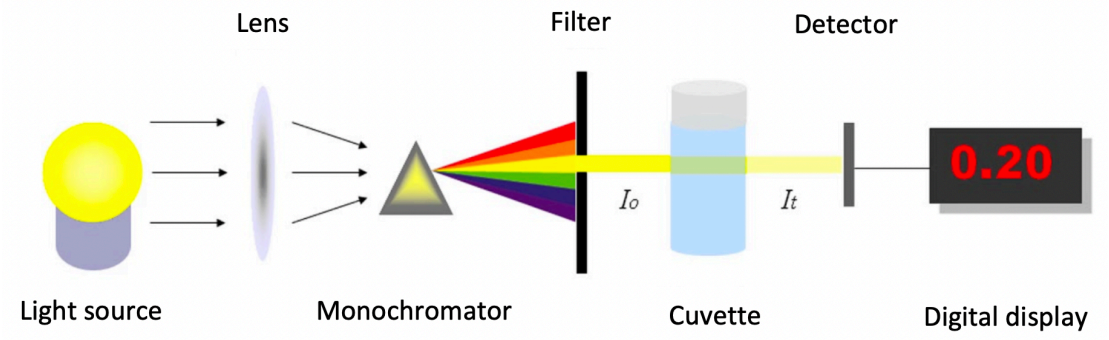
A. $CrCl_2$

B. $CrCl_3$

C. $CrCl_4$

D. $CrCl_6$

11. The diagram shows the components of a colorimeter.



Which of the following correctly matches the component to the function?

	Component	*Function*
A.	Lens	Selects a particular wavelength of light that travels through the sample.
B.	**Detector**	**Measures the intensity ratio between the absorbed and unabsorbed wavelength of light.**
C.	Light source	An element specific light globe used to match the absorbance of the species tested.
D.	Monochromator	Focuses the wavelengths of light to pass through the filter into the sample.

12. Which oxygen containing functional group is consistent with the information provided?

Source	*Observations*
Chemical test	No reaction with small piece of magnesium metal
Infrared spectrum	Strong signal at 1710 cm^{-1} Sharp signal at 1100 cm^{-1}
^{13}C NMR spectrum	Peak at 182 ppm

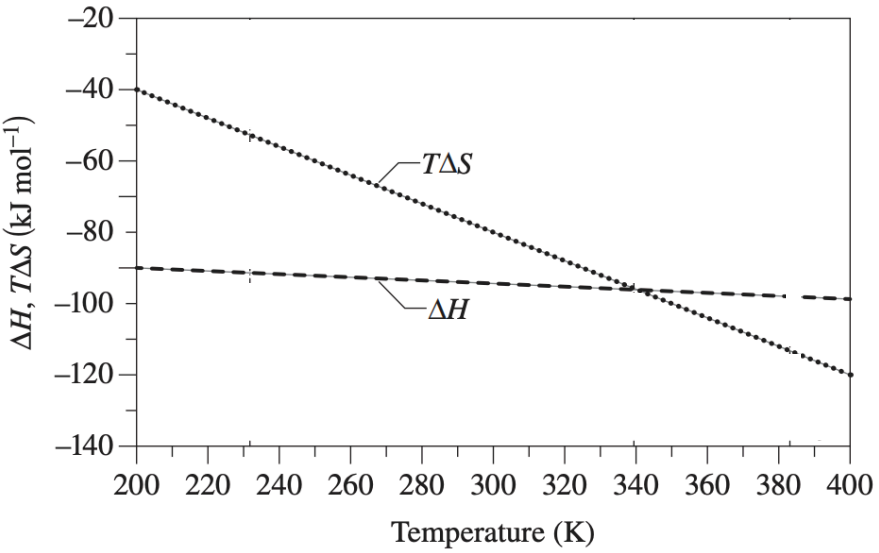
A. ester

B. ketone

C. alcohol

D. carboxylic acid

13. Use the data in the graph to determine what can be deduced about the system at 240 K.



A. ΔG is negative, and the reaction is spontaneous.

B. ΔG is positive, and the reaction is spontaneous.

C. ΔG is negative, and the reaction is non-spontaneous.

D. ΔG is positive, and the reaction is at equilibrium.

14. Consider the molecules CH_2CHCH_3, CH_3COCH_3 and $CHCCH_3$.
How many of these have a bond angle of approximately 120° around the central carbon atom?

A. 0

B. 1

C. 2

D. 3

15. Which chemical test and instrumental technique could be used to confirm that the hydration of an unsaturated hydrocarbon molecule has gone to completion?

A. sodium metal and ^{1}H NMR spectroscopy

B. bromine water and infrared spectroscopy

C. lucas reagent and ^{13}C NMR spectroscopy

D. potassium permanganate and mass spectrometry

16. Which of the following would produce the greatest mass of precipitate when mixed with 10 mL of a 0.1 mol L^{-1} solution of silver nitrate?

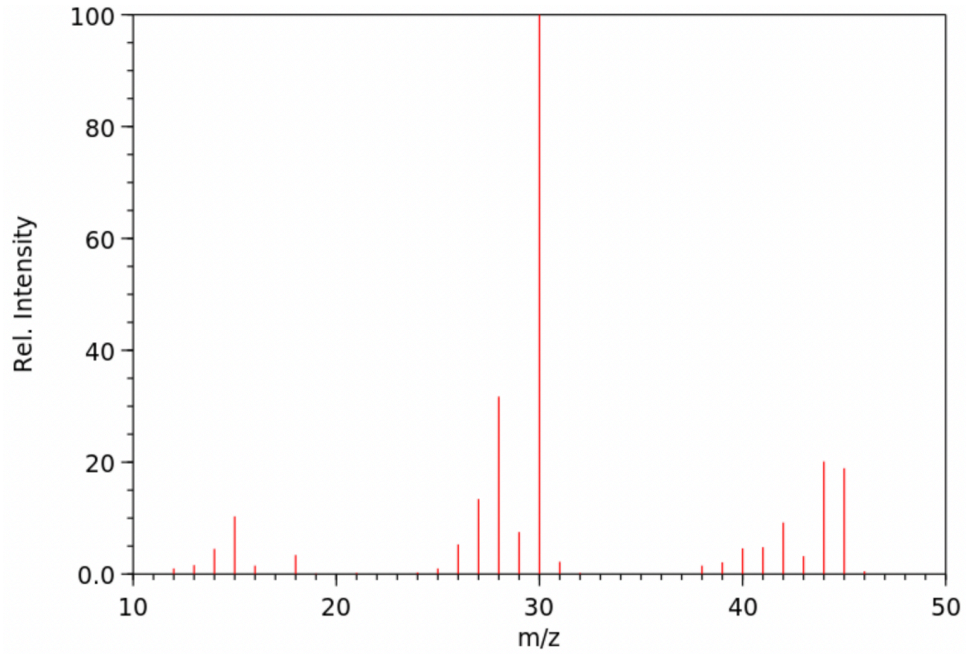
A. 10 mL of 0.1 mol L^{-1} sodium hydroxide

B. 10 mL of 0.1 mol L^{-1} sodium chloride

C. 10 mL of 0.1 mol L^{-1} sodium carbonate

D. 10 mL of 0.1 mol L^{-1} sodium phosphate

17. An organic molecule with the chemical formula C_2H_7N is given in the mass spectrum.



What is a possible identity for the base peak?

A. $[CH_3]^+$

B. $[CH_3CH_2]^+$

C. $[CH_2NH_2]^+$

D. $[CH_3CH_2NH_2]^+$

18. What mass of glucose must be fermented to fill a 5.0 L gas bottle with CO_2 to a pressure of 4100 kPa on an 18 °C, day?

A. 4.2 g

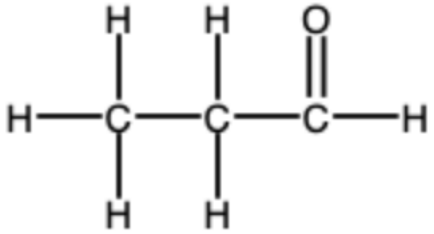
B. 760 g

C. 1500 g

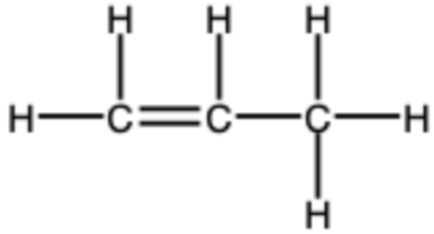
D. 12 000 g

19. Which of the following organic compounds would have a peak splitting pattern with a multiplicity of 5 in their ^{1}H NMR spectrum?

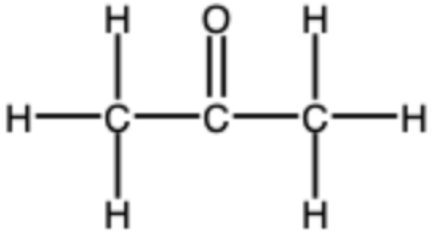
A.



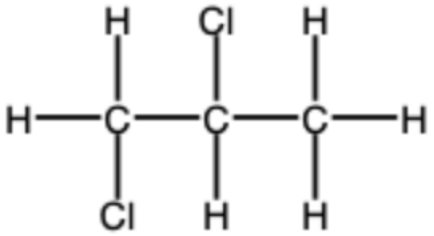
B.



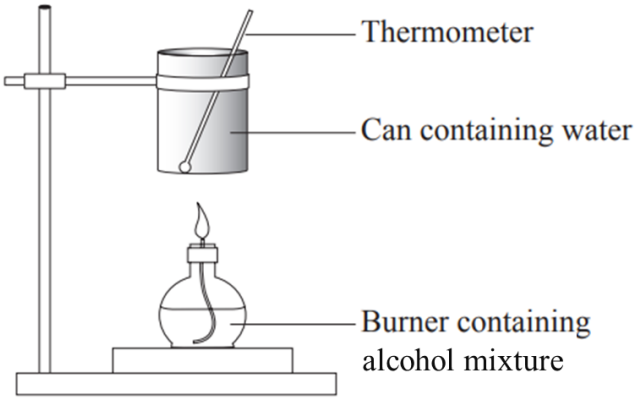
C.



D.



20. A student sets up the following apparatus in the school laboratory:



Instead of using a pure alcohol, the student burns a mixture of two alcohols.
The following results were obtained by the student:

Mass of water: 186.2 g
Initial temperature of water: 22.3 °C
Final temperature of water: 83.6 °C
Mass of alcohol burnt: 1.8 g

The heat of combustion for two alcohols is shown below:
Methanol 22.7 kJ g^{-1}
Ethanol 29.7 kJ g^{-1}

Assuming that the two alcohols do not react with one another and that all the heat released from the combustion is absorbed by the water, which of the following conclusions is consistent with this data?

A. The mixture is nearly pure methanol.

B. The mixture is nearly pure ethanol.

C. The mixture is a fairly equal mix of methanol and ethanol.

D. It is not a mixture of methanol and ethanol.

JRAHS Chemistry Trial 2025

Section I Multiple Choice Answers

1.	A ●	B ○	C ○	D ○
2.	A ○	B ●	C ○	D ○
3.	A ○	B ●	C ○	D ○
4.	A ○	B ○	C ○	D ●
5.	A ○	B ○	C ●	D ○
6.	A ●	B ○	C ○	D ○
7.	A ○	B ○	C ●	D ○
8.	A ○	B ○	C ○	D ●
9.	A ○	B ○	C ●	D ○
10.	A ○	B ○	C ○	D ●
11.	A ○	B ●	C ○	D ○
12.	A ●	B ○	C ○	D ○
13	A ●	B ○	C ○	D ○
14.	A ○	B ○	C ●	D ○
15.	A ○	B ●	C ○	D ○
16.	A ○	B ●	C ○	D ○
17.	A ○	B ○	C ●	D ○
18.	A ○	B ●	C ○	D ○
19.	A ●	B ○	C ○	D ○
20.	A ○	B ○	C ●	D ○

Question 21 (3 marks)

Use an example to explain how Aboriginal and Torres Strait Islanders used the principles of solubility equilibria to detoxify compounds from food. **3**

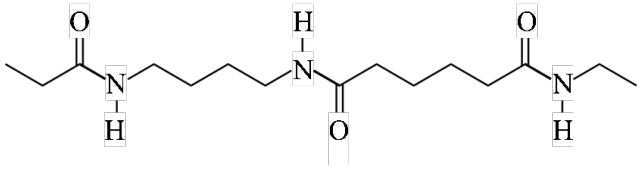
Sample answer

Native cycad fruits contain the toxin cycosin in their tissues. These toxins are relatively soluble in water. Aboriginal and Torres Strait Islander peoples crush the fruit, creating a high surface area and then soak the fruits in running water. The solid toxins dissolve into the water and the more water, the more toxin dissolves, utilising the principles of solubility equilibria in an open system.

Marking Criteria	*Mark(s)*
• Explains how solubility equilibria principles are used to detoxify a named example. • Whole fruit must be treated in some way, crushed, cut etc	3
• Gives some information about detoxifying a named example	2
• Gives some relevant information	1

Question 22 (3 marks)

Examine part of a nylon polymer shown below:

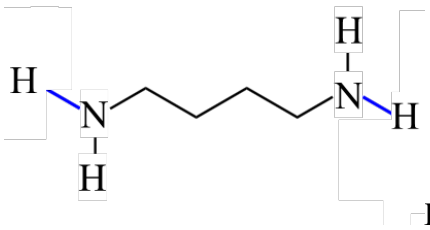


(a) Identify the name of the functional group in this polymer. **1**

(b) Draw the structural formula of ONE monomer used to make this polymer. **2**

Marking Criteria	*Mark(s)*
• Correct identification as an amide	1

Marking Criteria	*Mark(s)*
• Correct structure for one monomer	2
• Most features of structure correct	1



Dicarboxylic acid could also be accepted

Comments: peptide refers specifically to the bond between amino acids in polypeptides/proteins. A significant number of students were unable to provide a structure for either one of the two monomers, this would be a good area to revise.

Question 23 (4 marks)
The acid ionisation constants for three acids are given below.

Acid	*Acid ionisation constant, Ka*
Hydrofluoric	7.2×10^{-4}
Methanoic acid	1.77×10^{-4}
Ammonium ion	5.6×10^{-10}

(a) Write an equation showing the ammonium ion acting as an acid in water. **2**

$$NH_4^+ (aq) + H_2O (l) \rightleftharpoons NH_3 (aq) + H_3O^+ (aq)$$

Marking Criteria	*Mark(s)*
• Correct equation with reversible arrows	2
• Correct equation	1

(b) List the conjugate bases for these three acids in correct order of increasing base strength. **2**
F^- $HCOO^-$ NH_3

Marking Criteria	*Mark(s)*
• Correct conjugate bases listed in correct order	2
• Some correct order or identifications	1

Question 24 (5 marks)

Colourless nitrogen monoxide reacts with oxygen to form brown nitrogen dioxide according to the following reaction:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \quad \Delta H < 0$$

Equilibrium will shift to oppose any change (Le Chatelier). If the temperature is decreased the system will favour the reaction that makes heat i.e the exothermic reaction. This is the forward reaction so equilibrium will shift to the right and the colour will become more brown.

Marking Criteria	*Mark(s)*
• Explains the colour change using Le Chatelier's principle.	2
• Gives some relevant information	1

(b) A 2.0 L reaction vessel initially contained 0.50 mole nitrogen monoxide and 0.24 mole of oxygen. At equilibrium there was 0.10 mole of nitrogen monoxide. Calculate the equilibrium constant for this reaction. **3**

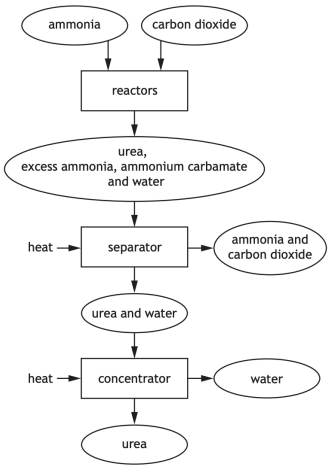
	$2NO(g)$	+	$O_2(g)$	⇌	$2NO_2(g)$
R					
I	0.50/2 = 0.25		0.24/2 = 0.12		0.0
C	- 0.20		-0.10		+0.20
E	0.10/2 = 0.05		0.02		0.20

$Keq = [NO_2]^2 / [O_2]/ [NO]^{2.} = 0.20^2 / 0.05^2 \times 0.02 = 800$

Marking Criteria	*Mark(s)*
• Correctly calculates Keq showing all relevant working and Keq expression	3
• Most relevant working shown	2
• Some relevant calculation given	1

Question 25 (2 marks)

Urea is an important chemical reagent used in the agricultural industry for fertilisers and animal food supplements. The industrial means of producing urea is shown in the flowchart below.



Explain ONE improvement that could be made to the industrial process shown. **2**

Sample answer:

The ammonia and carbon dioxide leftover in the separator can be recycled back into the reactors. This would reduce the amount of waste created and lower production costs since less raw materials will need to be purchased.

Marking Criteria	*Mark(s)*
• Explains ONE improvement with reference to the flowchart.	2
• Provides some relevant information.	1

Question 26 (8 marks)

Hydrochloric acid can be neutralised by using sodium carbonate.

A range of volumes of 1.00 mol L^{-1} hydrochloric acid solutions were mixed with 10.0 mL of a sodium carbonate solution of unknown concentration and the volume of the solution made up to 20.0 mL.

The change in temperature for each solution was measured and recorded in a table.

Volume of hydrochloric acid added (mL)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0
Temperature increase (^oC)	0.0	1.4	2.8	4.3	5.2	6.2	6.2	6.2

Graph the data in the table and use the graph and relevant calculations to determine the initial concentration of the sodium carbonate solution. **8**

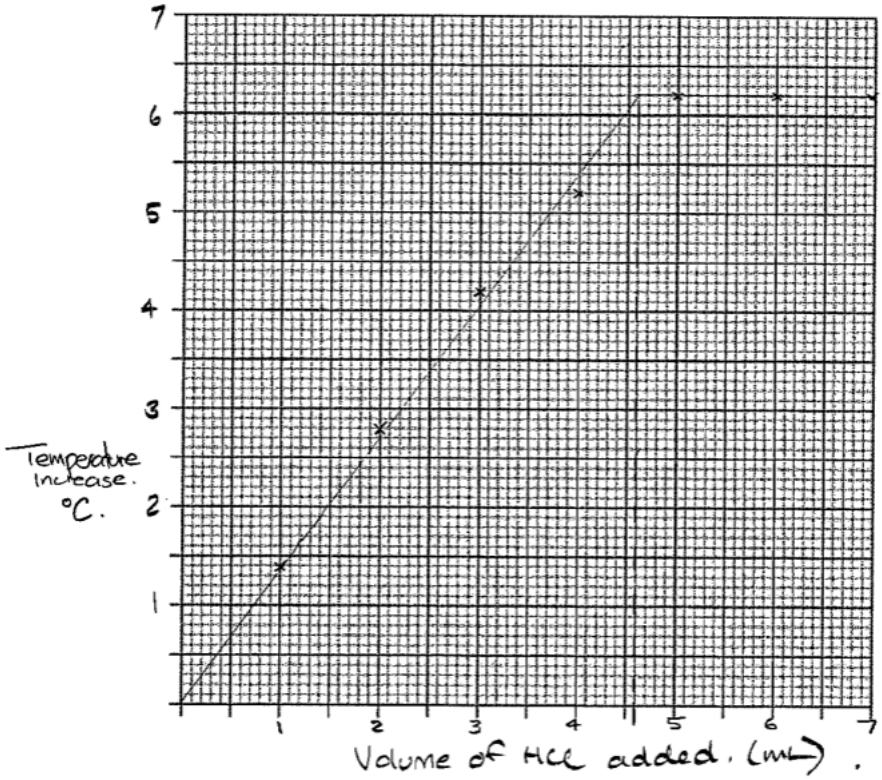
Na_2CO_3 (aq) + 2HCl(aq) $\rightarrow$ 2NaCl (aq) + H_2O (l) + CO_2 (g)

n HCl = c x V = 1.0 x 0.0046 = 0.0046 (from graph)

therefore n Na_2CO_3= ½ x 0.0046 = 0.0023

[Na_2CO_3] = n/V = 0.0023/0.01 = 0.23 $molL^{-1}$ 2 sig figs

Marking Criteria	*Mark(s)*
• Provides graph with: correctly labelled axes including units; appropriate scales; correctly plotted points; correct lines of best fit or curve • Correctly calculates the concentration of sodium carbonate solution with units & 2 sig figs • Gives a balanced chemical equation for the reaction with states	8
• Provides graph with correctly labelled axes including units; appropriate scales; correctly plotted points; correct lines of best fit • Provides most of the steps to calculate the concentration of sodium carbonate solution with units & 2 sig figs • Gives a balanced chemical equation for the reaction OR • Correctly calculates the concentration of sodium carbonate solution with units & 2 sig figs and • Provides a substantially correct graph	7
• Provides a substantially correct graph • Provides most steps to calculate the concentration of sodium carbonate solution. • May include a balanced chemical equation for the reaction	6
• Provides a substantially correct graph • Provides some steps to calculate the concentration of sodium carbonate solution • May include a balanced chemical equation for the reaction OR • Provides graph with correctly labelled axes including units; appropriate scales; correctly plotted points; correct lines of best fit or curve OR • Correctly calculates the concentration of sodium carbonate solution with units & 2 sig figs	4-5
• Provides a graph with some correct features AND/OR • Provides some steps for calculating the concentration of the sodium carbonate solution • May include a balanced chemical equation for the reaction with states	2-3
• Provides some relevant information eg correct chemical equation for the reaction with states	1



Question 27 (6 marks)

(a) Calculate the molar solubility of silver carbonate at 25 °C. **2**

$$Ag_2CO_3(s) \rightleftharpoons 2Ag^+(aq) + CO_3^{2-}(aq)$$

Let solubility = S = $[CO_3^{2-}]$ $[Ag^+] = 2S$

Ksp $Ag_2CO_3 = 8.46 \times 10^{-12} = [CO_3^{2-}][Ag^+]^{2.} = 4S^3$

$S = 1.2836 \times 10^{-4}$

-Marking Criteria	*Mark(s)*
• Correctly calculates the molar solubility with Ksp expression	2
• Some calculation given or correct Ksp	1

(b) Determine whether a precipitate will form when 100.0 mL of a 3.0×10^{-3} $molL^{-1}$ solution of silver nitrate is mixed with 100.0 mL of a 1.0×10^{-2} $molL^{-1}$ solution of sodium carbonate. **4**

n $Ag^+ = c \times v = 3.0 \times 10^{-3} \times 0.10 = 3.0 \times 10^{-4}$

n $CO_3^{2-} = c \times v = 1.0 \times 10^{-2} \times 0.10 = 1 \times 10^{-3}$

$[Ag^+] = n/v = 3.0 \times 10^{-4}/0.2 = 1.5 \times 10^{-3}$

$[CO_3^{2-}] = n/v = 1 \times 10^{-3}/0.2 = 5 \times 10^{-3}$

$Q = [CO_3^{2-}][Ag^+]^{2.} = 5 \times 10^{-3} (1.5 \times 10^{-3})^2 = 1.125 \times 10^{-8}$

$1.125 \times 10^{-8} > 8.46 \times 10^{-12}$

Therefore a precipitate will form

Marking Criteria	*Mark(s)*
• Calculates Q and correctly identifies that a precipitate will form	4
• Provides most relevant steps of the calculation	3
• Provides some relevant steps of the calculation • Limiting reagent calculation maximum of 2	2
• Provides some relevant information	1

Question 28 (5 marks)

In a reaction, 30.0mL of a 0.106 mol L^{-1} NaOH is added to 25.0 mL of 0.100 mol L^{-1} HCl solution.
What will be the pH of the final solution? **4**

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Initial nNaOH= c x v = 0.106 x 0.03 = 3.18 x 10^{-3}

Initial n(HCl) =c x v = 0.0250 x 0.100 = 2.5 x 10^{-3}

Thus NaOH is in excess therefore final nNaOH = 3.18 x 10^{-3} - 2.5 x 10^{-3}= 6.8 x 10^{-4}mol

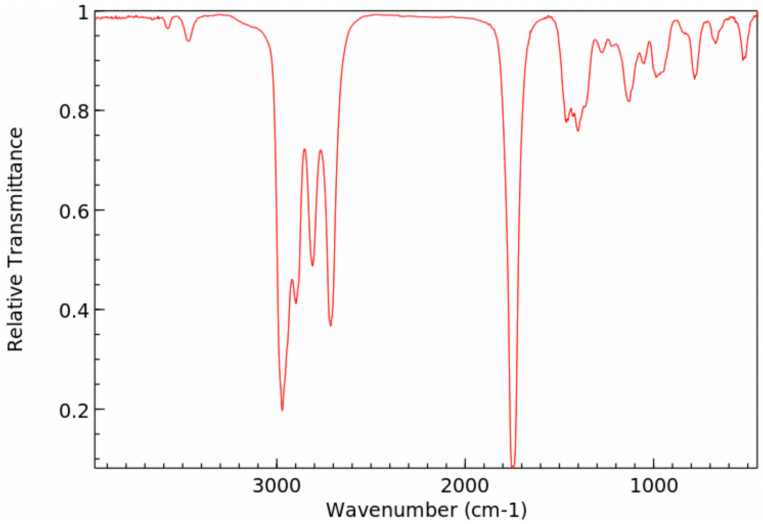
[NaOH] in excess =n/v = 6.8 x10^{-4}/ 0.03 + 0.025 = 1.24 x 10^{-2} mol L^{-1}

pOH = $-\log_{10}[OH^-] = -\log_{10}1.36 \times 10^{-2}$ = 1.90
therefore pH = 14 - 1.87 = 12.092

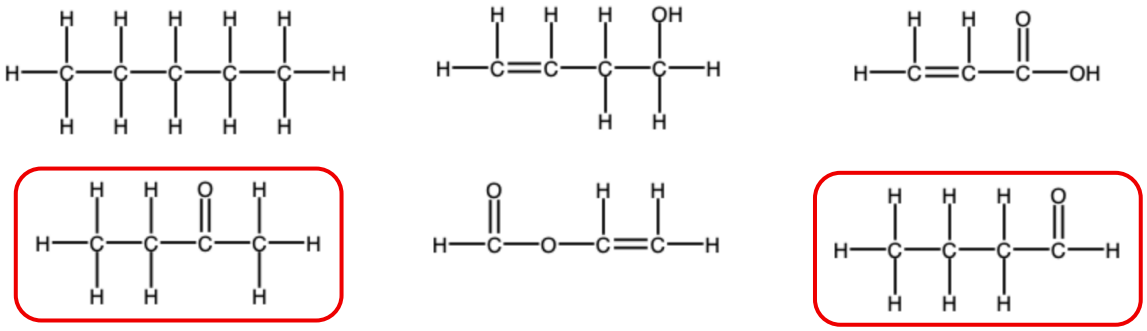
Marking Criteria	*Mark(s)*
• Correct calculation of pH of resultant solution showing all working	4
• Correct calculation of pH of resultant solution showing all working with one error in calculation	3
• Some correct calculations	2
• One correct calculation	1

Question 29 (4 marks)

The infrared spectrum has been provided for an unknown organic compound that contains a single functional group. This spectrum is misleading since that data can be used to deduce a variety of different possible functional groups for this compound.



(a) Circle the TWO possible structures for this spectrum



Marking Criteria	*Mark(s)*
• Identifies TWO correct structures.	2
• Identifies ONE correct structure.	1

(b) Select another spectroscopic technique and explain how it could be used to decide between the different possible functional groups you identified above.

Sample answer:

A ^{1}H NMR spectrophotometer could be used to confirm the identity of the functional group. If the unknown compound was an aldehyde there would be a 1H signal in the spectrum, whereas this would be absent for a ketone.

Other possible answers: the number of signals for ^{1}H NMR (aldehyde 4 vs ketone 3) was also accepted, the presence of the M-1 fragment in the aldehyde mass spectrum.

Marking Criteria	*Mark(s)*
• Explains functional group determination with reference to an appropriate spectroscopic technique.	2
• Provides some relevant information.	1

NOTE: follow through error was applied for incorrect structures selected in part (a).

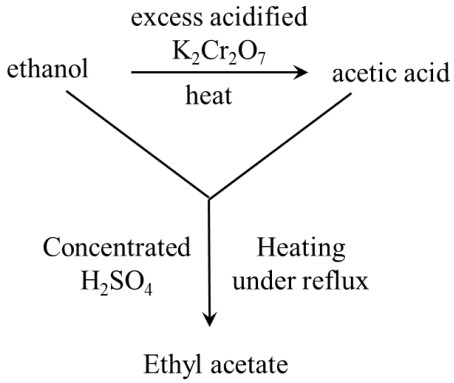
Question 30 (5 marks)

Ethyl acetate, $CH_3COOC_2H_5$, is produced in large quantities for use as a solvent. It can be synthesised using ethanol as the only organic reagent.

Draw a flowchart to show how ethanol can be used to produce ethyl acetate, including the inorganic chemicals requires and the reaction conditions for each step. Your response should identify any intermediate organic molecules but does not need to include any purification steps. **5**

• Correct reaction scheme and flowchart structure • Identifies acidified dichromate or permanganate for oxidation • Identifies acetic acid as intermediate • Identifies concentrated sulfuric acid and reflux conditions for esterification • Absence of unnecessary steps	5
• Correct reaction scheme • And 5 of the following • Correct flowchart structure • Acid conditions for oxidation reaction • Dichromate or permanganate for oxidation reaction • Acetic acid as intermediate • Concentrated sulfuric acid for esterification reaction • Reflux conditions for esterification	4
• Correct reaction scheme • And 3 of the following • Acid conditions for oxidation reaction • Dichromate or permanganate for oxidation reaction • Acetic acid as intermediate • Concentrated sulfuric acid for esterification reaction • Reflux conditions for esterification	3

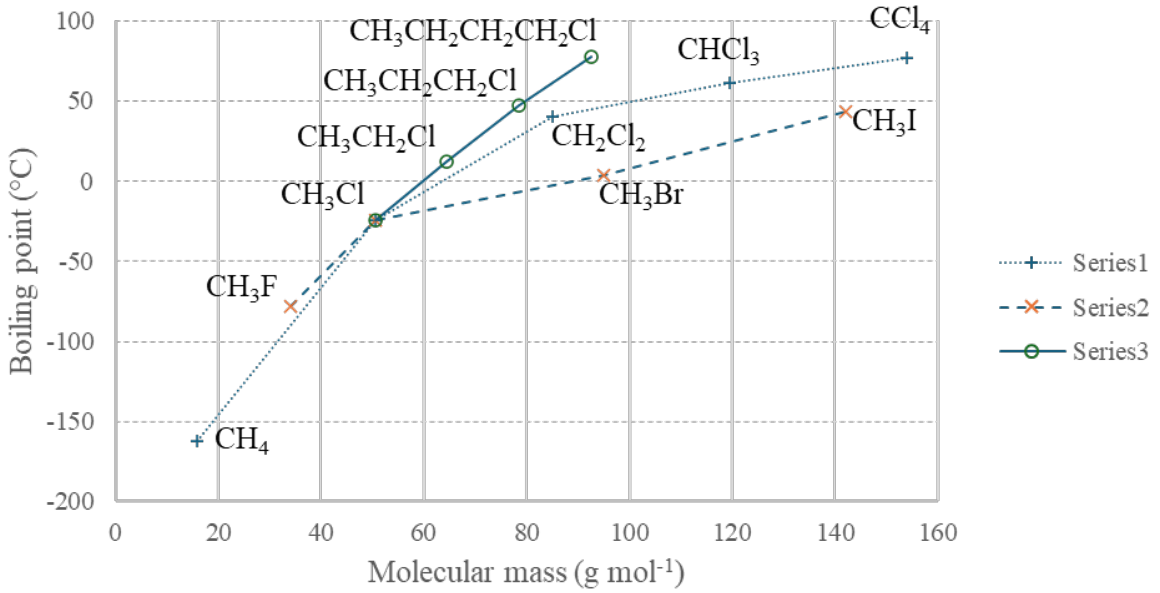
• TWO of the following • Acid conditions for oxidation reaction • Dichromate or permanganate for oxidation reaction • Acetic acid as intermediate • Concentrated sulfuric acid for esterification reaction • Reflux conditions for esterification	2
• Some relevant information	1



Comments: there was quite a bit of confusion about the purpose of the reagents. Permanganate or dichromate is an oxidant, not a catalyst, and no oxygen gas is required or hydrogen produced. Any reaction scheme which looked like a chemical reaction was not considered a flowchart.

Question 31 (8 marks)

Chloromethane is a compound produced both naturally and industrially. It can be grouped in a number of series of compounds, with three such series shown in the graph below.



(a) Identify the homologous series **1**

(b) Use your knowledge of intermolecular and intramolecular bonds to account for the trends in boiling points within each of these series. **7**

Marking Criteria	*Mark(s)*
• Correctly identifies series	1

Series 3

Marking Criteria	*Mark(s)*
• Provides comprehensive account of trend in each series of data discussing intramolecular and intermolecular bonds	7
• Discusses the trends by using 6 of the following • Correctly relates boiling point to intermolecular forces (B) • Identifies C-Cl as polar bond (P) • Identifies C-H as non-polar bond (N) • Identifies dipole-dipole forces in molecules with a permanent dipole (D) • Identifies symmetry as a reason for CCl_4 (and not CCl_2) having no permanent dipole (S) • Relates decrease in electronegativity down group 17 to reduced dipole-dipole force (E) • Relates increasing molecular mass to larger dispersion forces (M) • Relates longer chain to more dispersion forces using argument other than greater mass (L)	6
• Discusses the trends by using 5 of the above	5
• Discusses the trends by using 4 of the above, some done less well	4
• Discusses the trends by using 3 of the above, some done less well	3
• Discusses the trends by using 2 of the above, done less well	2
• Provides some relevant information	1

Chloromethane has a polar covalent (intramolecular) C-Cl bond, as Cl is significantly more electronegative than carbon, while the C-H bond is a non-polar covalent (intramolecular) bond as C and H have similar electronegativity. This causes CH_3Cl to have a permanent dipole, which causes a strong electrostatic attraction to other $CHCl_3$ molecule through dipole-dipole interactions.

The boiling point of a substance is determined by the strengths of the intermolecular forces, with higher intermolecular forces requiring more energy to separate molecules and therefore a higher boiling point. London dispersion forces and dipole-dipole interactions are the relevant intermolecular forces in these series. Due to fluctuations in electron density, all molecules experience temporary dipoles, which induce dipoles in nearby molecules, attracting them by these London dispersion forces. The strength of dispersion forces increase down a group, as the outer electrons are further from the nucleus and are more polarisable. The strength also increases with number of atoms, particularly increasing chain length, as there is more surface area for contact. Both these reasons can account for a general trend for boiling point to increase with molecular mass. Any dipole-dipole interaction would add to the London dispersion forces to form the intermolecular forces in these series. Thus chloromethane has a boiling point around -25 °C.

Series 1 has a central carbon atom tetrahedrally bound to 4 other atoms. The boiling point increases at a decreasing rate. Methane, with its low mass, symmetry and non-polar bonds has a very low boiling point due to weak dispersion forces. As hydrogens are successively

substituted by chlorines, much larger atoms are added, increasing dispersion forces. Polar bonds are formed, leading to dipole-dipole interactions for the next three members, with the strongest dipole in CH_2Cl_2 and none for CCl_4 due to symmetry. Hence there is an increase in boiling point along the series, with the second and fourth member above a linear trend and the third member significantly above it, leading to the curve observed.

Series 2 has a central carbon atom tetrahedrally bound to three hydrogens and one halogen. Along the series, the outermost shell on the halogen increases, thus the dispersion forces increase. However, going down the group, the halogens become less electronegative so the C-X bond becomes less polar and the dipole-dipole forces become weaker. They are most significant for CH_3F, and are dominated by the dispersion forces by CH_3I, hence the trend in boiling point is to increase at a decreasing rate.

Series 3 has an increasing carbon chain length, with each member having the same polar C-Cl bond. As the chain is unbranched, the molecules can pack closely together, so there is a substantial increase in surface area that can contact between two molecules, resulting in a significant increase in the number of dispersion forces and a large increase in boiling point along the series.

Comments: there was poor use of terminology here, such as electronegative bonds, please be careful. A significant number of students thought that the chlorides were added as Cl^- anions, replacing H atoms or even H^+ cations. There were also students who wrote about hydrogen bonding (remember that that hydrogen needs to be bound to O, F, N for a hydrogen bond). You needed to give two distinct explanations for increasing mass/number of atoms to get both the M and L code, if the wording was substantially the same you only got one code. Please don't just say the boiling point depends on the strength of intermolecular forces, be specific about the direction. Although CH_2Cl_2 has more symmetry than chloromethane, it still has a dipole moment!

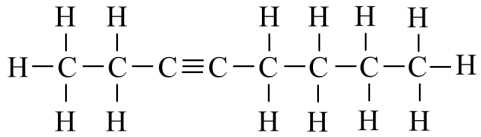
Question 32 (5 marks)

Oct-3-yne is a hydrophobic liquid at room temperature.

(a) Draw the structural formula for oct-3-yne. **1**

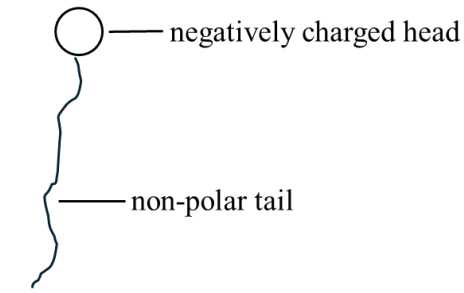
(b) Explain, with the use of a diagram, how a soap could be used to remove oct-3-yne from a surface. **4**

• Correct structure	1

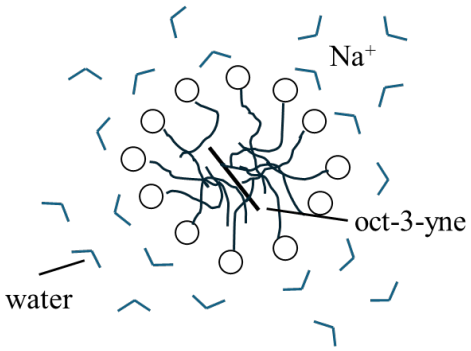


• Describes structure of soap • Describes the formation of micelle • Relates structure to function using cause and effect statement • Provides relevant labelled diagram	4
• Provides explanation and diagram back lacking some detail or clarity	3
• Describes structure and formation of micelle • OR • Describes interaction between soap and oil and/or soap and water • OR • Describes structure of soap	2
• Some relevant information	1

A soap is typically a sodium or potassium salt of a long-chain carboxylic acid. The chain has a polar/negatively charged end (carboxylate group) and a long non-polar tail which will interact with the hydrophobic non-polar oct-3-yne on a surface. With agitation and water the oil can be broken into droplets and stabilised in a micelle, an approximately spherical structure with the negatively charged heads on the surface, interacting with the slightly positive hydrogens of water molecules. Polar heads can form H-bonds with the water. The non-polar tails are in the centre, shieled from the water as they are hydrophobic. The hydrophobic oct-3-yne will dissolve in the centre of the micelle. This forms an emulsion as micelles repel one another due to the negative charge. The entire micelle can be washed away, removing the oily hydrocarbon.



soap



Solvated micelle

Comments: Students were generally able to explain using text, but there were many insufficiently labelled diagrams. Although your diagram is 2D, micelles are spherical, not circular, so be careful with your descriptions. Given the pKa of long chain fatty acids, only a few will actually be charged.

Question 33 (6 marks)

A standardised solution of 0.10 mol L^{-1} sodium hydroxide solution was titrated against 25.00 mL of a solution of ethanoic acid by 4 different students. The results are recorded in the table below

(a) Assess which student(s) have calculated reliable average titres. **3**

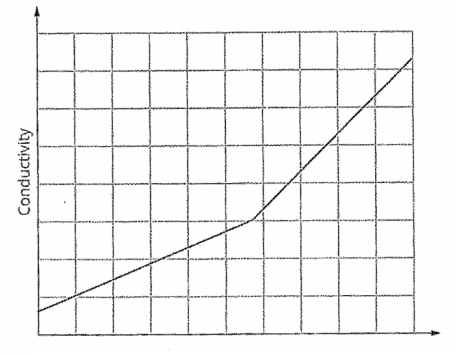
	Titre volumes (mL)					Correct
	Trial 1	Trial 2	Trial 3	Trial 4	Average titre	
A	16.70	16.10	16.00	16.20	16.25	16.05
B	15.75	15.30	15.40	15.25	15.35	15.32
C	17.85	17.50	16.80	17.45	17.25	17.50
D	17.00	16.40	17.00	17.45	16.95	16.95 (not reliable)

The average titre is calculated using at least 3 closely replicating titres. Student A has included the first rough titre that is a lot more than the others. Students B has either miscalculated 15.35 from 3 titres (15.32) or left out trial 4. Student C has included the outlier in Trial 3 in their calculation which is incorrect. Student D has calculated the average from 3 titres, but they are more than 1 mL different. No student has calculated a reliable titre.

Marking Criteria	*Mark(s)*

• Assesses the average titres calculated.	3
• Gives some relevant assessment at least 2 calculated titres	2
• Gives some relevant information	1

(b) Explain the shape of the conductometric graph for this titration. Include a relevant equation in your answer. **3**



Volume of NaOH added (mL)

The initial conductivity is low as the ethanoic acid is a weak acid. The equilibrium lies to the left and most of the species are molecular and therefore don't conduct. As sodium hydroxide is added, acid molecules are neutralised creating ethanoate ions and spectator sodium ions in solution, so the conductivity slowly increases to equivalence.

$$CH_3COOH\ (aq) \rightleftharpoons CH_3COO^-\ (aq) + H^+\ (aq)$$

After equivalence, conductivity rises rapidly as sodium and hydroxide ions, which do allow conductance, are added to the flask.

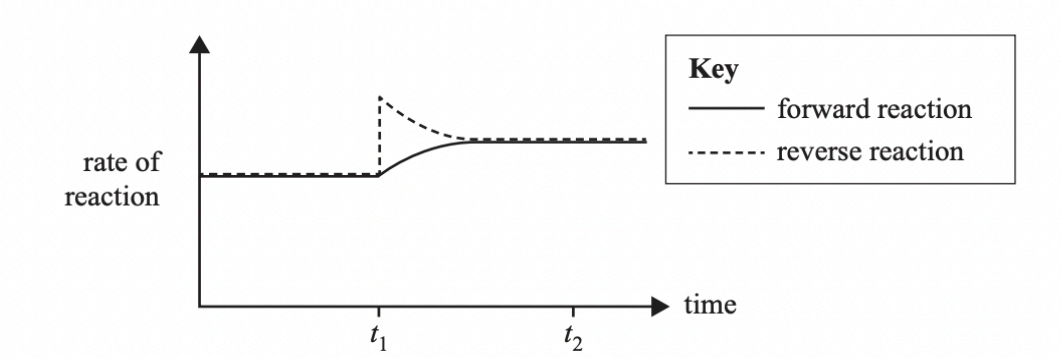
Marking Criteria	*Mark(s)*
• Explains the shape of the graph including a relevant equation	3
• Explains the shape of the graph, no equation OR • Describes the shape of the graph including a relevant equation	2
• Some relevant information given	1

Question 34 (4 marks)
An equilibrium of four gases is represented by the following equation.

$$A\ (g) + 2B\ (g) \rightleftharpoons C\ (g) + D\ (g) \quad \Delta H > 0$$

The graph below shows the rate of the forward and reverse reactions versus time.

A single change is made to the equilibrium mixture at time t_1 and equilibrium is re-established at t_2.



Use the graph and collision theory to explain a change that may have occurred at t_1. **4**

Sample answer

At t1, more products were added to the system. The rate of the reverse reaction increases as there are more successful collisions between C and D due to the higher concentration. As the products react, there will be fewer particles so the rate of the reverse reaction starts to decrease. As reactants A and B are being formed there is a higher concentration of them so there will be more successful collisions so the forward rate increases. A constant higher rate for both reactions occurs as there are more particles having more collisions in the system.

Marking Criteria	*Mark(s)*
• Provides a thorough explanation of the changes in rate for the reactants and products using collision theory • identifies a correct change that has occurred.	4
• Provides some explanation of the changes in rate for the reactants and products and identifies a correct change that has occurred	3
• Shows some understanding of the changes in rate for the reactants or products	2
• Gives some relevant information	1

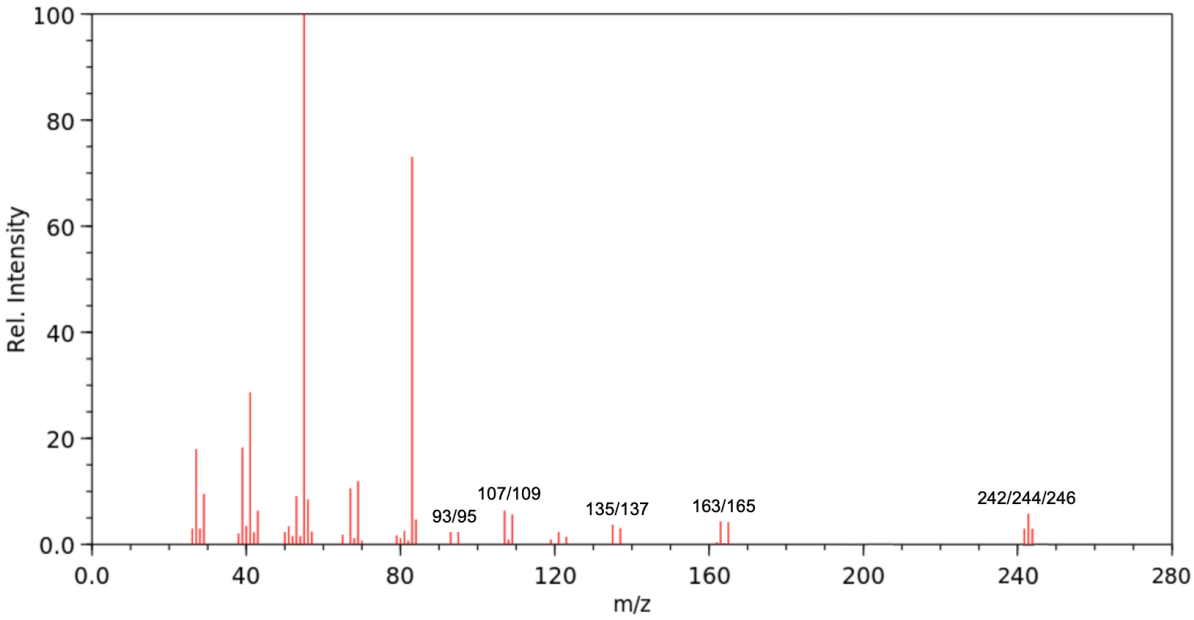
Question 35 (8 marks)

A chemist performed organic synthesis using compounds E, F and G according to the reaction pathway shown.

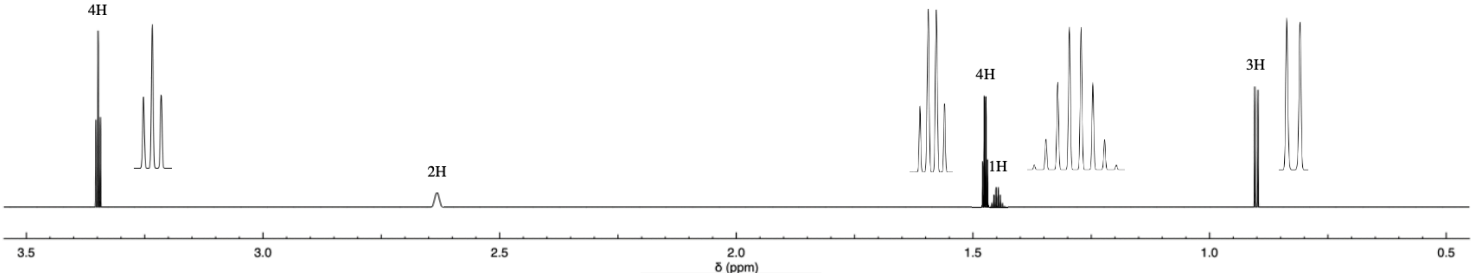
The molecular formula for the final product, compound G was partially derived as $C_6H_{10}O_X$.

Spectral data for these compounds is given below.

Mass Spectrum of Compound E



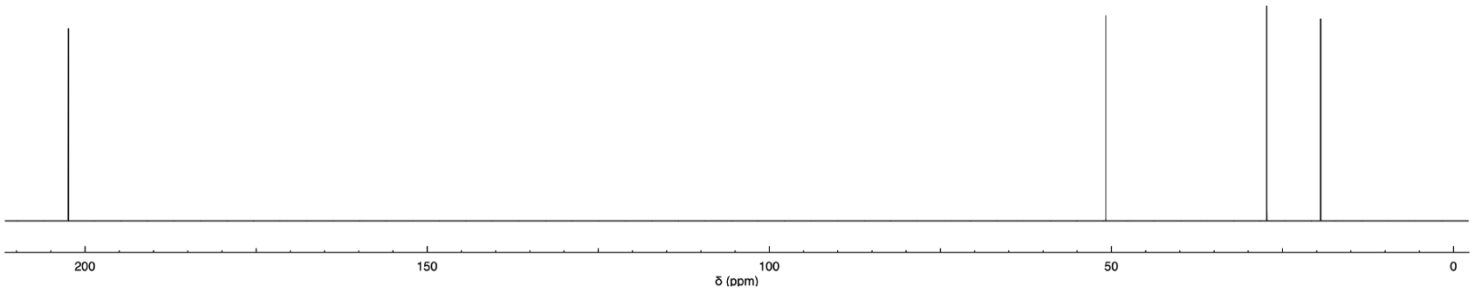
^{1}H NMR Spectrum of Compound F



^{1}H NMR Spectrum Data for Compound F

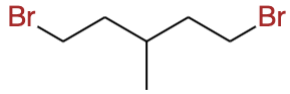
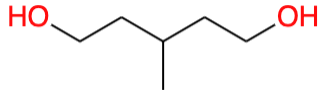
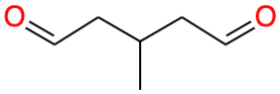
Chemical shift (ppm)	*Integration*	*Peak splitting*
0.90	3	Doublet
1.44	1	Multiplet (8)
1.47	4	Quartet
2.63	2	Singlet
3.35	4	Triplet

^{13}C NMR Spectrum of Compound G



Draw the structure of compounds E, F, and G. Justify your answer with reference to the information provided.

Sample answer:

Compound E	Compound F	Compound G
		

Using the approximate formula provided for compound G, $C_6H_{12}O_X$, which is oxidised from compound F, we can deduce that it contains either an alcohol or aldehyde functional group.

^{1}H NMR Spectrum: Compound F contains 5 distinct signals for 14 hydrogen atoms, indicative for a degree of symmetry. We can conclude the following:

-3H doublet at 0.90 ppm shows a CH_3 adjacent to a CH.
-1H multiplet (8) at 1.45 ppm shows a CH adjacent to 7 H atoms.
-4H quartet at 1.48 ppm shows two identical CH_2 groups adjacent to 3 H atoms (CH_2 & CH).
-4H triplet at 3.35 ppm shows two identical CH_2 groups adjacent to 2 H atoms (CH_2).

These coupled signals indicate connectivity to give a symmetrical carbon chain with the structure -$CH_2CH_2CH(CH_3)CH_2CH_2$-. 2H broad singlet at 2.64 ppm corresponds two identical OH groups that do not participate in coupling. This lack of splitting gives confirmation for the alcohol functionality.

^{13}C NMR Spectrum: Compound G contains 4 distinct signals for 6 carbon atoms, also indicative for a degree of symmetry. There are 3 signals within the range of 15 – 55 ppm that correspond to the carbon atoms within the stem, with the signal at 51 ppm being the most deshielded due to its close proximity to the electronegative oxygen. The signal at 203 ppm is conclusive for the presence of the aldehyde functional group given that Compound F has the structure of a primary alcohol.

Mass Spectrum: The alcohol group present in compound F is derived from a substitution reaction involving compound E, which suggests the replacement of a halogen. In the mass spectrum there are pairs of signals which are two units apart and similar intensities (1:1 ratio) indicative for the presence of certain halogen isotopes. Since the relative intensities are approximately equal, we can ascertain that the halogen is bromine. We can assign the fragment peaks:

m/z = 93/95 is $[BrCH_2]^+$
m/z = 107/109 is $[BrCH_2CH_2]^+$
m/z = 135/137 is $[BrCH_2CH_2CHCH_3]^+$
m/z = 163/165 is $[BrCH_2CH_2CHCH_3CH_2CH_2]+$
m/z = 242/244/246 is the molecular ion.

Marking Criteria	*Mark(s)*

• Draws the correct structures for compounds E, F and G. • Justifies the correct structures showing an extensive understanding of the interpretation of spectroscopic data and reaction pathways. **B2, C2, H2** • Refers to all relevant spectroscopic data.	8
• Draws the correct structures for at least two compounds. • Justifies the correct structures showing a thorough understanding of the interpretation of spectroscopic data and reaction pathways. **TWO of B2, C2, H2 with the other addressed.** • Refers to relevant spectroscopic data.	6-7
• Draws a plausible structure for at least one compound. • Shows a sound understanding of the interpretation of spectroscopic data **ONE of B2, C2, H2, with the others addressed.** • Refers to some spectroscopic data.	4-5
• Demonstrates some understanding of different reactions **OR** • Demonstrates some understanding of spectroscopic data.	2-3
• Provides some relevant information.	1

M2 – bromine identification + all fragment structures
C2 – diagnostic signal (ketone + aldehyde), symmetry, aldehyde confirmation
H2 – explained all splitting patterns + carbon chain structure deduced.

Question 36 (5 marks)

Hawaiian sea salt is a variation of table salt (sodium chloride) which has a unique flavour and colour due to a range of impurities, including calcium chloride, magnesium chloride, and magnesium sulfate.

A chemist carried out a series of precipitation titrations to determine the composition of the impurities present in a 100 g packet of Hawaiian sea salt which was dissolved in 200 mL of demineralised water.
To determine the calcium chloride content, 28.71 mL of a 2.40 mol L^{-1} solution of sodium hydroxide was required for complete precipitation.

$$CaCl_2\ (aq) + 2NaOH\ (aq) \longrightarrow Ca(OH)_2\ (s) + 2NaCl\ (aq)$$

Once the precipitate was filtered out of the solution, 31.61 mL of a 1.51 mol L^{-1} sodium carbonate solution was added to precipitate all the magnesium ions, which was also removed.

$$MgCl_2\ (aq) + Na_2CO_3\ (aq) \longrightarrow MgCO_3\ (s) + 2NaCl\ (aq)$$

$$MgSO_4\ (aq) + Na_2CO_3\ (aq) \longrightarrow MgCO_3\ (s) + Na_2SO_4\ (aq)$$

The resultant solution was reacted with 23.19 mL of a 0.672 mol L^{-1} solution of barium nitrate.

$$Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq) \longrightarrow BaSO_4\ (s) + 2NaNO_3\ (aq)$$

Calculate the masses of the calcium chloride, magnesium chloride and magnesium sulfate impurities. **5**

Sample answer:

$n(OH^-) = c \times v = 2.40 \times 28.71/1000 = 0.0689$ mol
$n(Ca^{2+}) = n(OH^-)/2 = 0.0345$ mol
$m(CaCl_2) = n \times MM = 0.0345 \times (40.08 + 35.45 \times 2) = 3.82$ g
$n(CO_3^{2-}) = 1.51 \times 31.61/1000 = 0.0477$ mol
$n(SO_4^{2-}) = 0.672 \times 23.19/1000 = 0.0156$ mol

$n(MgSO_4) = n(SO_4^{2-})$
$m(MgSO_4) = 0.0156 \times (24.31 + 32.07 + 16.00 \times 4) = 1.88$ g
$n(MgCl_2) = n(CO_3^{2-}) - n(SO_4^{2-}) = 0.0477 - 0.0156 = 0.0321$ mol
$m(MgCl_2) = 0.0321 \times (24.31 + 35.45 \times 2) = 3.06$ g

Marking Criteria	*Mark(s)*
• Provides correct calculations for all components of the impurity. (mass of $CaCl_2$, total amount of Mg, subtraction of SO_4^{2-} from total amount of Mg, mass of $MgSO_4$, and mass of $MgCl_2$)	5
• Provides correct calculations for at least two components of the impurity. (mass of $CaCl_2$ and mass of $MgSO_4$ or $MgCl_2$) **OR** • Provides correct calculations for at least one component of the impurity with the subtraction of SO_4^{2-} from total amount of Mg.	4
• Provides correct calculations for at least one component of the impurity. (up to mass of $CaCl_2$)	3
• Provides some relevant calculation steps.	2
• Provides a relevant calculation step.	1