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.

$$Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons 2CrO_4^{2-}{}_{(aq)} + 2H^+{}_{(aq)}$$

orange *yellow*

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 $Cr_2O_7^{2-}{}_{(aq)}$	Relative change in concentration of $CrO_4^{2-}{}_{(aq)}$	Relative change in concentration of $H^+{}_{(aq)}$	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 6.58×10^{-3} g/L of water at 25°C. Calculate the K_{sp} for barium phosphate at the given temperature.

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

3. Exactly 2.0 mol N_2O_4 is placed in an empty 1.0L container and is allowed to reach equilibrium as per the following equation.

$$N_2O_4{}_{(g)} \rightleftharpoons 2NO_2{}_{(g)}$$

If at equilibrium the N_2O_4 is 20% dissociated, what is the value of the equilibrium constant (K_{eq}) for the reaction under these conditions?

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

4. Silver acetate, $AgCH_3COO_{(s)}$ crystals are in equilibrium with a saturated solution. Which of the following would cause more $AgCH_3COO(s)$ 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 1.00×10^{-5} M $AgNO_3$ and 30.0 mL of 2.00×10^{-4} M NaCl are mixed.

   K_{sp} (AgCl) = 1.8×10^{-10}.

   Which one of the following is correct?

	Q_{sp}	Precipitate…
A)	3.75×10^{-10}	forms
B)	3.75×10^{-10}	does not form
C)	2.00×10^{-9}	forms
D)	2.00×10^{-9}	does not form

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

   A) HNO_3/NO_3^-
   B) H_3PO_4/PO_4^{3-}
   C) NH_4^+/NH_3
   D) SO_4^{2-}/SO_3^{2-}

7. Consider the hydrolysis equation below.

$$CH_3NH_{2\,(aq)} + H_2O_{(l)} \rightleftharpoons CH_3NH^{3+}{}_{(aq)} + OH^-{}_{(aq)}$$

   Which of the following are conjugate acid-base pairs?

   i. CH_3NH_2 and H_2O
   ii. CH_3NH_2 and CH_3NH^{3+}
   iii. H_2O and OH^-
   iv. CH_3NH^{3+} and 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. $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-{}_{(aq)}$
   ii. $CH_3COOH_{(aq)} + H_2O_{(l)} \rightarrow CH_3COO^-{}_{(aq)} + H_3O^+_{(aq)}$
   iii. $KOH_{(aq)} \rightarrow K^+_{(aq)} + OH^-{}_{(aq)}$
   iv. $H_2PO_3^-{}_{(aq)} + H_3O^+_{(aq)} \rightarrow H_2O_{(l)} + H_3PO_{4\,(aq)}$

   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 (HNO_2) is 4.6×10^{-4}
   - hydrocyanic acid (HCN) is 6.17×10^{-10}.

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

	Stronger acid	Higher pH
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?

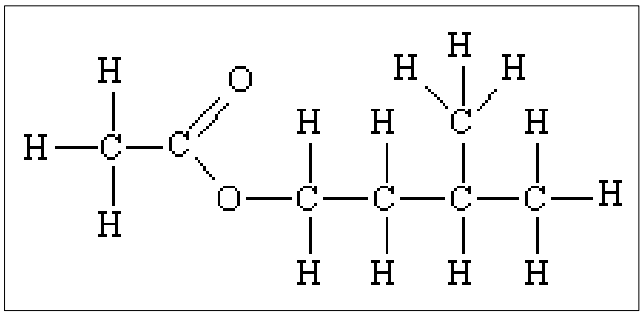
    i. Pure water is a weak electrolyte that undergoes self-ionisation.
    ii. The equilibrium constant for the ionisation of pure water at 25 °C is 1.00×10^{-14}.
    iii. Pure water ionises completely at 25 °C, hence [H+] = [OH-].
    iv. The ionisation of pure water produces twice as many hydrogen ions 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

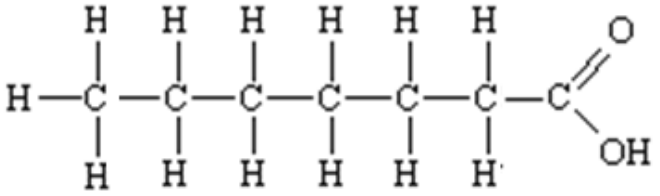
11. How many chain isomers does hexane have?

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

12. What is the functional isomer to methylbutyl acetate?



A)



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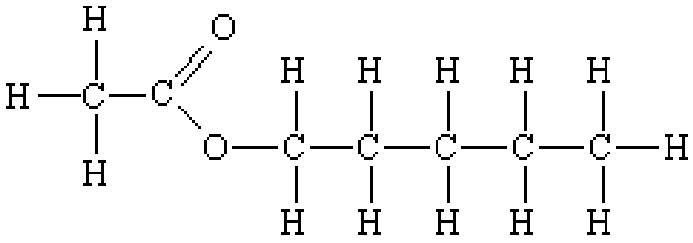
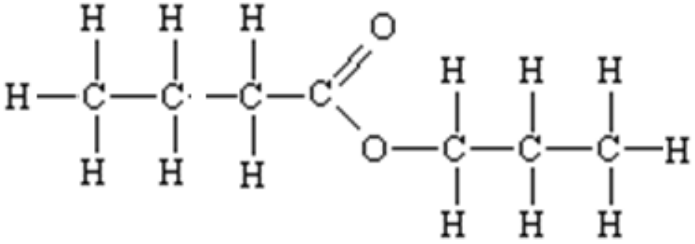
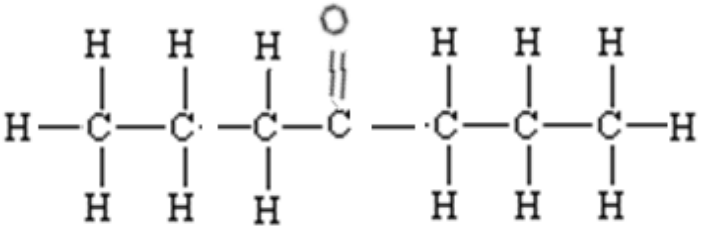


C)



D)



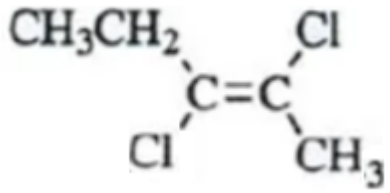
13. A student was provided with 2 unlabelled bottles. One bottle should contain butan-2-ol whilst the other holds butanone. The student conducted 2 types of tests.

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

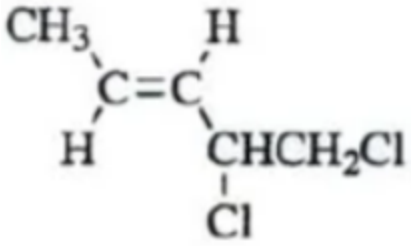
	Test	Butan-2-ol	Test	Butanone
A)	Anhydrous $ZnCl_2$	Turns cloudy immediately	Anhydrous $ZnCl_2$	No change
B)	H+ / $Cr_2O_7^{2-}$	Orange to green colour change	H+ / $Cr_2O_7^{2-}$	Orange to green colour change
C)	Anhydrous $ZnCl_2$	Turns cloudy in 5 minutes	Anhydrous $ZnCl_2$	No change
D)	H+ / $Cr_2O_7^{2-}$	No change	H+ / $Cr_2O_7^{2-}$	No change

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

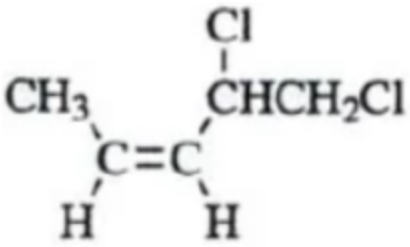
A)



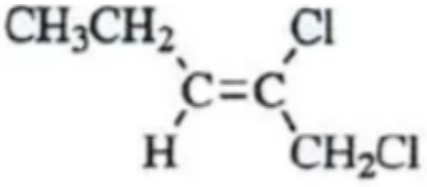
B)



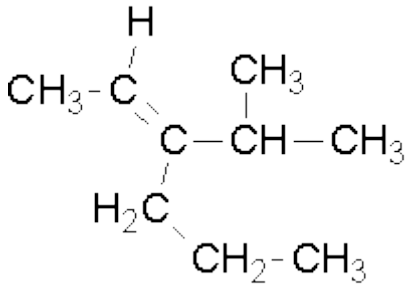
C)



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

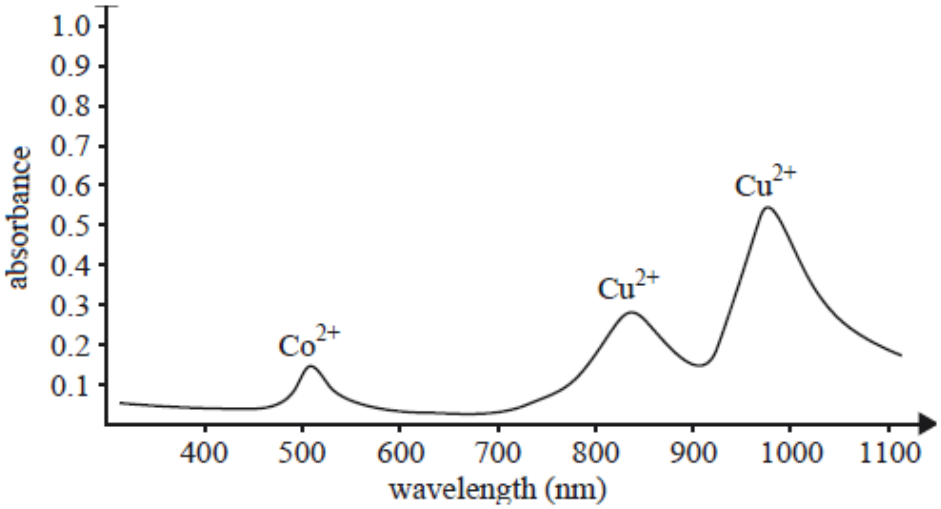
17. Electromagnetic radiation of a specific wavelength can interact with some molecules and atoms by promoting electrons at a low energy level to higher energy levels.

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 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.



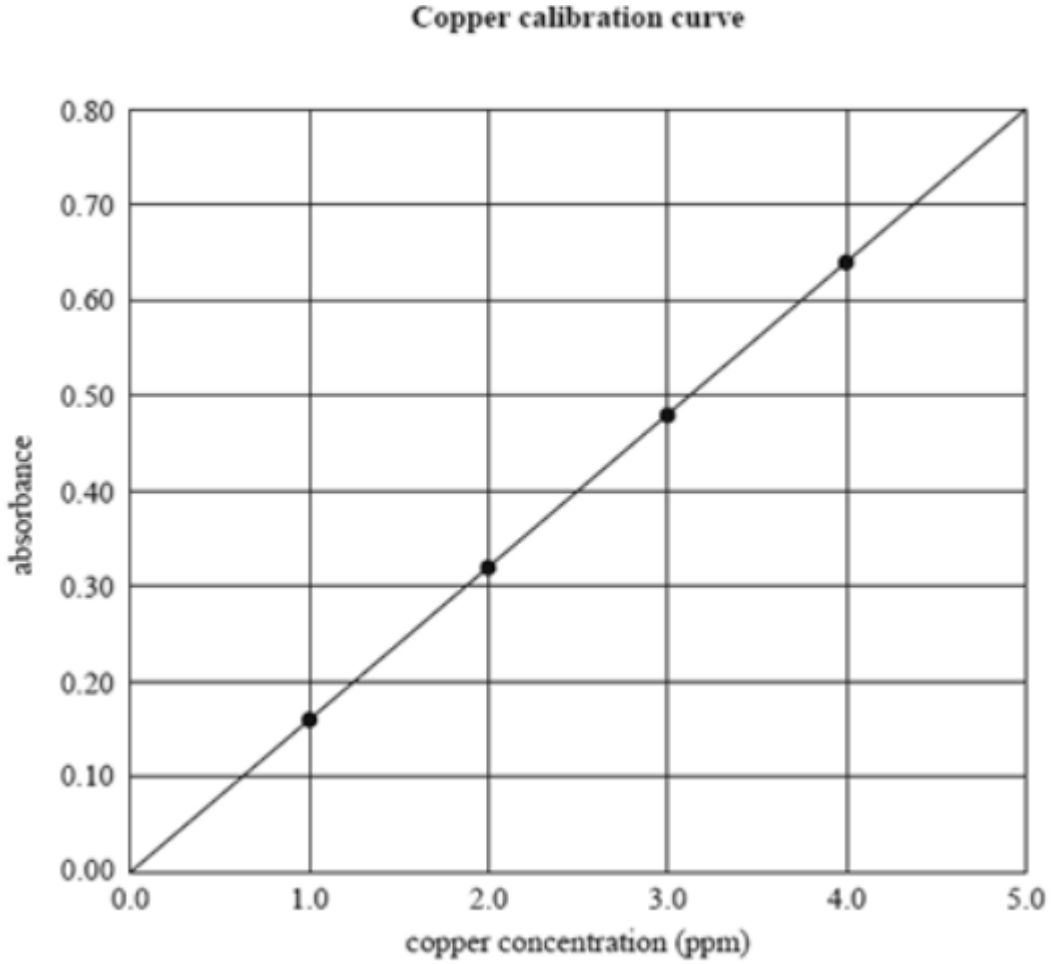
Which analytical technique was used to perform this analysis?

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^{-1}. (1 mg L^{-1} = 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) 3.9×10^{-5}
    C) 3.9×10^{-2}
    D) 2.5×10^{-6}

PART B – SHORT RESPONSES

Question 21 **3 marks**

A saturated solution of lead chloride has a ksp value of 1.70×10^{-5} at 25°C.

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

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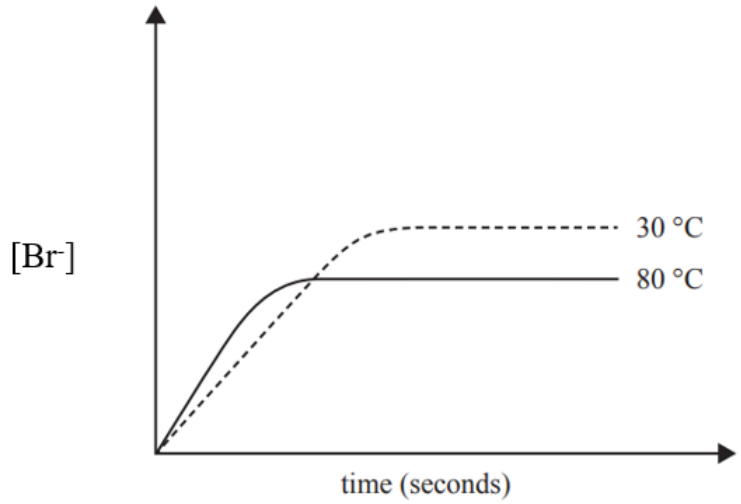
Question 22 **6 marks**

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

$$CH_3Br_{(g)} + OH^-_{(aq)} \rightleftharpoons CH_3OH_{(g)} + Br^-_{(aq)}$$

Two reactions vessels containing the equilibrium mixture were heated to two temperatures, 30 °C and 80 °C, and the concentration of Br^- 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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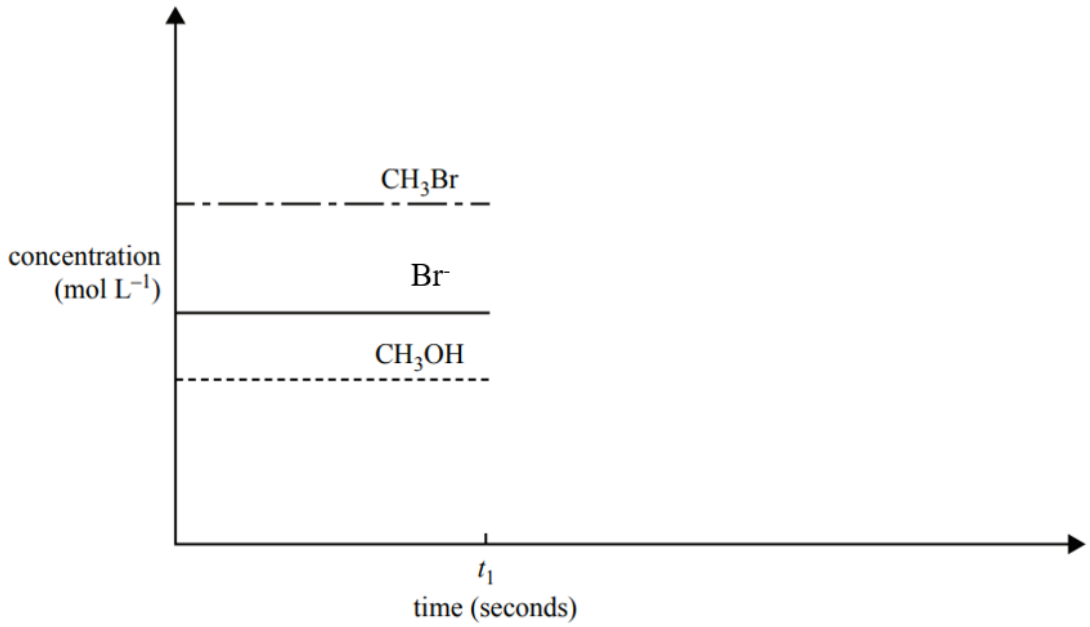
The graph below represents the concentration of three of the species involved when they are at equilibrium at constant temperature



b) Excess silver nitrate, $AgNO_3$, 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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Question 23 **7 marks**

Methanol is a useful fuel that can be manufactured from biogas as represented by the following equation: $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$ $\Delta H < 0$

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_2, 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_{eq}, 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, CH_3COOH, and one of ammonium chloride, NH_4Cl.

pKa (CH_3COOH) = 4.76	pKa (NH_4Cl) = 9.24

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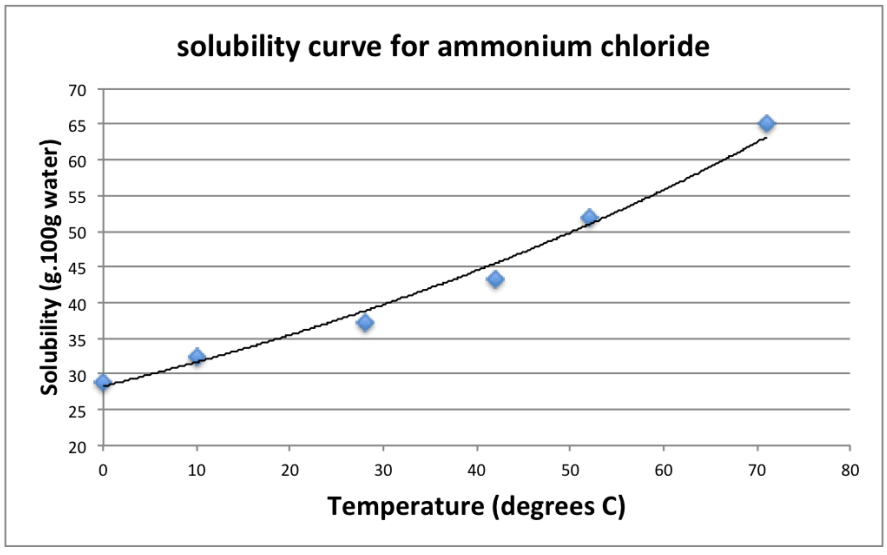
Observe the following graph created by Emilio on the solubility of ammonium chloride in water at varying temperatures.



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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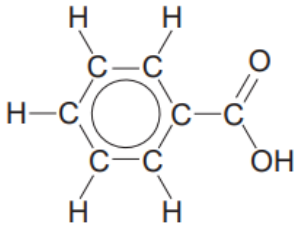
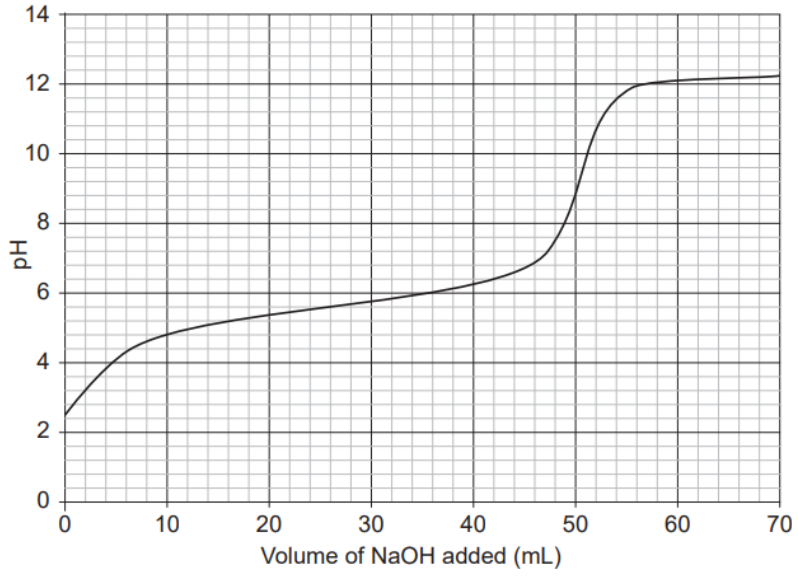
Question 25 **7 marks**

Benzoic acid (C_6H_5COOH) 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, C_6H_5COONa.

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, $HF_{(g)}$, 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:

$$HNO_{3\,(aq)} + HF_{\,(g)} \rightarrow H_2NO_{3\,(aq)} + F^-_{\,(aq)}$$

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^{-1}, given the $K_a = 6.8 \times 10^{-4}$. 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, $NaCH_2(OH)COO$, 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 1.0×10^6 mg per litre at 25°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 potasssium 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

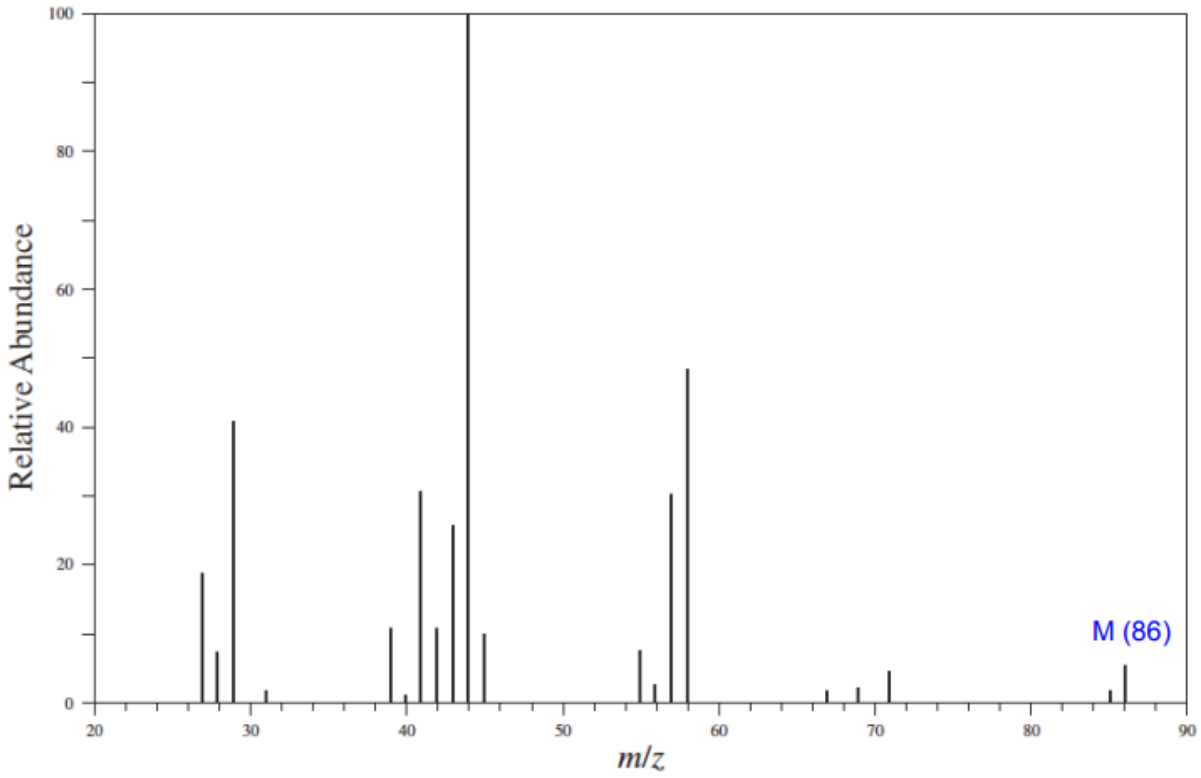

Image B. C^{13} – NMR spectrograph

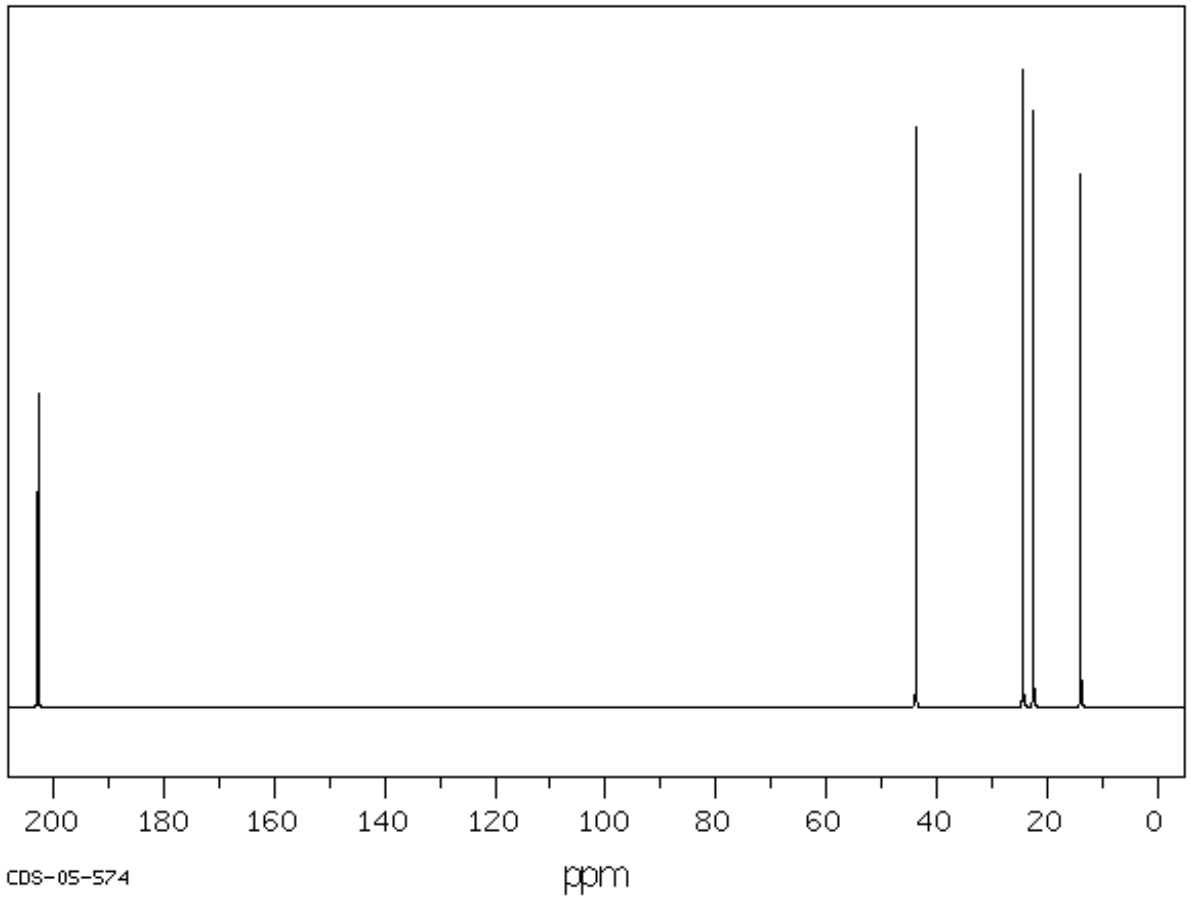

Image C. Infrared spectrosgraph

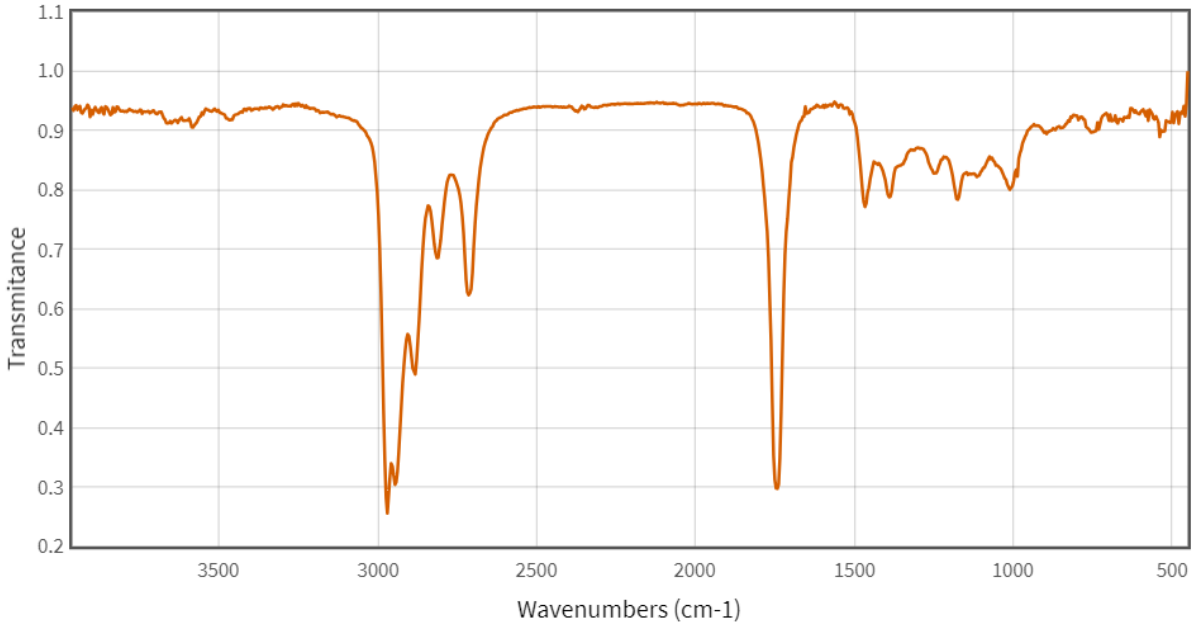

Table 1. Proton NMR peak data

Shift (ppm)	Number of peaks	Peak area ratio
0.90	3	3
1.35	6	2
1.60	5	2
2.40	3	2
9.20	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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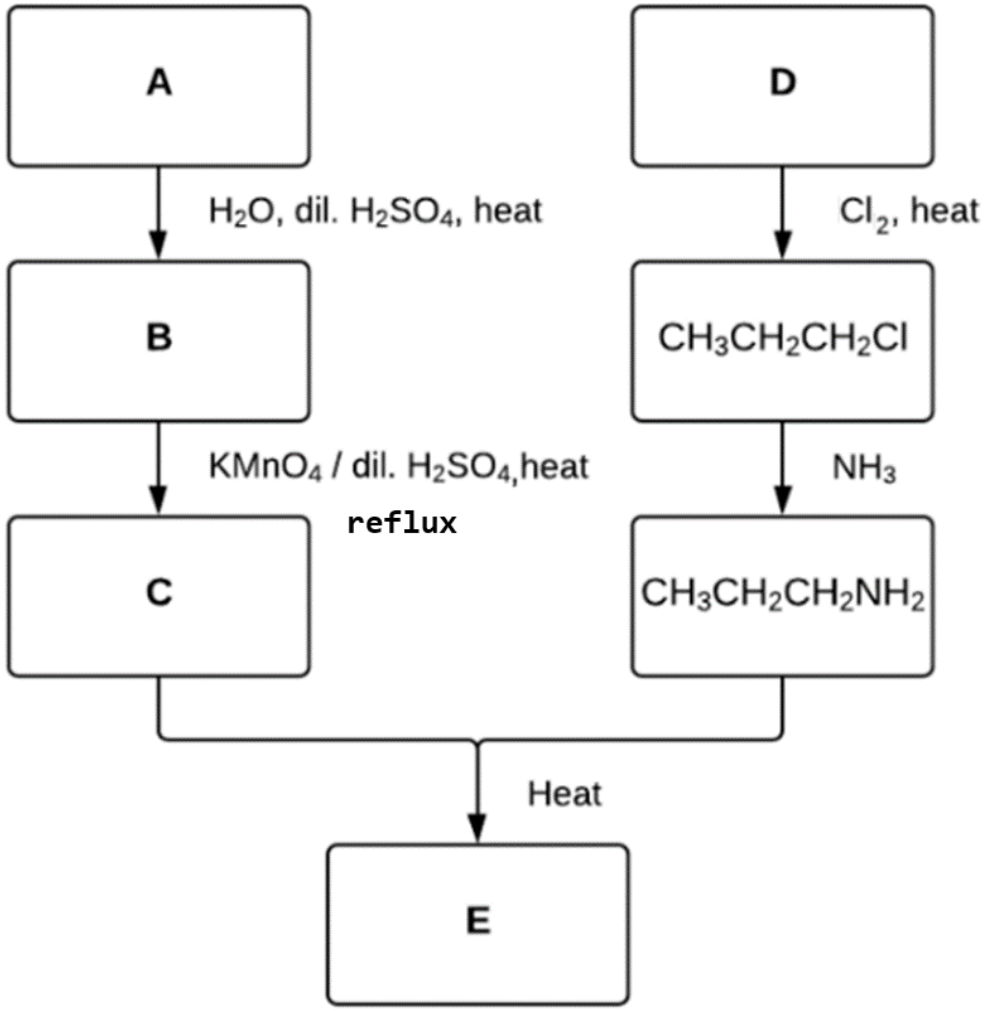
Question 29 **13 marks**

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 $CH_3CH_2CH_2Cl$: ……

b) Draw the chemical structures of compounds A to E. **5m**

A	**B**
C	**D**
E	

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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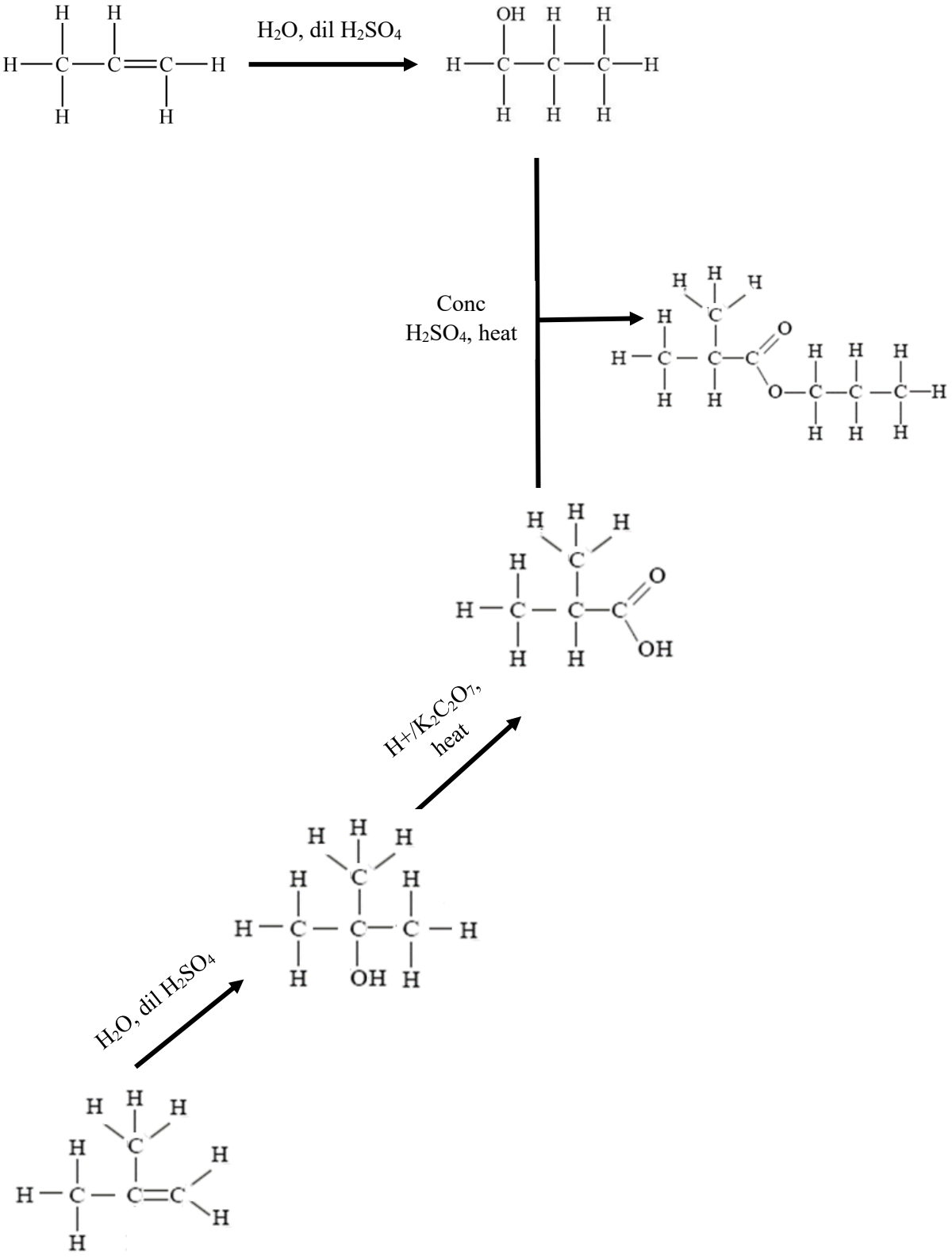
Question 30 **5 marks**

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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SPARE WRITING SPACE

PENRITH SELECTIVE HIGH SCHOOL
HSC CHEMISTRY TRIAL MARKING CRITERIA

PART A – MULTIPLE CHOICE

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

*accepted B; students MUST know for the HSC that the isomer count INCLUDES itself.

PART B

Question 21

A saturated solution of lead chloride has a ksp value of 1.70×10^{-5} at 25°C.

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

Criteria	Marks
Student: Substitutes the correct values into the Ksp expression for $PbCl_2$ for a correct final answer	3
Uses the values in the stimulus to work out the new $[Cl^-]$ and substitutes this value into the correct Ksp expression to solve for x; but has some mistake in calculations	2
Provides some relevant information/calculations OR Solves for x using the Ksp value but does not account for the additional values given in the syllabus regarding $[Cl^-]$ OR incorrectly accounts for the value AFTER Ksp substitution	1

Sample response

$C_2\ [Cl^-] = C_1V_1/V_2$

$= 0.150M \times 0.02L/0.05L$

$=0.06$

$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^-(aq)$

$Ksp = [Pb^{2+}]\ [Cl^-]^2$

$1.70 \times 10^{-5} = [x]\ [2x + 0.06]^2$

Since Ksp is $< 10^{-4}$; can assume 2x is negligible and all Cl^- ions come from HCl due to common ion effect. Hence:

$1.70 \times 10^{-5} = [x]\ [0.06]^2$

$x = 4.72 \times 10^{-3}$ mol/L = $[Pb^{2+}]$

Markers comment/s:

It is crucial that students revisit their understanding of module 5 as a surprising amount of the cohort answered this incorrectly. It was also quite obvious that students had not completed past papers as there was a similar question in a prior paper that required students to use the same process when answering. The marking criteria had to be changed quite a bit for this one, however the main difference between receiving a 1 or a 2 depended on whether the answer showed evidence of understanding about the common ion effect. To receive a 2, students needed to calculate the new $[Cl^-]$ BEFORE substituting it into the Ksp expression to show that they understand where the Cl^- ions are coming from. Those who solved for x without using any values for $[Cl^-]$ (e.g. wrote that $[Cl^-]$ was 2x) could not get higher than a 1 as they did not use the other values given in the stimulus, which showed a lack of understanding about the behaviour of saturated solutions and common ion effect.

Question 22

a) State whether the forward reaction is exothermic or endothermic. 1m

Criteria	Marks
Student: Correctly states that the forward reaction is exothermic	1

Sample response
Exothermic

Markers comment/s
Mostly answered well. Those who got it wrong are encouraged to practice their stimulus analysis.

b) Excess silver nitrate, $AgNO_3$, 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

Criteria	Marks
Student: Sketches all three species correctly and provides a clear explanation of ALL changes with extensive reference to Le Chatelier's Principle	5
Sketches all three species correctly and explains changes using Le Chatelier's Principle but misses some crucial information in explanation OR Makes a mistake when sketching the species but provides a clear explanation	4
Sketches correct reactants and products and outlines the immediate effects of adding $AgNO_3$ but misses some crucial information OR States that $AgNO_3$ will react with OH^- ions and clearly explains how this would affect the changes of the species in relation to LCP	3
Sketches some relevant changes and provides a basic explanation of the reasoning behind the changes.	2
Provides some relevant information	1

Sample response

When excess $AgNO_3$ is added to the solution it dissociates to form Ag^+ and NO_3^- ions. The Ag^+ ions react with the Br^- ions in the equilibrium, and since Ag^+ is in excess it completely removes Br^- from the reaction. Hence $[Br^-]$ completely reaches zero and does not increase due to the excess Ag^+ constantly reacting and removing any Br^- being produced. Due to a decrease in $[Br^-]$, the reaction shifts right, as per Le Chatelier's Principle, to counteract the change and attempt to create more Br^-. Thus, the $[CH_3OH]$ (product) increases gradually and the $[CH_3Br]$ (reactant) decreases gradually as shown in the graph until equilibrium is reached (as indicated by the straight line)

Markers comment/s

A mixed bag of responses, though most of the cohort received 3-4 with a small handful receiving full marks or less than 3. Students need to recognise that even though Ag^+ can form a precipitate with both OH^- and Br^-, AgBr is more insoluble (lower ksp value in data sheet) and Ag^+ would thus remove Br^- from the equilibrium mixture first. Also, OH^- was not present on the graph and students were expected to only refer to what species were present in the graph. The marking criteria was changed to accommodate the responses that focused on the changes that occurred from a precipitate of AgOH forming to ensure more students were able to get marks. These students could not receive higher than 3 as their graph would have been incorrect as well as their explanation (again due to missing out the fact that AgBr is more insoluble). The large majority of the cohort did not recognise that since $AgNO_3$ was added in excess, the $[Br^-]$ would be completely removed from the mixture and would not increase again as excess Ag^+ would continuously remove it from solution.

Question 23

Methanol is a useful fuel that can be manufactured from biogas as represented by the following equation: $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)} \quad \Delta H < 0$

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

Criteria	Marks
Student: ● Correctly identifies that the reaction is exothermic and links this to how the yield would change due to an increase or decrease in temperature, as per LCP. ● Correctly links the amount of moles of gas on the reactant and product side to yield of methanol when pressure is changed as per LCP	4
Missing some crucial information when linking temperature or pressure to yield	3
Provides a basic explanation about how temperature and pressure affect yield.	2
Provides some relevant information	1

Sample response

Temperature: The negative ΔH indicates that the reaction is exothermic. Thus a decrease in temperature will favour the forward reaction to counteract the change and increase the temperature again, as per Le Chatelier's Principle. This will lead to an increase in the yield of methanol.

Pressure: The product side is made up of less moles of gas, thus an increase in pressure will favour the forward reaction to reduce the pressure, as per Le Chatelier's Principle. This will also lead to an increase in the yield of methanol.

Markers comment/s

Overall answered quite well across the cohort. Main mistakes were students not clearly stating the effect on yield of methanol or students not explicitly stating the reason for the shifts (e.g. to use up excess heat, to reduce pressure etc). Students must also remember to refer to moles of GAS when talking about pressure and not just say "side with more/less moles" (this wasn't penalised in the exam but students must be more mindful for the HSC).

b) 0.840 mol of carbon monoxide, CO, and 0.325 mol of hydrogen, H_2, 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_{eq}, of the synthesis of methanol. 3m

Criteria	Marks
Student: ● Correctly utilises a RICE table ● Provides the correct Keq expression with correct values inputted to calculate a correct final answer	3
Missing one of the above components	2
Provides some relevant calculations	1

Sample response

	CO	H_2	CH_3OH
R	1	2	1
I	1.68	0.65	0
C	-0.3	-0.6	+0.3
E	1.38	0.05	0.3

$Keq= [CH_3OH]/[CO][H_2]^2$

$= [0.3]/[[1.38][0.05]^2$

$= 87.0$ (3.s.f)

Markers comment/s

Answered well across the cohort. Main mistakes were not including a keq expression or inputting incorrect values into the keq expression. Students were given 2 marks if they had a correct keq expression but made a mistake somewhere in their ICE table as long as they inputted the values correctly into the keq expression to calculate a correct subsequent answer. Those who had incorrect values AND no keq expression were only given a 1.

Question 24

a) Compare the pH and electrical conductivity of both solutions of equal concentration. Your answer should include relevant equation(s).

4m

Criteria	Marks
Student: ● Correctly calculates/comments on Ka for both solutions and links to pH ● Makes a statement about their electrical conductivity with reference to hydronium ions and degree of ionisation of the two solutions	4
As above but with one point missing	3
Missing two crucial points of information	2
Provides some relevant information	1

Sample response

CH_3COOH	NH_4Cl
- Has a low pKa and thus higher Ka (acid dissociation constant) value, meaning it dissociates to a higher degree than NH_4Cl - High dissociation means more H^+ ions produced as per following equation: $CH_3COOH\ (aq) \rightleftharpoons CH_3COO^-(aq) + H^+$ Thus the pH is lower. - More conductive due to more mobile H^+ ions produced	- Has a high pKa and thus lower Ka value, meaning it still dissociates to form H^+ ions but to a lower degree than CH_3COOH as per the following equation: $NH_4Cl(aq) \rightleftharpoons NH^+_4(aq) + Cl^-(aq)$ $NH^+_4(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$ - Less H^+ ions result in a higher pH - Solution is less conductive due to less mobile H^+ ions present.

Markers comment/s

This question was difficult to mark despite being quite straightforward. Many students made the assumption that this was a buffer-related question even though there is no conjugate acid-base pairing being shown in the stimulus. As a result, many students included the Henderson-Hasselbach equation in their response and stated that pH=pKa (we have no basis to make this assumption!). Many students also said that a low pKa=low pH but did not explain why by making that link to $[H^+]$. A handful of students did not use the stimulus at all while many did

not make a clear link between Ka, pH and conductivity. The equations were done well, however a few students started talking about pOH (which wasn't required to answer this question).

Emilio made the following statement:

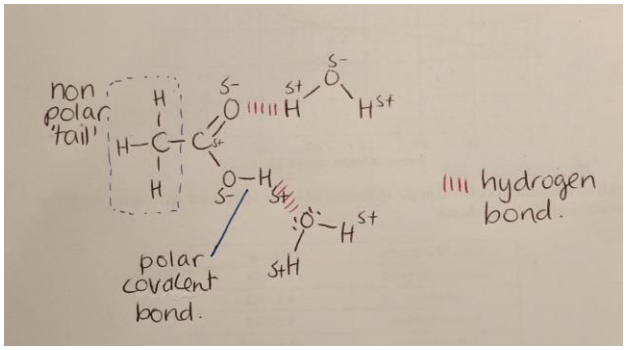
"Ethanoic acid is not soluble in water, it only ionises whereas ammonium chloride, irrespective of the mass, is 100% soluble in 100g of water"

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

Criteria	Marks
Student: ● Explains the solubility of ethanoic acid and ammonium chloride in water with reference to their structure and intermolecular bonds. ● Utilises information from the graph provided to demonstrate deep understanding on the nature and formation of saturated solutions. ● Provides a relevant and correctly labelled diagram to support **either** the solubility of ethanoic acid **or** the solubility of ammonium chloride. ● Correctly assesses the validity of Emilio's claims based on all evidence.	5
As above but with one piece of detail missing	4
Explains how ethanoic acid **or** ammonium chloride are soluble in water, including a suitable diagram, including one of the criteria below	3
Describes, without use of a diagram, The validity of the statement Or The solubility of the compounds Or The solubility of ethanoic acid and its partial ionisation	2
Writes something relevant	1

Sample response

Ethanoic acid is soluble in water and partially ionises in water. Ethanoic acid has a carbonyl group and a hydroxyl group in its molecule, resulting in the highly electronegative oxygen atoms forming polar bonds within the molecule. These polar bonds form hydrogen bonds (a strong IM bond) with water molecules as shown by the diagram below. These IM bonds and the fact that the nonpolar 'tail' is short enable ethanoic acid to be fully soluble in water. Therefore, the first part of Emilio's statement is invalid.



The O-H bond is polar and a small percentage of these bonds ionise in water forming hydronium ions and leaving a carboxylate ion.

Ammonium chloride is an ionic compound made up of positively charged ammonium ions and negatively charged chloride ions. This compound dissociates in water and the ions form ion-dipole bonds with the polar water molecules, enabling ammonium chloride to also be soluble in water. However, its solubility is temperature dependent, with an increase in temperature there is an increase in the solubility. Therefore, the claim that ammonium chloride is 100% soluble in 100g of water irrespective of the mass is invalid because the graph shows that at a given temperature only a certain mass of solute will dissolve and then the solution will become saturated. This is when a dynamic equilibrium exists between the dissolved solute and the undissolved solute in solution. All of these points support the fact that Emilio's statement is invalid.

Markers comment/s

There is some misunderstanding about the different types of intermolecular bonds and intramolecular bonds related to this question. These must be revised. Many students did not describe the process of dissolving correctly and confused it with ionisation. Some stated that ethanoic acid ionises and this is what allows it to dissolve, which is incorrect. Several responses showed hydrogen bonding between water molecules and the nonpolar end of the ethanoic acid molecule or, hydrogen bonds as the bonds within water molecules/hydroxyl group.

If a diagram was not present the maximum number of marks available was 2. If a diagram was present but was incorrect in part, then the written answer / annotations were used to assess whether it was worth 2 or 3 marks.

Question 25

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

Criteria	Marks
Student: ● Explains that the endpoint of a titration should be as close as possible to the equivalence point ● Recognises that the equivalence point of the titration is around 9 and thus cresolphthalein is the most appropriate indicator as it is the only one to change colour in this range.	3

Missing one of the above components	2
Provides some relevant information	1

Sample response

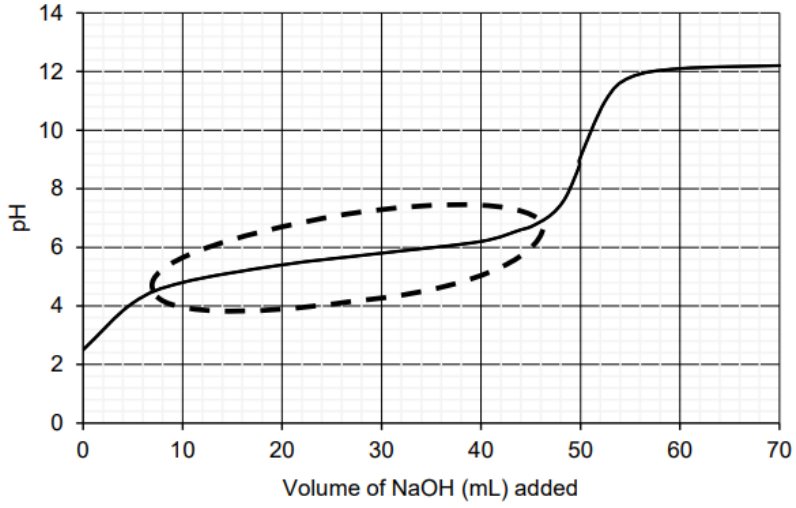
For accurate titration, the equivalence point must be as close as possible to the endpoint. The equivalence point, as shown on the graph, is at ~9. The only indicator that changes colour at this range is Cresolphtalein, thus it would be the most suitable to use for this titration.

Markers comment/s

Overall answered quite well across the cohort indicating students have a strong understanding of indicator ranges. Students were given 2 marks if they stated Azolimitin AND provided a correct justification of why they believe it to be the best indicator (although technically this would be incorrect as the equivalence point lies outside of the range given in the table if read correctly from the graph; this was allowed to try give more marks to students). Other indicators would be incorrect as the equivalence point does not fall within their ranges, however 1 mark was given for stating something relevant about the behaviour of indicators.

b) Buffering is observed during this titration.

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

Criteria	Marks
	1

Sample response

See above

Markers comment/s

Mostly answered correctly by the cohort. Students that extended their circle outside the range shown above were not given the mark as the buffer region can only be the region that shows a slight change in pH only (anything outside of this is showing a drastic change). Some

students circled the horizontal region at the pH=12 mark, however this is incorrect as the buffer region needs to be in between areas of pH change.

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

Criteria	Marks
Student: ● Extensively explains why buffering occurs in the circled region of the graph by referring to LCP ● Correctly defines the term "buffer" (equimolar amounts of weak acid/base conjugate pairs, resists changes in pH for small concentrations of added acid and base) ● Provides an appropriate equation	3
Missing one of the above components	2
Provides some relevant information	1

Sample response

A buffer is a solution of equimolar concentrations of a weak acid/base and its respective conjugate that resists pH changes when small amounts of acid or base are added. In the circled region of the graph the following occurs:

$C_6H_5COOH(aq) + H_2O(l) \rightleftarrows C_6H_5COO^-(aq) + H_3O^+(aq)$

where the weak acid and its conjugate base are present. When added, the OH^- ions react with the H_3O^+ ions, removing them from solution and thus shifting the reaction to the right to produce more H_3O^+ as per Le Chatelier's Principle. This results in the pH staying consistent. Eventually all of the benzoic acid will be ionised and reacted with OH- ions. At this point the buffer will no longer work - the pH will rise dramatically.

Markers comment/s

Mostly answered well by the cohort. The main mistakes were students not stating the correct features of a buffer (equimolar amounts of weak acid/base conjugate pairs, resists changes in pH for small concentrations of added acid and base) or not correctly linking the action of a buffer in relation to LCP.

Question 26

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

Criteria	Marks
Student: Provides a correct equation with all state symbols correct and reversible arrows	2
Provides a correct equation with some state symbol and/or arrow errors	1

Sample response

$HF_{(g)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + F^-_{(aq)}$

Markers comment/s

Most students answered correctly. Some wrote a single arrow when it is a weak acid and therefore a reversible arrow is needed. Minor errors with state symbols, students writing HF(aq) when the question says HF(g).

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

$$HNO_{3\,(aq)} + HF_{(g)} \rightarrow H_2NO_{3\,(aq)} + F^-_{(aq)}$$

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

Criteria	Marks
Student: ● Defines a BrØnsted-Lowry acid AND ● Correctly identifies the BrØnsted-Lowry acid reactant as HF(g) with reason	2
Defines a BrØnsted-Lowry acid Or Correctly identifies the BrØnsted-Lowry acid reactant	1

Sample response

A BrØnsted-Lowry acid is referred to as a proton donor. In the above reaction, HF is acting as BrØnsted-Lowry acid as it donates a proton to HNO_3, which becomes H_2NO_3. HF(g) forms the conjugate base, F^-(aq)

Markers comment/s

Mostly answered correctly. However, some students said both reactants were behaving as a BL acid, which cannot be the case AND the question clearly asks you to pick one reactant. The reactant donating the proton (HF) is the BL acid, therefore HNO_3 must be the BL base in this reaction.

c) Calculate the pH of a hydrofluoric acid solution of concentration 0.20 mol L^{-1}, given the $K_a = 6.8 \times 10^{-4}$. 3m

Criteria	Marks
Student: Uses value of x = [H+] to correctly calculate pH, including equation	3
Uses ICE table and/or states 'assumes x is negligible' to correctly calculate the value of x as 0.01166	2
Correctly states the equilibrium expression for the reaction Or Writes the dissociation equation	1

Sample response

$Ka = \frac{[H+][F-]}{[HF]}$ $\quad HF(aq) \rightleftarrows H+(aq) + F-(aq)$

I	0.2	0	0
C	-x	+x	+x
E	0.2-**x**	x	x

assume **x** is negligible

therefore: $6.8 \times 10^{-4} = \frac{[x][x]}{0.2}$

so $x^2 = 0.2\ (6.8 \times 10^{-4})$

x = 0.01166 = $[H^+]$ $\quad pH = -\log_{10}[H^+] = 1.93$

Markers comment/s

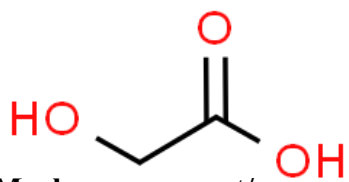
Most students answered this question well. An ICE table should be used to calculate the [H+] and if assuming the concentration HF decreases by a very small amount then 'assume x is negligible' should be written with the calculation. Students were not penalised if they did not do this. Allowed either 1.9 or 1.93. However, the answer should be to 2 sig fig, so for pH the numbers after the decimal are the sig figs. A handful of students tried to use the Henderson-Hasselbach equation to calculate the pH, but this was not a buffer and [F-] was not known so this equation was not appropriate to use.

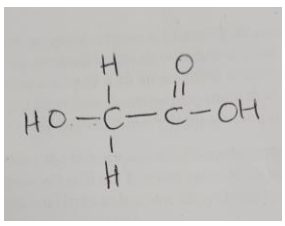
Question 27

a) Draw the structural formula of glycolic acid 2m

Criteria	Marks
Student: CORRECTLY draws the structural formula with no errors	2
Provides correct number of carbons	1

Sample responses





Markers comment/s

Answered well by the cohort. Some errors made with the number of O atoms.

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

Criteria	Marks
Student: Provides correctly balanced chemical equation	1

Sample response

$C_2H_4O_{3\,(aq)} + H_2O_{\,(aq)} \rightleftharpoons C_2H_3O_3^-{}_{\,(aq)} + H_3O^+{}_{\,(aq)}$

Markers comment/s
Mostly answered well. A few careless errors with the number of H atoms/O atoms in the formulae.

c) Sodium glycolate, $NaCH_2(OH)COO$, 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

Criteria	Marks
Student: ● Thoroughly explains the effect of the dissolution of sodium glycolate on the concentration of $C_2H_3O_3^-$ and thus the equilibrium system, with reference to Le Chatelier's principle. ● Clearly relates the change in hydronium concentration to the solutions pH.	3
Outlines the impact of sodium glycolate on the equilibrium system and the resulting pH.	2
Provides something relevant	1

Sample response

As more sodium glycolate dissolves the concentration of $C_2H_3O_3^-$ increases. By Le Chatelier's principle, the equilibrium system will shift to the left, to reduce the concentration of excess $C_2H_3O_3^-$ and thus reducing the concentration of H_3O^+ in solution. As pH = $-\log[H_3O^+]$, a lower concentration in H_3O^+ will cause the pH to increase.

Markers comment/s

Mostly answered well by the cohort. However, some students said that the pH would not change due to it forming a buffer. As we do not know any information about the concentrations we cannot assume it is a buffer (a buffer is an equimolar solution of a weak acid/base and its respective conjugate).

d) The solubility of glycolic acid is 1.0×10^6 mg per litre at 25°C. Calculate the concentration, in mol/L, of a saturated solution of glycolic acid. 3m

Criteria	Marks

Student: Provides all steps to obtain the correct answer.	3
Provides most steps in their calculation towards an answer..	2
Provides 1 correct conversion or calculation.	1

Sample response

1.0×10^6 mg / L = 1000 g/L

1000 g/L ÷ 2(12.01) + 4(1.008) + 3(16) = 1000 g/L ÷ 76.052 g/mol

= 13.13889812 mol/L

= 13 mol/L

Markers comment/s

Mostly answered well by the cohort. Some students approached this question as a Ksp calculation, which it wasn't, and got very bogged down trying to make it work in multiple steps of calculation. There were some careless mistakes calculating the molecular mass of glycolic acid and mistakes when converting mg/L to g/L. Students were not penalised for sig figs but should answer all calculations to the correct number of sig figs.

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

Criteria	Marks
Student: Provides all steps to obtain the correct answer to 2 significant figures	4
Provides most steps to obtain an answer or all steps but answer not correct to 2 significant figures	3
Provides two pieces of relevant information	2
Provides something relevant	1

Sample response

$Na_2CO_{3\,(s)} + 2CH_2(OH)COOH_{\,(aq)} \rightarrow 2NaCH_2(OH)COO^-_{(aq)} + H_2O_{\,(l)}$

c(acid) = 13 mol/L (from part d)

n = c x v

= 13 x 0.1 L

= 1.30 mols

n (Na_2CO_3) = ½ x n(acid) 1:2 mole ratio

= 0.65 mols

m(Na_2CO_3) = 0.65 x [2(22.99) + 12.01 + 3(16)]

= 68.8935 g

= 69 g (2.s.f)

Markers comment/s

Too many students did not write the correct balanced equation and therefore got the ratio of acid:base as 1:1 instead of 2:1. If the incorrect ratio was used then the maximum number of marks available was 2. Some students used NaOH instead of Na_2CO_3, so this gave the incorrect ratio acid:base and molecular mass of base. This question was marked to significant figures, which was two, based on part d and e, where 2 sig figs is the lowest number across the question. Lots of students lost a mark for giving the answer to 3 sig figs.

Question 28

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

Criteria	Marks
Student: Analyses the chemical formula and reactivity to correctly determine the type of compound.	3
Utilises only the chemical formula or reactivity to correctly determine the type of compound.	2
Provides something relevant	1

Sample response

The compound is an aldehyde. Both aldehydes and alcohols can oxidise with acidified potassium dichromate. However, the only compound that has the chemical formula $C_5H_{10}O$ is pentanal not pentanol which would be $C_5H_{12}O$.

OR

The compound is an aldehyde. The chemical formula CnH2nO is shared between functional isomers, aldehydes and ketones. However, ketones cannot be oxidised whereas aldehydes can, to form carboxylic acid.

Markers comment/s

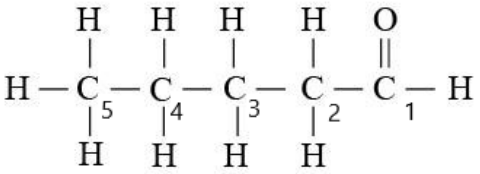
Generally well answered by the cohort. Students MUST give a definitive answer as to the TYPE of compound not a range/list of options. Note that you are not able to utilise the spectral data on subsequent pages as part of your answer to a) - you need to use the information provided before it. A handful of students need to review the content to understand what organic compounds can oxidise and the colours observed - whilst the colour wasn't necessary, students wrote wrong information with regards to the colour change for oxidation and this may impact your marks in future HSC questions.

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

Criteria	Marks

Student: Provides evidence of conducting an extensive analysis of all spectral graphs provided, chemical reactivity and chemical formula to deduce the most appropriate chemical compound.	7
Conducts a thorough analysis with a minor error/s or omissions	5-6
Conducts a sound analysis of the spectral graphs and information to deduce a valid chemical compound, with its structure correctly drawn. (*2 done well*)	4
Conducts a basic analysis of the spectral graphs to deduce a chemical compound	2-3
Provides ONE piece of relevant information	1

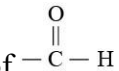
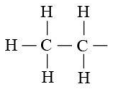
Sample response

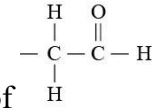


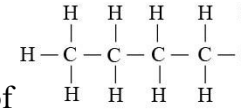
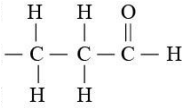
Pentanal

Mass spec

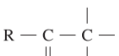
- Molecular mass of pentanal = 5(12) + 16 + 10(1) = 86 g/mol. this matches the parent ion mass of 86 labelled on the mass spec.

The fragment observed at 29 is representative of  or 

43 is representative of 

57 is representative of  or 

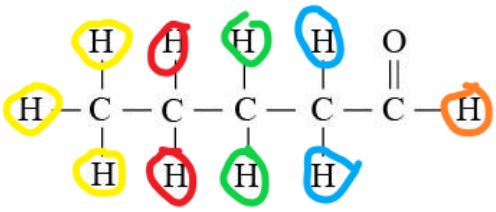
C-NMR

- indicates 5 Carbon environments. This corresponds to the 5 carbon environments labelled above and coincides with the chemical formula and asymmetric nature of pentanal structure.
- no signal at 160-185 ppm so no ester or acid; none at 50-90 therefore no alcohol
- The signal at ~205 ppm is representative of  for aldehydes (190-220). Ketones have been ruled out by the oxidation test.
- The signal at ~45ppm  (20-50) further supports the aldehyde structure

IR

- large absorption stretch at ~1750 coincides with C=O functional group (1680-1750 cm^{-1}). This suggests ketone, aldehyde and acid BUT C-NMR and reaction with acidified dichromate eliminates ketone and acids. Must be aldehyde.
- stretches at 2850 - 3000 cm^{-1} coincides with C-H bonds.
- no broad stretch or tongue between 3230 - 3550 or 2500 - 3000, rules out alcohols and acid, respectively.
- no double fanged stretch at 3300 - 3500 therefore not an amine.

H-NMR



- 5 hydrogen environment as colour coded above. Signal splitting observed following n+1 rule where n is the number of hydrogens on neighbouring carbon atoms.
- H (yellow) = would have a signal splitting of a triplet as neighbouring carbon has 2 H. signal coincides with the shift at 0.90, less affected by the shielding generated by the O-atom.
- H (red) = n+1 rule, has 5 hydrogens on neighbouring carbon, therefore has a signal splitting of sextet (1.35ppm)
- H (green) = 4+1 = 5, a quintet signal splitting at 1.60ppm
- H (blue) = the neighbouring carbons have a total of 3 hydrogens (green and orange) which means the splitting should be a quartet following the n+1 rule. This DOES NOT match any of the signal splitting provided.
- H (orange) = it should have a signal splitting of a triplet and again DOES NOT match any of the remaining HNMR data.

The HNMR does not really support the structure of pentanal, suggesting some error in the data. However, the compound must be an aldehyde given the reactivity and chemical formula. It is further supported by the mass spec, IR and CNMR. Isomeric chain structures of Pentanal such as 3-methylbutanal has only 4C environments whilst 2-methylbutanal has 5H but would observe a septet and 2 doublets which are not provided by the proton NMR data. Based on this, the best compound is pentanal.

Markers comment/s

Detail, detail, detail! Students are often too vague with what they write. It was disappointing to see that a fair number of students DID NOT ANNOTATE the stimulus materials or if they did, only wrote the obvious.

Not many students noticed that the HNMR did not correlate with the structure proposed. To get 4 marks students need to have analysed 2 spectral graphs very well.

Question 29

a) Name the type of reaction that occurs to convert compound: 4m

Criteria	Marks
Student: Correctly names all 4 types of chemical reactions	4
Correctly names 3 types of chemical reactions	3
Correctly names 2 types of chemical reactions	2
Correctly names 1 type of chemical reaction	1

Sample response
i) addition reaction
ii) oxidation reaction
iii) condensation reaction
iv) substitution reaction

Markers comment/s
The key word is TYPE of chemical reaction. Students need to distinguish the actual reaction with the type of reaction conducted. Leniency was present here as the marker ended up accepting the following:

i) hydration

iii) amidification

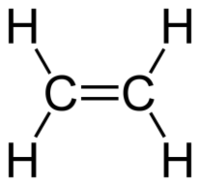
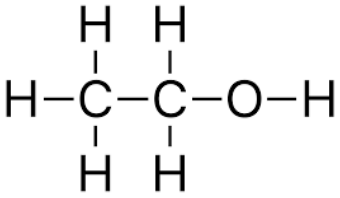
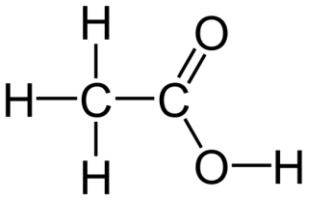
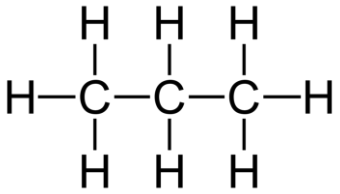
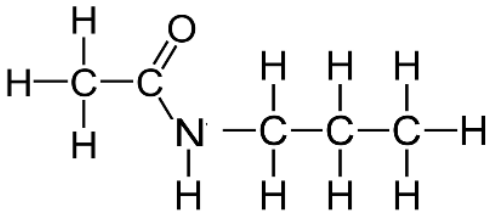
iv) halogenation

Students did not gain the mark if they provided contradicting names e.g hydration/substitution because it is wrong. This indicates that students do not understand the types of reactions and how they work. Neutralisation was NOT accepted for an alternative to the formation of amides. Whilst amines are basic and carboxylic acids are acidic, they would form ammonium carboxylate salts and water. The step is actually two fold causing the amide to form when heat is applied. Amidification is a type of condensation reaction as water is the small by-product from the reaction.

b) Draw the chemical structures of compounds A to E. 5m

Criteria	Marks
Student: Provides correct structural formulas for each compound A - E	5
Provides correct structural formulas for 4 compounds	4
Provides correct structural formulas for 3 compounds	3
Provides correct structural formulas for 2 compounds	2
Provides correct structural formula for 1 compound	1

Sample response

A **ethene** 	**B** **ethanol** 
C  **ethanoic acid**	**D**  **propane**
E  **N-propylethanamide**	

Markers comment/s

Note: The question did not require IUPAC names to be provided.

Unfortunately some students did not pay attention to the last part of the question - “no isomeric products possible”. This meant that students needed to make sure that A was ethene as it would only produce 1 possible product whereas compounds like propene, once hydrated can produce propan-1-ol or propan-2-ol which are isomers!!

Compound E should have been straight forward as amides are the derivatives of carboxylic acids. When carboxylic acids react with amines a small water molecule is produced, thus remove the OH from the acid and the H from the N, allows these ends to connect to form the amide. Some students drew the amide like an ester or as an amine instead. Please review!

Leniency in marking was applied. Students could obtain marks for the following

+1 - Incorrect alkene (A) but then drew the minor product for B and thus an acid for compound C.

+1 - Incorrect alkene (A) but then drew the major product for B (correct) but ended up with a ketone for compound C

+1 - drew the correct structure for E based on their structural formulae for C.

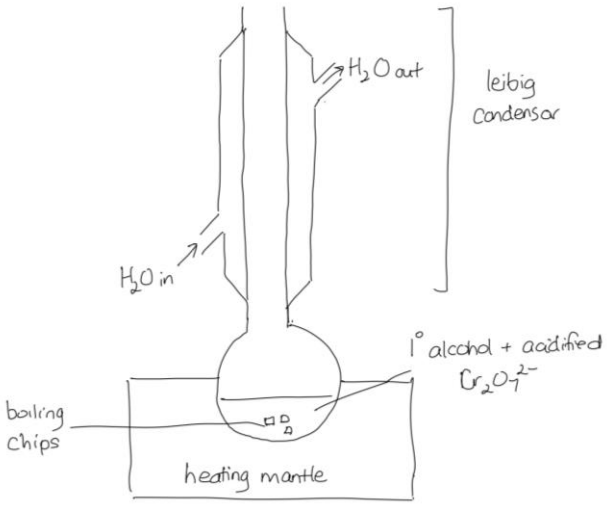
c) Explain the reaction conditions required to successfully convert compound B to C in the school laboratory. Include a labelled diagram of the apparatus. 4m

Criteria	Marks
Student: Thoroughly and correctly justifies each of the reaction conditions present to convert compound B to C and provides a correct scientifically labelled diagram of the apparatus.	4
Correctly justifies each of the reaction conditions with an error in the labelled diagram. **OR** Draws a scientifically correct diagram complete with labels and provides reasons for 2-3 of the reaction conditions.	3
Provides a partially or fully correct diagram and minimal reasoning for the reaction conditions	2
Provides something relevant	1

Sample response

To convert ethanol (B) to ethanoic acid (C), it is necessary to conduct the reaction as follows:

- excess oxidising agent ($KMnO_4$) - excess is required to ensure there is enough to successfully oxidise ethanol into ethanal and subsequently ethanal into ethanoic acid.
- dilute sulfuric acid - provides the acidic medium for the oxidising agent to work
- reflux apparatus - ensures no loss of volatile reactants and products as vapours condense back into liquid. It helps to ensure the half-way product, ethanal, remains in the reaction mixture to further oxidise into ethanoic acid. Therefore, increase the yield of ethanoic acid formed.
- heat - increases rate of oxidation reaction



Markers comment/s

Diagrams need to be scientific and labeled correctly. Please review this for all experimental set ups such as titration, esterification, distillation etc. It is important that students understand that reflux should be conducted using a heating mantle or with the reaction mixture placed in a water bath above a heat source, particularly if it is an open flame.

The reflux apparatus should not be drawn with a stopper attached. This is potentially dangerous, especially if the condenser does not work properly where a build of gas can cause the glassware to break under pressure. The water MUST be drawn with the water entering from the base of the condenser and exiting from the top.

Students would not obtain full marks if they did not make a point of stating the oxidising agent is in EXCESS. This is important. If the aim is to produce just an aldehyde and no carboxylic acid then the alcohol must be in excess.

Students seemed confused and tackled this question like a risk assessment question.

- boiling chips
- Not stopping the condensor
- Hot plate over naked flame

Note that the subject was 'reaction conditions' to convert B to C. The question was not asking how the experiment should be conducted safely or outline the risks/precautions.

Students confused the role of the dilute acid with esterification (?). This process is oxidation. The oxidising agent is $KMnO_4$ or $K_2Cr_2O_7$ and it works best in an acidic medium.

Question 30

The students' reaction pathway is riddled with errors.

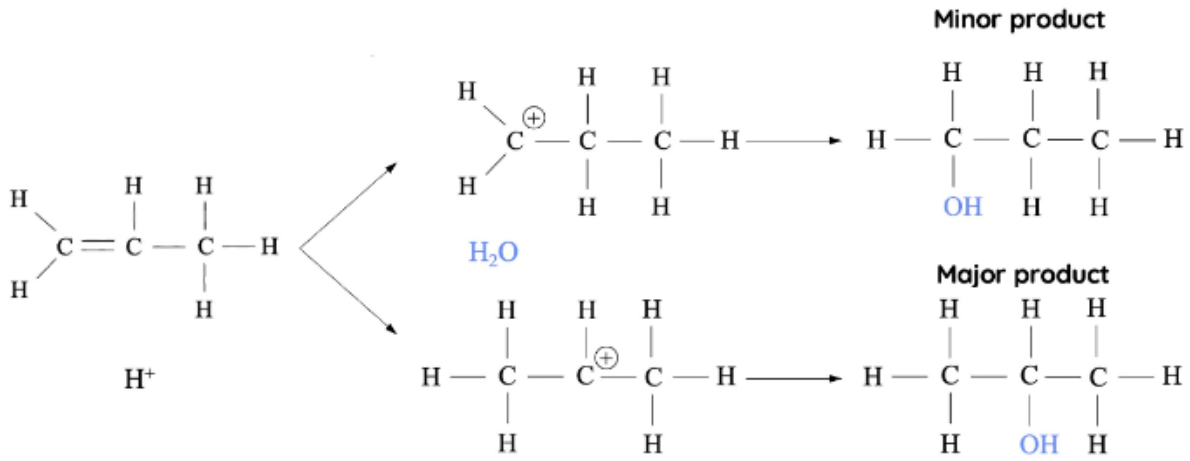
Identify and explain the errors in the students' reaction pathway with reference to ONE key chemistry principle. Support your answer with labelled diagrams. 5m

Criteria	Marks
Student: Explains the key principle with regards to the formation of specific products. Outlines THREE main errors, demonstrating an understanding of chemical reactions and their conditions, and provides TWO relevant diagrams.	5
Explains the key principle with regards to the formation of specific products. Outlines THREE errors (minor) and provides ONE relevant diagram.	4
Identifies ONE-TWO errors and describes ONE key principle with ONE relevant diagram.	3
Identifies ONE error and ONE key principle. Includes a diagram with little to no relevance. OR Identifies TWO errors and includes a diagram with little to no relevance.	2
Provides ONE relevant information	1

Sample response

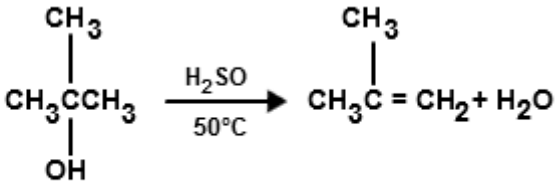
Markovnikov's rule states that reactions, particularly addition reactions, will produce major and minor products. Major products are produced in higher percentage and will occur when the double bond across 2 carbon atoms are broken and the hydrogen will bond to the carbon with the most hydrogen atoms attached.

Propene undergoes hydration with dilute sulfuric acid to produce propanol. The major product should be propan-2-ol whilst the minor product is propan-1-ol (drawn by the student). The students won't know which one is formed and should consider both products.



2-methylpropene is hydrated with dilute sulfuric acid to produce a tertiary alcohol. This correctly abides Markovnikov's rule to form the major product. However, a tertiary alcohol cannot be oxidised with an acidified solution of potassium dichromate. No reaction should be observed therefore, 2-methylpropanoic acid cannot be formed by this pathway. If the minor product was shown, 2-methylpropan-1-ol, then oxidation can occur to produce the acid.

Therefore, the tertiary alcohol (2-methylpropan-2-ol) when mixed with another alcohol (propan-2-ol) will not form an ester. With concentrated sulfuric acid and heat present, the alcohols are likely to become dehydrated back into alkenes.



It is also important to note that the oxidation of alcohols into carboxylic acids AND the process of esterification will need to be performed using reflux. The oxidising agent should also be potassium dichromate ($K_2Cr_2O_7$) not $C_2O_7^{2-}$.

Markers comment/s

To get to 3 marks students need to be able to describe Markovnikov's rule.

It is important that students understand that chemical reaction pathways generally show the key products formed, not the by-products, so water is not required to be shown in the esterification process.

Diagrams drawn should be something DIFFERENT or new to the question. Anything that was simply a regurgitation of the stimulus is not counted. The reflux apparatus is not a relevant diagram in this instance. Exams will not require students to repeat the same skills.

Some students mistook 2-methylpropan-2-ol as a secondary alcohol. PLEASE REVIEW THIS.