ABBOTSLEIGH

2
Centre Number

Student Number

2025 **TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – **20 marks** (pages 2 – 12)

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

Section II – **80 marks** (pages 13–40)

- Attempt Questions 21–34
- Allow about 2 hours and 25 minutes for this section

Section I

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

Use the multiple-choice answer sheet at the back of this paper for Questions 1–20.

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1 Which of the following situations correctly identifies a dynamic equilibrium system.

A. A saturated solution of potassium chloride.

B. A can of soft drink that has just been opened.

C. A coal power plant burning coal to heat water.

D. The combustion of magnesium to produce magnesium oxide.

2 Aboriginal and Torres Strait Islander Peoples have traditionally soaked or pounded toxic plant materials such as cycads or black beans in running water for several days before consumption.

What is the main scientific principle behind this process?

A. To decompose toxins into sugars and acids.

B. To promote fermentation which neutralises acids.

C. To dissolve water-soluble toxins and wash them away.

D. To allow oxygen to oxidise harmful compounds into safe ones.

3 Which of the following is considered to be a limitation of Arrhenius' model of acids and bases?

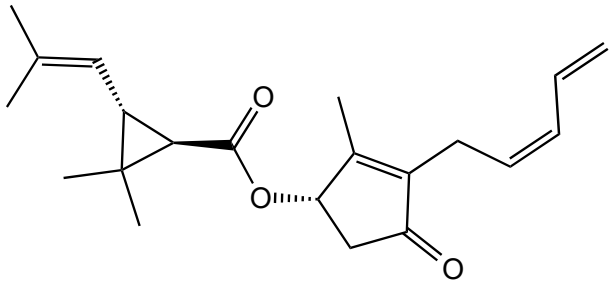
A. He did not account for acids that do not contain oxygen.

B. He did not recognise the importance of water as a solvent in the nature of acids and bases.

C. He did not recognise that some substances can act as acids or bases in the absence of solvents.

D. He did not account for the presence of hydrogen-containing compounds which are non-acidic in nature.

4 Pyrethrins belong to a naturally occurring group of insecticides produced by the chrysanthemum daisy. The formula of one such compound, pyrethrin I, and its structure are shown below.



pyrethrin I

$C_{21}H_{28}O_3$

Which analytical technique would NOT provide information that is useful in determining the structure of pyrethrin I?

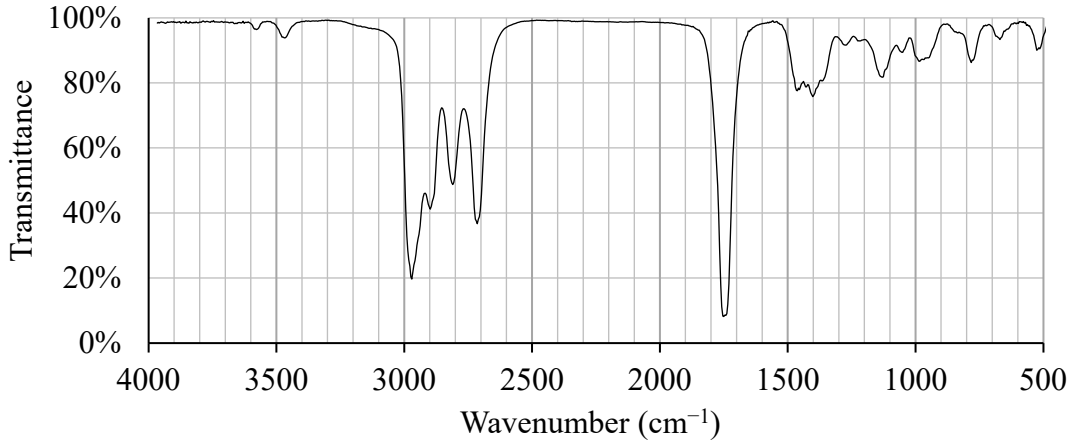
A. Mass Spectrometry

B. Infrared Spectroscopy

C. Atomic Absorption Spectroscopy

D. Nuclear Magnetic Resonance Spectroscopy

5 The infra-red spectrum of an unknown sample is shown below.



Identify the unknown sample.

A. butanal

B. butanoic acid

C. propanol

D. hex-3-ene

6 The following statements compare equimolar aqueous solutions of a weak monoprotic acid and a strong monoprotic acid.

I. The weak acid ionises less than the strong acid.

II. The strong acid reacts with a metal carbonate, but the weak acid does not.

III. The strong acid exhibits higher electrical conductivity than the weak acid.

Which of the above statements are true?

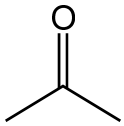
A. I and II only

B. I and III only

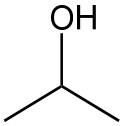
C. II and III only

D. I, II and III

7 Consider the two molecules below.



Molecule A

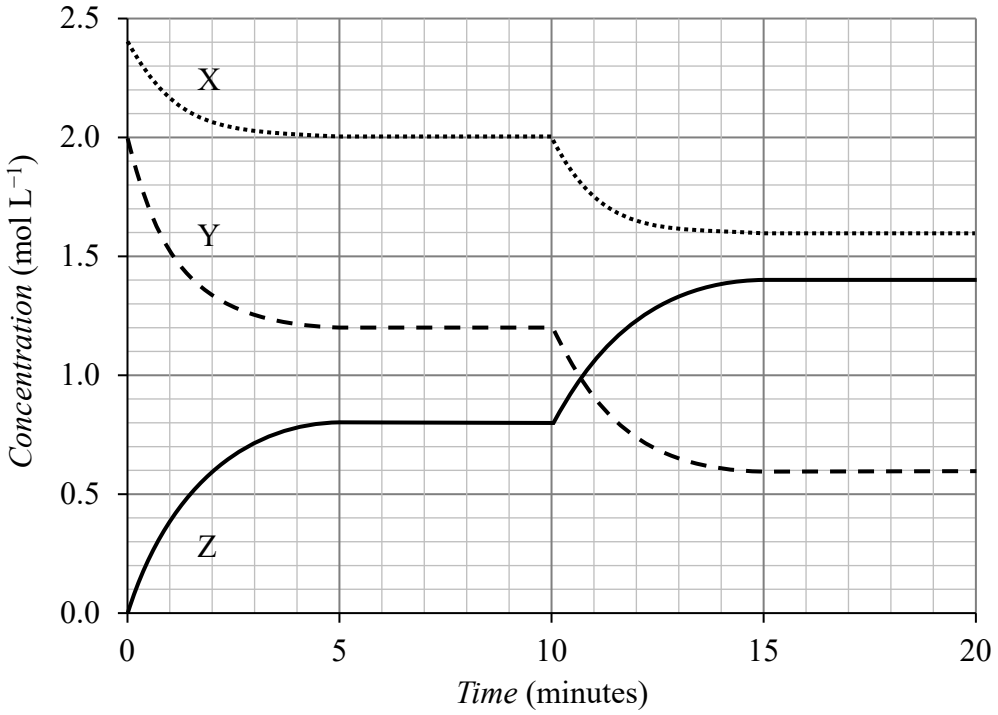


Molecule B

Which row of the table correctly identifies the shape around the central carbon atom of each molecule?

	Molecule A	*Molecule B*
A.	tetrahedral	tetrahedral
B.	tetrahedral	trigonal planar
C.	trigonal planar	tetrahedral
D.	trigonal planar	trigonal planar

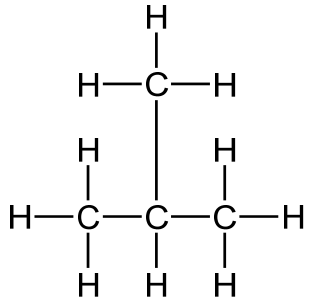
8 Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. At time t = 10 minutes the temperature of the equilibrium system increased. The concentration of each gas is plotted against time.



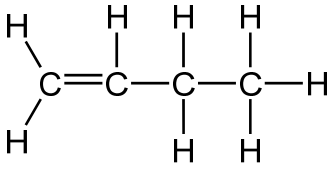
Which row of the table shows the correct reaction and enthalpy for the forward direction of the equilibrium represented by the graph?

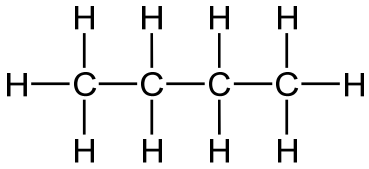
	Reaction	ΔH
A.	$2Z(g) \rightleftharpoons 3X(g) + 2Y(g)$	$\Delta H < 0$
B.	$2Z(g) \rightleftharpoons 3X(g) + 2Y(g)$	$\Delta H > 0$
C.	$2X(g) + 3Y(g) \rightleftharpoons 2Z(g)$	$\Delta H < 0$
D.	$2X(g) + 3Y(g) \rightleftharpoons 2Z(g)$	$\Delta H > 0$

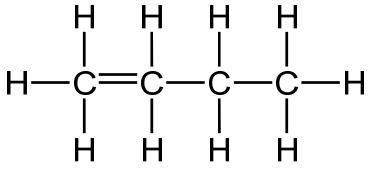
9 The structural formula of 2-methylpropane is given below.

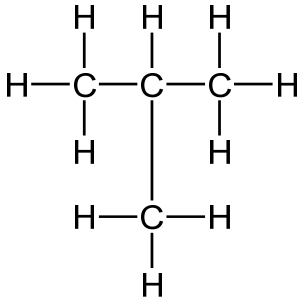


Which of the following structures is an isomer of 2-methylpropane?

A. 

B. 

C. 

D. 

10 Barium hydroxide is a strong base, that fully dissociates in water.

What is the pH of a 0.10 M barium hydroxide solution?

A. 7.70

B. 12.00

C. 13.00

D. 13.30

11 A saturated solution of calcium hydroxide was prepared using 3.0 g of solid calcium hydroxide containing calcium-41 which is radioactive. The solid was added to water in a beaker and the lid immediately closed.

After a period of time, radioactivity would be detected in

A. only the saturated calcium hydroxide solution.

B. both the solid calcium hydroxide and the saturated solution.

C. only the solid calcium hydroxide remaining undissolved in the beaker.

D. neither the solid nor the solution, as calcium-41 is stable in this condition.

12 Which statements are correct for the reaction of ethene with bromine in the absence of ultraviolet light?

I. The organic product is colourless.

II. It is an addition reaction.

III. The organic product is unsaturated.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

13 In a titration of a strong monoprotic acid with a strong monoprotic base a Year 12 student carried out the following procedure.

1. A burette was rinsed with distilled water and then filled with the standardised acid.
2. A bulb pipette was rinsed with distilled water and then rinsed with the base being analysed.
3. A conical flask was rinsed with distilled water and then with the base.
4. The bulb pipette was used to transfer 25.00 mL of base into the conical flask.
5. Phenolphthalein was added to the conical flask and the base was titrated to the endpoint with the acid from the burette.

Which statement is correct?

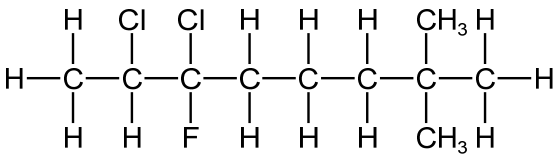
A. The calculated base concentration will be too low.

B. The calculated base concentration will be correct.

C. The calculated base concentration will be too high.

D. No conclusion can be reached as the choice of indicator used was incorrect.

14 Consider the molecule shown below.



What is the preferred IUPAC name for this molecule?

A. 2,3-dichloro-3-fluoro-7,7-dimethyloctane

B. 2,3-dichloro-7,7-dimethyl-3-fluorooctane

C. 6,7-dichloro-2,2-dimethyl-6-flurooctane

D. 6,7-dichloro-6-fluro-2,2-dimethyloctane

15 A 50.0 mL sample of tap water was collected to test for chloride ion (Cl^-) concentration.

The following procedure was used:

1. The sample was placed in a clean, dry beaker.
2. Excess silver nitrate solution was added.
3. A white precipitate formed.
4. The precipitate was filtered, dried, and weighed. It had a mass of 72.0 mg.

What was the concentration of chloride ions in mM, in the sample?

Note: 1 mM = 1×10^{-3} M

A. 0.502 mM

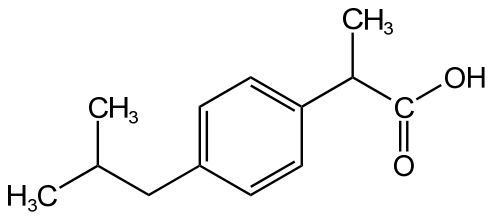
B. 1.00 mM

C. 2.00 mM

D. 10.0 mM

16 Ibuprofen is a widely used non-steroidal anti-inflammatory drug (NSAID) that helps reduce fever, pain, and inflammation.

The diagram below shows the molecular structure of Ibuprofen.

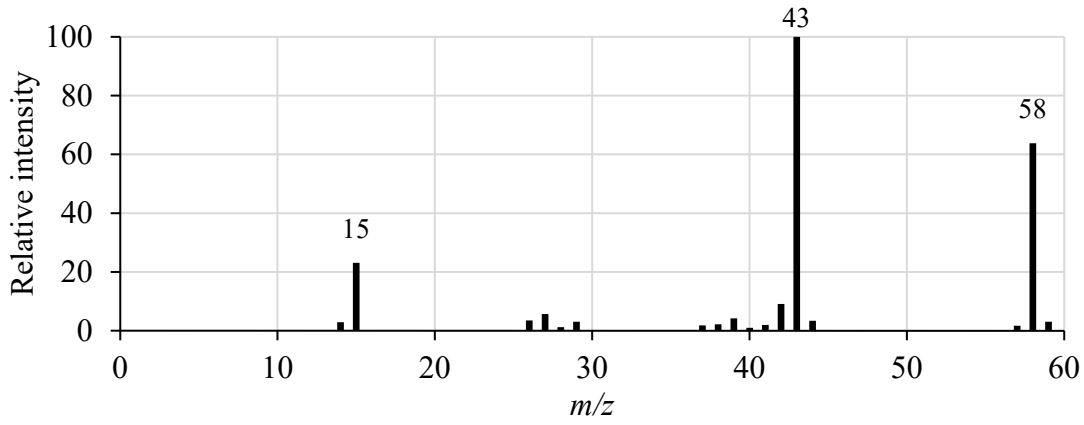


Ibuprofen

Which of the following reagents would you expect to react with ibuprofen at 25°C?

	$Na_2CO_3(aq)$	$KMnO_4/H_2SO_4(aq)$
A.	Yes	Yes
B.	No	Yes
C.	Yes	No
D.	No	No

17 The diagram below shows the mass spectrum of an organic molecule.



Which of the following molecules corresponds with the mass spectrum shown?

A. Propanal

B. Propan-1-ol

C. Propan-2-one

D. Propanoic acid

18 Which one of the following pairs reacts to form an organic product with only 2 singlets in its ^{1}HNMR spectrum?

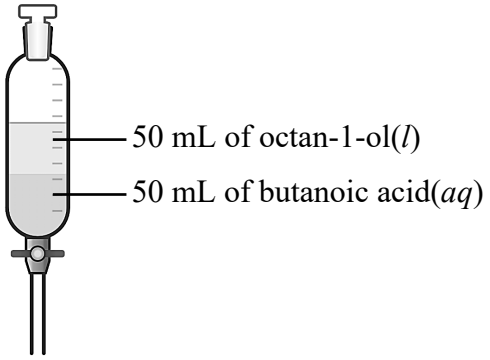
A. But-2-yne and hydrogen (Ni catalyst)

B. Ethene and bromine

C. Ethanol and concentrated sulfuric acid

D. Ethanal and acidified potassium dichromate (VI)

19 50 mL of an aqueous butanoic acid solution was added to a separating funnel with 50 mL of octan-1-ol as shown below. Water and octan-1-ol are immiscible solvents.



After shaking, the following equilibrium was established at 25°C.

$$CH_3CH_2CH_2COOH(aq) \rightleftharpoons CH_3CH_2CH_2COOH(octan\text{-}1\text{-}ol)$$

An extra 10 mL of octan-1-ol was added, the mixture shaken and equilibrium was allowed to re-establish.

Which of the following statements is correct?

A. K_a of butanoic acid increases.

B. K_a of butanoic acid decreases.

C. pH of the aqueous butanoic acid solution increases.

D. pH of the aqueous butanoic acid solution decreases.

20 50.0 mL of 0.10 M hydrochloric acid is added to 60.0 mL of 0.20 M aqueous ammonia solution ($K_b = 1.8 \times 10^{-5}$).

What is the pH of the resultant mixture?

A. 4.8

B. 5.3

C. 9.1

D. 9.4

End of Section I

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2025 TRIAL HSC EXAMINATION

2

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

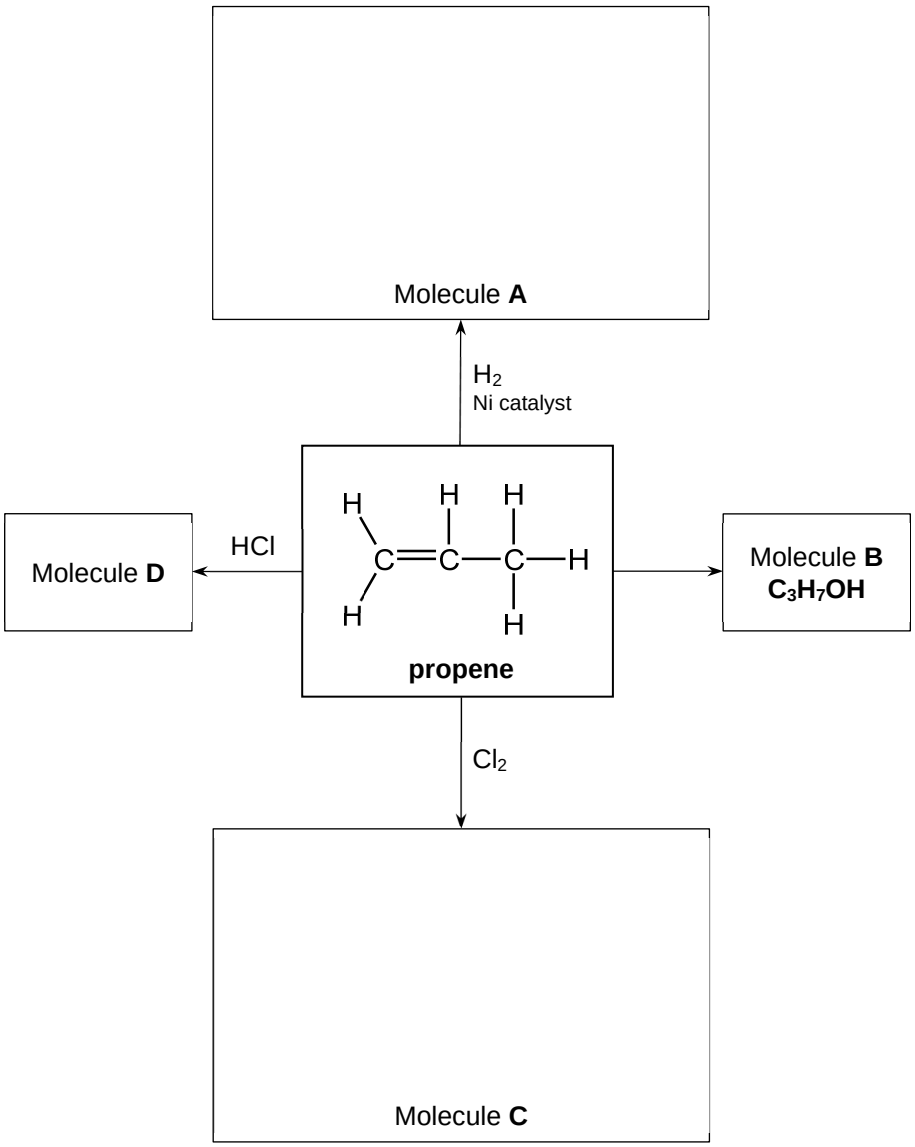
Instructions

- Write your Student Number at the top of this page.
- 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.

Please turn over

Question 21 (4 marks)

The flowchart below shows a series of reactions that take place with propene.



(a) Complete the flowchart above by drawing full structures of Molecules **A** and **C**. **2**

(b) Identify any necessary reaction conditions required to form Molecule **B**. **1**

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(c) Give an IUPAC name for Molecule **D**. **1**

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Question 22 (5 marks)

Hydrogen cyanide (HCN) is a gas at room temperature.

When it is bubbled into water, it dissolves and partially ionises, forming an acidic solution as shown in the equation below.

$$HCN(g) + H_2O(l) \rightleftharpoons CN^-(aq) + H_3O^+(aq)$$

The pK_a of hydrocyanic acid at 25°C is 9.21.

(a) Calculate K_a for hydrocyanic acid at 25°C. **1**

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(b) Write an expression for the equilibrium constant, K_a, for hydrocyanic acid. **1**

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(c) Calculate the pH of a 0.1080 M solution of HCN. **3**

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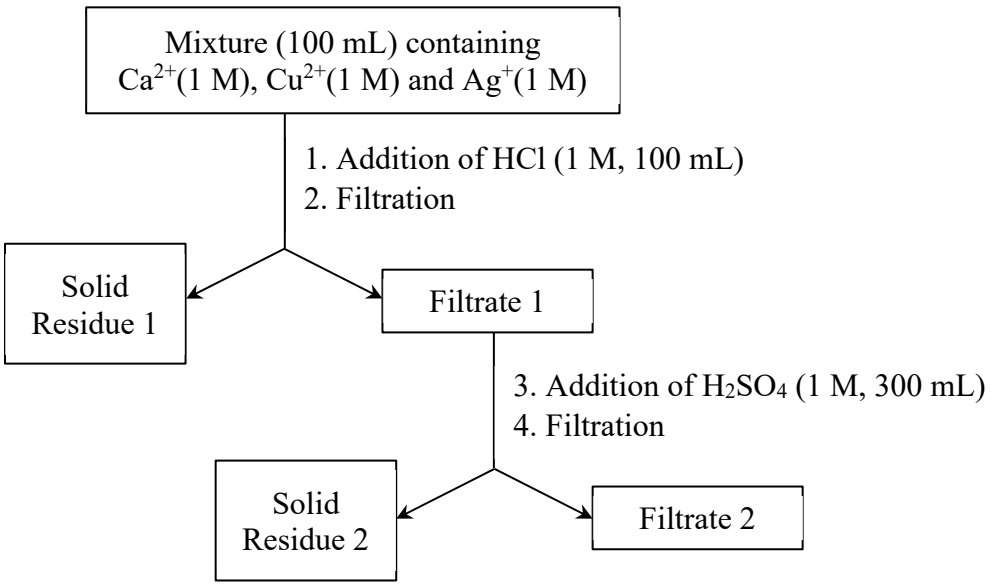
Question 23 (6 marks)

A mixture containing equal molar concentrations of Ca^{2+}, Cu^{2+} and Ag^{+} was analysed by the process shown in the flow chart.



(a) Identify Solid Residue 2. **1**

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(b) Identify the metal cation present in Filtrate 2 and describe a chemical test that could be performed to confirm the identify of this cation. **2**

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Question 23 continues on page 17

(c) A student performed the process shown in the flowchart with 0.01 M H_2SO_4 in Step 3 instead of 1.0 M H_2SO_4. **3**

Assess the validity of this change in reagent concentration.

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End of Question 23

Question 24 (9 marks)

Indicators can be derived from natural sources or produced synthetically, and they are used to determine the pH of substances.

(a) Outline a suitable method to prepare a natural indicator in the school laboratory. **2**

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(b) Outline how the natural indicator could be tested to ensure that it produces valid data when determining the pH of an unknown solution. **3**

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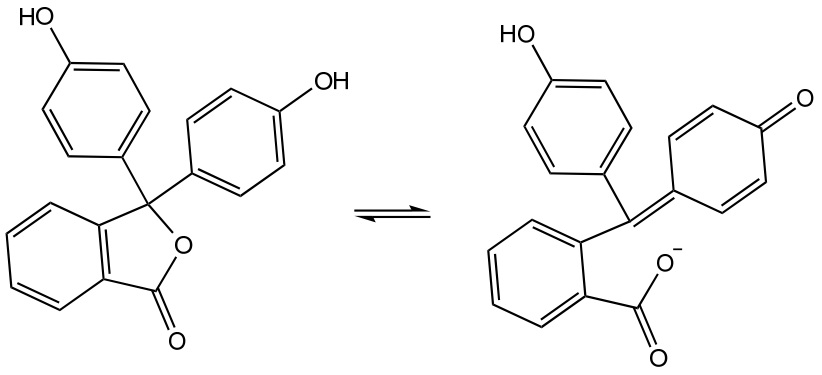
Question 24 continues on page 19

(c) Phenolphthalein (H*Phen*) is a common synthetic acid–base indicator that is useful for identifying the endpoint of titrations due to its distinct colour changes.

The chromophore (colour-changing part of a molecule) of Phenolphthalein exists in two forms: H*Phen*, a weak acid is colourless and $Phen^-$, its conjugate base is bright pink.

The structure and behaviour of this chromophore in aqueous solution is shown below.



H*Phen*
colourless
pH < 8

***Phen*$^-$**
bright pink
pH > 10

(i) Construct a balanced chemical equation that uses H*Phen* and $Phen^-$ to show the reversibility of phenolphthalein. **1**

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(ii) A few drops of phenolphthalein indicator were added to a solution of water. The resulting equilibrium mixture was colourless. **3**

Explain, with reference to Le Chatelier's Principle, any changes that would be observed in this system on addition of 6 M NaOH.

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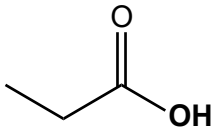
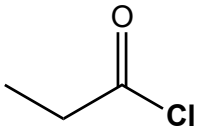
End of Question 24

Question 25 (6 marks)

Carboxylic acids and acyl chlorides are functional group analogues that both contain a carbonyl group (C=O) but differ in the atom or group bonded to the carbonyl carbon. In carboxylic acids, the carbonyl is bonded to a hydroxyl group (–OH), while in acyl chlorides it is bonded to a chlorine atom (–Cl). For example, propanoic acid is the carboxylic acid analogue of propanyl chloride.



propanoic acid
CH_3CH_2COOH

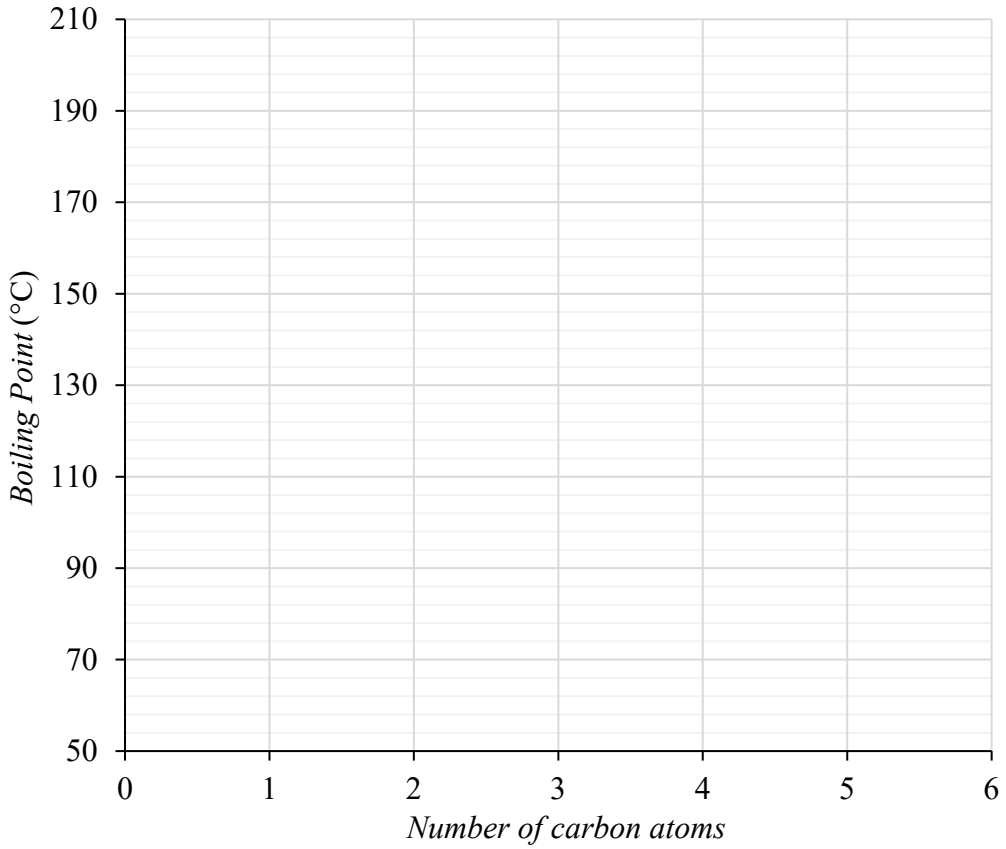


propanyl chloride
CH_3CH_2COCl

The boiling points of several straight-chain carboxylic acids and their corresponding acyl chlorides are shown in the following table.

Number of Carbon Atoms	2	3	4	5	6
Boiling point of carboxylic acid (°C)	118	141	163	187	205
Boiling point of acyl chloride (°C)	51	80	102	126	151

(a) On the grid, construct a graph of the data with TWO lines of best fit. **3**



Question 25 continues on page 21

(b) Explain the patterns of the boiling points shown in the graph. **3**

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End of Question 25

Question 26 (4 marks)

Consider a solution of ammonia, $K_a = 1.8 \times 10^{-5}$, in water at 25°C. **4**

Explain, using a suitable equation, what happens to the K_b and degree of ionisation if the solution evaporates to half its volume at 25°C.

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Question 27 (6 marks)

The following data apply to the dissolution of sodium chloride (NaCl) and silver chloride (AgCl) at standard room temperature and pressure.

	NaCl	AgCl
$\Delta H^{\ominus}$ (kJ mol^{-1})	+3.9	+19
$\Delta S^{\ominus}$ (J K^{-1} mol^{-1})	+43	−18
$\Delta G^{\ominus}$ (kJ/mol)	−8.914	+24.36
Solubility in water (g/L)	360	0.00193

(a) Describe the processes involved when sodium chloride dissolves in water by referring to the bonds broken and the bonds formed. **2**

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(b) Using the data above, justify the solubilities of both sodium chloride and silver chloride with reference to enthalpy, entropy and the spontaneity. **4**

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Question 28 (5 marks)

Consider the following Brønsted and Lowry acid-base reactions.

Reaction 1: $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

Reaction 2: $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

(a) Use the equations above to illustrate the amphiprotic nature of water. **2**

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(b) A solution was prepared by dissolving 0.50 mol $CH_3COO^-(aq)$ and 0.50 mol $CH_3COOH(aq)$ in 250 mL of water at 25°C. **3**

Explain how the pH of this solution would be affected by the addition of small amounts of a strong base.

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Question 29 (4 marks)

A 1.00 L saturated solution of barium fluoride (BaF_2) was prepared at 25°C. The solubility product constant for BaF_2 at 25°C is 1.7×10^{-6}. **4**

0.100 g of NaF is added to the solution. Calculate Q_{sp} after the addition of NaF and predict how the reaction will proceed in response to this change.

Assume all added fluoride ions fully dissociate and that the final volume of the solution is unchanged on addition of the solid.

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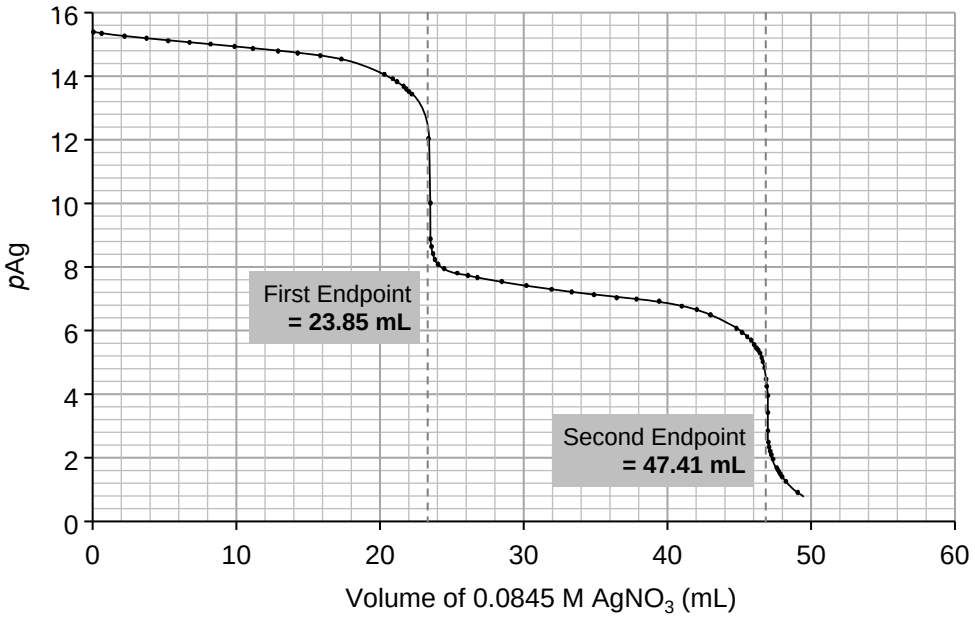
Question 30 (7 marks)

A precipitation titration was performed with a 40.00 mL mixture of potassium iodide and potassium chloride using 0.0845 M silver nitrate. The titration curve for this reaction is shown, where $p\text{Ag} = -\log_{10}[\text{Ag}^+]$.



(a) Explain the changes in silver ion concentration during the titration. **4**

In your response, include TWO balanced chemical equations to show formation of any precipitates and refer to relevant solubility products.

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Question 30 continues on page 27

Question 30 (continued)

(b) Determine the concentration of each anion present in the original mixture. **3**

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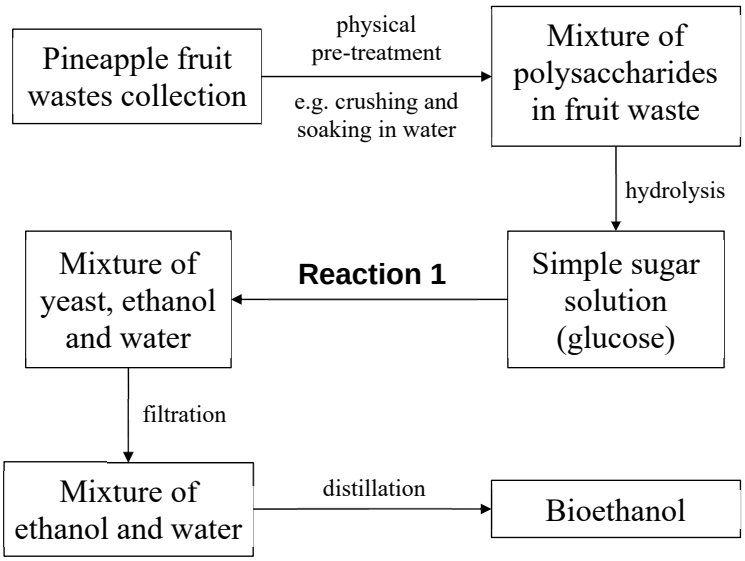
End of Question 30

Please turn over

Question 31 (8 marks)

The following flowchart summarises a process to produce bioethanol from pineapple fruit waste juice using bakery yeast.



Source: Adapted from Mgeni *et al.* (2024)

(a) Name the chemical reaction labelled as **Reaction 1** in the flowchart and provide a balanced chemical equation for this reaction. **2**

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Question 31 continues on page 29

(b) The biofuel produced from this process was analysed and compared with petroleum produced from fossil fuels. **3**

The table below summarises some of the data form this analysis.

	Petroleum	*Bioethanol*
Molecular weight (kg/kmol)	111	48
Density (kg/L) at 15°C	0.82	0.75
Energy density (MJ/kg)	41.3	26.4

When 50.0 L of petroleum is combusted in a typical engine, 1784 MJ of energy is released. What volume of the bioethanol product would be required to produce the same amount of energy?

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(c) Evaluate the viability of this method for production of bioethanol from pineapple juice as an alternative to petroleum. **3**

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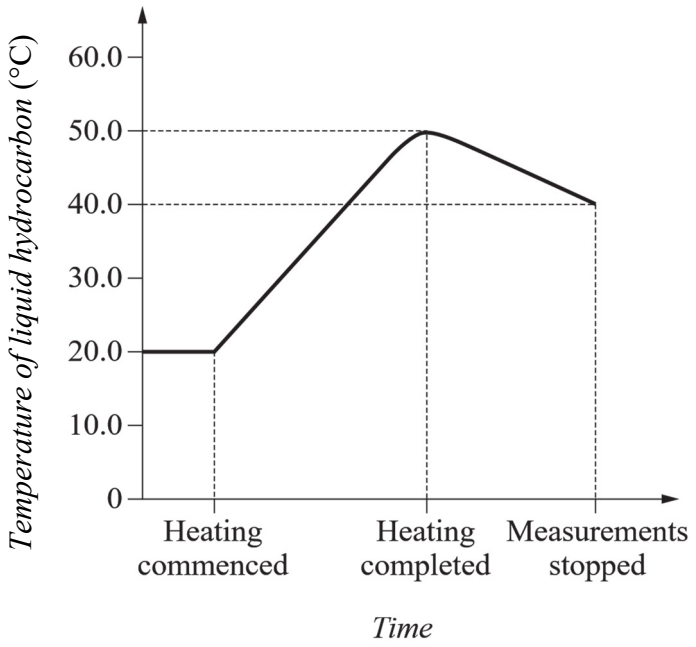
End of Question 31

Question 32 (5 marks)

A 0.352 g sample of ethanol is burnt to raise the temperature of 100.0 g of liquid hydrocarbon, as shown in the graph. Assume there is no loss of heat to the surroundings.



(a) Using the information shown on the graph, calculate the specific heat capacity of the liquid hydrocarbon in J/g/K. **3**

The heat of combustion of ethanol is 1367 kJ mol^{-1}.

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Question 32 continues on page 31

(b) Name ONE risk associated with the use of an organic compound in this experiment AND describe a safety precaution that should be taken when handling it in the laboratory. **2**

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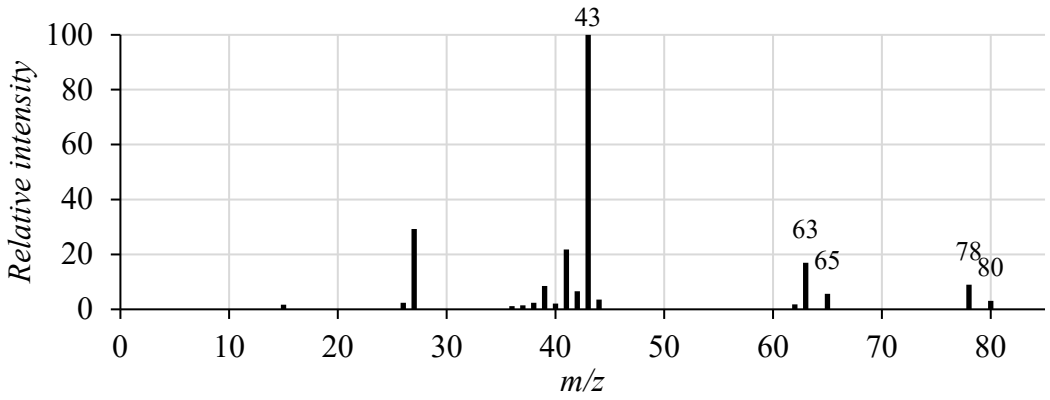
End of Question 32

Please turn over

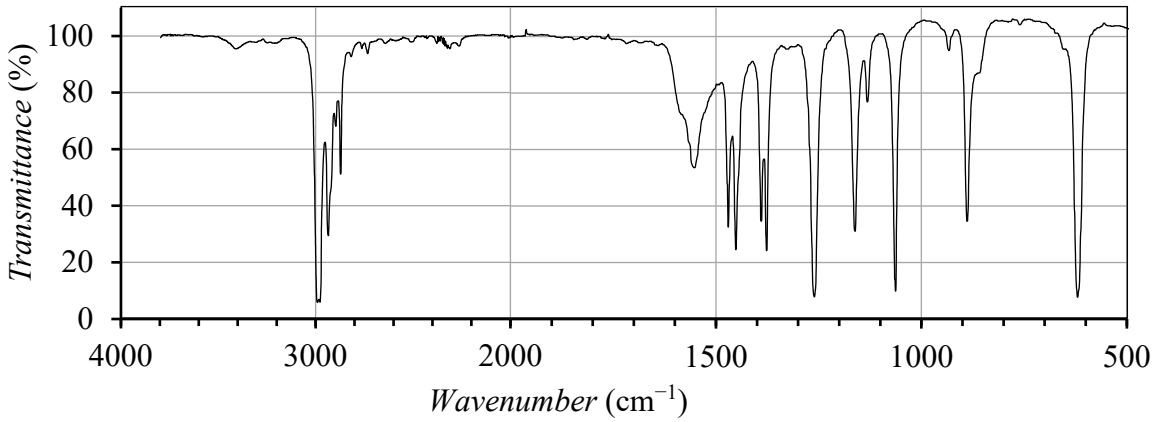
Question 33 (7 marks)

The following data were obtained from analysis of an organic compound known to contain a halogen. The compound is a colourless liquid that shows no visible reaction on addition of bromine water or with acidified potassium dichromate.

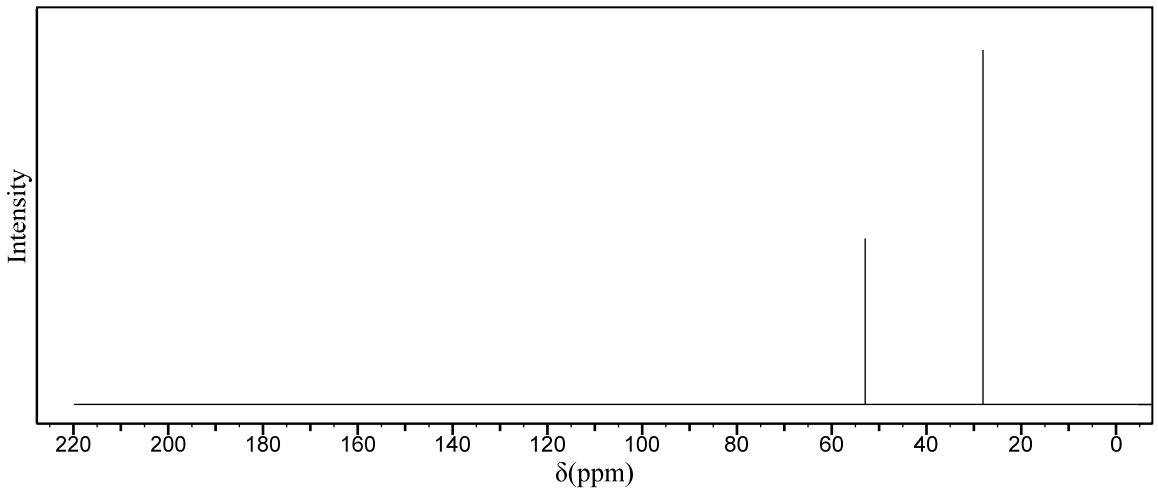
Mass Spectrum



IR Spectrum

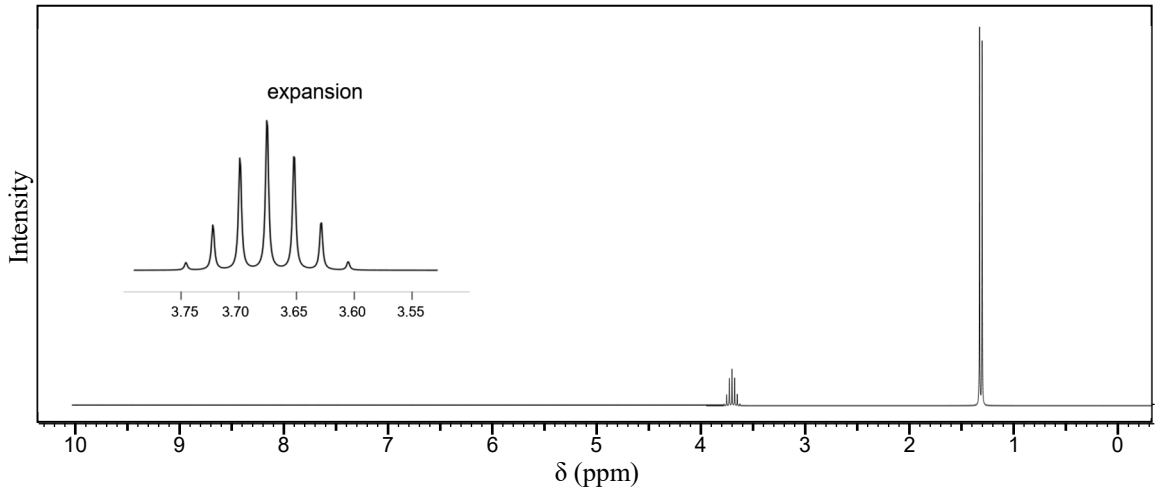


^{13}CNMR Spectrum



Question 33 continues on page 33

1HNMR Spectrum



What is the structural formula of this compound? Justify your answer with reference to the information given on its reactivity and to all spectra provided. **7**

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Question 33 continues on page 34

Question 33 (continued)

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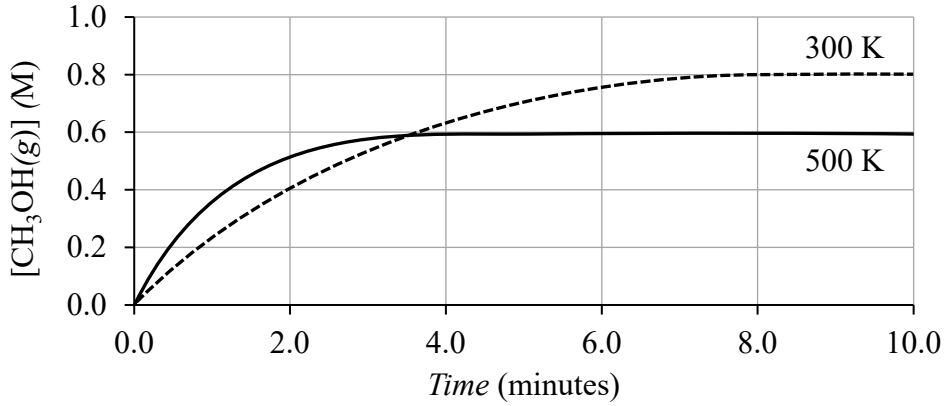
End of Question 33

Question 34 (4 marks)

Methanol can be synthesised from carbon monoxide and hydrogen gas according to the following equilibrium reaction. **4**

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -92 \text{ kJmol}^{-1}$$

The graph shows the concentration of methanol over time at two different temperatures (300 K and 500 K), under constant pressure. At 300 K, $K_{eq} = 0.233$, while at 500 K, $K_{eq} = 3.27 \times 10^{-8}$.



Using collision theory, rate of reaction and the relative values of K_{eq}, explain the observed differences in methanol production between the two temperature conditions.

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End of Paper

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HSC Chemistry Task 4
Marking Guidelines, Sample Answers and Marker's Feedback

General feedback:

- Avoid writing outside of the lines, particularly avoid writing close to the edge of the page → use extra writing space.
- Clearly state if extra writing space is used (you want the marker to find your answer!)
- Think through explanations before starting to write (especially longer responses), as you want your answer to have a logical flow.
- Answer the question clearly – this might mean a writing a short sentence in a calculation question.
- Either when checking the paper or before you go to the next question double check that your response matches the verb in the question.
- Show all working in calculation questions → including stating equations, giving explanatory statements and being clear what you are calculating.
- In calculation questions check the significant figures and units.

Section 1 (20 marks)

Question 1-20 Multiple Choice 2025

Question	Answer	
1	A	• In **option A**, a saturated solution of potassium chloride (KCl) has solid KCl dissolving into the solution at the same rate that dissolved KCl is precipitating out. This is a classic example of dynamic equilibrium in a physical system. • **Option B** (a can of soft drink just opened) is not at equilibrium because carbon dioxide is escaping, disrupting the balance. **Option C** and **D** involve combustion reactions, which are **irreversible** and do not establish equilibrium.
2	C	The correct answer is: **C. To dissolve water-soluble toxins and wash them away.** • **Option A** is incorrect because decomposition into sugars and acids is not the goal. • **Option B** refers to fermentation, which is not the process used here. **Option D** involves oxidation, which requires oxygen and is not the primary mechanism in this context.
3	C	✓ **C** is correct because Arrhenius' model only applies to aqueous solutions and does not account for acid-base behaviour in the absence of solvents. ✗ **A** is incorrect as the model does not rely on oxygen content to define acids. ✗ **B** is incorrect because Arrhenius actually emphasised the role of water as a solvent. ✗ **D** is incorrect since the presence of non-acidic hydrogen-containing compounds does not contradict the model's definition, which is based on ion formation in water.
4	C	The correct answer i**s C:** (AAS) is used to identify and quantify metal elements • **A.** Mass Spectrometry (MS): Provides the molecular mass and fragmentation pattern, which helps deduce the structure. • **B.** Infrared Spectroscopy (IR): Identifies functional groups (like esters, alcohols, etc.) based on bond vibrations. **D.** Nuclear Magnetic Resonance (NMR) Spectroscopy: Gives detailed information about the carbon and hydrogen framework, maps out the molecular structure.
5	A	✗ **B** and **C** incorrect. No broad peak around 3400 cm^{-1} → **absence** of O–H stretch, typical of alcohols or carboxylic acids ✗ **D** incorrect. No characteristic alkyne stretch around 2100-2250cm^{-1} ✓ Sharp peak near 1700 cm^{-1} → indicates a C=O stretch, characteristic of carbonyl groups (found in aldehydes, ketones, carboxylic acids).

		✓Peak near 2900 cm^{-1} → corresponds to C–H stretches from alkyl groups. **Therefore, A butanal**
B	B	✓ **B** is correct because **I** is true — a weak acid only partially ionises in solution, unlike a strong acid which ionises completely — and **III** is also true, as strong acids produce more free ions, resulting in higher electrical conductivity. ✗ **A** is incorrect because while **I** is true, **II** is false — both strong and weak acids react with metal carbonates, though the reaction with a weak acid is slower. ✗ **C** is incorrect because **II** is false, as explained above, even though **III** is true. ✗ **D** is incorrect because **II** is not a true statement, even though **I** and **III** are correct.
7C	C	✓ **C** is correct because **Molecule A** has a central carbon atom bonded to **three atoms** (including a double bond to oxygen), giving it **three regions of electron density** and a **trigonal planar** shape. **Molecule B** has a central carbon bonded to **four atoms** — two carbon atoms, one OH group, and one implicit hydrogen — resulting in **four regions of electron density** and a **tetrahedral** shape. ✗ **A** is incorrect because Molecule A is not tetrahedral. ✗ **B** is incorrect because Molecule B is not trigonal planar. ✗ **D** is incorrect because neither molecule has trigonal planar geometry.
8	D	✓ **D is the most correct**. At t = 10 minutes, the temperature increases and the concentrations of X and Y decrease while Z increases, indicating the equilibrium shifts to favour the formation of Z. This means the forward reaction is favoured, so the forward reaction must be endothermic (**$\Delta H > 0$**). None of the given options match both the correct reaction direction and enthalpy sign, so all other options are incorrect based on incorrect changes in product and reactant concentrations with the given change in enthalpy.
9	B	✓ **B** is correct because it shows butane, a structural isomer of 2-methylpropane. Both have the molecular formula C_4H_{10}, but differ in structure: 2-methylpropane is branched, while butane is straight-chained. ✗ **A** is incorrect because it shows a molecule with the formula C_4H_8, which is an alkene, not an isomer of 2-methylpropane (C_4H_{10}). ✗ **C** is incorrect because although it contains C_4H_{10}, the bonding arrangement is invalid — the central carbon is shown with five bonds, which violates carbon's tetravalency, making it not a valid isomer. ✗ **D** is incorrect because it is identical to 2-methylpropane, not a different structure — therefore, it is not an isomer.
10	D	✓ **D** is correct because barium hydroxide ($Ba(OH)_2$) is a strong base that fully dissociates in water, releasing two OH^- ions per formula unit. A 0.10 M solution of $Ba(OH)_2$ therefore produces 0.20 M OH^-. To calculate pH: $pOH = -\log [OH^-] = -\log(0.20) \approx 0.70$ **pH** $= 14 - pOH = 14 - 0.70 = 13.30$ ✗ **A** is incorrect because a pH of 7.70 is too low for a strong base. ✗ **B** is incorrect because it underestimates the OH^- concentration by assuming only 0.10 M OH^- is produced. ✗ **C** is incorrect because it still underestimates the OH^- concentration slightly negating that barium hydroxide dissociates to produce TWO moles of OH^-.
11	B	✓ **B** is correct because calcium-41 is a radioactive isotope of calcium, and when calcium hydroxide dissolves in water, Ca^{2+} ions enter the solution. Since the solid contains calcium-41, both the undissolved solid and the saturated solution will contain radioactive calcium ions. ✗ **A** is incorrect because the radioactivity is not limited to the solution — the undissolved solid also contains calcium-41. ✗ **C** is incorrect because some of the calcium-41 dissolves, so radioactivity will be present in the solution as well. ✗ **D** is incorrect because calcium-41 is not stable — it is radioactive, and its presence will be detectable in both phases.

12	A	✓ **A** is correct because: • Statement I is true: the product of ethene reacting with bromine is 1,2-dibromoethane, which is colourless, causing the reddish-brown colour of bromine to disappear. • Statement II is true: the reaction is an addition reaction, where bromine adds across the double bond in ethene. • ✗ Statement III is false: the product is saturated, as the double bond is broken and replaced with single bonds to bromine atoms. ✗ **B** is incorrect because Statement III is false. ✗ **C** is incorrect because Statement I is true. ✗ **D** is incorrect because Statement III is false.
13	C	In a titration of a strong monoprotic acid with a strong monoprotic base a Year 12 student carried out the following procedure. 1. A burette was rinsed with distilled water and then filled with the standardised acid. 2. A bulb pipette was rinsed with distilled water and then rinsed with the base being analysed. 3. A conical flask was rinsed with distilled water and then with the base. 4. The bulb pipette was used to transfer 25.00 mL of base into the conical flask. 5. Phenolphthalein was added to the conical flask and the base was titrated to the endpoint with the acid from the burette. Which statement is correct? A. The calculated base concentration will be too low. B. The calculated base concentration will be correct. C. The calculated base concentration will be too high. D. No conclusion can be reached as the choice of indicator used was incorrect.
14	D	✓ **D** is correct because it follows all key IUPAC conventions: • The longest carbon chain has eight carbon atoms, so the base name is **octane**. • Numbering starts from the end closest to the first substituent, which gives the lowest possible locants: fluoro at C6, chloro at C6 and C7, and methyl groups at C2. • The **first point of difference rule** ensures substituents get the lowest possible numbers when comparing locants. • **Alphabetical order** is respected: chloro, dimethyl, fluoro → hence the name: 6,7-dichloro-6-fluoro-2,2-dimethyloctane. ✗ **A** is incorrect because although it uses correct alphabetical order, it violates the first point of difference rule, assigning higher locants unnecessarily. ✗ **B** is incorrect because it uses the sum of locants rule, which is outdated and not preferred over the first point of difference rule. It also misorders substituents alphabetically. ✗ **C** is incorrect because while the locants are correct, it violates alphabetical order — fluoro should come before methyl.
15	D	**Step-by-step solution:** 1. Reaction: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ 2. Mass of AgCl formed: Mass = 72.0 mg = 0.0720 g 3. Molar mass of AgCl: Molar mass = 107.87 + 35.45 = 143.32 g/mol 4. Moles of AgCl (and thus Cl^-): n = 0.0720143.32 ≈ 5.02×10^{-4} mol 5. Volume of water sample: V = 50.0 mL = 0.0500 L 6. Concentration of Cl^- ions: $[Cl^-] = 5.02\times10^{-4} / 0.0500 = 0.0100$ mol/L = 10.0 mM

		✓ **D** is correct: the chloride ion concentration is **10.0 mM**. ✗ **A**, **B**, and **C** are incorrect because they underestimate the amount of chloride based on incorrect stoichiometry or mass-to-mole conversion.
16	A	✓ **A** is correct because ibuprofen contains both: • A **carboxylic acid** group, which will react with sodium carbonate (Na_2CO_3) to produce carbon dioxide gas — a typical acid–carbonate reaction. • An **alkylbenzene** side chain, which can be oxidised by acidified potassium permanganate ($KMnO_4/H_2SO_4$) under mild conditions, especially at the benzylic position. ✗ **B** is incorrect because ibuprofen **does** react with Na_2CO_3 due to its carboxylic acid group. ✗ **C** is incorrect because $KMnO_4/H_2SO_4$ **can** oxidise the benzylic position in ibuprofen. ✗ **D** is incorrect because ibuprofen reacts with **both** reagents.
17	C	✓ **C is correct** because **propan-2-one (acetone)**: • Has a **molecular ion peak at m/z = 58**, matching the observed spectrum. • Fragments to give CH_3^+ (m/z = 15) and CH_3CO^+ (m/z = 43), both of which are present. • Does not produce a $C_2H_5^+$ (m/z = 29) fragment, consistent with the absence of that peak. ✗ **A** is incorrect because propanal can fragment to give $C_2H_5^+$ (m/z = 29), which is absent in the spectrum. ✗ **B** is incorrect because propan-1-ol has a molecular ion of 60, which does not match the observed m/z = 58 peak. ✗ **D** is incorrect because propanoic acid has a molecular ion of 74, which is too high to correspond with the m/z = 58 peak.
18	D	**D.** Ethanal and acidified potassium dichromate (VI) Reaction: Oxidation of ethanal (CH_3CHO) → ethanoic acid (CH_3COOH) ^{1}H NMR of ethanoic acid: • CH_3 (methyl) protons: singlet • COOH proton: singlet Why only 2 singlets? • No adjacent non-equivalent protons to cause splitting • COOH proton exchanges rapidly → does not couple ✓ 2 singlets → matches the condition ✗ **A** Reaction: Full hydrogenation → butane ($CH_3–CH_2–CH_2–CH_3$) ^{1}H NMR of butane shows CH_3 protons: triplet +CH_2 protons: multiplet/quartet. **More than 2 peaks, and not singlets**. ✗ **B** Reaction: Addition of Br_2 → 1,2-dibromoethane ($BrCH_2–CH_2Br$) ^{1}H NMR shows all protons equivalent → 1 singlet. **Only 1 singlet, not 2**. ✗ **C.** Reaction: Dehydration → ethene ($CH_2=CH_2$). ^{1}H NMR of ethene shows two equivalent CH_2 groups → 1 singlet. **Only 1 singlet, not 2**.
19	C	✓ **C** is correct because adding more octan-1-ol shifts the equilibrium: $CH_3CH_2CH_2COOH$ (aq) ⇌ $CH_3CH_2CH_2COOH$ (octan-1-ol) • This causes more butanoic acid to leave the aqueous phase, reducing its concentration in water. • Since butanoic acid is a weak acid, lower concentration means fewer H^+ ions in solution. • ✓ **Lower [H^+] → higher pH** ✗ **A** is incorrect because the K_a of butanoic acid is a constant that depends only on temperature and the acid itself — it does not change due to solvent distribution. ✗ **B** is incorrect because K_a remains unchanged; it's not affected by the presence of octan-1-ol. ✗ **D** is incorrect because the pH increases, not decreases, as the acid concentration in water drops.
``	D	✓ **D is correct** because the reaction between **hydrochloric acid (HCl)** and **aqueous ammonia (NH_3)** forms a **buffer solution** of **NH_4^+/NH_3**: • Moles of HCl = 0.050 L × 0.10 mol/L = **0.0050 mol** • Moles of NH_3 = 0.060 L × 0.20 mol/L = **0.012 mol** • After neutralization:

		• **0.0050 mol NH_4^+** formed • **0.0070 mol NH_3** remains • Use the **Henderson–Hasselbalch equation** with **pKa = 9.25** (from $K_b = 1.8 \times 10^{-5}$): pH = p*K*a + log([acid][base]) pH = 9.25 + log(0.00500.0070) = 9.25 + log(1.4) ≈ 9.25 + 0.15 = 9.40 ✓ Final pH ≈ **9.4** ✗ **A is incorrect** because a pH of 4.8 would indicate a strongly acidic solution, which is not the case after partial neutralization with excess weak base. ✗ **B is incorrect** because 5.3 is still too acidic for a buffer made from excess ammonia and its conjugate acid. ✗ **C is incorrect** because 9.1 underestimates the buffer's pH; the correct value is closer to 9.4.

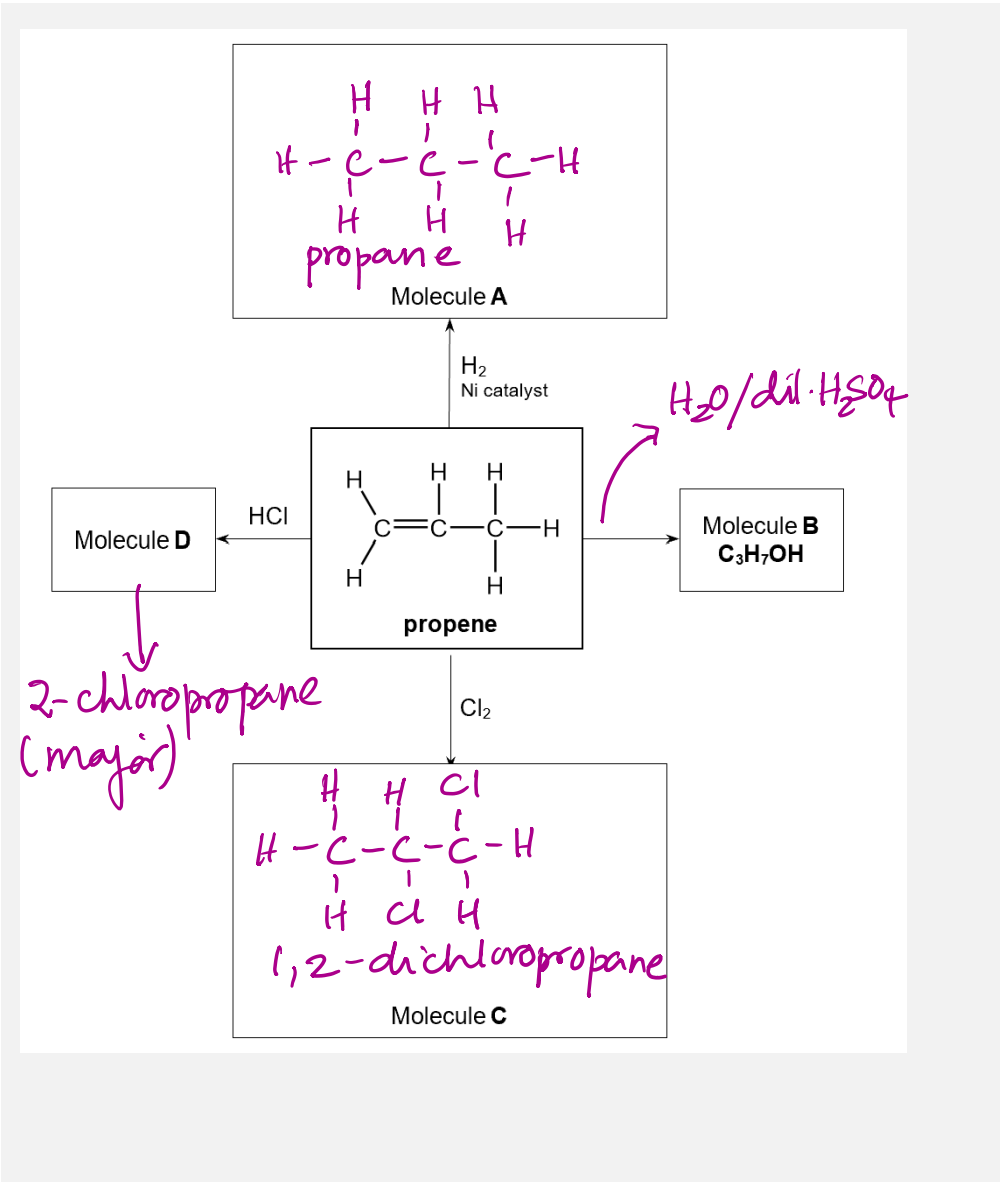
Section 2 (80 marks)

Question 21 (5 marks) 2025 Marker: SN

Marking guidelines

Criteria	Marks
• Correct structures of A and C • Correct reagents/conditions for molecule B • Correct IUPAC name for Molecule D	4
• ONE incorrect structure, reagent or name	3
• TWO incorrect structure, reagent or name	2
• More than 2 incorrect structure, reagent or name	1

Sample response:



Marker feedback:

- Answered well by most students.
- For molecule D marks were given for both 2-chloropropane (major product) and 1-chloropropane (minor product).
- 21(b) reaction conditions must have dilute sulfuric acid OR H_2O and acid

Loss of marks mostly due to drawing incorrect structure for A and C. v

Question 22a (1 mark) Marker: SN

Marking guidelines

Criteria	Marks
• Ka = 10^{-pKa} with value as 6.17 x 10^{-10}	1

Sample response:

Ka = 10-pKa $10^{-9.21}$ = 6.17 x 10^{-10}

Marker feedback:

- Done well by all.
- Some calculation errors. Please remember to double check calculations

Question 22b (1 mark) Marker: SN

Marking guidelines

Criteria	Marks
• Correct expression of Ka	1

Sample response:

$$Ka = \frac{[H_3O^+][CN^-]}{[HCN]}$$

Marker feedback:

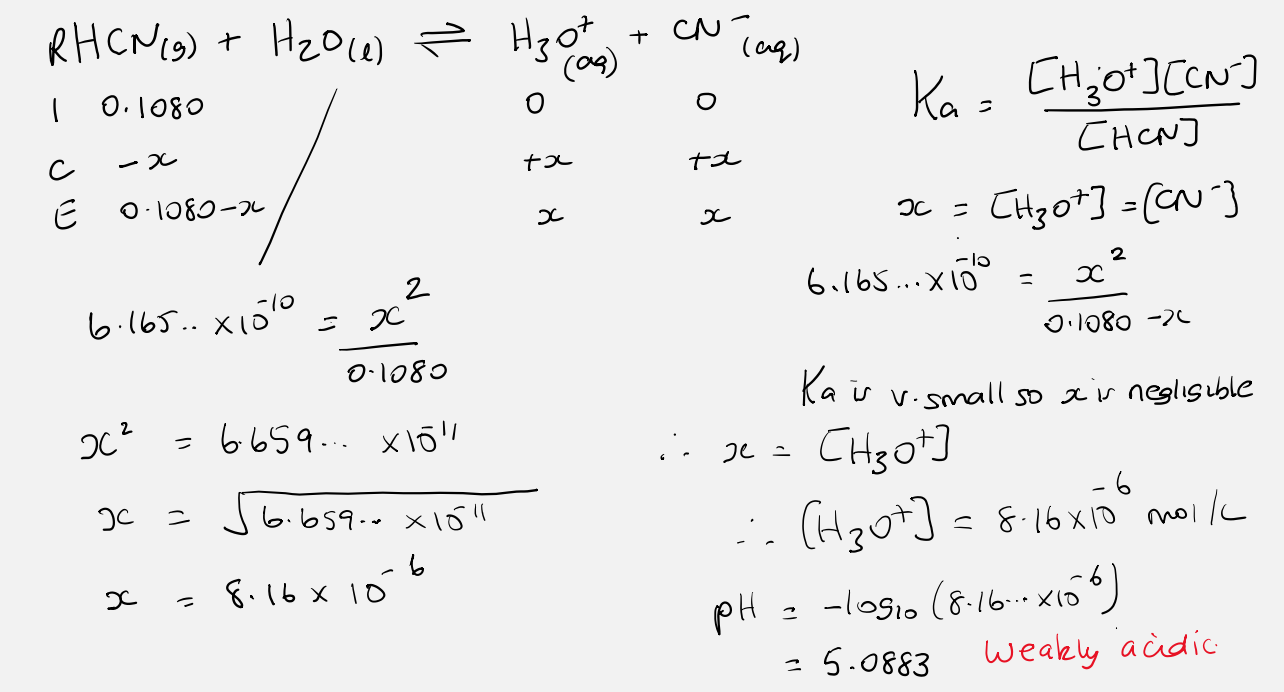
- Done well by all.
- If charges for H_3O^+ and CN^- were missing or forgotten to include [HCN] in expression- NO Marks

Question 22c (3 marks) Marker: SN

Marking guidelines

Criteria	Marks
• pH correctly calculated (ecf applied if necessary)	3
• One mistake in calculation	2
• A piece of relevant information	1

Sample response:



Marker feedback:

Again, mostly well done. Most responses used the Ka expression and Ka worked out in part a to calculate pH of the solution.

ICE table not used to calculate concentrations at equilibrium-no marks taken away as pH can be calculated without ICE table as long as understanding of weak acid is shown

Question 23(a) (1 marks) Marker : SN

Marking guidelines

Criteria	Marks
• Correctly identifies solid residue 2 as $CaSO_4$	1

Sample response:

Calcium sulfate ($CaSO_4$)

- Most students answered this correctly
- A few mixed the residues up- not reading question?

Question 23(b) (2 marks)

Marking guidelines

Criteria	Marks
• Identifies the metal cation present in Filtrate 2. • Describes a chemical test that could be performed to determine cation.	2
• ONE of the above.	

Sample response:

To confirm the presence of Cu^{2+} ions in a sample, sodium hydroxide solution can be added. A blue precipitate of copper(II) hydroxide forms, indicating Cu^{2+}:

$$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s).$$

This precipitate is insoluble in excess NaOH.

Alternate solution:

Adding aqueous ammonia (NH_3) also forms the same blue precipitate initially:

$$Cu^{2+}(aq) + 2NH_3(aq) + 2H_2O(l) \rightarrow Cu(OH)_2(s) + 2NH_4^{+}(aq).$$

With excess NH_3, the precipitate dissolves to form a deep blue solution of the complex ion:

$$Cu(OH)_2(s) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^{-}(aq).$$

This characteristic colour change confirms the presence of Cu^{2+} ions.

Marker feedback:
Most students correctly identified Cu^{2+} as the metal cation in the filtrate.
To confirm presence of Cu^{2+} ions in a sample, **a chemical test** must be performed not **a flame test**. The chemical test maybe one of the above using either NaOH or ammonia to precipitate **copper** out and include the **colour** (observation) of the precipitate for the 2 marks.

Question 23(c) (3 marks)

Marking guidelines

Criteria	Marks
1. States the change in reagent concentration is an invalid step (use evidence to make a judgement)- 1 mark *Read Note 2. States that the concentration of sulfate ions supplied would not be sufficient to precipitate all Ca^{2+} ions OR uses a calculation to show that 0.01M of H_2SO_4 is insufficient to precipitate all Ca^{2+} ions (using Qsp to show that it is >> Ksp) OR using mass calculation to show that lower concentration only precipitates 3% while higher concentration precipitates 100% OR using limiting reagent argument to show that sulfate from 0.01M H_2SO_4 will not precipitate out ALL Ca^{2+} 3. Therefore, link 1 and 2 to show that not all Ca^{2+} will precipitate as residue 2 and would remain in filtrate 2 – thus not allowing separation of ions OR may refer to a negative test when solid residue 2 is tested/Ca^{2+} not distinguishable	3
• TWO of the above.	2
• ONE relevant piece of information.	1

Sample response:

The substitution of 0.01 M H_2SO_4 for 1.0 M H_2SO_4 in Step 3 would significantly reduce the validity of the separation process, particularly in the precipitation of calcium ions (Ca^{2+}) as calcium sulfate ($CaSO_4$). At a lower H_2SO_4 concentration, precipitation may not occur, or only a partial amount of Ca^{2+} would precipitate.

This would result in less or no solid residue 2, and calcium ions would remain in filtrate 2, leading to an incomplete separation of the original metal ions.

Note:
If response says valid because the question was interpreted as being about ion separation rather than separation via gravimetric analysis, then there must be some evidence in the form of Qsp vs Ksp to show that precipitation of CaSO4 will still occur with 0.01M acid -to get the second mark

Marker feedback:

Not an easy question to mark due to the various interpretation of this question. Most students were able to show that using the lower concentration of H_2SO_4 not all Ca^{2+} ions were precipitated out. But, some stopped short of saying where the calcium ions would then be found-in the filtrate

- Students who only looked at validity of an experiment in general without engaging in the method and talked about controlling variables-using 1M H_2SO_4 because 1M HCl was used-did not get any marks.

Alternate arguments using Ksp/limiting reagent:

Using (1.0 M H_2SO_4, 300 mL) reagent

- moles SO_4^{2-} added = 0.300 L × 1.0 M = 0.300 mol.
- total volume after addition = 0.200 + 0.300 = 0.500 L.
- [Ca2+](if no Ca precipitated yet) = 0.100 mol / 0.500 L = **0.20 M**.
- [$SO4^{2-}$]= 0.300 mol / 0.500 L = **0.60 M**.
- Ion product Qsp=[Ca2+][SO42−]=0.20×0.60=0.12.

Compare to Ksp (CaSO4) from HSC data sheet : 4.93 x 10^{-5}. Because Qsp≫ Ksp (0.12 ≫ 4.93 x10^{-5}), $CaSO_4$ will precipitate until either all Ca^{2+} is removed or sulfate is consumed. With 0.300 mol sulfate available there is plenty to precipitate all 0.100 mol Ca^{2+} (needs only 0.100 mol SO_4^{2-}), so **all Ca^{2+} will precipitate** in the original procedure

Using changed reagent (0.01 M H_2SO_4, 300 mL)

- moles SO_4^{2-} added = 0.300 L × 0.01 M = **0.00300 mol**.
- total volume again = 0.500 L.
- [$SO4^{2-}$]=0.00300/0.500=0.00600 M
- [Ca2+] (initially) = 0.100 / 0.500 = **0.20 M**.
- Ion product Qsp=0.20×0.00600=1.2×10^{-3}.
- Compare with Ksp ($CaSO_4$) 4.93 x 10^{-5}: Qsp (1.2×10^{-3})≫Ksp

- In both cases Qsp>Ksp so $CaSO_4$ **will begin to precipitate**.
- **But** with 0.01 M H_2SO_4 there is only **0.00300 mol SO_4^{2-}** available, so at most 0.00300 mol Ca (3% of the original 0.100 mol) can precipitate → only **~0.41 g** $CaSO_4$ (anhydrous). The remaining Ca^{2+} stays dissolved ([Ca^{2+}]final≈0.194 M).
- With 1.0 M H_2SO_4 there is large excess sulfate (0.300 mol), so **all Ca^{2+}** can be removed (≈13.6 g $CaSO_4$ anhydrous).

Question 24a (2 marks) Marker: ER

Marking guidelines

Criteria	Marks
• Sound understanding of the method outlined which would produce a natural indicator	2
• One piece of relevant information	1

Sample response:

Chop up some red cabbage and grind with a small volume of distilled water in a mortar and pestle. The purple liquid can be used as a natural indicator.
Alternate method is to boil shredded red cabbage in distilled water for a few minutes to extract the colour. Leave to cool and then use as a natural indicator.
[Note: beetroot, blueberries, purple carrots, coloured flower petals can all be used]

Marker feedback
Most students outlined the basic methodology of producing a natural indicator. Better responses clearly identified a natural material which was coloured and would therefore produce a coloured solution.
Weaker responses neglected to give a specific vegetable or fruit, writing cabbage rather than red cabbage.
Water was missing from many responses.

Question 24b (3 marks) Marker: ER

Marking guidelines

Criteria	Marks
• Clear method which shows sound understanding of the process needed for valid testing of the natural indicator so it can determine the pH of an unknown solution	3
• Limited understanding of the process for valid testing of the natural indicator	2
• One piece of relevant information	1

Sample response:

Series of solutions [could give e.g.] of known pH, measured using a pH probe, ranging from low pH to high pH including neutral prepared. Need to cover from strongly acidic through neutral to strongly basic.
1mL of each solution put into small test tube to which 1 drop of natural indicator added. [volume of solution not as important as indicating same volume of indicator being used each time]
Colour of indicator in each solution of known pH noted.
1mL of unknown solution placed in small test tube and 1 drop of natural indicator added.
Colour of the indicator noted and compared with the colours for solution of known pH to then determine the pH of the unknown.

Marker feedback
Better responses indicated a large range of solutions of known pH (determined with a pH probe) and clearly indicated that the volume of the natural indicator would be the same for all the solutions. Reference was

made to the noting of the colour of the natural indicator in the solutions of known pH. Then moved onto saying how the pH of the unknown solution could be determined.
Weaker responses were vague in the wording and used too few solutions of known pH or neglected to indicate how the natural indicator could be used to determine the pH of an unknown solution.

Question 24c (i) (1 mark) Marker: ER

Marking guidelines

Criteria	Marks
• Correct equation including water	1

Sample response:

$H\mathit{Phen}\ (aq) + H_20\ (l) \rightleftharpoons \mathit{Phen}^-\ (aq) + H_30^+\ (aq)$

Marker feedback
Overall done well but a lot of responses did not include water in the equation and good things states were not being marked.

Question 24c (ii) (3 marks) Marker:

Marking guidelines

Criteria	Marks
• Thorough understanding of the effect on an indicator when hydroxide ions are added. • Correctly links the disturbance to a decrease in hydronium ion concentration due to neutralisation reaction between hydroxide ion and hydronium ion • Correctly uses LCP to explain the direction the equilibrium shifts • Links the colour change to a more bright pink since [Phen^-] increases as a consequence	3
• Limited response	2
• A relevant piece of information	1

Sample response:

The hydronium ion concentration will decrease because of hydroxide ions from sodium hydroxide undergoing neutralisation reactions with them.

According to LCP, the equilibrium position will shift to the right in favour of the products to minimise this disturbance. This is because the forward reaction produced more hydronium ions.

Since Phen^- is also a product, its concentration will increase and the solution will turn more bright pink.

Marker feedback
Better responses were logical and showed a clear understanding of how indicators work using Le Chateliers Principle with a clear cause and effect relationship linked to the equation in (i) evident. Error carried forward was applied if the equation in part (i) was incorrect. Unfortunately, many responses did not link the observed effect of the indicator turning pink to the decrease in hydronium ion concentration and from there the reaction shifting to the right.

Question 25a (3 mark) 2025 Marker: ER

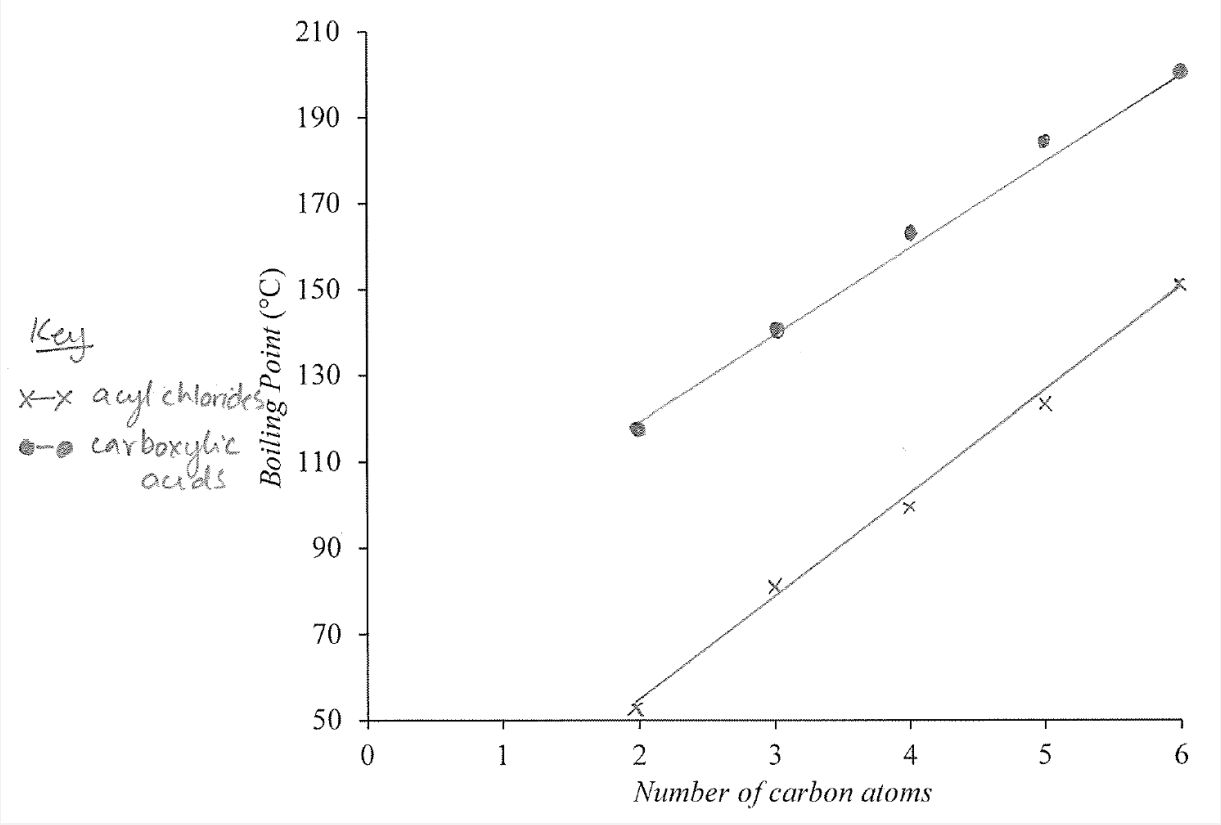
Marking guidelines

Criteria	Marks
• Plots data correctly • Draws 2 graphs with lines of best fit. • Must mention which graph is which	3
• Errors in plotting or no LOBF	2
• One of the above	1

Marker feedback
Poor plotting was evident in many of the graphs. Pleasingly most graphs had a clear key. A few poor lines of best fit but on the whole the lines were good. In a HSC examination it is worth double checking the plotting of a graph because they are good marks to have.

Sample response:

Graph:



Question 25b (3 marks)

Marking guidelines

Criteria	Marks
Thorough understanding of the intermolecular forces responsible for the physical property of boiling point. ○ link strength of IMF to increase in BP; ○ identify COOH have H bonding and dipole-dipole in addition to dispersion forces ○ identify COCl only have dipole-dipole forces, in addition to dispersion forces, requiring less energy to break hence lower BP.	3
• Two of the above covered with sound understanding	2
• Some relevant information linked to intermolecular forces or the trends visible in the graph.	1

Sample response:

The graph shows an increase in boiling point as the number of carbon atoms increases for both carboxylic acids and acyl chlorides. This trend occurs because increasing the carbon chain length increases the molecular mass and surface area, resulting in stronger dispersion forces between molecules. These intermolecular forces require more energy to overcome, leading to higher boiling points.
Carboxylic acids consistently exhibit higher boiling points than their corresponding acyl chlorides. This difference is due to the presence of strong hydrogen bonding between carboxylic acid molecules as well as dipole-dipole interactions, which occurs through the –OH and C=O groups. Additionally the carboxylic acid molecules can also form dimers, further increasing the BPs. In contrast, acyl chlorides do not form hydrogen bonds and rely only on dipole–dipole and dispersion forces, which are weaker than hydrogen bonding.

Marker feedback
Better responses were logical in their approach to the question and used comparative language well to link the relevant IMF to the boiling point for the two homologous series. Also used the appropriate intermolecular forces for the acids and the acyl chlorides.

Question 26(4 marks) Marker: ER

Marking guidelines

Criteria	Marks
• Explains how the concentration of ammonia is doubled because the volume is halved as a result of evaporation. • Identifies that Kb remains constant since temperature does not change. • Writes the equation for the solution. • Writes the Kb expression based on the equation. • Explains, using the equilibrium equation and Kb expression and proportionality, how the concentrations of reagents change if Kb is constant. • Links the concentration changes of reagents to how the equilibrium shifts and thus the degree of ionisation.	4
• Missing one key aspect of the explanation	3
• Two of the above e.g. equation plus expression or equation and a relevant correct statement	2
• One piece of relevant information.	1

Sample response:

When a solution of ammonia evaporates to **half its volume**, the **concentration of ammonia doubles**, since the amount of solute remains the same while the volume decreases. However, Kb remains the same since Kb only depends on temperature not concentration.

The equilibrium existing an an ammonia solution is:
$NH_{3(aq)} + H2O_{(l)} \rightleftharpoons NH_{4+(aq)} + OH_{-(aq)}$, and thus Kb= [NH4+][OH−]/[NH3]. Since [NH3] is the denominator [NH4+] and [OH−] in the numerator must decrease to ensure Kb remains constant.

Thus, this suggests that the equilibrium position has shifted left in favour of the reactants in the above equation and the degree of ionisation of ammonia should decrease.

Marker feedback:
To answer this question well it was best to start with the equation and the appropriate Kb expression. Then move onto the effect of decreasing volume on concentration before using of Le Chatelier to indicate the effect on the equilibrium. Better answers were able to use the proportionality of ammonia, ammonium and hydroxide to maintain Kb as a constant. Important to note that the only factor to impact the value of Kb would be a change in temperature. Change in the degree of ionisation was often stated correctly but linked to incorrect chemistry. The best responses were very logical in their approach.

Question 27a (3 marks) Marker:

Marking guidelines

Criteria	Marks
• Identifies that sodium chloride dissolves as a result of the ions forming ion-dipole bonds with water • Explains ion-dipole interactions only arise as a result of breaking hydrogen bonding between water and the electrostatic attraction (ionic bonds) between the sodium and chloride ions.	2
• One of the above • OR mentions when bonds break AND form between correct species	1

Sample response:

Sodium chloride dissolves in water because the sodium and chloride ions form **ion-dipole interactions** with water molecules. These interactions occur when the **partially negative oxygen end** of water is attracted to the positive sodium ion, and the **partially positive hydrogen end** of water is attracted to the negative chloride ion.

These **ion-dipole forces** are only able to form because they are **stronger than both** the **electrostatic (ionic) attraction** between the sodium and chloride ions in the solid lattice and the **hydrogen bonding** between water molecules.

Marker feedback:

- 1 mark was awarded for correctly identifying either the bond being broken *or* the bond being formed.
- 1 mark was awarded if you identified both the correct bonds broken and formed and specified which species these bonds involved.
- A total of 2 marks was awarded only if students correctly identified both the bonds that were broken and those that were formed, and clearly stated the species involved in each case.

Question 27b (3 marks) Marker:

Marking guidelines

Criteria	Marks
• Links Gibbs free energy to spontaneity of dissolution. • Compares the enthalpy values by linking to spontaneity to the equation • Compares the entropy values and links to spontaneity to the equation • Must link to solubility data	4
• Two of the above or three explained incomplete	2-3
• One of the above or any relevant information	1

Sample response:

For dissolution to occur spontaneously, ΔG must be negative. This means that a negative ΔH and positive ΔS favours dissolution.

1. NaCl – Dissolution is thermodynamically favourable:

- From the table, $\Delta H>0$ which does not favour dissolution
- $\Delta S >0$ +43 J/K.mol which favours dissolution.

However, since both factors are drivers of chemical reactions, the larger ΔS still ensures that dissolutions occur. Thus, the resulting $\Delta G<0$ shows that dissolution is spontaneous and why the solubility value is high at 360g/L

2. AgCl – Dissolution is thermodynamically unfavourable:

- $\Delta H° >0$ which does not favour dissolution
- $\Delta S° = –18$ J/K.mol which also does not favour dissolution.

Thus, the resulting $\Delta G>0$ and thus dissolution is not spontaneous why the solubility value is low at 0.00193g/L

Marker feedback:

- Many girls did quote data in their responses. However, please take care to include units. No marks were taken off for this as this was not question that tested for units.
- Many girls discussed what a positive and negative enthalpy/entropy value meant in terms of their definitions. However, we wanted a discussion based on spontaneity—how does each of these drivers of reactions contribute to a negative Gibb's Free energy and thus spontaneity.
- TP: Take care to answer the questions specifically— it's the spontaneity of dissolution (spontaneity of reaction is vague and you cannot have a 'spontaneous sodium chloride')

Question 28a (2 marks) Marker: DY

Marking guidelines

Criteria	Marks
• Specify where it is acting as an acid when it is acting as a base • Uses the equations above to illustrate the amphiprotic nature of water in relation to the Bronsted-Lowry theory	2
• One of the above or any relevant piece of information	1

Sample response:

- **In reaction 1:**
  Water acts as an acid as it donates a proton to the acetate ion.
- **In reaction 2:**
  Water acts as a base as it accepts a proton from acetic acid
- Since it can act as both a Bronsted-Lowry acid and base, it can be considered an amphiprotic substance.

Marker feedback:

- **2 marks** were awarded if the student correctly identified in which specific reaction water was acting as an acid or a base, and explained why — including whether water was donating or accepting a proton, and which species it was donating to or accepting from.
- **1 mark** was given if the student correctly identified either where water was donating or accepting a proton, even if the overall acid/base role was misidentified.
  (Note: Referring to the transfer of a "hydrogen" was not accepted — it must be identified as a hydrogen ion (proton)).
- **Teacher's Point (TP):**
  Be sure to mention:
  → If water is donating a proton, specify which species it is donating it to.
  → If water is accepting a proton, specify which species it is accepting it from.

Question 28b (3 marks) Marker: DY

Marking guidelines

Criteria	Marks
• Identifies solution is a buffer system and thus the pH has a small increase/negligible change. • Small increase/negligible in pH explained by providing: o how the added OH^- is neutralised/removed by the buffer o how pH change is minimised by the buffer by referring to the concentration of both [$CH3COO^-$] and [CH3COOH] OR linking the pH to minimal change in [H+] or [OH-].	3
• Incomplete explanation with relevant chemical equation. OR Sound explanation without a relevant chemical equation.	2
• One piece of relevant information provided.	1

Sample response(s)

The buffer system has relatively large and equal concentrations of acetic acid molecules and acetate ions. When the NaOH is added the hydroxide ions combine with acetic acid molecules to form acetate ions and water: $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$
Although this reaction is reversible, since the [CH_3COOH] is much greater than that of the added [OH^-], most of the hydroxide ions are neutralised and so the [H_3O^+] and therefore pH remains near their original level.

OR

Buffer equation: $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
When the NaOH is added the [H_3O^+] decreases due to $H_3O^+ + OH^- \rightarrow 2H_2O$. According to Le Chatelier's Principle, equilibrium position will shift right to counteract this disturbance because the forward reaction will produce and thus and increase the [H_3O^+]. Because the buffer contains relatively large and equal concentrations of CH_3COOH and CH_3COO^- the shift right returns the [H_3O^+] and hence pH to close to the original value (only slightly higher).

Marker feedback:

- Marks were awarded leniently.
  If a student correctly identified the system as a buffer and stated that a negligible change in pH would occur (even without explaining why), 1 mark was still awarded.
- Many students vaguely referred to Le Chatelier's Principle to explain the minimal change in pH. However, to gain full marks, the following elements were required:
  1. Correct identification of the disturbance (e.g. addition of acid or base).
  2. The buffer equation was either written or clearly referred to.
  3. Le Chatelier's Principle was used to:
     - Identify the direction the equilibrium shifts in response to the disturbance.
     - Explain why the shift occurs (i.e. to counteract the change).

- The final mark was awarded for stating in some way, the concentration of hydroxide ions returns close to its original value being the reason why pH is maintained.
- TP:
  - Realise a buffer is formed because it contained a weak acid and its conjugate in large and comparable amounts.
  - For an acidic buffer like this one, it is best to write the equilibrium equation including the hydronium ion (not the hydroxide ion) so:
    $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
    as opposed to:
    $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

Question 29 (4 marks) Marker:

Marking guidelines

Criteria	Marks
• Correctly calculates the concentration of Fluoride ions added. • Correctly calculates the concentration of Barium and the new fluoride concentration • Determines the correct Qsp from the correct Qsp general expression. • Deduces the correct direction the reaction will proceed from the Qsp expression using the correct BaF_2 ionisation reaction.	4
• Four or the above but missing working out. • Three of the above Or • Determines the initial concentrations/moles Barium or fluoride • Determines the initial concentration of Barium or fluoride • Determines the correct Qsp from the correct Qsp general expression. • Makes a correct conclusion of whether a precipitate will form.	3
• Two of the above and missing working out	2
• One of the above or any relevant piece of information	1

Sample response

[1] Determines the correct $[F^-]$ added

$MM_{(NaF)} = 22.99 + 19.00 = 41.99$

$n_{(NaF)} = \frac{0.100}{41.99} = 0.0023815194\ldots$ mol

$[F^-] = [NaF] = \frac{0.0023815194}{1} = 0.0023815194\ldots$ M (1:1)

[1] Determine the concentration of $[Ba^{2+}]$ and original $[F^-]$ from the Ksp

Let x= the solubility of BaF_2 in water

R	BaF_2	Ba^{2+}	$2F^-$
I	x	0	0
C	$-x$	x	$2x$
E		x	$2x$

$Ksp = 1.7 \times 10^{-6} = [Ba^{2+}][F^-]^2 = (x)(2x)^2 = 4x^3$

Therefore: $x = \sqrt[3]{\frac{1.7 \times 10^{-6}}{4}} =$ 0.00751847298…. M

Therefore:

- $[Ba^{2+}] = x$ = 0.00751847298…. M and
- Original $[F^-] = 2x$ = 0.00751847298... x 2 = 0.01503694596… M

[1] Determines the Final $[F^-]$

$[F^-] = 0.01503694596 + 0.0023815194 = 0.01741846537…$ M

[1] Determines which direction the equilibrium position shifts using the calculates Qsp

$Qsp = [Ba^{2+}][F^-]^2 = (0.00751847298….)(0.01741846537…)^2$

$= 2.3 \times 10^{-6}$ (2 significant figures)

Since Qsp>Ksp, the equilibrium position will shift left in favour of the reactants.

Marker feedback:

- **Show all working out clearly.**
  A mark was deducted if insufficient working was shown — for example, if no substitutions were included in your calculations.
- **Do not "chunk" together working out.**
  Each step should be written separately and clearly. In the HSC, marks may be deducted if your working is not logically and clearly presented.

Question 30 (7 marks) Marker: LT

Question 30(a) (4 marks)

Marking guidelines

Criteria	Marks

• Describes the changes in silver concentration around the first and second endpoint with reference to halide concentration in solution:
  ○ $[Ag^+]$ increases sharply around first endpoint (as all I^- is precipitated out).
  ○ $[Ag^+]$ increases sharply around second endpoint (as all Cl^- is precipitated out).
• Refers to relative K_{sp} values to determine that AgI will precipitate before AgCl.
• Provides two correctly balanced chemical equations to show formation of both AgCl and AgI.
• Demonstrates understanding of the relationship between $[Ag^+]$ and pAg
	4

• ONE of the above missing.	3
• TWO of the above missing.	2
• ONE relevant piece of information.	1

Sample response:

When silver nitrate is added to a solution containing both iodide and chloride ions, precipitation occurs in order of solubility. Since silver iodide is far less soluble (Ksp = 8.52×10^{-17}) than silver chloride (Ksp = 1.77×10^{-10}), AgI forms first:

$$Ag^+(aq) + I^-(aq) \rightarrow AgI(s).$$

The concentration of silver ions, $[Ag^+]$, remains very low and nearly constant while I^- is being removed. At the first endpoint (23.85 mL), all iodide is consumed, so $[Ag^+]$ rises sharply and pAg decreases suddenly. Silver ions then react with chloride ions according to:

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s).$$

Between the first and second endpoints, $[Ag^+]$ is relatively constant due to the solubility equilibrium of AgCl, keeping pAg relatively stable. At the second endpoint (47.41 mL), all Cl^- is consumed, and further addition of Ag^+ leads to a sharp increase in $[Ag^+]$ and a corresponding steep drop in pAg.

Question 30(b) (3 marks)

Marking guidelines

Criteria	Marks
• Correctly calculates number of moles of Ag^+ required to reach endpoint for I^- • Correctly calculates number of moles of Ag+ required to reach endpoint for Cl^- • Correctly determines concentration of both anions in solution.	3
• ONE mistake in calculation.	2
• ONE relevant step in calculation.	1

Sample response:

To calculate the number of moles of Ag^+ added to each endpoint:

First endpoint:

$$n(\mathrm{Ag^+}) = C \times V = (0.0845\,\mathrm{mol/L}) \times (0.02385\,\mathrm{L}) = 2.015 \times 10^{-3}\,\mathrm{mol}$$

Second endpoint:

Volume of Ag^+ added between endpoints = 47.41 mL − 23.85 mL = 23.56 mL = 0.02356 L

$$n(\mathrm{Ag^+}) = (0.0845\,\mathrm{mol/L}) \times (0.02356\,\mathrm{L}) = 1.990 \times 10^{-3}\,\mathrm{mol}$$

The concentration of each anion in solution can then be determined:

$$[\mathrm{I^-}] = \frac{2.015 \times 10^{-3}\,\mathrm{mol}}{0.04000\,\mathrm{L}} = 0.0504\,\mathrm{mol/L}$$

$$[\mathrm{Cl^-}] = \frac{1.990 \times 10^{-3}\,\mathrm{mol}}{0.04000\,\mathrm{L}} = 0.0498\,\mathrm{mol/L}$$

Question 31 (8 marks) Marker: LT

Question 31(a) (2 marks)

Marking guidelines

Criteria	Marks
• Correctly provides name of **Reaction 1**. • Provides correct balanced chemical equation for **Reaction 1**.	2
• ANY ONE of the above.	1

Sample response:

Reaction 1 is fermentation.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH(aq) + 2CO_2(g)$$

Note: Ethanol is often written as (*aq*) in the fermentation broth; some texts write it as (*l*) if considering the separated product. The presence of yeast was not required in the balanced chemical equation.

Question 31(b) (3 marks)

Marking guidelines

Criteria	Marks
• Correctly calculates the mass of bioethanol product required to release 1784 MJ. • Correctly calculates the volume of bioethanol product required from density. • States correct units.	3
• ONE error in calculation.	2
• ONE relevant step in calculation.	1

Sample response:

We know that 50.0 L of petroleum produces 11784 MJ of energy. Using the energy density provided we can determine the mass of biofuel product required:

$$\text{Mass} = \frac{\text{Energy required}}{\text{Energy density}} = \frac{1784\,\text{MJ}}{26.4\,\text{MJ/kg}} = 67.6\,\text{kg}$$

The volume of bioethanol product can be determined using the density provided 0.75 kg/L:

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{67.6\,\text{kg}}{0.75\,\text{kg/L}} = 90.1\,\text{L}$$

To produce the same amount of energy as 50.0 L of petroleum, 90.1 L of bioethanol is required.

Question 31(c) (3 marks)

Marking guidelines

Criteria	Marks
• Provides a judgement statement of the viability of bioethanol as an alternative to petroleum. • Provides a benefit to use of bioethanol as an alternative to fossil fuels. • Provides a limitation to the use of bioethanol as an alternative to fossil fuels.	3
• ONE - TWO of the above.	1 - 2

Sample response:

Bioethanol from pineapple juice is not a viable large-scale alternative to petroleum, as its lower energy density means much greater volumes are required to match the energy output of fossil fuels. While it offers the benefit of being renewable and producing fewer net greenhouse gas emissions, this limitation makes it impractical as a complete replacement for petroleum in meeting energy demands.

Other *benefits* could include (only ONE is required):

- Renewable resource (sustainable)
- Low/less energy needed for the process or lower temperatures required
- Uses waste plant material
- Low safety risk in process

Other *limitations* could include (only ONE required):

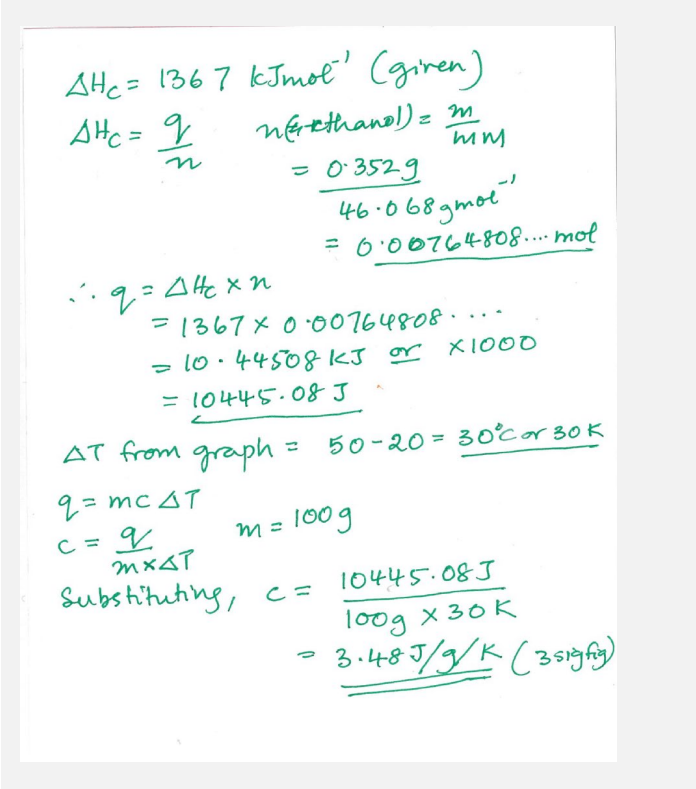
- Batch process/production of bioethanol is slow
- Ethanol is impure and contains water which needs to be further distilled.
- Petroleum produces more energy than biofuel product per unit mass of fuel

Question 32a (3 mark) Marker: SN

Marking guidelines

Criteria	Marks
• Using information provided in graph and stimulus, calculates specific heat capacity of oily liquid in J/g/K -calculates moles of ethanol -calculates dT from graph and substitutes in equation to correctly calculates sp.heat with correct units (J/g/K) • Values stated correctly to 3 s.f.	3
• One error in calculation or sig fig error	2
• A correct step or ecf of information	1

Sample response:



Marker feedback:

Most students understood question and were able to start with working out n(ethanol), then q and finally substitute in mcdt and work out 'c' of oily liquid with answer in J/g/K.

Many students are still not showing all their working to their detriment- often ending with unit and calculations mistakes which cost a mark.

Where students lost mark:

- Incorrect conversion of kJ to J (1kJ=1000J)
- Incorrect calculations of n(ethanol) -not knowing formula as C_2H_5OH?
- General calculation errors-
- A negative sign for calculated specific heat of liquid 'c'
- Incorrect sig figs (marked in this question)

Question 32b (2 marks) Marker: SN

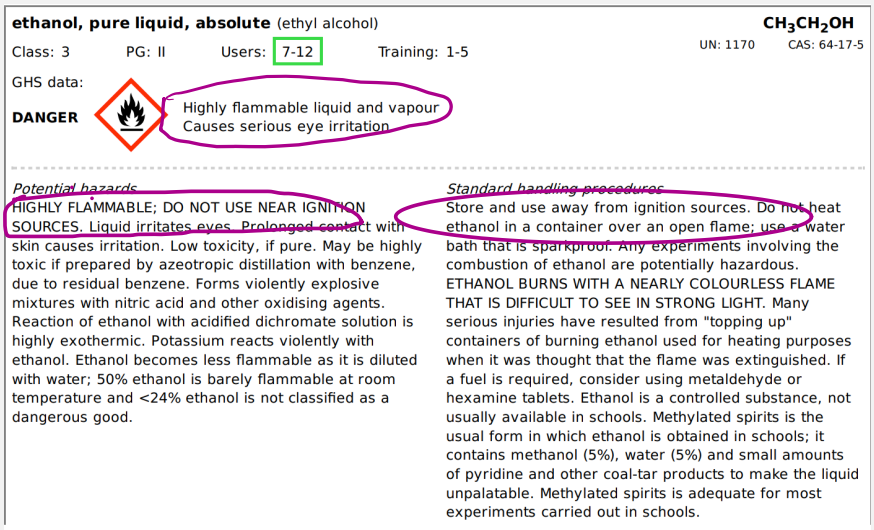
Marking guidelines

Criteria	Marks
• Identifies ONE risk associated with the use of an organic compound • Describes ONE safety precaution given (does not have to relate to the risk)	2
• Only risk identified with no precaution • One relevant piece of information	1

Sample response:

Note: safety glasses is 1 mark

Risk: Ethanol is highly flammable and volatile, eye irritant
Precaution: Keep away from flames and use in a well-ventilated area/fumehood



ethanol, pure liquid, absolute (ethyl alcohol) CH_3CH_2OH

Class: 3 PG: II Users: 7-12 Training: 1-5 UN: 1170 CAS: 64-17-5

GHS data:

DANGER

Highly flammable liquid and vapour
Causes serious eye irritation

Potential hazards

HIGHLY FLAMMABLE; DO NOT USE NEAR IGNITION SOURCES. Liquid irritates eyes. Prolonged contact with skin causes irritation. Low toxicity, if pure. May be highly toxic if prepared by azeotropic distillation with benzene, due to residual benzene. Forms violently explosive mixtures with nitric acid and other oxidising agents. Reaction of ethanol with acidified dichromate solution is highly exothermic. Potassium reacts violently with ethanol. Ethanol becomes less flammable as it is diluted with water; 50% ethanol is barely flammable at room temperature and <24% ethanol is not classified as a dangerous good.

Standard handling procedures

Store and use away from ignition sources. Do not heat ethanol in a container over an open flame; use a water bath that is sparkproof. Any experiments involving the combustion of ethanol are potentially hazardous. ETHANOL BURNS WITH A NEARLY COLOURLESS FLAME THAT IS DIFFICULT TO SEE IN STRONG LIGHT. Many serious injuries have resulted from "topping up" containers of burning ethanol used for heating purposes when it was thought that the flame was extinguished. If a fuel is required, consider using metaldehyde or hexamine tablets. Ethanol is a controlled substance, not usually available in schools. Methylated spirits is the usual form in which ethanol is obtained in schools; it contains methanol (5%), water (5%) and small amounts of pyridine and other coal-tar products to make the liquid unpalatable. Methylated spirits is adequate for most experiments carried out in schools.

Marker feedback:

Lack of engaging with the stimulus provided evident in many responses.
The question says 'ethanol was used to heat up a liquid hydrocarbon' – the response should be that hydrocarbons are 'flammable or volatile' (burning ethanol) and 'keep away from flame or use in well ventilated space/fumehood'.

- Most students had good understanding about the risk and precaution of using and handling hydrocarbons but many students did not read the stimulus carefully and used risks like 'reactive', toxic', 'corrosive' that were not relevant risks for ethanol/hydrocarbons in general- No marks were given for just those responses unless a specific risk was associated- eg. Burning hydrocarbon produces toxic fumes that irritate lung/skin (1 mark) and if the precaution was to conduct experiment in fumehood or well ventilated space then that earned 2 marks.
- Similarly responses like 'Irritate the skin and washing hands – only earned 1 mark as in the experiment the more obvious risk was the flammable and volatile hydrocarbon.
- For safety precautions- wearing safety glasses was only given 1 mark as this is a standard safety precaution for all Chemistry students conducting practicals and not specific to handling of hydrocarbons alone.

NOTE: Tying hair back, safety glasses, wear gloves etc only given a mark

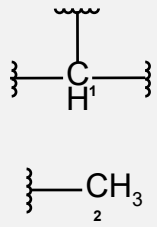
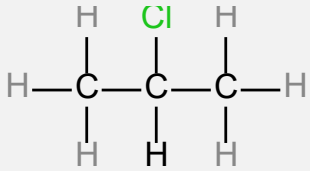
Question 33 (7 marks) - LT

Marking guidelines

Criteria	Marks
• Provides a correct structural formula (full traditional representation, skeletal or condensed structure) of 2-chloropropane. • Provides at least ONE correct conclusion from each observation of chemical test given. • Justifies the correct structure showing an extensive understanding of the interpretation of all necessary spectral features, including (but not limited to): o Provides ONE relevant piece of information from MS consistent with structure determination: ▪ shows an understanding that the two molecular ions (M^+ 78/80) ▪ fragment ions at m/z 63/65 arise from the two naturally occurring isotopes of Cl. ▪ provides a structure consistent with the fragment ion formed at m/z 43. o the absorption at approx $\tilde{\nu}_{max}$ 3000 cm^{-1} indicating the presence of the C-H stretch of the alkane functional group. o identifies the presence of TWO distinct carbon environments within the molecule = two carbons are in the same environment (evidence of symmetry) o identifies the presence of TWO distinct H environments: ▪ 1 × septet (δ 3.69 ppm) = 6 adj Hs (H next to two CH_3 groups) ▪ 1 × doublet (δ 1.4 ppm) = 1 adj Hs • Refers explicitly to the relevant spectral data.	7
• Provides a correct structural formula for an isomer of 2-chloropropane. • Justifies the correct structure showing a thorough understanding of the interpretation of all necessary spectral features. • Refers to ALL relevant spectral data.	5 - 6
• Shows a sound understanding of the interpretation of spectroscopic data. • Uses relevant information presented in the question to justify the structure of the chemical. • Provides a structural formula consistent with analysis.	3 - 4
• Shows some understanding of the interpretation of spectroscopic data.	1 - 2

Sample response:

Spectra	*Feature*	*Conclusion*
Chemical tests	No addition reaction with bromine (not alkene/alkyne) No reaction with acidified potassium dichromate (not 1,2 alcohol or aldehyde)	= saturated molecule = alkane?
IR	Sharp absorptions at $\tilde{\nu}_{max}$ 3000 cm^{-1} indicating the presence of the C-H stretch of the alkane functional group	= alkane = haloalkane (known to contain halogen)

^{13}CNMR	2 carbon environments: - 1×C_1 δ 55 ppm chemical shift indicative of possible -CH/-CCl - 1×C_2 δ 29 ppm chemical shift indicative of possible -CH_3	
^{1}HNMR	2 H total in 2 distinct chemical environments: - H_a at δ 3.69 ppm septet = 6 chemically equivalent adjacent Hs = next to 2 × −CH_3 - H_b at δ 1.4 ppm doublet = next to −CH	
MS	2 × M^+ ions confirms the presence of ONE chlorine atom: - $M^{+\bullet}$ at *m/z* 80 = evidence of ^{37}Cl in molecular ion - $M^{+\bullet}$ at *m/z* 78 = evidence of ^{35}Cl in molecular ion - *m/z* 65 = $[CH_3CH^{37}Cl]^+$ = loss of CH_3 from $M^{+\bullet}$ at *m/z* 80 - *m/z* 63 = $[CH_3CH^{35}Cl]^+$ = loss of CH_3 from $M^{+\bullet}$ at *m/z* 78 - *m/z* 43 = $[CH_3CHCH_3]^+$ = loss of Cl (no isotopic contribution to this fragment)	
Putting it all together		

Question 34 (5 marks)

Marking guidelines

Criteria	Marks
• Mentions the observed trends displayed on the graph – Steeper initial gradient or reaches equilibrium faster – Lower yield • Correctly explains using collision theory and rate of reaction for the initial steeper gradient. • Links the lower yield of methanol at 500K with reference to Keq, the endothermic reverse reaction, higher activation energy, rate of reaction and equilibrium position shift.	4
• Three of the above	3
• Two of the above	2
• One of the above or any relevant information.	1

Sample response:

At a higher temperature, all reagents have a higher average kinetic energy. The collision theory states that this results in a greater frequency of successful collisions above the activation energy, and thus greater reaction rate, assuming reactants collide in the correct orientation. For this reason, the 500K curve has a steeper initial gradient and reaches equilibrium faster than the 300K.

However, since the $\Delta H < 0$, the reverse reaction is endothermic. Since it has a higher activation energy, the increase in temperature will enable methanol to undergo a greater increase in the frequency of successful collisions in comparison to the reactants and the equilibrium position shifts to the left. The consequence is that, at 500K the equilibrium concentration of methanol is lower. This explains its lower Keq value ($3.27 \times 10^{-8} < 0.233$) is directly proportional to the [reactant] and inversely proportional to the [product].

Marker feedback:

- Avoid using Le Chatelier's Principle when the question specifically requires an explanation using collision theory. Using the wrong theory may result in a loss of marks.

- To gain marks for collision theory, students must clearly link the concept to reaction rate. This includes references to:
  - An increased frequency of successful collisions, or
  - More successful collisions per unit time,

  and how this leads to a steeper initial gradient on a graph or equilibrium being reached faster.
- To achieve the final, students were expected to:
  - Discuss the lower equilibrium concentration of methanol at 500 K,
  - Explain this in terms of the endothermic reaction being favoured,
  - Recognise that the endothermic pathway has a lower activation energy,
  - Link this to the proportionality of Keq