SYDNEY GRAMMAR SCHOOL

2019
TRIAL EXAMINATION

CHEMISTRY
Form VI

STRUCTURE OF PAPER

SECTION I Pages 3-10

A: Multiple Choice 20 marks

Allow about 30 minutes for this section.

SECTION II Pages 11-32 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE: **Friday 9th 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 SEPARATE SECTION.

Authors: EJS, AKBB, CRMR, MTK, BED Master in charge: EJS

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SECTION I : MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following statements about collision theory is ALWAYS true?

(A) An increase in temperature will increase the chance of collision and therefore result in more products being formed.

(B) Increasing the rate of collisions increases reaction rate.

(C) A catalyst will increase the rate of collisions between reactant particles.

(D) The greater the energy of collision, the less likely a reaction will occur.

2 Consider the equilibrium system below:

$$wW + xX \rightleftharpoons yY + zZ$$

At equilibrium, which of the following statements is true?

(A) $w + x = y + z$

(B) $[W] + [X] = [Y] + [Z]$

(C) the forward rate of reaction = the reverse rate of reaction

(D) the forward activation energy = the reverse activation energy

3 The immediate effect of increasing the temperature of an equilibrium system will be:

(A) an increase in the rate of the endothermic reaction and a decrease in the rate of the exothermic reaction.

(B) an increase in the rate of both the endothermic and exothermic reactions.

(C) an increase in the activation energy of both the endothermic and exothermic reactions.

(D) an increase in the activation energy of the endothermic reaction and a decrease the activation energy of the exothermic reaction.

4 Which of the following will change the value of the equilibrium constant (K_{eq}) for a gaseous reaction?

(A) Addition of heat.

(B) Addition of a catalyst.

(C) Addition of a reactant.

(D) Addition of an inert gas at a constant volume.

5 What is the correct equilibrium expression for the reaction shown below?

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g) + 92\ kJmol^{-1}$$

(A) $K_{eq} = \frac{[NH_3]^2[92]}{[N_2][H_2]^3}$

(B) $K_{eq} = \frac{[2NH_3][92]}{[N_2][3H_2]}$

(C) $K_{eq} = \frac{[2NH_3]}{[N_2][3H_2]}$

(D) $K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$

6 A saturated solution of AgCl is maintained at a constant temperature. Solid soluble NaCl is added to this solution. What happens to the Ag^+ and Cl^- ion concentrations in the resultant solution compared to the initial solution?

(A) Ag^+ concentration increases and Cl^- concentration remains the same

(B) Ag^+ concentration increases and Cl^- concentration increases

(C) Ag^+ concentration decreases and Cl^- concentration increases

(D) Ag^+ concentration decreases and Cl^- concentration remains the same

7 If HCl and H_2O react with each other in an acid-base reaction to form their Bronsted-Lowry conjugates, the products would be:

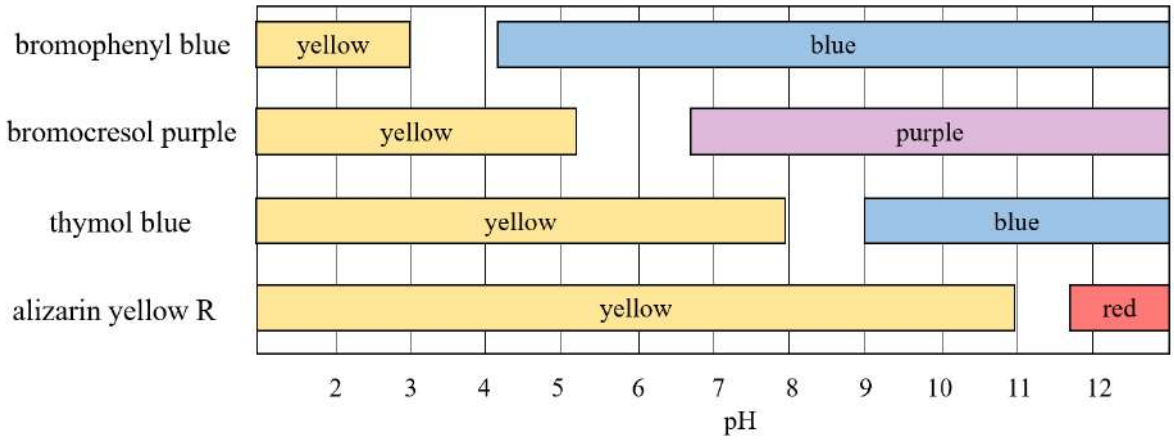
(A) HCl and H_3O^+

(B) Cl^- and OH^-

(C) H_2, Cl_2 and OH^-

(D) Cl^- and H_3O^+

8 The graph below shows four indicators and their colours at different pH values.



Which indicator would be most appropriate for a titration between dilute KOH and dilute propanoic acid?

(A) bromophenyl blue

(B) bromocresol purple

(C) thymol blue

(D) alizarin yellow R

9 As a solution of NaOH is gradually added to a solution of HCl at a constant temperature, the product of $[H_3O^+][OH^-]$

(A) increases

(B) decreases

(C) remains constant

(D) fluctuates depending on the rate that the NaOH is added

10 If a solution (at 298 K) has a hydroxide concentration of 1×10^{-9} M, then this solution will be:

(A) basic with a pH of 9.

(B) basic with a pH of 5.

(C) acidic with a pH of 9.

(D) acidic with a pH of 5.

11 Which of the following combinations will form a buffer solution?

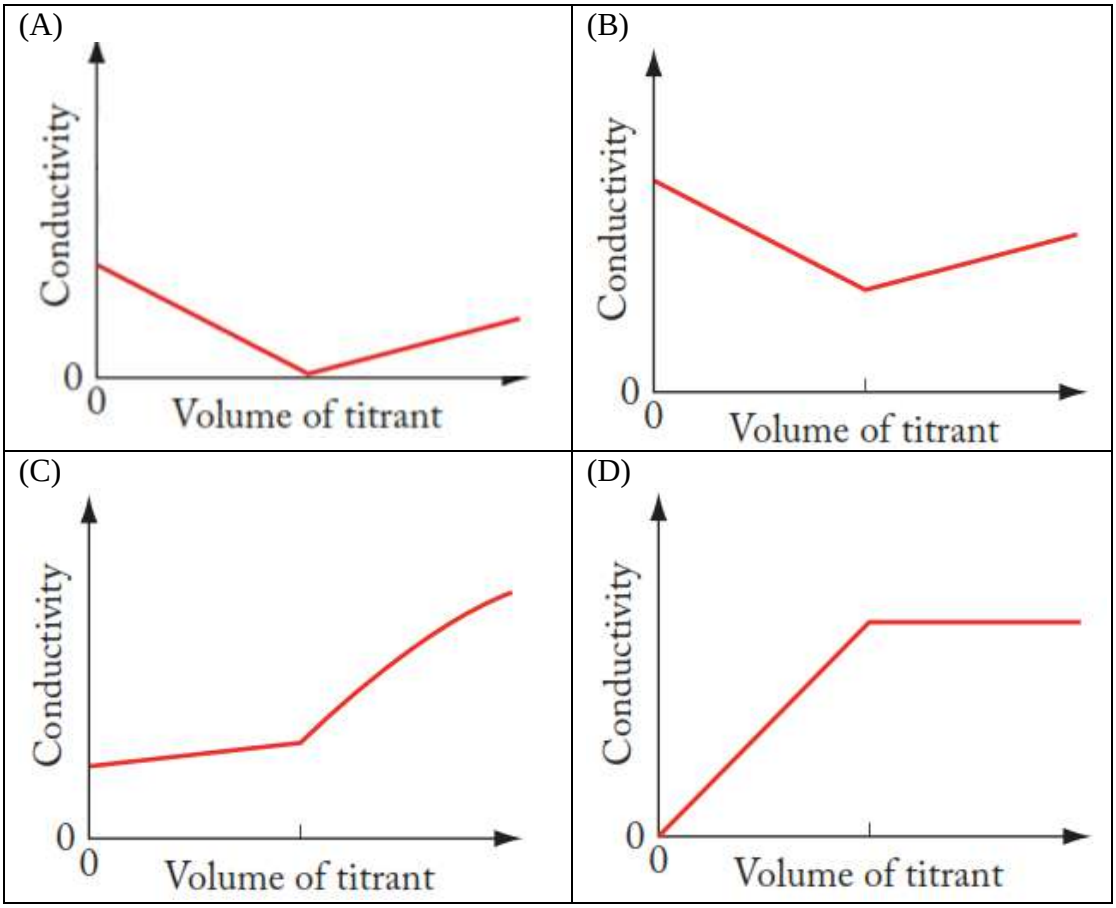
(A) NaOH (aq) / Na^+ (aq)

(B) $H_2PO_4^-$ (aq) / HPO_4^{2-} (aq)

(C) HNO_3 (aq) / NO_3^- (aq)

(D) H_2O (l) / H_3O^+ (aq)

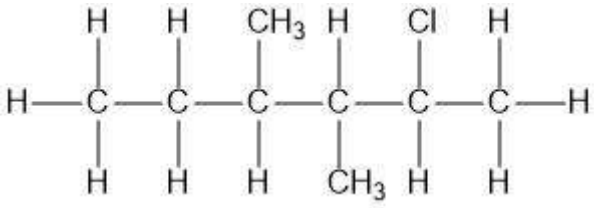
12 Which of the following conductivity curves correctly depicts the titration of hydrochloric acid against potassium hydroxide?



13 Which of the following correctly identifies the molecular geometry of the central carbon atom?

	Compound	**Geometry**
(A)	propyne	bent
(B)	propane	trigonal pyramidal
(C)	methanal	trigonal planar
(D)	methanol	linear

14 What is the IUPAC name for the following organic compound?



(A) 2-chloro-3,4-dimethylhexane

(B) 5-chloro-3,4-dimethylhexane

(C) 2-chloro-4-ethyl-3-methylpentane

(D) 4-chloro-2-ethyl-3-methylpentane

15 Concentrated sulfuric acid can be used as a catalyst for which of the following reactions?

(A) hydration of alkenes

(B) combustion of alkanes

(C) substitution of alcohols

(D) dehydration of alcohols

16 What is the minimum mass of glucose required to produce 10.0 g of ethanol by fermentation?

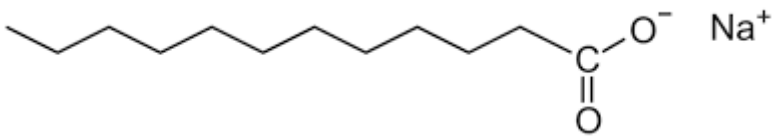
(A) 19.6 g

(B) 23.5 g

(C) 29.3 g

(D) 39.1 g

17 The substance shown below is an example of:



(A) a soap.

(B) an ester.

(C) a cationic detergent.

(D) a long chain fatty acid.

18 Which of the following tests is the best choice to identify the presence of an alkene?

(A) Lucas test

(B) silver mirror test

(C) bromine water test

(D) ceric ammonium nitrate test

19 How many **hydrogen** environments are there in propan-2-ol?

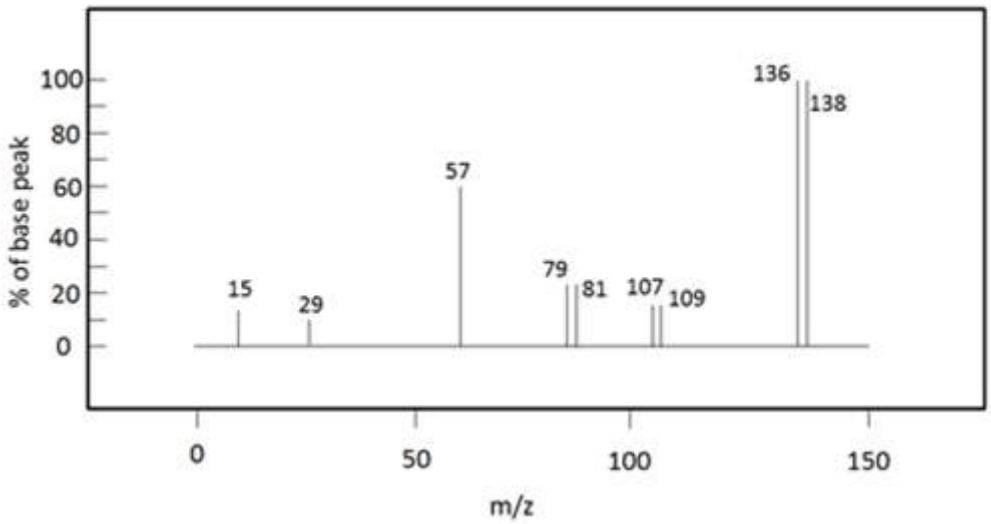
(A) 2

(B) 3

(C) 4

(D) 5

20 The mass spectrum of an unknown compound was produced and is shown below.



Which of the following could be the unknown compound?

(A) 2-chlorobutane

(B) 1-bromobutane

(C) 1-bromobut-1-ene

(D) 1,1-dichloropent-1-ene

CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 21 (2 marks) **Marks**

Write balanced chemical equations for the following reactions.

(a) Dilute sulfuric acid reacts with solid sodium carbonate.

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(b) Magnesium is added to dilute hydrochloric acid.

..... **1**

Question 22 (2 marks)

From the following list of chemicals, H_2CO_3 (aq), HBr (aq), LiOH (aq), $NaNO_3$ (aq), complete the table below, using each of the four chemicals once only.

Chemical	Acid/Base Properties
	a base
	a strong acid
	no acid-base properties
	a weak acid

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Question 23 (3 marks)

Explain the amphiprotic nature of sodium hydrogencarbonate. Include balanced chemical equations in your answer.

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Question 24 (3 marks)

If 100.0 mL of 0.065 M NaOH is mixed with 400.0 mL of 0.08 M $CaCl_2$ at 25 °C, will a precipitate of $Ca(OH)_2$ be produced? Support your answer with relevant calculations.

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Question 25 (3 marks) **Marks**

Describe what is meant by the terms open and closed chemical systems and explain why it is much harder to achieve an equilibrium in an open system than in a closed system.

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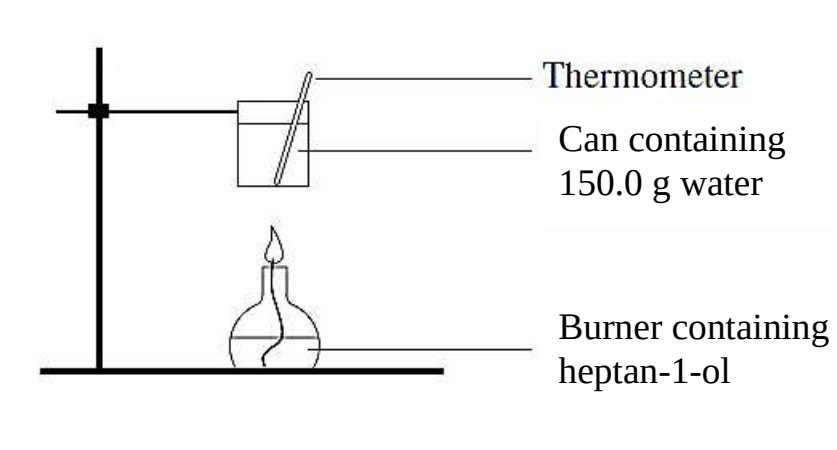
Question 26 (5 marks) **Marks**

150.0 g of water was heated in a calorimeter (as shown below) to measure the heat of combustion of heptan-1-ol. The initial temperature of the water was 20.0 °C, the final temperature was 63.0 °C and the mass of heptan-1-ol burnt was 0.750 g. Using this information answer the following questions.



(a) Write a balanced chemical equation for the complete combustion of heptan-1-ol.

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(b) Calculate the enthalpy of combustion measured for heptan-1-ol.

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CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 27 (11 marks) **Marks**

At high temperatures, sulfur dioxide gas reacts with oxygen gas to produce sulfur trioxide gas in an equilibrium reaction.

(a) Write a balanced chemical equation for this process.

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(b) Using collision theory and reaction rates, explain how this system at equilibrium would respond to a decrease in volume.

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(c) Sulfur dioxide and oxygen were placed in a 2.00 L vessel at 1200 K. After equilibrium was established, the vessel was found to contain 2.00 moles of sulfur dioxide, 0.400 moles of oxygen and 2.80 moles of sulfur trioxide.

Calculate K_{eq} for this reaction at 1200 K.

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Question 27 continued on next page.

Question 27 continued.

(d) The system in (c) was then heated to 1500 K, and once equilibrium was re-established the concentration of sulfur dioxide was found to be 1.20 M.

i. Is the forward reaction exothermic or endothermic?

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ii. Calculate K_{eq} for this reaction at 1500 K.

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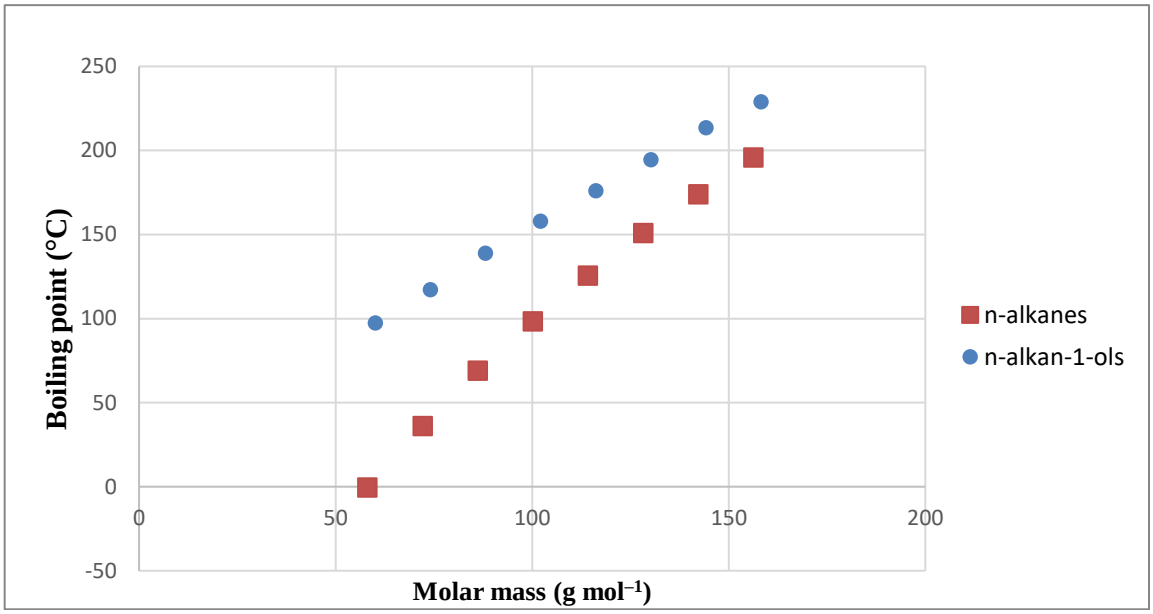
Question 28 (4 marks) **Marks**

Explain the trends in boiling point shown in the graph below for alkanes and alcohols (alkanols).



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CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 29 (4 marks) **Marks**

Calculate the final pH (at 298 K) after 40.00 mL of 0.0250 M barium hydroxide is added to 50.00 mL of 0.0100 M hydrochloric acid.

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Question 30 (3 marks)

The K_a of hydrocyanic acid (HCN) at 298 K is 6.17×10^{-10}. Calculate the pH of a 0.200 M solution of hydrocyanic acid at this temperature.

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Question 31 (7 marks)

Consider the following thermodynamic data for the dissolution of potassium chloride in water at 25 °C.

$\Delta_r H^\ominus$ (kJ mol^{-1})	$\Delta_r S^\ominus$ (J K^{-1} mol^{-1})
16.3	76.3

With reference to this data and the resultant $\Delta_r G^\ominus$, describe and analyse the processes involved when potassium chloride dissolves in water at 25 °C. Include a diagram in your answer.

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CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 32 (6 marks)

A 1.746 g sample of fertiliser contains nitrogen as ammonium sulfate. The sample was analysed to determine the nitrogen composition. First, it reacted with excess sodium hydroxide as per the reaction below,

$$(NH_4)_2SO_4\,(s) + 2NaOH\,(aq) \rightarrow Na_2SO_4\,(aq) + 2H_2O\,(l) + 2NH_3\,(g)$$

The ammonia gas produced from this reaction reacted with 50.0 mL of 2.00 M hydrochloric acid by bubbling it through the acid. The excess hydrochloric acid was titrated with 2.00 M sodium hydroxide solution. The results from this titration are below;

	Titre 1 (mL)	Titre 2 (mL)	Titre 3 (mL)	Titre 4 (mL)
Sodium hydroxide	37.9	36.9	37.0	36.8

(a) Write the equation for the reaction between hydrochloric acid and ammonia.

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(b) Calculate the moles of sodium hydroxide used in the titration.

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(c) Calculate the percentage of nitrogen by mass in the original fertiliser sample.

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Question 33 (2 marks) **Marks**

Complete the following chemical reactions using structural formulae of all organic reactant/s and/or organic product/s.

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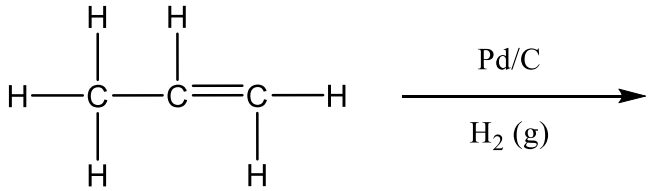
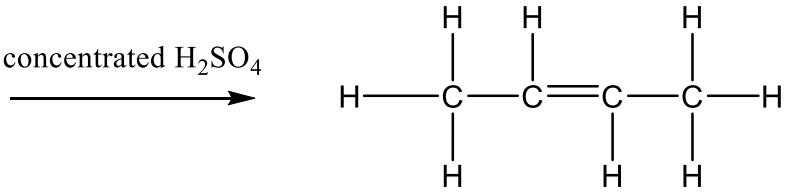


1

(b)



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Question 34 (6 marks) **Marks**

A chemist needed to prepare ethyl ethanoate in the laboratory. They had access to all of the reagents and equipment that you have studied in this course, as well as a supply of chloroethane.

In the space below, show how the chemist could prepare ethyl ethanoate from chloroethane as the ONLY organic reagent. Write equations using structural formulae showing the reactant/s, product/s and all necessary reagents.

6

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CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 35 (6 marks) **Marks**

The use of materials such as polymers are determined by the relationship between their structure and their properties.

Discuss this statement by comparing TWO polymers that you have studied. Include relevant diagrams in your answer.

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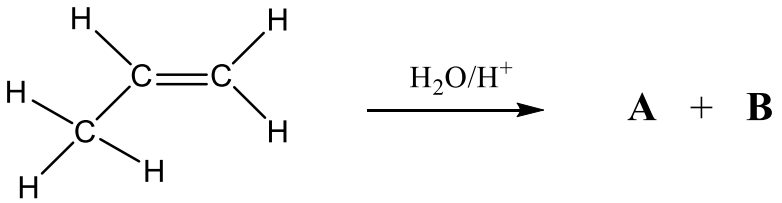
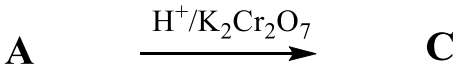
Question 36 (8 marks) **Marks**

A chemist bubbled gaseous propene through a dilute acidic solution and found that two organic products (**A** and **B**) were formed as shown below.



A and **B** were separated, and then a further reaction was performed on **A**. **A** was added to a solution of acidified potassium dichromate, producing a single organic product (**C**) as shown below.

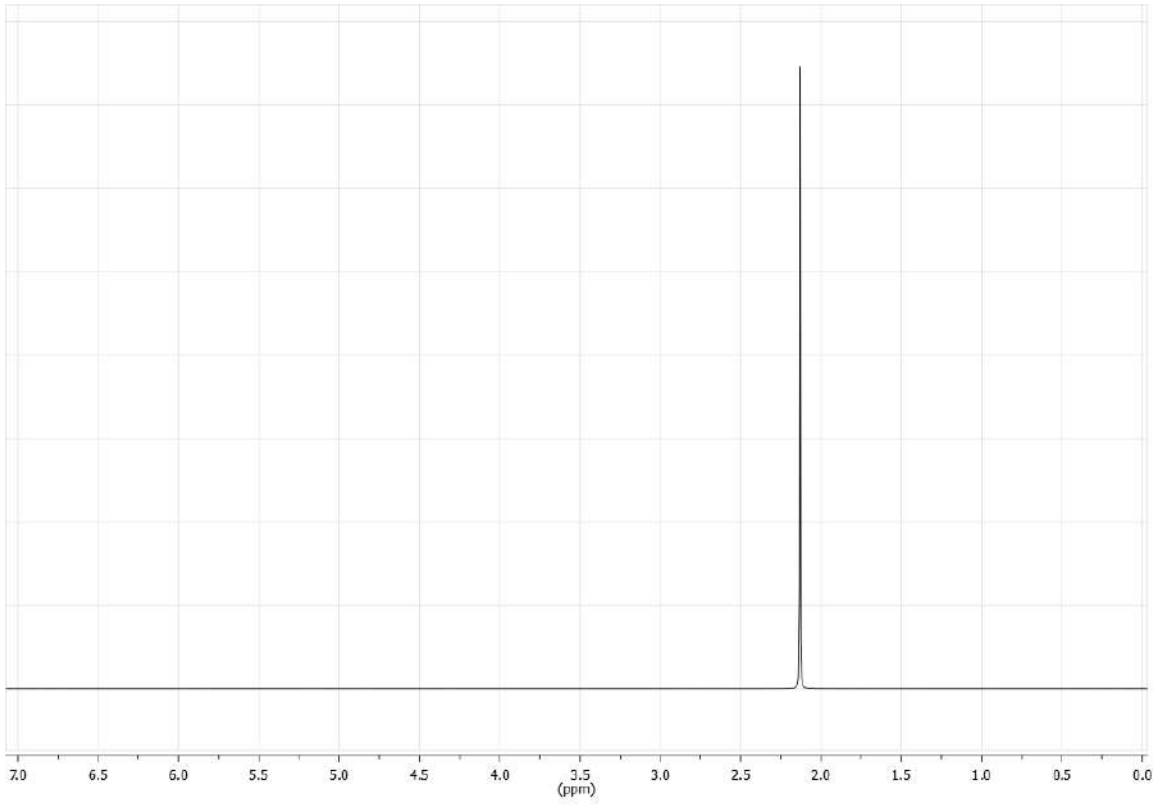


The chemist performed ^{1}H and ^{13}C NMR on compound **C**, and produced the two spectra shown over the page.

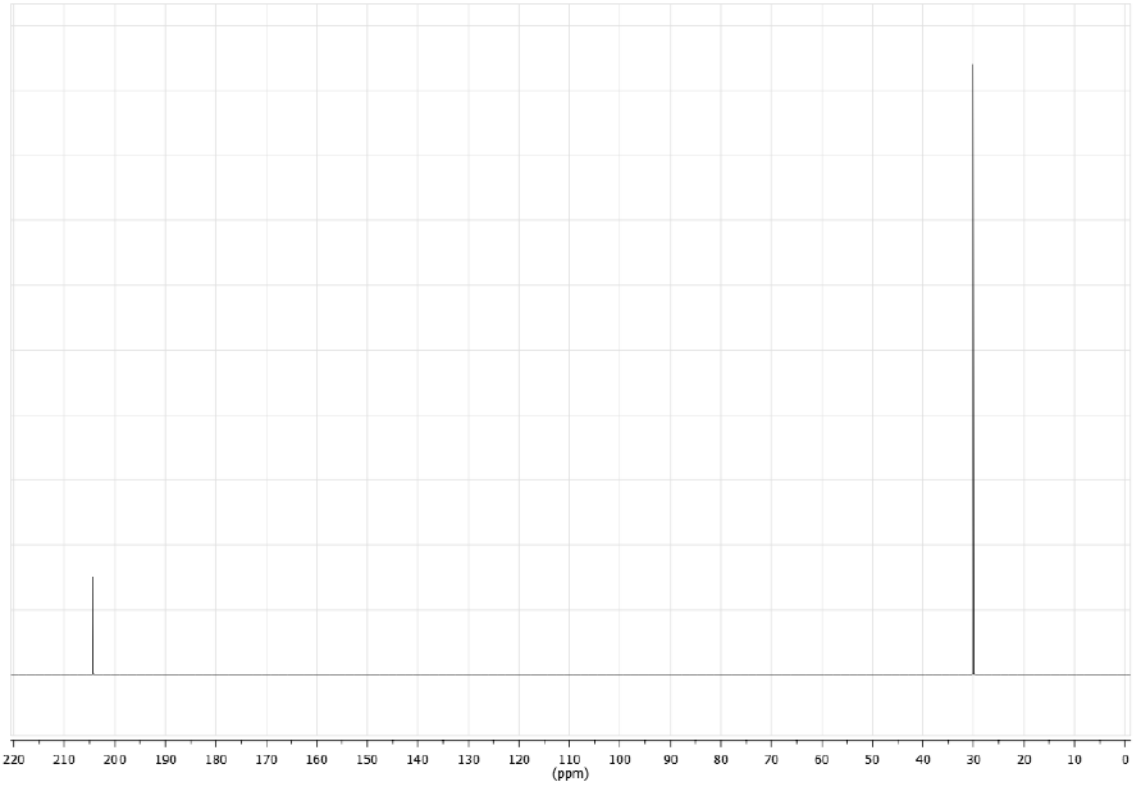
Question 36 continued on next page.

Question 36 continued.

^{1}H NMR



^{13}C NMR



Question 36 continued on next page.

Question 36 continued.

(a) Use this information to draw the structural formulae of **A**, **B** and **C**, and give the IUPAC name of each compound.

A:

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B:

.....

C:

..... **6**

Question 36 continued on next page.

Question 36 continued.

(b) Identify a test that could be used to directly distinguish between **A** and **B**, and state the expected results of this test.

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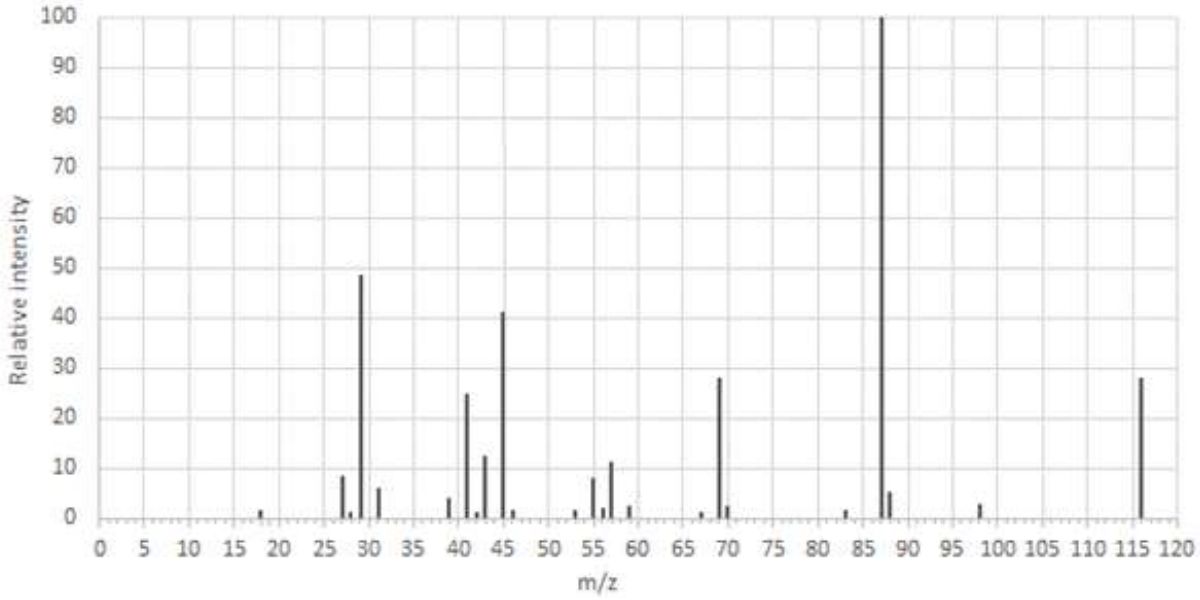
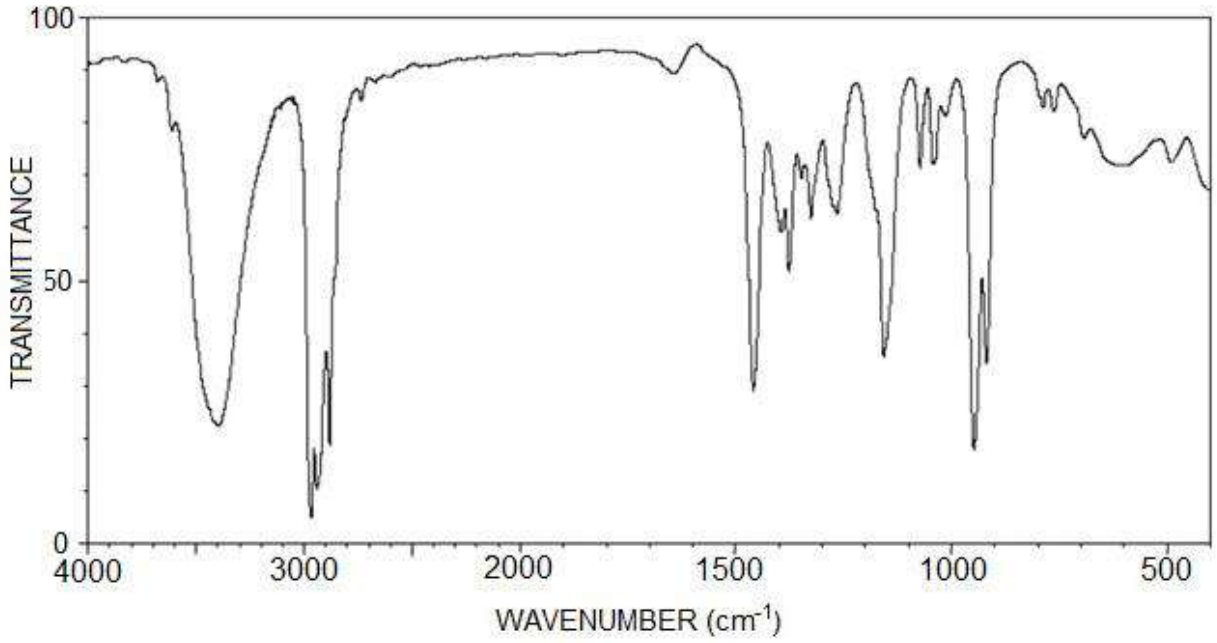
Question 37 (5 marks) **Marks**

The following four spectra (MS, IR, ^{1}H NMR and ^{13}C NMR) were collected for a single organic compound.

MS



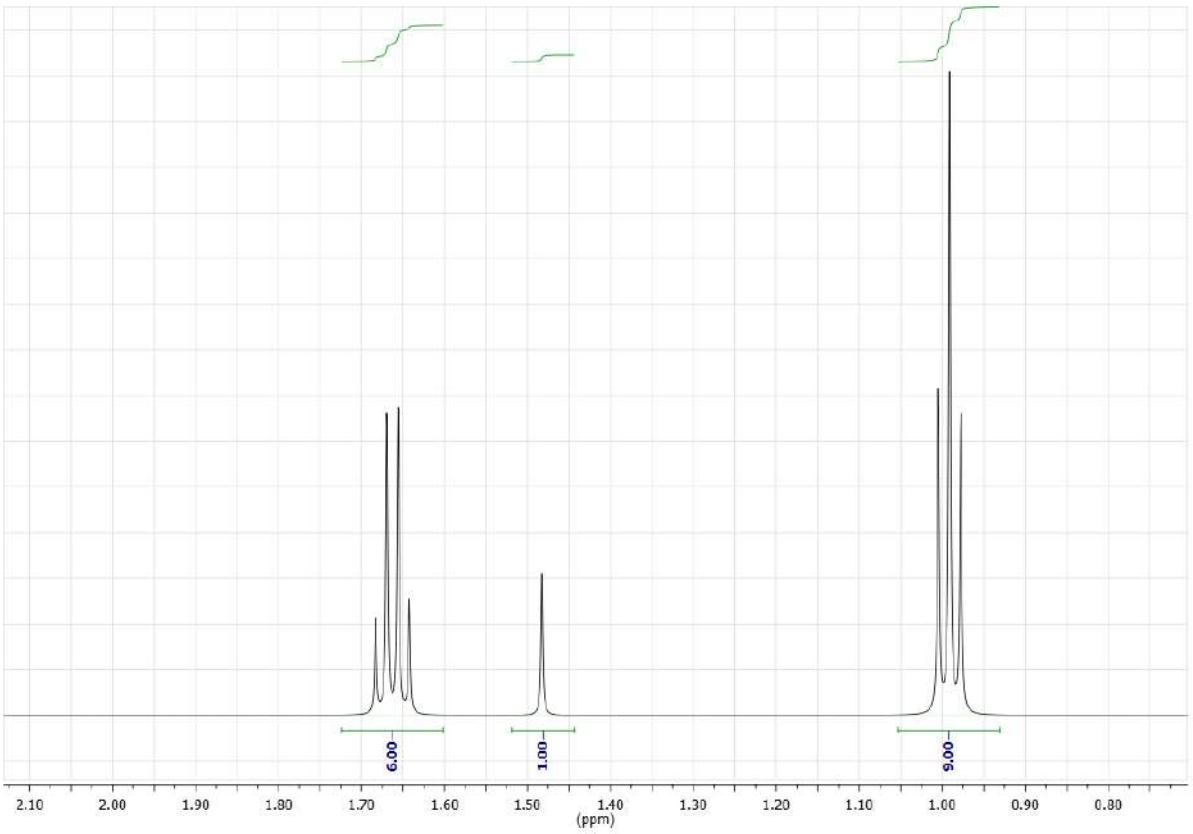
IR



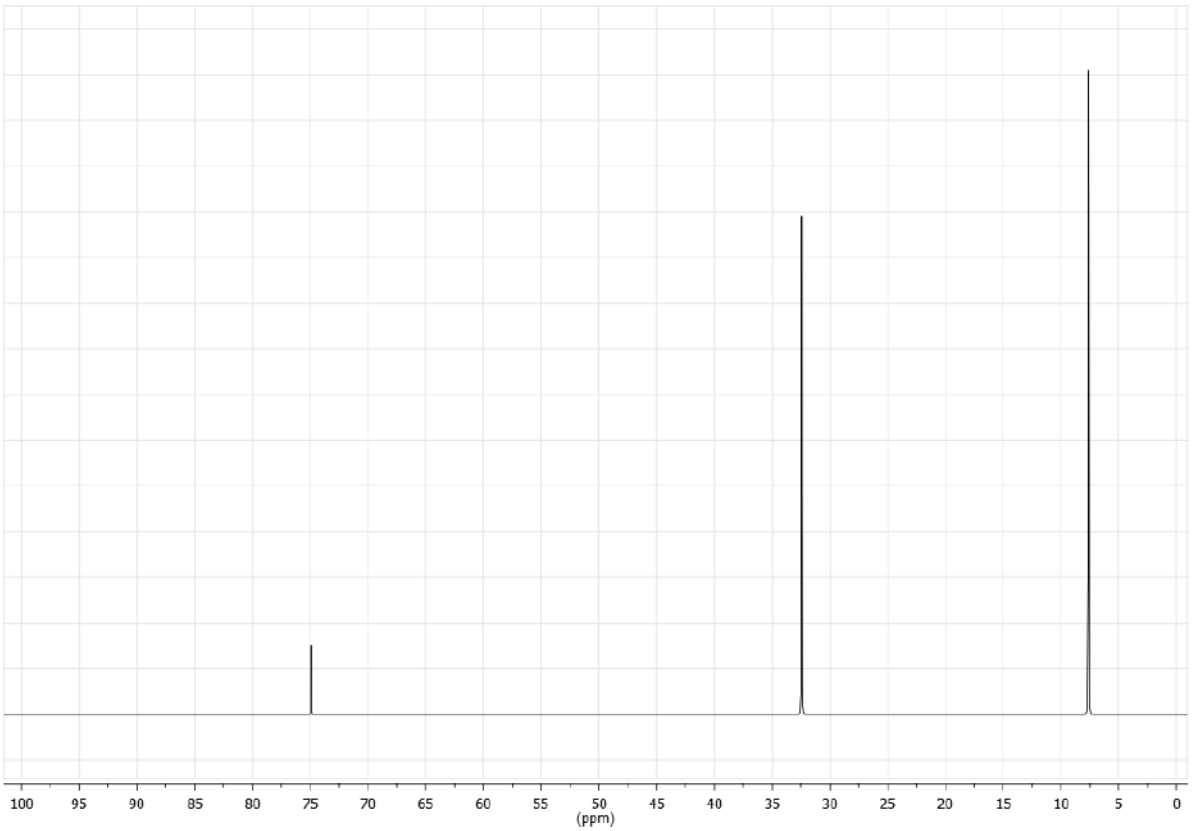
Question 37 continued on next page.

Question 37 continued.

^{1}H NMR



^{13}C NMR



Question 37 continued on next page.

Question 37 continued.

(a) Identify the functional group that produces the 3400 cm^{-1} peak seen in the IR spectrum.

..... **1**

(b) What is the mass of the molecular ion?

..... **1**

(c) How many **carbon** environments are there in this compound?

..... **1**

(d) Draw the structural formula of this compound.

2

END OF EXAMINATION

Chemistry

FORMULAE SHEET

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

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

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

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

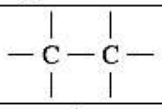
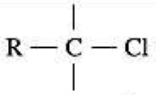
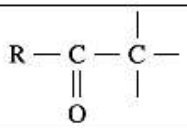
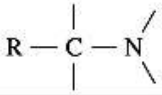
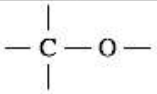
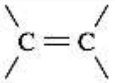
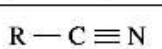
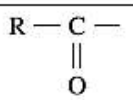
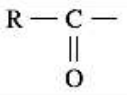
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	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

2019
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 ○

CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 21 (2 marks) **Marks**

Write balanced chemical equations for the following reactions.

(a) Dilute sulfuric acid reacts with solid sodium carbonate.

$H_2SO_{4(aq)} + Na_2CO_{3(s)} \longrightarrow H_2O_{(l)} + CO_{2(g)} + Na_2SO_{4(aq)}$ 1

(b) Magnesium is added to dilute hydrochloric acid.

$Mg_{(s)} + 2\,HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$ 1

Question 22 (2 marks)

From the following list of chemicals, H_2CO_3 (aq), HBr (aq), LiOH (aq), $NaNO_3$ (aq), complete the table below, using each of the four chemicals once only.

Chemical	Acid/Base Properties
LiOH	a base
HBr	a strong acid
$NaNO_3$	no acid-base properties
H_2CO_3	a weak acid

all 4 correct for 2 marks
2-3 " 1 mark
1-0 " 0 marks

2

Question 23 (3 marks)

Explain the amphiprotic nature of sodium hydrogencarbonate. Include balanced chemical equations in your answer.

3

① amphiprotic means it can accept or Donate protons/hydrogen ions.

① ∴ Acts as an acid or a base with

① linking correct, balanced equations

Note: hydrogen is not accepted also many boys have significant errors in their equations. $NaH_2CO_3^+$ - does not happen.

Question 24 (3 marks)

If 100.0 mL of 0.065 M NaOH is mixed with 400.0 mL of 0.08 M $CaCl_2$ at 25 °C, will a precipitate of $Ca(OH)_2$ be produced? Support your answer with relevant calculations.

3

2 methods

① 1st

① $n_{OH^-} = 0.0065$ $[OH^-]_{500} = 0.013M$

$n_{Ca^{2+}} = 0.032$ $[Ca^{2+}]_{500} = 0.064M$

① $Q_{sp} = [OH^-]^2[Ca^{2+}]$

$= 0.013^2 \times 0.064$

$= 1.082 \times 10^{-5}$

① $Q_{sp} > K_{sp}$

∴ precipate of $Ca(OH)_2$ will form

2nd

$Ca(OH)_{2(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2OH^-_{(aq)}$

① $K_{sp} = x \cdot (2x)^2$

$5.02 \times 10^{-6} = 4x^3$

$x = 1.08 \times 10^{-2}$

① ∴ Molar solubility is 1.08×10^{-2}

$[Ca^{2+}] = 0.064M$ $[OH^-] = 0.013M$

① Both concentrations are larger ∴ precipitate forms.

Question 25 (3 marks) **Marks**

Describe what is meant by the terms open and closed chemical systems and explain why it is much harder to achieve an equilibrium in an open system than in a closed system.

3

max 2 marks

(2) marks for a detailed explanation on Open and Closed system including matter & Energy transfer

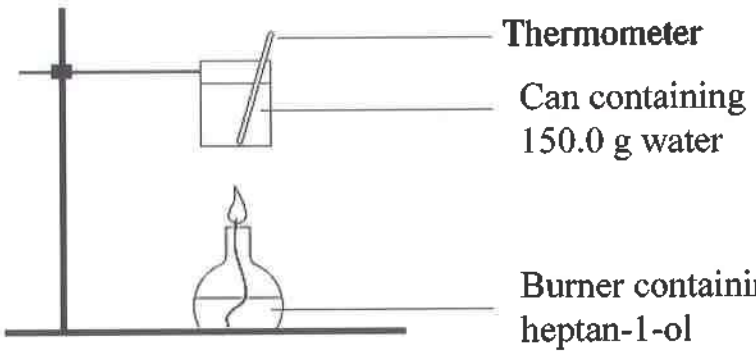
(1) mark only if details and clarity are lacking.
↳ Poor explanation

(1) • Explaining why it is easier to achieve equilibrium in a closed system - Linking to matter movement.

It is important to note that in a closed system matter can not be exchanged but Energy can.

Question 26 (5 marks) **Marks**

150.0 g of water was heated in a calorimeter (as shown below) to measure the heat of combustion of heptan-1-ol. The initial temperature of the water was 20.0 °C, the final temperature was 63.0 °C and the mass of heptan-1-ol burnt was 0.750 g. Using this information answer the following questions.



Note a few boys were confused between C_6 & C_7.

(a) Write a balanced chemical equation for the complete combustion of heptan-1-ol. **1**

either $C_7H_{16}O_{(l)} + 10\,H_2O_2 \longrightarrow 7CO_2 + 8H_2O$

$2C_7H_{16}O + 21O_2 \longrightarrow 14CO_2 + 16H_2O$.

(b) Calculate the enthalpy of combustion measured for heptan-1-ol. **4**

① $q = mc\Delta T$

$= 150 \times 4.18 \times (63-20)$

$= 26961$ J

① $n_{C_7} = \frac{0.750}{116.198}$

$= 0.00645467$

① $\Delta H = \frac{-q}{n}$

$= \frac{-26961}{0.00645467}$

$= -4176.97$ kJ mol^{-1}

$= -4180$ kJ mol^{-1}

① 3 sig. fig.

Note many tried using moles of water produced and put mass of fuel into q

XUBB

CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 27 (11 marks) **Marks**

At high temperatures, sulfur dioxide gas reacts with oxygen gas to produce sulfur trioxide gas in an equilibrium reaction.

(a) Write a balanced chemical equation for this process.

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ (1)

(b) Using collision theory and reaction rates, explain how this system at equilibrium would respond to a decrease in volume.

(1) Decrease in volume leads to more collisions V.C↑ 3

(1) both forward & reverse rates increase, but (initially) there will be a greater increase in the forward direction F↑>R↑

(1) This causes the equilibrium to shift to the right ⇌→

(c) Sulfur dioxide and oxygen were placed in a 2.00 L vessel at 1200 K. After equilibrium was established, the vessel was found to contain 2.00 moles of sulfur dioxide, 0.400 moles of oxygen and 2.80 moles of sulfur trioxide.

Calculate K_{eq} for this reaction at 1200 K.

$[SO_3] = \frac{2.8}{2} = 1.4M$ $[SO_2] = \frac{2}{2} = 1M$ $[O_2] = \frac{0.4}{2} = 0.2$ (1) 3

$K = \frac{[SO_3]^2}{[SO_2]^2 \cdot [O_2]}$ (1) $= \frac{1.4^2}{1^2 \times 0.2}$ (1) $= 9.8$

Question 27 continued on next page.

Question 27 continued.

(d) The system in (c) was then heated to 1500 K, and once equilibrium was re-established the concentration of sulfur dioxide was found to be 1.20 M.

i. Is the forward reaction exothermic or endothermic?

exothermic 1

ii. Calculate K_{eq} for this reaction at 1500 K.

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ 3

	SO_2	O_2	SO_3	
I	1	0.2	1.4	-1 for each mistake (2)
C	+0.2	+0.1	-0.2	
E	1.2	0.3	1.2	

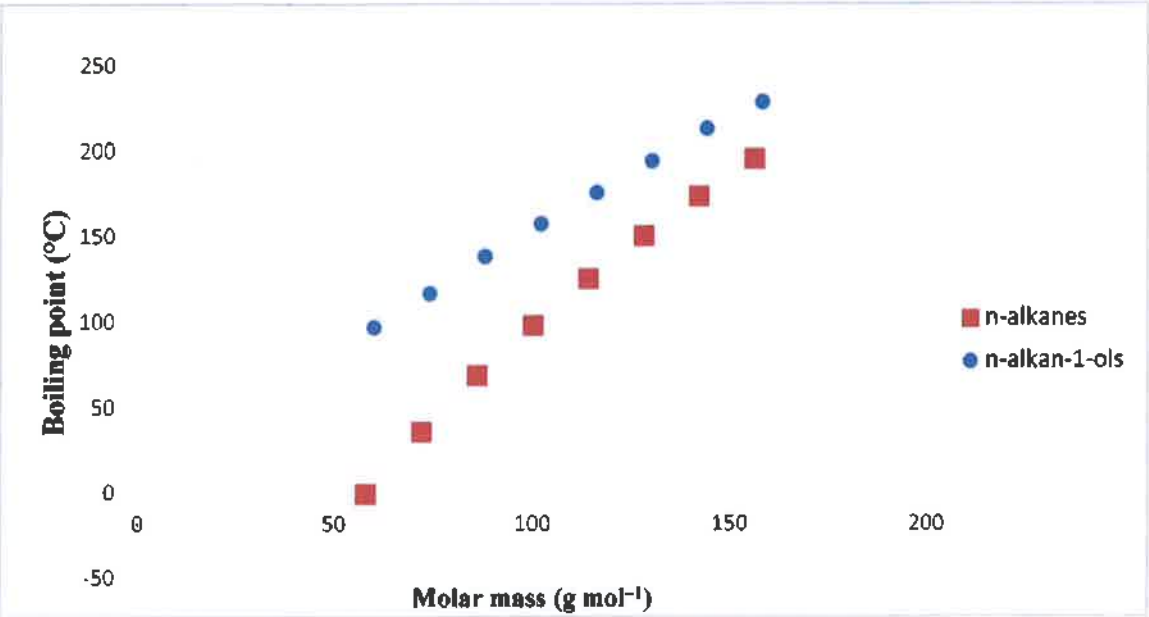
Values should be consistent with part c

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2 \cdot [O_2]}$$

$$= 3.33 \quad (1)$$

Question 28 (4 marks) **Marks**

Explain the trends in boiling point shown in the graph below for alkanes and alcohols (alkanols).



The stronger the bond the more energy (BP) is required to overcome them BE / BP

The larger the molecule the stronger the dispersion forces ↑Mm ↑E

Alkanols have strong H-bond as well as dispersion forces therefore have higher boiling points -OH E

The two paths converge as molar mass increases due to the diminishing influence of the hydrogen bonded -OH relative to the increasing dispersion forces. COM

4

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Question 29 (4 marks) **Marks**

Calculate the final pH (at 298 K) after 40.00 mL of 0.0250 M barium hydroxide is added to 50.00 mL of 0.0100 M hydrochloric acid.

$Ba(OH)_2 + 2HCl$

1 mark *$n(OH) = 2 \times 0.04 \times 0.025 = 2$ mmol*
$n(H) = 0.05 \times 0.01 = 0.5$ mmol

1 mark *$n(OH\ excess) = 2 - 0.5 = 1.5$ mmol*

1 mark *$[OH] = 1.5 \times 10^{-3} / ((40+50) \times 10^{-3}) = 1.667 \times 10\text{-}2$*
$pOH = 1.778$

1 mark *$pH = 14 - pOH = 12.222$* *(sig figs ignored)*

-1 each error except max 2 marks awarded if determined nothing was in excess and pH = 7.

* *too many boys used BaOH*
* *K_{sp} is not relevant as it is not saturated and question said it was in solution.*

Question 30 (3 marks)

The K_a of hydrocyanic acid (HCN) at 298 K is 6.17×10^{-10}. Calculate the pH of a 0.200 M solution of hydrocyanic acid at this temperature.

$HCN \rightarrow H^+ + CN^-$
$0.2 - x \quad x \quad x$

1 mark *$K_a = 6.17 \times 10^{-10} = [H^+][CN^-] / [HCN] = x^2 / 0.2\text{-}x$*

1 mark *assume x is small compared to 0.2:* *$x^2 = 6.17 \times 10^{-10} * 0.2$*
$x = 1.11 \times 10^{-5}$ (assumption was good)

1 mark *$pH = -\log_{10}[1.11 \times 10^{-5}] = 4.954$* *(sig figs ignored)*

-1 each error
* *most common error was to write K_{sp} equation – not K_a*

Question 31 (7 marks)

Consider the following thermodynamic data for the dissolution of potassium chloride in water at 25 °C.

$\Delta_r H^\ominus$ (kJ mol^{-1})	$\Delta_r S^\ominus$ (J K^{-1} mol^{-1})
16.3	76.3

With reference to this data and the resultant $\Delta_r G^\ominus$, describe and analyse the processes involved when potassium chloride dissolves in water at 25 °C. Include a diagram in your answer.

Marked holistically but roughly following codes explained missing / incomplete information:

P1 – describes breaking of KCl ionic lattice with polar water molecules

P2 – describes formation of ion-dipole hydration bonds with water

ΔH – explains breaking lattice is endothermic and not outweighed by release of energy when ion-dipoles formed, hence ΔH is positive

ΔS – explains entropy increase in terms of P1 AND P2.

ΔGC – calculates ΔG to be -6.4 kJ/mol (units ignored)

ΔGA – analyses contribution of ΔH and ΔS to ΔG i.e. enthalpy is unfavourable hence dissolving must be entropy-driven. ΔG being negative means spontaneous.

D – relevant and correct diagram

-1 for E – errors

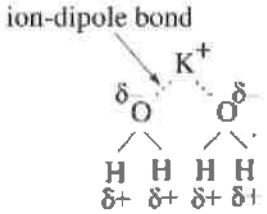
Note: many boys discussed equilibrium at length – but equilibrium is not reached until the solution is saturated. Given standard condition thermodynamic data was given, saturation would not be reached, so any answers about equilibrium were ignored.

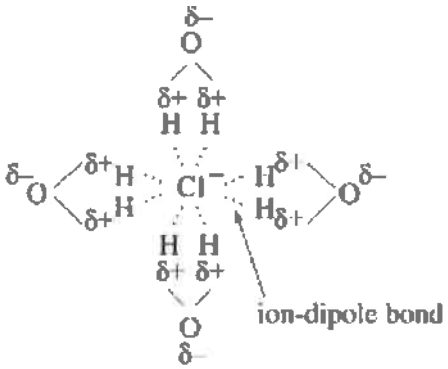
Some boys said that KCl would be insoluble – against the solubility rules and when the question says it dissolves.

Sample answer

Potassium chloride is an ionic solid that is soluble in polar water. To dissolve, the potassium and chloride ions must first be dissociated from each other. This process absorbs energy as it breaks the ionic bonds to overcome the electrostatic attraction. As the ions move from the ordered 3D lattice, entropy is increased. The next step is the organisation of water molecules around the dissociated ions. As shown in the diagram below, this hydration process involves ion-dipole forces forming as the slightly positive hydrogen atoms of water are attracted to the negative chloride ion, while the slightly negative oxygen atoms of water are attracted to the positive potassium ions. This step releases energy but reduces entropy.

Calculated $\Delta G = 16.3 - 298 * 76.3 / 1000 = -6.4$ kJ/mol.
Overall, as the positive ΔH data shows, the dissolution of KCl is endothermic, so the energy required to break the lattice must be greater than that released during the formation of the ion-dipole bonds. Thus ΔH is thermodynamically unfavourable. However, as entropy is positive, the breakdown of the lattice must be entropically greater than the rearrangement of water. Thus the dissolution is entropy-driven. This is shown in the calculated ΔG which is negative, leading to the dissolution being spontaneous at this temperature.





CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 32 (6 marks)

A 1.746 g sample of fertiliser contains nitrogen as ammonium sulfate. The sample was analysed to determine the nitrogen composition. First, it reacted with excess sodium hydroxide as per the reaction below,

$$(NH_4)_2SO_4\,(s) + 2NaOH\,(aq) \rightarrow Na_2SO_4\,(aq) + 2H_2O\,(l) + 2NH_3\,(g)$$

∴ 2×N N : NH_3 1 : 1

The ammonia gas produced from this reaction reacted with 50.0 mL of 2.00 M hydrochloric acid by bubbling it through the acid. The excess hydrochloric acid was titrated with 2.00 M sodium hydroxide solution. The results from this titration are below;

	Titre 1 (mL)	Titre 2 (mL)	Titre 3 (mL)	Titre 4 (mL)
Sodium hydroxide	37.9	36.9	37.0	36.8

omit

average = 36.9 mL

(a) Write the equation for the reaction between hydrochloric acid and ammonia. **1**

$HCl_{(aq)} + NH_{3(g)} \rightarrow NH_4Cl_{(aq)}$

↑ aq accepted

States marked

(b) Calculate the moles of sodium hydroxide used in the titration. **1**

$n = CV$

$= 2 \times 0.0369$

$= 0.0738$ mol

(c) Calculate the percentage of nitrogen by mass in the original fertiliser sample. **4**

$NaOH + HCl \rightarrow NaCl + H_2O$

$n HCl_{excess} = 0.0738$ mol

$n HCl_{initial} = CV$

$= 0.05 \times 2 = 0.1$ mol (1)

$n HCl_{reacted} = 0.1 - 0.0738$

$= 0.0262$ mol (1)

$n NH_3 = 0.0262$ mol

Using above equation,

$n NH_3 : n N$ is 1 : 1

∴ $n N = 0.0262$ mol (1)

$m N = 0.0262 \times 14.01$

$= 0.3671$ g

$\%N = 0.3671 / 1.746 \times 100$

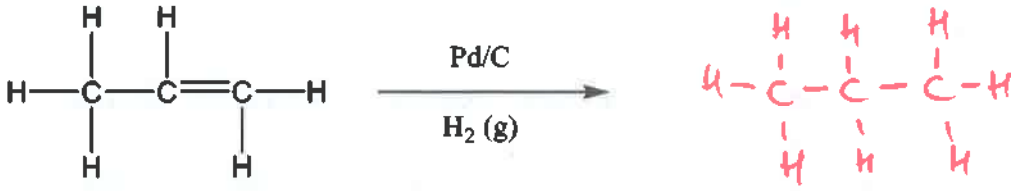
$= 21.0\%$ (1)

To get full C/O mark, you need to use the mass of N, not NH_3 or $(NH_4)_2SO_4$.

Question 33 (2 marks) **Marks**

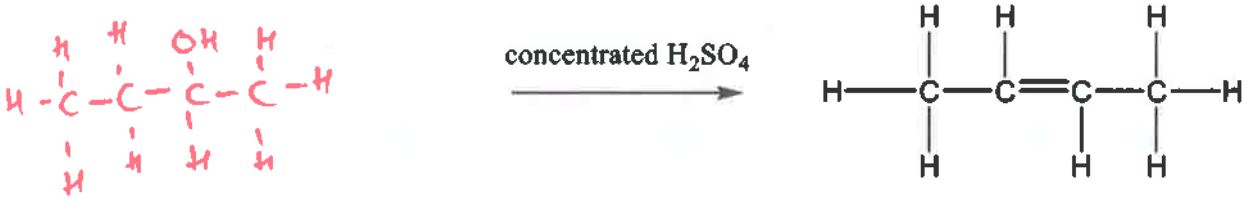
Complete the following chemical reactions using structural formulae of all organic reactant/s and/or organic product/s.

(a)



1

(b)



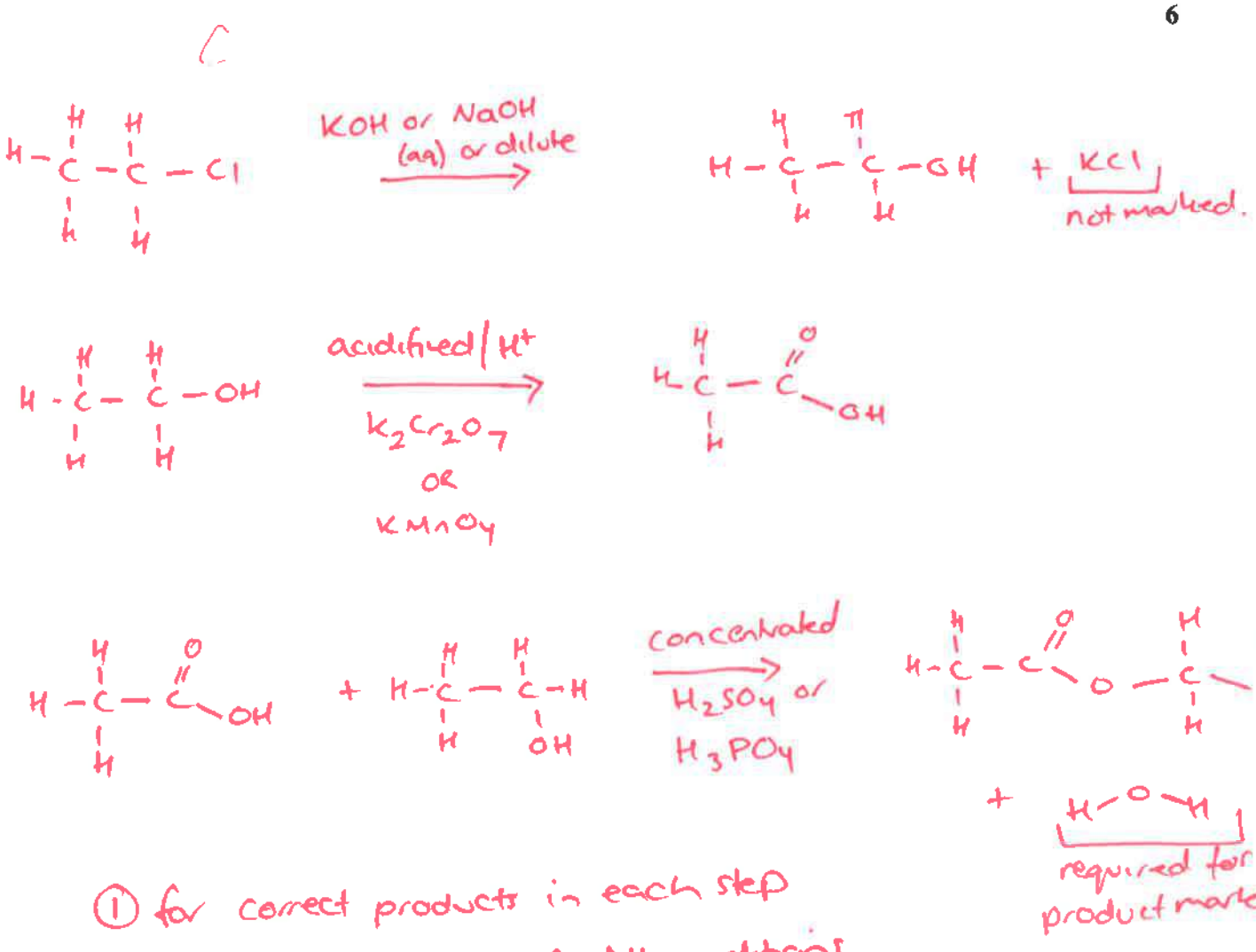
1

Question 34 (6 marks) **Marks**

A chemist needed to prepare ethyl ethanoate in the laboratory. They had access to all of the reagents and equipment that you have studied in this course, as well as a supply of chloroethane.

In the space below, show how the chemist could prepare ethyl ethanoate from chloroethane as the ONLY organic reagent. Write equations using structural formulae showing the reactant/s, product/s and all necessary reagents.

6



① for correct products in each step

① for correct conditions. All conditions in CRIB were required for the mark

eg. KOH was incorrect, KOH(aq) was correct

H_2SO_4 was incorrect, concentrated H_2SO_4 was correct.

CANDIDATE NUMBER

Attempt ALL Questions
Write your answer in the space provided

Question 35 (6 marks) **Marks**

The use of materials such as polymers are determined by the relationship between their structure and their properties.

Discuss this statement by comparing TWO polymers that you have studied. Include relevant diagrams in your answer.

Correct comparison of two polymers including comparison of: • Structures • Properties, clearly linked to structures • Use appropriate to relevant properties Includes a correct diagram of each polymer or monomer	6
Missing one or two of the above but must include comparison	4-5
Correct discussion, without comparison, of the two polymers including: • Structures • Properties, clearly linked to structures • Use appropriate to relevant properties Includes a correct diagram of each polymer or monomer OR Insufficient for 4 marks	3
Description/diagram of at least one polymer and EITHER a correct use OR correct properties	2
Correct relevant information about 1 polymer	1

Notes:

Many boys did three polymers (remember HDPE and LDPE are different polymers)

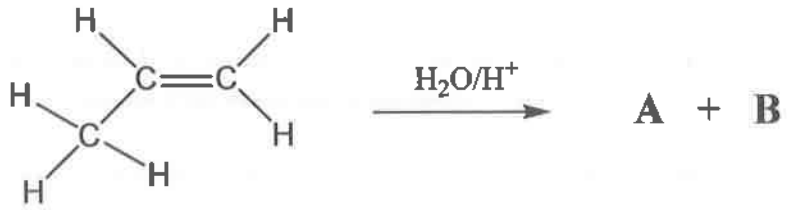
Many boys missed the link/relationship between the structure and the property.

The question asked for a comparison, so it helped to think carefully about the polymers chosen to make sure meaningful comparisons could be made.

Take care with diagrams! These need to be clear and accurate, not squashed in the corner with no labelling.

Question 36 (8 marks) **Marks**

A chemist bubbled gaseous propene through a dilute acidic solution and found that two organic products (**A** and **B**) were formed as shown below.



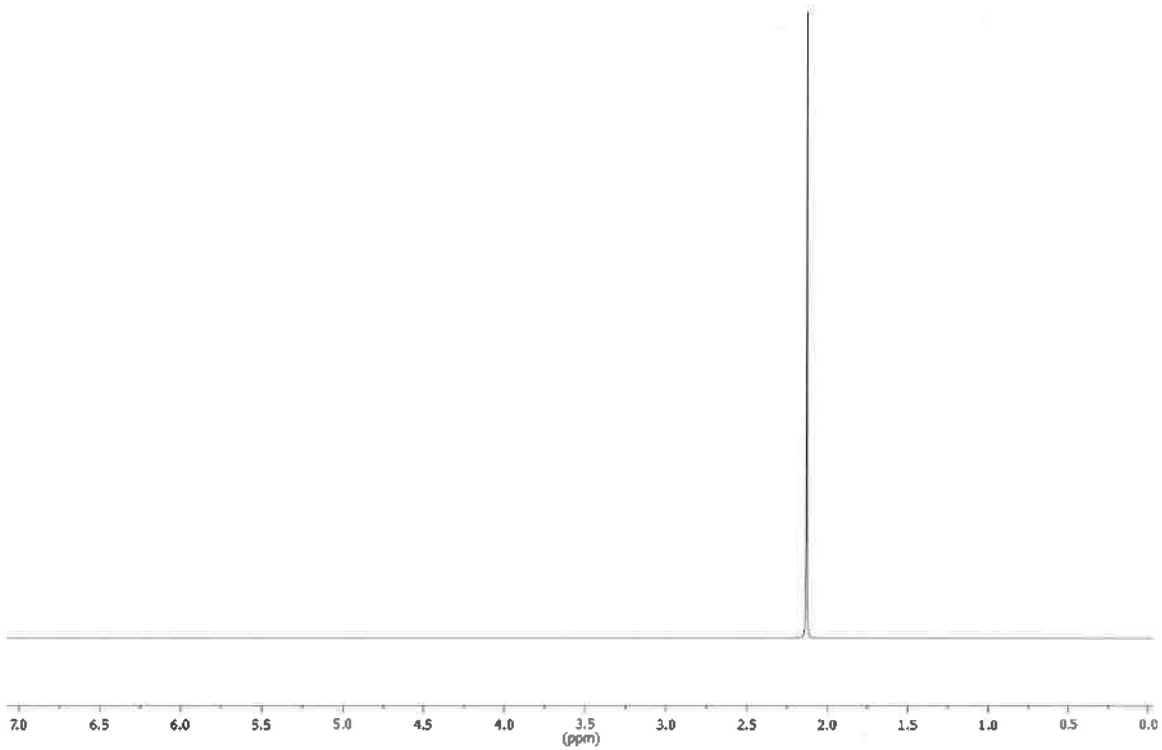
A and **B** were separated, and then a further reaction was performed on **A**. **A** was added to a solution of acidified potassium dichromate, producing a single organic product (**C**) as shown below.

The chemist performed ^1H and ^{13}C NMR on compound **C**, and produced the two spectra shown over the page.

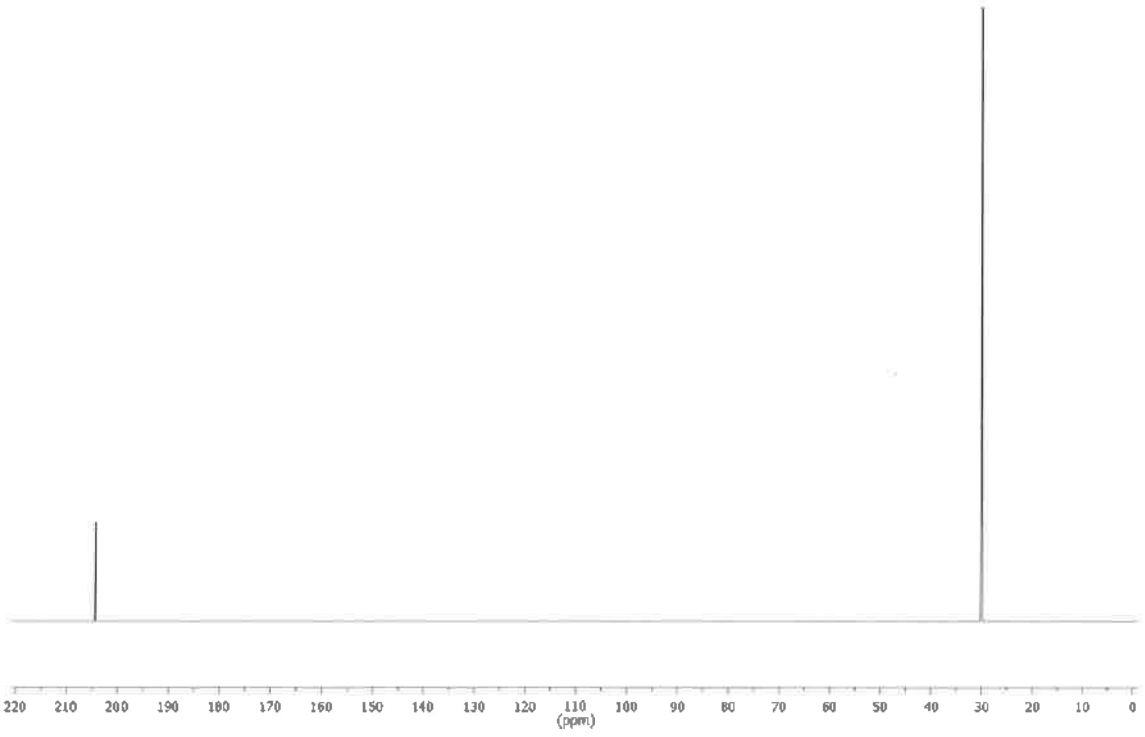
Question 36 continued on next page.

Question 36 continued.

^{1}H NMR



^{13}C NMR

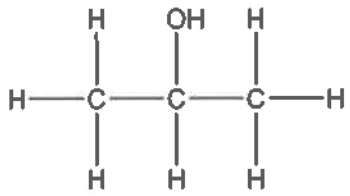


Question 36 continued on next page.

Question 36 continued.

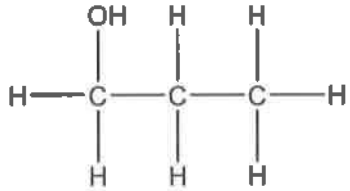
(a) Use this information to draw the structural formulae of **A**, **B** and **C**, and give the IUPAC name of each compound.

A:



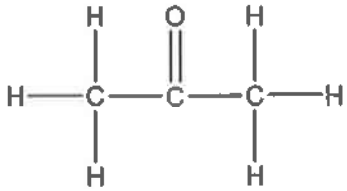
***Propan-2-ol*.....**

B:



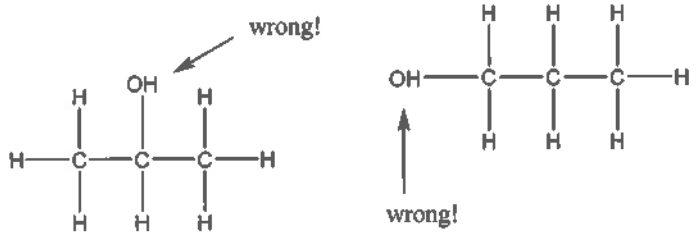
***Propan-1-ol*.....**

C:



Propanone (or propan-2-one) **6**

Note that a maximum of 1 mark across this section was lost for incorrectly drawing the hydroxyl group (if the mistake was made in Q36 and Q37, the mark was lost from Q37).



Question 36 continued on next page.

Question 36 continued.

(b) Identify a test that could be used to directly distinguish between **A** and **B**, and state the expected results of this test.

1 mark – identifying appropriate test (Lucas test or adding $ZnCl_2$/conc HCl) **2**

1 mark – Secondary alcohols (like A) will produce a turbid/cloudy solution within 30 min. Primary alcohols (like B) will not react so solution will remain clear.

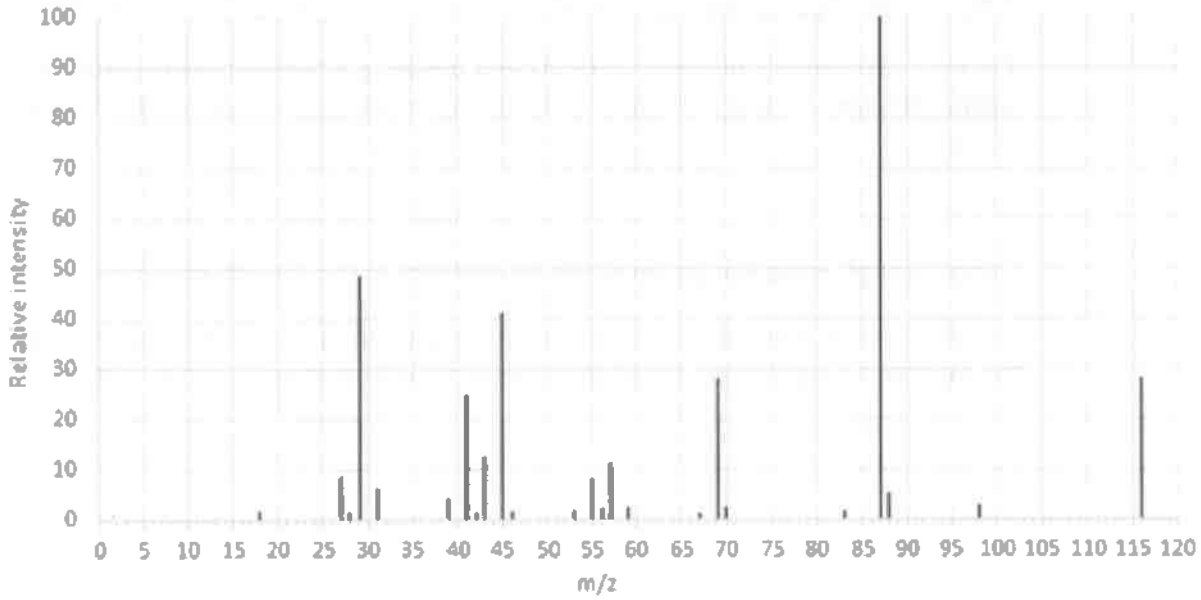
Carry through error was given based on answers to (a), though tests had to be reasonable.

^1H of ^{13}C NMR were also accepted, with the second mark given for correct predictions of the number of signals for A and B (or splitting information A and B if for ^1H NMR).

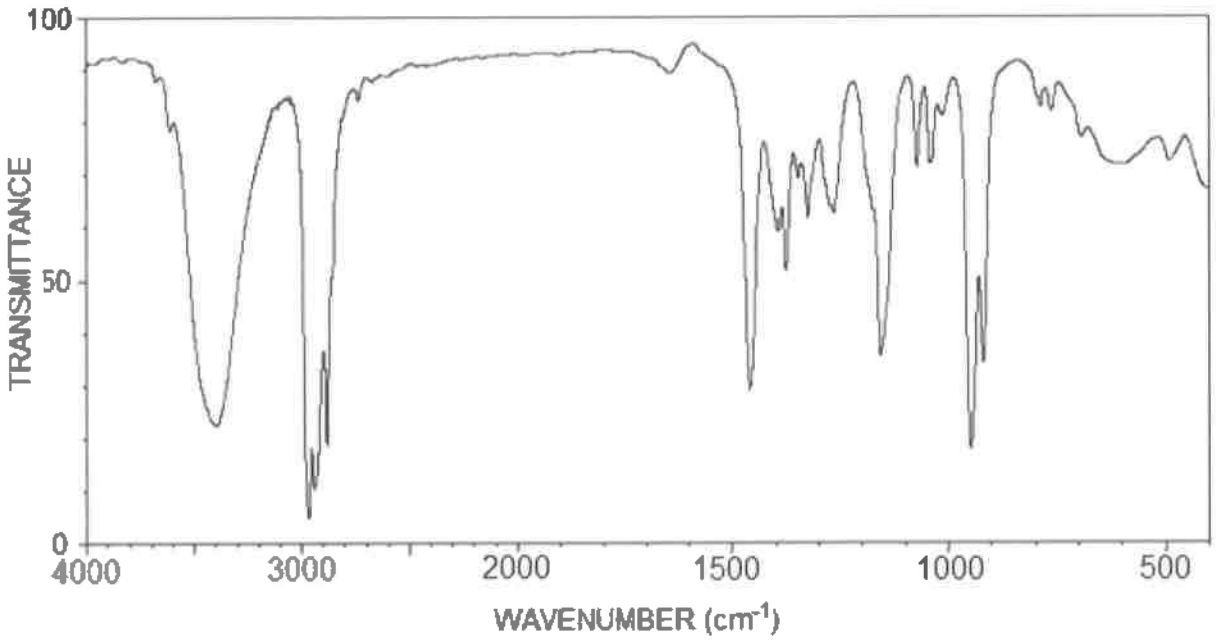
Question 37 (5 marks) **Marks**

The following four spectra (MS, IR, ^{1}H NMR and ^{13}C NMR) were collected for a single organic compound.

MS



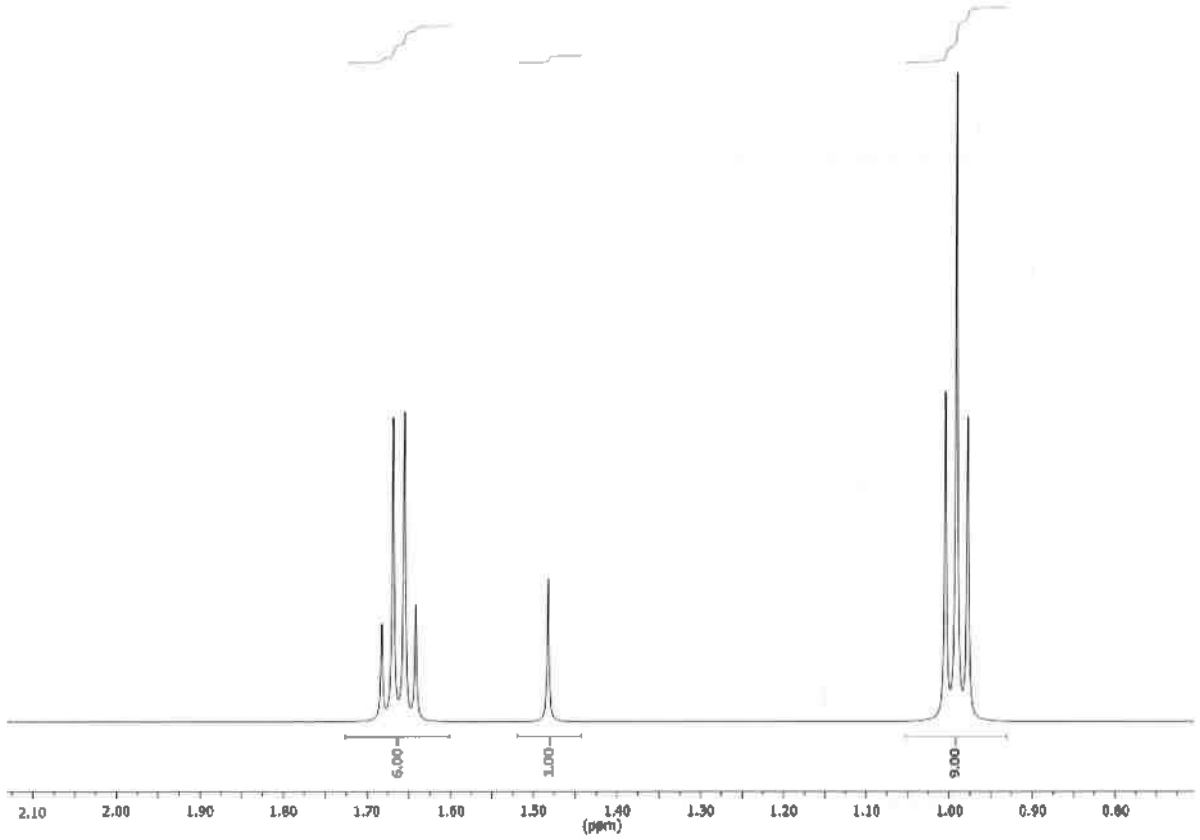
IR



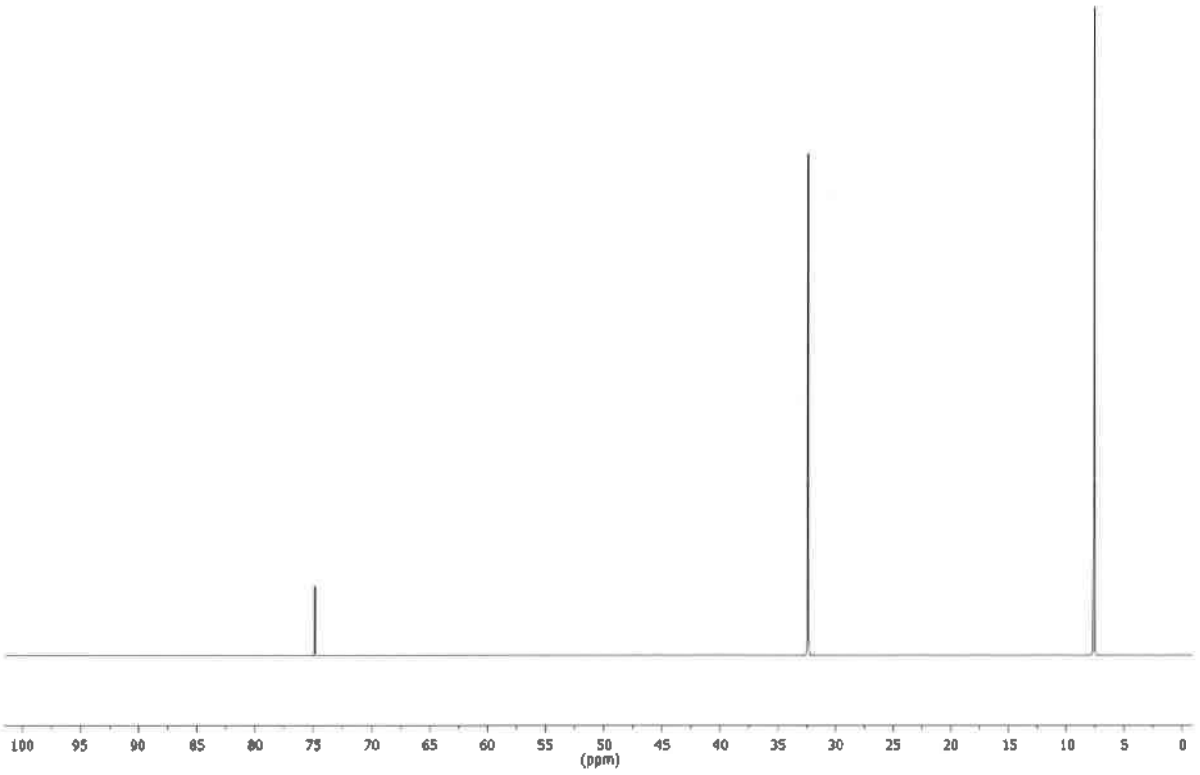
Question 37 continued on next page.

Question 37 continued.

^{1}H NMR



^{13}C NMR



Question 37 continued on next page.

Question 37 continued.

(a) Identify the functional group that produces the 3400 cm^{-1} peak seen in the IR spectrum.

Hydroxyl group (or OH) **1**

(b) What is the mass of the molecular ion?

116 ..... **1**

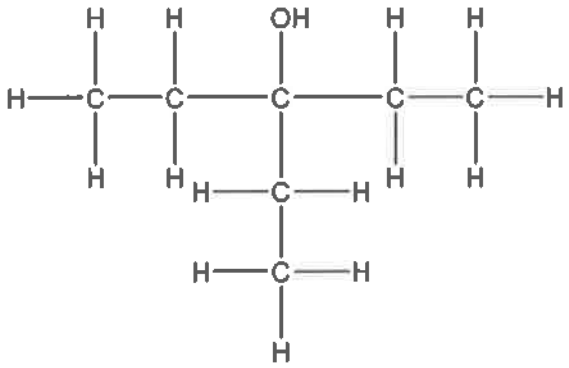
(c) How many **carbon** environments are there in this compound?

3 ..... **1**

(d) Draw the structural formula of this compound.

2 marks for correct structure

2



1 mark – a structure that meet at least one of the criteria from (a)-(c)

END OF EXAMINATION