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Centre Number

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Student Number

Sigma Science Education

2026 MOCK 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
- Write your Centre Number and Student Number at the top of this page

Total marks:
100

Section I – 20 marks (pages 2–9)

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

Section II – 80 marks (pages 11–34)

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section



Revision edition. The Σ tags in the right margin list past HSC Chemistry questions (year and question number, 2019–2025) that test similar content or skills. Use them for targeted practice after attempting each question.

Section I

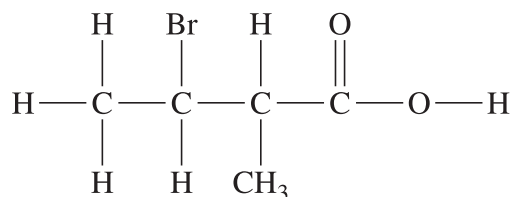
20 marks

Attempt Questions 1–20

Allow about 35 minutes for this section

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

- 1 What is the preferred IUPAC name of this compound?



- A. 2-bromo-3-methylbutanoic acid
- B. 2-methyl-3-bromobutanoic acid
- C. 3-bromo-2-methylbutanoic acid
- D. 3-bromo-2-methylpropanoic acid

 **SIMILAR**
2020 Q6
2022 Q7
2024 Q12

- 2 Which reagent could be used to distinguish between separate solutions of sodium carbonate and sodium sulfate?

- A. Dilute nitric acid
- B. Barium nitrate solution
- C. Sodium hydroxide solution
- D. Potassium nitrate solution

 **SIMILAR**
2022 Q5
2023 Q30
2025 Q4

- 3 Which of the following reactions produces propan-2-ol as the ONLY organic product?

- A. Propene reacting with water in the presence of dilute sulfuric acid
- B. 1-bromopropane heated with aqueous sodium hydroxide
- C. Propanal heated under reflux with acidified potassium permanganate
- D. 2-bromopropane heated with aqueous sodium hydroxide

 **SIMILAR**
2021 Q7
2021 Q13

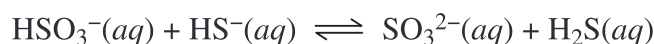
- 4 A colourless organic liquid rapidly decolourises bromine water in the absence of UV light. It also produces bubbles of gas when added to sodium carbonate solution.

 SIMILAR
2020 Q9
2021 Q21(b)
2024 Q35

Which of the following could be the liquid?

- A. Pentanoic acid
- B. Pent-4-enoic acid
- C. Pent-4-en-2-ol
- D. Pent-2-ene

- 5 Consider the following reaction.



 SIMILAR
2019 Q18
2022 Q10
2022 Q22

Which pair of species are BOTH acting as Brønsted–Lowry acids?

- A. HSO_3^- and HS^-
- B. HS^- and SO_3^{2-}
- C. HSO_3^- and H_2S
- D. SO_3^{2-} and H_2S

- 6 Which alcohol produces only ONE alkene when heated with concentrated sulfuric acid? (Ignore geometric isomers.)

 SIMILAR
2020 Q29
2022 Q11

- A. Butan-2-ol
- B. 2-methylbutan-2-ol
- C. Pentan-2-ol
- D. Pentan-3-ol

- 7 Consider the following equilibrium.



 SIMILAR
2021 Q11
2023 Q12
2024 Q7

Which change would DECREASE the equilibrium amount of NOBr?

- A. Adding argon gas at constant pressure
- B. Adding argon gas at constant volume
- C. Decreasing the temperature
- D. Adding more bromine gas

- 8 Bromine has two isotopes, ^{79}Br and ^{81}Br , in almost equal abundance. Chlorine has two isotopes, ^{35}Cl and ^{37}Cl , in an approximate ratio of 3 : 1.

 SIMILAR
2020 Q15
2024 Q38

The mass spectrum of a haloalkane shows two molecular ion peaks, at $m/z = 122$ and $m/z = 124$, of almost equal height.

Which compound was analysed?

- A. 1-chloropropane
 - B. 1-bromopropane
 - C. Bromoethane
 - D. 2-bromobutane
- 9 Oxalic acid ($\text{H}_2\text{C}_2\text{O}_4$) is a diprotic acid. A 25.00 mL aliquot of an oxalic acid solution required 22.40 mL of $0.1000 \text{ mol L}^{-1}$ sodium hydroxide solution for complete neutralisation.

 SIMILAR
2020 Q25
2022 Q32(a)
2023 Q14

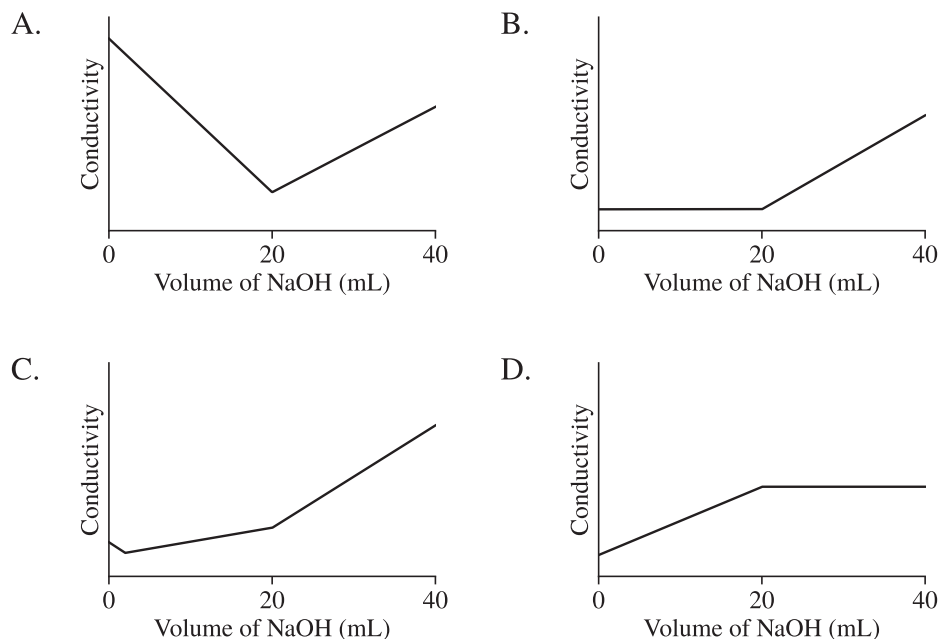
What is the concentration of the oxalic acid solution?

- A. $0.04480 \text{ mol L}^{-1}$
- B. $0.05580 \text{ mol L}^{-1}$
- C. $0.08960 \text{ mol L}^{-1}$
- D. $0.1116 \text{ mol L}^{-1}$

- 10 A 0.10 mol L^{-1} sodium hydroxide solution is added from a burette to 20.0 mL of 0.10 mol L^{-1} ethanoic acid.

SIMILAR
2019 Q24(a)
2022 Q15
2024 Q34

Which graph best represents the change in conductivity of the solution in the flask?



- 11 Consider the thermal decomposition of calcium carbonate.



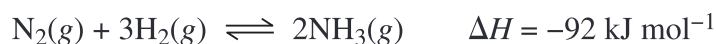
$$\begin{aligned}\Delta H^\circ &+178 \text{ kJ mol}^{-1} \\ \Delta S^\circ &+161 \text{ J K}^{-1} \text{ mol}^{-1}\end{aligned}$$

SIMILAR
2019 Q30
2021 Q33(a)
2024 Q37

Under standard conditions, this reaction is spontaneous

- A. at all temperatures.
B. only above 1106 K .
C. only below 1106 K .
D. at no temperature.

- 12 Consider the following system at equilibrium in a sealed container.



 **SIMILAR**
2019 Q25(b)
2022 Q23(c)
2024 Q26(b)

The volume of the container is halved at constant temperature.

Which statement best describes the rates of the forward and reverse reactions immediately after the change?

- A. Both rates increase by the same factor.
B. The forward rate increases and the reverse rate decreases.
C. Both rates are unchanged because the temperature is constant.
D. Both rates increase, but the forward rate increases more than the reverse rate.
- 13 The concentration of lead ions in a sample of drinking water was determined using atomic absorption spectroscopy (AAS). A 50.0 mL sample was diluted to 250.0 mL with distilled water.

 **SIMILAR**
2019 Q20
2021 Q14
2022 Q4

The calibration curve for the analysis has the equation $A = 0.0750c$, where A is the absorbance and c is the concentration of lead in mg L^{-1} . The absorbance of the diluted sample was 0.0180.

What was the concentration of lead ions in the original water sample?

- A. $1.16 \times 10^{-6} \text{ mol L}^{-1}$
B. $5.79 \times 10^{-6} \text{ mol L}^{-1}$
C. $2.90 \times 10^{-5} \text{ mol L}^{-1}$
D. $1.20 \times 10^{-3} \text{ mol L}^{-1}$
- 14 A student burnt 0.740 g of butan-1-ol ($MM = 74.12 \text{ g mol}^{-1}$) in a spirit burner to heat 250.0 g of water. The temperature of the water increased by 15.6°C . The molar enthalpy of combustion of butan-1-ol is $-2676 \text{ kJ mol}^{-1}$.

 **SIMILAR**
2019 Q23(a)
2023 Q25(a)
2024 Q13

What percentage of the heat released by the combustion was absorbed by the water?

- A. 0.61%
B. 39%
C. 61%
D. 82%

- 15 A buffer solution with a pH of approximately 9.2 is required.

<i>Acid</i>	<i>Conjugate base</i>	<i>pK_a of acid</i>
NH ₄ ⁺	NH ₃	9.25
HOCl	OCl ⁻	7.53
CH ₃ COOH	CH ₃ COO ⁻	4.76
HCO ₃ ⁻	CO ₃ ²⁻	10.33

Which acid and its conjugate base would be most suitable for preparing this buffer?

- A. NH₄⁺ and NH₃
B. HOCl and OCl⁻
C. CH₃COOH and CH₃COO⁻
D. HCO₃⁻ and CO₃²⁻
- 16 0.400 mol of chlorine gas and 0.400 mol of fluorine gas were placed in a sealed 2.00 L vessel and allowed to reach equilibrium.



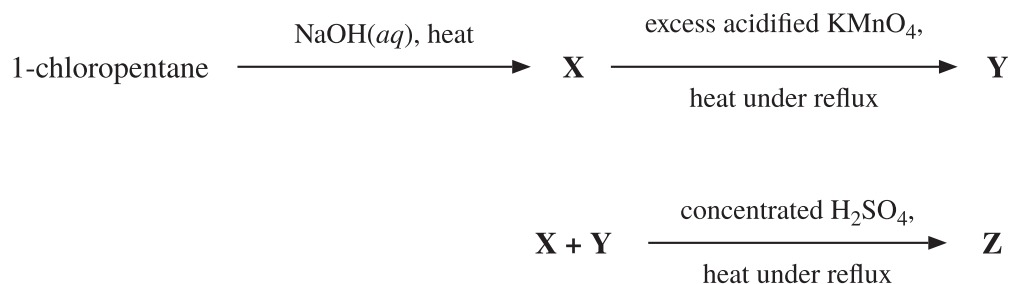
What is the equilibrium concentration of ClF?

- A. 0.0444 mol L⁻¹
B. 0.133 mol L⁻¹
C. 0.320 mol L⁻¹
D. 0.267 mol L⁻¹

 **SIMILAR**
2019 Q22
2024 Q16
2025 Q19

 **SIMILAR**
2022 Q13
2023 Q7
2024 Q30

- 17 Consider the following reaction sequence.



What is the molar mass of compound Z?

- A. 158.2 g mol⁻¹
B. 172.3 g mol⁻¹
C. 186.3 g mol⁻¹
D. 144.2 g mol⁻¹
- 18 Consider the ¹H NMR spectrum of 1-bromo-3-chloropropane, BrCH₂CH₂CH₂Cl.

Using the $n + 1$ rule, which row of the table correctly identifies the number of signals in the spectrum and the splitting pattern of the signal produced by the protons on the central carbon atom?

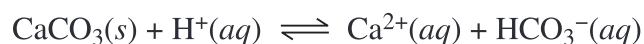
	<i>Number of signals</i>	<i>Splitting of central CH₂ signal</i>
A.	3	quintet
B.	2	quintet
C.	3	triplet
D.	2	triplet

Σ SIMILAR
2019 Q34
2021 Q26(a)
2025 Q15

Σ SIMILAR
2019 Q14
2021 Q18
2024 Q19

- 19 Calcium carbonate dissolves in acidic solutions.

 SIMILAR
2019 Q27(a)
2021 Q36



The acid dissociation constant of the hydrogen carbonate ion is shown.



Using this information and data from the data sheet, what is the equilibrium constant for the dissolution of calcium carbonate in acid?

- A. 1.6×10^{-19}
B. 1.4×10^{-2}
C. 6.3×10^{18}
D. 71
- 20 100.0 mL of 0.0400 mol L⁻¹ silver nitrate solution is mixed with 100.0 mL of 0.0300 mol L⁻¹ sodium chloride solution at 25°C.

 SIMILAR
2019 Q17
2022 Q35
2023 Q34

What is the concentration of chloride ions in the resulting solution once equilibrium has been established?

- A. $1.33 \times 10^{-5} \text{ mol L}^{-1}$
B. $1.77 \times 10^{-8} \text{ mol L}^{-1}$
C. $3.54 \times 10^{-8} \text{ mol L}^{-1}$
D. $8.85 \times 10^{-9} \text{ mol L}^{-1}$

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Centre Number

Chemistry

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Student Number

Section II Answer Booklet

80 marks

Attempt Questions 21–36

Allow about 2 hours and 25 minutes for this section

Instructions

- Write your Centre Number and 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 (5 marks)

Butan-2-ol can be oxidised to butanone.

- (a) Using structural formulae, write a chemical equation for this reaction. Include the reagent and conditions required. You may use [O] to represent the oxidising agent.

2

 **SIMILAR**
2019 Q21(c)
2022 Q27(c)

- (b) The table shows data for three organic compounds.

3

 **SIMILAR**
2019 Q32
2020 Q32
2024 Q24(b)

<i>Compound</i>	<i>Molecular formula</i>	<i>Molar mass (g mol⁻¹)</i>	<i>Boiling point (°C)</i>
Butan-2-ol	C ₄ H ₁₀ O	74.12	100
Butanone	C ₄ H ₈ O	72.10	80
Pentane	C ₅ H ₁₂	72.15	36

Explain the differences in the boiling points of these compounds with reference to their intermolecular forces.

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Question 22 (4 marks)

Phosphoric acid (H_3PO_4) is a triprotic acid. The acid dissociation constants for phosphoric acid at 25°C are shown.

Equilibrium	K_a
$\text{H}_3\text{PO}_4(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{H}_2\text{PO}_4^-(\text{aq})$	7.1×10^{-3}
$\text{H}_2\text{PO}_4^-(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HPO}_4^{2-}(\text{aq})$	6.3×10^{-8}
$\text{HPO}_4^{2-}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$	4.5×10^{-13}

- (a) Write the formulae of the conjugate acid and the conjugate base of the dihydrogen phosphate ion, H_2PO_4^- .

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1

Σ SIMILAR
 2022 Q22
 2023 Q24

- (b) A 0.10 mol L^{-1} solution of sodium dihydrogen phosphate (NaH_2PO_4) is acidic, while a 0.10 mol L^{-1} solution of disodium hydrogen phosphate (Na_2HPO_4) is basic.

Explain these observations. Support your answer with relevant chemical equations and calculations using the data provided.

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3

Σ SIMILAR
 2020 Q10
 2020 Q18
 2021 Q23(b)

Question 23 (5 marks)

40.0 mL of 0.500 mol L⁻¹ sulfuric acid and 60.0 mL of 0.700 mol L⁻¹ potassium hydroxide solution, both initially at 22.1°C, were mixed in a polystyrene calorimeter. The maximum temperature reached was 27.1°C.

The heat capacity of the calorimeter is 41.0 J K⁻¹. Assume that the solutions have the same density and specific heat capacity as water.

- (a) Calculate the molar enthalpy of neutralisation, in kJ mol⁻¹.

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 **SIMILAR**
2020 Q36
2022 Q26(a)

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- (b) The experiment was repeated using 60.0 mL of 0.700 mol L⁻¹ aqueous ammonia in place of the potassium hydroxide solution.

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 **SIMILAR**
2021 Q32
2022 Q26(b)

Predict how the temperature rise would compare with the first experiment. Justify your prediction.

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Question 24 (5 marks)

A solution contains 0.010 mol L^{-1} barium ions and 0.010 mol L^{-1} calcium ions. A chemist plans to separate the two ions by slowly adding sodium sulfate solution. Assume that the volume of the solution does not change.

- (a) Explain why a flame test would NOT be a suitable method to confirm that both ions are present in this solution.

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 **SIMILAR**
2021 Q30
2022 Q5
2024 Q8

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- (b) Calculate the percentage of the barium ions that remain in solution at the moment calcium sulfate begins to precipitate. Use data from the data sheet.

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 **SIMILAR**
2024 Q27
2025 Q32

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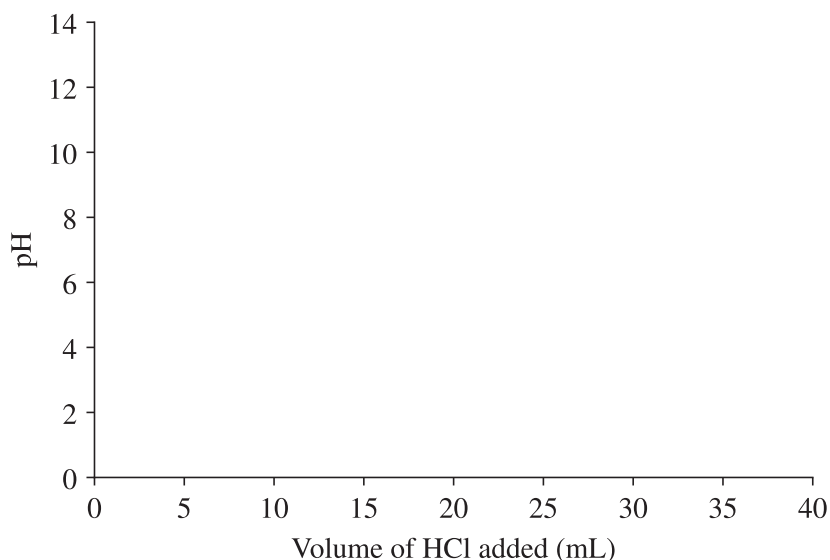
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Question 25 (6 marks)

Ammonia-based buffers are used in laboratory tests for magnesium ions. A student titrated 20.0 mL of a 0.10 mol L⁻¹ ammonia solution with 0.10 mol L⁻¹ hydrochloric acid.

- (a) On the axes provided, sketch the expected titration curve. Label the equivalence point.



- (b) A buffer solution contains 0.250 mol L⁻¹ ammonia and 0.150 mol L⁻¹ ammonium chloride. K_b for ammonia is 1.8×10^{-5} at 25°C.

Explain how this buffer minimises the change in pH when a small amount of hydrochloric acid is added, and calculate the pH of the buffer at 25°C. Include a relevant chemical equation.

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Σ SIMILAR
2019 Q6
2020 Q8

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Σ SIMILAR
2019 Q22
2021 Q34
2023 Q23

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Question 26 (5 marks)

Ethanol for use as a fuel can be produced by two different methods. Some information about each method is shown.

5

 **SIMILAR**
2020 Q24(d)
2023 Q25(b)
2025 Q27(b)

	<i>Fermentation of sugar cane</i>	<i>Hydration of ethene</i>
<i>Raw material</i>	Glucose from sugar cane (renewable)	Ethene from crude oil (non-renewable)
<i>Conditions</i>	30–37°C, yeast, absence of oxygen, atmospheric pressure	300°C, 6–7 MPa, phosphoric acid catalyst
<i>Rate and process</i>	Slow; batch process taking several days	Fast; continuous process
<i>Product</i>	Aqueous mixture containing about 15% ethanol	About 5% conversion per pass; unreacted ethene is recycled; high-purity ethanol
<i>By-products</i>	Carbon dioxide	Small amounts of ethoxyethane

Evaluate the suitability of each method for producing ethanol for use as a fuel. Include a relevant chemical equation for each method.

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Question 27 (4 marks)

A flavour manufacturer produces pentyl ethanoate ($MM = 130.18 \text{ g mol}^{-1}$) by heating pentan-1-ol ($MM = 88.15 \text{ g mol}^{-1}$) with excess ethanoic acid and a small amount of concentrated sulfuric acid under reflux.

The process has a yield of 70.0%, based on the amount of pentan-1-ol used.

- (a) Explain why the mixture is heated under reflux, and why excess ethanoic acid is used.

2

 **SIMILAR**
2021 Q26(b)
2022 Q33

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- (b) Calculate the mass of pentan-1-ol needed to produce 50.0 g of pentyl ethanoate.

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 **SIMILAR**
2025 Q25
2025 Q27(c)

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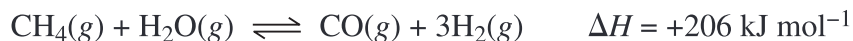
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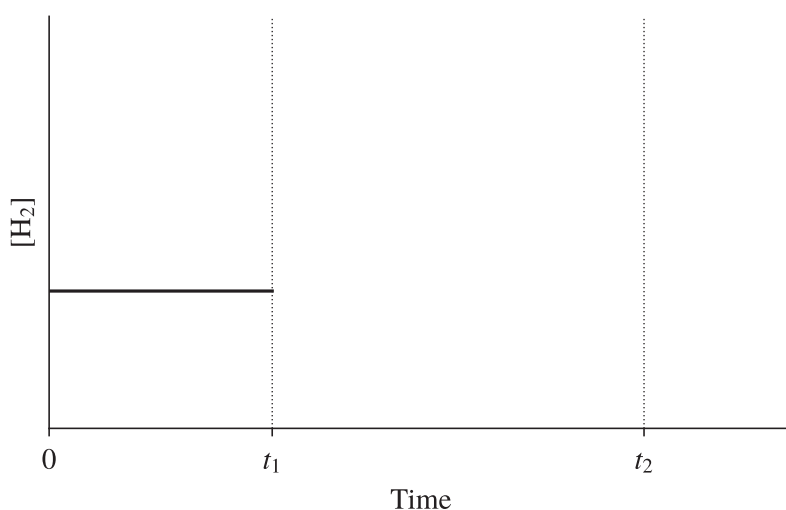
Question 28 (4 marks)

Hydrogen gas is produced industrially by the steam reforming of methane.



A mixture of these gases was at equilibrium in a sealed container of fixed volume. At time t_1 , the temperature of the container was increased. The system reached a new equilibrium at time t_2 .

The graph shows the concentration of hydrogen gas up to time t_1 .



On the graph, sketch the change in the concentration of hydrogen gas from time t_1 to time t_2 . Using collision theory, explain the changes in the rates of the forward and reverse reactions after time t_1 .

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SIMILAR
2019 Q25
2024 Q26
2025 Q29

Do NOT write in this area.

Question 29 (4 marks)

A 0.150 mol L^{-1} solution of propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$) has a pH of 2.85 at 25°C .

10.0 mL of this solution was diluted to 100.0 mL with distilled water.

Calculate the pH of the diluted solution. Include a relevant chemical equation.

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 **SIMILAR**
2021 Q6
2023 Q35(a)
2024 Q28

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Question 30 (3 marks)

A 2.000 g sample containing only sodium chloride and potassium chloride was dissolved in water. Excess silver nitrate solution was added. The precipitate was filtered, washed and dried to constant mass. The mass of the dry precipitate was 4.482 g.

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 **SIMILAR**
2021 Q28
2022 Q28(b)
2025 Q23

Calculate the percentage by mass of sodium chloride in the sample.

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Question 31 (4 marks)

The K_{sp} of calcium fluoride (CaF_2) is 3.45×10^{-11} at 25°C .

- (a) Calculate the molar solubility of calcium fluoride in pure water at 25°C .

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 **SIMILAR**
2022 Q19
2024 Q32

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- (b) A town's water supply contains $4.0 \times 10^{-3} \text{ mol L}^{-1}$ calcium ions. Fluoride ions are added to the water.

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 **SIMILAR**
2021 Q19
2023 Q34

Calculate the maximum concentration of fluoride ions, in mg L^{-1} , that can be present in the water without calcium fluoride precipitating.

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Question 32 (3 marks)

The overall equation for photosynthesis is shown.



$$\begin{array}{ll} \Delta H^\circ & +2803 \text{ kJ mol}^{-1} \\ \Delta S^\circ & -262 \text{ J K}^{-1} \text{ mol}^{-1} \end{array}$$

3

 **SIMILAR**
2021 Q33(b)
2022 Q36
2024 Q37

Photosynthesis in a leaf is described as a non-equilibrium system. Explain why. Support your answer with a calculation at 25°C.

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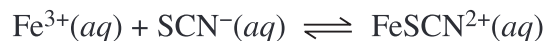
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Question 33 (7 marks)

Iron(III) ions react with thiocyanate ions to form the red complex ion FeSCN^{2+} .



FeSCN^{2+} is the only species in the mixture that absorbs light at 447 nm. At this wavelength, its molar absorptivity (ϵ) is $4.60 \times 10^3 \text{ L mol}^{-1} \text{ cm}^{-1}$.

A student prepared three mixtures using $2.00 \times 10^{-3} \text{ mol L}^{-1} \text{ Fe}(\text{NO}_3)_3$ solution, $2.00 \times 10^{-3} \text{ mol L}^{-1} \text{ KSCN}$ solution and distilled water. Once each mixture reached equilibrium at 25°C , its absorbance was measured in a cell with a path length of 1.00 cm.

Mixture	Volume of $\text{Fe}(\text{NO}_3)_3$ solution (mL)	Volume of KSCN solution (mL)	Volume of water (mL)	Absorbance
1	5.00	5.00	0.00	0.495
2	6.00	3.00	1.00	0.372
3	3.00	4.00	3.00	0.256

Calculate the average value of the equilibrium constant for this reaction at 25°C .

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Question 33 continues on page 25

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 **SIMILAR**
2022 Q31
2023 Q31
2024 Q25

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Question 33 (continued)

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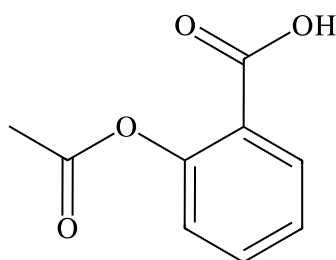
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End of Question 33

Question 34 (9 marks)

Aspirin (acetylsalicylic acid, $\text{C}_9\text{H}_8\text{O}_4$, $MM = 180.16 \text{ g mol}^{-1}$) has the structure shown.



When heated, aspirin reacts completely with excess hydroxide ions.



The label on a packet of aspirin tablets states that each tablet contains 300 mg of aspirin. Regulations require the actual mass of aspirin in each tablet to be within 5% of the stated mass.

A tablet was analysed using the following procedure.

- The tablet was crushed and added to 25.00 mL of $0.2000 \text{ mol L}^{-1}$ sodium hydroxide solution.
- The mixture was heated to complete the reaction, then cooled.
- The mixture was transferred quantitatively to a 100.0 mL volumetric flask and made up to the mark with distilled water.
- 20.00 mL aliquots of this solution were titrated with $0.02500 \text{ mol L}^{-1}$ hydrochloric acid, using phenolphthalein as the indicator.

<i>Titration</i>	1	2	3	4
<i>Volume of HCl (mL)</i>	15.42	14.98	14.92	14.97

Question 34 continues on page 27

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Question 35 (4 marks)

Propyl ethanoate is used as a solvent and as a food flavouring.

Using 1-chloropropane and ethene as the **ONLY** organic starting materials, outline a reaction pathway to synthesise propyl ethanoate. Include structural formulae, reagents and conditions for each step.

4

 **SIMILAR**
2019 Q34
2021 Q26(a)
2025 Q37

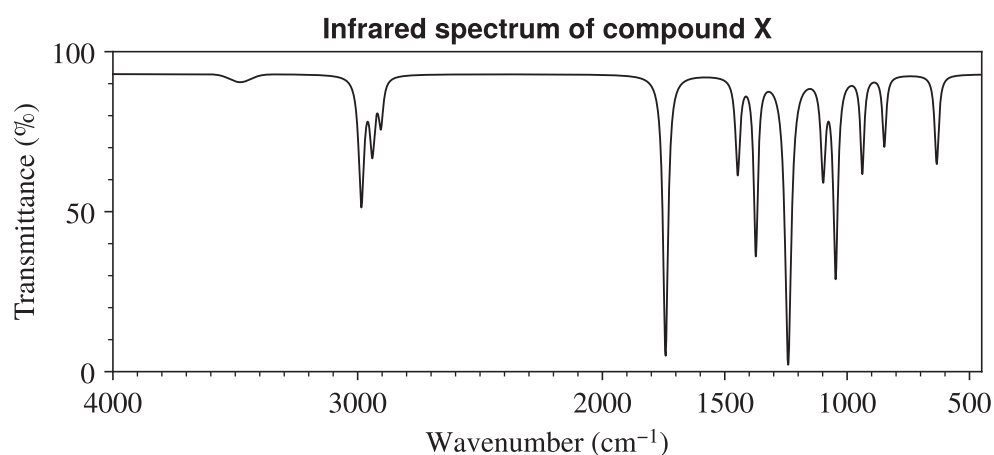
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Question 36 (8 marks)

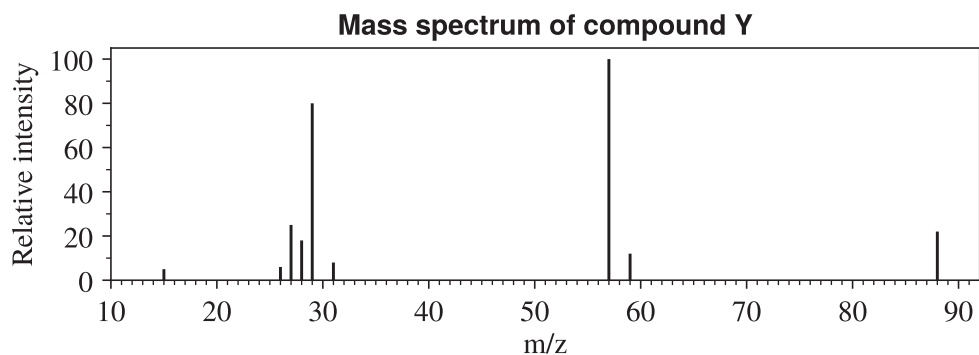
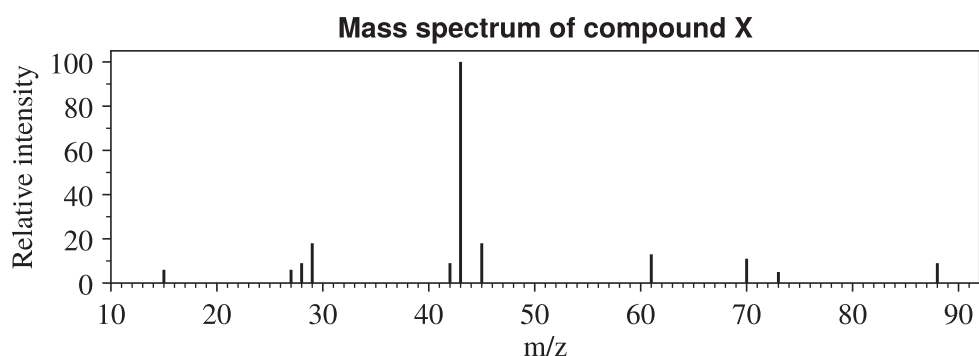
Use the data sheet provided and the information in the tables to answer this question.

Compounds X and Y are isomers with the molecular formula $C_4H_8O_2$. Neither compound reacts with sodium carbonate solution.

The infrared spectrum of X is shown. The infrared spectrum of Y is very similar.



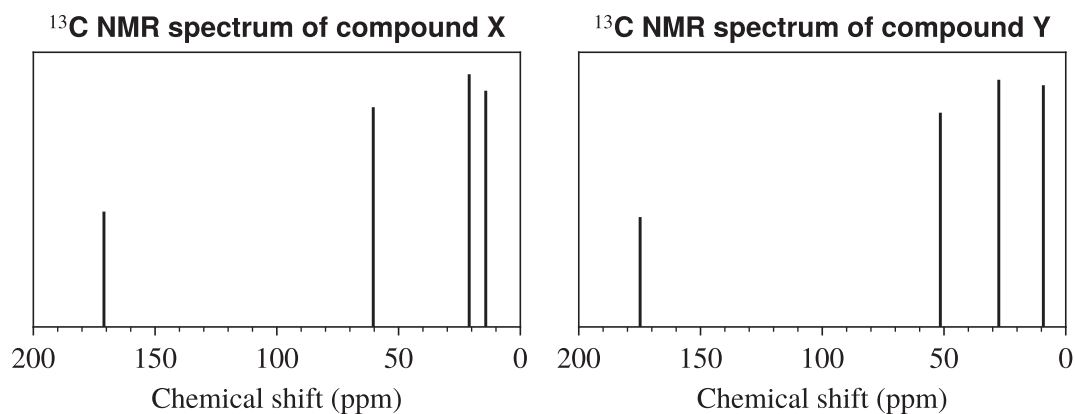
The mass spectra of X and Y are shown.



Question 36 continues on page 30

Question 36 (continued)

The ^{13}C NMR spectra of X and Y are shown.



Data from ^1H NMR spectra

Compound	Chemical shift (ppm)	Relative peak area	Splitting pattern
X	1.26	3	triplet
	2.04	3	singlet
	4.12	2	quartet
Y	1.14	3	triplet
	2.32	2	quartet
	3.67	3	singlet

^1H NMR chemical shift data

Type of proton	δ/ppm
$\text{R}-\text{CH}_3$, $\text{R}-\text{CH}_2-\text{R}$	0.7–1.5
$\text{H}_3\text{C}-\text{CO}-$, $-\text{CH}_2-\text{CO}-$ (aldehydes, ketones, carboxylic acids or esters)	2.0–2.6
$\text{H}_3\text{C}-\text{O}-$, $-\text{CH}_2-\text{O}-$ (alcohols or esters)	3.2–4.3
$\text{H}-\text{COO}-$ (methanoate esters)	8.0–8.2
$\text{R}-\text{COOH}$	9.0–13.0

Question 36 continues on page 31

Question 36 (continued)

- (a) With reference to the infrared spectrum and the information provided, explain why X is an ester rather than a carboxylic acid.

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 **SIMILAR**
2020 Q30
2024 Q4

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- (b) Identify compounds X and Y by drawing their structural formulae. Name the alcohol and the carboxylic acid that could be used to prepare each compound. Justify your answer with reference to the NMR data and the mass spectra.

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 **SIMILAR**
2020 Q30
2022 Q30
2025 Q36

<i>Compound X</i>	<i>Compound Y</i>
Alcohol:	Alcohol:
Acid:	Acid:

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Question 36 continues on page 32

Question 36 (continued)

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End of Question 36

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