SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

2021
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section I - Multiple Choice

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 ○

Start Here →

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

SYDNEY GRAMMAR SCHOOL

2021
TRIAL EXAMINATION

CHEMISTRY
Form VI

STRUCTURE OF PAPER

SECTION I

A: Multiple Choice 20 marks

Allow about 30 minutes for this section.

SECTION II 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE: Wed 25 August 8.40 am

DURATION: 3 hours + 5 minutes reading time

MARKS: 100

CHECKLIST

Each boy should have the following:

- ☐ 1 Examination Paper (data sheet attached on back)
- ☐ 1 Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the paper in a neat bundle.
- WRITE YOUR CANDIDATE NUMBER IN THE SPACE PROVIDED AT THE TOP OF EACH PAGE WHERE INDICATED.

Authors: MTK, CXS, JLS, TW

SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which one of the following is an acid-base conjugate pair?

(A) HCl (aq) / NaOH (aq)

(B) H_2O (l) / OH^- (aq)

(C) H_2SO_4 (aq) / SO_4^{2-} (aq)

(D) CH_3COOH (aq) / CH_3CHO (aq)

2 Which change increases the pH of a solution from 3 to 6?

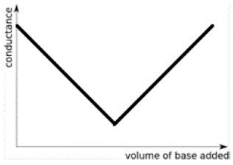
(A) Doubling the $[H_3O^+]$

(B) Halving the $[OH^-]$

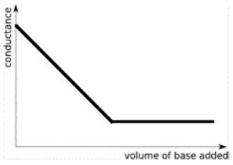
(C) Decreasing the $[H_3O^+]$ by a factor of 1000

(D) Decreasing the $[OH^-]$ by a factor of 1000

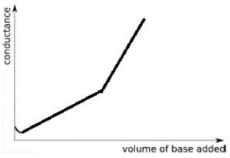
3 Which one of the following conductivity curves represents a titration that has a weak acid in the beaker with a strong base being added to it?



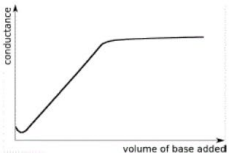
(A)



(B)



(C)



(D)

4 Which of the following solutions (at the same concentration) will have the lowest pH value?

(A) Ammonium chloride

(B) Sodium nitrate

(C) Potassium carbonate

(D) Sodium ethanoate

5 Tollens' reagent was added to an unknown organic compound. This compound reduced this reagent to a silver mirror as shown below.

Which of the following could the unknown organic compound be?

(A) propanal

(B) propanone

(C) propanoic acid

(D) 2-propanol

6 Which of the following statements must be true for a reaction where K_{eq} is very large?

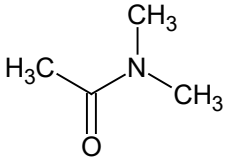
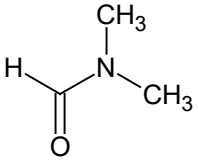
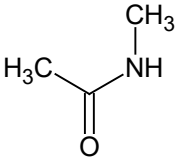
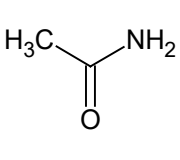
(A) Equilibrium is reached very quickly.

(B) The forward reaction is extremely endothermic.

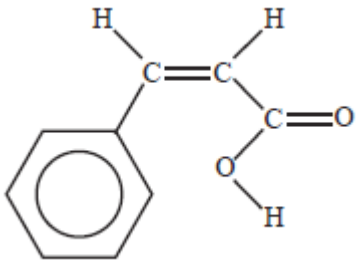
(C) At equilibrium, the forward reaction rate is much greater than the reverse reaction rate.

(D) The reaction essentially proceeds to completion.

7 Which of the following molecules is a secondary amide?

			
(A)	(B)	(C)	(D)

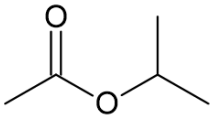
8 Cinnamic acid, shown below, is an organic compound that is the main flavour component of cinnamon.

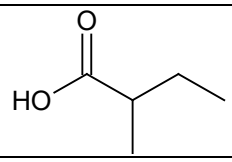
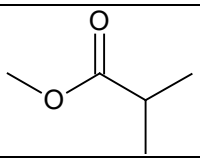
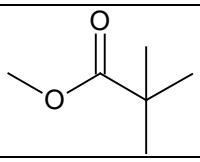
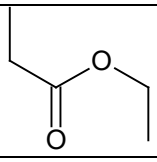


Which of the following reagents would you expect to react with cinnamic acid under the conditions given?

Reagent	Bromine water at room temperature	Sodium carbonate solution
(A)	Yes	Yes
(B)	No	Yes
(C)	Yes	No
(D)	No	No

9 Which molecules are isomers of propan-2-yl acetate, shown below?



			
I	II	III	IV

(A) I and II

(B) II and IV

(C) I, II and IV

(D) II, III and IV

10 When 0.1 mol L^{-1} solutions of the following pairs of substances are mixed, which pair will produce a precipitate?

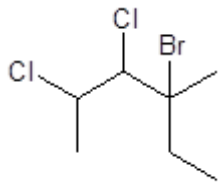
(A) zinc chloride and sodium sulfate

(B) copper(II) sulfate and barium nitrate

(C) magnesium nitrate and sodium chloride

(D) ammonium chloride and sodium hydroxide

11 What is the IUPAC name of Compound A?



Compound A

(A) 2-bromo-3,4-dichloro-2-ethylpentane

(B) 2,3-dichloro-4-bromo-4-ethylpentane

(C) 2,3-dichloro-4-bromo-4-methylhexane

(D) 4-bromo-2,3-dichloro-4-methylhexane

12 Which of the following molecules contains a carbon atom that bonds to adjacent atoms with trigonal planar geometry?

(A) C_2H_6

(B) CH_3NH_2

(C) CH_3CHO

(D) CH_3OH

13 Complete combustion of one of the following organic compounds formed equal volumes of carbon dioxide and water vapour, under the same conditions of temperature and pressure. What is the molecular formula of the organic compound?

(A) C_3H_8

(B) C_2H_2O

(C) C_2H_6O

(D) C_2H_4

14 Which of the following equilibria will produce a greater amount (in mol) of products when the temperature of the system is decreased and when the total pressure is increased by decreasing the volume of the reaction vessel?

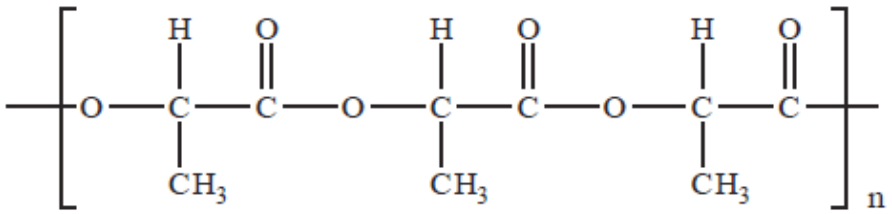
(A) $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$ $\Delta H^{\ominus} = -92\ kJ\ mol^{-1}$

(B) $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$ $\Delta H^{\ominus} = +57\ kJ\ mol^{-1}$

(C) $H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ $\Delta H^{\ominus} = -9.5\ kJ\ mol^{-1}$

(D) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $\Delta H^{\ominus} = +88\ kJ\ mol^{-1}$

15 The polymer polylactic acid, PLA, shown below, is a condensation polymer made from a single monomer.



How many unique proton environments would there be in the ^1H NMR spectrum of PLA's **monomer**?

(A) 1

(B) 2

(C) 3

(D) 4

16 Which mixture would produce a buffer solution when dissolved in 1.0 L of water?

(A) 0.50 mol of CH_3COOH and 0.50 mol of NaOH

(B) 0.50 mol of CH_3COOH and 0.25 mol of NaOH

(C) 0.50 mol of CH_3COOH and 1.00 mol of NaOH

(D) 0.50 mol of CH_3COOH and 0.25 mol of $Ba(OH)_2$

17 What is the molar concentration of H_3O^+ ions in an acetic acid solution in which the $[CH_3COOH] = 2.0$ mol L^{-1} and $[CH_3COO^-] = 1.0$ mol L^{-1} given $K_a = 1.8 \times 10^{-5}$.

(A) 6.0×10^{-3} M

(B) 3.6×10^{-5} M

(C) 1.8×10^{-5} M

(D) 9.1×10^{-6} M

18 Consider the ionisation of water at 25°C:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14}$$

At 37°C, $K_w = 2.4 \times 10^{-14}$. What can be deduced from this?

(A) The pH value of pure water decreases when heated.

(B) The enthalpy of ionisation of water is negative.

(C) The $[OH^-]$ at 37°C is lower than at 25°C.

(D) The conductivity of water at 37°C is lower than at 25°C.

19 Consider the following reactions and their K_{eq} values at 700 °C.

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ $\qquad K_1$ (at 700 °C) = 49

$2\ H_2(g) + S_2(g) \rightleftharpoons 2\ H_2S(g)$ $\qquad K_2$ (at 700 °C) = 1.1×10^8

Which of the following is the value of K_{eq} (at 700 °C) for the following reaction?

$$2\ I_2(g) + 2\ H_2S(g) \rightleftharpoons S_2(g) + 4\ HI(g)$$

(A) $\frac{49^2}{1.1\times10^8}$

(B) $\frac{49}{1.1\times10^8}$

(C) $\frac{2\times49}{1.1\times10^8}$

(D) $2 \times 49 - 1.1 \times 10^8$

20 When gaseous nitrosyl bromide (NOBr) decomposes in a closed container at a certain temperature and pressure, the following equilibrium is established:

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

4.0 mol of NOBr(g) were placed in a 1.0 L container and allowed to reach equilibrium. At equilibrium, the concentration of $Br_2(g)$ was 1.0 mol L^{-1}. What is the value of K_{eq} under these conditions?

(A) 0.5

(B) 1.0

(C) 1.5

(D) 2.0

SECTION II: 80 marks

Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 21 (3 marks)

Acetic acid is flammable. Thermodynamic data (at 298 K) for the complete combustion of acetic acid is presented in the table below.

$\Delta_c H^{\ominus} = -874.2$ kJ mol^{-1}	$\Delta_c S^{\ominus} = -2.6$ J K^{-1} mol^{-1}

Using the information in the table, explain why combustion of acetic acid does not come to equilibrium but instead proceeds to completion.

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CANDIDATE NUMBER

Question 22 (4 marks)

Formaldehyde (CH_2O) trimerises in acidic aqueous solution, according to the following equation:

$$3\ CH_2O(aq) \rightleftharpoons C_3H_6O_3(aq) \qquad K_{eq} = 3.0 \times 10^{-5}$$

1.2 mol of formaldehyde is dissolved in water to form 1.0 L of solution; this system is allowed to come to equilibrium.

Calculate the concentration of $C_3H_6O_3(aq)$ in the resulting solution.

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Question 23 (3 marks)

Aluminium sulfate has a solubility of 36.4 g per 100 mL. Calculate K_{sp} for aluminium sulfate.

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CANDIDATE NUMBER

Question 24 (8 marks) **Marks**

The industrial manufacture of methanol involves the following reversible reaction:

$$CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta_c H^{\ominus} = -331.84\ kJ\ mol^{-1}$$

(a) Write the equilibrium constant expression for this reaction.

..... **1**

A mixture of CO, H_2 and methanol is placed in a reaction vessel of variable volume and allowed to reach equilibrium.

(b) By referring to the reaction quotient, Q, and the equilibrium constant, K_{eq}, explain the effect of halving volume of the vessel on the amount (in mol) of methanol present.

..... **3**

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(c) Using collision theory, explain the effect of increasing the temperature of this system on the equilibrium constant, K_{eq}.

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CANDIDATE NUMBER

Question 25 (6 marks) **Marks**

27.82 g of hydrated sodium carbonate crystals, $Na_2CO_3 \cdot xH_2O$, was dissolved in water and made up to 1.000 L. 25.00 mL of this solution was neutralised by 48.80 mL of hydrochloric acid of concentration 0.1000 mol L^{-1}.

(a) Write an equation for the reaction between sodium carbonate and hydrochloric acid.

..... **1**

(b) Calculate the molar concentration of the sodium carbonate solution neutralised by the hydrochloric acid.

..... **2**

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(c) By calculating the mass of water in the hydrated crystals, find the value of *x*.

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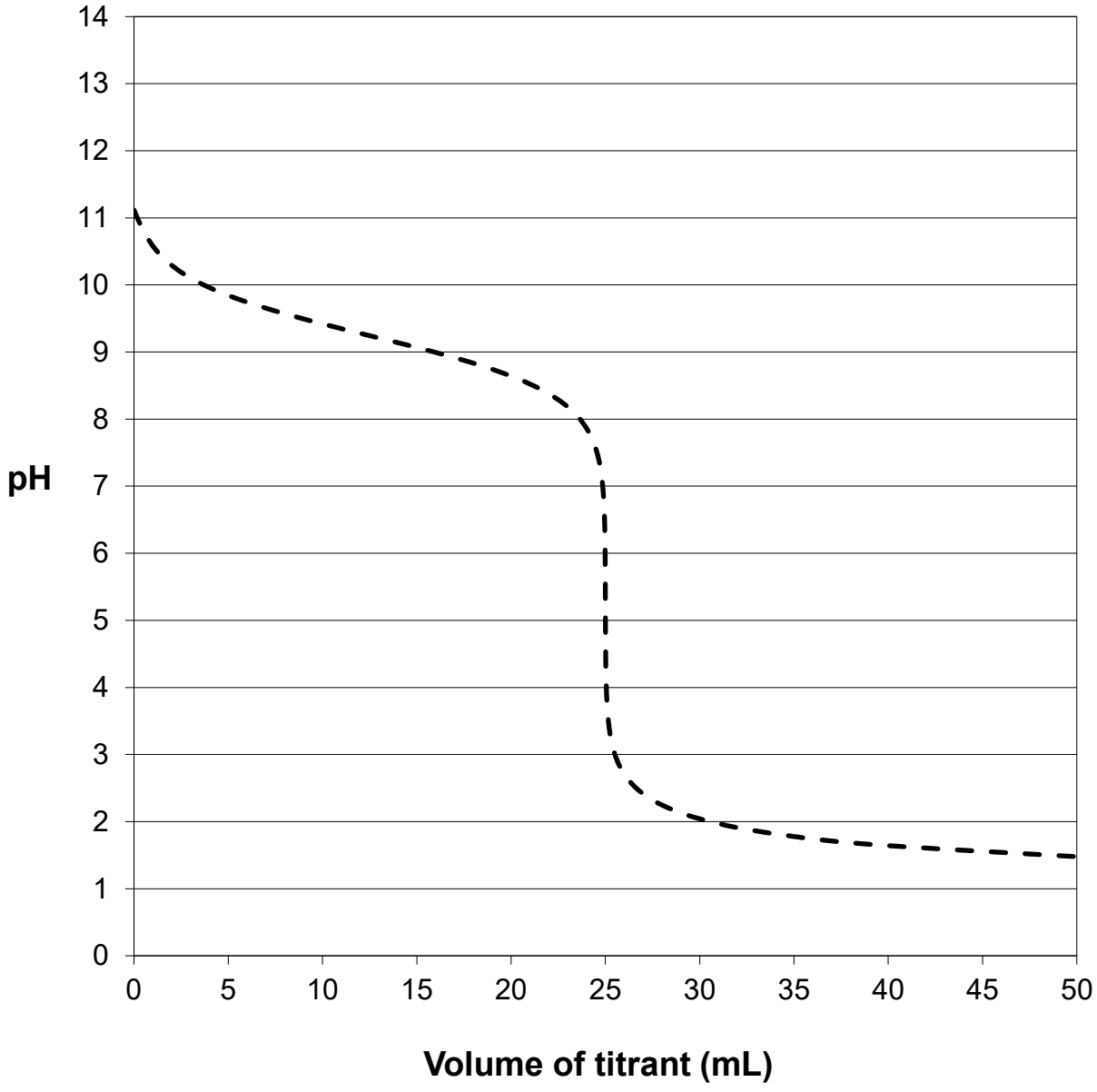
CANDIDATE NUMBER

Question 26 (2 marks)

The graph below represents a titration curve for a 0.100 mol L^{-1} ammonia (NH_3) solution, when it is titrated with a strong acid.



On the diagram above, draw the titration curve that would result if the ammonia is replaced by a solution of sodium hydroxide of the same concentration.

CANDIDATE NUMBER

Question 27 (3 marks)

Explain the term amphiprotic as it relates to the behaviour of salts in solution. Use the salt, potassium hydrogen sulfate, $KHSO_4$, and equations to illustrate your answer.

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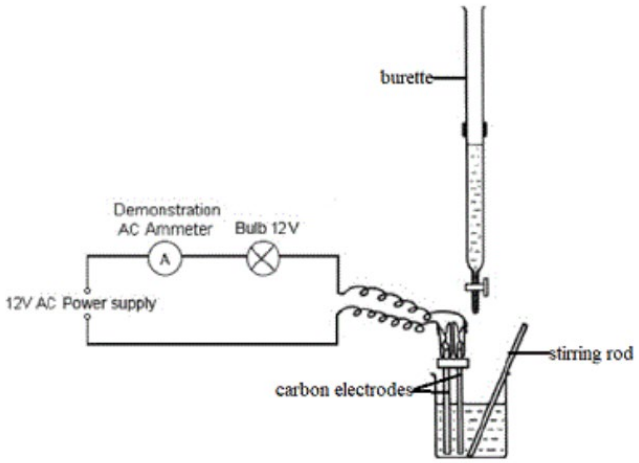
Question 28 (4 marks)

The setup below can be used to determine the end point of an acid/base titration by measuring conductivity.

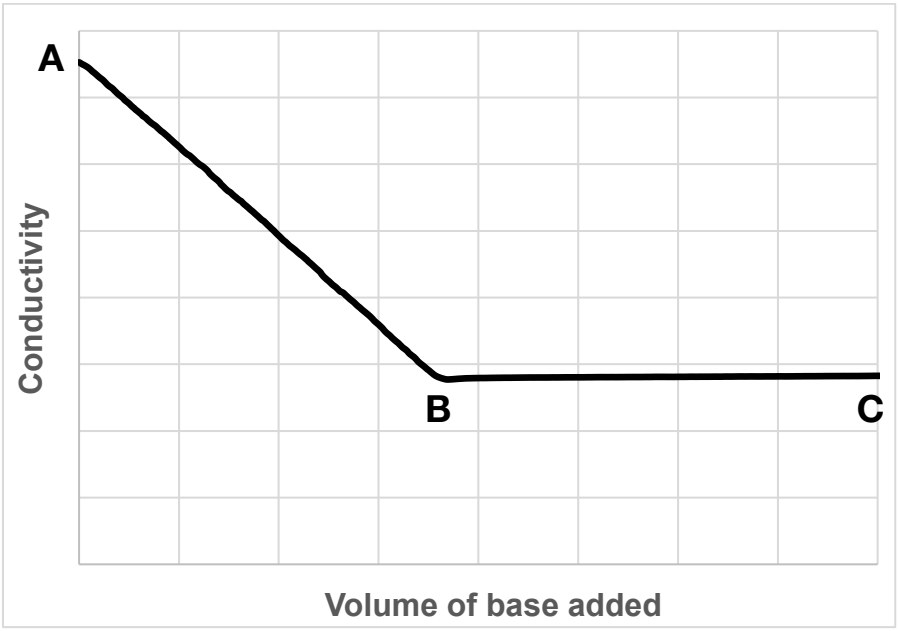


The graph that follows shows the changes in conductivity of the solution when a solution of ammonia from the burette is added to a solution of sulfuric acid in the beaker during a conductometric titration:

Question continued

CANDIDATE NUMBER

Question continued **Marks**



(a) Using A, B or C, identify the equivalence point of this titration.

..... **1**

(b) Explain why this conductivity curve has this shape.

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CANDIDATE NUMBER

Question 29 (8 marks) **Marks**

Propanoic acid, CH_3CH_2COOH, is classified as a weak acid.

(a) According to Brønsted-Lowry Theory, state the meaning of the term *weak acid*.

..... **1**

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(b) Write a balanced chemical equation for the reaction of propanoic acid with water.

..... **1**

(c) Determine the pH of a 0.100 mol L^{-1} solution of propanoic acid, given its $pK_a = 4.87$.

..... **3**

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(d) A mixture of propanoic acid and sodium propanoate can act as a *buffer solution*. Calculate the pH of a solution containing 4.81 g of sodium propanoate in 1.0 L of 2.0×10^{-2} mol L^{-1} propanoic acid, stating any assumptions you have made.

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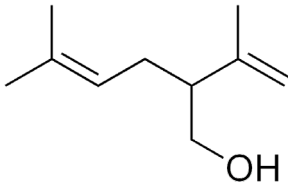
CANDIDATE NUMBER

Question 30 (4 marks) **Marks**

Lavandulol is a compound that is found in lavender oil. The structural formula of lavandulol is shown below.



Lavandulol

(a) Give the molecular formula of lavandulol.

…… **1**

(b) Identify the two functional groups found in lavandulol.

…… **2**

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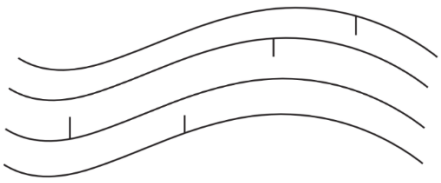
(c) Draw the structural formula of the molecule that is formed when lavandulol is exposed to an excess of chlorine gas. **1**

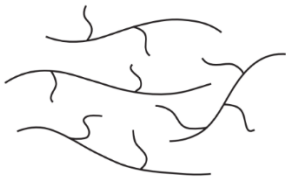
CANDIDATE NUMBER

Question 31 (3 marks)

There are two forms of the polyethylene polymer formed from the ethene monomer. The two forms can be distinguished from each other based on the extent of branching**.**



Type I Polyethylene



Type II Polyethylene

Identify a property that differs between the two types of polyethylene. Explain why there is a difference.

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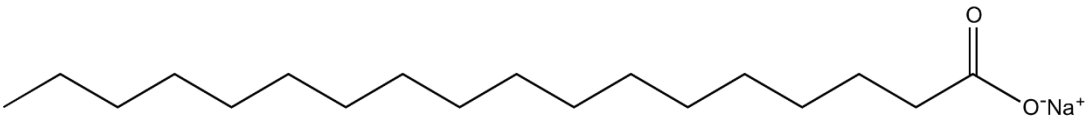
CANDIDATE NUMBER

Question 32 (3 marks)

The structure of a soap molecule is shown below.



Soap molecule

With reference to its structural features, explain the cleaning action of soap.

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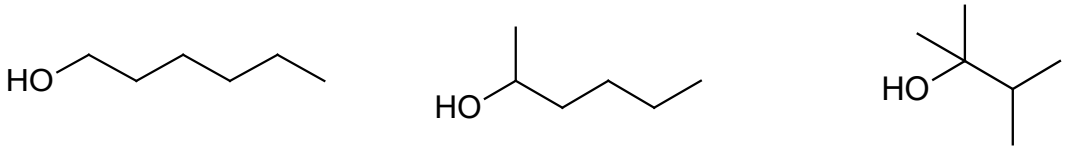
CANDIDATE NUMBER

Question 33 (7 marks) **Marks**

The structural formulae of three isomeric alcohols are shown below.



Alcohol A ***Alcohol B*** ***Alcohol C***

(a) State which of the three alcohols is resistant to oxidation using acidified potassium dichromate.

…… **1**

(b) Write a balanced chemical equation to show the complete combustion of Alcohol A.

…….... **1**

(c) State the type of reaction Alcohol B will undergo to produce 2-bromohexane.

…… **1**

(d) State the IUPAC name for Alcohol C.

…… **1**

(e) State which of the three alcohols would have the lowest boiling point and explain why.

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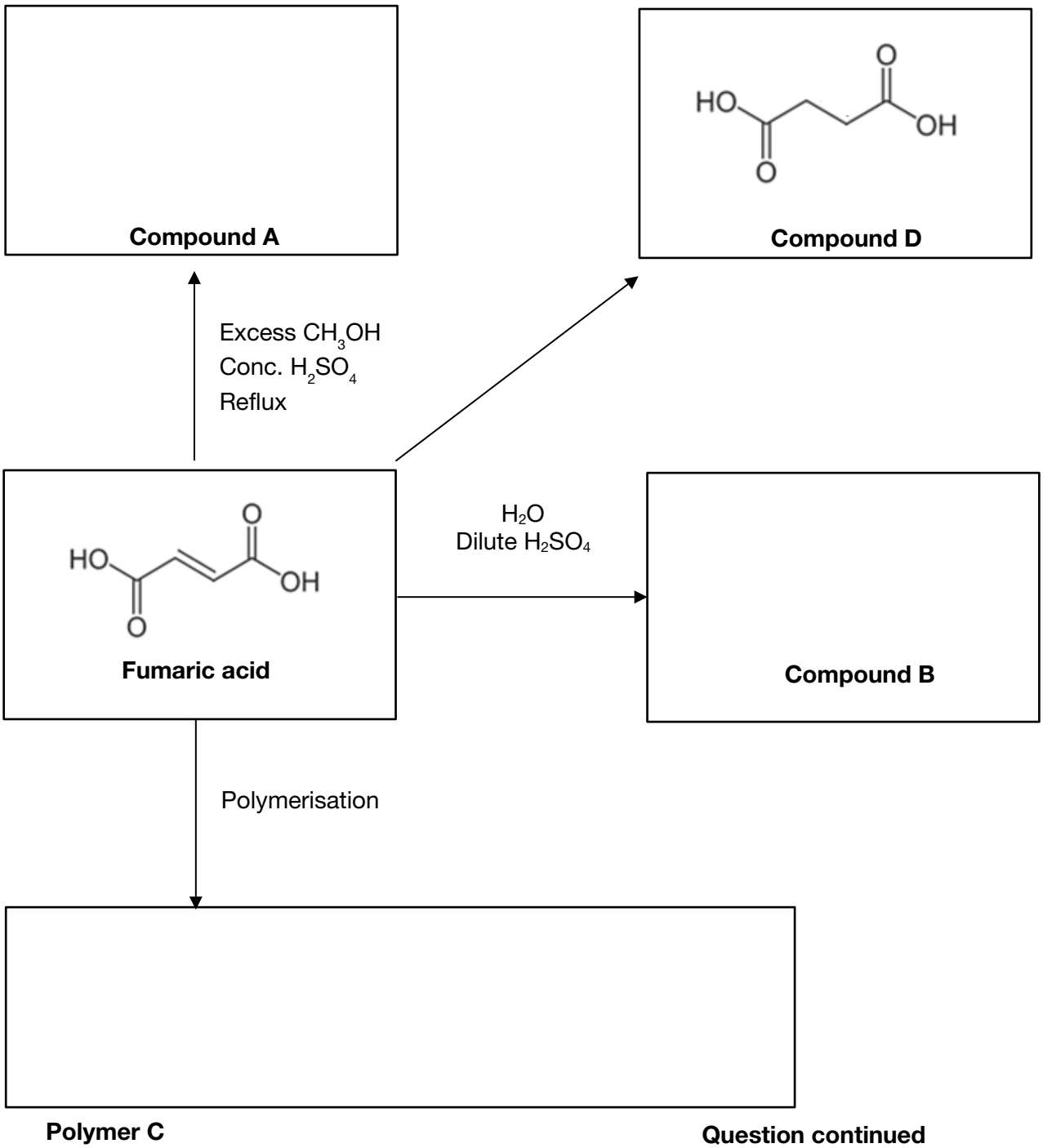
CANDIDATE NUMBER

Question 34 (5 marks) **Marks**

Fumaric acid is a naturally occurring dicarboxylic acid. It is a key intermediate in human metabolism and it is often used as a food additive. Fumaric acid is an important molecule in synthesis as it can be readily converted into a range of molecules as seen in the reaction scheme below.

(a) Using the reaction conditions given in the scheme below, deduce and draw the structures of Compound A, Compound B and a section of polymer C**.** **3**



Question continued

CANDIDATE NUMBER

Question continued **Marks**

(b) State the reagent/conditions required to prepare Compound D from fumaric acid.

..... **1**

.....

(c) Identify the type of polymerisation fumaric acid must undergo to produce polymer C.

..... **1**

.....

CANDIDATE NUMBER

Question 35 (5 marks)

A dilute solution of an unknown salt is to be analysed. The cation is one of Mg^{2+}, Ba^{2+} or Fe^{3+}. The anion is one of chloride, acetate or sulfate.
Outline a sequence of tests that could be performed in a school laboratory to confirm the identity of this salt solution. Include expected observations and a balanced chemical equation in your answer.

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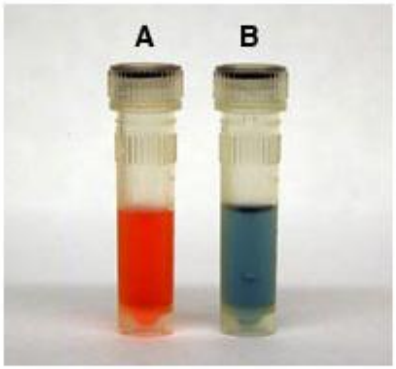
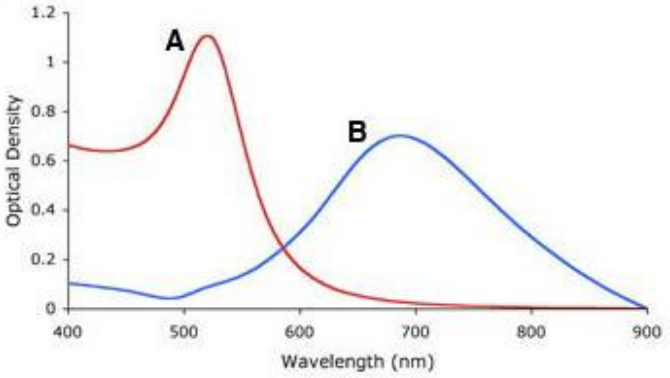
CANDIDATE NUMBER

Question 36 (5 marks) **Marks**

UV-Vis spectrophotometry was performed on two samples, A and B, with the results shown below.

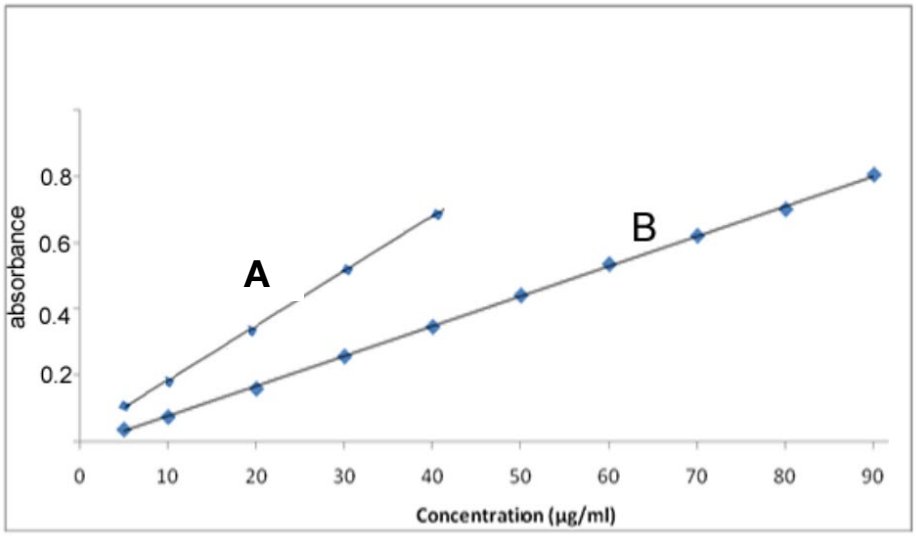




(a) If equal volumes of solution A and solution B were mixed, identify the wavelength that should be used to measure the absorbance of Solution B in this unreacted mixture? Justify your answer.

…… **1**

(b) A chemist used the appropriate wavelengths for each solution and constructed two calibration curves on the same set of axes, as shown below.



Question continued

CANDIDATE NUMBER

Question continued **Marks**

The chemist found that, when it was measured at the appropriate wavelength, Solution B had an absorbance of 0.400. If Solution B contained an organic substance with molecular formula $C_{23}H_{27}N_3O_{15}S$ (molar mass 617.53 g mol^{-1}), determine its concentration in mol L^{-1}.

..... **2**

.....

.....

.....

(c) A sample of contaminated water containing the same compound as found in solution A was analysed and found to have an absorbance of 0.80. Can the calibration curve above be used validly to analyse the sample of contaminated water for its concentration of the compound found in solution A? Justify your answer.

..... **2**

.....

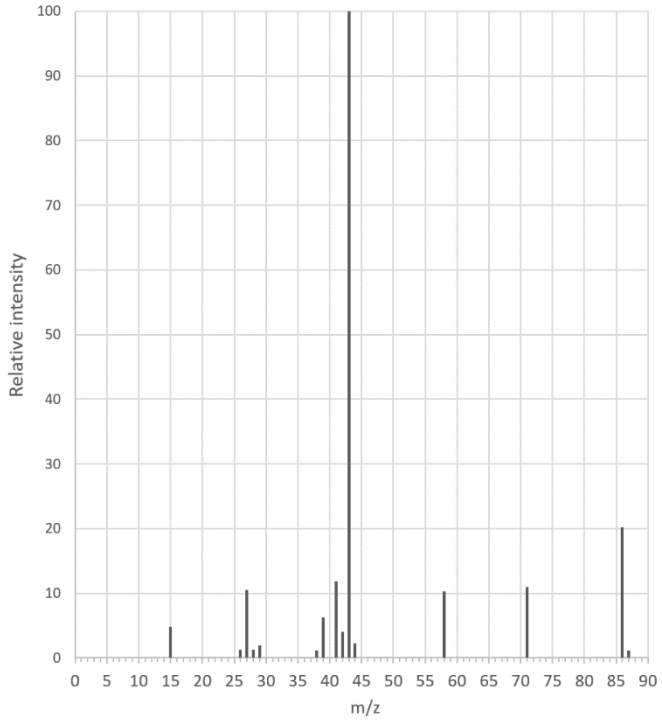
.....

.....

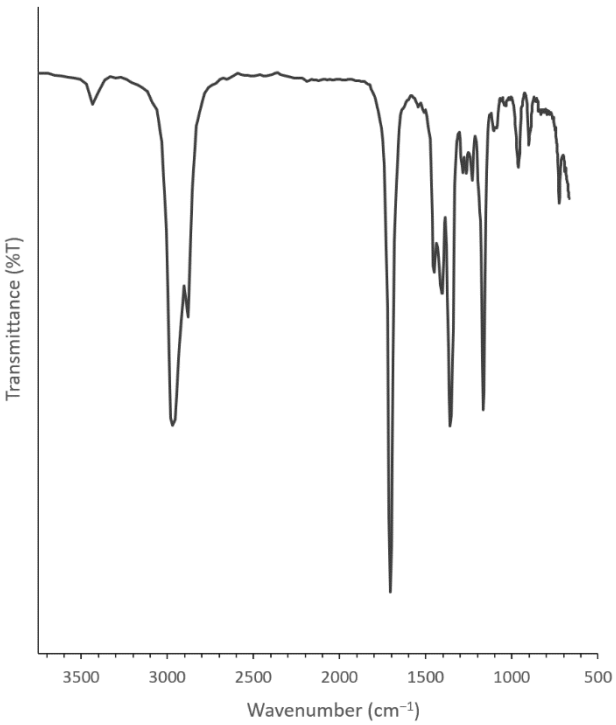
CANDIDATE NUMBER

Question 37 (7 marks)

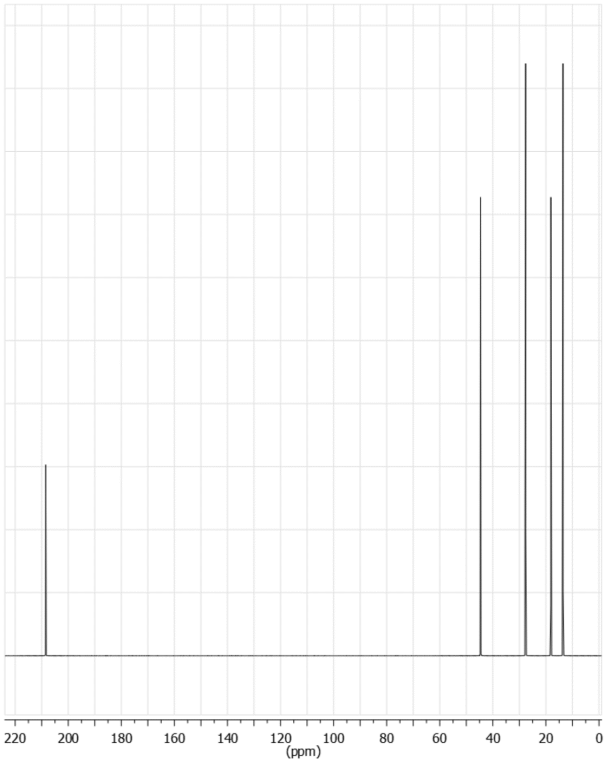
A sample of an unknown organic compound was analysed using mass spectrometry, IR spectroscopy and proton and carbon-13 NMR. The resulting spectra are shown below.



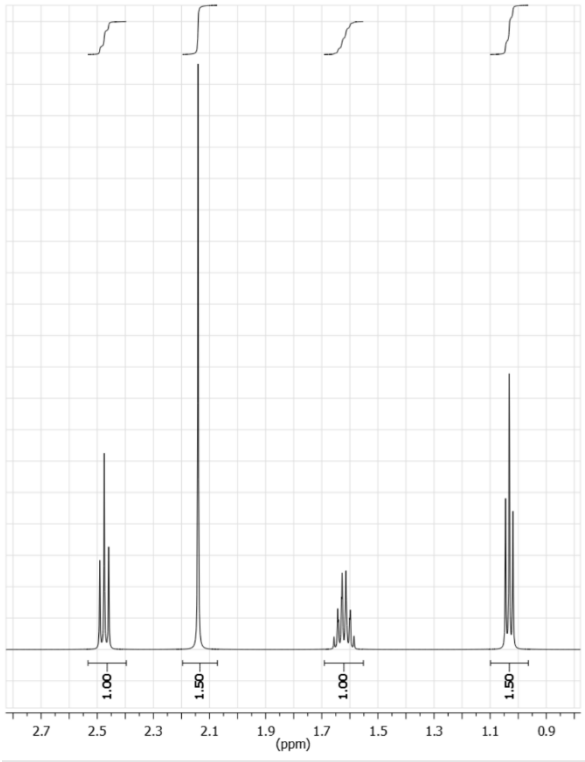
Mass Spectrum



IR Spectrum



^{13}C NMR spectrum



^{1}H NMR spectrum

CANDIDATE NUMBER

Question continued.

Deduce and draw the structural formula of the unknown compound, justifying your answer with reference to the spectra. Note the proton NMR shift data has not been provided.

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Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{v} \qquad PV = nRT$$

$$q = mC\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

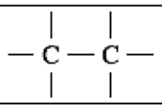
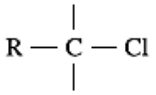
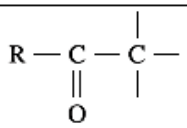
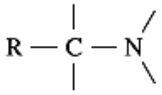
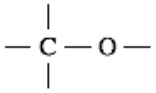
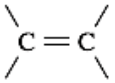
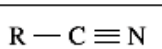
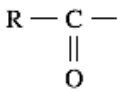
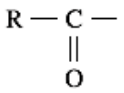
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

2021
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section I - Multiple Choice

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.

correct

A ⊗ B ⊗ C ○ D ○

Start Here →

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

SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

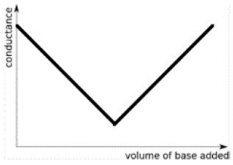
1 Which one of the following is an acid-base conjugate pair?

(A) HCl (aq) / NaOH (aq)
(B) H_2O (l) / OH^- (aq)
(C) H_2SO_4 (aq) / SO_4^{2-} (aq)
(D) CH_3COOH (aq) / CH_3CHO (aq)

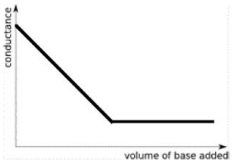
2 Which change increases the pH of a solution from 3 to 6?

(A) Doubling the $[H_3O^+]$
(B) Halving the $[OH^-]$
(C) Decreasing the $[H_3O^+]$ by a factor of 1000
(D) Decreasing the $[OH^-]$ by a factor of 1000

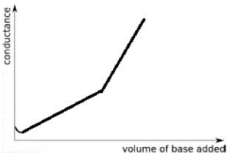
3 Which one of the following conductivity curves represents a titration that has a weak acid in the beaker with a strong base being added to it?



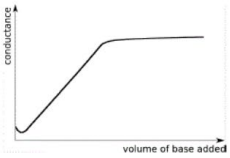
(A)



(B)



(C)



(D)

4 Which of the following solutions (at the same concentration) will have the lowest pH value?

(A) Ammonium chloride
(B) Sodium nitrate
(C) Potassium carbonate
(D) Sodium ethanoate

5 Tollens' reagent was added to an unknown organic compound. This compound reduced this reagent to a silver mirror as shown below.

Which of the following could the unknown organic compound be?

(A) propanal

(B) propanone

(C) propanoic acid

(D) 2-propanol

6 Which of the following statements must be true for a reaction where K_{eq} is very large?

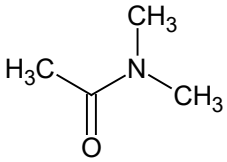
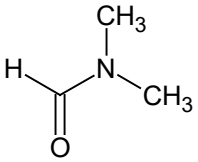
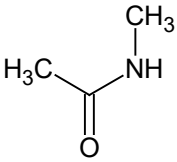
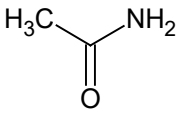
(A) Equilibrium is reached very quickly.

(B) The forward reaction is extremely endothermic.

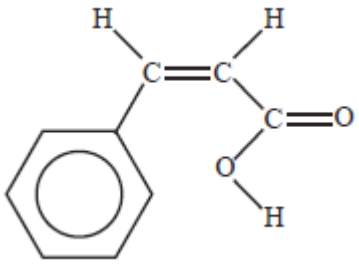
(C) At equilibrium, the forward reaction rate is much greater than the reverse reaction rate.

(D) The reaction essentially proceeds to completion.

7 Which of the following molecules is a secondary amide?

			
(A)	(B)	(C)	(D)

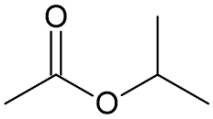
8 Cinnamic acid, shown below, is an organic compound that is the main flavour component of cinnamon.

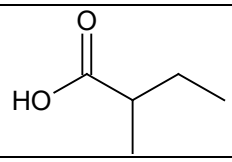
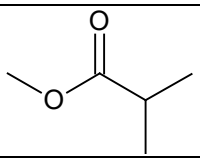
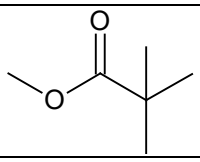
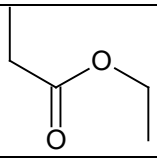


Which of the following reagents would you expect to react with cinnamic acid under the conditions given?

Reagent	Bromine water at room temperature	Sodium carbonate solution
(A)	Yes	Yes
(B)	No	Yes
(C)	Yes	No
(D)	No	No

9 Which molecules are isomers of propan-2-yl acetate, shown below?



			
I	II	III	IV

(A) I and II

(B) II and IV

(C) I, II and IV

(D) II, III and IV

10 When 0.1 mol L^{-1} solutions of the following pairs of substances are mixed, which pair will produce a precipitate?

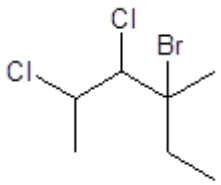
(A) zinc chloride and sodium sulfate

(B) copper(II) sulfate and barium nitrate

(C) magnesium nitrate and sodium chloride

(D) ammonium chloride and sodium hydroxide

11 What is the IUPAC name of Compound A?



Compound A

(A) 2-bromo-3,4-dichloro-2-ethylpentane

(B) 2,3-dichloro-4-bromo-4-ethylpentane

(C) 2,3-dichloro-4-bromo-4-methylhexane

(D) 4-bromo-2,3-dichloro-4-methylhexane

12 Which of the following molecules contains a carbon atom that bonds to adjacent atoms with trigonal planar geometry?

(A) C_2H_6

(B) CH_3NH_2

(C) CH_3CHO

(D) CH_3OH

13 Complete combustion of one of the following organic compounds formed equal volumes of carbon dioxide and water vapour, under the same conditions of temperature and pressure. What is the molecular formula of the organic compound?

(A) C_3H_8

(B) C_2H_2O

(C) C_2H_6O

(D) C_2H_4

14 Which of the following equilibria will produce a greater amount (in mol) of products when the temperature of the system is decreased and when the total pressure is increased by decreasing the volume of the reaction vessel?

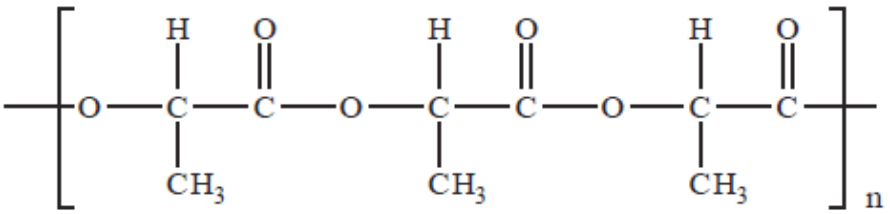
(A) $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$ $\Delta H^{\ominus} = -92\ kJ\ mol^{-1}$

(B) $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$ $\Delta H^{\ominus} = +57\ kJ\ mol^{-1}$

(C) $H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ $\Delta H^{\ominus} = -9.5\ kJ\ mol^{-1}$

(D) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $\Delta H^{\ominus} = +88\ kJ\ mol^{-1}$

15 The polymer polylactic acid, PLA, shown below, is a condensation polymer made from a single monomer.



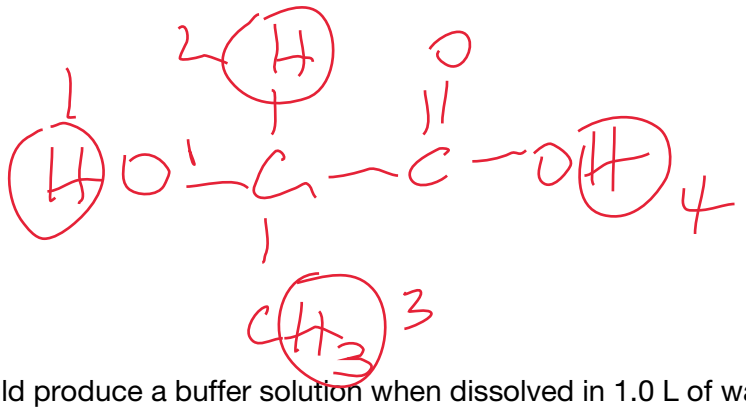
How many unique proton environments would there be in the ^1H NMR spectrum of PLA's **monomer**?

(A) 1

(B) 2

(C) 3

(D) 4



16 Which mixture would produce a buffer solution when dissolved in 1.0 L of water?

(A) 0.50 mol of CH_3COOH and 0.50 mol of NaOH

(B) 0.50 mol of CH_3COOH and 0.25 mol of NaOH

(C) 0.50 mol of CH_3COOH and 1.00 mol of NaOH

(D) 0.50 mol of CH_3COOH and 0.25 mol of $Ba(OH)_2$

17 What is the molar concentration of H_3O^+ ions in an acetic acid solution in which the $[CH_3COOH] = 2.0$ mol L^{-1} and $[CH_3COO^-] = 1.0$ mol L^{-1} given $K_a = 1.8 \times 10^{-5}$.

(A) 6.0×10^{-3} M

(B) 3.6×10^{-5} M

(C) 1.8×10^{-5} M

(D) 9.1×10^{-6} M

18 Consider the ionisation of water at 25°C:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14}$$

At 37°C, $K_w = 2.4 \times 10^{-14}$. What can be deduced from this?

(A) The pH value of pure water decreases when heated.

(B) The enthalpy of ionisation of water is negative.

(C) The $[OH^-]$ at 37°C is lower than at 25°C.

(D) The conductivity of water at 37°C is lower than at 25°C.

19 Consider the following reactions and their K_{eq} values at 700 °C.

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ $\qquad K_1$ (at 700 °C) = 49

$2\ H_2(g) + S_2(g) \rightleftharpoons 2\ H_2S(g)$ $\qquad K_2$ (at 700 °C) = 1.1×10^8

Which of the following is the value of K_{eq} (at 700 °C) for the following reaction?

$$2\ I_2(g) + 2\ H_2S(g) \rightleftharpoons S_2(g) + 4\ HI(g)$$

(A) $\frac{49^2}{1.1\times10^8}$

(B) $\frac{49}{1.1\times10^8}$

(C) $\frac{2\times49}{1.1\times10^8}$

(D) $2 \times 49 - 1.1 \times 10^8$

$K_1^2 \times \frac{1}{K_2}$

20 When gaseous nitrosyl bromide (NOBr) decomposes in a closed container at a certain temperature and pressure, the following equilibrium is established:

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

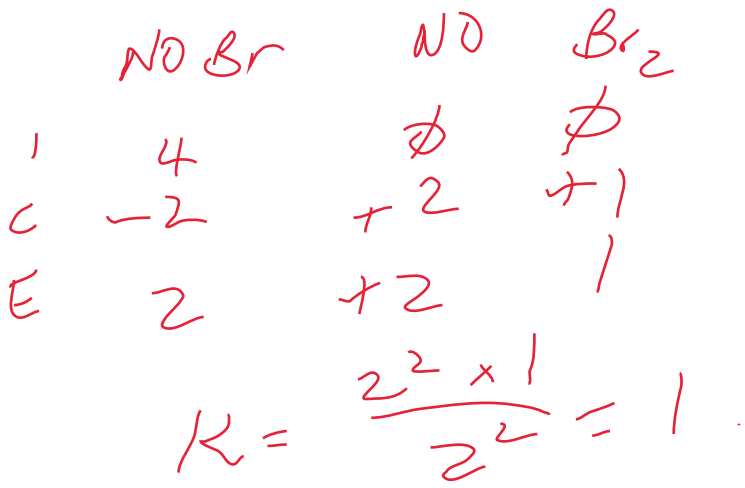
4.0 mol of NOBr(g) were placed in a 1.0 L container and allowed to reach equilibrium. At equilibrium, the concentration of $Br_2(g)$ was 1.0 mol L^{-1}. What is the value of K_{eq} under these conditions?

(A) 0.5

(B) 1.0

(C) 1.5

(D) 2.0



SECTION II: 80 marks
Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 21 (3 marks)

Acetic acid is flammable. Thermodynamic data (at 298 K) for the complete combustion of acetic acid is presented in the table below.

$\Delta_c H^\ominus = -874.2$ kJ mol^{-1}	$\Delta_c S^\ominus = -2.6$ J K^{-1} mol^{-1}

Using the information in the table, explain why combustion of acetic acid does not come to equilibrium but instead proceeds to completion.

$\Delta G^\theta = \Delta H^\theta - T\Delta S^\theta$

$= -874.2\,kJ\,mol^{-1} - 298 \times (-2.6 \times 10^{-3})$

$= -874.2 + 0.77$

$= -873.4\,kJ\,mol^{-1}$

For a reaction to come to equilibrium, ΔG^θ must be small. In this case ΔG^θ is large, so this reaction does not come to equilibrium. Indeed, the large negative ΔG^θ means this reaction will proceed to completion.

Marking (1 mark each):
- small ΔG^θ for equilibrium system
- large negative ΔG^θ → proceeds to completion
- calculate ΔG^θ or explicitly compare enthalpic and entropic contributions to ΔG^θ.

Question 22 (4 marks)

Formaldehyde (CH_2O) trimerises in acidic aqueous solution, according to the following equation:

$$3\ CH_2O(aq) \rightleftharpoons C_3H_6O_3(aq) \qquad K_{eq} = 3.0 \times 10^{-5}$$

1.2 mol of formaldehyde is dissolved in water to form 1.0 L of solution; this system is allowed to come to equilibrium.

Calculate the concentration of $C_3H_6O_3(aq)$ in the resulting solution.

$3CH_2O(aq) \rightleftharpoons C_3H_6O_3(aq)$ $K_{eq} = \frac{[C_3H_6O_3]}{[CH_2O]^3}$ (1)

	$3CH_2O$	$C_3H_6O_3$
I	1.2	0
C	$-3x$	$+x$
E	$1.2-3x$	x

This is what you want to calculate, so let it be x.

$\therefore \frac{x}{(1.2-3x)^3} = 3.0 \times 10^{-5}$ (1)

Assuming $1.2-3x \doteq 1.2$, $x = 1.2^3 \times 3.0 \times 10^{-5}$ (1)

$= 5.2 \times 10^{-5}$

$\therefore [C_3H_6O_3] = 5.2 \times 10^{-5}$ mol L^{-1}.

↳ assumption justified

Question 23 (3 marks)

Aluminium sulfate has a solubility of 36.4 g per 100 mL. Calculate K_{sp} for aluminium sulfate.

$Al_2(SO_4)_3(aq) \rightleftharpoons 2Al^{3+}_{(aq)} + 3SO_4^{2-}(aq)$

$K_{sp} = [Al^{3+}]^2[SO_4^{2-}]^3$ (1)

$[Al_2(SO_4)_3] = \frac{364\ g\ L^{-1}}{342.17\ g\ mol^{-1}} = 1.06$ mol L^{-1} (1)

$K_{sp} = (2 \times 1.06)^2 \times (3 \times 1.06)^3$ (1)

$= 108 \times (1.06)^5$

$= 147$ (to 3 s.f.).

Question 24 (8 marks) **Marks**

The industrial manufacture of methanol involves the following reversible reaction:

$$CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta_c H^{\ominus} = -331.84\ kJ\ mol^{-1}$$

(a) Write the equilibrium constant expression for this reaction.

$K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$ **1**

A mixture of CO, H_2 and methanol is placed in a reaction vessel of variable volume and allowed to reach equilibrium.

(b) By referring to the reaction quotient, Q, and the equilibrium constant, K_{eq}, explain the effect of halving volume of the vessel on the amount (in mol) of methanol present.

– Halving the volume doubles the concentration of all gases. **3**

– Immediately after the change in volume, $Q = \frac{1}{4}K$, i.e. $Q < K$.

– As the system re-approaches equilibrium, $Q \rightarrow K$ so $[CH_3OH] \uparrow \therefore n(CH_3OH) \uparrow$.

Many boys used LCP-type arguments here, unnecessarily. This is the argument

(c) Using collision theory, explain the effect of increasing the temperature of this system on the equilibrium constant, K_{eq}.

(1) * ↑T ↑ kinetic energy of all molecules, leading to more collisions and a higher proportion of successful collisions, so both forward & reverse reaction rates increase. **4**

(1) * The reverse reaction has a higher activation energy than the forward reaction, so it experiences a larger increase in rate.

(1) * so $[CH_3OH] \downarrow$; $[CO]$ & $[H_2] \uparrow$

(1) * $\therefore K_{eq}$ decreases.

Need to compare E_A for the two reactions

Q 25 - Q 29 MODULE 6 - CRIB (CXS)

Question 25 (6 marks) **Marks**

27.82 g of hydrated sodium carbonate crystals, $Na_2CO_3 \cdot xH_2O$, was dissolved in water and made up to 1.000 L. 25.00 mL of this solution was neutralised by 48.80 mL of hydrochloric acid of concentration 0.1000 mol L^{-1}.

(a) Write an equation for the reaction between sodium carbonate and hydrochloric acid. **1**

$Na_2CO_3(aq)\text{ or }(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(\ell)$

(b) Calculate the molar concentration of the sodium carbonate solution neutralised by the hydrochloric acid. **2**

$n(HCl) = 0.1000 \times 0.04880 = 0.004880$ mol

$n(Na_2CO_3) = 0.004880/2 = 0.002440$ mol

$c(Na_2CO_3) = 0.002440/0.025 = 0.09760$ M

2 marks = correct answer to 4 sig figs

1 mark = correct answer to 3 sig figs OR one calculation error

(c) By calculating the mass of water in the hydrated crystals, find the value of x. **3**

$MM(Na_2CO_3) = 105.99$ g mol^{-1}

$n(Na_2CO_3)$ in 1.0 L $= 0.002440 \times \frac{1000}{25}$

$= 0.0976$ mol

$m(Na_2CO_3)$ in 1.0 L $= 0.0976 \times 105.99$

$= 10.34$ g

$m(H_2O) = 27.82 - 10.34 = 17.48$ g

$n(H_2O) = 17.48/18.016 = 0.970$ mol

Mole ratio $Na_2CO_3 : H_2O$

$= 0.0976 : 0.970$

$= 1 : 9.94 \approx 1 : 10$

$x = 10$

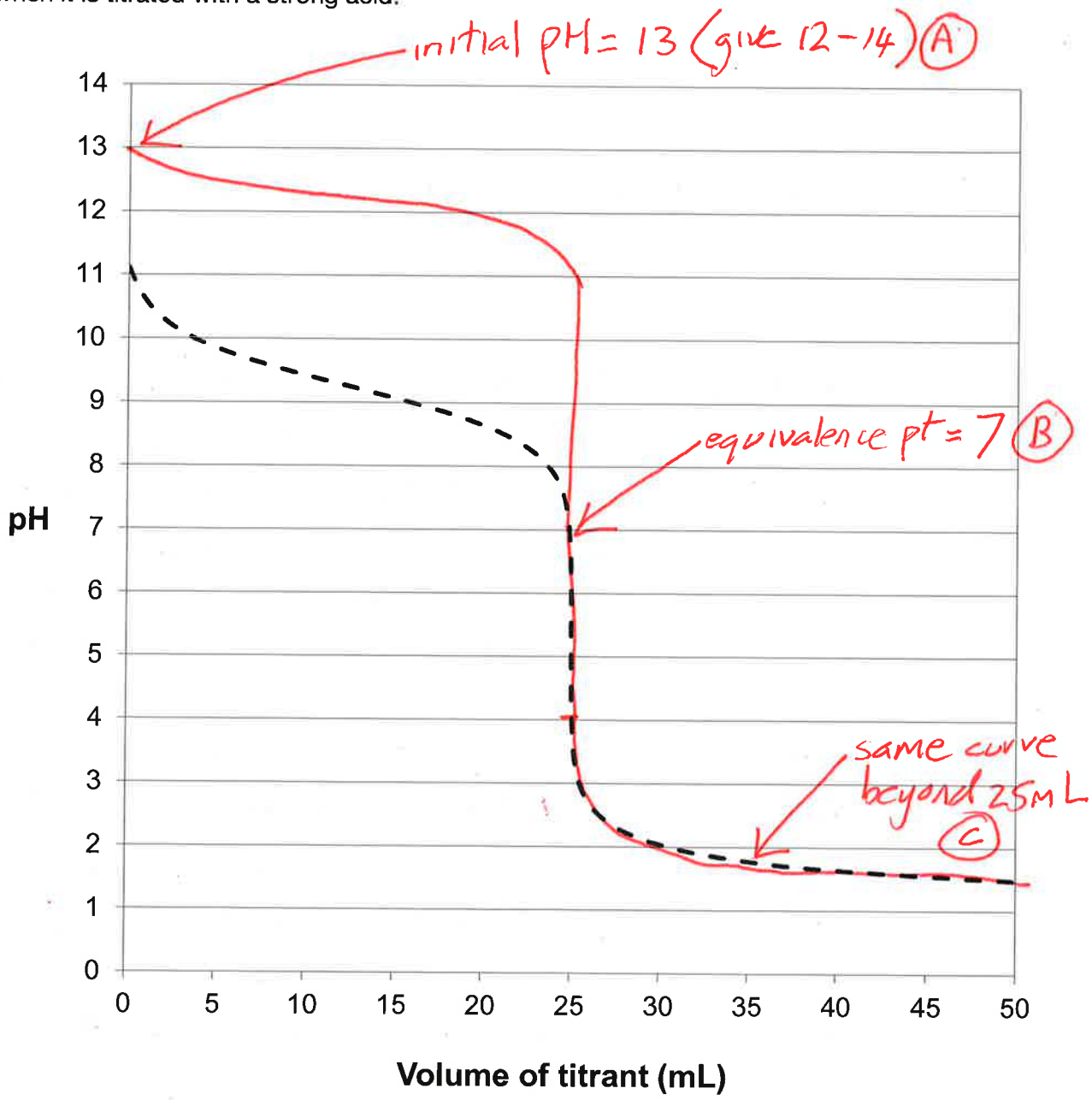
3 marks = correct answer justified by working

2 marks = incorrect answer with ONE calculation error

1 mark = one correct step useful in this problem

Question 26 (2 marks)

The graph below represents a titration curve for a 0.100 mol L^{-1} ammonia (NH_3) solution, when it is titrated with a strong acid.



On the diagram above, draw the titration curve that would result if the ammonia is replaced by a solution of sodium hydroxide of the same concentration.

2 marks for (A), (B) and (C) correct
1 mark for one of (A), (B) or (C) correct

Question 28 (3 marks) **Marks**

Explain the term amphiprotic as it relates to the behaviour of salts in solution. Use the salt, potassium hydrogen sulfate, $KHSO_4$, and equations to illustrate your answer.

Amphiprotic: can act as an acid or a base 3

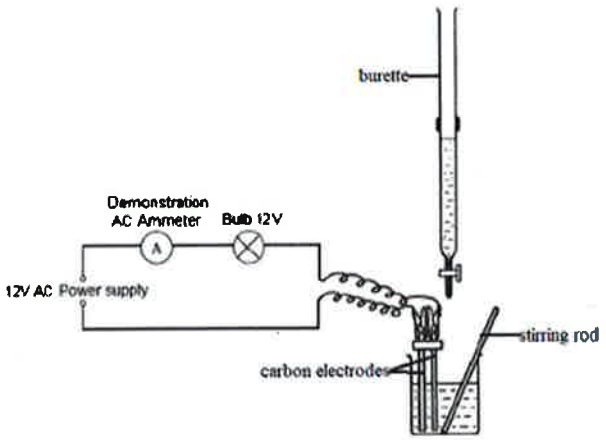
$HSO_4^-_{(aq)} + OH^-_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + H_2O_{(l)}$

$HSO_4^-_{(aq)} + H_3O^+_{(aq)} \rightarrow H_2SO_4 + H_2O_{(l)}$

1 mark for equation showing HSO_4^- acting as acid.
1 mark for equation showing HSO_4^- acting as base.

Question 29 (4 marks)

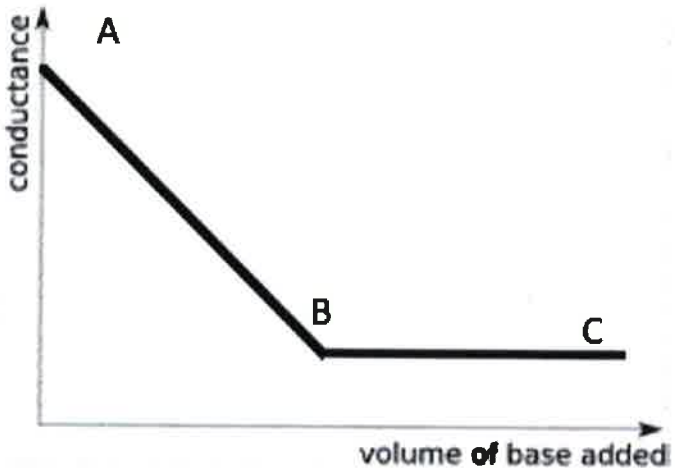
The setup below can be used to determine the end point of an acid/base titration by measuring conductivity.



The graph below shows the changes in conductivity of the solution when a solution of ammonia from the burette is added to a solution of sulfuric acid in the beaker during a conductometric titration:

Question continued

Question continued **Marks**



(a) Using A, B or C, identify the equivalence point of this titration.

B 1

(b) Explain why this conductivity curve has this shape. 3

CODE

(i) A - initially high conductivity owing to H^+

(n) A-B - conductivity decreases as H^+ is neutralised by OH^-

(e) B - all H^+ is neutralised - SO_4^{2-} and NH_4^+ conduct poorly

(m) B-C - adding NH_3 doesn't increase conductivity as it is molecular (weak base) and a poor conductor.

3 marks - all four positions explained
2 marks - one position only not explained
1 mark - one of these positions explained

(m) = explains small increase in conduct owing to NH_3 being molecular

(i) Explains the high concentration of H^+ giving high conductivity

(n) Explains the drop in conductivity owing to reduced $[H^+]$ due to neutralisation by ammonia

(e) Explains why solution still conducts at equivalence point - Must specify conducting ions.

Question ~~35~~ 29 (8 marks) **Marks**

Propanoic acid, CH_3CH_2COOH, is classified as a weak acid.

(a) According to Brønsted-Lowry Theory, state the meaning of the term *weak acid*.

Acid = proton donor
Weak = fewer than 100% of molecules donate 1

(b) Write a balanced chemical equation for the reaction of propanoic acid with water.

$CH_3CH_2COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3CH_2COO^-_{(aq)} + H_3O^+_{(aq)}$ 1

(c) Determine the pH of a 0.100 mol L^{-1} solution of propanoic acid, given its pK_a = 4.87.

$K_a = 10^{-pK_a} = 1.349 \times 10^{-5}$ 3

$CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$

[I]	0.100	0	0
[C]	$-x$	$+x$	$+x$
[E]	$0.100 - x$	x	x

$K_a = 1.349 \times 10^{-5} = \frac{[CH_3CH_2COO^-][H_3O^+]}{[CH_3CH_2COOH]} = \frac{x^2}{0.100 - x}$

$x = 1.16 \times 10^{-3}$

$pH = 2.94$

Loss of 1 mark per calculation error

(d) A mixture of propanoic acid and sodium propanoate can act as a *buffer solution*. Calculate the pH of a solution containing 4.81 g of sodium propanoate in 1.0 L of 2.0×10^{-2} mol L^{-1} propanoic acid, stating any assumptions you have made.

$n(CH_3CH_2COO^-) = 4.81 / 96.06 = 0.05007$ mol 3

$CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$

[I]	2×10^{-2}	0.05007	0
[C]	$-x$	$+x$	$+x$
[E]	$2 \times 10^{-2} - x$	$0.05007 + x$	x

These are negligible relative to 2×10^{-2} and 0.05007 ∴ ignored

$K_a = \frac{0.05007 \times x}{2.0 \times 10^{-2}} = 1.349 \times 10^{-5}$

$x = 5.39 \times 10^{-6}$

$pH = 5.27$

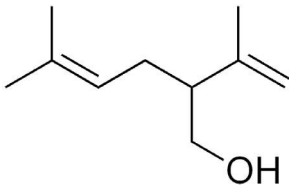
Loss of 1 mark per calculation error. For 3 marks, must have assumption.

CRIB - JLS

CANDIDATE NUMBER

Question 30 (4 marks) **Marks**

Lavandulol is a compound that is found in lavender oil. The structural formula of lavandulol is shown below.



Lavandulol

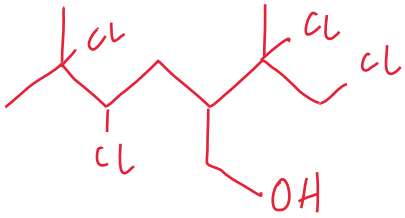
(a) Give the molecular formula of lavandulol.

$C_{10}H_{18}O$ ACCEPT: $C_{10}H_{17}OH$ **1**

(b) Identify the two functional groups found in lavandulol.

Hydroxyl group / alcohol / OH group **2**
Alkenyl group / alkene / C=C group .....

(c) Draw the structural formula of the molecule that is formed when lavandulol is exposed to an excess of chlorine gas. **1**

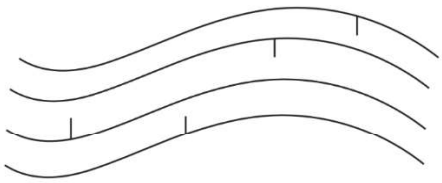


Molecule can be drawn using any structural form

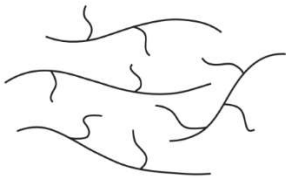
CANDIDATE NUMBER

Question 31 (3 marks)

There are two forms of the polyethylene polymer formed from the ethene monomer. The two forms can be distinguished from each other based on the extent of branching.



Type I Polyethylene



Type II Polyethylene

Identify a property that differs between the two types of polyethylene. Explain why there is a difference.

(M1) Property : Melting point / flexibility / hardness

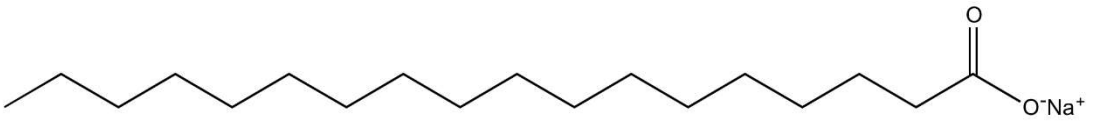
(M2) Polymer chains have a greater area of contact / polymer chains pack more closely together in type I

(M3) Dispersion forces between polymer chains are stronger in type I PE.

CANDIDATE NUMBER

Question 32 (3 marks)

The structure of a soap molecule is shown below.



Soap molecule

With reference to its structural features, explain the cleaning action of soap.

M1 Polar carboxylate head group forms strong H bonds with water (H bonding not required for mark)
Must state polar / hydrophilic

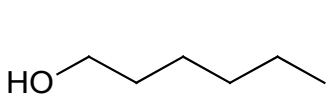
M2 Non-polar tail forms strong dispersion forces with oil / grease
Must state non-polar / hydrophobic

M3 Upon agitation, micelles form which allows grease to be removed using running water / allows grease particles to be dissolved in water

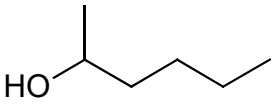
CANDIDATE NUMBER

Question 33 (7 marks) **Marks**

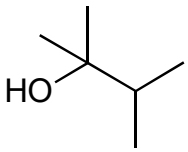
The structural formulae of three isomeric alcohols are shown below.



Alcohol A



Alcohol B



Alcohol C

(a) State which of the three alcohols is resistant to oxidation using acidified potassium dichromate.

Alcohol C **1**

(b) Write a balanced chemical equation to show the complete combustion of Alcohol A.

$C_6H_{14}O_{(l)} + 9O_{2(g)} \rightarrow 6CO_{2(g)} + 7H_2O_{(l)}$ **1**

ACCEPT Multiples States not marked

(c) State the type of reaction Alcohol B will undergo to produce 2-bromohexane.

Substitution / halogenation **1**

Many boys gave hydrohalogenation here - this was not accepted as we are only substituting an OH group for a Br atom

(d) State the IUPAC name for Alcohol C.

2,3-dimethyl butan-2-ol **1**

(e) State which of the three alcohols would have the lowest boiling point and explain why.

(M1) Alcohol C **3**

Dispersion forces argument

(M2) Molecules are more spherical and therefore smaller area of contact between molecules

(M3) Dispersion forces are weaker

H-bonding argument

(M2) There is more crowding around the hydroxyl group due to two additional CH_3 groups

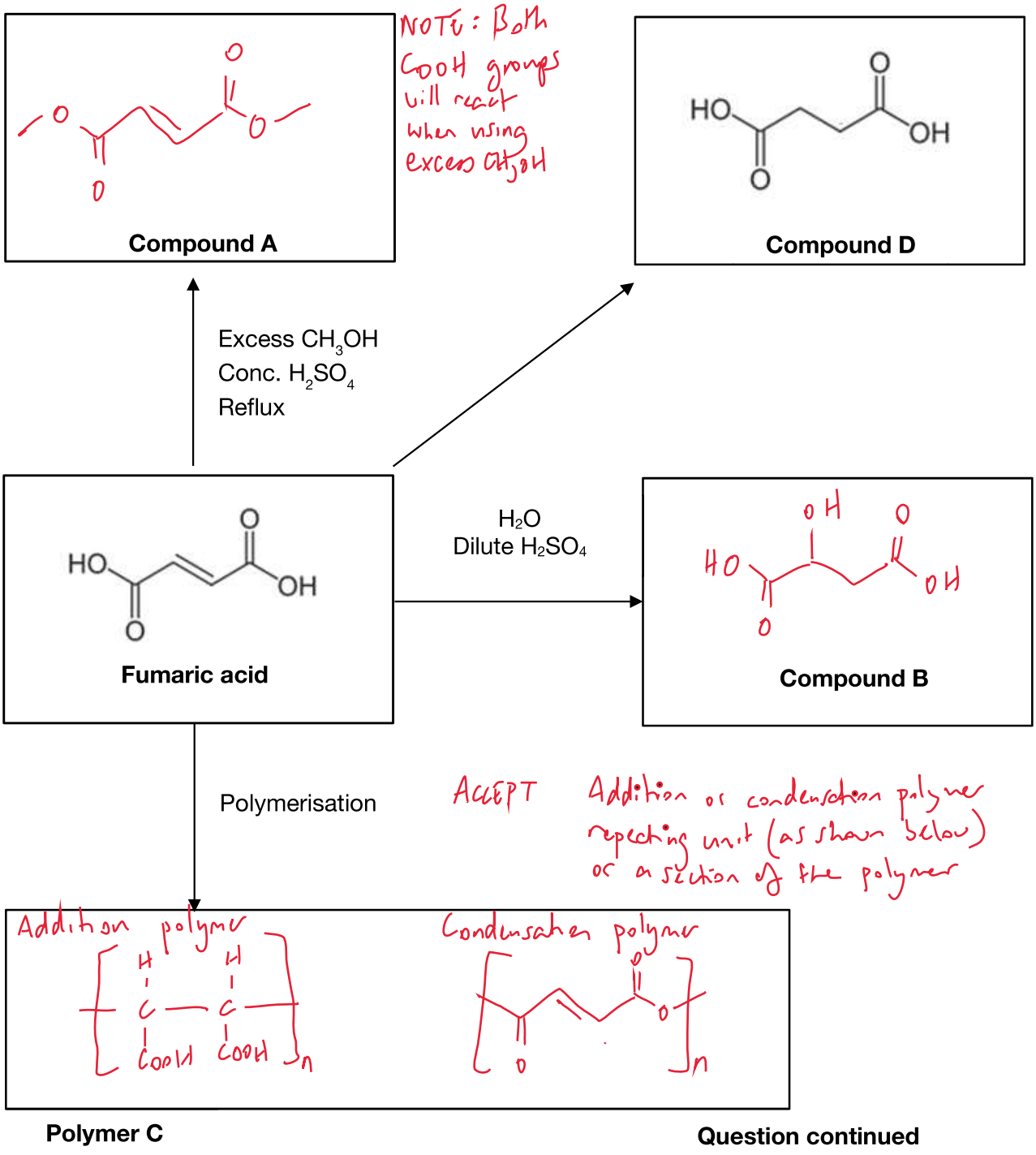
(M3) H-bonding is weaker

CANDIDATE NUMBER

Question 34 (5 marks) **Marks**

Fumaric acid is a naturally occurring dicarboxylic acid. It is a key intermediate in human metabolism and it is often used as a food additive. Fumaric acid is an important molecule in synthesis as it can be readily converted into a range of molecules as seen in the reaction scheme below.

(a) Using the reaction conditions given in the scheme below, deduce and draw the structures of Compound A, Compound B and a section of polymer C. **3**



Question continued

CANDIDATE NUMBER

Question continued **Marks**

(b) State the reagent/conditions required to prepare Compound D from fumaric acid.

Hydrogen gas
Pd/C catalyst **1**

(c) Identify the type of polymerisation fumaric acid must undergo to produce polymer C.

Addition / condensation **1**

Must match the structure drawn / attempted in qn 34a

General comments about Module 7 section

1. You should always state the type of intermolecular force in your explanations
2. Check that all your equations are balanced – too many boys did not balance combustion equation correctly.
3. When drawing molecules in full structural form always check that you have included the right number of H atoms

CANDIDATE NUMBER

Question 35 (5 marks)

A dilute solution of an unknown salt is to be analysed. The cation is one of Mg^{2+}, Ba^{2+} or Fe^{3+}. The anion is one of chloride, acetate or sulfate.

Outline a sequence of tests that could be performed in a school laboratory to confirm the identity of this salt solution. Include expected observations and a balanced chemical equation in your answer.

Criteria	Marks
• Outlines a sequence of suitable tests with expected observations • Includes a balanced chemical equation	5
• Outlines a sequence of suitable tests and most of the expected observations • Includes a substantially correct balanced chemical equation	4
• Provides suitable tests that can identify cation(s) and anion(s) present • Includes some expected observations and/or a balanced chemical equation	3
• Provides one test and observation that can identify a cation OR anion present OR • Provides tests that can identify cations and anions present OR • Provides a balanced chemical equation and one test that can identify a cation OR anion present	2
• Provides some relevant information	1

Notes:

- Many sequences are possible - sample answers follow.
- Better answers gave sequence and confirmation tests.
- Observations need colours of precipitates.
- Magnesium hydroxide is insoluble - use data sheet for Ksp for confirmation - many boys neglected this, hence did not have a full sequence.
- Magnesium does not give a white flame test - many boys mixed up combustion of magnesium metal for flame test of magnesium ion.
- Silver sulfate is slightly soluble (see Ksp); should have been discussed if silver nitrate added in sequence e.g. silver sulfate is unlikely to ppt since the solution is dilute (from question).
- Many boys wrote equations when NVR?
- If no relevant equation given, then you cannot get more than 3 marks. Read the question.
- Must have sequence for both cations and anions - else 2 is max marks.

Question 35 (5 marks)

A dilute solution of an unknown salt is to be analysed. The cation is one of Mg^{2+}, Ba^{2+} or Fe^{3+}. The anion is one of chloride, acetate or sulfate.

Outline a sequence of tests that could be performed in a school laboratory to confirm the identity of this salt solution. Include expected observations and a balanced chemical equation in your answer.

For each test, measure out a 5mL sample of the unknown salt solution into a test tube.

1. Add excess 2M sulfuric acid to the test tube. If a white precipitate forms, the cation is Ba^{2+}; test for anions in step 3.

($Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$)

2. Add excess 2M NaOH solution to the test tube. If the precipitate is white, the cation is Mg^{2+}; if it is brown, the cation is Fe^{3+}.

($Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$; $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Fe(OH)_{3(s)}$)

3. Add excess 2M silver nitrate. If a white precipitate forms that darkens on exposure to UV light, the anion is chloride (Cl^-).

4. Add a few drops of a solution of $FeCl_3$. If the solution goes red, then the anion is acetate, which forms a coloured complex with $FeCl_3$.

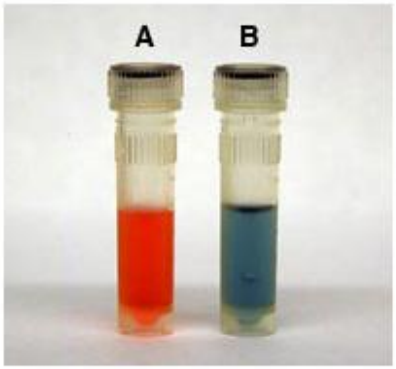
5. (confirm sulfate) Add excess 2M barium nitrate ($Ba(NO_3)_2$). If a white precipitate forms, the anion is sulfate.

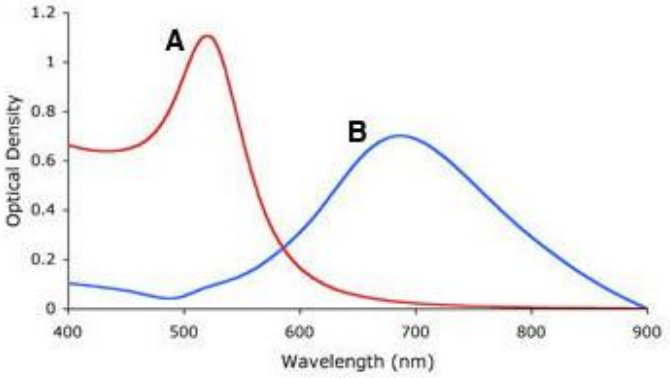
337 7942

CANDIDATE NUMBER

Question 36 (5 marks) **Marks**

UV-Vis spectrophotometry was performed on two samples, A and B, with the results shown below.



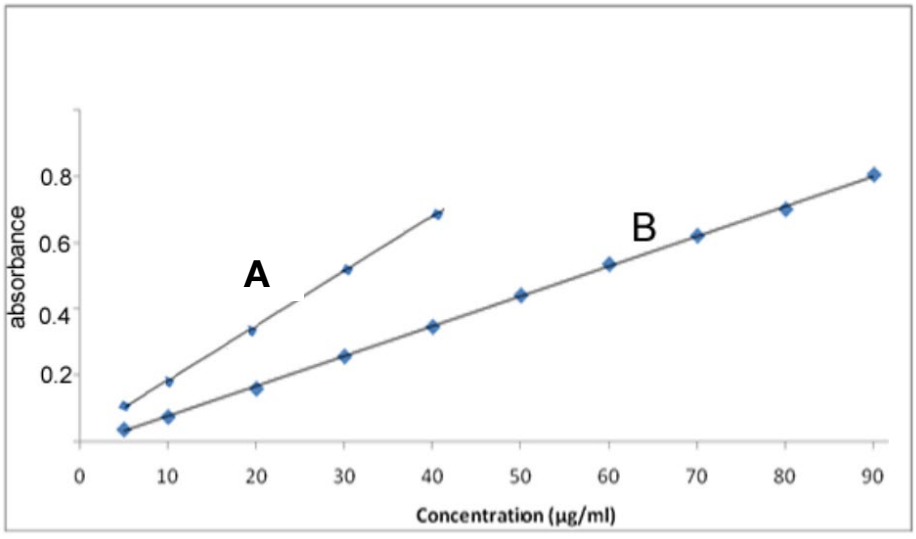


(a) If equal volumes of solution A and solution B were mixed, identify the wavelength that should be used to measure the absorbance of Solution B in this unreacted mixture? Justify your answer.

Paid range 680-720 nm - units not marked

..... **1**

(b) A chemist used the appropriate wavelengths for each solution and constructed two calibration curves on the same set of axes, as shown below.



Question continued

CANDIDATE NUMBER

Question continued **Marks**

The chemist found that, when it was measured at the appropriate wavelength, Solution B had an absorbance of 0.400. If Solution B contained an organic substance with molecular formula $C_{23}H_{27}N_3O_{15}S$ (molar mass 617.53 g mol^{-1}), determine its concentration in mol L^{-1}.

1mark - Reading off graph - range 43-47

1mark - Converting (say) 45 µg / L to mol L^{-1} to get approx 7.3×10^{-5} **2**

(c) A sample of contaminated water containing the same compound as found in solution A was analysed and found to have an absorbance of 0.80. Can the calibration curve above be used validly to analyse the sample of contaminated water for its concentration of the compound found in solution A? Justify your answer.

1 mark - not valid

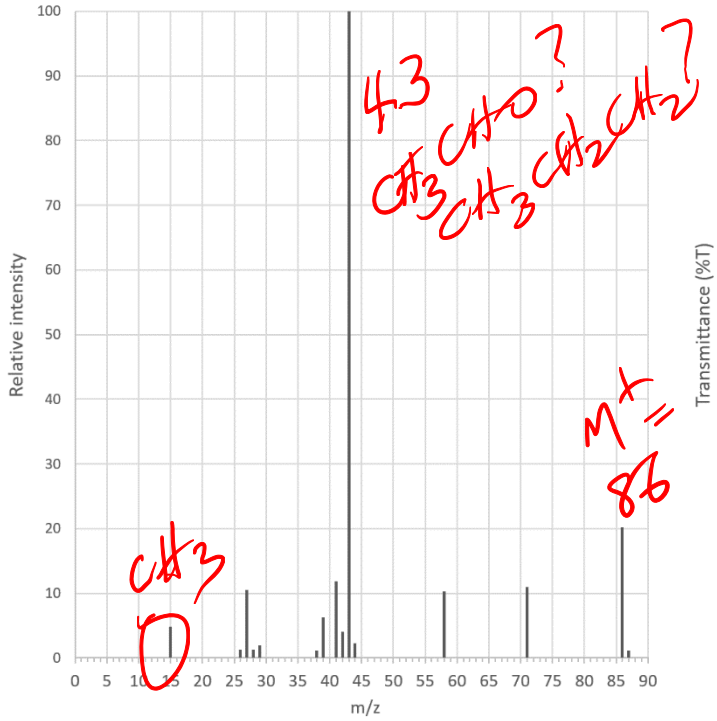
1 mark - reason e.g. cannot extrapolate; new standards should be made to cover the range **2**

Paid 1 mark if said yes, due to Beer Lambert's

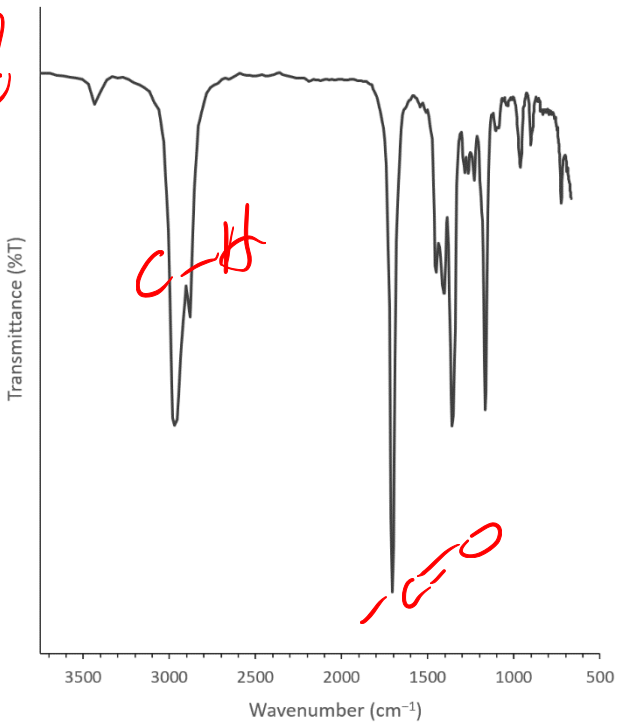
CANDIDATE NUMBER

Question 37 (7 marks)

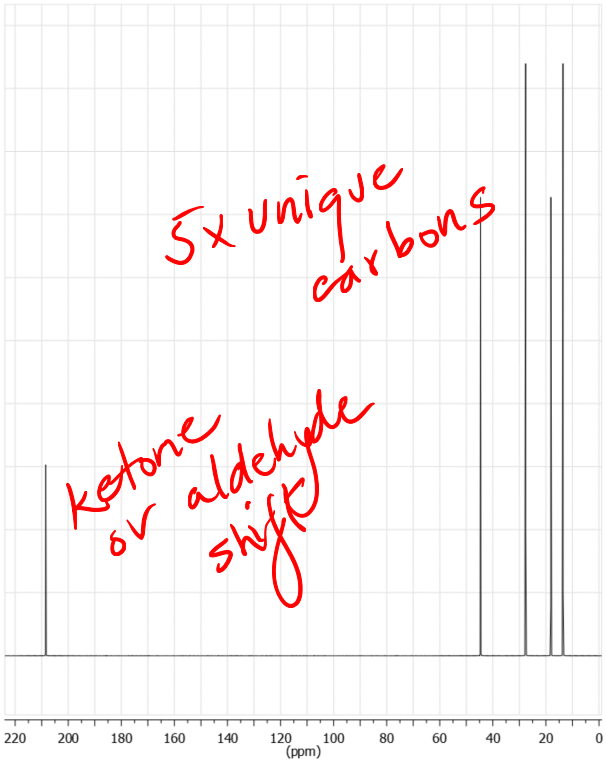
A sample of an unknown organic compound was analysed using mass spectrometry, IR spectroscopy and proton and carbon-13 NMR. The resulting spectra are shown below.



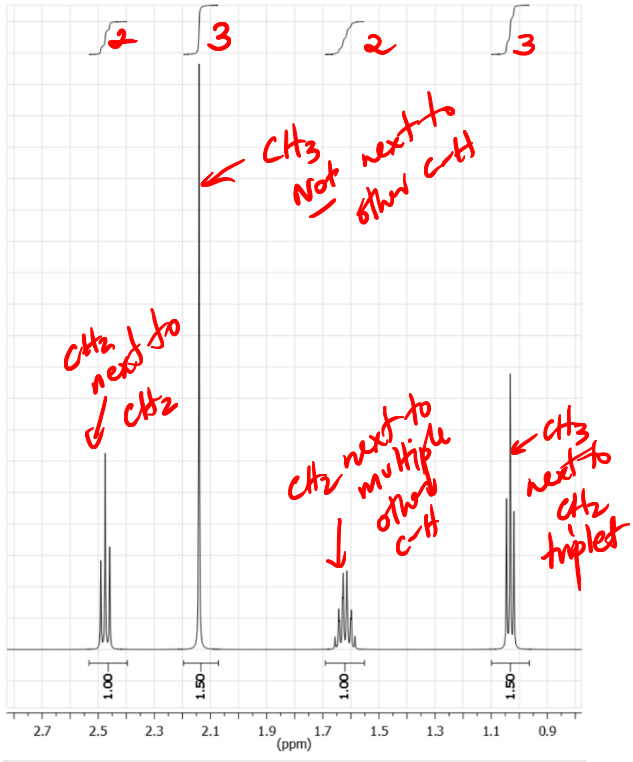
Mass Spectrum



IR Spectrum



^{13}C NMR spectrum



^{1}H NMR spectrum

Question 32

Deduce and draw the structural formula of the unknown compound, justifying your answer with reference to the spectra.

M**arks**	C**riteria**
7	• Draws pentan-2-one • Clear and logical justification with reference to all four spectra • Eliminates alternatives e.g. matches M^+ 87 to carbon-13
6	• As for 7 marks less 1 point
4-5	• Correctly relates most spectral data to structure drawn, even if incorrect structure has been given
3	• **Identifies** information from all four spectra
1-2	• Identifies some relevant information from any spectra.

Marked holistically

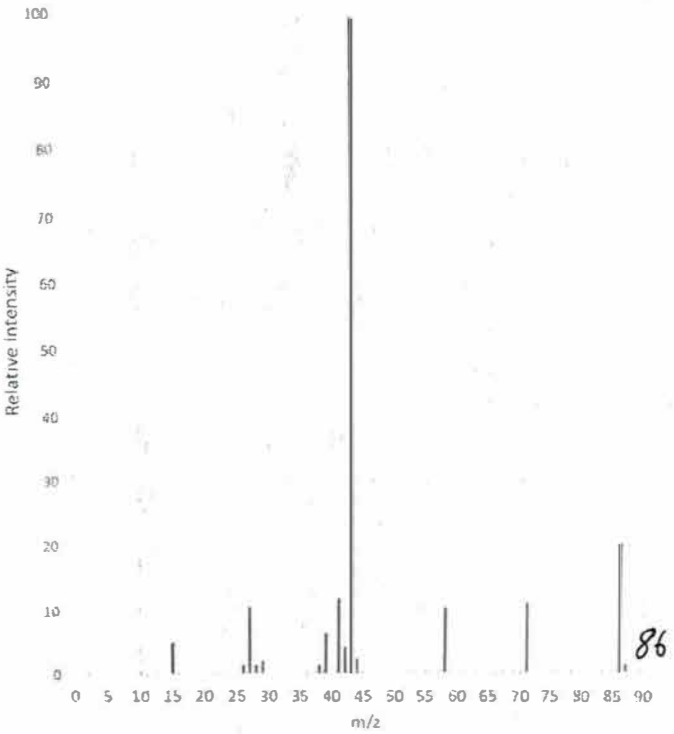
Too many boys just **identified** a list of features and did not relate them to the structure, nor justified how these features helped establish their structure.

Note it was possible to guess correct structure and still not answer the question, so less than 7 was given.

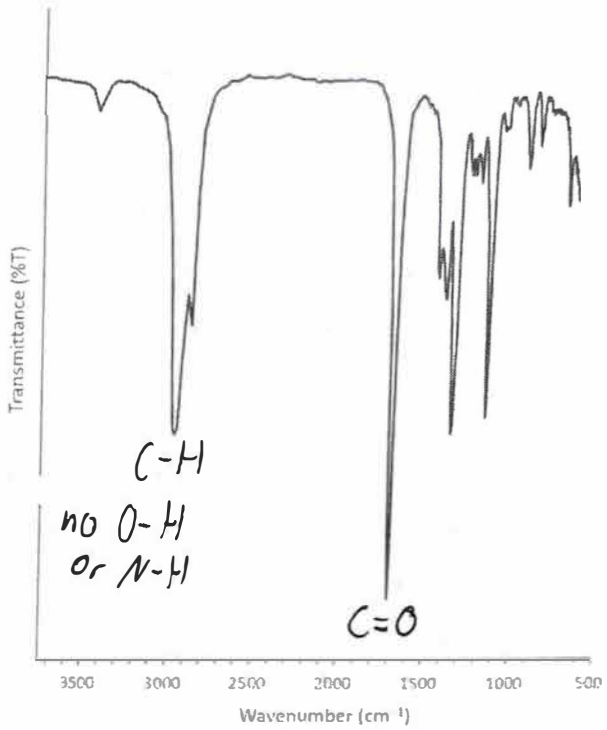
CANDIDATE NUMBER

Question 37 (7 marks)

A sample of an unknown organic compound was analysed using mass spectrometry, IR spectroscopy and proton and carbon-13 NMR. The resulting spectra are shown below.



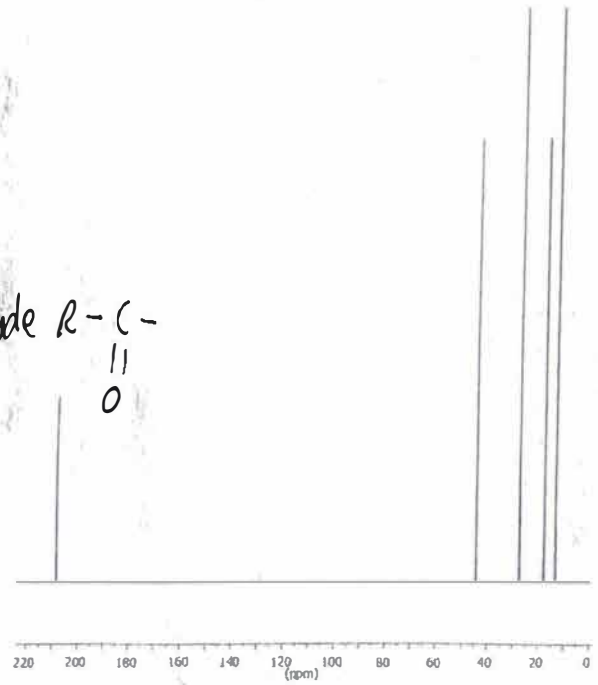
Mass Spectrum



IR Spectrum

5 carbon environments

aldehyde R-C(=O)-H
or
ketone



^{13}C NMR spectrum

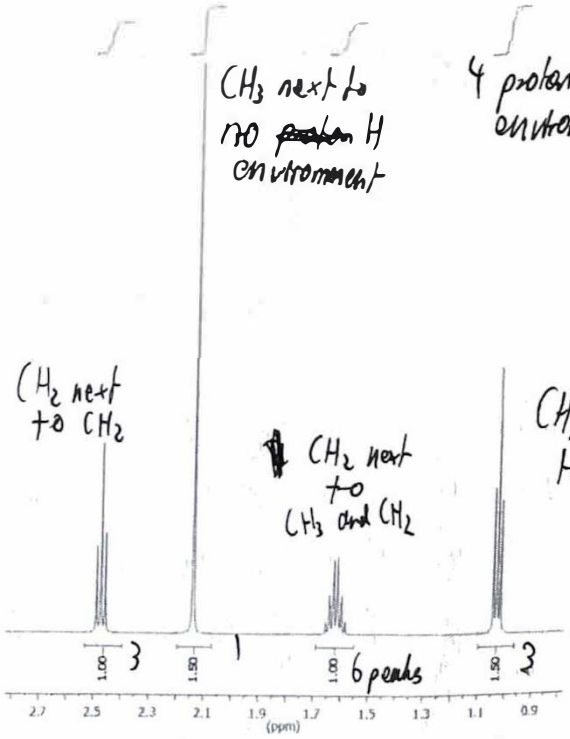
CH_3 next to no H environment

4 proton environments

CH_2 next to CH_2

CH_2 next to CH_3 and CH_2

CH_3 next to CH_2

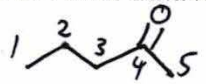


^{1}H NMR spectrum

CANDIDATE NUMBER

Question continued.

Deduce and draw the structural formula of the unknown compound, justifying your answer with reference to the spectra. Note the proton NMR shift data has not been provided.



The ~~com~~ unknown compound is pentan-2-one. From the IR spectrum, the presence of a carbonyl group is indicated by the peak at 1700 cm^{-1}, and a lack of a broad peak from 2500-3500 cm^{-1} indicate that there are no hydroxyl groups present. 5 ~~car~~ carbon environments are displayed in the ^{13}C ~~NM~~ NMR spectrum, one of which indicates that the compound is an aldehyde or ketone with around 210ppm. The ^{1}H NMR spectrum shows 4 ~~proton~~ hydrogen environments, aligning with the compound being a ketone as an aldehyde would contain 5 proton environments with 5 carbon environments. Since the integration values contain 1.5, they are all doubled to find the number of hydrogen atoms in each environment, and the number of peaks indicate a CH_3 next to a CH_2 (Carbon 1 in the structural formula above), a CH_2 next a CH_3 and CH_2 (Carbon 2), a CH_3 next to a CH_2 (Carbon 3), and a CH_3 next to ~~a~~ a ~~C~~ C with no H atoms (carbon 5). This suggests $C_5H_{10}O$, and this is verified by the mass spectrum as the final m/z value is 86 and $C_5H_{10}O$ has a mola mass of ~~86g~~ around 86 $g \cdot mol^{-1}$. The compound cannot be ~~the~~ any other isome of $C_5H_{10}O$ as an aldehyde has more proton environments, and the other ketone or different branching reduces the number of carbon and proton environments respectively.

7 good answer!