
Student Identification Number

Section A

2021 TRIAL EXAMINATION
Chemistry

General Instructions

- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using blue or black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.
- A laminated formulae sheet, data sheet and Periodic Table are provided along with the exam.

Total marks: 100

Section A (20 marks)

- 20 x Multiple Choice (20 marks)
- Attempt Questions 1–20
- Allow about 35 minutes for this section
- The multiple- choice **answer sheet** is provided as a separate sheet.

Section II Short (80 marks)

- **Section 2A- Extended Responses (40 marks)**
- Allow about 1 hr 15 min for this section
- **Section 2B- Extended Responses (40 marks)**
- Allow about 1 hr 15 min for this section

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.

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

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

A ○ B ● C ○ D ○

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

A ● B ● C ○ D ○

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

A ● B ● C ○ D ○

correct

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1. In which one of the following would the position of the equilibrium **not** be affected by a volume change at constant temperature?

(A) $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$

(B) $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$

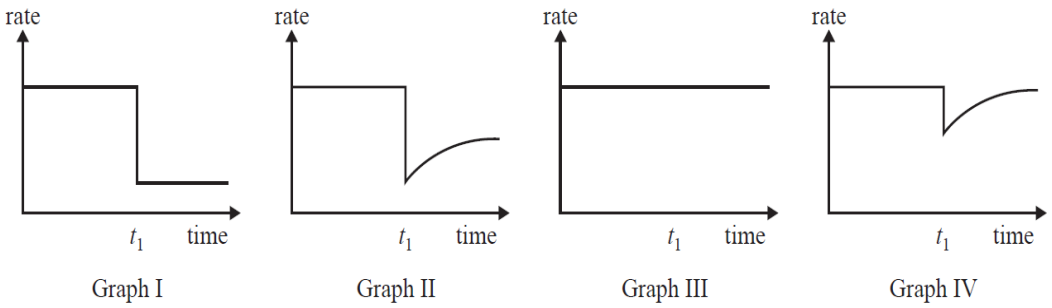
(C) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(D) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$

2. Reactants A and B are placed in a sealed container with a suitable catalyst where they react according to the equation:

$$A\,(g) + B\,(g) \rightleftharpoons C\,(g)$$

After the reaction reaches equilibrium, a small amount of a compound is added to the container at time t_1. The compound 'poisons' the catalyst and stops it working.



Which one of the graphs best represents the **rate** of the forward reaction versus time?

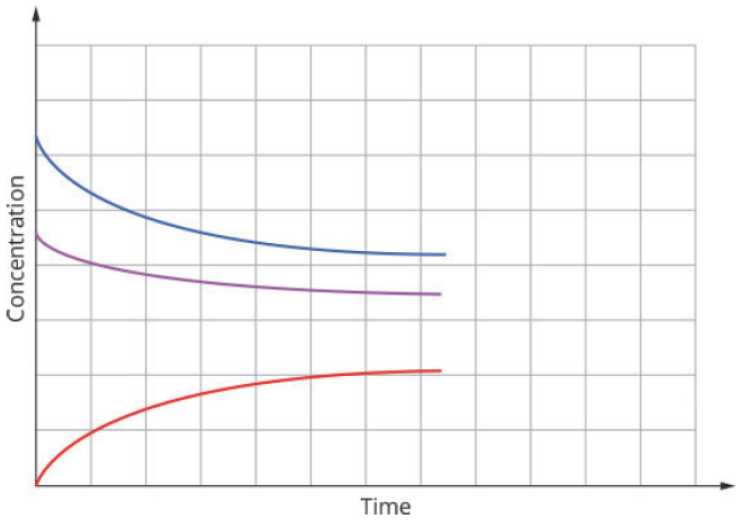
(A) Graph I

(B) Graph II

(C) Graph III

(D) Graph IV

3. The concentrations of species in an equilibrium reaction are shown in the graph below



A reaction that matches the concentrations shown could be:

(A) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(B) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(C) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

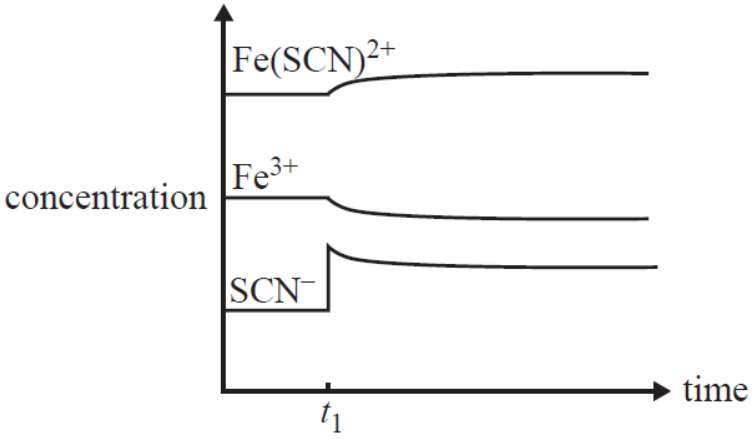
(D) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

4. Consider the following equilibrium reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$$

pale yellow colourless intense deep red

The concentration profile below represents a change to the above equilibrium system at time t_1.



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

(A) the addition of SCN^- causing the solution to become deeper red once equilibrium is re-established.

(B) the removal of Fe^{3+} causing the solution to become deeper red once equilibrium is re established.

(C) the addition of SCN^- causing the solution to become more yellow once equilibrium is re-established.

(D) Increase in temperature causing the solution to become more yellow once equilibrium is re-established.

5. What will happen when sulfuric acid is added to a saturated solution of sparingly soluble calcium sulfate?

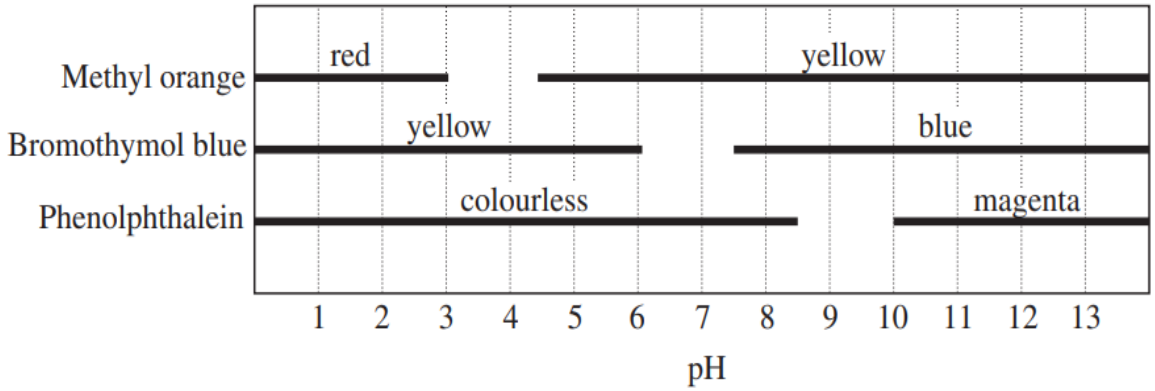
(A) The concentration of calcium and sulfate ions will increase over time due to the presence of H^+ ions.

(B) The concentration of calcium and sulfate ions will decrease over time due to the presence of H^+ ions.

(C) The concentration of calcium and sulfate ions will increase over time due to the presence of SO_4^{2-} ions.

(D) The concentration of calcium and sulfate ions will decrease over time due to the presence of SO_4^{2-} ions.

6. The graph shows colour changes of the acid -base indicators methyl orange, bromothymol blue and phenolphthalein.



A solution is yellow in methyl orange, blue in bromothymol blue and colourless in phenolphthalein. The pH range of the solution is

(A) 4.5 – 7.5

(B) 7.5- 8.5

(C) 6.0 – 7.5

(D) 8.5-10.0

7. Which of the following is least acidic?

	Acid	**pK_a**
(A)	Oxalic acid	1.23
(B)	Sulfurous acid	1.81
(C)	Phosphoric acid	2.12
(D)	Chloroacetic acid	2.85

8. Chlorine gas is an acidic gas. Dissolution of chlorine gas in water lowers the pH of the water, due to the following chemical reactions:

$$Cl_{2(g)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + HCl_{(aq)}$$

$$HOCl_{(aq)} + H_2O_{(l)} \rightleftharpoons OCl^-_{(aq)} + H_3O^+_{(aq)}$$

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$$

Which of the following acid- base theories account for the fact that chlorine gas is an acid?

(A) Arrhenius theory only

(B) Bronsted-Lowry theory only

(C) Both of the above theories

(D) Neither of the above theories

9. Which of the following statements regarding strength and concentration of given acids and bases is true?

(A) A weak acid is unable to neutralise a strong base.

(B) The pOH of a strong concentrated base will be greater than that of a weak dilute acid.

(C) To neutralise a given amount of strong base, the number of moles of a monoprotic weak acid is the same as that required for a monoprotic strong acid.

(D) To neutralise a given amount of strong base, the number of moles of a monoprotic weak acid is greater than that required for a monoprotic strong acid.

10. In which of the following alternatives are the three compounds listed in order of increasing boiling point?

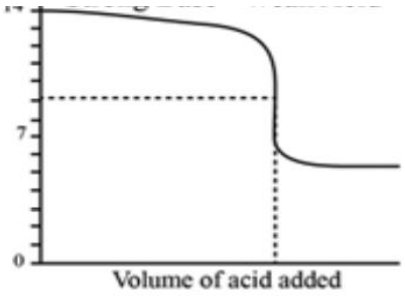
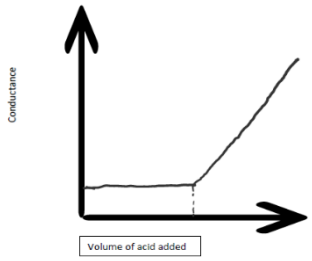
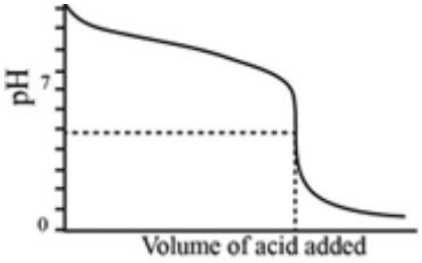
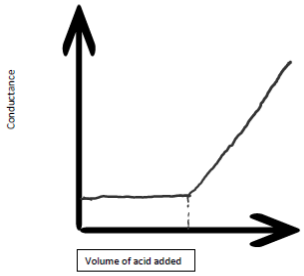
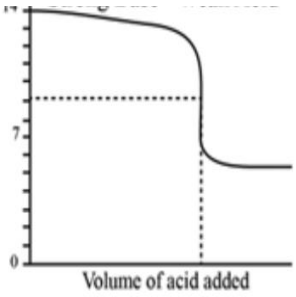
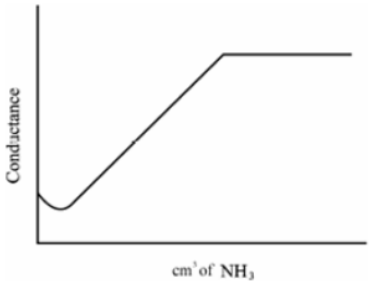
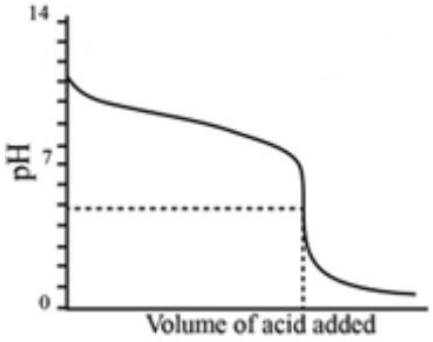
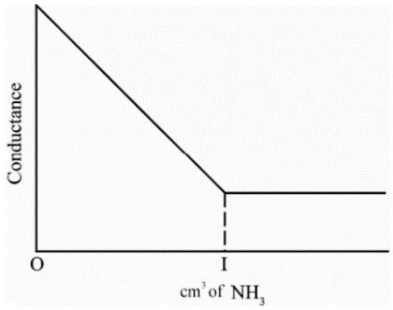
(A) Pentane, butan-1-ol, propanoic acid

(B) Propanoic acid, butan-1-ol, pentane

(C) Propanoic acid, pentane, butan-1-ol

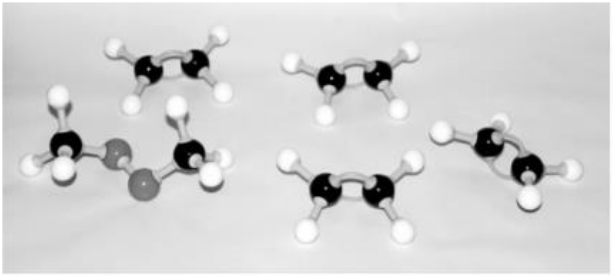
(D) Butan-1-ol, propanoic acid, pentane

11. Which of the following pair of curves correctly represent the neutralisation of a strong acid and given amount of a weak base?

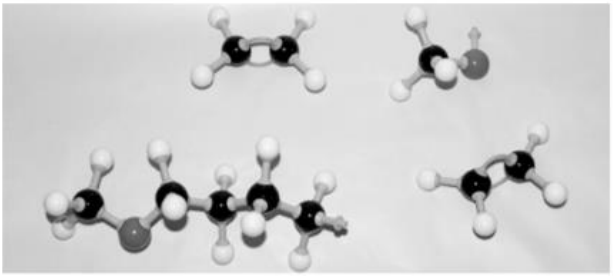
	Titration curve	Conductivity curve
(A)		
(B)		
(C)		
(D)		

12. A student created the following model to demonstrate a chemical process.

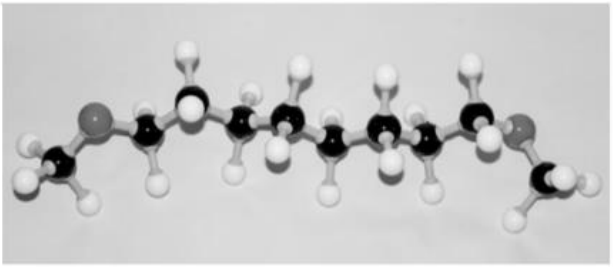
I



II



III



The chemical process modelled is

(A) Esterification between two different monomers

(B) Condensation polymerisation between two different monomers

(C) Addition polymerisation between two different monomers

(D) Addition polymerisation between identical monomers.

13. Which alternative is the best explanation of the action of soaps?

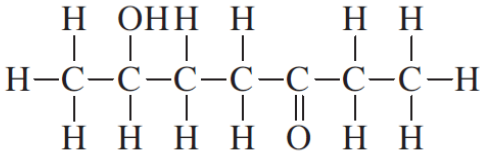
(A) The hydrophilic end of a soap molecule allows it to break up grease and fats while the hydrophobic end increases the surface tension of the water.

(B) One end of the soap molecule is cationic while the other end is non-polar.

(C) The hydrophobic end of a soap molecule allows it to break up grease and fats while the hydrophilic end decreases the surface tension of the water.

(D) One end of the soap molecule is cationic while the other end is anionic

14. What is the preferred IUPAC name of the structure below



(A) 2-hydroxyheptan-5-one

(B) 5-hydroxyheptanone

(C) 6- hydroxyheptan-3-one

(D) heptan-2-ol-5-one

15. Which one of the following molecules exhibits a planar shape.

(A) methane

(B) ethene

(C) propene

(D) butane

16. What mass of magnesium hydroxide is required to be added to 100 mL nitric acid with a pH of 3.5 in order to change the pH to 7.0?

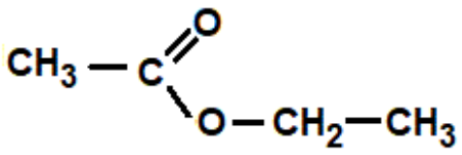
(A) 6.5×10^{-4} g

(B) 9.2×10^{-4} g

(C) 1.3×10^{-3} g

(D) 1.8×10^{-3} g

17. The structure of ethyl ethanoate is shown below.



The mass spectrum of the above molecule has the highest peak at m/z = 43 and the smallest peak at 89.

What are the most likely sources of these peaks?

(A) $C_2H_3O^+$ and $^{13}C_{12}C_3H_8O_2$

(B) $C_2H_5O^+$ and $^{13}C_{12}C_3H_8O_2$

(C) $C_2H_3O^+$ and $^{12}C_{12}C_3H_8O_2$

(D) $C_2H_5O^+$ and $^{12}C_{12}C_3H_8O_2$

18. The 1H NMR spectrum of an organic molecule with molecular formula $C_3H_6O_2$has a triplet at 1.3ppm, a quartet at 4.2ppm and a singlet at 8ppm.

Which of the following is likely to be a property of this organic compound?

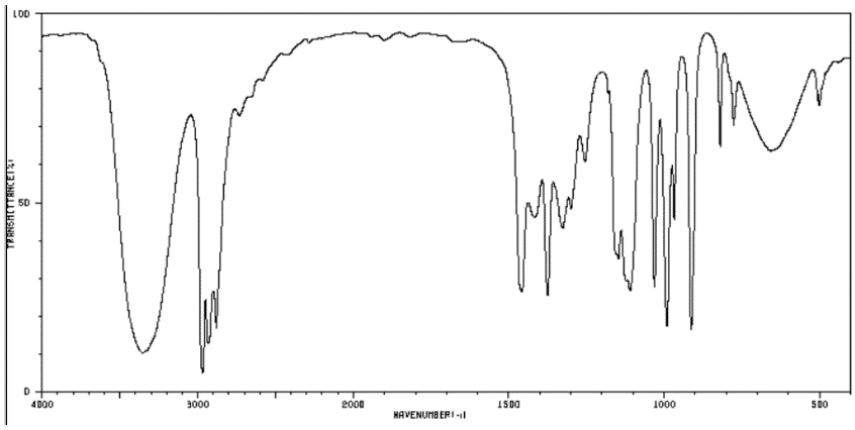
(A) Acidic

(B) Basic

(C) Neither acidic nor basic

(D) Amphiprotic

19. Lisa has an unidentified liquid in a vial. She tests the sample with orange coloured bromine water and the colour remains unchanged. An oxidation test with acidified potassium dichromate turns the solution green. She then conducts a test for carboxylic acids using sodium carbonate, the solution shows no visible change. She then puts the sample through the IR spectrometer and receives the following spectrum.



Which of the following compounds matches the above test results?

(A) Ethanol

(B) But-2-ene

(C) Butan-2-ol

(D) Butanoic acid

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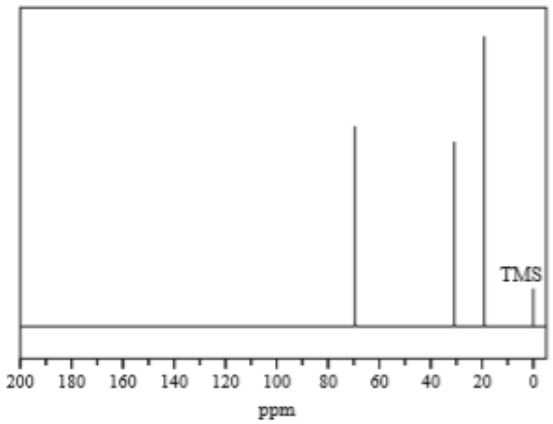

The ^{13}C NMR spectrum above corresponds to which one of the following compounds?

(A) Propane

(B) 2-methylbutane

(C) 2-methylpropan-2-ol

(D) 2-methylpropan-1-ol

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2021 HSC Trial Examination

Chemistry

Section II-2A

Section 2A	
General Instructions • **Allow about 75 minutes for this part.** • **Board-approved calculator may be used** • **Write using blue or black pen** • **Write your NESA Number at the top of this page .** • **Show all relevant working.** • **Data sheet & Periodic Table provided**	• **Marks for Section 2A - 40** • **Knowledge and Understanding** • **Calculations** • **Working Scientific skills.**

Question 1 (2 marks)

A reaction has an enthalpy value (ΔH°) of –27 kJ mol^{-1} and an entropy value (ΔS°) of – 65 J K^{-1} mol^{-1}. Calculate the temperature at which the reaction will change from spontaneous to non- spontaneous when both reactants and products are at 1 mol/L.

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Question 2 (3 marks)

NO decomposes to N_2 and O_2 according to the following equation.

$2NO\ (g) \rightleftharpoons N_2(g) + O2(g)\ \ \Delta H = -180.8\ kJ\ mol^{-1}$

Sketch, on the axes provided below, a fully labelled energy profile diagram for the decomposition reaction of NO. Indicate on the diagram the effect of using a catalyst in this reaction.

Question 3 (3 marks)

At 448 °C the equilibrium constant *K*eq is 50.5 for the reaction:

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$$

Predict in which direction the reaction proceeds to reach equilibrium if we start with 2.2×10^{-2} mol of HI, 1.1×10^{-2} mol of H_2, and 3.0×10^{-2} mol of I_2 in a 2.00 L container.

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Question 4 (3 marks)

Determine whether silver sulfate will precipitate when 50 mL of 0.015 mol L^{-1} silver nitrate and 20 mL of 0.010 mol L^{-1} sodium sulfate are mixed at 25°C.

The *K*sp (silver sulfate) = 1.20×10^{-5}.

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Question 5 (8 marks)

Nitrogen dioxide (NO_2) is a brown gas and dinitrogen tetroxide (N_2O_4) is a colourless gas. At 25°C, the two gases exist in equilibrium according to the equation:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ}$$

A 0.00250 mol sample of NO_2 was placed in a 25 mL sealed glass tube. When equilibrium was achieved at 60°C, 0.00022 mol of N_2O_4 was present.

a. Calculate the value of the equilibrium constant. (3 marks)

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b. Use Le Chatelier's principle and collision theory to explain any visible changes in the tube if it was cooled. (5 marks)

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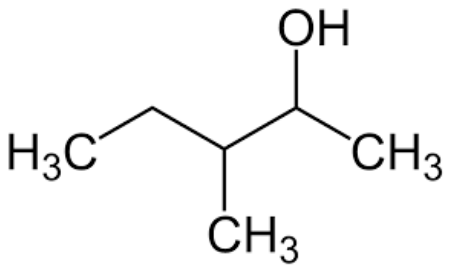
Question 6 (2 marks)

Identify the compound shown in the diagram and **determine** if it is primary, secondary or tertiary. (2 marks)



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Question 7 (4 marks)

This table shows the boiling points of a variety of organic substances with similar molar masses.

Compound	*Molar mass* (g mol^{-1})	*Boiling point* (°C)
propan-1-amine	59	49
ethanamide	59	210
ethanoic acid	60	118

Using specific examples, explain the physical properties of the above organic substances.

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Question 8 (4 marks)

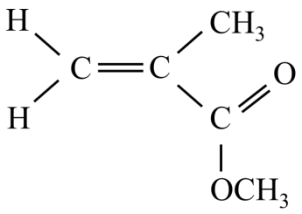
Many organic compounds can exist as isomers. **Draw the full structural formula** and write correct **IUPAC name** for TWO chain isomers and TWO functional isomers of the compound with molecular formula **$C_5H_{10}O$**. **All 4 isomers must be different.**

Structural formula for chain isomer	**Structural formula** for functional isomer
correct **IUPAC name**	correct **IUPAC name**
Structural formula for other chain isomer	**Structural formula** for other functional isomer
correct **IUPAC name**	correct **IUPAC name**

Question 9 (6 marks)

a. Polymethyl methacrylate is an example of an addition polymer. Its monomer, properties and applications are shown in the table. (4 marks)

Complete the table with details of another named addition polymer that you have studied.

Polymer name	*Monomer name and structural formula*	*Properties*	*Uses*
polymethyl methacrylate	methyl-2-methylpropenoate 	• transparent • strong	shatter-proof glass substitute

b. Outline the difference between a condensation polymer and an addition polymer. (2 marks).

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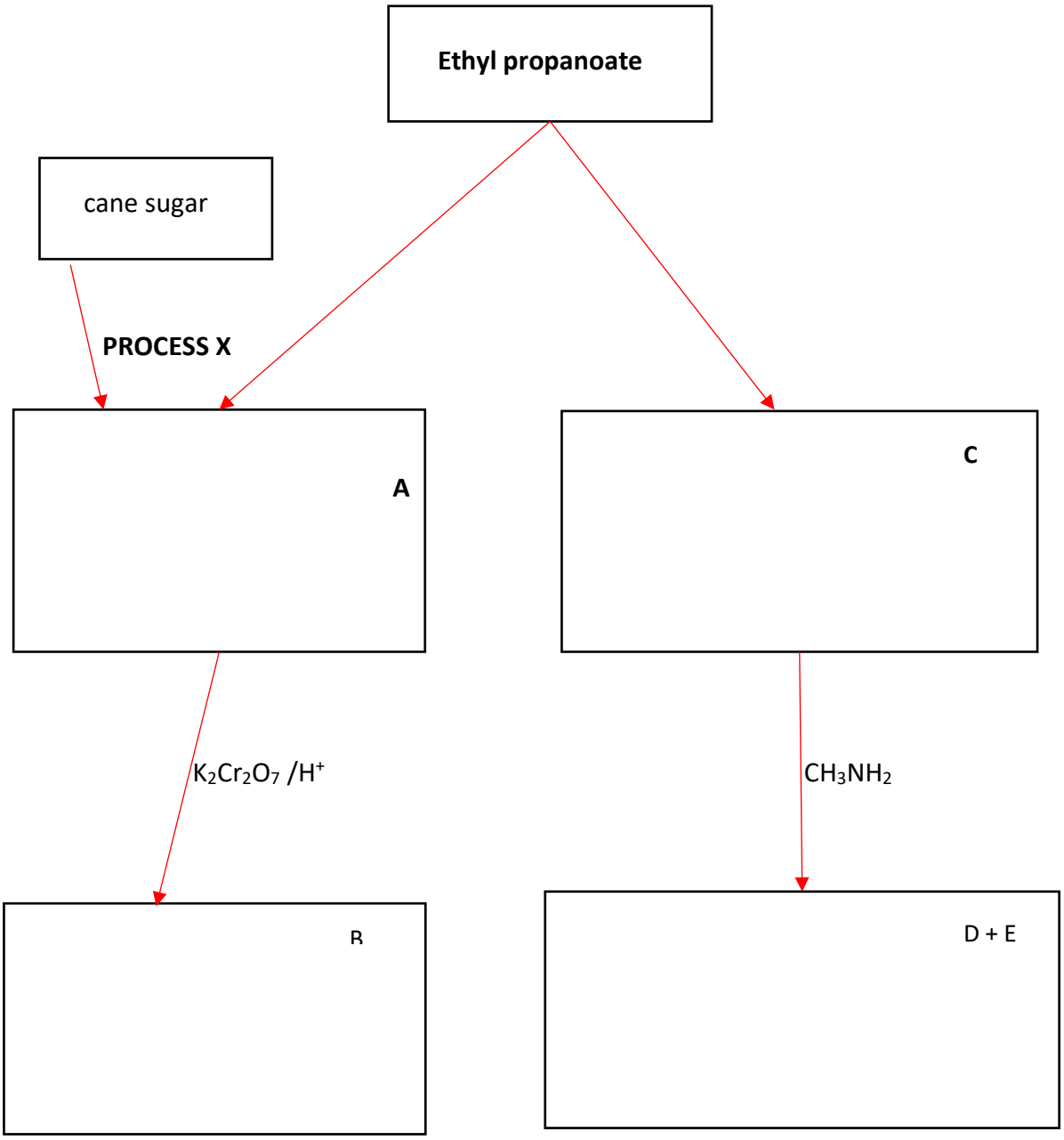
Question10 (5 marks)

Ethyl propanoate is an ester that is found in strawberries. It can be used in the manufacture of other chemicals by breaking the ester bond to form two other smaller molecules.

The flow chart below shows further reactions of the two molecules formed.



a. **Identify** and write up a **balanced chemical equation** for process X. (1 mark)

Process X	Balanced chemical equation

b. Draw the **structural formulae** for compounds A-E in the boxes above. (3 marks)

c. Write a balanced chemical equation for the reaction that occurs to form molecules D and E. (1 mark)

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Chemistry

Section II-2B

Section 2B	
General Instructions • **Allow about 75 minutes for this part.** • **Board-approved calculator may be used** • **Write using blue or black pen** • **Write your NESA Number at the top of this page .** • **Show all relevant working.** • **Data sheet & Periodic Table provided**	• **Marks for Section 2B - 40** • **Knowledge and Understanding** • **Calculations** • **Working Scientific skills.**

Question 1 (3 marks)

Veer added 2.3 g of $Ca(OH)_2$ to a beaker containing 200 ml of 0.100M $HNO_{3(aq)}$. He then poured another 300 ml of distilled water to the beaker and stirred continuously till $Ca(OH)_2$ dissolved completely.

Calculate the pH of the resulting solution.

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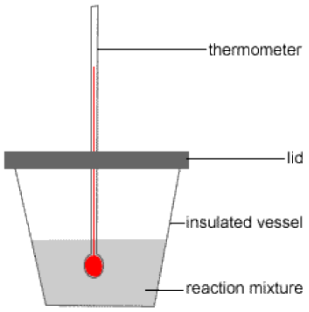
Question 2 (4 marks)

100.00 ml of 2.00M $HNO_3(aq)$ (density = 1.03 gml^{-1}) was placed in a 100% insulated vessel as shown below. The initial temperature was measured to be 22.5° C.

20.0g of solid sodium hydroxide was added to the vessel and stirred till the solid dissolved completely, releasing 44.5kJmol^{-1} of energy during the process. The specific heat capacity of the resulting solution was 3.99 $Jg^{-1}K^{-1}$. The enthalpy of neutralisation for this reaction may be written as:

$$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) \qquad \Delta H = -56.1 kJmol^{-1}$$



Calculate the maximum temperature reached by the solution.

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Question 3 (4 marks)

Various volumes of 0.800M oxalic acid and 0.685M sodium hydroxide solution, initially at room temperature, were added in varying volumes as outlined in the table below. The increase in temperature of each solution was measured and recorded in the following table.

Volume of sodium hydroxide solution (ml)	Volume of Oxalic acid (ml)	Temperature change (K)
5	45	1.03
10	40	2.05
15	35	3.08
20	30	4.11
25	25	5.14
30	20	6.16
35	15	7.19
40	10	4.79
45	5	2.40

By graphing the data in the table and performing relevant calculations, determine the number of moles of sodium hydroxide required to exactly neutralise the oxalic acid.

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Question 4 (2 marks)

Account for the amphiprotic nature of the dihydrogen arsenate ion ($H_2AsO_4^-$) using relevant chemical equations.

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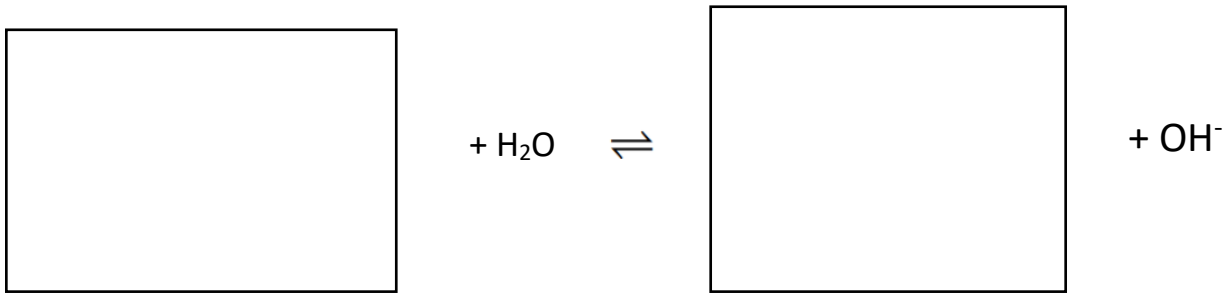
Question 5 (4 marks)

Joseph makes up a solution of methylamine in water with a concentration of 2.00molL^{-1}.

(a) Using structural formulae, complete the equation for the reaction of methylamine with water. (1 mark)



(b) The K_b for the hydrolysis of methylamine is 4.2×10^{-4} at 25° C. Calculate the concentration of hydroxide ions in solution and therefore the value of pK_a for the corresponding conjugate acid. (3 marks)

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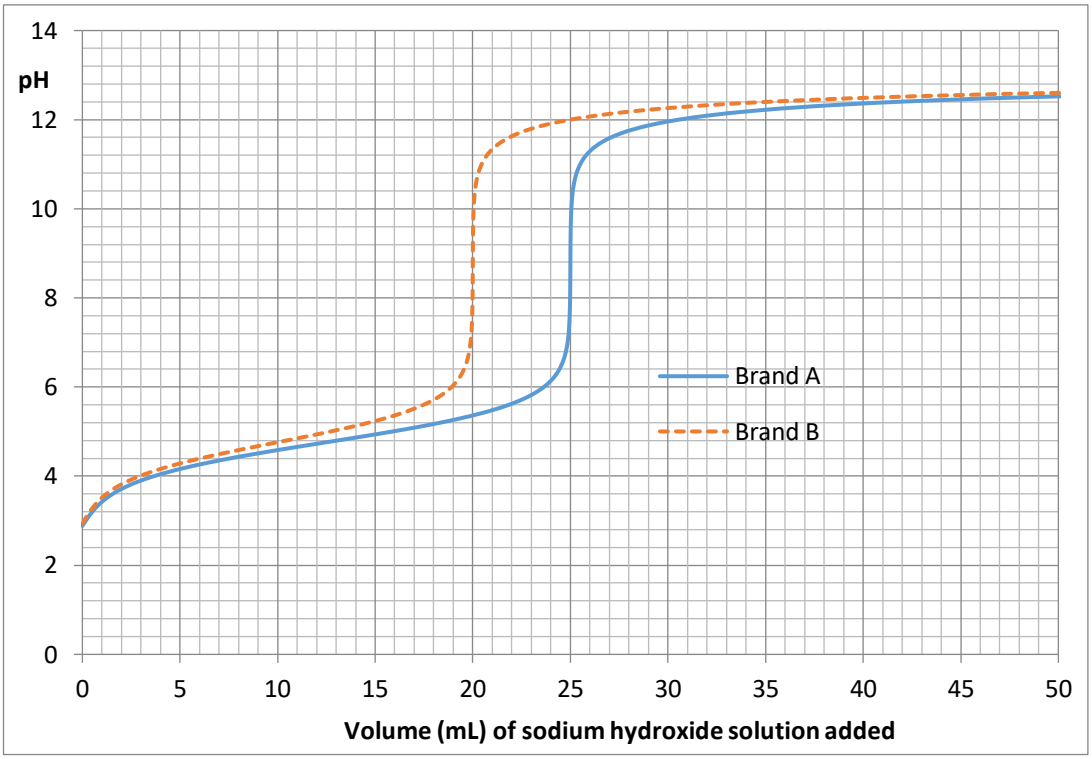
Question 6 (7 marks)

An investigation to determine the concentration of acetic acid in two brands of domestic vinegar, Brand A and Brand B. Equal volumes of vinegar were titrated using the same standardardised sodium hydroxide solution. The results of these titrations are shown below.



(a) Identify the vinegar brand that had the higher concentration of acetic acid. Show relevant calculations to derive your answer. (3 marks)

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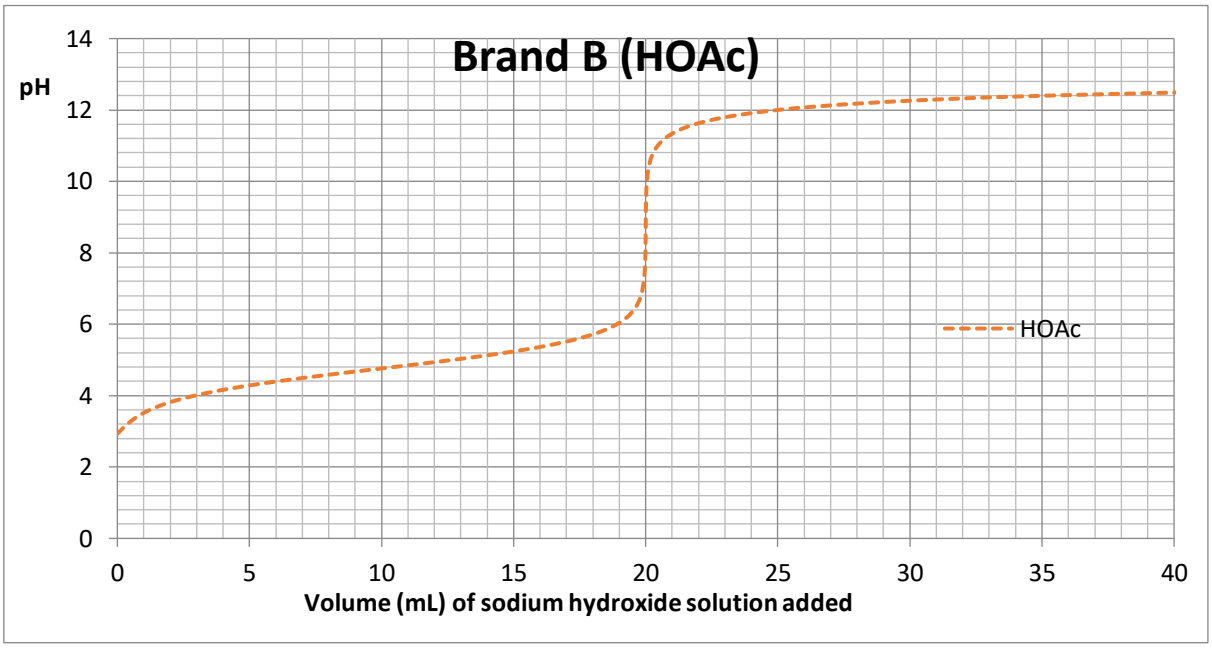
Question 6 *Continued*

(b) Suppose hydrochloric acid of the same concentration as Brand B acetic acid was also titrated using the same standardised sodium hydroxide solution. The same volume of hydrochloric acid as Brand B was also used. On the Brand B grid below, draw the titration curve for this titration. Contrast the titration curve for Brand B with the hydrochloric acid curve and explain any differences. (4 marks)



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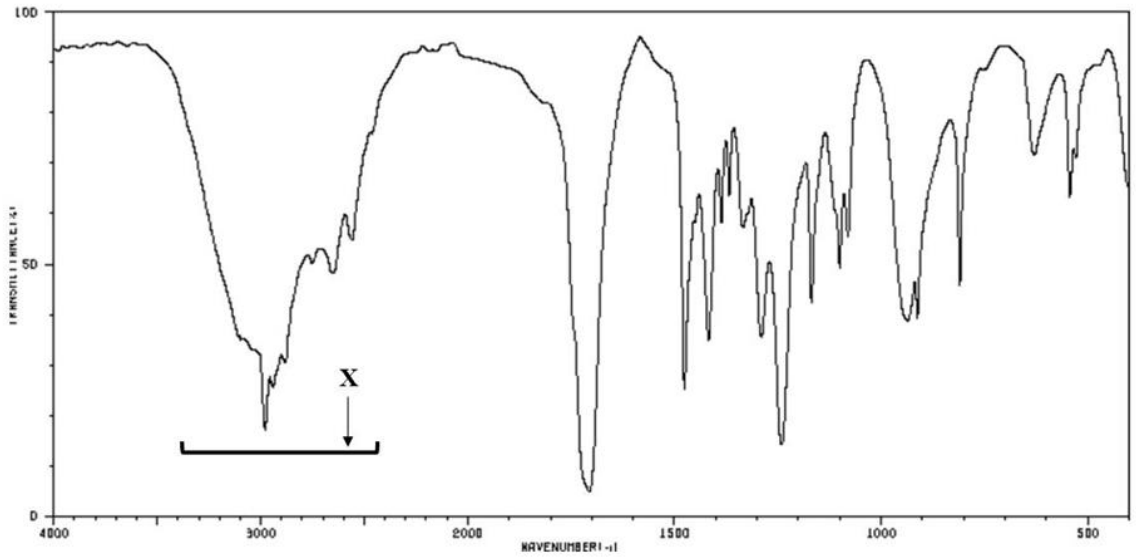
Question 7 (8 marks)

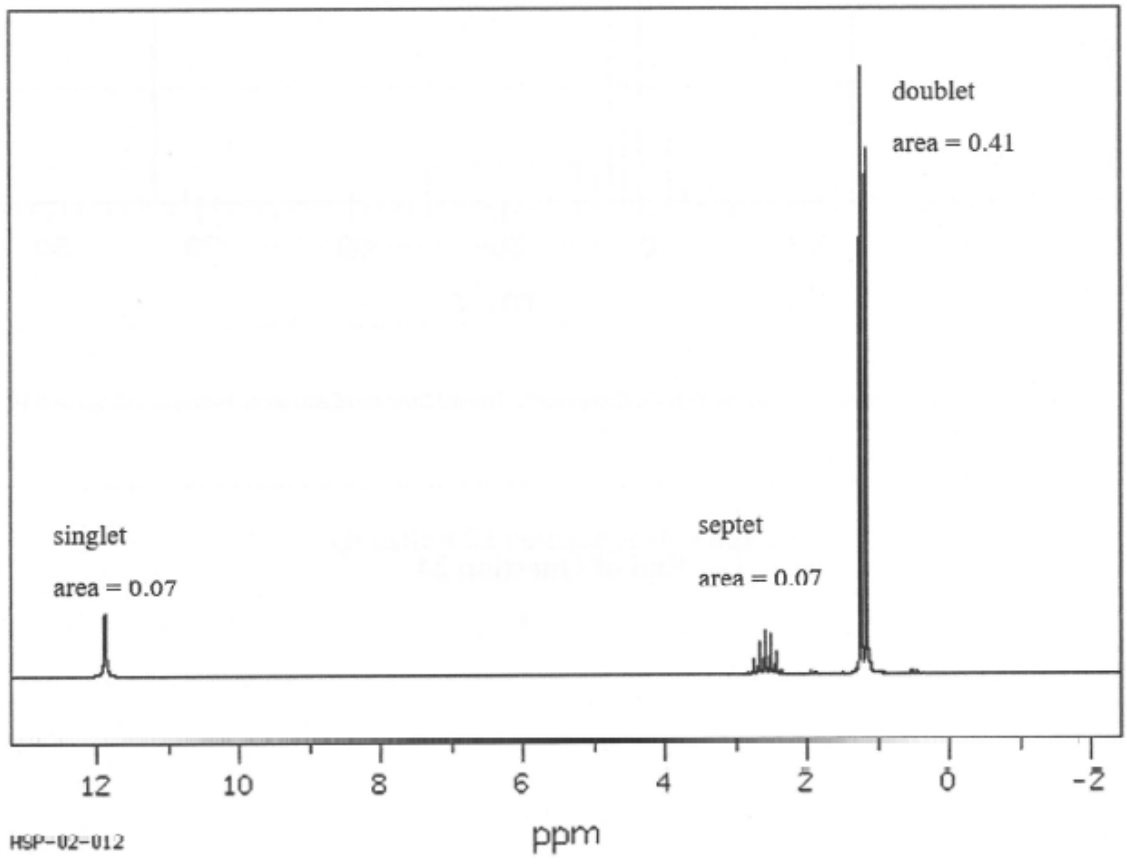
Joshua is determining the structure of an organic molecule. Microanalytic data shows that this molecule consists of 54.5% carbon, 9.1% hydrogen and 36.4 % oxygen by mass.

The IR, H^1 NMR and mass spectra of compound A are shown below. Draw the possible structure of the organic molecule using the spectral data and write the IUPAC name of the molecule. Justify your structure in reference to all three spectral data.

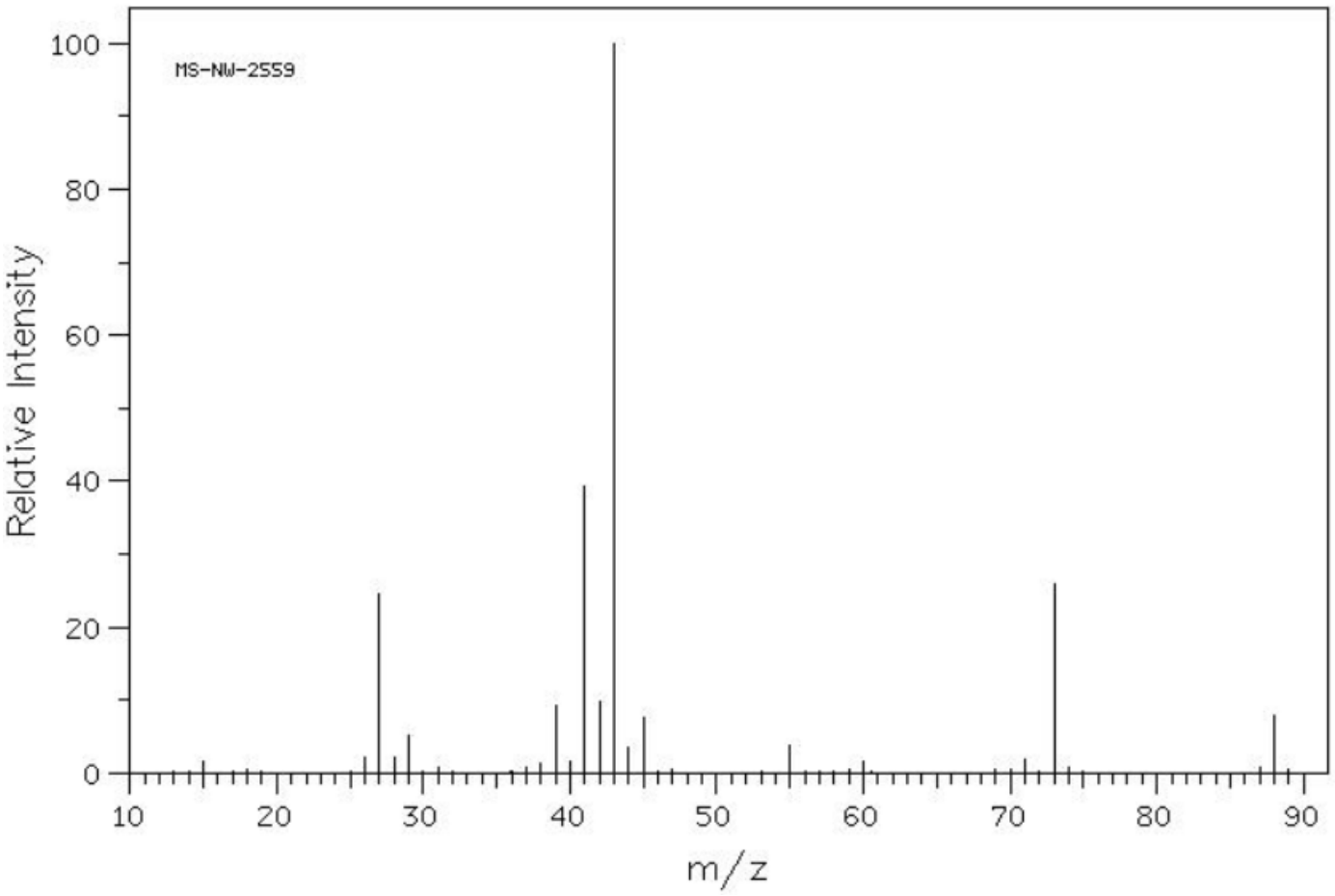
IR spectrum for compound A



H^1 NMR for compound A



(Source: Spectral Database for Organic Compounds, National Institute of Advanced Industrial Science and Technology, Japan)



(a) Calculate the empirical formula and at least two possible molecular formulas. (3 marks)

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(b) Use the appropriate spectrum to confirm the molecular formulae for the compound Joshua is analysing. (2 marks)

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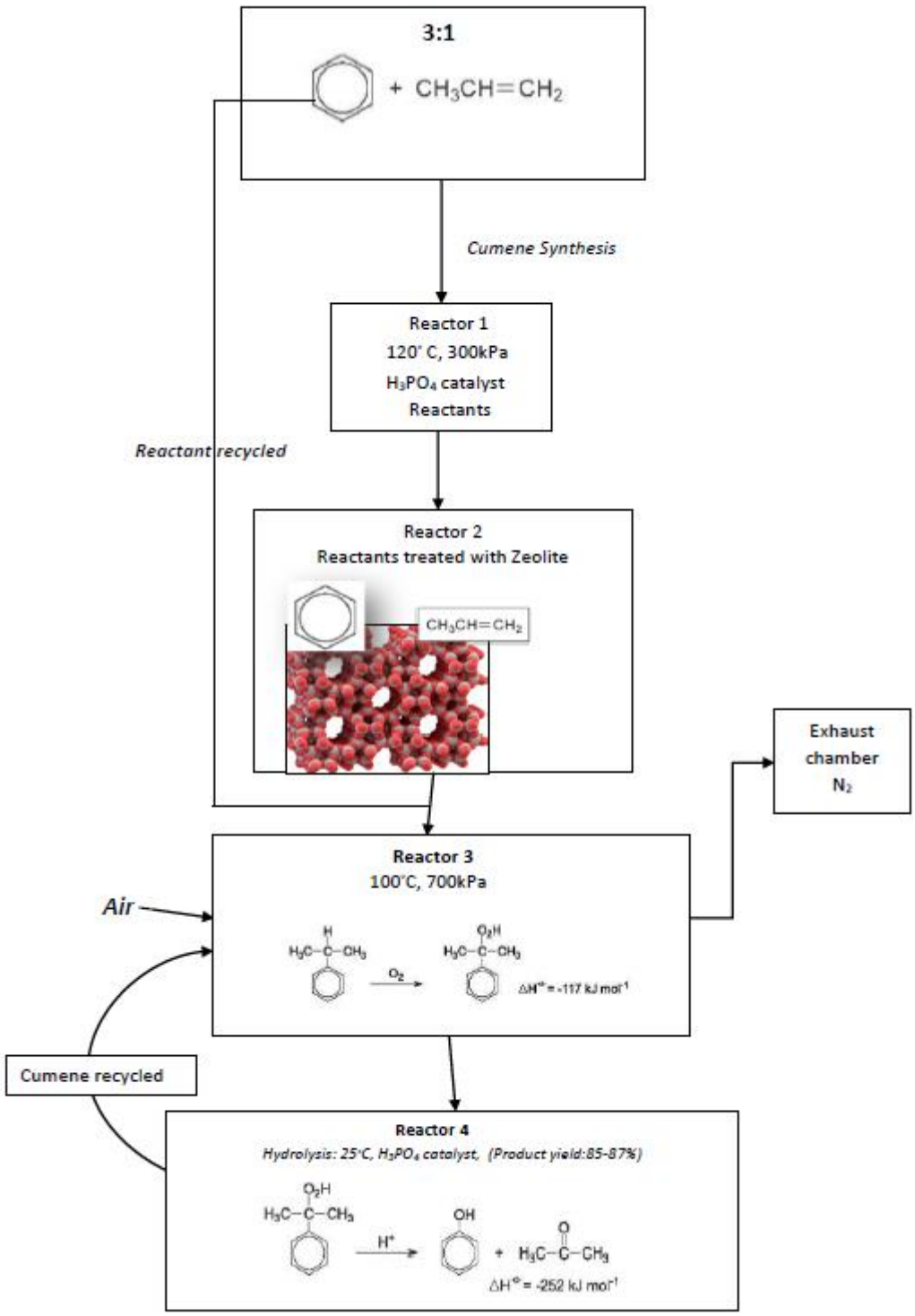
(c) Determine and draw the structure of the molecule and justify using the spectral data provided. (3 marks)

Question 8 (4 marks)

The flowchart below summarises the industrial process for the **synthesis of phenol and acetone** by using the cumene synthesis technique.



Explain **TWO** factors that may have been considered in the synthesis of phenol. Annotate the above diagram and make specific reference to the diagram in explaining each factor.

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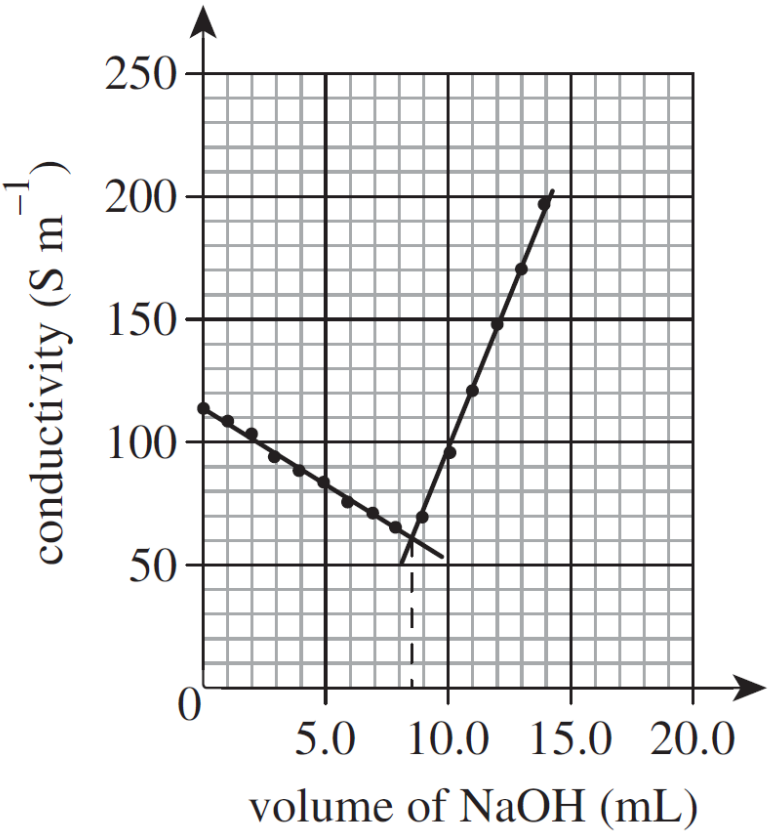
Question 9 (4 marks)

Roger was looking for an alternative to the cleaning agent they used at home. He found the following information.

> *Vinegar is a solution of ethanoic acid in water. Vinegar has been used as a cleaning agent for centuries. Studies have shown that vinegar must have a concentration of 7-12% (w/v) for it to be an effective cleaning agent.*

He decided to analyse a sample of 'white vinegar' from the supermarket to determine the concentration of ethanoic acid and therefore performed a conductimetric titration. A 25.00 mL sample was taken of the vinegar and diluted to 250 mL in a volumetric flask. A 25.0 mL portion of this diluted solution was titrated using standardised 0.120 mol L^{-1} sodium hydroxide solution.

The conductivity of the diluted vinegar solution was taken. 1.00 mL of NaOH solution was then added in increments, the mixture stirred, and the new conductivity was taken after each addition. Roger took the results and drew the following conductivity graph.



Perform relevant calculations and determine whether the vinegar was of the required concentration to be an effective cleaning agent. (4 marks)

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Extra Writing Space provide for rough work

End of Section

2021 Mock Trial Marking Guidelines SA mod 5 and 7

Question 1

A reaction has an enthalpy value ($\Delta H°$) of –27 kJ mol^{-1} and an entropy value ($\Delta S°$) of –65 J K^{-1} mol^{-1}. Calculate the temperature at which the reaction will change from spontaneous to non- spontaneous when both reactants and products are at 1 mol/L. (2 marks)

Criteria	Marks
Uses the correct formula for determining if a reaction is spontaneous and then correctly substitutes into formula.	2
Uses the correct formula for determining if a reaction is spontaneous OR correctly substitutes into formula.	1

Sample Answer

Joules

$\Delta G° = \Delta H° – T\Delta S°$ For the reaction to be **non-spontaneous**, the value of Δ**G°** needs to be **greater than zero.** Reactions are spontaneous when $\Delta G°$ is less than zero.

Substitute values of enthalpy and entropy to solve for the temperature where Gibbs free energy is zero.

$0 = –27{,}000 – (T \times – 65)$

$65 \times T = 27000$

$T = 27000/65$

$\therefore T = 415.38$ K

Question 2

NO decomposes to N_2 and O_2 according to the following equation.

$2NO(g) \rightleftharpoons N_2(g) + O2(g)$ $\Delta H = -180.8$ kJ mol^{-1}

Sketch, on the axes provided below, a fully labelled energy profile diagram for the decomposition reaction of NO. Indicate on the diagram the effect of using a catalyst in this reaction. (3 marks)

Marking guidelines	Marks
• Sketches a fully labelled energy profile diagram for the decomposition reaction of NO. • Indicates on the diagram the effect of using a catalyst in this reaction. • Includes data	3
• Sketches an energy profile diagram for the decomposition reaction of NO. • Indicates on the diagram the effect of using a catalyst in this reaction •	2
• Sketches an energy profile	1

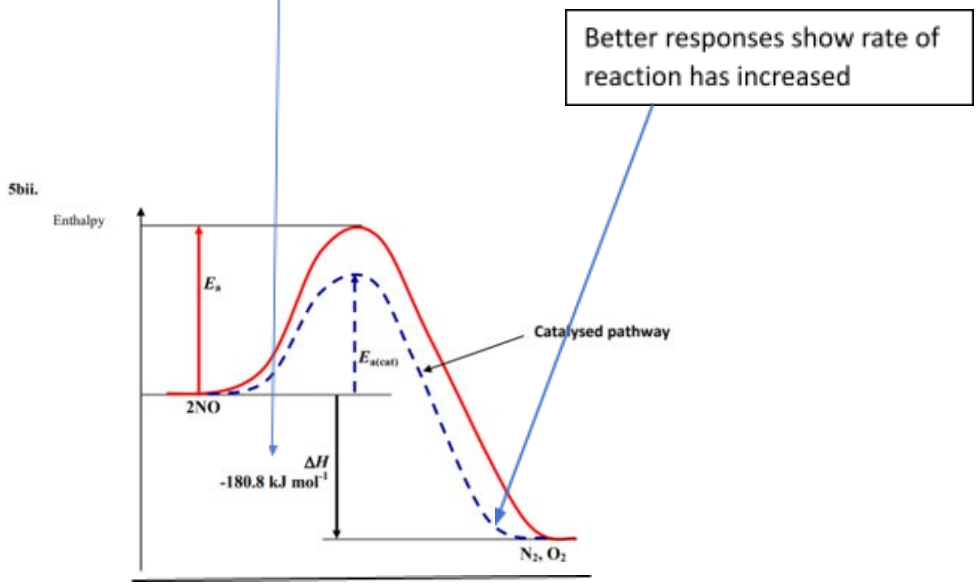
$2NO(g) \rightleftharpoons N_2(g) + O2(g)$ $\Delta H = -180.8$ kJ mol^{-1}

Has NO, N_2, O_2, should be labelled on graph,

Includes data ΔH = -180.8

Some confusion between Ea and ΔH

Sample Answer



Time

Question 3

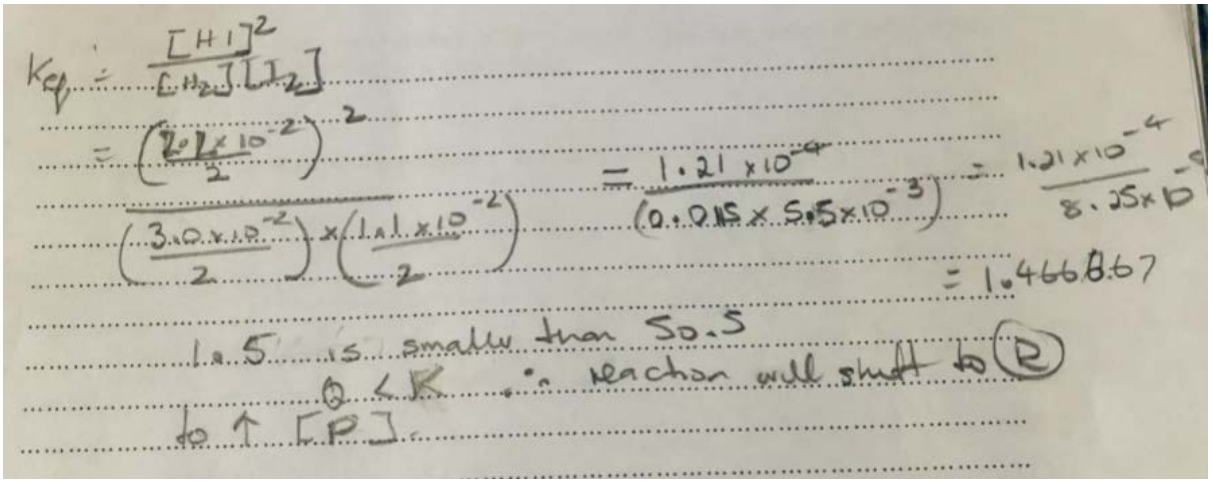
At 448 °C the equilibrium constant *K*eq is 50.5 for the reaction:

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$$

Predict in which direction the reaction proceeds to reach equilibrium if we start with 2.2 x 10^{-2} mol of HI, 1.1 x 10^{-2} mol of H_2, and 3.0 x10^{-2} mol of I_2 in a 2.00 L container. (3 marks)

Marking guidelines	Marks
• Calculates concentrations of species in moles per litre • Calculates Q • Compares magnitude of reaction quotient against equilibrium constant • Direction in which the reaction will proceed	3
• Provides THREE relevant steps OR has a one calculation error	2
• Provides any relevant information	1

Sample Answer



The concentration of reactants will decrease, and the concentration of products will increase. Hence reaction will proceed in the forward direction.

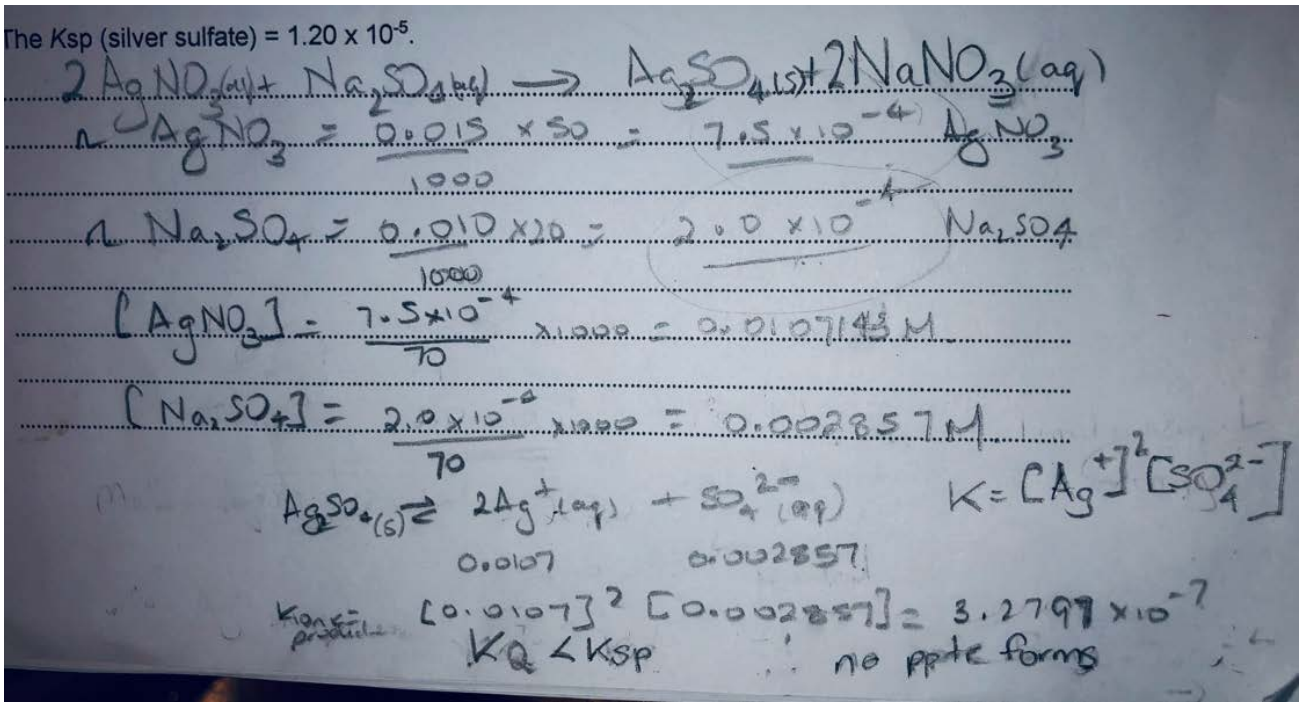
Question 4

Determine whether silver sulfate will precipitate when 50 ml of 0.015 mol L^{-1} silver nitrate and 20 mL of 0.010 mol L^{-1} sodium sulfate are mixed at 25°C. (3 marks)

The *K*sp (silver sulfate) = 1.20 x 10^{-5}.

Marking guidelines	Marks
• Determine whether silver sulfate will precipitate • Includes balanced equation • Includes all working • Must compare Qsp with Ksp	3
• Provides THREE relevant steps OR has a one calculation error	2
• Some correct steps	1

Sample answer



Question 5

Nitrogen dioxide (NO_2) is a brown gas and dinitrogen tetroxide (N_2O_4) is a colourless gas. At 25°C The two gases exist in equilibrium according to the equation:

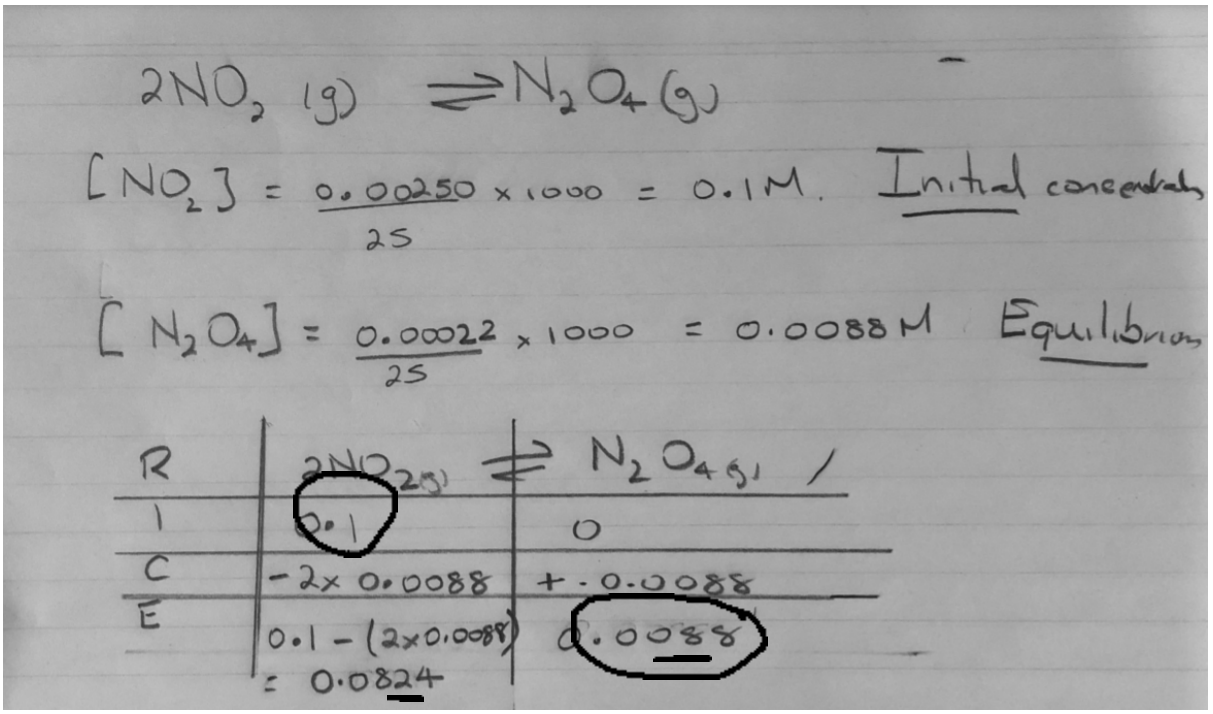
$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ}$$

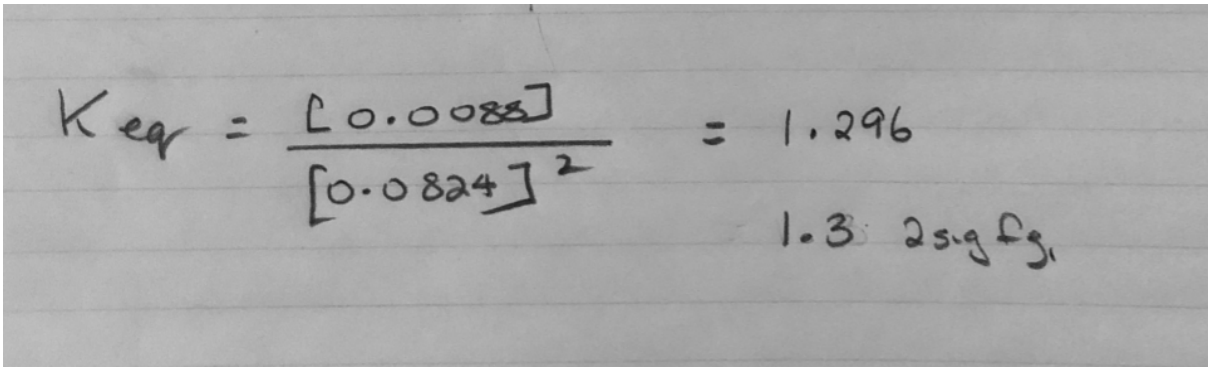
A 0.00250 mol sample of NO_2 was placed in a 25 mL sealed glass tube. When equilibrium was achieved at 60°C, 0.00022 mol of N_2O_4 was present.

a. Calculate the value of the equilibrium constant. (3 marks)

Marking guidelines	Marks
• Calculate the value of the equilibrium constant. • Shows all working	4
• one calculation error	3
• Two calculation errors	2
• A correct step	1

Sample answer





b. Use Le Chatelier's principle and collision theory to explain any visible changes in the tube if it was cooled. (5 marks)

Marking guidelines	Marks
• Uses BOTH Le Chatelier's principle and collision theory – makes reference to maxwell boltzman theory to **explain** any visible changes in the tube if it was cooled. • Refers to the **proportion of particles able to react in the exothermic reaction is greater than in the endothermic reaction.** • Refers to forward reaction being exothermic or backward being endothermic. • Refers to the **colour change** in the vessel • Links colour changes to colours gases- NO_2 is brown • Coherent and logical	5
• Uses BOTH Le Chatelier's principle and collision theory to **explain** any visible changes in the tube. • Refers to the **colour change** in the vessel	4
• Use Le Chatelier's principle **AND** collision theory to **outline** shift in direction.	3
• Use Le Chatelier's principle **OR** collision theory to **outline** shift in direction. • OR • Use Le Chatelier's principle AND collision theory to identify the shift in direction.	2
• Use Le Chatelier's principle **OR** collision theory and to **identify** shift in direction.	1

Sample Answer

NOTE: Must make it clear that the FORWARD reaction is exothermic. Can't say the reaction is exothermic. Which reaction is??

LCP

Since the **forward reaction** is exothermic, cooling the reaction would favour the R as the E will shift to minimise the disturbance – ie cause temperature increase. By shifting to the R the system will release heat and therefore minimise the disturbance. The system will become a lighter shade of brown because more **colourless N_2O_4** is produced and **less brown NO_2** molecules are produced.

Collision Theory

When the temperature of any system is decreased, the **rate of both the forward and reverse reactions will decrease** since **all molecules have less kinetic energy**, and hence, have a smaller chance of **successfully colliding and reacting.**

However, **the rate of the exothermic reaction will be affected less- this is due to the lower activation energy of the exothermic reaction. The decrease in temperature will decrease the <u>proportion</u> of particles able to collide and therefore to react in the endothermic reaction more than in the exothermic reaction. Thus the forward reaction will be favoured.**

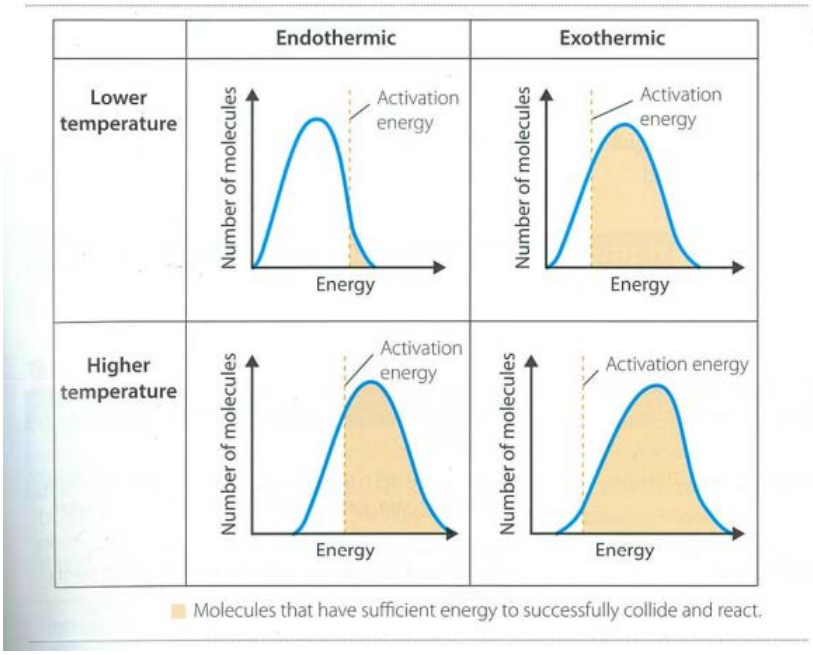


FIGURE 2.21
Effect of an increase in temperature on the proportion of molecules with sufficient energy to react for both endothermic and exothermic reactions

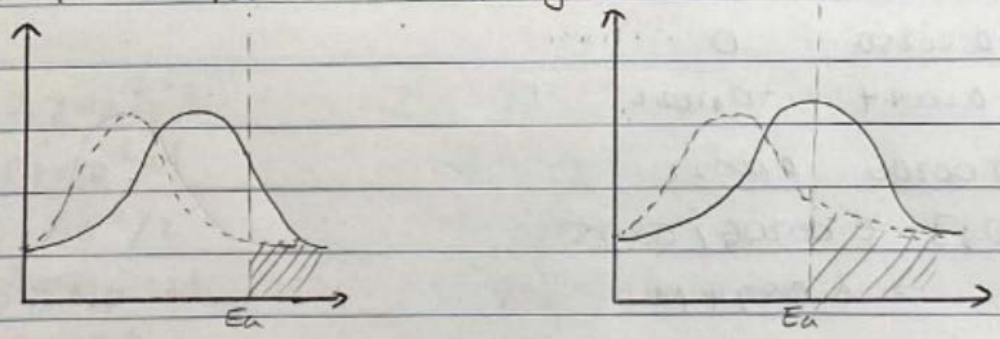
Student Sample answer

5.b) The forward reaction of the equation is exothermic shown by $\Delta H = -58 kJ$ @ 25°C.

↳ ~~Using LCP,~~ According to LCP, a system minimises the impact of a change by imposing a shift in the equilibrium. To minimise the cooling temperature and its subsequent impact, the reaction would attempt minimise by producing more heat. ∴ this will favour exothermic reaction (forward reaction), shifting the equilibrium to right to produce more product (N_2O_4). Since N_2O_4 is colourless gas, the colour would approach colourless making the brown ~~that~~ fainter.

↳ In Collision Theory, cooling the system (or decreasing the overall temperature) results in slowing in kinetic energy for both forward and reverse reaction.

However, the impact of this average KE decrease will be greater reverse reaction as shown in Maxwell Boltzmann Diagram below.



endothermic $N_2O_4 \rightarrow 2NO_2$

exothermic $2NO_2 \rightarrow N_2O_4$

Due to exthermic reaction generally lower Ea, the impact of decrease in average KE on rate of reaction will be lower. ∴ forward exothermic reaction is

favoured shifting eq to right, producing more colourless N_2O_4. ∴ Colour would once again approach colourless with brown fading.

Student Sample answer

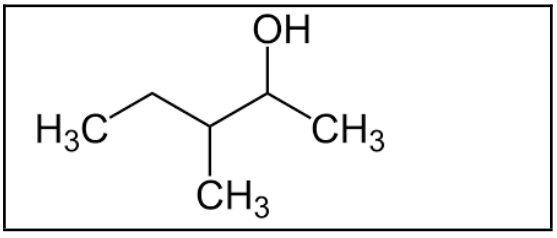
Le Chatelier's Principle (LCP) states that a reaction at equilibrium in a closed system will shift to minimise any disturbances imposed upon it. Hence by LCP, when the reaction is cooled, it shifts exothermically to release heat and minimise the temperature change. Thus, the reaction shifts right, ↓ decreasing $[NO_2]$ and making the gas appear less / paler brown.

Collision Theory states that a reaction can only occur if reagents have sufficient energy to overcome activation energy (E_A) and are in the correct molecular orientation when reacting. Thus, by Collision Theory, decreasing temperature would reduce kinetic energy and likelihood of effective collisions. Hence, side with greater moles, NO_2, would have more collisions, leading to greater forward rate of reaction (↑ Hence, forward ROR increases until equilibrium is re-established making gas appear a paler brown.

Question 6 (2 marks) compound shown in the diagram and **determine** if it is primary, secondary or

Question 6

Identify the compound shown in the diagram and **determine** if it is primary, secondary or tertiary. (2 marks)



Marking guidelines	Marks
● Identify the compound shown in the diagram ● Determine -secondary alcohol	2
● Identify the compound shown in the diagram OR ● Determine -secondary alcohol	1

Sample Answer

3- methylpentan-2-ol

Secondary alcohol

Question 7

This table shows the boiling points of a variety of organic substances with similar molar masses.

Compound	*Molar mass* (g mol^{-1})	*Boiling point* (°C)
propan-1-amine	59	49
ethanamide	59	210
ethanoic acid	60	118

Explain the differences in boiling points of the three organic substances. (4 marks)

Marking guidelines	Marks
• Explains the differences in boiling points of all three organic substances. • Mentions **H bonding more extensive ethanamide, then ethanoic acid, then propan-1-amine**. • Refers to Dispersion Forces being similar as similar MM • Refers to data • Includes a relevant diagram • Clear, detailed, and logical	4
• Explains the differences in boiling points of all three organic substances. • Clear and logical	3
• Explains the differences in boiling points of TWO organic substances OR • Outlines the differences in boiling points of THREE organic substances.	2
• Identifies some of the bonding occurring between molecules	1

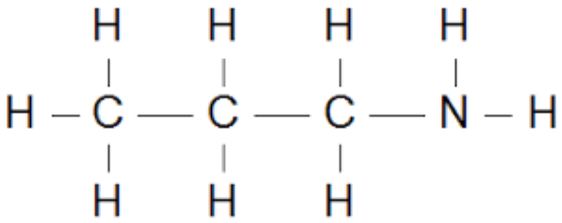
Sample answer

Boiling point increases as the forces of attraction between the molecules increases as more energy is required to break the IMF between the molecules.

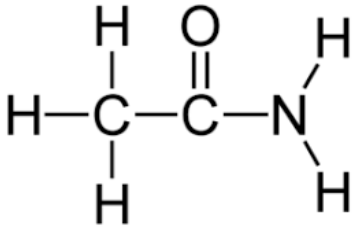
All three compounds have similar masses (59 -60) so the London dispersion forces and dipole-dipole forces will be similar.

Much more important are the hydrogen bonds. Propan-1-amine has a lone pair on the N atom so it can form one hydrogen bond between neighbouring molecules. Ethanoic acid has lone pairs on both O atoms. It can form pairs of hydrogen bonds between neighbouring

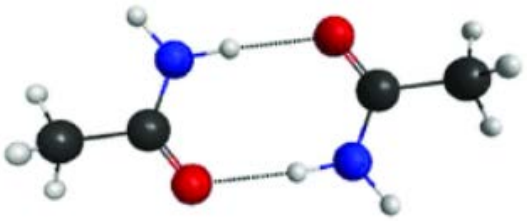
molecules, effectively making a dimer. This is the usual gas molecule, twice as big so a much larger BP. Ethanamide can arrange similarly- dimer, but the leftover N-H bond can be attracted to an O lone pair in a third molecule, raising the BP even further. Ethanamide has more extensive H bonding. (Amides have two hydrogen atoms bound to a nitrogen which allows them to form more hydrogen bonds than carboxylic acids).



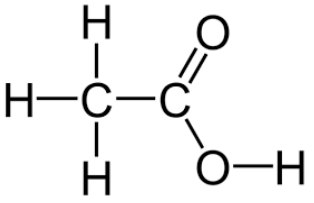
Propan-1-amine



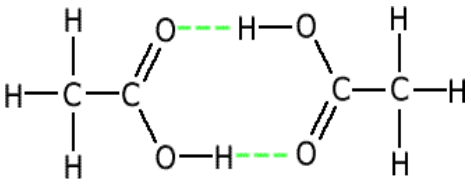
Ethanamide



Ethanamide dimer



Ethanoic acid

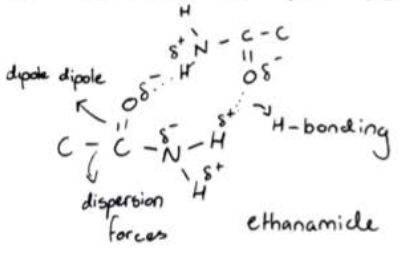


Ethanoic acid dimerisation

Student sample answer

- Despite the similarity in terms of molar mass between the 3 molecules, there is a large difference in BP which arises due to differences in IMF, and not e^- density.

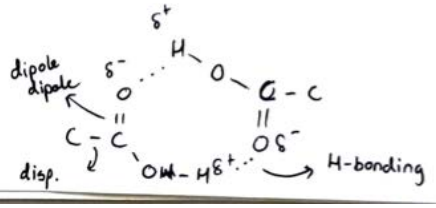
- Ethanamide has a MM of 59 g/mol but retains the highest BP (210°C). This is mainly because of the polar C=O, and N-H in addition to the ability to form dimers.



As seen on the ~~right~~ left, amides are able to form dimers between the positively charged H on the N-H and the negatively charged O atom. These structures enhance the H-bonding between each molecule and thus ↑BP.

Furthermore, the C=O bond is also able to create dipole dipole bonds whilst the C-C bonds retain dispersion forces which both ↑BP.

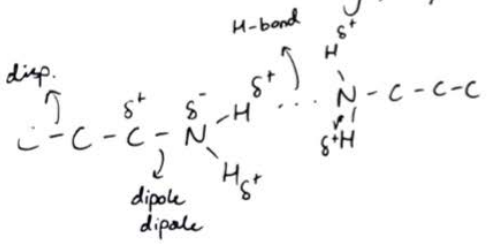
- Ethanoic acid has a MM of 60 g/mol and has the 2nd highest BP (118°C). This is due to the polar O-H and C=O bonds which provide the molecule H-bonding, dipole dipole and disp. forces



As seen on the ~~right~~ left, ethanoic acid can also form dimers between the positive H atom and the negative O atom.

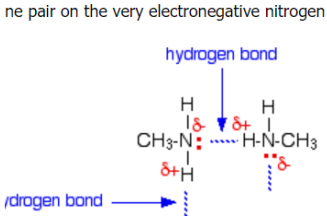
However, as ethanamide has the ability to form more H-bonds, it retains a higher ~~exact~~ BP. Ethanoic acid also maintains dipole dipole forces vice the C=O and dispersion forces between the C-C to ↑BP

- Propan-1-amine has an MM of 59 gmol⁻ and has the lowest BP of 49°C because it is unable to form dimers but does have H-bonding, dipole dipole and disp forces.



As seen on the left the H-bonds form through interaction of the positive H atom and the negative N atom. Since the molecule cannot form dimer structures, these H-bonds are weaker than those of ethanamide and ethanoic acid ~~acid~~ which ultimatley results in a ↓BP. propan-1-amine also retains dipole dipole C-N, and dispersion forces C-C to ↑BP

ne reason for the higher boiling points of the primary amines is that they can form hydrogen bonds with each other as well as van der Waals dispersion forces and dipole-dipole interactions. H
ne pair on the very electronegative nitrogen atom and the slightly positive hydrogen atom in another molecule.

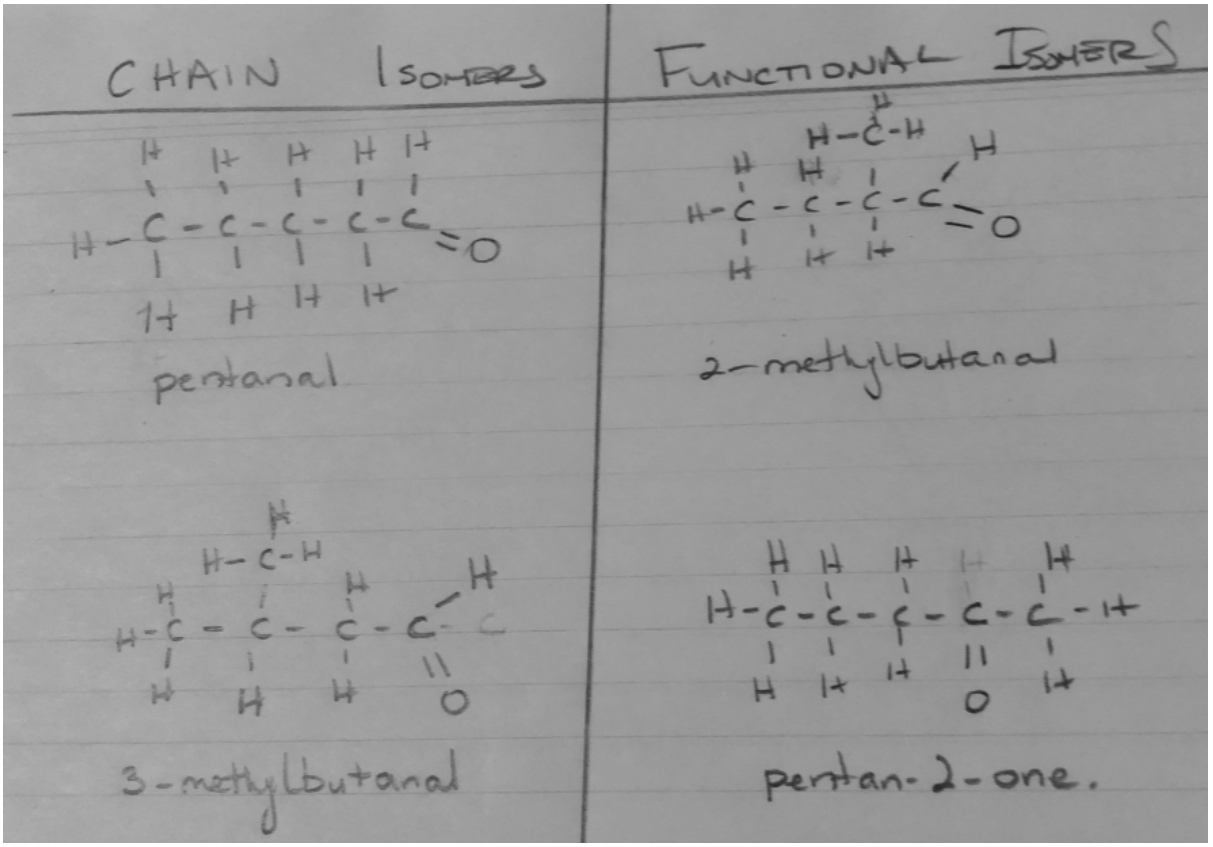


Question 8

Many organic compounds can exist as isomers. **Draw the full structural formula** and write correct **IUPAC name** for TWO chain isomers and TWO functional isomers of the compound with molecular formula **$C_5H_{10}O$**. All **4** isomers must be different. (4 marks)

Marking guidelines	Marks
• Draws the full structural formula and gives the correct IUPAC name TWO chain isomers and TWO functional isomers of the compound with molecular formula $C_5H_{10}O$	4
• One incorrect name or structure	3
• Draws the full structural formula and gives the correct IUPAC name for at least two isomers	2
• Draws the full structural formula and gives the correct IUPAC name for an isomer	1

Sample Answer



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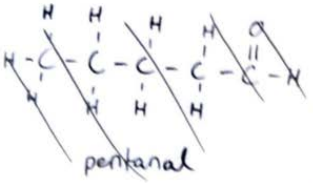
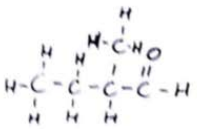
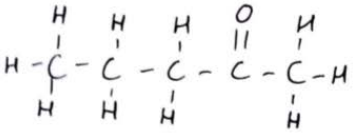


pentanal



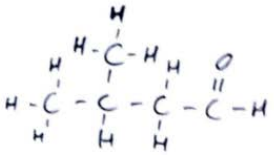
2-methylbutanal

Chain ~~Structural~~ #2

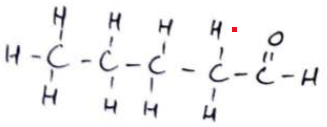


pentan-2-one

Functional #2

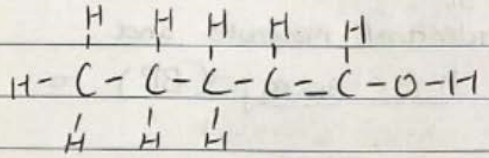


3-methylbutanal

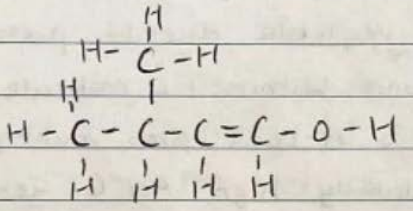


pentanal

8. Chain Isomer

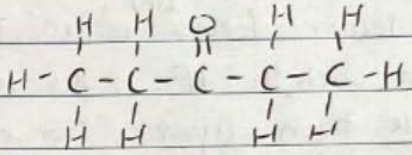


Pent-1-en-1-ol

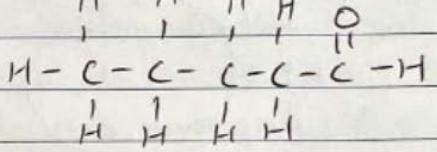


3-methyl but-1-en-1-ol

Functional Isomer



pentan-3-one

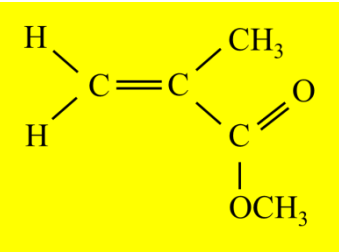


pentanal

Question 9

a. Polymethyl methacrylate is an example of an addition polymer. Its monomer, properties and applications are shown in the table.

Complete the table with details of another named addition polymer that you have studied. **4**

Polymer name	*Monomer name and structural formula*	*Properties*	*Uses*
polymethyl methacrylate	methyl-2-methylpropenoate 	• transparent • strong	shatter-proof glass substitute

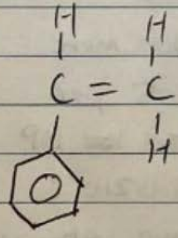
Marking criteria	Mark
Completes the table with all 4 details of another named addition polymer	4
Completes the table with 3 details of another named addition polymer	3
Completes the table with 2 details of another named addition polymer OR Completes the table with all 4 details of another named condensation polymer	2
One detail	1

Polymer name

9.a) Polystyrene
(PS)

Monomer name and structural formula

Styrene / phenylethene

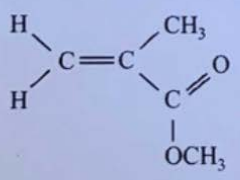
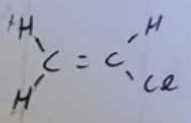


Properties

↳ heat insulator
↳ light
↳ rigid and brittle
↳ poor UV and chemical resistance

Uses

↳ polystyrene cup
↳ insulating cover found with coolers
↳ one use plates and takeaway boxes

Polymer name	Monomer name and structural formula	Properties	Uses
polymethyl methacrylate	methyl-2-methylpropenoate 	• transparent • strong	shatter-proof glass substitute
polyvinyl chloride	chloroethene 	*rigid *brittle *degrades under UV light	*piping *electrical conduits *garden hoses

b. Outline the difference between a condensation polymer and an addition polymer. (2 marks).

Marking guidelines	Marks
● Outlines the difference between a condensation polymer and an addition polymer. ● Mentions polymer is made up of **monomer units.** ● Mentions **double bond** for addition polymerisation ● Mentions **loss of a small molecule**.	2
● Some correct information	1

Sample Answer

An addition polymer is formed when a **double bond** breaks open and the **monomer** ends join together to form a long chain **without the loss of a small molecule**.

A condensation polymer is formed when the monomers join to form a polymer chain **with the loss of a small molecule**, usually water. Needs two functional groups.

Question 10

a. **Identify** and write up a **balanced chemical equation** for PROCESS X. (1 mark)

Process X	Balanced chemical equation

Marking guidelines	Marks
● Identifies process X and correct balanced equation for fermentation	1

Sample Answer

Process X	Balanced chemical equation
fermentation of glucose → ethanol)	$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2CH_3CH_2OH + 2CO_{2(g)}$

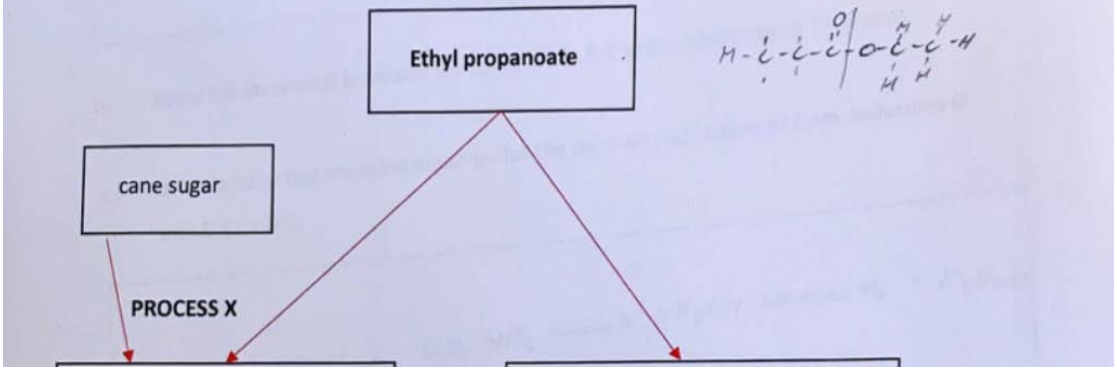
Marking guidelines	Marks
• Draws correct structural formulae for A-E	3
• 2-3 correct	2
• 1 correct	1

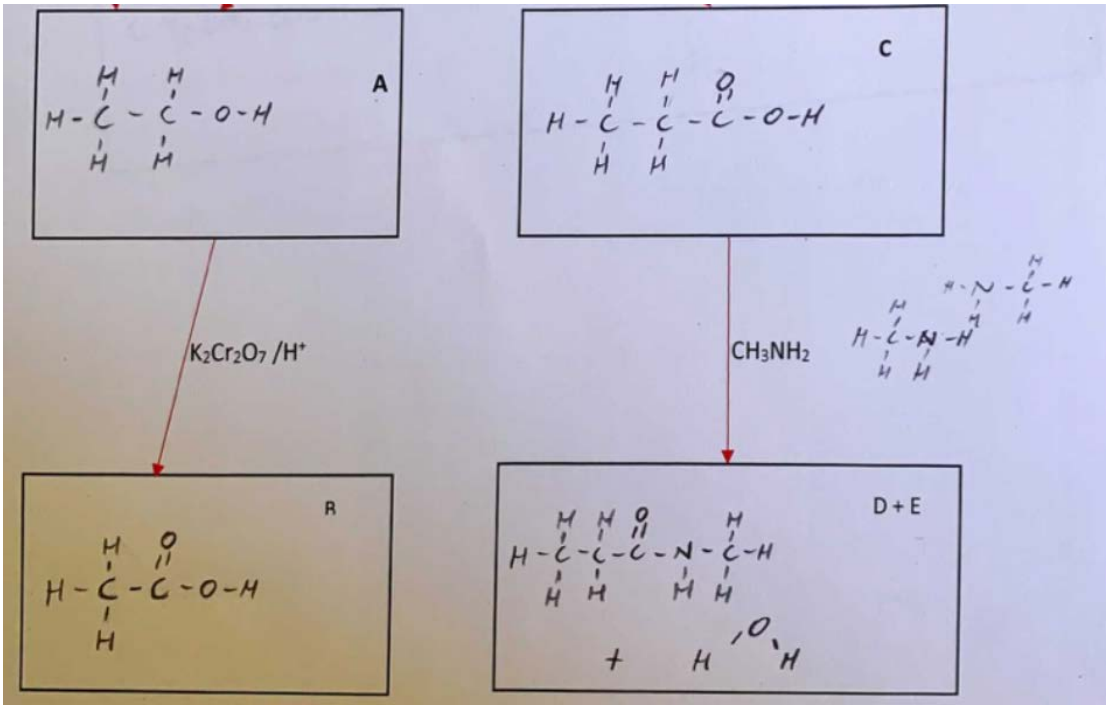
Sample Answer

Question10 (5 marks)

Ethyl propanoate is an ester that is found in strawberries. It can be used in the manufacture of other chemicals by breaking the ester bond to form two other smaller molecules.

The flow chart below shows further reactions of the two molecules formed.





b.

A:

C:

B:

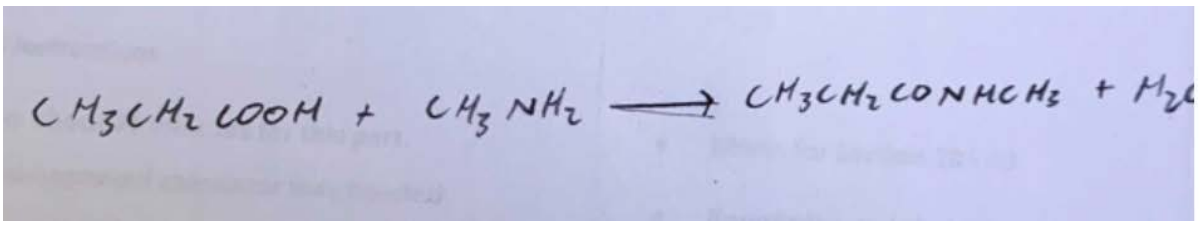
[COMPLETION]

[NOT COMPLETION]

D+E:

Q 5 c

Marking guidelines	Marks
• Correct balanced equation	1



Student BOS Number

2021 HSC Depth Study Assessment
Chemistry

Section II-2B

Section 2B ***General Instructions*** • **Allow about 75 minutes for this part.** • **Board-approved calculator may be used** • **Write using blue or black pen** • **Write your NESA Number at the top of this page .** • **Show all relevant working.** • **Data sheet & Periodic Table provided**	• **Marks for Section 2B - 40** • **Knowledge and Understanding** • **Calculations** • **Working Scientific skills.**

Question 1 (3 marks)

Veer added 2.3 g of $Ca(OH)_2$ to a beaker containing 200 ml of 0.100M $HNO_{3(aq)}$. He then poured another 300 ml of distilled water to the beaker and stirred continuously till $Ca(OH)_2$ dissolved completely.

Calculate the pH of the resulting solution.

Criteria	Marks
Shows relevant working to determine excess Ca(OH)2 in solution = 0.021	**1**
Shows relevant working to determine $[OH^-]$ in solution = 0.084M	**1**
Shows relevant working to determine pH of solution after neutralisation **pH= 12.92 or 12.9**	**1**

Solution

2021 TRIAL Solution to Q 1 Sec IIB

Tuesday, 6 July 2021 10:02 AM

$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2H_2O$

$n = \frac{2.3g}{74.096} = 0.03$ (excess) as only 0.01 moles of $Ca(OH)_2$ reqd to neutralise 0.02 moles of HNO_3.

$0.2L \times 0.1M = 0.02$ moles

$Ca(OH)_2$ left in soln after neutralisation $= 0.03 - 0.01 = 0.021$

Total volume = 500 mL = 0.5L

$[OH^-] = \frac{(2 \times 0.021)mol}{0.5L} = 0.084\ M$ (2 sigfig)

$pOH = 1.0757 \simeq 1.076$

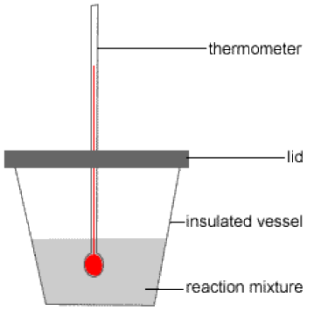
$pH = 14 - 1.076 = 12.92$

Question 2 (4 marks)

100.00 ml of 2.00M $HNO_3(aq)$ (density = 1.03 gml^{-1}) was placed in a 100% insulated vessel as shown below. The initial temperature was measured to be 22.5˚C.

20.0g of solid sodium hydroxide was added to the vessel and stirred till the solid dissolved completely, releasing 44.5kJmol^{-1} of energy during the process. The specific heat capacity of the resulting solution was 3.99 $Jg^{-1}K^{-1}$. The enthalpy of neutralisation for this reaction may be written as:

$$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) \qquad \Delta H = -56.1 kJmol^{-1}$$



Calculate the maximum temperature reached by the solution.

Criteria	Marks
Shows relevant working to determine total mass of solution = 123g	**1**
Shows relevant working to determine total energy reqd =33.475KJ	**1**
Substitutes correct values into Q=mcΔT as: **33475J = 123g × 3.99J/gK × (T_f - 22.5)K**	**1**
Correct answer with unit = 90.71˚C	**1**

Tuesday, 6 July 2021 10:22 AM

Total mass of soln = $(100.00\ mL \times 1.03 \frac{g}{mL}) + 20g$

$= 123g$

$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

$n_{HNO_3} = 0.1L \times 2.00M = 0.20\ HNO_3 = H^+$

$n_{NaOH} = \frac{20\ g}{22.99 + 16 + 1.008} = 0.5001$

(Ltd Rgt) $HNO_3 : NaOH = 1:1 \Rightarrow$ 0.2 moles H^+ & OH^- reqd for neut.

So 0.2 moles H^+ will neutralise 0.2 moles OH^- releasing 56.1 KJ mol^{-1}.

$q_1 = 0.2\ moles \times 56.1 \frac{KJ}{mol} = 11.22\ KJ$

q_2 (dissolution of NaOH) $= 44.5 \frac{KJ}{mol} \times 0.50\ mol$

$= 22.255 KJ$

Total energy released $= 11.22 + 22.255$

$= 33.475\ KJ$

$Q = m c \Delta T$

$33475\ J = 123g \times 3.99 \frac{J}{g K} (T_f - 22.5)K$

$33475\ J = 490.77\ J\ (T_f - 22.5)$

$68.2091\ J = T_f - 22.5$

$T_f = 90.71\ ^0C$

Question 3 (4 marks)

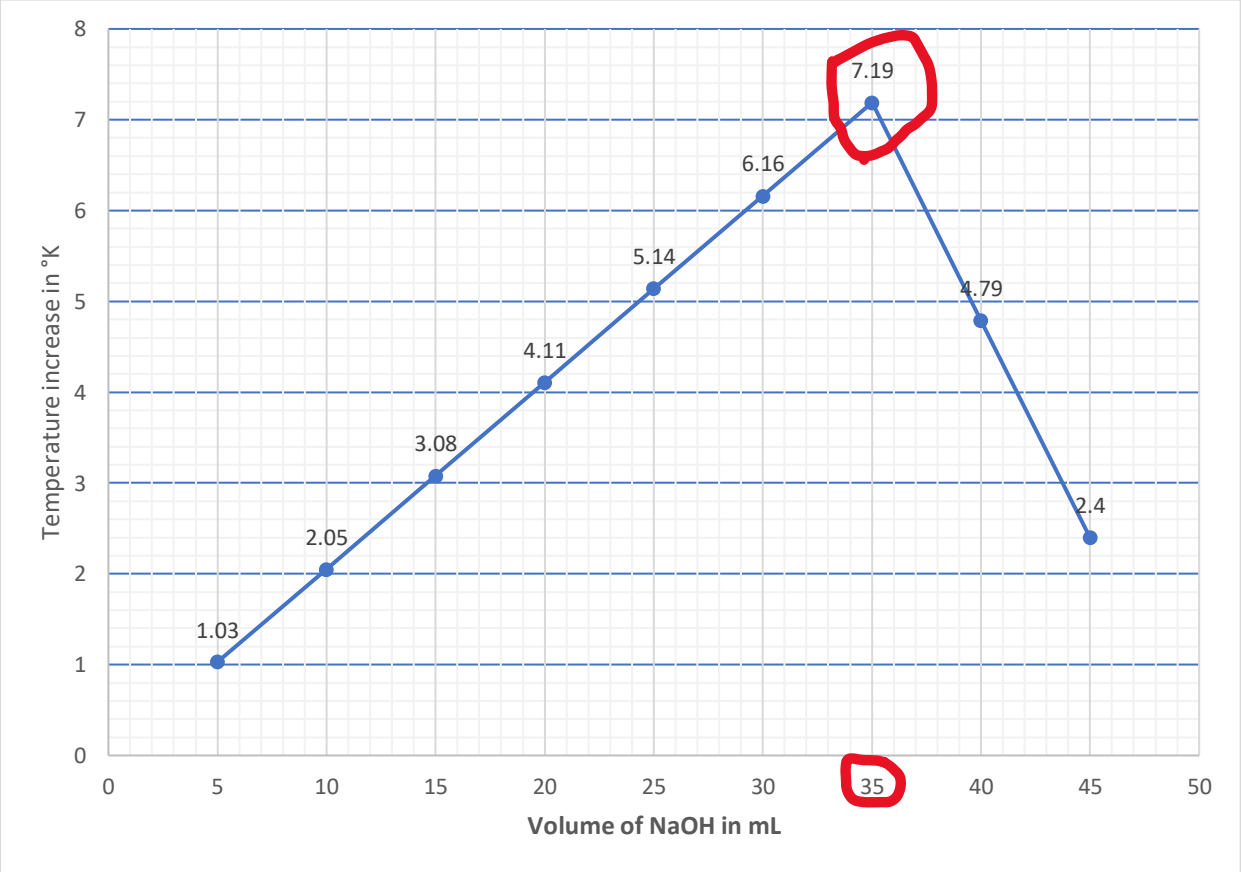
Various volumes of 0.800M oxalic acid and 0.685M sodium hydroxide solution, initially at room temperature, were added in varying volumes as outlined in the table below. The increase in temperature of each solution was measured and recorded in the following table.

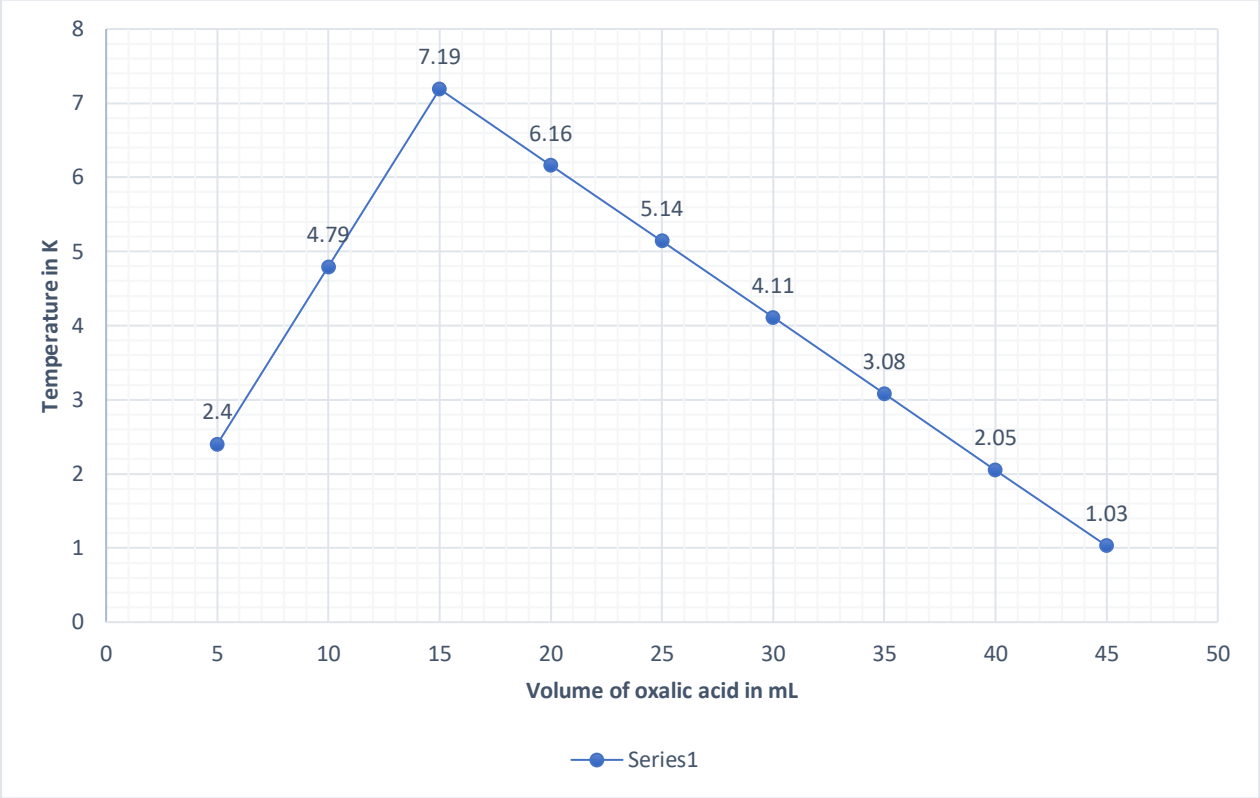
Volume of sodium hydroxide solution (mL)	Volume of Oxalic acid (mL)	Temperature increase (K)
5	45	1.03
10	40	2.05
15	35	3.08
20	30	4.11
25	25	5.14
30	20	6.16
35	15	7.19
40	10	4.79
45	5	2.40

By graphing the data in the table and performing relevant calculations, determine the number of moles of sodium hydroxide required to exactly neutralise the oxalic acid.

Criteria	Marks
Two lines of best fit with sharp point of intersection at the point of neutralisation	1
Volume of oxalic acid needed to neutralise NaOH = 35ml while NaOH reqd = 35ml from table	1
Correct use of grid, labelled axes with units	1
Correct calculation using value from the graph drawn	1

Solution:





At point of neutralisation: 15 mL of 0·800 M oxalic acid was used.

$n_{oxalic\ acid} = 0.015\ L \times 0.800\ M = 0.012$ moles

At PON: 35 mL of 0·685 M NaOH was used

$n_{NaOH} = 0.035\ L \times 0.685\ M = 0.024$ moles

$n_{oxalic\ acid} : n_{NaOH} = 1 : 2$

$$\begin{matrix} COOH \\ | \\ COOH \end{matrix} + 2NaOH \rightarrow \begin{matrix} COONa \\ | \\ COONa \end{matrix} + 2H_2O$$

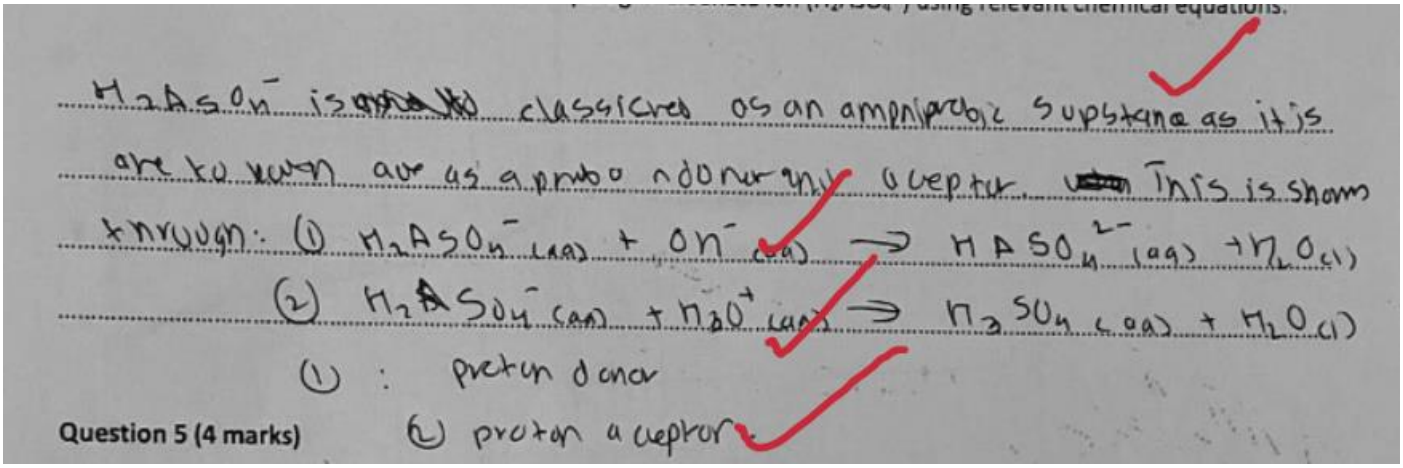
Marker's Note:

Some students drew two graphs clearly not understanding why the graph is even required. Only one PON is required to figure out the moles of NaOH needed.
Several students drew the graph correct but did not calculate number of moles of NaOH.
Graphing skills showed improvement. Most students scored at least 2.

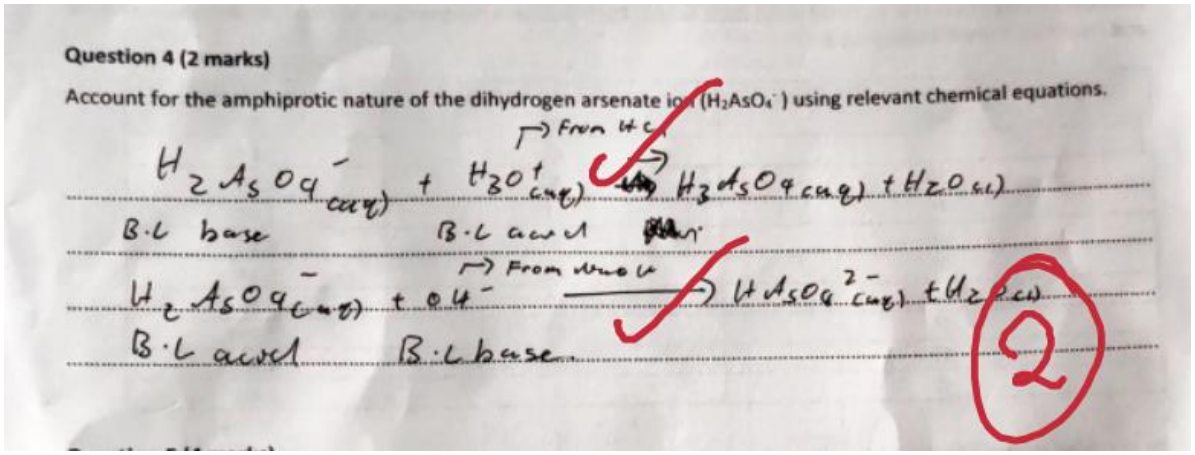
Question 4 (2 marks)
Account for the amphiprotic nature of the dihydrogen arsenate ion ($H_2AsO_4^-$) using relevant chemical equations.

Criteria	Marks
Shows a relevant equation between $H_2AsO_4^-$ and a **strong acid such as HCl and identifies** $H_2AsO_4^-$ as the proton acceptor. $H_2AsO_4^- + H_3O^+ \rightarrow H_3AsO_4 + H_2O$	1
Shows a relevant equation between $H_2AsO_4^-$ and a **strong base such as NaOH and identifies** $H_2AsO_4^-$ as the proton donor. $H_2AsO_4^- + OH^- \rightarrow HAsO_4^{-2} + H_2O$	1
Any one error OR Proton donor/acceptor not mentioned OR Shows correct reactions with water instead of strong acid/strong base	0

From Joseph Ng



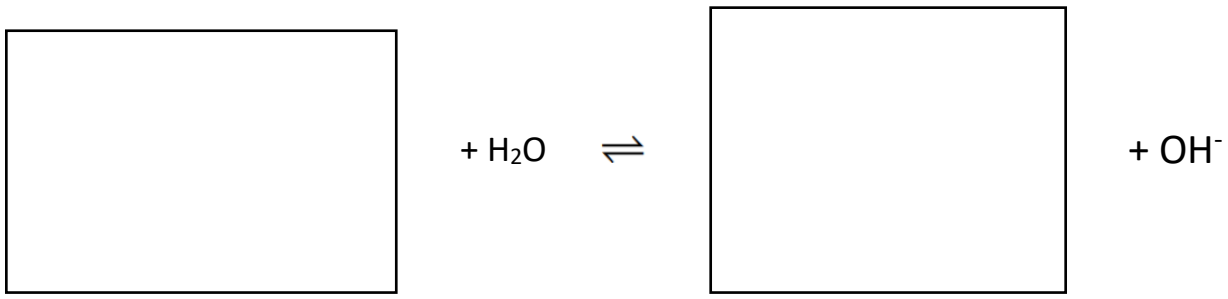
Alec Peng



Question 5 (4 marks)

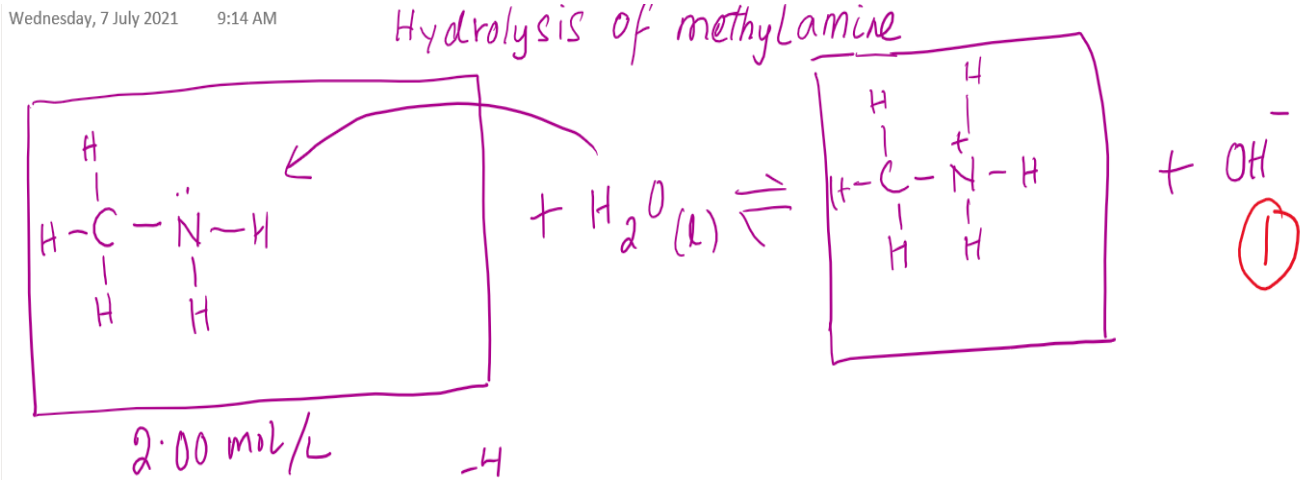
Joseph makes up a solution of methylamine in water with a concentration of 2.00molL^{-1}.

(a) Using structural formulae, complete the equation for the reaction of methylamine with water. (1 mark)



The K_b for the hydrolysis of methylamine is 4.2×10^{-4} at 25° C. Calculate the concentration of hydroxide ions in solution and therefore the value of pK_a for the corresponding conjugate acid. (3 marks)

Criteria	Marks
Correct structural formula for methylamine and its conjugate acid	1
Correct Kb equation and justifying the value of each product AND Correct substitution into the Kb equation	1
Correct value for concentration of OH^- ions = 0.03M	1
Relevant justification/working out to calculate the value of pKa = 10.62	1



Given $K_b = 4.2 \times 10$

At Eq $K_b = \dfrac{[CH_3\overset{+}{N}H_3][OH^-]}{[CH_3NH_2]}$ where $[CH_3\overset{+}{N}H_3] = [OH^-]$ (1)

	CH_3NH_2	$CH_3\overset{+}{N}H_3$	OH^-
I	2.00	0	0
C	$-x$	$+x$	$+x$
E	$2-x$	x	x

$$4.2 \times 10^{-4} = \frac{x^2}{2-x} = \frac{x^2}{2} \quad (2-x \simeq 2)$$

$$\sqrt{4.2 \times 10^{-4} \times 2} = x$$

$$0.02898 = x$$

$$0.03 \simeq x$$

$[OH^-] = 0.03\ M$ ——— (1)

$CH_3\overset{+}{N}H_3 / CH_3NH_2$ are conjugate acid/base pair. Hence at 25°C

$$K_a \times K_b = K_w$$

$$\text{So } K_a = \frac{K_w}{K_b} = \frac{10^{-14}}{4.2 \times 10^{-4}} = 2.4 \times 10^{-11}$$

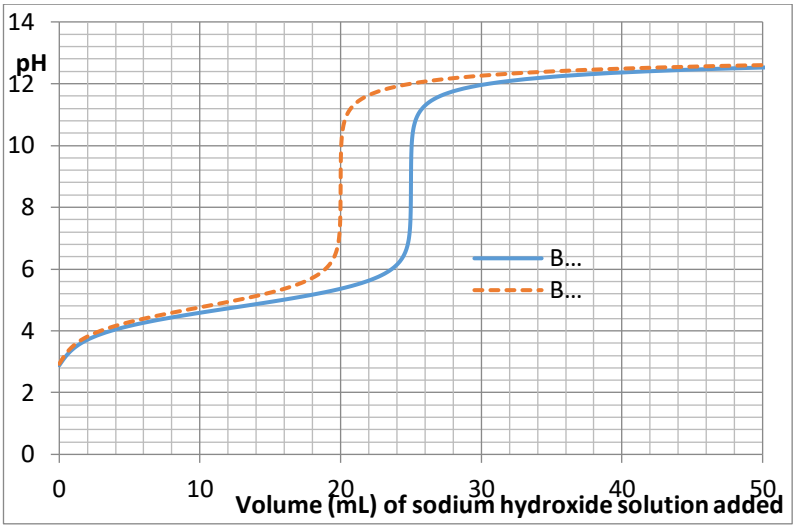
$pK_a = 10.62$ ——— (1)

$pK_b = 3.38$

Check $pK_a + pK_b = 14$

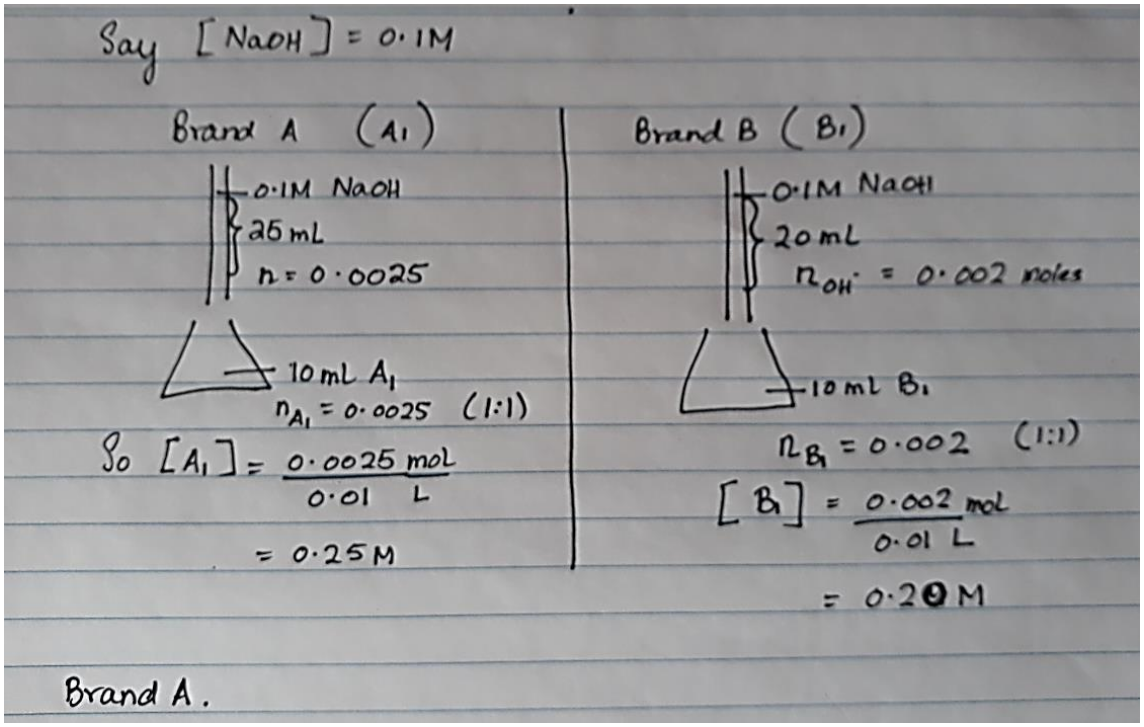
Question 6 (7 marks)

An investigation to determine the concentration of acetic acid in two brands of domestic vinegar, Brand A and Brand B. Equal volumes of vinegar were titrated using the same standardardised sodium hydroxide solution. The results of these titrations are shown below.



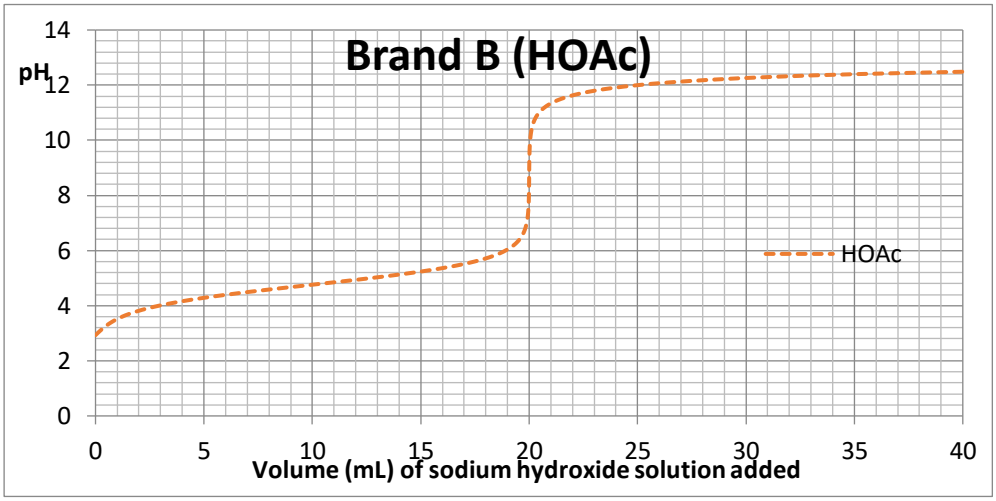
(a) Identify the vinegar brand that had the higher concentration of acetic acid. Show relevant calculations to derive your answer. (3 marks)

Outcome criteria	Marks
Uses the information given to perform relevant calculations for Brand A AND Uses the information given to perform relevant calculations for Brand B AND Derives the correct conclusion = Brand A has higher concentration	3
Identifies Brand A and gives a reason using the data given.	2
Brand A identified	1



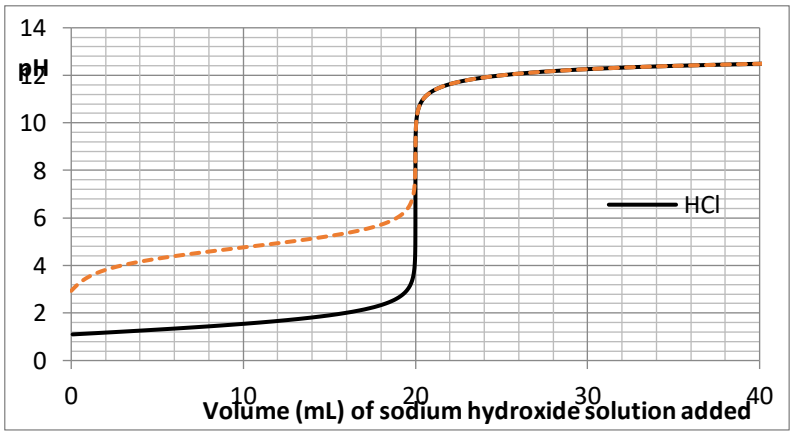
Question 6 *Continued*

(b) Suppose hydrochloric acid of the same concentration as Brand B acetic acid was also titrated using the same standardised sodium hydroxide solution. The same volume of hydrochloric acid as Brand B was also used. On the Brand B grid below, draw the titration curve for this titration. Contrast the titration curve for Brand B with the hydrochloric acid curve and explain any differences. (4 marks)



Solution

Criteria	Marks
Explains two differences in the titration curve (buffer section and equivalence point) AND Shows correct curve	4
Explains two differences in the titration curve (buffer section and equivalence point) AND Incorrect curve	3
Explains one difference in the titration curve (buffer section and equivalence point); describes the other difference correct or incorrect curve	2
Describes one difference	1



Buffer section of curve differences

The initial pH is less than the vinegar curve since HCl (aq) is a strong acid and furnishes more H^+ than the ethanoic acid in the vinegar.

Equivalence point differences

The salt formed at the equivalence point for the HCl (aq) titration is **neutral** as its anion is a very weak base (compared to water). E.g., HCl + NaOH → H_2O + NaCl

Explains the pH of CH_3COONa :

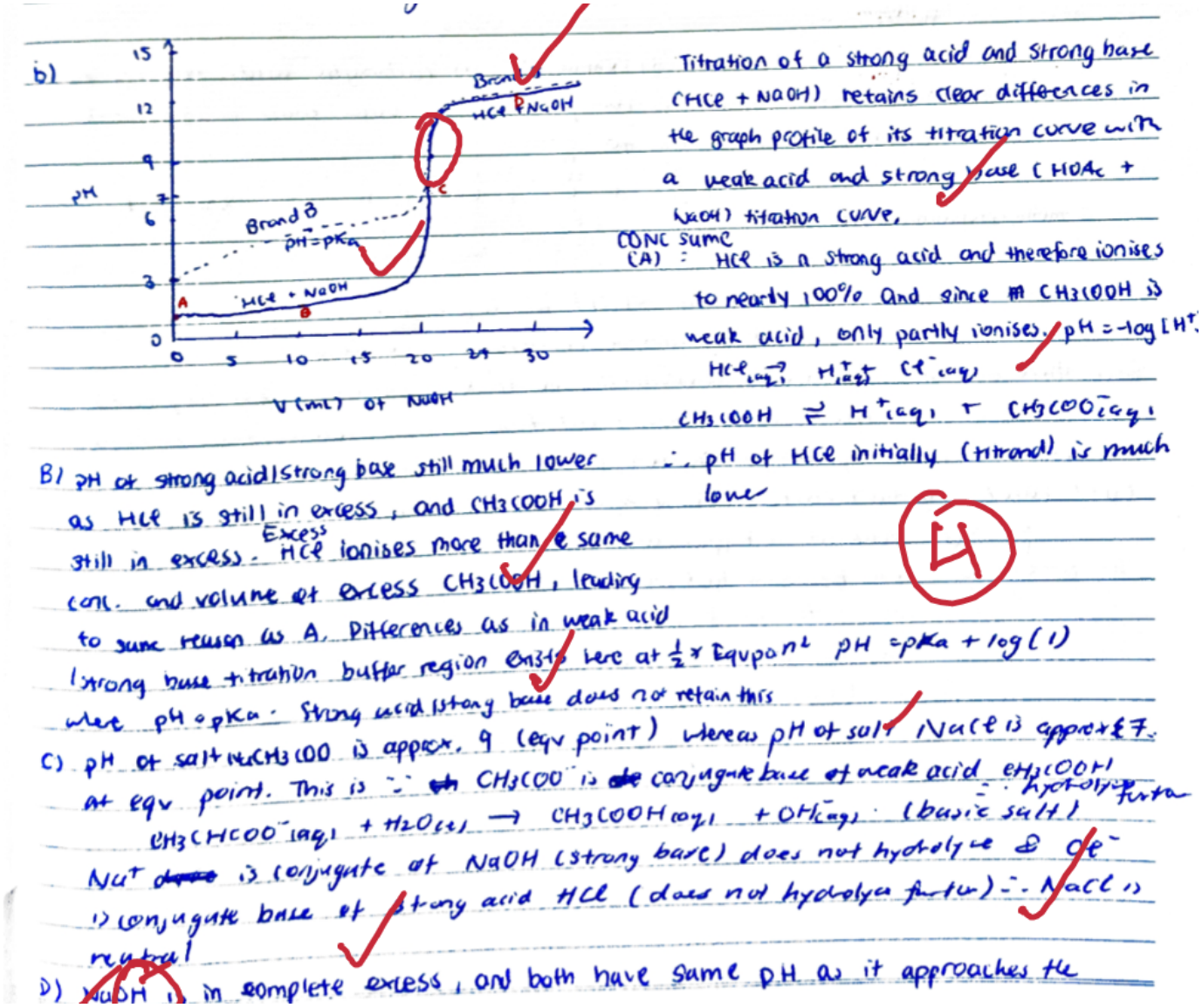
The salt formed at the equivalence point for the vinegar titration is a basic salt. This salt furnishes hydroxide ions as it loses them to water in an equilibrium reaction that favours

$HCH_3COOH + NaOH \rightarrow H_2O + CH_3COONa$

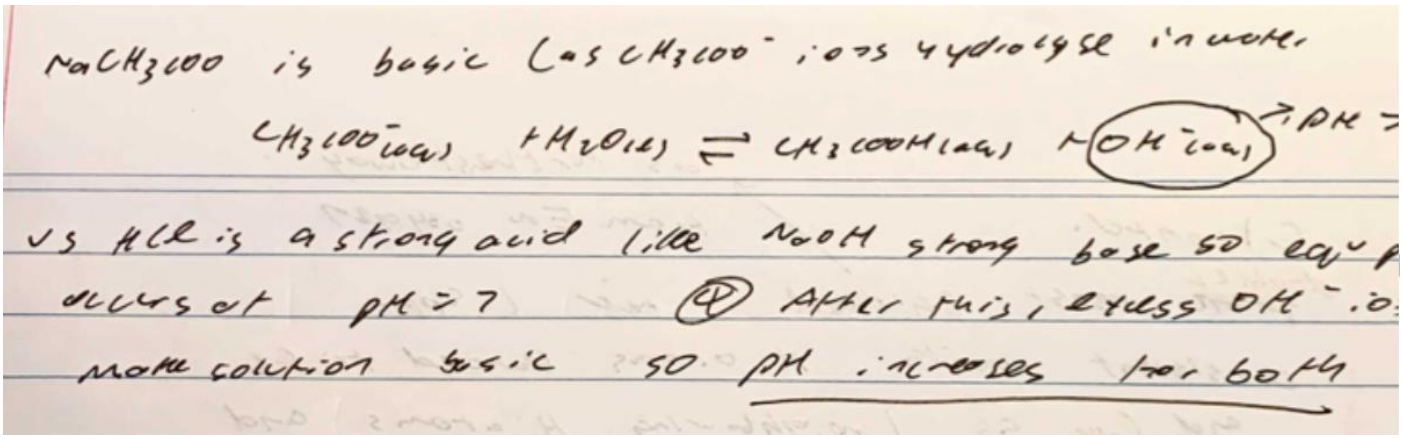
$H_2O + CH_3COO^- \rightleftharpoons CH_3COOH + OH^-$

C1 (curve #1) and C2 (curve #2) = correct differences displayed on the sketched titration curve for HCl(aq)
D1 = reasons given for curve #1 difference D2 = reason given for curve #2 difference

Sample of good answer A. Foo



R. Arora

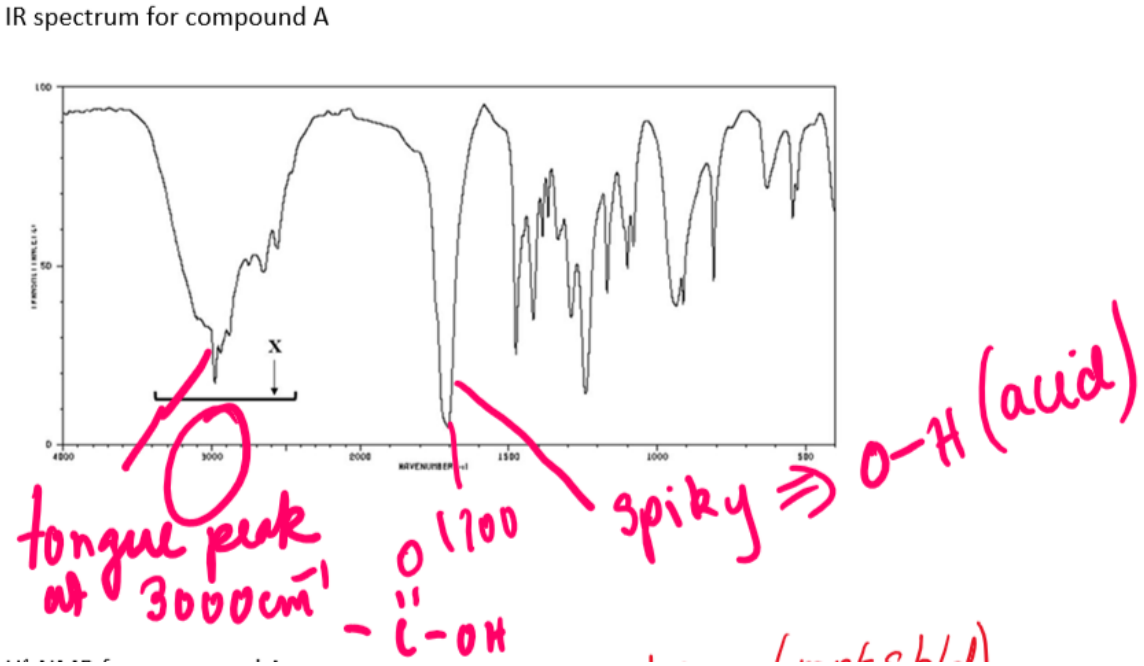


Question 7 (8 marks)

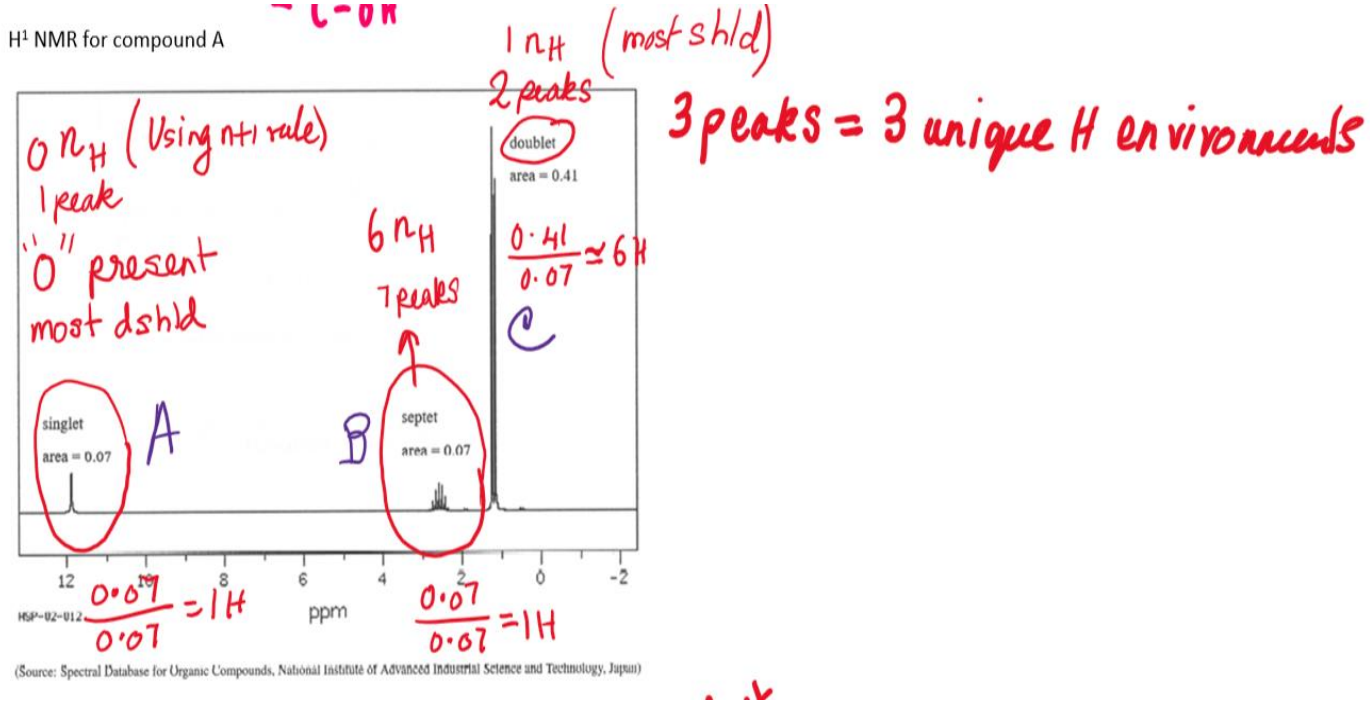
Joshua is determining the structure of an organic molecule. Microanalytic data shows that this molecule consists of 54.5% carbon, 9.1% hydrogen and 36.4 % oxygen by mass.

The IR, H^1 NMR and mass spectra of compound A are shown below. Draw the possible structure of the organic molecule using the spectral data and write the IUPAC name of the molecule. Justify your structure in reference to all three spectral data.

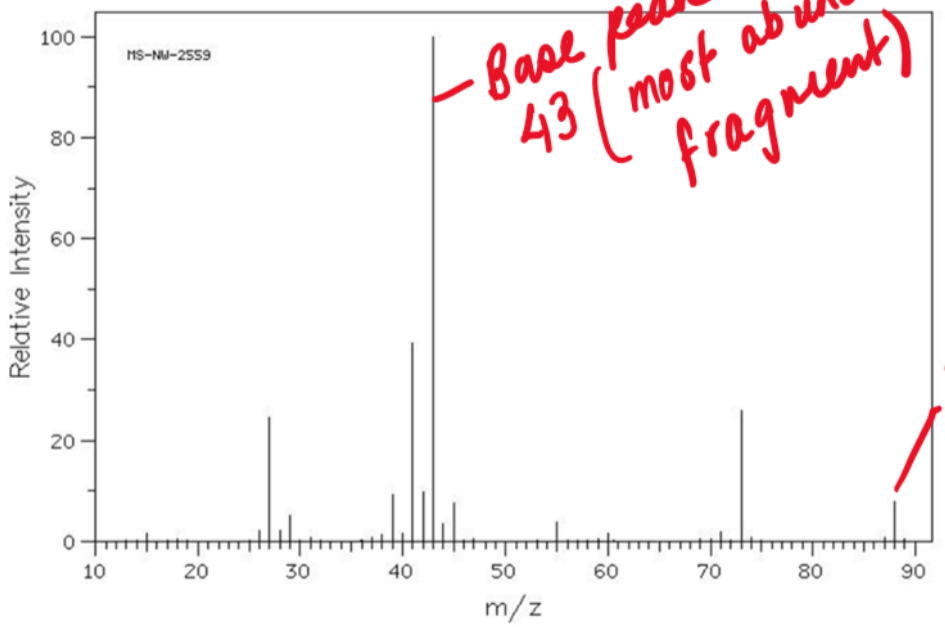
IR spectrum for compound A



H^1 NMR for compound A



(Source: Spectral Database for Organic Compounds, National Institute of Advanced Industrial Science and Technology, Japan)



Base peak 43 (most abundant fragment)

88 (mol. ion peak)

(a) Calculate the empirical formula and at least two possible molecular formulas. (2 marks) (3)

	C	H	O
In 100g,	C = 54.5	H = 9.1	O = 36.4
$n \Rightarrow$	$= \frac{54.5}{12.01}$	$\frac{9.1}{1.008}$	$\frac{36.4}{16}$
simplest ratio	≃ 2	4	1

1 mark — E.F = C_2H_4O

(1) mark for relevant working to calculate E.F

Possible M.F E.F × 2 = $C_4H_8O_2$ or $C_6H_{12}O_3$

(1) mark for both M.F

(b) Use the appropriate spectrum to confirm the molecular formulae for the compound Joshua is analysing. (2 marks)

mass of EF = 12.01 × 2 + 1.008 × 4 + 16 = 44.052

So EF × 2 = 44.052 × 2 ≃ 88 g/mol } 1 mark

Using mass spectra, molecular ion peak at 88 g/mol

M.F = $C_4H_8O_2$ ← 1 mark

Must use molecular ion peak to confirm not just 88 g/mol.

(c) Determine and draw the structure of the molecule and justify using the spectral data provided. (3 marks)

Criteria	Marks
Annotates spectrum (IR & Mass spec) correctly and makes relevant observations for each spectrum. & Annotates H NMR & Identifies all chemical environments and uses chemical shift data for H NMR to draw accurate conclusions & Identifies **peak A and makes all observations and draws possible structure** it represents & Identifies **peak B and makes all observations and draws possible structure** it represents & Identifies **peak C and makes all observations and draws possible structure** it represents & Uses **base peak of mass spectrum to confirm structure** shown by peak C & **Draws full structure and correctly writes IUPAC name** of structure	**3**
Annotates correctly and makes relevant observations for any two spectra and **full structure** and correctly writes IUPAC name of structure **OR** **Any one of the above missing**	**2**
Some relevant information such as one spectral information correct and partial correct structure	**1**

From IR spectra 2 possibilities

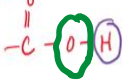
Spiky band O-H (acid) at 1700 cm^{-1}

& tongue peak at 3000 cm^{-1} for $-\overset{O}{\overset{\|}{C}}-O-H$

The above combination ⇒ possible structure in molecule

" $-\overset{O}{\overset{\|}{C}}-O-H$ "

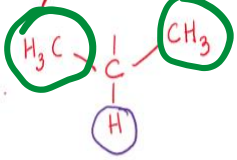
peak A
chem shift at 12 ppm singlet (no split), most deshielded (0 atoms present due to MF).
↳ indicating the H NOT adjacent to any other H, only possible for OH.
Using n+1 rule :- n protons have "n+1" peaks so 1 peak implies 0 neighbouring protons. Confirms the structure



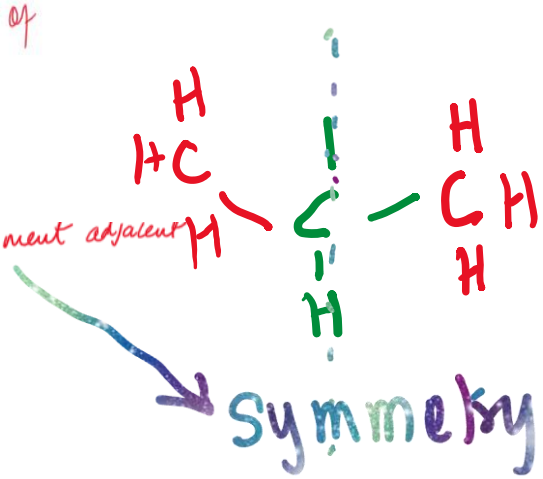
Peak area ratio = 1 ⇒ 1H

deshld

peak B
septet at 3 ppm. Integration peak area = 0.07 ⇒ $\frac{0.07}{0.07} = 1$ ⇒ one single chem environment of 1H
7 peaks ⇒ 6 neighbouring Hatoms

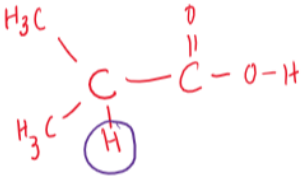


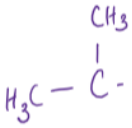
peak C
doublet at 1 ppm, split into 2 peaks, sheided ⇒ H environment adjacent to 1 more unique H environment.



Symmetry

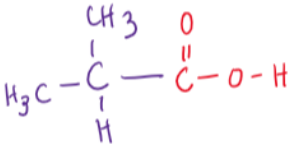
Combining all above together :-





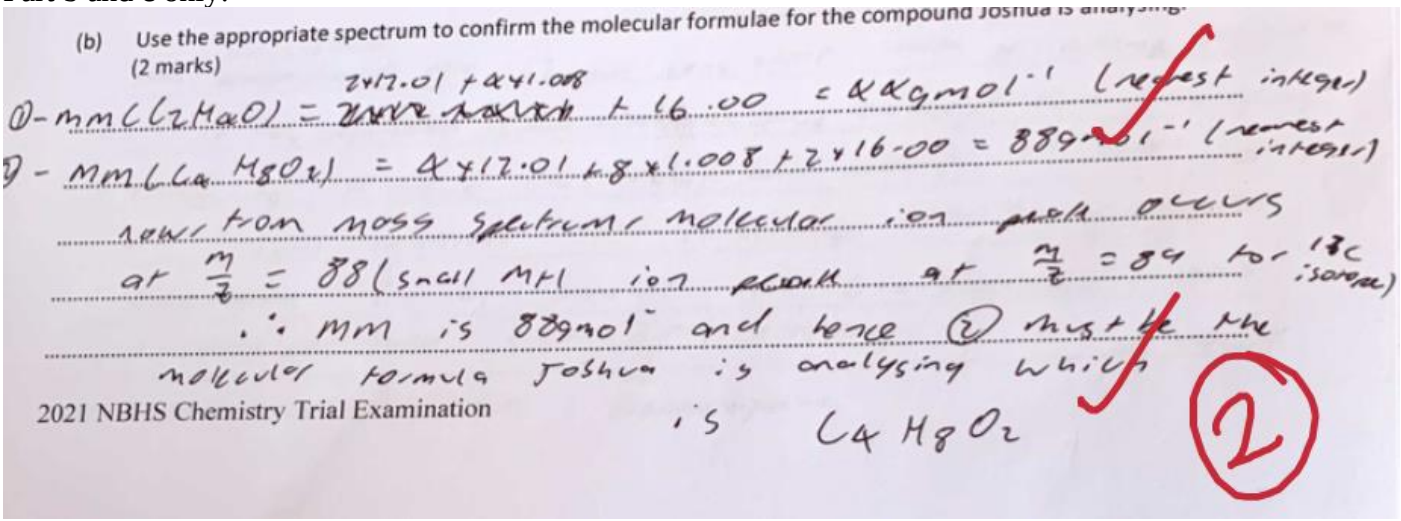
⇒ mass 43 ⇒ most abundant base peak on mass spectrum.

Hence confirmed structure

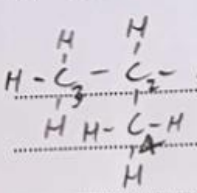


IUPAC name : 2-methyl propanoic acid.

Some sample answers from various great answers: R. Arora, R. Luo
Part b and c only:



(c) Determine and draw the structure of the molecule and justify using the spectral data provided. (3 marks)

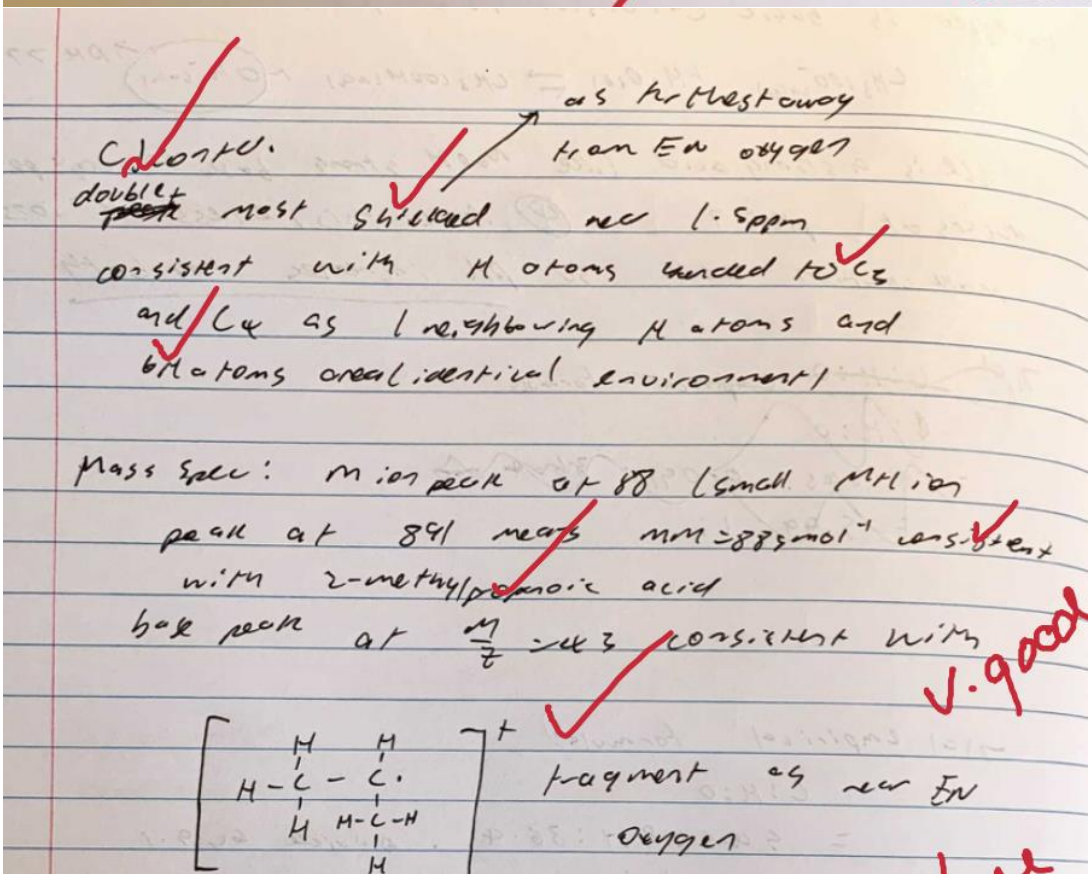


2-methylpropanoic acid

IR: of X there is a very broad absorption band in region near 3000 cm^{-1} so the molecule likely contains an OH (acid) or OH (alcohol). It cannot contain a N-H bond (can't be amine) as molecular formula is $C_4H_8O_2$ This vast OH peak draws out CH peak but at 1700 cm^{-1} there is a sharp absorption band consistent with C=O most likely or C=C but likely C=O as it lies outside 1620-1680 cm^{-1} range). The molecule is some either a carboxylic acid/ester or aldehyde/ketone but due to peak at X (OH) it is most likely a carboxylic acid. From ^1H NMR spectrum, three peaks = 3 hydrogen environments this as it is a carboxylic acid. with mm = 88 $gmol^{-1}$ the only possible option is 2-methylpropanoic acid (can't be butanoic acid → has 4 H environments)

peak area ratio = 0.07 : 0.07 : 0.42

= 1 : 1 : 6.



C closest. as furthest away from EN oxygen

doublet most shielded near 1.5ppm

consistent with H atoms bonded to C_3 and C_4 as 1 neighbouring H atoms and 6H atoms are identical environment

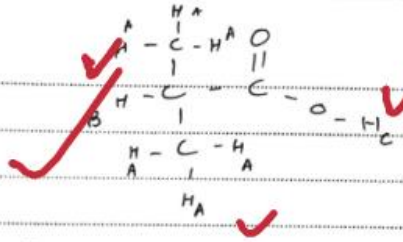
Mass spec: M ion peak of 88 (small M+1 ion peak at 89 means mm = 88 $gmol^{-1}$ consistent with 2-methylpropanoic acid

base peak at $\frac{m}{z}$ = 43 consistent with

fragment as near EN Oxygen

V. good

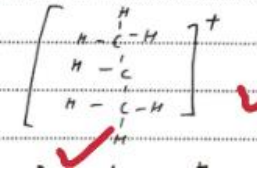
(c) Determine and draw the structure of the molecule and justify using the spectral data provided. (3 marks)



2-methyl propanoic acid. ✓ ✓ ✓ (1)

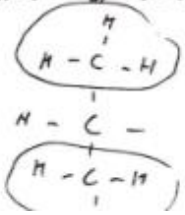
IR spec shows a broad, strong trough that stretches from 2400 - 3400, which suggests the presence of -OH or -NH. However, as there are no N_2 in the molecule, this correlates to the OH group of a carboxylic acid. The sharp trough at 3000 indicates CH. The sharp, strong trough at 1700 corresponds to a C=O group. Hence, this confirms that the molecule is a carboxylic acid. ✓ ✓ ✓ well annotated

In the mass spec, the molecular ion peak at 88 indicates a mm of 88 g/mol. This confirms the molecular formula $C_4H_8O_2$ (in (b)). It also confirms the structure as the base peak at 43 corresponds to the fragment: ✓ ✓ ✓ (2)



v. good

In the HNMR, there are 3 signals, so there must be 3 unique H environments. ✓ ✓ This correlates to the 3 H env: A, B, C. The singlet at 12 ppm has only one hydrogen as the peak ratios 0.07 : 0.07 : 0.41 = 1 : 1 : 6. ✓ ✓ Only the H in the hydroxyl group is capable of this peak due to separation of this env. from others due to the electronegative O. This causes it to have a high shift due to being deshielded and have no neighbouring Hs (n+1 rule), ✓ the double at shift 1 ppm corresponds to the H env. A as the peak ratios indicate 6 Hs in the env. This is confirmed in the molecule due to the plane of symmetry about ✓ ✓



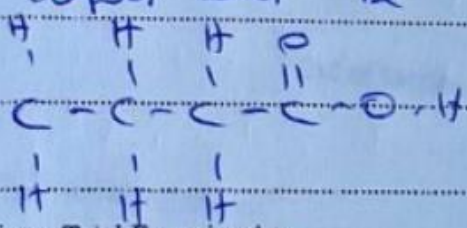
IR

- Large peak at ~ 3300 - 3150 ppm indicative of a carboxylic acid group which is supported by the peak at 1700 ppm which is a big and narrow 'sword' peak.
- No peaks at/or between 1500 - 2100 ∴ no double bond
- acid cannot be nitrile for acid because absence of N in the MS/analytical data.
- C=O stretches seen in fingerprint region at ~1300 ppm
- C-H stretch at ~ 2800 - 3000 ppm are common to MOST organic molecules.

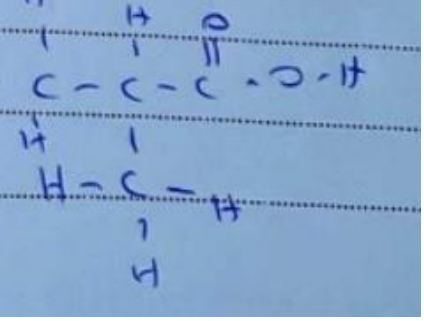
Mass spectrum

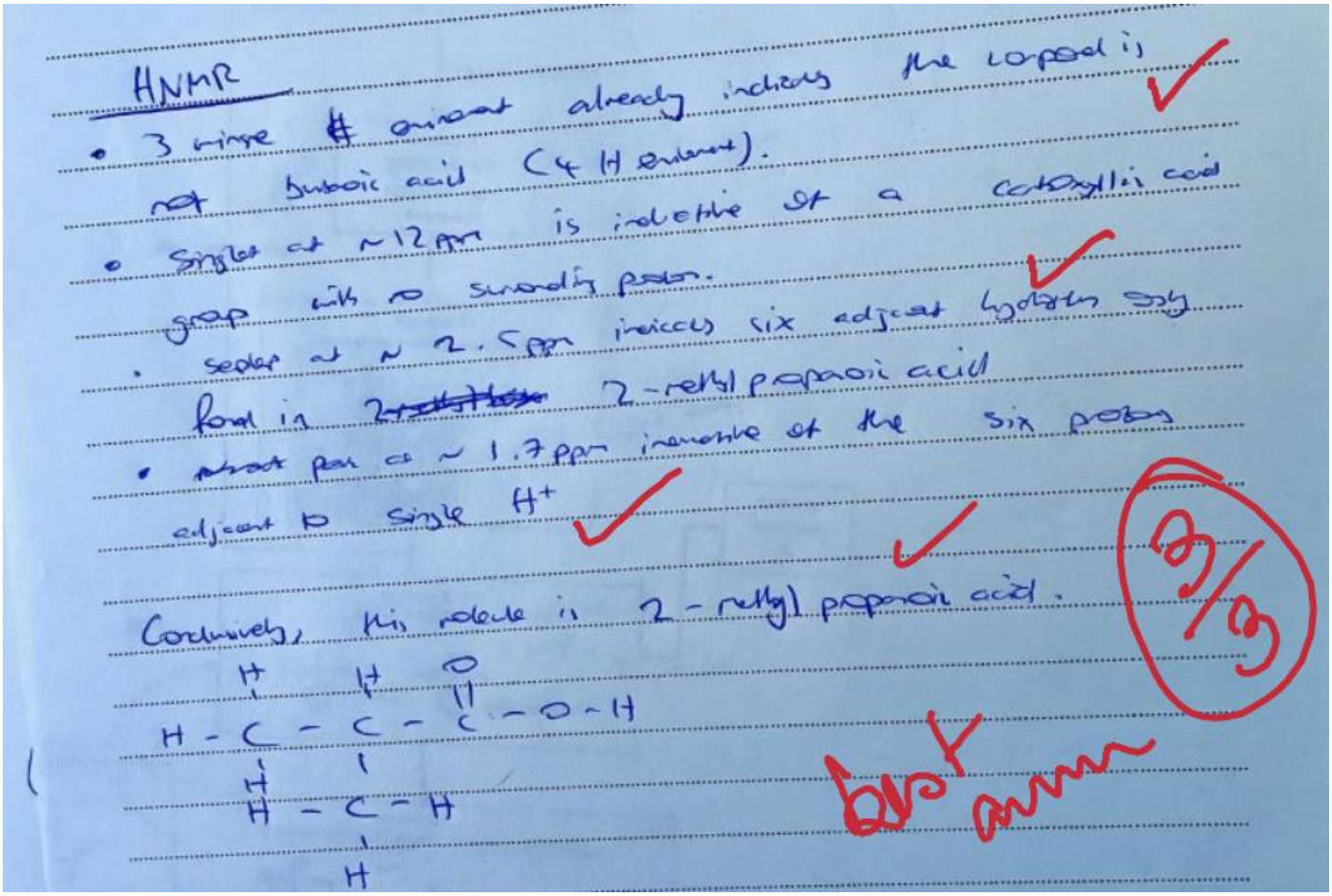
- M1P at 88 indicating either an alcohol or acid present in the molecule, knew given the short M1P (often seen in mid-long chain carboxylic acids) and absence of peak at 17 or 29 m/z (often seen in alcohols $[O-H^+]^+$ and $[C-O-H]^+$ indicate it is an acid.
- base peak at 43 indicates a propyl chain present $[CH_3-CH_2-CH_2]^+$

∴ compound could be



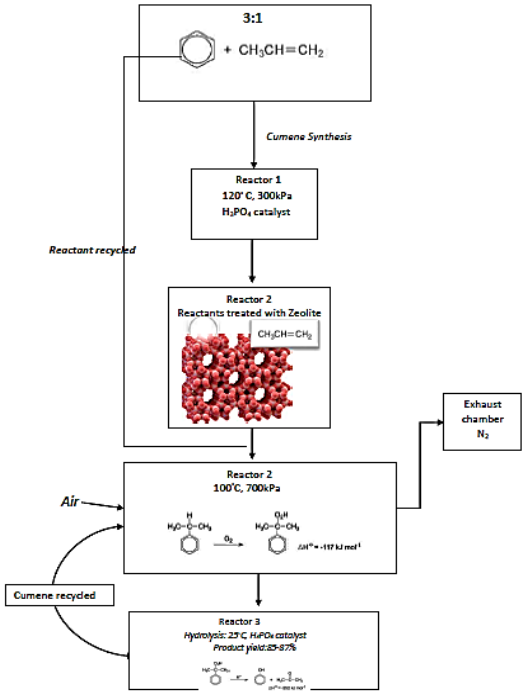
or





Question 8 (4 marks)

The flowchart below summarises the industrial process for the synthesis of phenol and acetone by using the cumene synthesis technique.



Explain **TWO factors** that may have been considered in the synthesis of phenol. Annotate the above diagram and make specific reference to the diagram in explaining each factor.

Criteria	Marks
Subheadings with factor 1 and factor 2 Relevant annotations from the given stimulus making multiple refences to the stimuli Explain each factor as: this happens because…… Link each explanation showing deeper understanding of industrial process	4
Chronological order not maintained otherwise all above points addressed OR Any one point missed/one error	3
Outline two factors and annotates diagram to a limited extent and/or explains using LCP OR Explains well but makes limited refence to stimulus provided	2
Outlines two factors no explanation provided but attempts to state safety and economic viability OR Shows conceptual error in understanding the question and/OR writes a preprepared answer for this inquiry question rather than addressing the question	1

Any two:

1. **Maintaining ratio to minimise waste:**

The two reagents (propene and benzene) are reacted in stoichiometric ratio of (3:1) to maximise the yield both valuable products (acetone and phenol).

The design process includes **two recycle loops** that ensure no loss of starting materials (economic gain and minimising pollutant release)

The only exhaust produced is nitrogen gas, so no environmental pollutants are produced and it is extracted to a separate chamber to stop interence with main reaction.

2. **Use of catalyst: Reactor vessels**

Zeolite- increases surface area, hence maximising successful collisions between reactants. Reactor 1 and 4 use a cheap catalyst of phosphoric acid (H3PO4) to reduce the temperature and pressure. This allows reaction to continue at a reasonable rate (maximising yield) while increasing safety.

While reactor 3 uses excess oxygen for complete combustion/oxidation, thus maximising the yield of hydrated cumene.

3. **Maintaining compromise temperature and pressure**

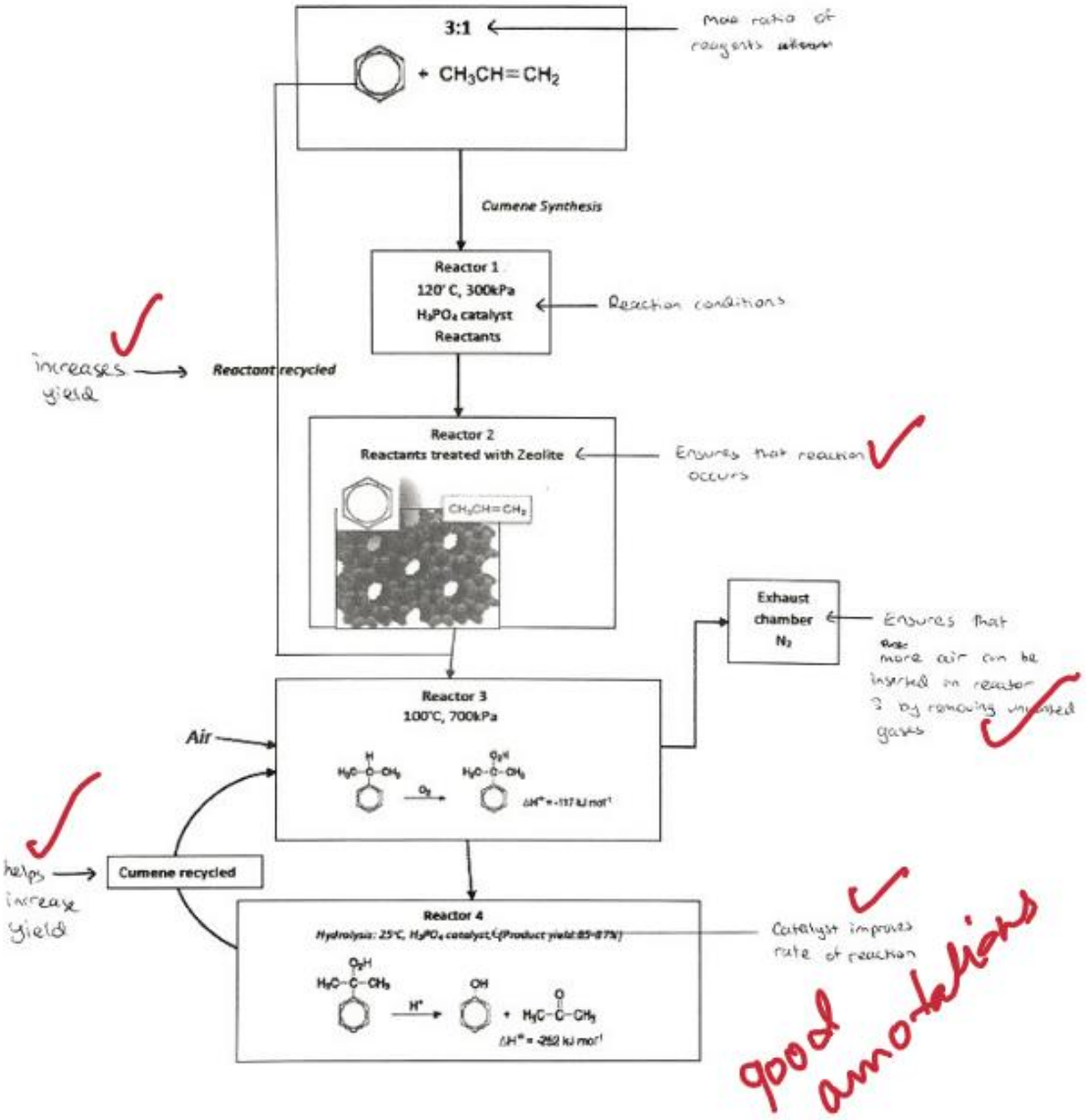
Make reference to reactor 1 or 3 and identify the exothermic nature of reactions in these chambers hence the need for lower T and P. The reaction conditions are maintained at reasonably low temperature and low pressure, thus increasing safety and reducing maintenance cost.

Concluding statement must include: By maintaining the above factors the yield of phenol and acetone is achieved at 85-87%

Kavusik K:

Question 8 (4 marks)

The flowchart below summarises the industrial process for the **synthesis of phenol and acetone** by using the cumene synthesis technique.



T. M

Explain **TWO** factors that may have been considered in the synthesis of phenol. Annotate the above diagram and make specific reference to the diagram in explaining each factor.

4

Reaction conditions

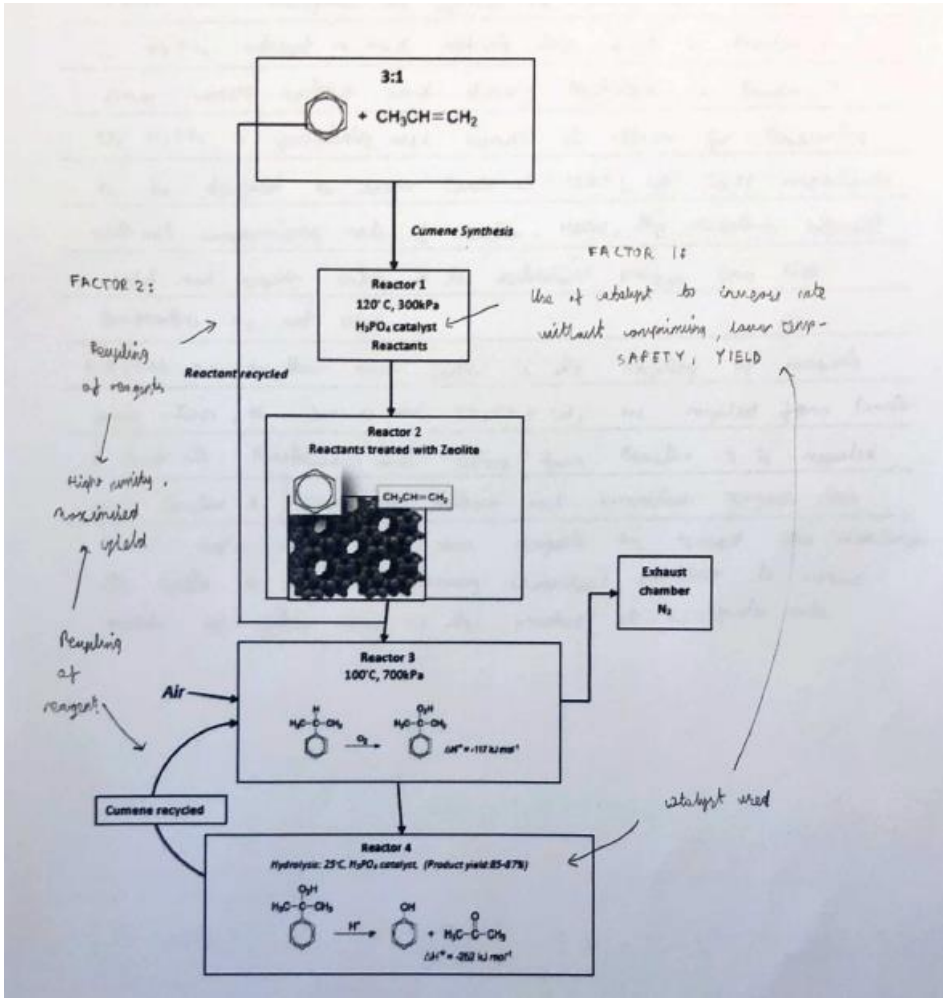
- None of the reactions are reversible therefore no considerations need to be made in terms of altering yield with heat / pressure
- Reactor 1 uses ↑ temperature and ↑ pressure in order to ↑ the rate of reaction. Collision theory states that as ↑ KE, more reactant molecules have an E_k KE > E_A meaning that the chance of successful collisions has increased. Similarly, by ↑ the pressure particles are closer together as $P \propto \frac{1}{V}$, therefore more successful collisions are occurring more often hence rate of reaction is increased.
- Furthermore the use of catalyst decreases the E_A for the reaction hence only lower temperatures* need to be used in the production which is a more safe practice and more economically viable. * to achieve the same rate of reaction.

Yield

- NO equilibrium considerations (single arrows)
- products produced in the stoichiometric ratio in order to minimise wastage and ↑ overall yield.
- reactants are recycled back together so that any unused reactants are put through the plant again rather than being pollutants into the environment.
- Use of zeolite resin means that a higher surface area is present, therefore there is more contact between the two substances, and there is more chance the reaction occurs hence ↑ yield.
- recycling the cumene into reactor 3 also ↑ yield as it allows the reactants to react again (given they were initially unreacted)

↳ all of these process achieved a yield of 85 – 87 %.

Veer Menon



Explain TWO factors that may have been considered in the synthesis of phenol. Annotate the above diagram and make specific reference to the diagram in explaining each factor.

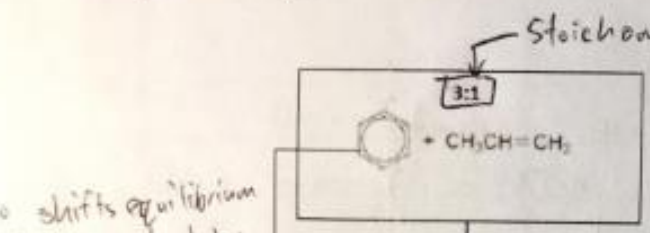
FACTOR 1: Throughout the synthesis of phenol and acetone a H_3PO_4 catalyst is used multiple times, first in Reactor 1 during cumene synthesis and during hydrolysis in Reactor 4. The H_3PO_4 is specifically used because it allows for temperature to be decreased to lower levels at 120°C & 25°C respectively without compromising rate of reaction. Hence, this maintains efficient yield and ensures safety in the industrial process since high temperatures are not used

FACTOR 2: Another major factor is the recycling of reagents many times, as benzene and $CH_3CH=CH_2$ are recycled from Reactor 2 back into Reactor 1 and cumene from Reactor 4 is recycled into Reactor 3. Hence, by filtering out unreacted reagents this ensures higher purity, and since reagents are reused this maximises the yield of products, allowing industrial producers to increase profits by selling more of their product at a faster rate

Angus Stewart

Question 8 (4 marks)

The flowchart below summarises the industrial process for the **synthesis of phenol and acetone** by using the cumene synthesis technique.



Stoichometric ratio so no wasted reactants (which cost $) and best reaction rate

Also shifts equilibrium towards the products by ↓ reactants.

Cumene Synthesis

Reactor 1
120° C, 300kPa
H_3PO_4 catalyst
Reactants

selected reaction conditions to maximise yield but also be safe.

Increase rate of reaction

As with all reversible reactions 100% products is impossible so filter out reactants and reuse

Reactants recycled

Reactor 2
Reactants treated with Zeolite

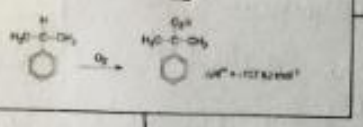
Exothermic so lower temp: used to ↑ yield

Exhaust chamber
N_2

Increases concentration of $O_{2(g)}$ which is needed from the reaction. Obviously cheaper than purchasing pure $O_{2(g)}$ to react.

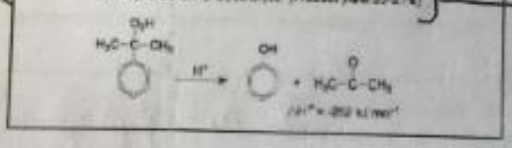
Reactor 3
100 C, 700kPa

Air



Cumene recycled

Reactor 4



Again conditions to ↑ yield. ~~A to~~ A low temp is wanted to ↑ yield (as exothermic) but ↓ temp ↓ reaction rate hence a catalyst to ↑ reaction rate. They have managed to get a fairly high yield.

Explain **TWO** factors that may have been considered in the synthesis of phenol. Annotate the above diagram and make specific reference to the diagram in explaining each factor.

Maximising yield through reaction conditions (while remaining safe) has been considered). For example in reactor 3 a temp of 100°C and pressure of 700 kPa has been used. A temperature has been chosen that is low enough to push the reaction towards the products (as it is exothermic) but not so low that reaction rate is slow. A high pressure is also used to ↑ yield but not so high as to be unsafe.

Also in reactor 3 an exhaust chamber removes $N_2(g)$. This is because $O_2(g)$ is a required reactant and is just being sourced from the air. By removing $N_2(g)$ (a major component of air) it increases reaction rate and yield as a higher relative concentration of O_2 is achieved. It would have been considered whether this option or purchasing pure oxygen was cheaper when designing this synthesis & process.

Question 9 (4 marks)
Roger was looking for an alternative to the cleaning agent they used at home. He found the following information.

> *Vinegar – an alternative to harsh chemical cleaning agents?*
> Vinegar is a solution of acetic (ethanoic) acid in water. Vinegar has been used as a cleaning agent for centuries. Studies have shown that the vinegar needs to have a concentration of 7–12% w/v* before it is an effective cleaning agent. Vinegar that has this concentration can be used as an alternative to synthetic cleaning agents.

He decided to analyse a sample of 'white vinegar' from the supermarket to determine the concentration of acetic acid and therefore performed a conductimetric titration. A 25.00 mL sample was taken of the vinegar and diluted to 250 mL in a volumetric flask. A 25.0 mL portion of this diluted solution was titrated using standardised 0.120 mol L^{-1} sodium hydroxide solution.

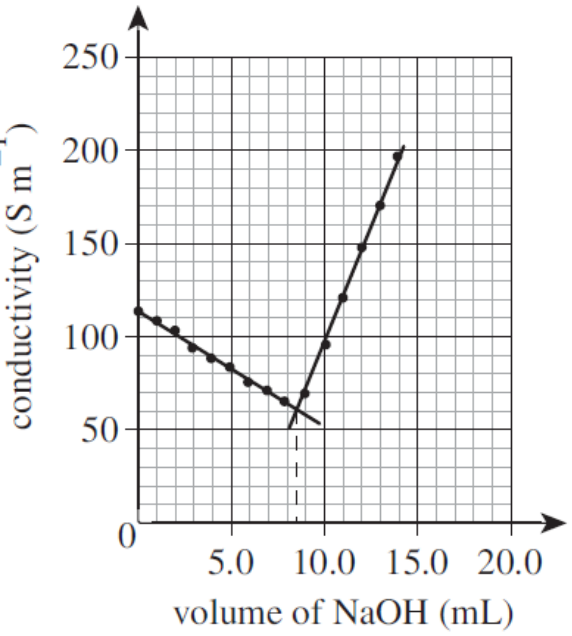
The conductivity of the diluted vinegar solution was taken. 1.00 mL of NaOH solution was then added in increments, the mixture stirred, and the new conductivity was taken after each addition.

Roger took the results and drew the following conductivity graph.

Perform relevant calculations and determine whether the vinegar was of the required concentration to be an effective cleaning agent. (4 marks)

Criteria	Marks
Identifies the equivalence point on the graph AND Shows working AND **Calculates concentration accurately**. AND **Makes the correct conclusion** based on concentration	4
Correct endpoint data showing lines of best fit. AND Calculates concentration accurately. **OR** Makes the correct conclusion based on concentration **OR** **Any one error**	3
Some correct calculations AND Shows working	1-2

$$NaOH(aq) + CH_3COOH(aq) \rightarrow CH_3COONa\ (aq) + H_2O(l)$$



$$\text{end point} = 8.5 \text{ mL}$$
$$= 0.0085 \text{ L NaOH}$$

For dilute solution:

$$\text{moles of NaOH} = 0.0085 \times 0.12$$
$$= 0.00102 \text{ mol}$$

$$\text{moles of } CH_3COOH = 0.00102 \text{ mol}$$

For original sample:

$$\text{moles of } CH_3COOH = 0.00102 \times \frac{250}{25}$$
$$= 0.0102 \text{ mol}$$

$$\text{molar mass of } CH_3COOH = 2 \times 12.01 + 4 \times 1.008 + 2 \times 16.00$$
$$= 60.052 \text{ g mol}^{-1}$$

$$\text{mass of } CH_3COOH = 0.0102 \times 60.052$$
$$= 0.613 \text{ g}$$

$$\%\ CH_3COOH = \frac{0.613}{25.00} \times 100$$
$$= 2.45$$
$$= 2.5\%$$

The concentration of the vinegar is less than the 7% minimum required concentration to be an effective cleaning agent.

0.00102 mol AA in 25 mL

$[AA]_{diluted} = \frac{0.00102\ mol}{0.025\ L} = 0.0408\ \frac{mol}{L}$

$[AA]_{original} = [\ \ ] \times 10 = 0.408\ \frac{mol}{L}$

So 1 L vinegar has $0.408\ mol \times 60.052\ \frac{g}{mol}$

$= 24.501\ g$

So 25 mL " has $\frac{24.501\ g}{1000\ mL} \times 25\ mL = 0.613\ g$

$\%\ w/v = \frac{0.613\ g}{25\ mL} \times 100 \rightarrow 2.45\%\ (w/v)$

Patrick L

volume of NaOH = 8.5 mL

n(NaOH) = 0.00102 mol

molar ratio 1:1

∴ n(acetic acid) = 0.00102 mol

~~acetic~~ [dil. acetic acid] = 0.00102 ÷ 0.025

= 0.0408 M

[acetic acid] = 0.0408 × 10

= 0.408 M

= 0.408 mol L^{-1}

~~= 0.408 × (2×12 + 6×16 + 6) g L^{-1}~~

~~= 1.11 g L^{-1}~~

~~= 0.14% w/v < 4%~~

~~∴ it is not effective.~~

$0.408 \times (2\times16 + 2\times16 + 3) = 24.072\ g\ L^{-1}$

$= 2.4\%\ w/v < 4\%$

∴ it is not effective.

4

Student Identification Number

Section A

2021 TRIAL EXAMINATION
Chemistry

General Instructions

- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using blue or black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.
- A laminated formulae sheet, data sheet and Periodic Table are provided along with the exam.

Total marks: 100

Section I (20 marks)

- 20 x Multiple Choice (20 marks)
- Attempt Questions 1–20
- Allow about 35 minutes for this section
- The multiple- choice **answer sheet** is provided as a separate sheet.

Section II Short (80 marks)

- **Section 2A- Extended Responses (40 marks)**
- Allow about 1 hr 15 min for this section
- **Section 2B- Extended Responses (40 marks)**
- Allow about 1 hr 15 min for this section

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.

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

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

A ○ B ● C ○ D ○

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

A ● B ● C ○ D ○

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

A ○ B ● C ○ D ○ **correct**

---

1. In which one of the following would the position of the equilibrium **not** be affected by a volume change at constant temperature?

(A) $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$

(B) $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$

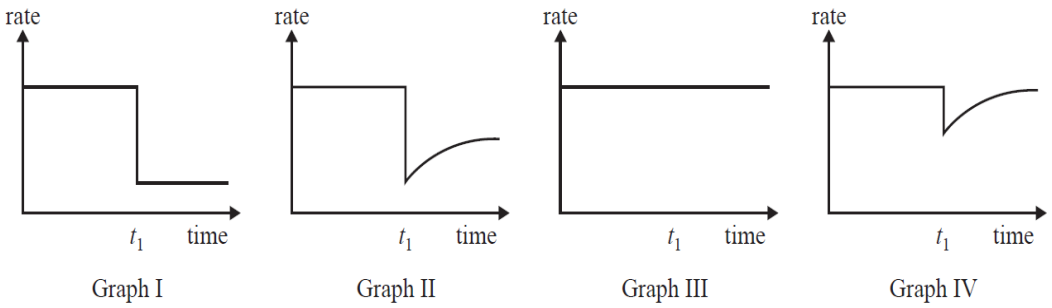
(C) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(D) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$

2. Reactants A and B are placed in a sealed container with a suitable catalyst where they react according to the equation:

$$A\,(g) + B\,(g) \rightleftharpoons C\,(g)$$

After the reaction reaches equilibrium, a small amount of a compound is added to the container at time t_1. The compound 'poisons' the catalyst and stops it working.



Which one of the graphs best represents the **rate** of the forward reaction versus time?

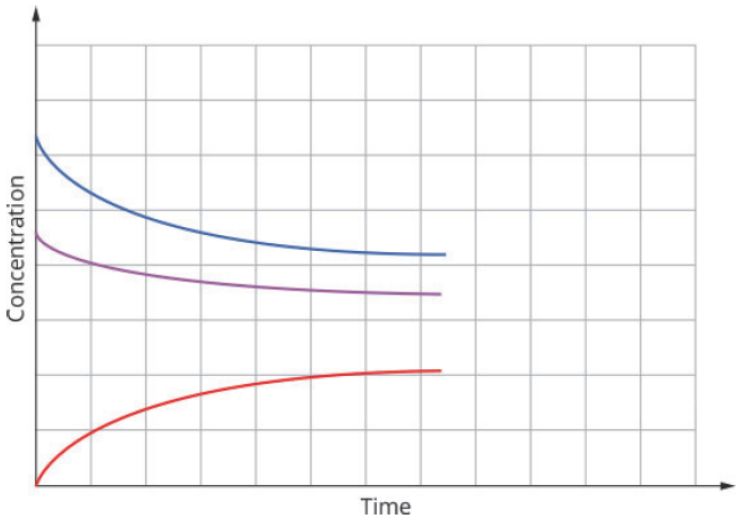
(A) Graph I

(B) Graph II

(C) Graph III

(D) Graph IV

3. The concentrations of species in an equilibrium reaction are shown in the graph below



A reaction that matches the concentrations shown could be:

(A) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(B) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(C) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

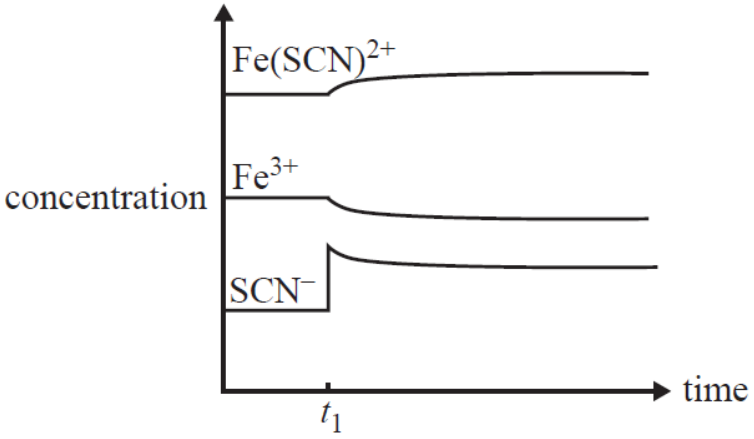
(D) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

4. Consider the following equilibrium reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$$

pale yellow colourless intense deep red

The concentration profile below represents a change to the above equilibrium system at time t_1.



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

(A) the addition of SCN^- causing the solution to become deeper red once equilibrium is re-established.

(B) the removal of Fe^{3+} causing the solution to become deeper red once equilibrium is re established.

(C) the addition of SCN^- causing the solution to become more yellow once equilibrium is re-established.

(D) Increase in temperature causing the solution to become more yellow once equilibrium is re-established.

5. What will happen when sulfuric acid is added to a saturated solution of sparingly soluble calcium sulfate?

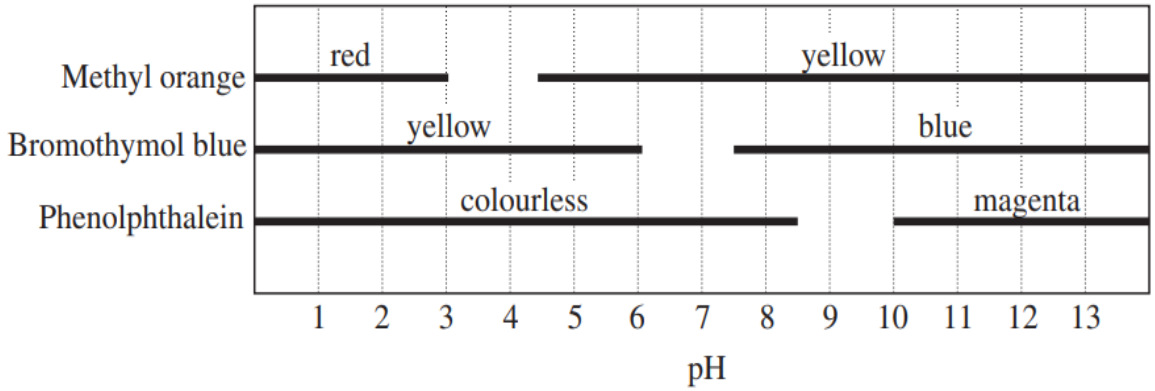
(A) The concentration of calcium and sulfate ions will increase over time due to the presence of H^+ ions.

(B) The concentration of calcium and sulfate ions will decrease over time due to the presence of H^+ ions.

(C) The concentration of calcium and sulfate ions will increase over time due to the presence of SO_4^{2-} ions.

(D) The concentration of calcium and sulfate ions will decrease over time due to the presence of SO_4^{2-} ions.

6. The graph shows colour changes of the acid -base indicators methyl orange, bromothymol blue and phenolphthalein.



A solution is yellow in methyl orange, blue in bromothymol blue and colourless in phenolphthalein. The pH range of the solution is

(A) 4.5 – 7.5

(B) 7.5- 8.5

(C) 6.0 – 7.5

(D) 8.5-10.0

7. Which of the following is least acidic?

	Acid	**pK_a**
(A)	Oxalic acid	1.23
(B)	Sulfurous acid	1.81
(C)	Phosphoric acid	2.12
(D)	Chloroacetic acid	2.85

Least acidic will have the highest pKa value

8. Chlorine gas is an acidic gas. Dissolution of chlorine gas in water lowers the pH of the water, due to the following chemical reactions:

$$Cl_{2(g)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + HCl_{(aq)}$$

$$HOCl_{(aq)} + H_2O_{(l)} \rightleftharpoons OCl^-_{(aq)} + H_3O^+_{(aq)}$$

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$$

Which of the following acid- base theories account for the fact that chlorine gas is an acid?

(A) Arrhenius theory only

(B) Bronsted-Lowry theory only

(C) Both of the above theories

(D) Neither of the above theories

Arrhenius theory
– Cl2 does not dissociate in the reaction; the first reaction (1) does not look like the Cl atoms
simply "separate" from each other.
• Lowry-Bronsted theory
– Cl2 does not have any H atoms and therefore does not have any protons (H+) to donate!
Therefore, neither theory explains why chlorine gas is an acid. In fact, the theory that explains this
is called Lewis theory, where an acid is an electron acceptor and

https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Acids_and_Bases/Acid/Lewis_Concept_of_Acids_and_Bases

9. Which of the following statements regarding strength and concentration of given acids and bases is true?

(A) A weak acid is unable to neutralise a strong base.

(B) The pOH of a strong concentrated base will be greater than that of a weak dilute acid.

(C) To neutralise a given amount of strong base, the number of moles of a monoprotic weak acid is the same as that required for a monoprotic strong acid.

(D) To neutralise a given amount of strong base, the number of moles of a monoprotic weak acid is greater than that required for a monoprotic strong acid.

10. In which of the following alternatives are the three compounds listed in order of increasing boiling point?

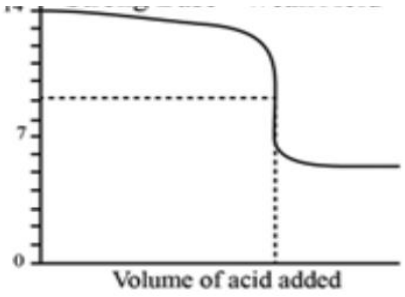
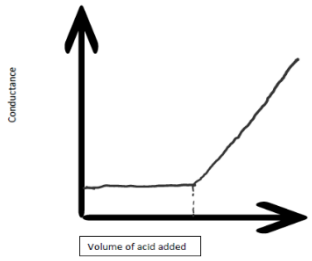
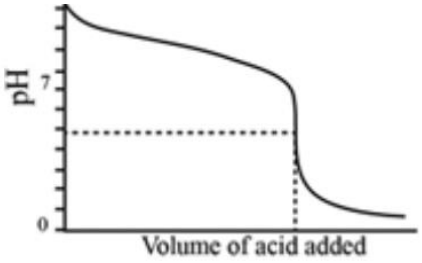
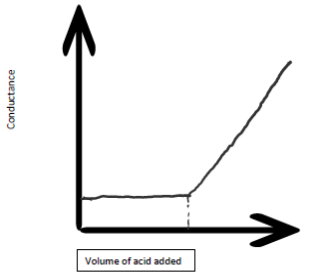
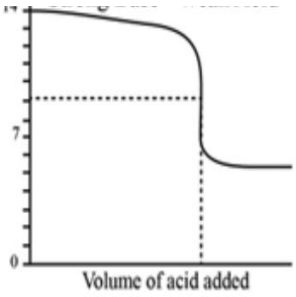
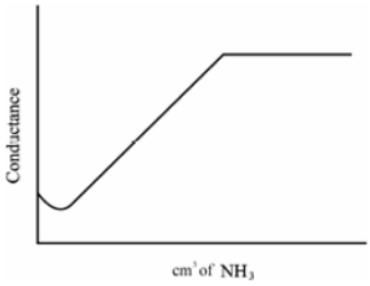
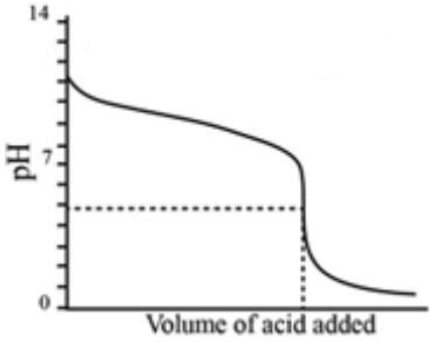
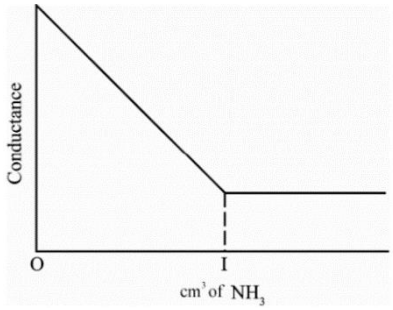
(A) Pentane, butan-1-ol, propanoic acid

(B) Propanoic acid, butan-1-ol, pentane

(C) Propanoic acid, pentane, butan-1-ol

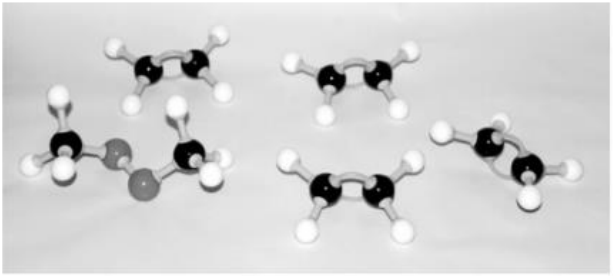
(D) Butan-1-ol, propanoic acid, pentane

11. Which of the following pair of curves correctly represent the neutralisation of a strong acid and given amount of a weak base?

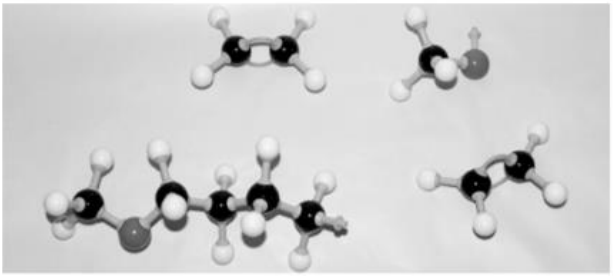
	Titration curve	Conductivity curve
(A)		
(B)		
(C)		
(D)		

12. A student created the following model to demonstrate a chemical process.

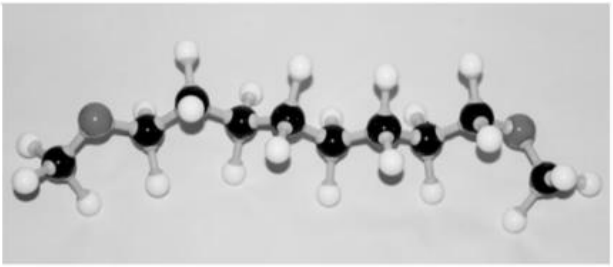
I



II



III



The chemical process modelled is

(A) Esterification between two different monomers

(B) Condensation polymerisation between two different monomers

(C) Addition polymerisation between two different monomers

(D) Addition polymerisation between identical monomers.

13. Which alternative is the best explanation of the action of soaps?

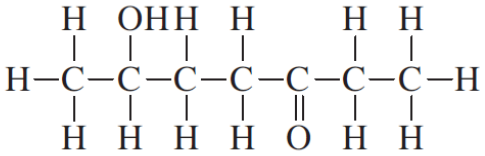
(A) The hydrophilic end of a soap molecule allows it to break up grease and fats while the hydrophobic end increases the surface tension of the water.

(B) One end of the soap molecule is cationic while the other end is non-polar.

(C) The hydrophobic end of a soap molecule allows it to break up grease and fats while the hydrophilic end decreases the surface tension of the water.

(D) One end of the soap molecule is cationic while the other end is anionic

14. What is the preferred IUPAC name of the structure below



(A) 2-hydroxyheptan-5-one

(B) 5-hydroxyheptanone

(C) 6- hydroxyheptan-3-one

(D) heptan-2-ol-5-one

15. Which one of the following molecules exhibits a planar shape.

(A) methane

(B) ethene

(C) propene

(D) butane

16. What mass of magnesium hydroxide is required to be added to 100 mL nitric acid with a pH of 3.5 in order to change the pH to 7.0?

(A) 6.5 x10^{-4} g

(B) 9.2 x10^{-4} g

(C) 1.3 x10^{-3} g

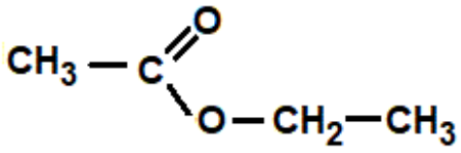
(D) 1.8 x10^{-3} g

$[H^+] = 10^{-3.5} = 3.16 \times 10^{-4}$ so moles of nitric acid = $3.16 \times 10^{-4} \times (0.1L) = 3.16 \times 10^{-5}$

HNO_3: $Mg(OH)_2 = 2:1$ so moles of $Mg(OH)_2 = \frac{1}{2} \times 3.16 \times 10^{-4} = 1.58 \times 10^{-5}$

Mass of $Mg(OH)_2 = 1.58 \times 10^{-5} \times 58.326 = 9.21 \times 10^{-4}$

17. The structure of ethyl ethanoate is shown below.



The mass spectrum of the above molecule has the highest peak at m/z = 43 and the smallest peak at 89.

What are the most likely sources of these peaks?

(A) $C_2H_3O^+$ and $^{13}C_{12}C_3H_8O_2$

(B) $C_2H_5O^+$ and $^{13}C_{12}C_3H_8O_2$

(C) $C_2H_3O^+$ and $^{12}C_{12}C_3H_8O_2$

(D) $C_2H_5O^+$ and $^{12}C_{12}C_3H_8O_2$

18. The 1H NMR spectrum of an organic molecule with molecular formula $C_3H_6O_2$has a triplet at 1.3ppm, a quartet at 4.2ppm and a singlet at 8ppm.

Which of the following is likely to be a property of this organic compound?

(A) Acidic
(B) Basic
(C) Neither acidic nor basic
(D) Amphiprotic

(a) ^{1}H Chemical shift 8.03 ppm, lone hydrogen atom : $HCOOCH_2CH_3$

This 1H resonance is NOT split by any other proton magnetic field - a singlet resonance spectral line.

There are no protons on an adjacent atom to cause spin - spin coupling.

Evidence for the presence of a 'lone' proton in the molecule of ethyl methanoate

(b) ^{1}H Chemical shift 4.22 ppm, CH_2 protons: $HCOOCH_2CH_3$

This 1H resonance is split by the adjacent methyl group protons into a 1:3:3:1 quartet (n+1 = 4)..

Evidence for the presence of a CH_3 group in the molecule of ethyl methanoate

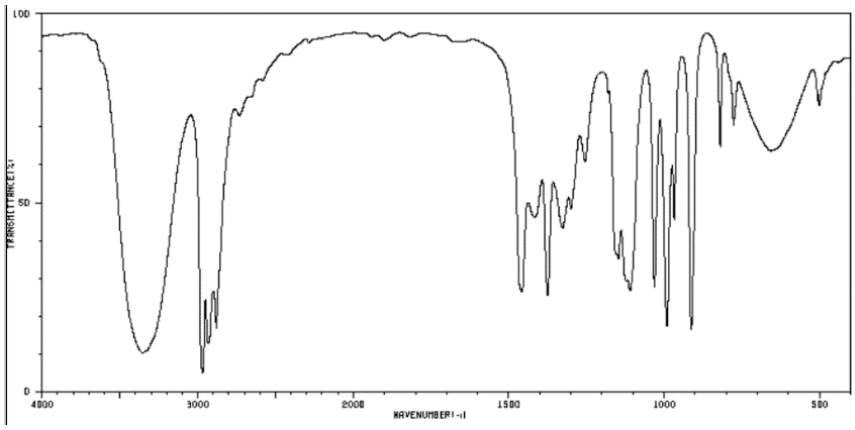
(c) ^{1}H Chemical shift 1.29 ppm, methyl protons: $HCOOCH_2CH_3$

This 1H methyl group resonance is split by the adjacent CH_2 group protons into a 1:2:1 triplet (n+1 = 3)..

Evidence for the presence of a CH_2 group in the molecule of ethyl methanoate

C3H6O2 is the molecular formula for propanoic acid
(C2H5COOH) has 1 double bond. Hence, all isomers will have 1 double bond, as they all have the same molecular formula.
A singlet at around 8 ppm. This usually corresponds to an aldehyde (RCHO) or methanoate (HCOOR) group, which makes it highly likely that the molecule is an ester – a methanoate. That would also explain the presence of a double bond (by means of the C=O group).
There are no other double bonds in the compound, and we only have two carbon atoms to arrange, knowing we have a HCOOR structure.
There is a triplet and a quartet in the NMR spectrum, meaning (by the n+1 rule) that one carbon is bonded to two hydrogen atoms, whereas the other is bonded to three; this means that we most likely have an ethyl (CH3CH2) group bonded to a carbon atom that itself has no hydrogens attached to it. Hence we get the structure ethyl methanoate – HCOOCH2CH3.

19. Lisa has an unidentified liquid in a vial. She tests the sample with orange coloured bromine water and the colour remains unchanged. An oxidation test with acidified potassium dichromate turns the solution green. She then conducts a test for carboxylic acids using sodium carbonate, the solution shows no visible change. She then puts the sample through the IR spectrometer and receives the following spectrum.



Which of the following compounds matches the above test results?

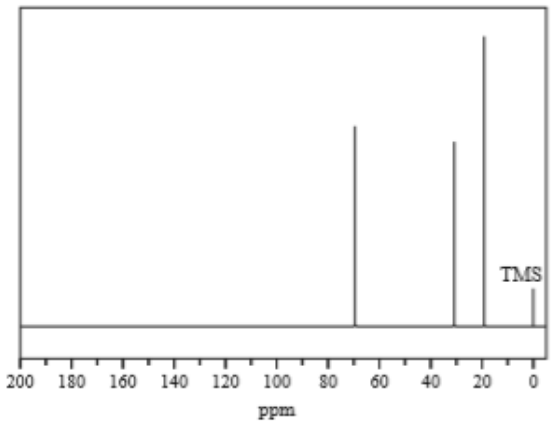
(A) Ethanol

(B) But-2-ene

(C) Butan-2-ol

(D) Butanoic acid

20.



The ^{13}C NMR spectrum above corresponds to which one of the following compounds?

(A) Propane

(B) 2-methylbutane

(C) 2-methylpropan-2-ol

(D) 2-methylpropan-1-ol