SYDNEY GRAMMAR SCHOOL

2020
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: **Thursday 20th August 8:40am**

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, AKBB, CXS, JLS

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SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following matches the inorganic acid and base with their correct formula?

	Acid		Base	
(A)	H_2PO_4	phosphoric	NaOH	sodium hydroxide
(B)	HNO_3	nitrous	NH_3	ammonia
(C)	NH_4^+	ammonium	CO_3^{2-}	carbonate
(D)	H_2SO_3	sulfurous	CaO	calcium dioxide

2 Which of the following is considered to be a limitation of Arrhenius' model of acids and bases?

(A) He did not account for acids that do not contain oxygen.

(B) He did not account for the presence of hydrogen-containing compounds which are non-acidic in nature.

(C) He did not recognise the importance of water as a solvent in the nature of acids and bases.

(D) He did not recognise that some substances can act as acids or bases in the absence of solvents.

3 Which of the following statements with regards to acid and base strength and concentration is true?

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

(B) The same concentration of strong and weak monoprotic acids will contain the same chemical amount of hydrogen ions.

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

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

4 If the pH of a solution was shown to be 10.5, what could we conclude about the following parameters?

(A) The pOH will be $10^{-3.5}$

(B) The H^+ concentration will be 1.02

(C) The OH^- concentration will be 3.16×10^{-4}

(D) The H^+ concentration x the OH^- concentration will be 10^{14}

5 Which of the following statements correctly describes the relationship between the strength of an acid, its hydrogen ion concentration, its pH and its pK_a?

(A) The stronger the acid, the lower the pK_a value.

(B) A strong acid will have a pKa somewhere between 0.001 and 1000.

(C) An acid with a low pH will have a very large pK_a.

(D) The greater the K_a, the larger the pK_a value.

6 If a monoprotic acid has pH value of 3.2 and a concentration of 0.15 mol/L, what will its K_a value be closest to?

(A) 2.7×10^{-6}

(B) 6.3×10^{-4}

(C) 5.6

(D) 3.8×10^{5}

7 Solid potassium amide KNH_2 reacts with water according to the equation:

$$KNH_2\,(s) + H_2O\,(l) \rightarrow KOH\,(aq) + NH_3\,(g)$$

The acid and its respective conjugate base in this reaction are:

(A) K^+ and KOH

(B) H_2O and OH^-

(C) NH_2^- and NH_3

(D) NH_3 and NH_2^-

8 A reaction in dynamic equilibrium is one in which:

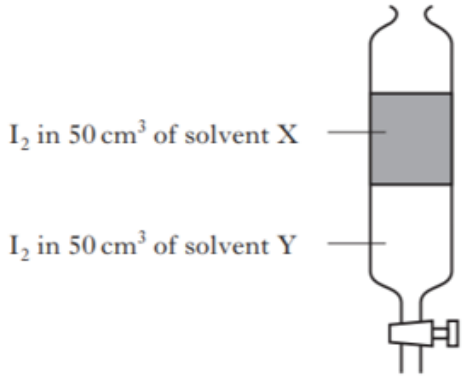
(A) the concentration of the product is always independent of reaction conditions

(B) the enthalpy changes for the forward and the reverse reactions are equal

(C) the activation energies for the forward and the reverse reactions are equal

(D) the rates of the forward and the reverse reactions are equal

9 Iodine was added to 50 mL of each of two immiscible solvents X and Y in a separating funnel as shown below.



After shaking, the following equilibrium was established:

$$I_2\,(Y) \rightleftharpoons I_2\,(X)$$

An extra 10 mL of solvent X was added, the mixture shaken and equilibrium was allowed to re-establish. Which of the following statements is correct?

(A) The concentration of I_2 in Y increases

(B) The concentration of I_2 in Y decreases

(C) The equilibrium constant increases

(D) The equilibrium constant decreases

10 Photosynthesis is not considered to be an equilibrium reaction because:

(A) it has a large negative ΔH value

(B) it has a small negative ΔS value

(C) it has a large positive ΔG value

(D) it has a zero ΔG value

11 Will lead(II) chloride precipitate when 50 mL of 0.10 M $Pb(NO_3)_2$ solution is mixed with 50 mL of 0.10 M NaCl solution?

(A) Yes, because the ion product is greater than the K_{sp}.

(B) Yes, because the K_{sp} is greater than the ion product.

(C) No, because the ion product is smaller than the $K_{sp.}$

(D) No, because the K_{sp} is smaller than the ion product.

12 The reaction:

$$CO\ (g) + 3\ H_2\ (g) \rightleftharpoons CH_4\ (g) + H_2O\ (g)$$

has an equilibrium constant of 3.9 at 950 °C.

The equilibrium concentrations of CO (g), H_2 (g) and H_2O (g) are given in the table.

Substance	**Equilibrium concentration (mol L^{-1})**
CO (g)	5.0×10^{-2}
H_2 (g)	1.0×10^{-2}
H_2O (g)	4.0×10^{-3}

What is the equilibrium concentration of CH_4 (g), in mol L^{-1}, at 950 °C?

(A) 2.0×10^{-7}

(B) 4.9×10^{-5}

(C) 3.1×10^{-5}

(D) 4.9×10^{-1}

13 A solution is made by dissolving solid sodium hydroxide and barium hydroxide in water. Which of the following must be true regarding the concentrations of each of the ions in solution formed?

(A) $[Na^+] = [Ba^{2+}] = [OH^-]$

(B) $[Na^+] = [Ba^{2+}] = 3\ [OH^-]$

(C) $[Na^+] + 2\ [Ba^{2+}] = 3\ [OH^-]$

(D) $[Na^+] + 2\ [Ba^{2+}] = [OH^-]$

14 Complete combustion of an organic compound forms 40 mL of carbon dioxide and 40 mL of water vapour, under the same conditions of temperature and pressure. Which of the following could be the molecular formula of the organic compound?

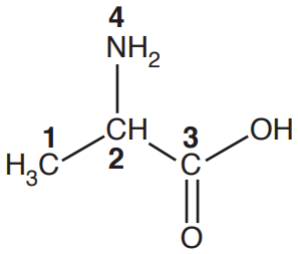
(A) C_3H_8

(B) C_2H_2O

(C) C_2H_3N

(D) C_2H_4O

15 Four atoms, 1–4, are labelled in the structure below.



Which atom has a trigonal **planar** arrangement of bonds around it?

(A) Atom 1

(B) Atom 2

(C) Atom 3

(D) Atom 4

16 Which compound(s) is/are structural isomer(s) of $C_6H_{12}O_2$?

I hexanoic acid
II ethyl butanoate
III propyl propanoate

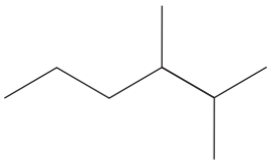
(A) Only I

(B) I and II only

(C) II and III only

(D) All of I, II and III

17 What is the IUPAC name of the following compound?



(A) 1,1,2-trimethylpentane

(B) 2,3-dimethylhexane

(C) 4,5-dimethylhexane

(D) 4,5,5-trimethylpentane

18 In the infra-red spectrum of an organic compound, a strong band is observed at 3000 cm^{-1}. The most likely explanation for this band is:

(A) the electrons absorb this IR radiation and are excited to a higher orbital.

(B) protons absorb the radiation at this frequency and change their spin.

(C) absorption of this IR radiation wavenumber causes vibrations of the C-H bonds.

(D) absorption of this wavenumber of IR radiation causes a substitution reaction.

19 Bromine water can be used to test for the presence of which of the following organic functional groups?

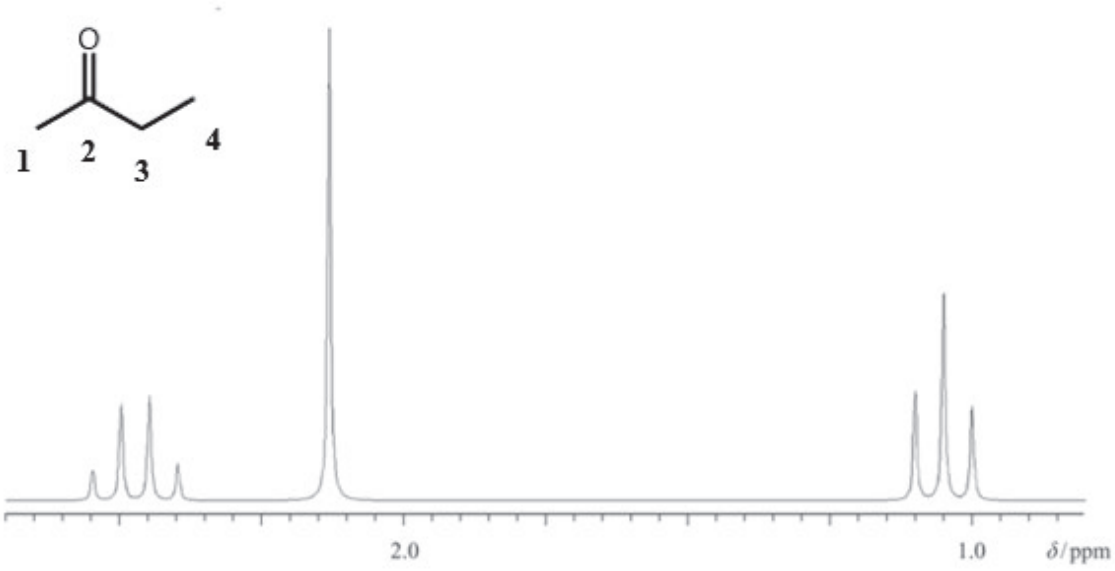
(A) Carbon-carbon double bonds

(B) Hydroxyl groups

(C) Carboxylic acids

(D) Aldehydes and ketones

20 The proton NMR spectrum for butan-2-one is shown below, along with a numbered structure of butan-2-one.



Identify the position (1-4) of hydrogen atoms that are responsible for the singlet peak at 2.1 ppm.

(A) 1

(B) 2

(C) 3

(D) 4

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SECTION II: 80 marks

Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 21 (4 marks) **Marks**

Acids react with carbonates in predictable ways. Formic acid has the formula HCOOH and its pK_a is 3.75.

(a) Write a balanced chemical equation to represent the reaction between formic acid and sodium carbonate.

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(b) State whether you would expect the salt formed in part (a) to be acidic, neutral or basic. Explain your answer including an appropriate equation.

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Question 22 (3 marks) **Marks**

The dihydrogen phosphate ion has the formula $H_2PO_4^-$.

(a) Write an equation to show dihydrogen phosphate reacting with:

(i) an acid

..... **1**

(ii) a base

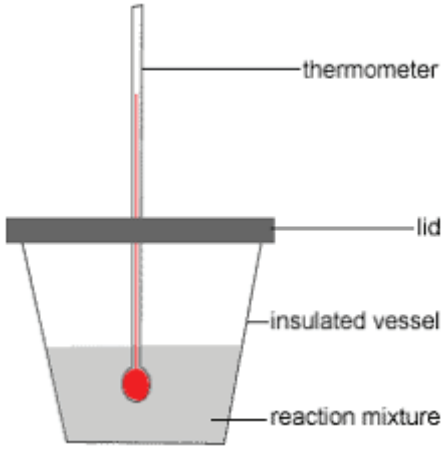
..... **1**

(b) Identify the term that we use to describe substances that can act as both acids and bases, such as dihydrogen phosphate.

..... **1**

Question 23 (4 marks) **Marks**

The equipment shown below may be used to measure the enthalpy of neutralisation.



10.0 mL of 0.500 M solution of HCl are mixed with 10.0 mL of 0.500 M solution of NaOH in the cup shown. The enthalpy change for this reaction is -55.8 kJ mol^{-1}.

(a) If the initial temperature of the reactants was 25.0 °C, calculate the final temperature once the reaction had finished. **3**

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(b) State one assumption you made in this calculation. **1**

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Question 24 (5 marks) **Marks**

50.0 mL of a solution of HCl with pH 3.0 was mixed with 30.0 mL of a solution of HNO_3 with pH 5.0.

(a) Calculate the pH of the resultant solution.

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(b) Explain how the pH and H^+ concentration of the resultant solution would differ from that calculated above, if ethanoic acid was used instead of nitric acid.

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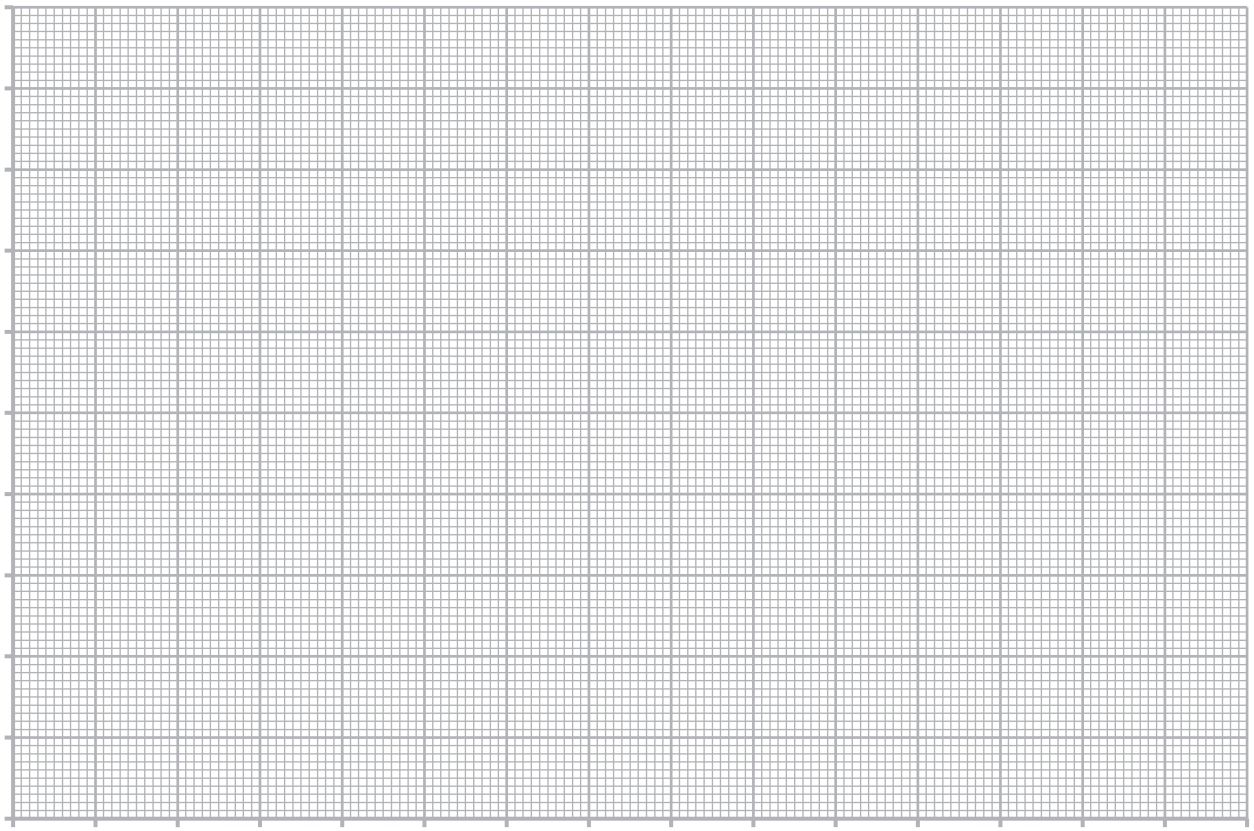
Question 25 (9 marks) **Marks**

An acid / base titration was undertaken using an electronic pH meter. The resultant data is shown in the table below.

Volume of acid added (mL)	pH
40	9.4
88	8.6
94	8.0
98	7.6
101	2.2
104	1.4
116	1.2
140	0.8

(a) Plot the data provided on the grid below and draw a line of best fit.



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Question continued on next page.

Question continued. **Marks**

(b) By analysing your graph, deduce the strength of the base used in this titration.

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(c) Titrations can also be done by means of a chemical indicator in place of a pH meter. These indicators are usually weak acids in equilibrium with their conjugate bases, at roughly equal concentrations when they change colour. Explain why it is important during titrations to keep the amount of indicator added to a minimum.

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CANDIDATE NUMBER

Question 26 (9 marks) **Marks**

Silver carbonate and silver chloride are only slightly soluble in water.

In the following, assume that the temperature is a constant 25°C.

(a) Write an ionic equation for the dissociation of solid silver carbonate, Ag_2CO_3, in water.

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(b) Write the solubility product expression, K_{sp}, for silver carbonate.

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(c) Use the K_{sp} values on the data sheet to compare the concentrations, in mol L^{-1}, of silver ions in separate saturated solutions of silver carbonate and silver chloride.

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Question continued. **Marks**

(d) Calculate the mass (in g) of silver chloride that will dissolve to form 1.00 L of a saturated solution.

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(e) Calculate the molar solubility of silver chloride in a 0.15 mol L^{-1} sodium chloride solution.

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Question 27 (4 marks) **Marks**

A reaction mixture consists of 0.12 mol Br_2 (g) and 0.12 mol H_2 (g) in a 2.50 L sealed container. At a set temperature, the mixture was left to reach equilibrium according to the equation:

$$Br_2\,(g) + H_2\,(g) \rightleftharpoons 2\,HBr\,(g) \qquad K_{eq} = 1.9 \times 10^{-5}$$

(a) Calculate the initial concentration of hydrogen gas.

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(b) Calculate the amount, in mol, of HBr produced at equilibrium at the set temperature.

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Question 28 (8 marks) **Marks**

When the following reaction is at equilibrium at 298 K, it is orange in colour.

$$H_2O\ (l) + Cr_2O_7^{2-}\ (aq) \rightleftharpoons 2\ CrO_4^{2-}\ (aq) + 2\ H^+\ (aq)$$
orange yellow

(a) Predict and explain the colour change, if any, of the reaction mixture if aqueous sodium hydroxide is added to it.

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(b) Consider the following reversible reaction at equilibrium:

$$N_2O_4\ (g) \quad \rightleftharpoons \quad 2\ NO_2\ (g) \qquad \Delta H = +ve$$

i. Predict and explain, in terms of reaction rates, the effect on the equilibrium position when the pressure increases on this system.

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Question continued. **Marks**

ii. Explain how an increase in temperature affects the yield of NO_2 and the K_{eq} value of the reaction. **3**

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CANDIDATE NUMBER

Question 29 (14 marks) **Marks**

This question is about alcohols.

(a) Construct a chemical equation to show the complete combustion of hexan-1-ol.

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(b) Many alcohols, including ethanol, are soluble in water.

i. Explain, with the aid of a diagram, how ethanol interacts with water. **2**

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ii. Using the data in the table below, explain the difference in solubility between hexan-1-ol and hexane-1,6-diol.

Alcohol	**Solubility in water (g L^{-1})**
hexan-1-ol	5.9
hexane-1,6-diol	500

..... **1**

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Question continued on next page.

Question continued. **Marks**

(c) Hexan-1-ol has a number of different structural isomers.

i. **Draw**, using full structural formula, and **name** one position isomer of hexan-1-ol. **2**

Name: ……

ii. **Draw**, using a skeletal formula, and **name** one chain isomer of hexan-1-ol. **2**

Name: ……

iii. **Name** the isomer that is resistant to oxidation by acidified potassium dichromate.

..... **1**

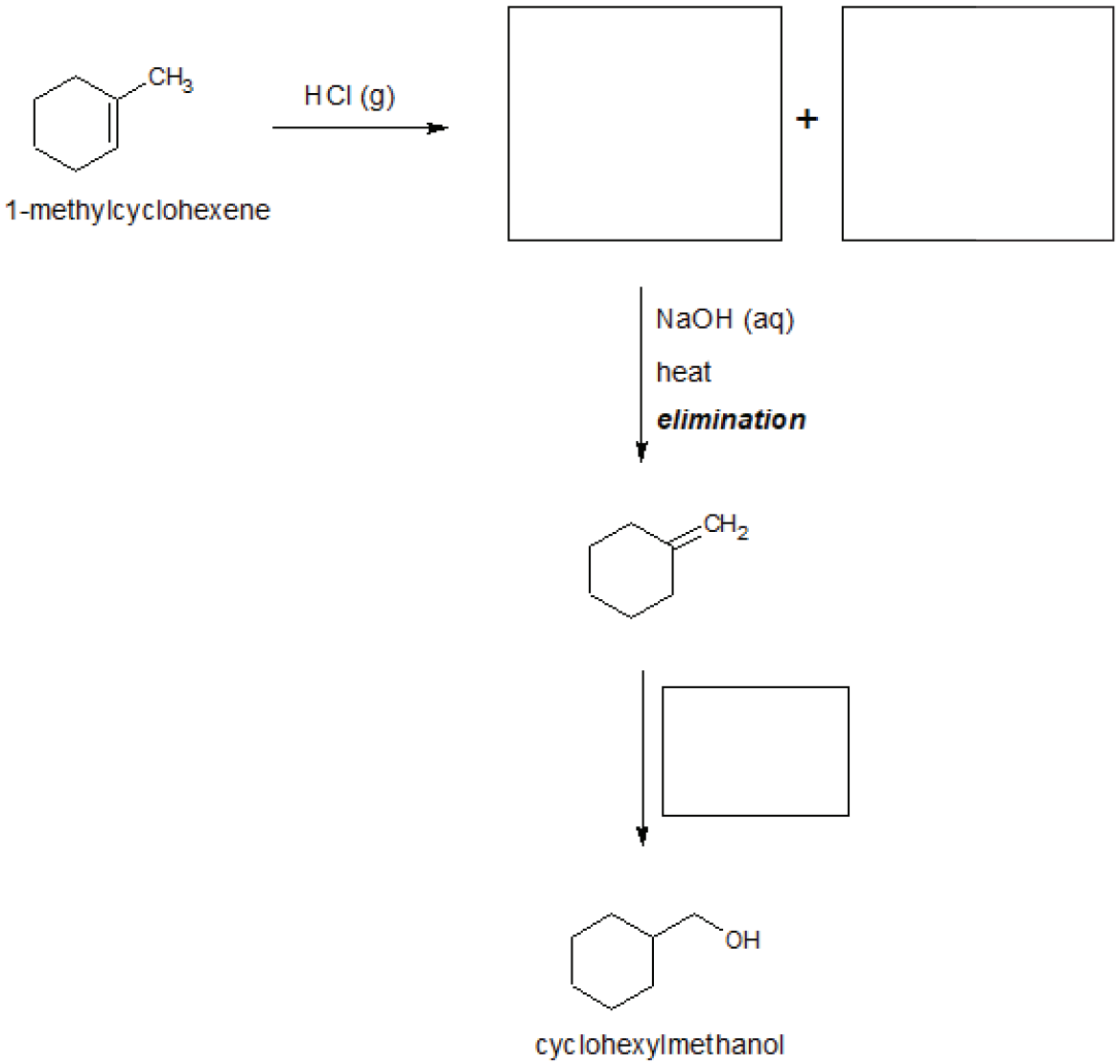
(d) Hexan-1-ol can be reacted with ethanoic acid to make an ester. Using structural formula, write the equation, identifying the catalyst, for this reaction. **2**

Question continued on next page.

Question continued. **Marks**

(e) Alcohols are important in organic synthesis and can be synthesised from halogenated alkanes.

Complete the flow chart, by drawing structures of the intermediates and identifying reagents, to show how cyclohexylmethanol can be synthesised from 1-methylcyclohexene.



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Question 30 (8 marks) **Marks**

Polymers offer a wide range of properties, enabling them to be used in many different applications.

(a) Polyethene and polyvinyl chloride are two commonly used addition polymers.

(i) Identify the feature found in these monomers that allows them to produce addition polymers.

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(ii) Polyvinyl chloride has a much higher melting point than polyethene. Explain this difference in melting point in terms of their structures.

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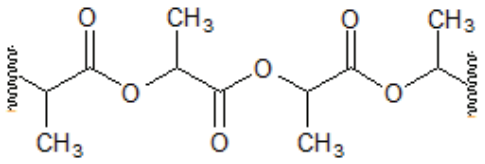
Question continued on next page.

Question continued. **Marks**

(b) The campaign to end the use of some plastics has led scientists to develop new biodegradable polymers. Polylactic acid, PLA, is a condensation polymer which was originally developed from lactic acid for medicinal applications but can also be used for biodegradable packaging.

A section of the polymer is shown below.



i. Draw the structure of the lactic acid monomer.

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ii. If a sample of PLA has a mass of 0.125 g, estimate the number of monomers used to make this sample.

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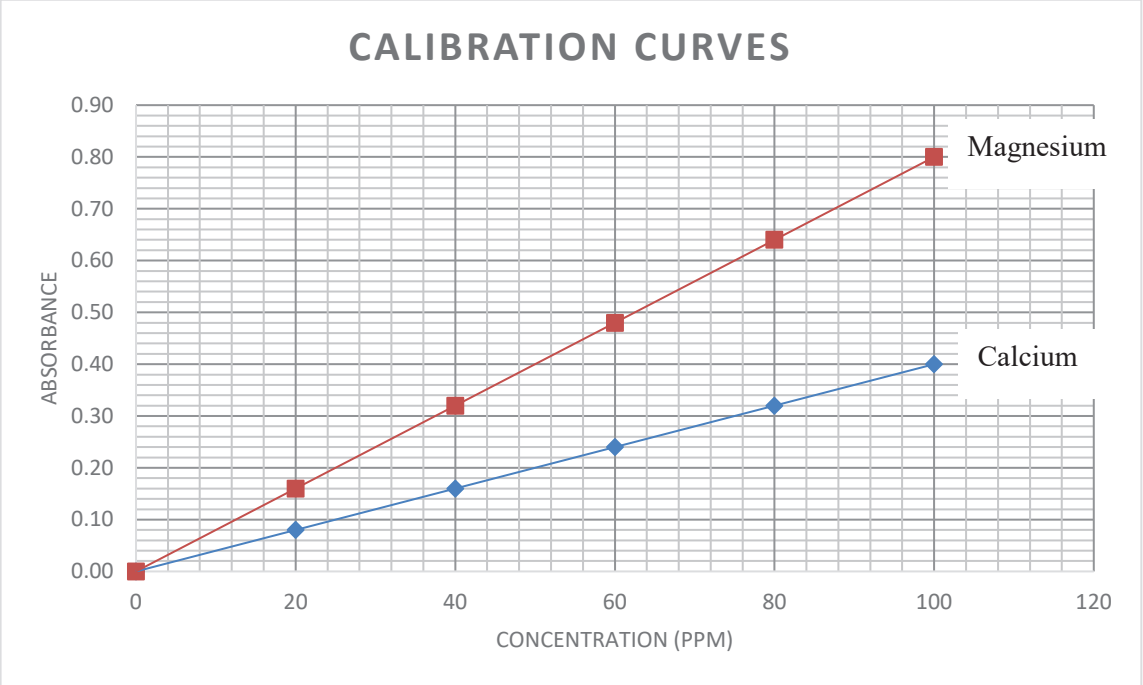
CANDIDATE NUMBER

Question 31 (5 marks) **Marks**

The presence of calcium and magnesium ions in water can cause 'water hardness' that affects the taste of water. Recommendations have been made for the maximum level of calcium (80 ppm) and magnesium (30 ppm) in drinking water, and a total hardness, expressed as the sum of the calcium and magnesium concentrations, of 3 mmol/L.

A 500.00 mL sample of water was analysed using Atomic Absorption Spectroscopy (AAS). The calibration curves and sample data are given below.



Sample – Calcium absorbance	0.20
Sample – Magnesium absorbance	0.32

(a) Explain why AAS can be used as a quantitative technique for a solution that contains both ions. **1**

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Question continued on next page.

Question continued. **Marks**

(b) Is this water suitable for drinking? Support your conclusion with evidence.

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(c) Is this water hard? Support your conclusion with calculations.

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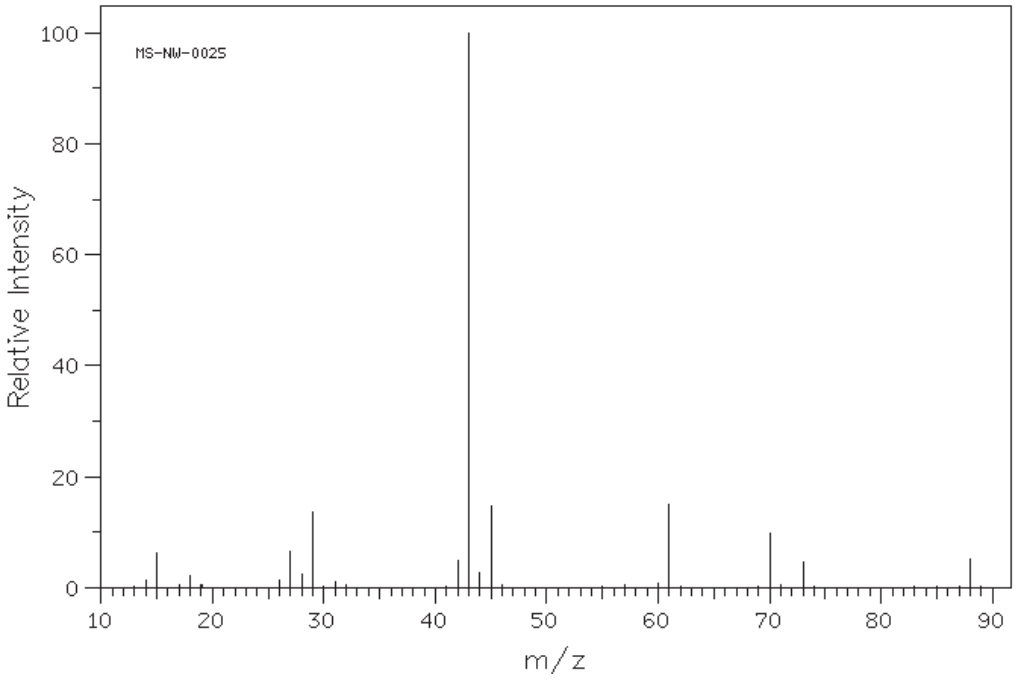
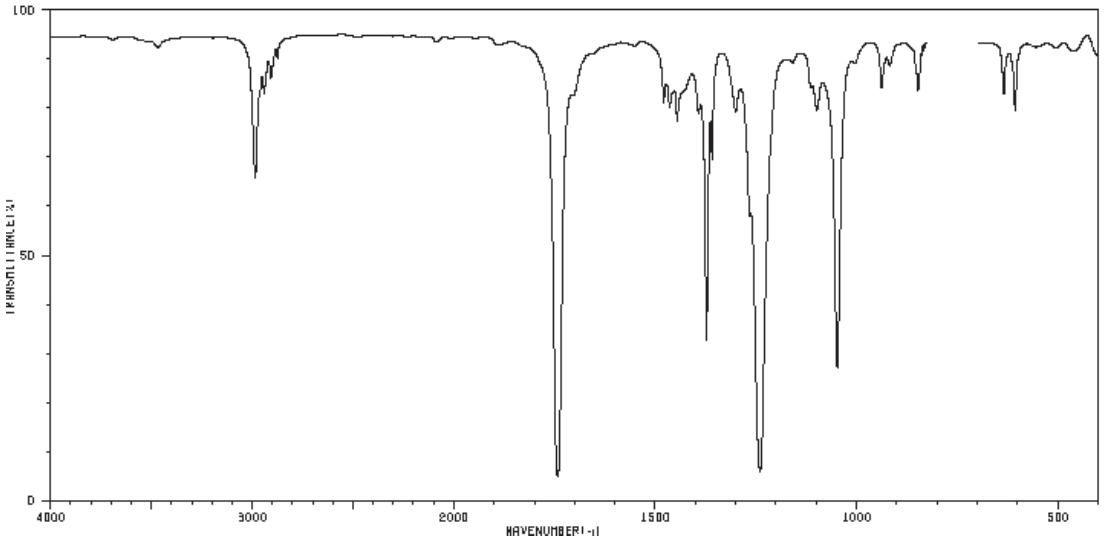
Question 32 (7 marks)

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





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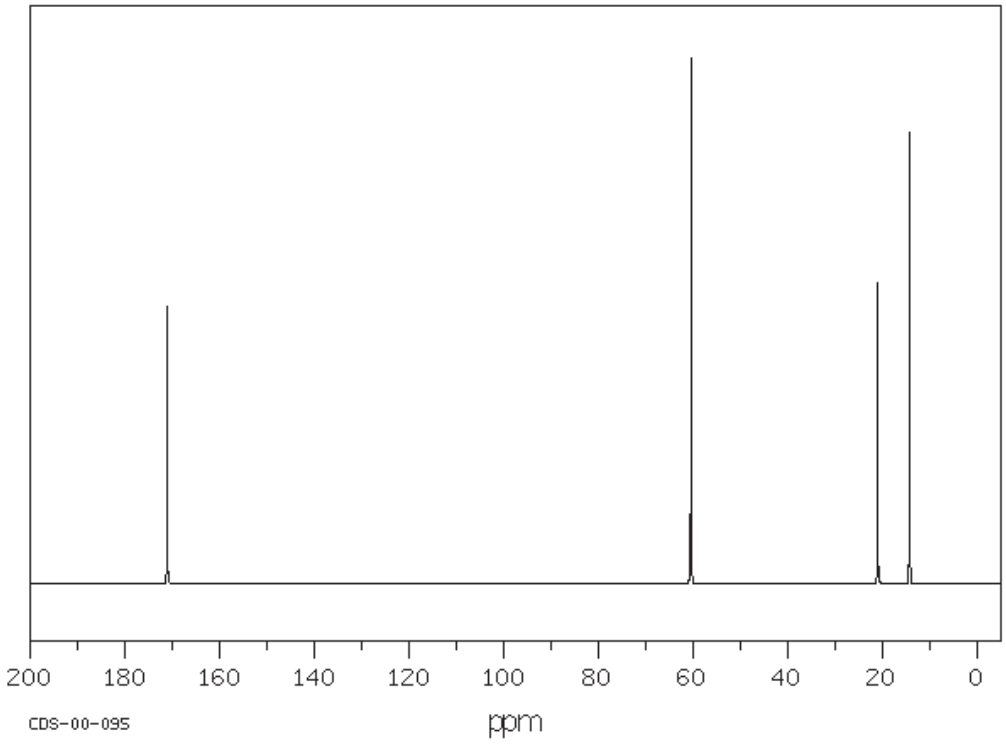
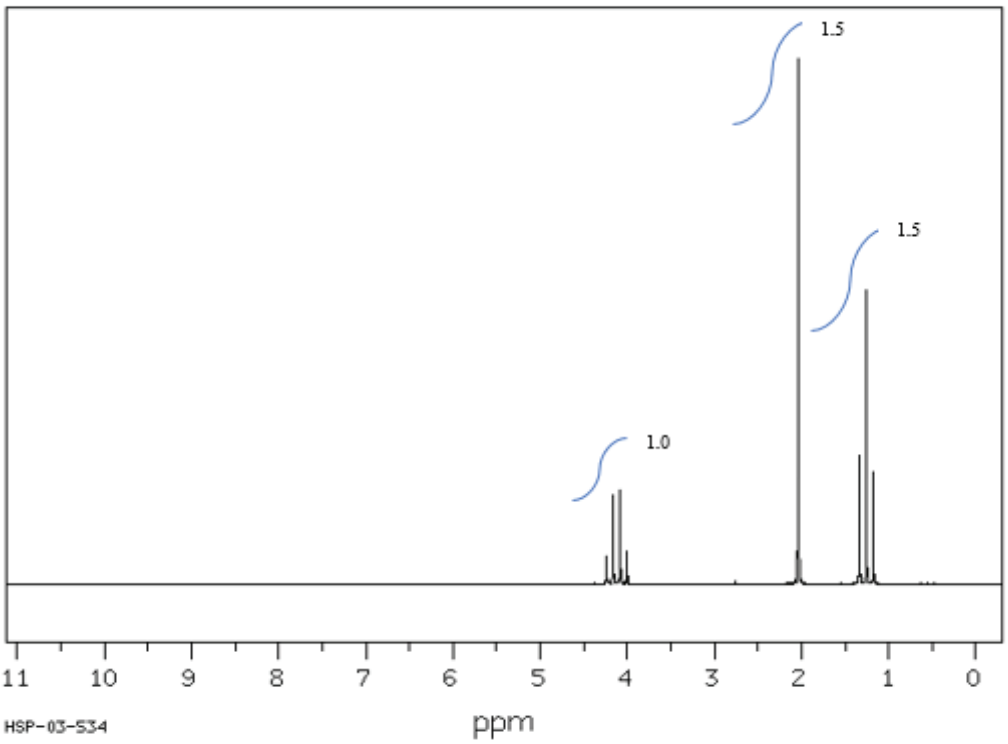
Question continued.

^{13}C NMR spectrum



^{1}H NMR spectrum



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Question continued.

^{1}H NMR chemical shift data

Type of proton	δ/ppm
$Si(C\mathbf{H}_3)_4$ (TMS)	0
R–C$\mathbf{H}_3$	0.9–1.0
R–C$\mathbf{H}_2$–R	1.2–1.5
R–C$\mathbf{H}$R$_2$	1.5–2.0
R–C≡C–**H** (alkyne)	2.0–3.1
–CO–C$\mathbf{H}_2$– (aldehydes, ketones or esters)	2.1-2.7
R–C$\mathbf{H}_2$–NH$_2$	2.4–3.0
R–C$\mathbf{H}_2$–X (X = F, Cl, Br, I)	3.0–4.5
–C$\mathbf{H}_2$–O– (alcohols, ethers or esters)	3.3–4.8
R–O**H**	1–6
R–N$\mathbf{H}_2$	1–5
R$_2$C=C**H**R (alkene)	4.5–7.0
R–COON**H**–R (amide)	5–9
Ar-**H** (aromatic)	6.9–9.0
R–C**H**O (aldehyde)	9.4–10.0
R–COO**H**	9.0–13.0

Question continued. **Marks**

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

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END OF EXAMINATION

2019 | HIGHER SCHOOL CERTIFICATE EXAMINATION

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}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

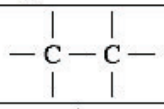
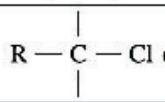
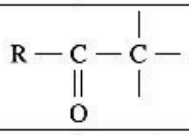
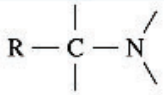
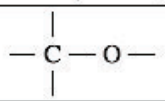
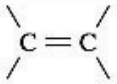
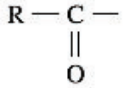
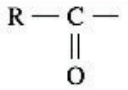
Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
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
R — C ≡ N		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

				C	R	1	B
CANDIDATE NUMBER							

2020
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 of the following matches the inorganic acid and base with their correct formula?

	Acid		Base	
(A)	H_2PO_4	phosphoric	NaOH	sodium hydroxide
(B)	HNO_3	nitrous	NH_3	ammonia
(C)	NH_4^+	ammonium	CO_3^{2-}	carbonate
(D)	H_2SO_3	sulfurous	CaO	calcium dioxide

2 Which of the following is considered to be a limitation of Arrhenius' model of acids and bases?

(A) He did not account for acids that do not contain oxygen.

(B) He did not account for the presence of hydrogen-containing compounds which are non-acidic in nature.

(C) He did not recognise the importance of water as a solvent in the nature of acids and bases.

(D) He did not recognise that some substances can act as acids or bases in the absence of solvents.

3 Which of the following statements with regards to acid and base strength and concentration is true?

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

(B) The same concentration of strong and weak monoprotic acids will contain the same chemical amount of hydrogen ions.

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

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

4 If the pH of a solution was shown to be 10.5, what could we conclude about the following parameters?

(A) The pOH will be $10^{-3.5}$

(B) The H^+ concentration will be 1.02

(C) The OH^- concentration will be 3.16×10^{-4}

(D) The H^+ concentration x the OH^- concentration will be 10^{14}

5 Which of the following statements correctly describes the relationship between the strength of an acid, its hydrogen ion concentration, its pH and its pK_a?

(A) The stronger the acid, the lower the pK_a value.

(B) A strong acid will have a pKa somewhere between 0.001 and 1000.

(C) An acid with a low pH will have a very large pK_a.

(D) The greater the K_a, the larger the pK_a value.

6 If a monoprotic acid has pH value of 3.2 and a concentration of 0.15 mol/L, what will its K_a value be closest to?

(A) 2.7×10^{-6}

(B) 6.3×10^{-4}

(C) 5.6

(D) 3.8×10^{5}

7 Solid potassium amide KNH_2 reacts with water according to the equation:

$$KNH_2\,(s) + H_2O\,(l) \rightarrow KOH\,(aq) + NH_3\,(g)$$

The acid and its respective conjugate base in this reaction are:

(A) K^+ and KOH

(B) H_2O and OH^-

(C) NH_2^- and NH_3

(D) NH_3 and NH_2^-

8 A reaction in dynamic equilibrium is one in which:

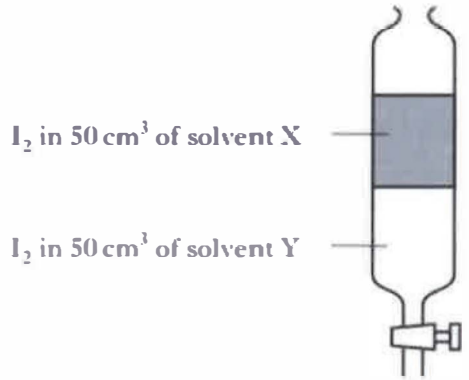
(A) the concentration of the product is always independent of reaction conditions

(B) the enthalpy changes for the forward and the reverse reactions are equal

(C) the activation energies for the forward and the reverse reactions are equal

(D) the rates of the forward and the reverse reactions are equal

9 Iodine was added to 50 mL of each of two immiscible solvents X and Y in a separating funnel as shown below.



After shaking, the following equilibrium was established:

$$I_2\,(Y) \rightleftharpoons I_2\,(X)$$

An extra 10 mL of solvent X was added, the mixture shaken and equilibrium was allowed to re-establish. Which of the following statements is correct?

(A) The concentration of I_2 in Y increases

(B) The concentration of I_2 in Y decreases

(C) The equilibrium constant increases

(D) The equilibrium constant decreases

10 Photosynthesis is not considered to be an equilibrium reaction because:

(A) it has a large negative ΔH value

(B) it has a small negative ΔS value

(C) it has a large positive ΔG value

(D) it has a zero ΔG value

11 Will lead(II) chloride precipitate when 50 mL of 0.10 M $Pb(NO_3)_2$ solution is mixed with 50 mL of 0.10 M NaCl solution?

(A) Yes, because the ion product is greater than the K_{sp}.

(B) Yes, because the K_{sp} is greater than the ion product.

(C) No, because the ion product is smaller than the K_{sp}.

(D) No, because the K_{sp} is smaller than the ion product.

12 The reaction:

$$CO\ (g) + 3\ H_2\ (g) \rightleftharpoons CH_4\ (g) + H_2O\ (g)$$

has an equilibrium constant of 3.9 at 950 °C.

The equilibrium concentrations of CO (g), H_2 (g) and H_2O (g) are given in the table.

Substance	**Equilibrium concentration (mol L^{-1})**
CO (g)	5.0×10^{-2}
H_2 (g)	1.0×10^{-2}
H_2O (g)	4.0×10^{-3}

What is the equilibrium concentration of CH_4 (g), in mol L^{-1}, at 950 °C?

(A) 2.0×10^{-7}

(B) 4.9×10^{-5}

(C) 3.1×10^{-5}

(D) 4.9×10^{-1}

13 A solution is made by dissolving solid sodium hydroxide and barium hydroxide in water. Which of the following must be true regarding the concentrations of each of the ions in solution formed?

(A) $[Na^+] = [Ba^{2+}] = [OH^-]$

(B) $[Na^+] = [Ba^{2+}] = 3\ [OH^-]$

(C) $[Na^+] + 2\ [Ba^{2+}] = 3\ [OH^-]$

(D) $[Na^+] + 2\ [Ba^{2+}] = [OH^-]$

14 Complete combustion of an organic compound forms 40 mL of carbon dioxide and 40 mL of water vapour, under the same conditions of temperature and pressure. Which of the following could be the molecular formula of the organic compound?

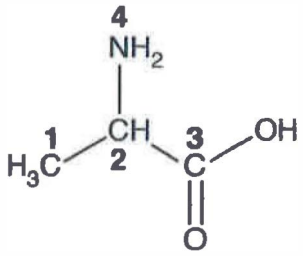
(A) C_3H_8

(B) C_2H_2O

(C) C_2H_3N

(D) C_2H_4O

15 Four atoms, 1–4, are labelled in the structure below.



Which atom has a trigonal **planar** arrangement of bonds around it?

(A) Atom 1

(B) Atom 2

(C) Atom 3

(D) Atom 4

16 Which compound(s) is/are structural isomer(s) of $C_6H_{12}O_2$?

I hexanoic acid
II ethyl butanoate
III propyl propanoate

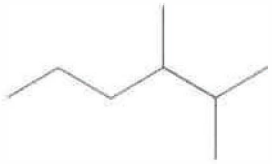
(A) Only I

(B) I and II only

(C) II and III only

(D) All of I, II and III

17 What is the IUPAC name of the following compound?



(A) 1,1,2-trimethylpentane

(B) 2,3-dimethylhexane

(C) 4,5-dimethylhexane

(D) 4,5,5-trimethylpentane

18 In the infra-red spectrum of an organic compound, a strong band is observed at 3000 cm^{-1}. The most likely explanation for this band is:

(A) the electrons absorb this IR radiation and are excited to a higher orbital.

(B) protons absorb the radiation at this frequency and change their spin.

(C) absorption of this IR radiation wavenumber causes vibrations of the C-H bonds.

(D) absorption of this wavenumber of IR radiation causes a substitution reaction.

19 Bromine water can be used to test for the presence of which of the following organic functional groups?

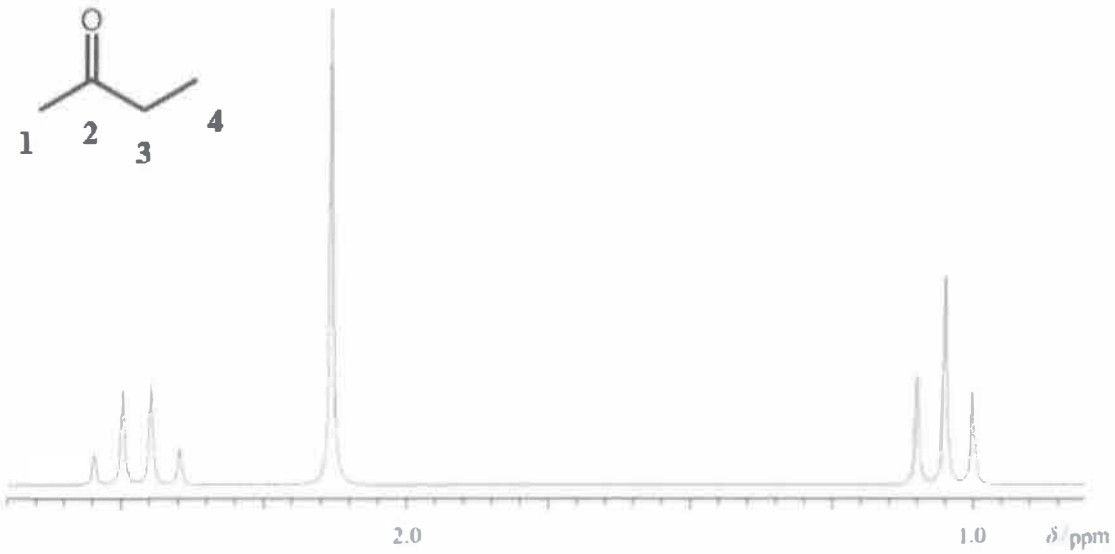
(A) Carbon-carbon double bonds

(B) Hydroxyl groups

(C) Carboxylic acids

(D) Aldehydes and ketones

20 The proton NMR spectrum for butan-2-one is shown below, along with a numbered structure of butan-2-one.



Identify the position (1-4) of hydrogen atoms that are responsible for the singlet peak at 2.1 ppm.

(A) 1

(B) 2

(C) 3

(D) 4

SECTION II: 80 marks

Attempt ALL Questions
Write your answer in the space provided.

MARKING SCHEME - AUSB

CANDIDATE NUMBER

Question 21 (4 marks) **Marks**

Acids react with carbonates in predictable ways. Formic acid has the formula HCOOH and its pK_a is 3.75.

(a) Write a balanced chemical equation to represent the reaction between formic acid and sodium carbonate.

$2HCOOH + Na_2CO_3 \rightarrow 2NaHCOO + H_2O + CO_2$ 1

(b) State whether you would expect the salt formed in part (a) to be acidic, neutral or basic. Explain your answer including an appropriate equation.

3 MARKS * From pKa we can tell that HCOOH is a weak acid 3
so $HCOO^- + H_2O \rightleftharpoons HCOOH + OH^-$
AND * so produces OH^- OR accepts protons
AND * therefore salt is basic

2 MARKS Either * equation above
OR * produces OH^- OR accepts protons
AND * salt is basic

1 MARK Identifies any piece of relevant information given above.

Question 22 (3 marks) **Marks**

The dihydrogen phosphate ion has the formula $H_2PO_4^-$.

(a) Write an equation to show dihydrogen phosphate reacting with:

(i) an acid

$H_2PO_4^- + H^+ \rightarrow H_3PO_4$ 1

(ii) a base

$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$ 1

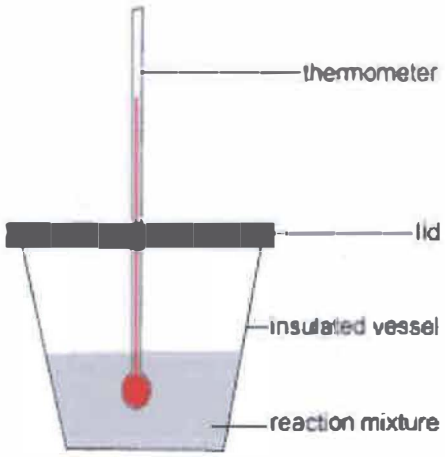
If $H_2PO_4^-$ was shown to be used as both acid & base in equations above then a maximum of 1 mark given.

(b) Identify the term that we use to describe substances that can act as both acids and bases, such as dihydrogen phosphate.

Amphiprotic 1

Question 23 (4 marks) **Marks**

The equipment shown below may be used to measure the enthalpy of neutralisation.



10.0 mL of 0.500 M solution of HCl are mixed with 10.0 mL of 0.500 M solution of NaOH in the cup shown. The enthalpy change for this reaction is -55.8 kJ mol^{-1}.

(a) If the initial temperature of the reactants was 25.0 °C, calculate the final temperature once the reaction had finished. 3

$\Delta T = \frac{\Delta H \times n}{-mc}$

$= \frac{-55800 \times 0.005}{-20 \times 4.18}$

$= 3.337\ K$

Final Temp = 25 + 3.337

= 28.337

= 28.3 °C (3 sig fig)

One mark lost for each mistake.

(b) State one assumption you made in this calculation. 1

* All the energy produced by the reaction was absorbed by the measured environment & none escaped

OR * The specific heat capacity of the solution was $4.18\ J\ g^{-1}\ K^{-1}$

OR * The density of the solution was 1 g/mL

CANDIDATE NUMBER

Question 24 (5 marks) **Marks**

50.0 mL of a solution of HCl with pH 3.0 was mixed with 30.0 mL of a solution of HNO_3 with pH 5.0.

(a) Calculate the pH of the resultant solution.

	HCl	HNO_3	
pH	3	5	
H^+ conc	10^{-3}	10^{-5}	**Step 1**
vol	0.05L	0.03L	
n	5×10^{-5}	3×10^{-7}	**Step 2**
n total	0.08L		**Step 3**
H^+ conc total	0.00062875M		**Step 4**
pH	3.2		**Step 5**

3 marks - 5 correct steps

2 marks - 4 correct steps

1 mark – 1 to 3 correct steps

(b) Explain how the pH and H^+ concentration of the resultant solution would differ from that calculated above, if ethanoic acid was used instead of nitric acid.

2 marks	$CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$ • **Addition of H^+ from HCl would shift equilibrium to RHS** • **therefore decreasing the H^+ conc and increasing the pH** **OR having no effect on the pH due to the relative concs of the 2 acids.** **NB 2nd point must follow on from first logical explanation**
1 mark	• **Addition of H^+ from HCl would shift equilibrium to RHS** • **OR (see below)**

The fact that ethanoic acid is weak and only partially ionises does not EXPLAIN the difference since the pH and hence original H^+ conc of the ethanoic and nitric acids was initially the same.

This answer was awarded 1 mark.

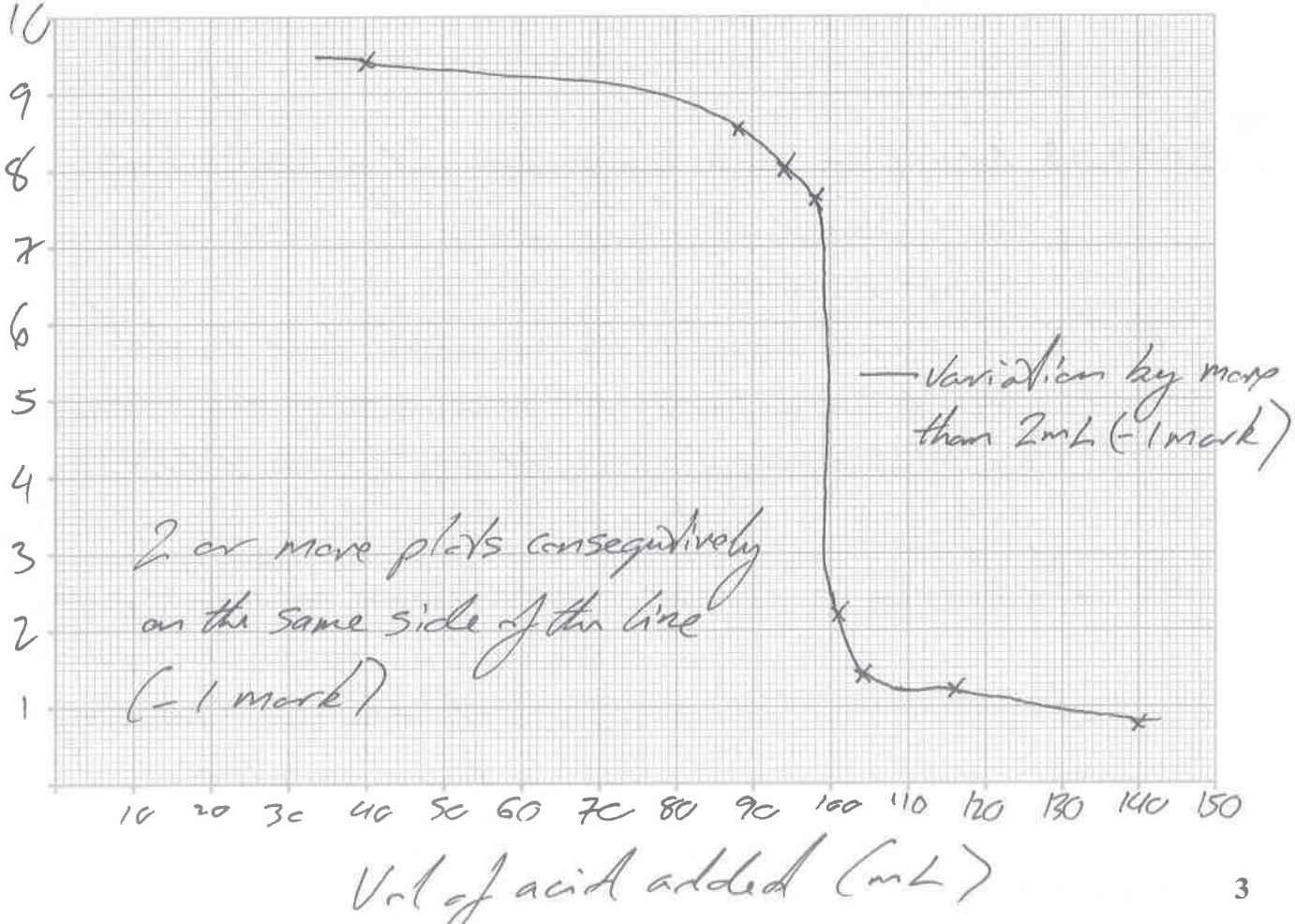
Question 25 (9 marks) **Marks**

An acid / base titration was undertaken using an electronic pH meter. The resultant data is shown in the table below.

Scale/labels (1)
Plots (1)
Line of best fit (1)

Volume of acid added (mL)	pH
40	9.4
88	8.6
94	8.0
98	7.6
101	2.2
104	1.4
116	1.2
140	0.8

(a) Plot the data provided on the grid below and draw a line of best fit.



3

Question continued on next page.

Question 25 continued **Marks**

(b) By analysing your graph, deduce the strength of the base used in this titration.

3 marks	**Base is weak because - any 2 of the following points**	• **Equivalence point is around pH 4.5 - 5** • **Point of inflection is around pH 4.5 – 5** • **Salt produced is acidic, around pH 4.5 –5**
2 marks	**Base is weak because - any 1 of the following points**	• **Equivalence point is around pH 4.5 - 5** • **Point of inflection is around pH 4.5 – 5** • **Salt produced is acidic, around pH 4.5 –5**
1 mark	**Any of the following points** **OR**	• **Equivalence point is around pH 4.5 - 5** • **Point of inflection is around pH 4.5 – 5** • **Salt produced is acidic, around pH 4.5 –5** **Base is weak because the initial pH is 9.4 (this would also be true for a dilute strong base)**

(c) Titrations can also be done by means of a chemical indicator in place of a pH meter. These indicators are usually weak acids in equilibrium with their conjugate bases, at roughly equal concentrations when they change colour. Explain why it is important during titrations to keep the amount of indicator added to a minimum.

3 marks	**AND** **AND**	***Addition of a large amount of indicator could change the H^+ conc and pH of the solutions in the conical flask.** ***The weak acid and its conjugate base could absorb or release H^+ ions minimising any changes to H^+ conc or pH which would result from addition of acid or base (ie it would buffer the solutions).** ***This could cause – additional inflection points OR - changes in equivalence points OR - accurate or valid readings being hard to achieve**
2 marks	**Any 2 of above points**	
1 mark	**Any 1 of above points**	

21

CRIB - CXS

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Question 26 (9 marks) **Marks**

Silver carbonate and silver chloride are only slightly soluble in water.

In the following, assume that the temperature is a constant 25°C.

(a) Write an ionic equation for the dissociation of solid silver carbonate, Ag_2CO_3, in water.

$Ag_2CO_3(s) \rightarrow 2Ag^+(aq) + CO_3^{2-}(aq)$ **1**

(b) Write the solubility product expression, K_{sp}, for silver carbonate.

$K_{sp} = [Ag^+]^2[CO_3^{2-}]$ **1**

(c) Use the K_{sp} values on the data sheet to compare the concentrations, in mol L^{-1}, of silver ions in separate saturated solutions of silver carbonate and silver chloride.

Ag_2CO_3 $[Ag^+] = 4x^3 = 8.46 \times 10^{-12}$ **3**

$x = 1.3 \times 10^{-4}$ mol L^{-1} (1)

$\therefore [Ag^+] = 2 \times 1.3 \times 10^{-4} = 2.6 \times 10^{-4}$ M (1)

$AgCl$ $[Ag^+] = x^2 = 1.77 \times 10^{-10}$

$x = 1.33 \times 10^{-5}$ mol L^{-1} (1)

Comparison : Ag_2CO_3 has a higher concentration of Ag^+ ions (1)

Question continued on next page.

Question continued. **Marks**

(d) Calculate the mass (in g) of silver chloride that will dissolve to form 1.00 L of a saturated solution. **2**

$m(AgCl) = 1.33 \times 10^{-5} \times 143.4$

$= 1.91 \times 10^{-3}$ g

(e) Calculate the molar solubility of silver chloride in a 0.15 mol L^{-1} sodium chloride solution. **2**

solubility $= [Ag^+][Cl^-] = 1.77 \times 10^{-10}$

when $[Cl^-] = 0.15$

solubility $= \frac{1.77 \times 10^{-10}}{0.15}$

$= 1.18 \times 10^{-9}$ mol L^{-1}

$= 1.2 \times 10^{-9}$ mol L^{-1}

Question 27 (4 marks) **Marks**

A reaction mixture consists of 0.12 mol Br_2 (g) and 0.12 mol H_2 (g) in a 2.50 L sealed container. At a set temperature, the mixture was left to reach equilibrium according to the equation:

$$Br_2\,(g) + H_2\,(g) \rightleftharpoons 2\,HBr\,(g) \qquad K_{eq} = 1.9 \times 10^{-5}$$

(a) Calculate the initial concentration of hydrogen gas. 1

initial $[H_2] = \frac{0.12}{2.5} = 0.048\ mol\,L^{-1}$

(b) Calculate the amount, in mol, of HBr produced at equilibrium at the set temperature. 3

	Br_2	+	H_2	$\rightleftharpoons$	$2\,HBr$
I	0.048		0.048		0
C	$-x$		$-x$		$+2x$
E	$0.048-x$		$0.048-x$		$2x$

$\leftarrow$ ignore as $\ll 0.048$

$$\therefore K = \frac{(2x)^2}{(0.048)^2} = 1.9 \times 10^{-5}$$

$$4x^2 = 4.377 \times 10^{-8}$$

$$x^2 = 1.094 \times 10^{-8}$$

$$x = 1.046 \times 10^{-4}\ M$$

$$\therefore [HBr] = 2 \times 1.046 \times 10^{-4}$$

$$= 2.09 \times 10^{-4}\ M$$

$$n(HBr) = 2.09 \times 10^{-4} \times 2.5$$

$$= 5.2 \times 10^{-4}\ mol$$

Question 28 (8 marks) **Marks**

When the following reaction is at equilibrium at 298 K, it is orange in colour.

$$H_2O\ (l) + Cr_2O_7^{2-}\ (aq) \rightleftharpoons 2\ CrO_4^{2-}\ (aq) + 2\ H^+\ (aq)$$
orange yellow

(a) Predict and explain the colour change, if any, of the reaction mixture if aqueous sodium hydroxide is added to it. **2**

Prediction = Turns yellow (1)

Explanation = OH^- neutralises H^+ reducing $[H^+]$ (1)

OR (2) Equilibrium shifts to right to counteract loss of H^+ by OH^-.

(b) Consider the following reversible reaction at equilibrium:

$$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g) \qquad \Delta H = +ve$$

i. Predict and explain, in terms of reaction rates, the effect on the equilibrium position when the pressure increases on this system. **3**

PREDICTION : Shift left (1)

EXPLANATION : • Increased pressure increases [ ] of both N_2O_4 and NO_2 but increases $[NO_2]$ more. (1)

• This is because the mole ratio of $NO_2 : N_2O_4$ is 2:1 ∴ increase rate of collisions (1)

• A shift to the left as more NO_2 molecules are colliding successfully than N_2O_4.

1 mark for When pressure increases the effect on RATE of NO_2 is greater but both increase

1 mark for the reason in terms of mole ratio

Question continued on next page.

Question continued. **Marks**

ii. Explain how an increase in temperature affects the yield of NO_2 and the K_{eq} value of the reaction. **3**

1. Increasing temperature favours the endothermic reaction, in this case the forward reaction (1)

2. Increasing forward reaction increases the yield of NO_2 (1)

3. K_{eq} value will increase as $[NO_2]$ is the numerator in the K expression, so as it gets larger so does the K_{eq} value, (1)

OR Gives the equilibrium expression

$$K = \frac{[NO_2]^2}{[N_2O_4]}$$

* Revised #3. K is increased is given the mark.

CANDIDATE NUMBER

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MARKERS NOTES

Question 29 (14 marks) **Marks**

This question is about alcohols.

(a) Construct a chemical equation to show the complete combustion of hexan-1-ol.

$C_6H_{13}OH + 9O_2 \rightarrow 6CO_2 + 7H_2O$ **1**

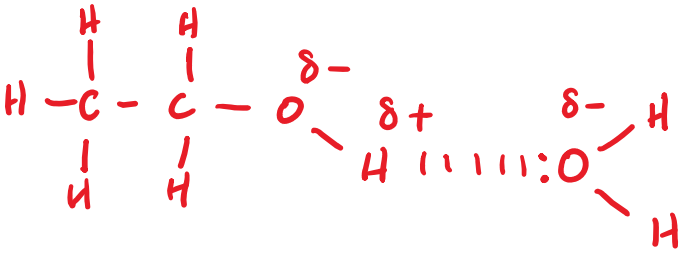
IGNORE : STATE SYMBOLS

ACCEPT : MULTIPLES

ACCEPT : $C_6H_{14}O$ or $CH_3CH_2CH_2CH_2CH_2CH_2OH$ for hexan-1-ol

(b) Many alcohols, including ethanol, are soluble in water.

i. Explain, with the aid of a diagram, how ethanol interacts with water. **2**



Ethanol molecules form H-bonds with water

NOTE : LONE PAIR IS NOT REQUIRED

ACCEPT : — / ---- / ~~~ / |||| FOR H BOND.

NOTE : MUST SHOW δ+ ON H AND δ- ON O INVOLVED

ii. Using the data in the table below, explain the difference in solubility between hexan-1-ol and hexane-1,6-diol.

Alcohol	Solubility in water (g L^{-1})
hexan-1-ol	5.9
hexane-1,6-diol	500

More H bonds can form per molecule **1**

NOTE : Error carried forward marks awarded

ACCEPT : More dipole-dipole interactions (if incorrect in 29b)

ACCEPT : More polar O-H groups, more interactions with water (if incorrect in 29b)

REJECT : More O-H bonds without explanation

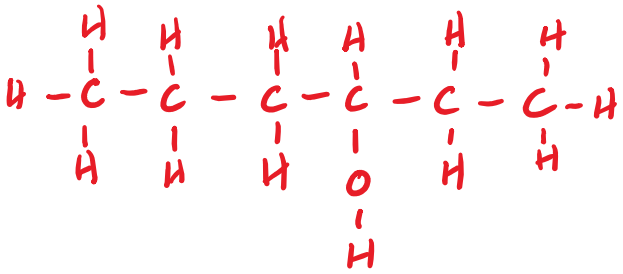
REJECT : More polar

Question continued on next page.

Question continued. **Marks**

(c) Hexan-1-ol has a number of different structural isomers.

i. **Draw**, using full structural formula, and **name** one position isomer of hexan-1-ol. **2**



hexan-3-ol

ACCEPT : -OH

ii. **Draw**, using skeletal formula, and **name** one chain isomer of hexan-1-ol. **2**

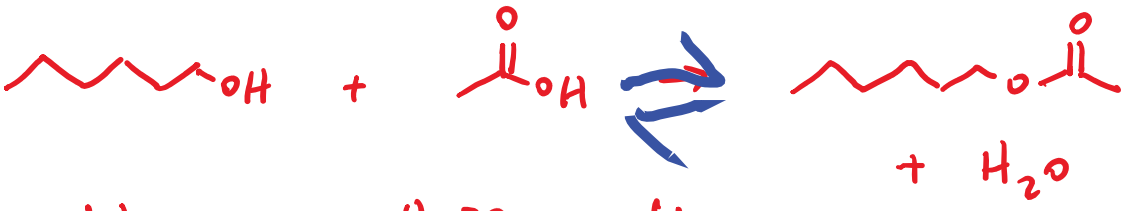
3-methylpentan-1-ol

ACCEPT : Isomers that are both chain + position manomers.

iii. **Name** the isomer that is resistant to oxidation by acidified potassium dichromate.

2-methylpentan-2-ol
/3-methylpentan-3-ol **1**

(d) Hexan-1-ol can be reacted with ethanoic acid to make an ester. Using structural formula, write the equation for this reaction. **2**



+ H_2O

Conditions : conc. H_2SO_4, reflux

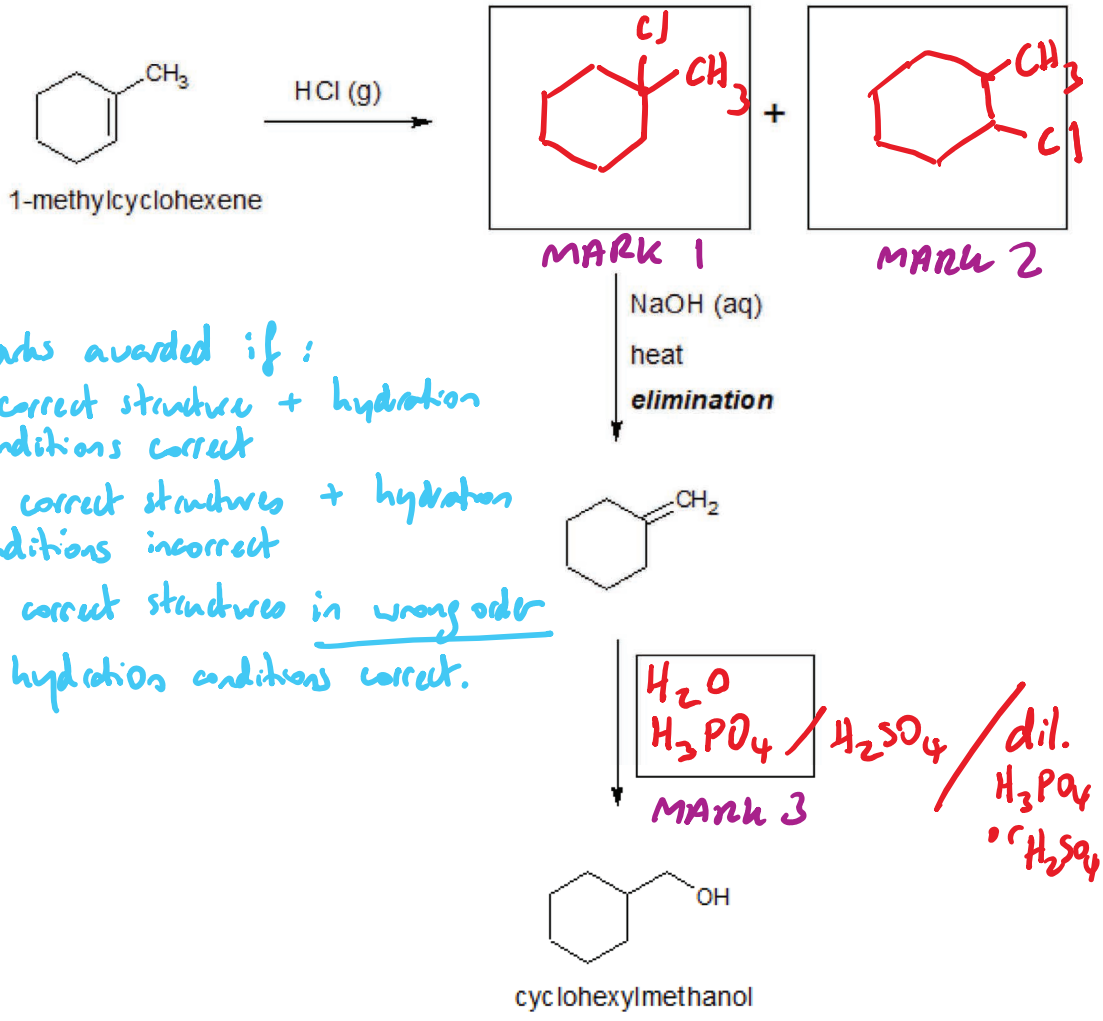
Question continued on next page.

MARK 1 : Equation
MARK 2 : conc. H_2SO_4 catalyst

Question continued. **Marks**

(e) Alcohols are important in organic synthesis and can be synthesised from halogenated alkanes.

Complete the flow chart, by drawing structures of the intermediates and identifying reagents, to show how cyclohexylmethanol can be synthesised from 1-methylcyclohexene.



NOTE: 2 marks awarded if:
- 1 correct structure + hydration conditions correct
- 2 correct structures + hydration conditions incorrect
- 2 correct structures in wrong order + hydration conditions correct.

NOTE: If product 1 and product 2 are wrong way around deduct 1 mark

H_2O, H_3PO_4/H_2SO_4 or dil H_3PO_4/H_2SO_4

3

Question 30 (8 marks) **Marks**

Polymers offer a wide range of properties, enabling them to be used in many different applications.

(a) Polyethene and polyvinyl chloride are two commonly used addition polymers.

(i) Identify the feature found in these monomers that allows them to produce addition polymers.

Carbon - carbon double bond 1

ACCEPT: double bond between carbons

ACCEPT: Alkene functional group

REJECT: Double bond

(ii) Polyvinyl chloride has a much higher melting point than polyethene. Explain this difference in melting point in terms of their structures.

C - Cl bonds are polar / strands are polar (M1) 3

Permanent dipole-dipole interactions stronger than dispersion forces (M2)

More energy required to separate strands (M3)

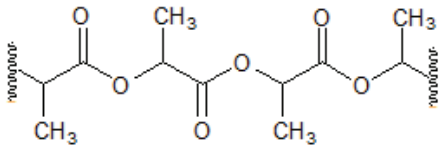
ACCEPT: stronger dispersion forces (max 1 mark)

Question continued on next page.

Question continued. **Marks**

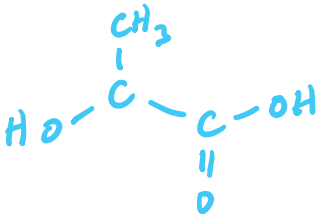
(b) The campaign to end the use of some plastics has led scientists to develop new biodegradable polymers. Polylactic acid, PLA, is a condensation polymer which was originally developed for medicinal applications but can also be used for biodegradable packaging.

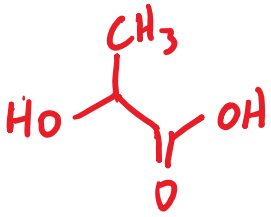
A section of the polymer is shown below.



i. Draw the structure of lactic acid.

REJECT :





1

ii. A sample of PLA has a mass of 0.125 g, estimate the number of monomers used to make this sample.

ACCEPT: mass of monomer / mass of unit

NOTE : Error carried forward marks awarded

Formula of repeating unit : $C_3H_4O_2$ (M1)

M_r of repeating unit = 72.062 g mol^{-1}

n(repeating unit) = $\frac{0.125\ g}{72.062\ g\,mol^{-1}}$

= 0.001735 mol (M2)

no. of monomers = no. of repeating unit

= 1.04×10^{21} (M3)

3

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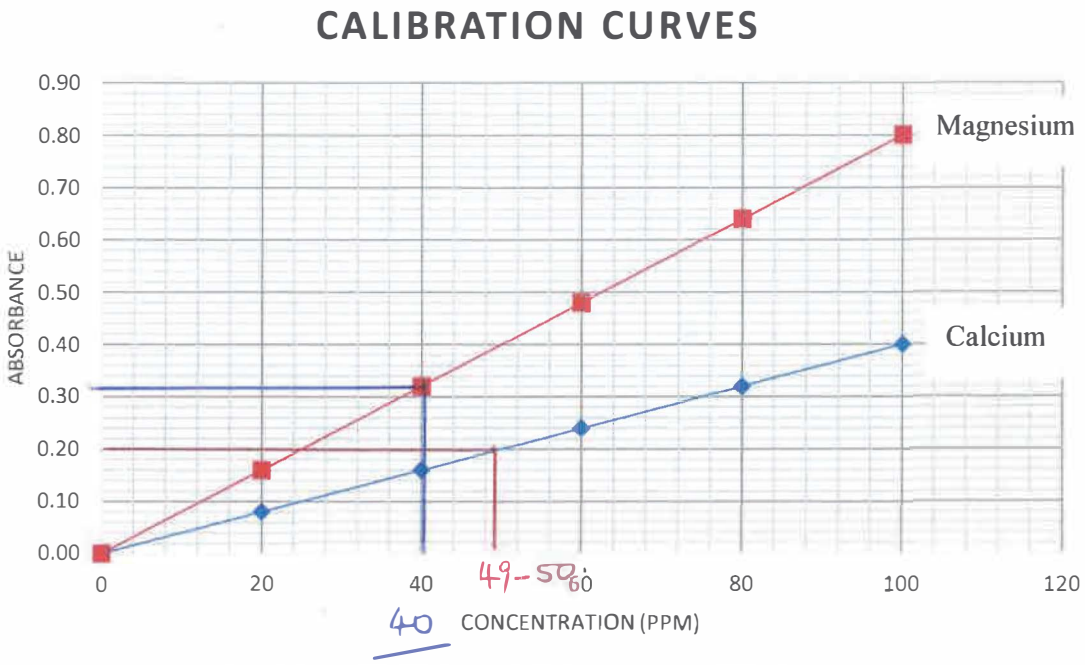
Question 31 (5 marks) **Marks**

The presence of calcium and magnesium ions in water can cause 'water hardness' that affects the taste of water. Recommendations have been made for the maximum level of calcium (80 ppm) and magnesium (30 ppm) in drinking water, and a total hardness, expressed as the sum of the calcium and magnesium concentrations, of 3 mmol/L.

A 500.00 mL sample of water was analysed using Atomic Absorption Spectroscopy (AAS). The calibration curves and sample data are given below.



Sample – Calcium absorbance	0.20
Sample – Magnesium absorbance	0.32

(a) Explain why AAS can be used as a quantitative technique for a solution that contains both ions.

Different ions absorb different λ's from specialised lamps & will not interfere with each other. (1)

Question continued on next page.

Question continued. **Marks**

(b) Is this water suitable for drinking? Support your conclusion with evidence.

(1) From graph; Mg^{2+} 40 ppm
Ca^{2+} 49-50 ppm **2**

(1) ∴ Mg^{2+} > limit, so not suitable for drinking

(c) Is this water hard? Support your conclusion with calculations.

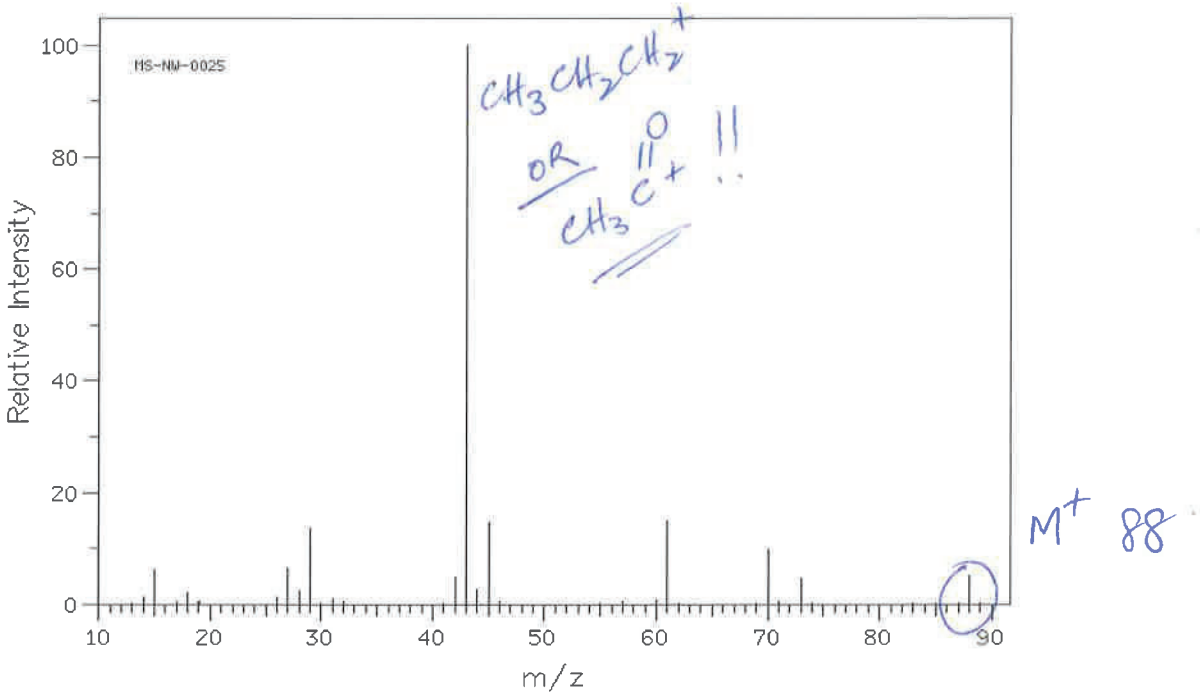
(1) Mg^{2+} $\frac{40 \times 10^{-3}}{24.31} = 1.65$ mmol L^{-1} **2**
Ca^{2+} $\frac{50 \times 10^{-3}}{40.08} = 1.25$ mmol L^{-1}
2.90 mmol L^{-1}

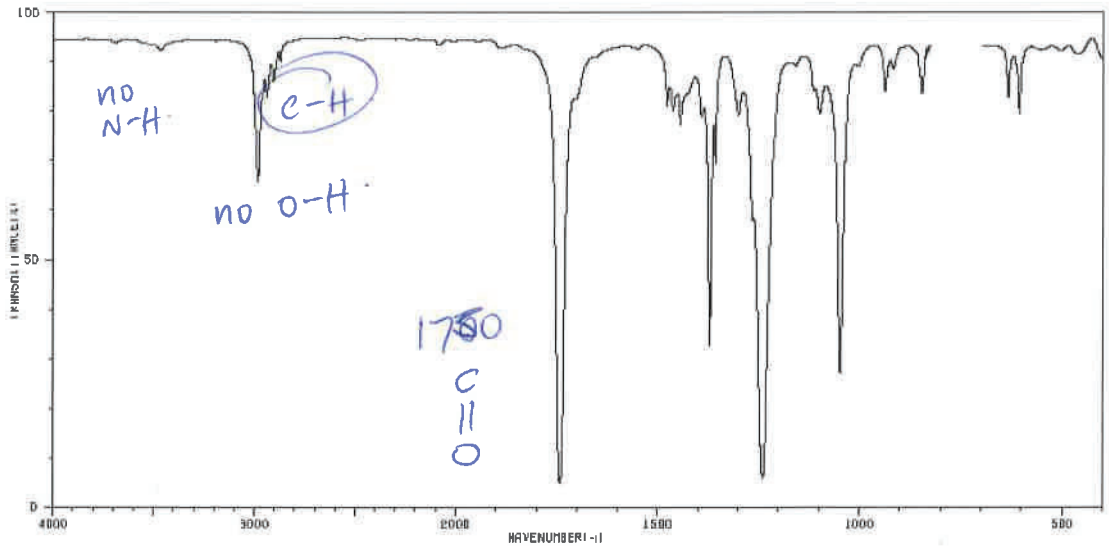
(1) ∴ it is not hard as 2.9 < 3.0

* Must have a calculation that involves mmol/L
* Note: ppm = mg/L so 500mL is not relevant.
* Must compare to 3 mmol/L
* CE if mmol L^{-1} calc is wrong, but made correct comparison

Question 32 (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, along with the proton NMR chemical shift data, are shown below.

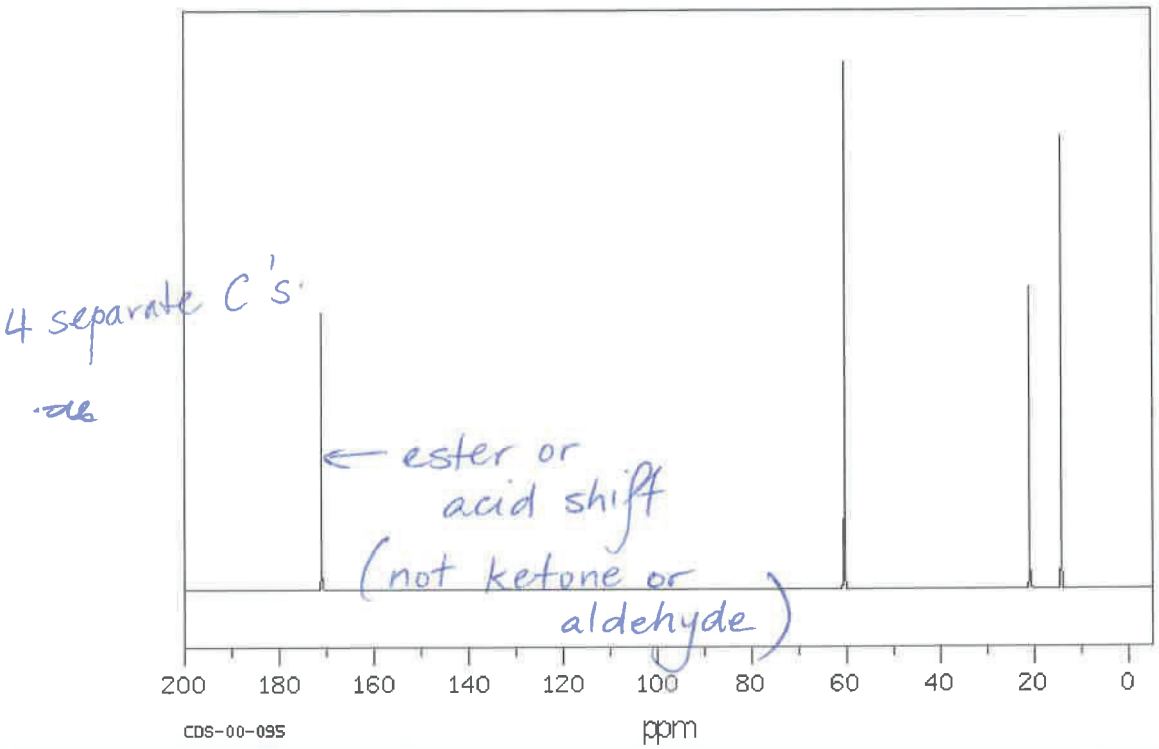




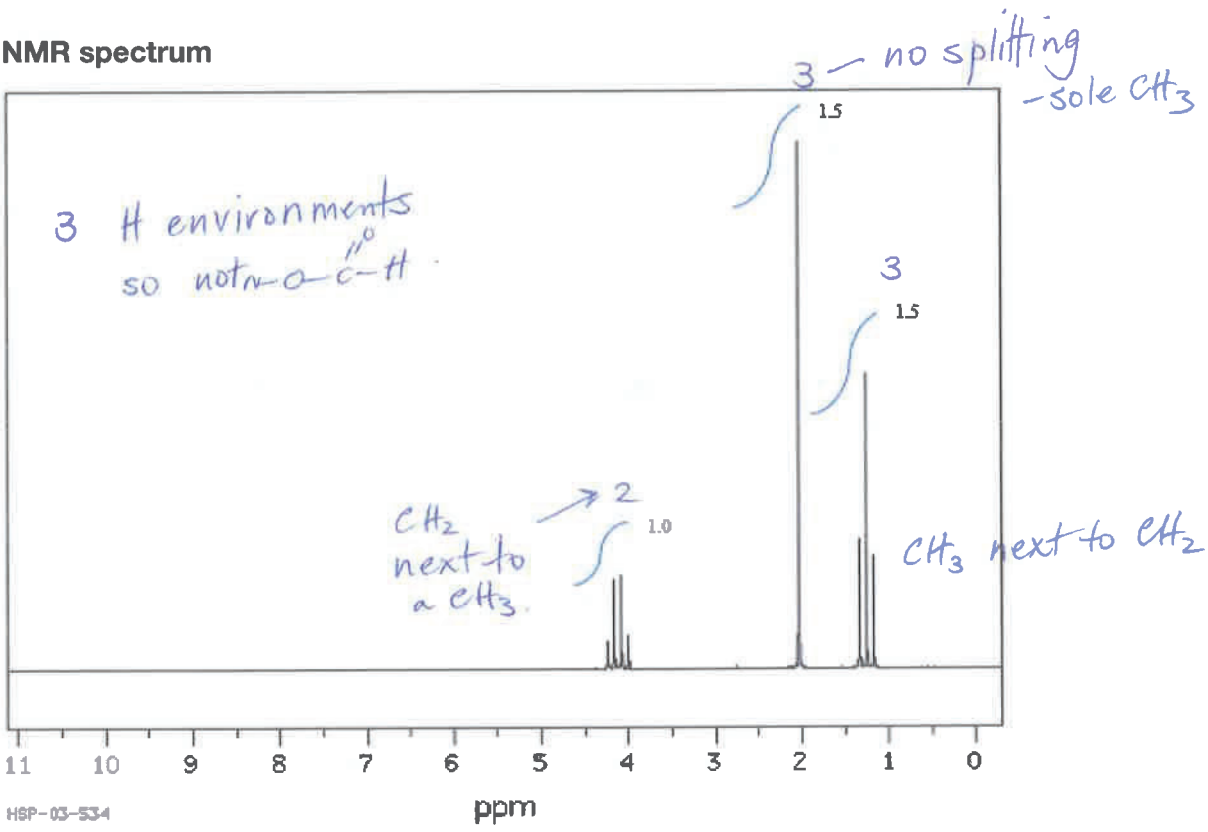
Question continued on next page.

Question continued.

^{13}C NMR spectrum



^{1}H NMR spectrum



Question continued on next page.

Question continued.

^{1}H NMR chemical shift data

Type of proton	δ/ppm
$Si(C\mathbf{H}_3)_4$ (TMS)	0
R–C$\mathbf{H}_3$	0.9–1.0
R–C$\mathbf{H}_2$–R	1.2–1.5
R–C$\mathbf{H}$R$_2$	1.5–2.0
R–C≡C–**H** (alkyne)	2.0–3.1
–CO–C$\mathbf{H}_2$– (aldehydes, ketones or esters)	2.1-2.7
R–C$\mathbf{H}_2$–NH_2	2.4–3.0
R–C$\mathbf{H}_2$–X (X = F, Cl, Br, I)	3.0–4.5
–C$\mathbf{H}_2$–O– (alcohols, ethers or esters)	3.3–4.8
R–O**H**	1–6
R–N$\mathbf{H}_2$	1–5
R$_2$C=C**H**R (alkene)	4.5–7.0
R–COON**H**–R (amide)	5–9
Ar-**H** (aromatic)	6.9–9.0
R–C**H**O (aldehyde)	9.4–10.0
R–COO**H**	9.0–13.0

only CH_3 near $\overset{O}{\overset{\|}{C}}$.

shift means $CH_2-O-\overset{O}{\overset{\|}{C}}$

not an aldehyde.

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 ethyl ethanoate • Clear and logical justification with reference to all 4 spectra • Eliminates alternatives e.g. methyl propanoate using proton NMR or MS
6	• As for 7 marks less 1 point (usually alternatives)
4-5	• Correctly relates most spectral data to structure drawn, even if incorrect structure has been given
3	• Identifies information from all 4 spectra
1-2	• Identifies some relevant information from any spectra.

Marked holistically

MP = did not justify why the structure is not methyl propanoate

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.