

STUDENT NUMBER: .....



# PENRITH SELECTIVE HIGH SCHOOL

## HSC CHEMISTRY 2023

### TRIAL EXAMINATION

#### General Instructions

- Reading time – 5 minutes
- Exam time – 3 hrs
- Board-approved calculators may be used
- Write using **blue or black** pen
- Chemistry Data Sheet is provided with this examination
- Answers written in pencil may be disqualified from review

#### PART A

##### *Multiple Choice (20)*

- Attempt Questions 1 – 20
- Allow about 30 minutes
- Provide responses on the Multiple Choice Answer Sheet

#### PART B

##### *Written response (80)*

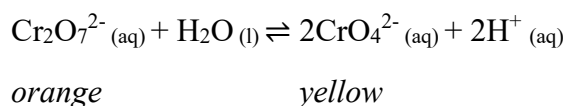
- Attempt Questions 21 – 30
- Allow 2 hrs and 30 minutes

TOTAL:            / 100

**THIS EXAM PAPER MUST BE SUBMITTED AT THE END OF THE EXAMINATION**

## PART A - MULTIPLE CHOICE QUESTIONS

1. A 500 mL solution of dichromate ions and chromate ions at equilibrium is described by the equation below.



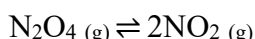
Which of the following best describes the effect of adding 5 drops of concentrated potassium hydroxide solution to the system.

	Relative change in concentration of $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$	Relative change in concentration of $\text{CrO}_4^{2-}(\text{aq})$	Relative change in concentration of $\text{H}^+(\text{aq})$	Colour change of solution
A)	decrease	increase	increase	more yellow
B)	no change	no change	no change	no change
C)	decrease	increase	decrease	more yellow
D)	increase	decrease	decrease	more orange

2. The molar solubility of barium phosphate is  $6.58 \times 10^{-3}$  g/L of water at 25°C. Calculate the  $K_{\text{sp}}$  for barium phosphate at the given temperature.

- A)  $3.40 \times 10^{-23}$   
B)  $1.70 \times 10^{-23}$   
C)  $2.70 \times 10^{-9}$   
D)  $2.50 \times 10^{-16}$

3. Exactly 2.0 mol  $\text{N}_2\text{O}_4$  is placed in an empty 1.0L container and is allowed to reach equilibrium as per the following equation.



If at equilibrium the  $\text{N}_2\text{O}_4$  is 20% dissociated, what is the value of the equilibrium constant ( $K_{\text{eq}}$ ) for the reaction under these conditions?

- A) 0.4  
B) 0.1  
C) 1.0  
D) 40

4. Silver acetate,  $\text{AgCH}_3\text{COO}(\text{s})$  crystals are in equilibrium with a saturated solution. Which of the following would cause more  $\text{AgCH}_3\text{COO}(\text{s})$  to dissolve?

- A) The addition of a few crystals of silver nitrate.  
B) The evaporation of some water from the solution with no temperature change.  
C) The addition of a few crystals of sodium acetate.  
D) The addition of a few drops of hydrochloric acid.

5. 10.0 mL of  $1.00 \times 10^{-5}$  M  $\text{AgNO}_3$  and 30.0 mL of  $2.00 \times 10^{-4}$  M  $\text{NaCl}$  are mixed.

$$K_{\text{sp}}(\text{AgCl}) = 1.8 \times 10^{-10}.$$

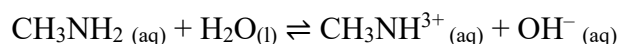
Which one of the following is correct?

	$Q_{\text{sp}}$	Precipitate...
A)	$3.75 \times 10^{-10}$	forms
B)	$3.75 \times 10^{-10}$	does not form
C)	$2.00 \times 10^{-9}$	forms
D)	$2.00 \times 10^{-9}$	does not form

6. Which of the following is a conjugate acid/base pair that can act as a buffer?

- A)  $\text{HNO}_3/\text{NO}_3^-$
- B)  $\text{H}_3\text{PO}_4/\text{PO}_4^{3-}$
- C)  $\text{NH}_4^+/\text{NH}_3$
- D)  $\text{SO}_4^{2-}/\text{SO}_3^{2-}$

7. Consider the hydrolysis equation below.



Which of the following are conjugate acid-base pairs?

- i.  $\text{CH}_3\text{NH}_2$  and  $\text{H}_2\text{O}$
- ii.  $\text{CH}_3\text{NH}_2$  and  $\text{CH}_3\text{NH}_3^+$
- iii.  $\text{H}_2\text{O}$  and  $\text{OH}^-$
- iv.  $\text{CH}_3\text{NH}_3^+$  and  $\text{OH}^-$

- A) ii only
- B) ii and iii only
- C) i and iv only
- D) i, ii, iii and iv

8. Which of the following equation/s demonstrate/s the Arrhenius model of acids and bases?

- i.  $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
- ii.  $\text{CH}_3\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
- iii.  $\text{KOH}(\text{aq}) \rightarrow \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$
- iv.  $\text{H}_2\text{PO}_3^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{H}_3\text{PO}_4(\text{aq})$

- A) i, ii, iii and iv
- B) i only
- C) ii and iii only
- D) i and iii only

9. A chemist prepares solutions of nitrous acid and hydrocyanic acid that have the same concentration.

The  $K_a$  values of these acids are:

- nitrous acid ( $\text{HNO}_2$ ) is  $4.6 \times 10^{-4}$
- hydrocyanic acid ( $\text{HCN}$ ) is  $6.17 \times 10^{-10}$ .

Which of these two acids is stronger and which has the higher pH?

	<b>Stronger acid</b>	<b>Higher pH</b>
A)	nitrous acid	nitrous acid
B)	nitrous acid	hydrocyanic acid
C)	hydrocyanic acid	hydrocyanic acid
D)	hydrocyanic acid	nitrous acid

10. Which of the following statements about pure water are correct?

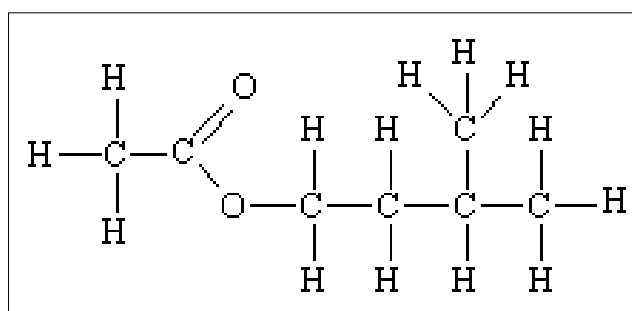
- Pure water is a weak electrolyte that undergoes self-ionisation.
- The equilibrium constant for the ionisation of pure water at  $25^\circ\text{C}$  is  $1.00 \times 10^{-14}$ .
- Pure water ionises completely at  $25^\circ\text{C}$ , hence  $[\text{H}^+] = [\text{OH}^-]$ .
- The ionisation of pure water produces twice as many hydrogen ions as hydroxide ions.

- A) i and ii only  
B) i, ii and iii only  
C) iii and iv only  
D) i, ii, iii and iv

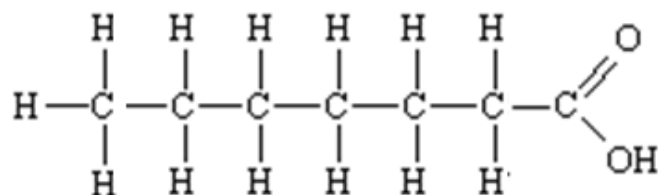
11. How many chain isomers does hexane have?

- A) 3  
B) 4  
C) 5  
D) 6

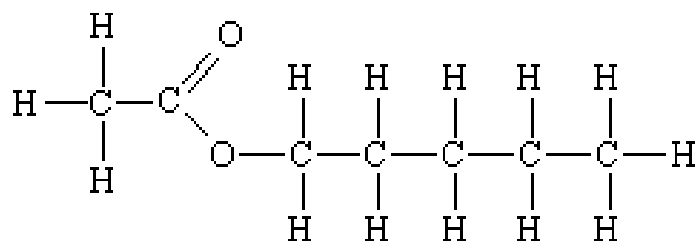
12. What is the functional isomer to methylbutyl acetate?



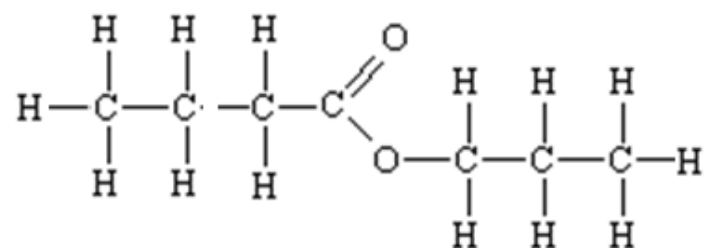
A)



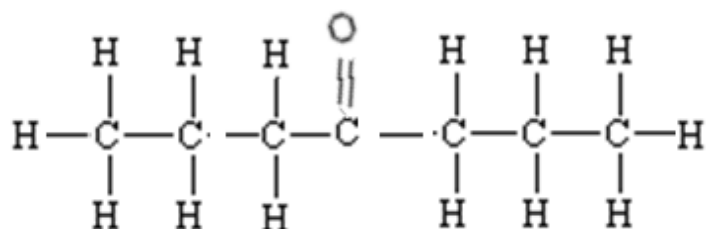
B)



C)



D)



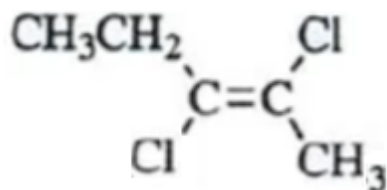
13. A student was provided with 2 unlabelled bottles. One bottle should contain butan-2-ol whilst the other holds butanone. The student conducted 2 types of tests.

Which of the following observations would be correctly observed for the two compounds?

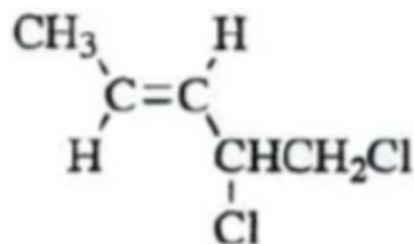
	Test	Butan-2-ol	Test	Butanone
A)	Anhydrous $\text{ZnCl}_2$	Turns cloudy immediately	Anhydrous $\text{ZnCl}_2$	No change
B)	$\text{H}^+ / \text{Cr}_2\text{O}_7^{2-}$	Orange to green colour change	$\text{H}^+ / \text{Cr}_2\text{O}_7^{2-}$	Orange to green colour change
C)	Anhydrous $\text{ZnCl}_2$	Turns cloudy in 5 minutes	Anhydrous $\text{ZnCl}_2$	No change
D)	$\text{H}^+ / \text{Cr}_2\text{O}_7^{2-}$	No change	$\text{H}^+ / \text{Cr}_2\text{O}_7^{2-}$	No change

14. Which of the following compound is 1,2-dichloro-2-pentene?

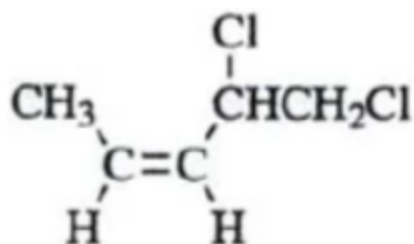
A)



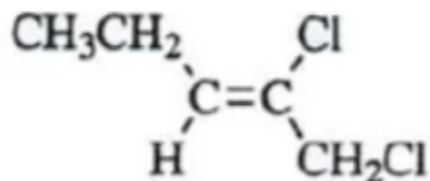
B)



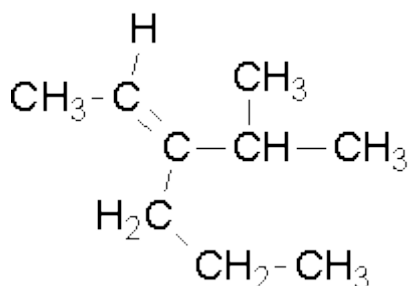
C)



D)



15. In a  $C^{13}$ -NMR, how many carbon environments would the following compound present?



- A) 9
- B) 8
- C) 7
- D) 6

16. The high resolution proton NMR spectrum of chloroethane has two sets of peaks. Both peaks are split.

Which of the following correctly describes the splitting pattern that would be observed?

- A) A singlet and a doublet
- B) A doublet and a doublet
- C) A doublet and a triplet
- D) A triplet and a quartet

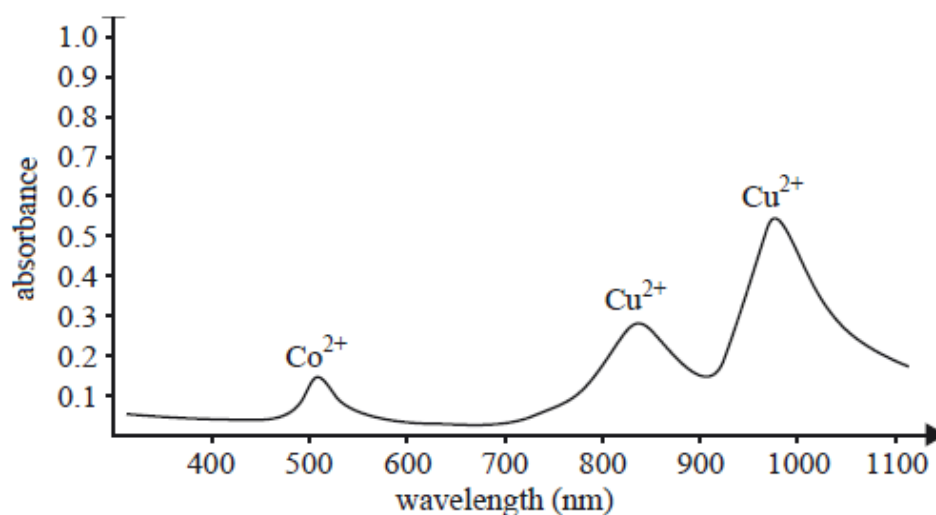
17. Electromagnetic radiation of a specific wavelength can interact with some molecules and atoms by promoting electrons at a low energy level to higher energy levels.

Which pair of analytical techniques relies on the measurement of these electronic transitions?

- A) Atomic absorption spectroscopy and UV-visible spectroscopy
- B) Infrared spectroscopy and atomic absorption spectroscopy
- C) Proton NMR spectroscopy and mass spectrometry
- D) Mass spectrometry and infrared spectroscopy

18. A chemist suspected that an impure copper lump contained a significant amount of cobalt. Cobalt would be oxidised to  $\text{Co}^{2+}$  ions which would remain in the electrolyte solution.

The spectrogram below gives the results of an analysis conducted on the solution. The two ions absorb at distinctly different wavelengths.



Which analytical technique was used to perform this analysis?

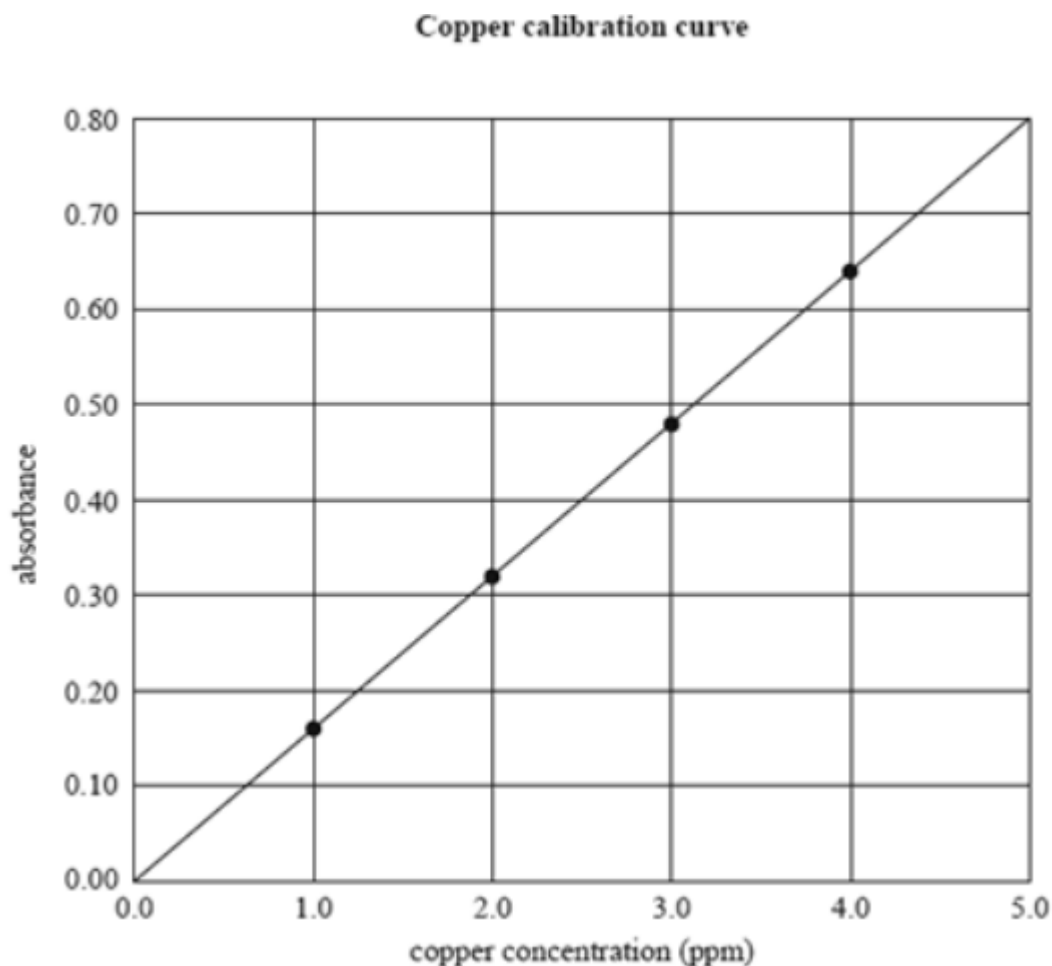
- A) Atomic absorption spectroscopy
- B) Mass spectrometry
- C) UV-visible spectroscopy
- D) Infrared spectroscopy



**Refer to the following information to answer Questions 19 and 20**

An atomic absorption spectrometer can be used to determine the level of copper in soils. The calibration curve below plots the absorbance of four standard copper solutions against the concentration of copper ions in ppm.

The concentrations of copper ions in the standard solutions were 1.0, 2.0, 3.0 and 4.0 mg L<sup>-1</sup>. (1 mg L<sup>-1</sup> = 1 ppm)



19. The concentration of copper in a test solution can be determined most accurately from the calibration curve if it is between
- A) 0.0 ppm and 5.0 ppm
  - B) 0.0 ppm and 4.0 ppm
  - C) 1.0 ppm and 4.0 ppm
  - D) 1.0 ppm and 5.0 ppm
20. If the sample solution gave an absorbance reading of 0.40, what would be the concentration, in mol/L, of copper ions in the solution?
- A) 2.5
  - B)  $3.9 \times 10^{-5}$
  - C)  $3.9 \times 10^{-2}$
  - D)  $2.5 \times 10^{-6}$

**PART B – SHORT RESPONSES**

**Question 21**

**3 marks**

A saturated solution of lead chloride has a  $K_{sp}$  value of  $1.70 \times 10^{-5}$  at  $25^{\circ}\text{C}$ .

Calculate the concentration of  $\text{Pb}^{2+}$  ions in a solution after 20.0 mL of  $0.150 \text{ mol L}^{-1} \text{ HCl}$  is added to 30.0 mL of a saturated lead chloride solution. 3m

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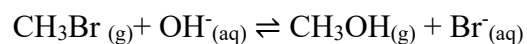
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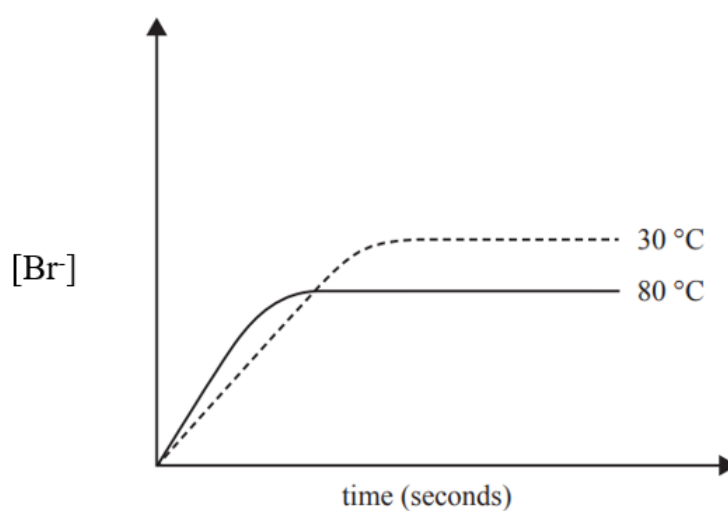
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**Question 22****6 marks**

Bromomethane reacts with hydroxide to form methanol and bromide ion as shown in the reaction below:



Two reactions vessels containing the equilibrium mixture were heated to two temperatures, 30 °C and 80 °C, and the concentration of Br<sup>-</sup> was recorded. The results are shown in the graph below.

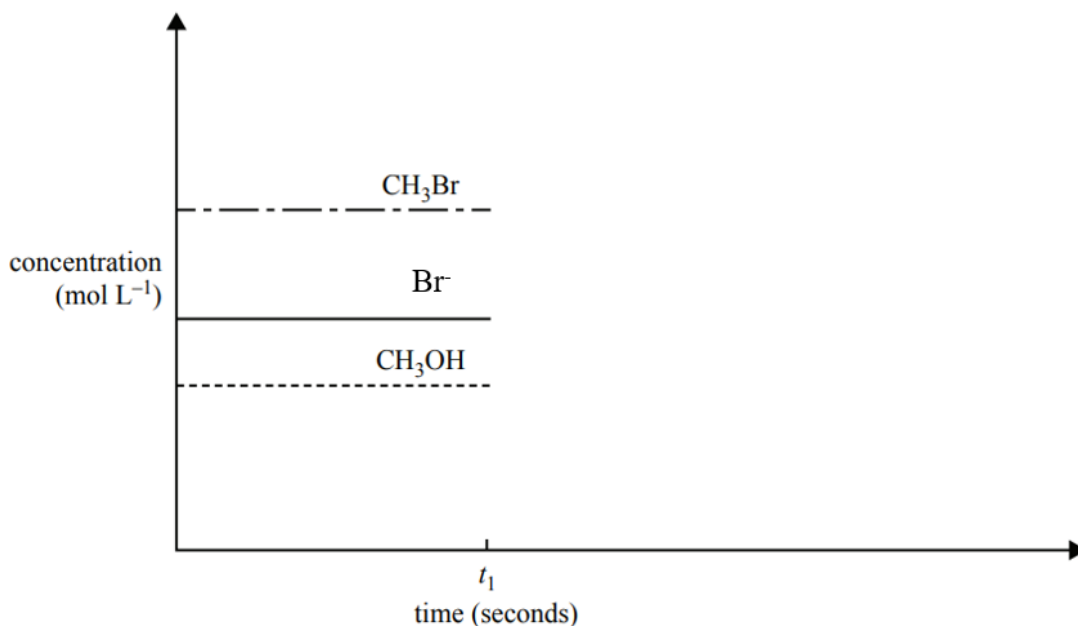


a) State whether the forward reaction is exothermic or endothermic.

1m

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The graph below represents the concentration of three of the species involved when they are at equilibrium at constant temperature



- b) Excess silver nitrate,  $\text{AgNO}_3$ , solution was added to the equilibrium mixture at time  $t_1$ . Sketch the impact that the addition of silver nitrate would have on each of the species in the solution. **Explain** the shape of the graph you have drawn. 5m

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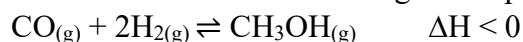
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**Question 23****7 marks**

Methanol is a useful fuel that can be manufactured from biogas as represented by the following equation:



- a) Explain, with reference to ONE key principle, how reaction temperature and pressure can affect the yield of methanol from biogas. 4m

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- b) 0.840 mol of carbon monoxide, CO, and 0.325 mol of hydrogen, H<sub>2</sub>, were allowed to reach equilibrium in a 500 mL container. At equilibrium the mixture contained 0.150 mol of methanol. Calculate the equilibrium constant, K<sub>eq</sub>, of the synthesis of methanol. 3m

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**Question 24****9 marks**

Two solutions of equal concentration were prepared: one of ethanoic acid,  $\text{CH}_3\text{COOH}$ , and one of ammonium chloride,  $\text{NH}_4\text{Cl}$ .

$\text{pK}_a(\text{CH}_3\text{COOH}) = 4.76$	$\text{pK}_a(\text{NH}_4\text{Cl}) = 9.24$
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- a) Compare the pH and electrical conductivity of both solutions of equal concentration. Your answer should include relevant equation(s). 4m

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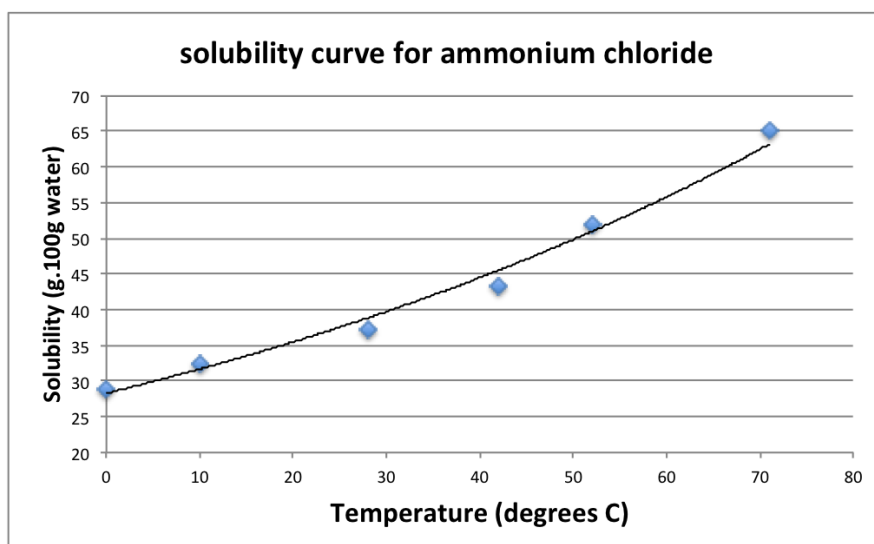
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Observe the following graph created by Emilio on the solubility of ammonium chloride in water at varying temperatures.



Question 24 is continued over the page

Emilio made the following statement:

*“Ethanoic acid is not soluble in water, it only ionises whereas ammonium chloride, irrespective of the mass, is 100% soluble in 100g of water”*

- b) Assess the validity of Emilio’s statement regarding the solubility of ethanoic acid and ammonium chloride, using your own knowledge and the stimulus provided. Include a labelled diagram to support your answer. 5m

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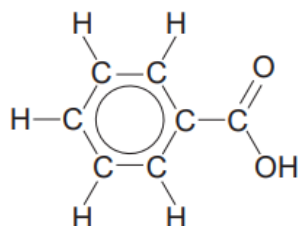
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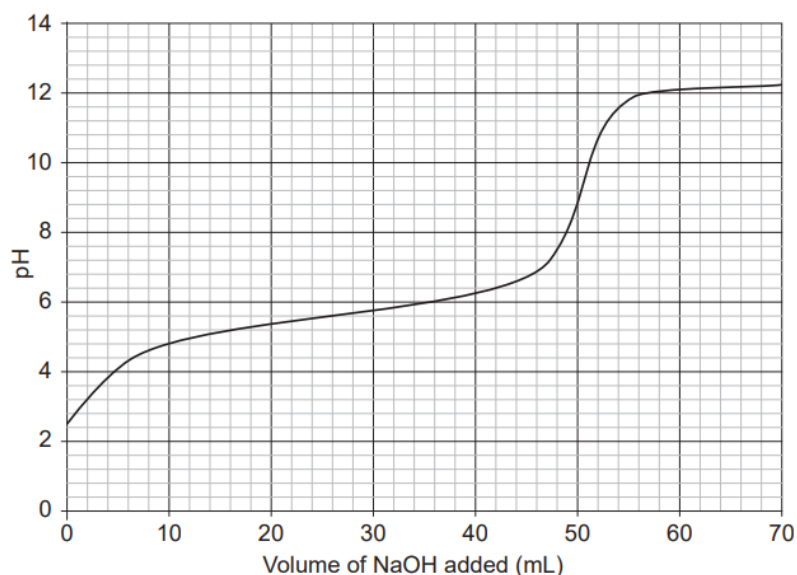
**Question 25****7 marks**

Benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) is a weak acid. Its structural formula is shown below.



Benzoic acid has a range of uses, including the manufacture of dyes, perfumes and insect repellents. The benzoic acid content of these products can be determined by titration with sodium hydroxide. The salt produced in the titration reaction is sodium benzoate,  $\text{C}_6\text{H}_5\text{COONa}$ .

The following graph shows a typical acid-base titration curve for benzoic acid and sodium hydroxide.



- a) Which of the indicators listed in the following table would be most suitable for use in this titration? Explain your choice. 3m

Name of Indicator	pH Range
Bromocresol green	3.8 – 5.4
Azolitmin	4.5 – 8.3
Cresolphthalein	8.2 – 9.8
Indigo carmine	11.4 – 13.0

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b) Buffering is observed during this titration.

i) Circle the buffer region on the titration curve on the previous page. 1m

ii) Define the term 'buffer' and explain why there is a buffer present in the region that you circled in part bi). Include an equation to support your explanation. 3m

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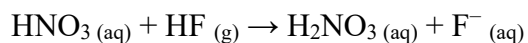
**Question 26****7 marks**

When bubbled into water, hydrogen fluoride gas, HF<sub>(g)</sub>, reacts with water to form a weak acidic solution.

- a) Write a chemical equation to show the reaction of hydrogen fluoride gas with water. 2m

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- b) Hydrogen fluoride gas dissolves in pure nitric acid as follows:



- State, with a reason, which of the two reactants is acting as a Brønsted-Lowry acid. 2m

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- c) Calculate the pH of a hydrofluoric acid solution of concentration 0.20 mol L<sup>-1</sup>, given the K<sub>a</sub> = 6.8 × 10<sup>-4</sup>. 3m

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**Question 27****13 marks**

Glycolic acid (2-hydroxyethanoic acid) is a weak monoprotic acid used in some skincare products.

a) Draw the structural formula of glycolic acid 2m

b) Write the chemical equation to show the acid dissociation of glycolic acid. 1m

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c) Sodium glycolate,  $\text{NaCH}_2(\text{OH})\text{COO}$ , is a soluble salt of glycolic acid. If some solid sodium glycolate is dissolved in a solution of glycolic acid, explain the effect this would have on its pH. 3m

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d) The solubility of glycolic acid is  $1.0 \times 10^6$  mg per litre at  $25^\circ\text{C}$ . Calculate the concentration, in mol/L, of a saturated solution of glycolic acid. 3m

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- e) 100ml of the saturated solution of glycolic acid is spilt onto the floor. What is the minimum mass of sodium carbonate that should be used to neutralise the spill? 4m

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**Question 28****10 marks**

A colorless volatile liquid compound has a chemical formula of  $C_5H_{10}O$ . It was observed to successfully oxidise in the presence of acidified potassium dichromate

- a) Based on the information provided, what type of compound would the colorless liquid be? Justify your response. 3m

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Image A. Mass Spectrograph

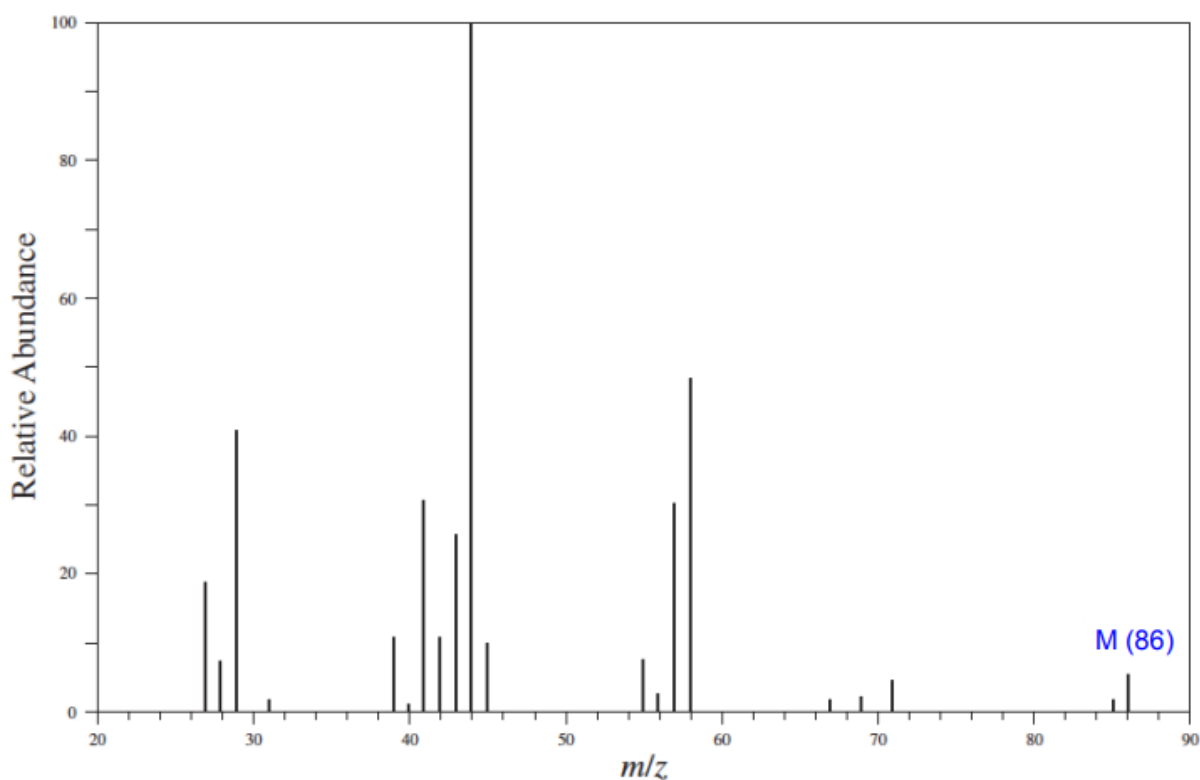


Image B.  $C^{13}$  – NMR spectrograph

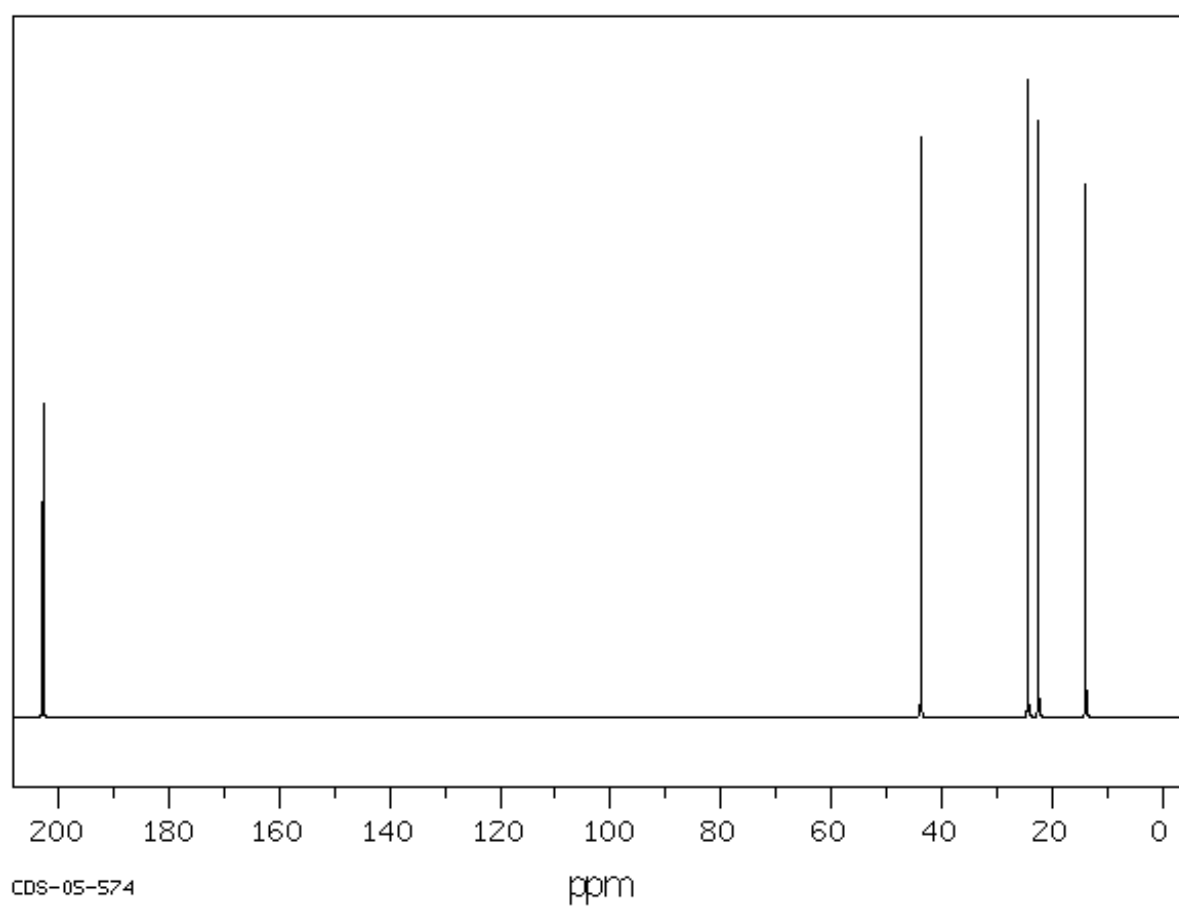


Image C. Infrared spectrograph

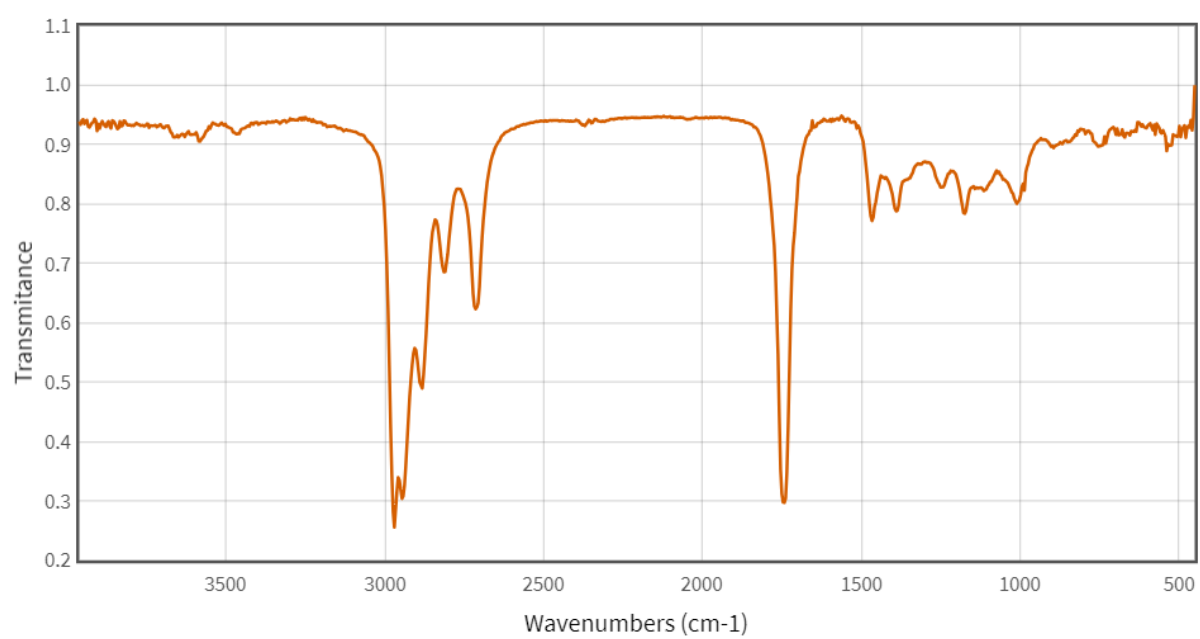


Table 1. Proton NMR peak data

Shift (ppm)	Number of peaks	Peak area ratio
<b>0.90</b>	3	3
<b>1.35</b>	6	2
<b>1.60</b>	5	2
<b>2.40</b>	3	2
<b>9.20</b>	1	1

- b) Draw and name the unknown compound that is consistent with ALL of the information provided. Justify your answer with reference to the information provided. 7m

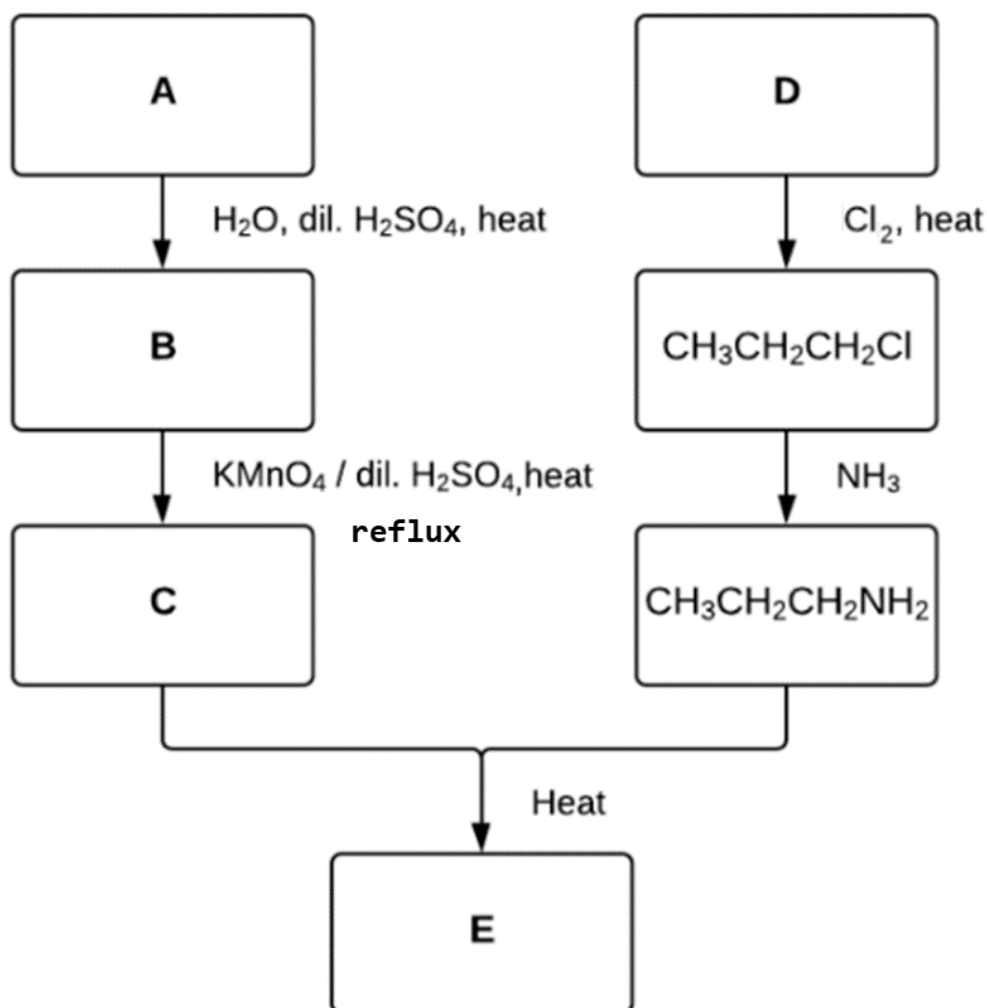
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**Question 29****13 marks**

The reaction pathway below represents the synthesis of compound E.

Only ONE organic product is formed in each step - no isomeric products possible.



a) Name the type of reaction that occurs to convert compound:

4m

- i) A into B: .....
- ii) B into C: .....
- iii) C into E: .....
- iv) D into  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ : .....

b) Draw the chemical structures of compounds A to E.

**5m**

<b>A</b>	<b>B</b>
<b>C</b>	<b>D</b>
<b>E</b>	

Question 29 is continued on the next page

- c) Explain the reaction conditions required to successfully convert compound B to C in the school laboratory. Include a labelled diagram of the apparatus. 4m

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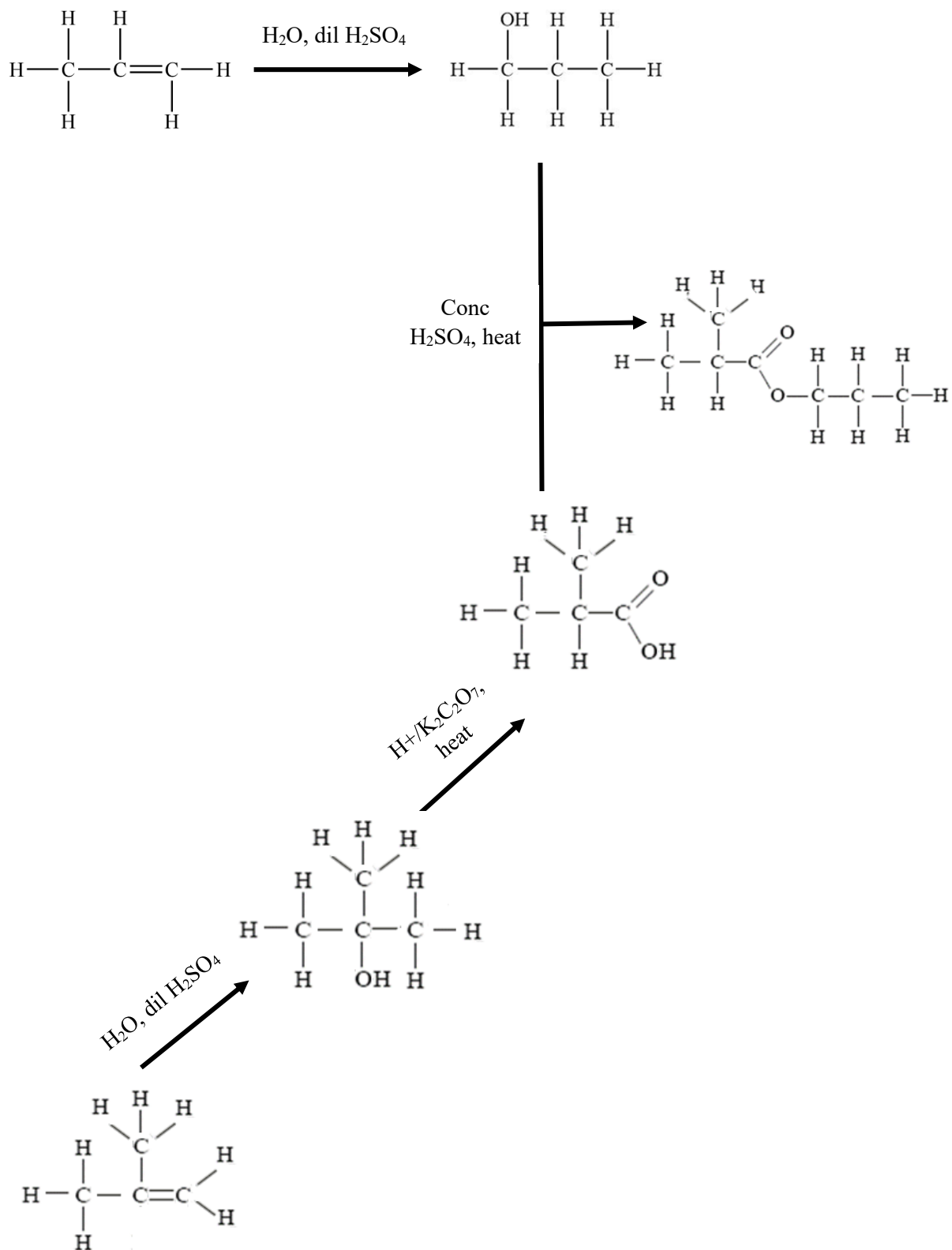
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**Question 30**

**5 marks**

Consider the following reaction pathway drawn by a chemistry student, showing the production of an ester.



The students' reaction pathway is riddled with errors.

Identify and explain the errors in the students' reaction pathway with reference to ONE key chemistry principle. Support your answer with labelled diagrams. 5m

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