Candidate Name	Centre Number					Candidate Number				

AS CHEMISTRY

COMPONENT 2

Energy, Rate and Chemistry of Carbon Compounds

SPECIMEN PAPER

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 8.**	**10**	
Section B	**9.**	**12**	
	10.	**10**	
	11.	**7**	
	12.	**8**	
	13.	**14**	
	14.	**7**	
	15.	**12**	
	Total	**80**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the need for good English and orderly, clear presentation in your answers.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

SECTION A

Answer **all** *questions in the spaces provided.*

1. Cobalt reacts with hydrochloric acid to give cobalt(II) chloride and hydrogen gas.

$$Co(s) + 2HCl(aq) \rightarrow CoCl_2(aq) + H_2(g)$$

(a) Suggest a method for measuring the rate of this reaction. [1]

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(b) State what could be done to the cobalt to increase the rate of the reaction. [1]

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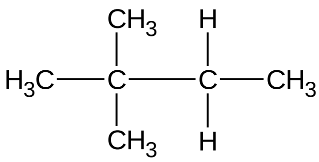
2. Give the systematic name for the compound with the following structure. [1]



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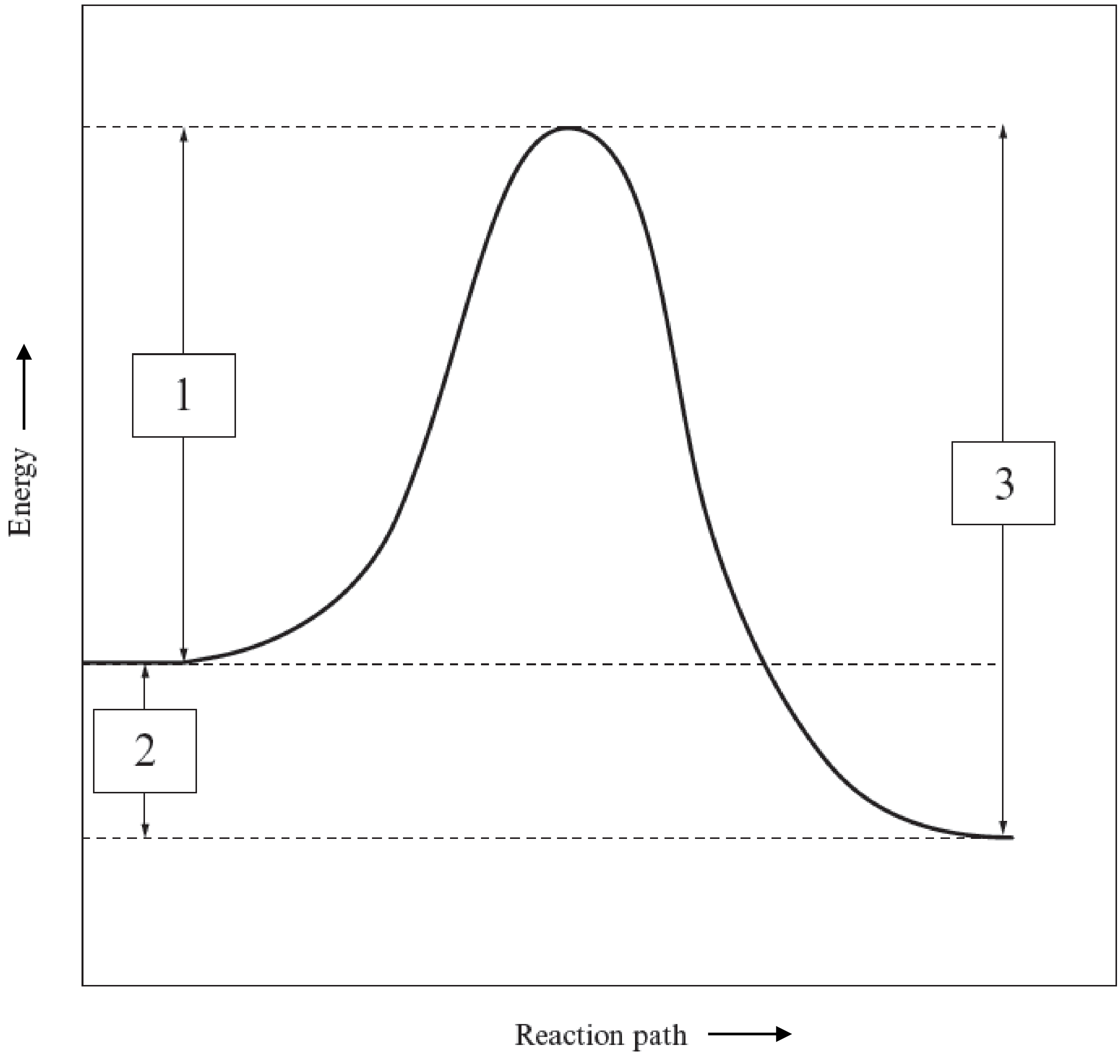
3. Draw the **skeletal** formula of methylpropan-1-ol. [1]

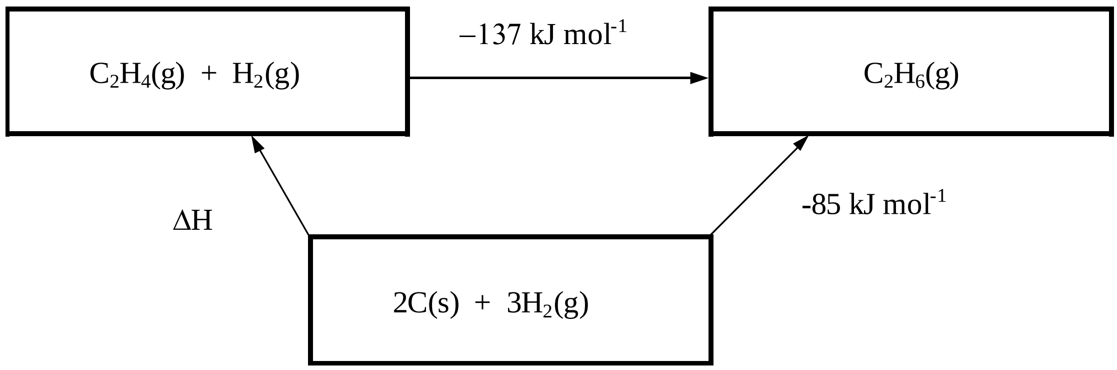
4. The diagram below shows the reaction profile for a chemical reaction. Three energy differences are marked on it with arrows labelled 1, 2 and 3.



Complete the table below by entering the numbers which correspond to the energy differences shown. [1]

activation energy of reverse reaction	
enthalpy change of reaction	

5. Determine the value of ΔH, in kJ mol^{-1}, in the energy cycle below. [2]



ΔH = …………….. kJ mol^{-1}

6. Name an instrumental technique that can be used to identify which bonds are present in an organic compound. [1]

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7. Write an equation for the reaction between ethanoic acid, CH_3COOH, and sodium hydroxide, NaOH. [1]

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8. Give the name of the critical piece of glassware used in carrying out a distillation and a reflux procedure. [1]

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10

SECTION B

Answer **all** *questions in the spaces provided.*

9. *(a)* Lisa was asked to measure the molar enthalpy change for the reaction between magnesium and copper(II) sulfate solution.

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$$

She accurately measured 50.0 cm^3 of copper(II) sulfate solution of concentration 0.505 mol dm^{-3} into a well-insulated polystyrene cup. The temperature of the solution was 20.5 °C. She then added 0.90 g of powdered magnesium and stirred the mixture thoroughly.

Lisa observed the temperature rise and recorded a maximum temperature of 30.1 °C.

(i) Calculate the heat given out during **this** experiment. You must show your working.

[Assume that the density of the solution is 1.00 g cm^{-3} and its specific heat capacity is 4.18 J $°C^{-1}$ g^{-1}] [2]

Heat = ……….……….. J

(ii) Determine which reagent is present in excess and calculate the molar enthalpy change, ΔH, for the reaction. You must show your working.

[3]

Enthalpy change = ………..…………….. kJ mol^{-1}

(iii) Explain why it is better to use powdered magnesium rather than a strip of magnesium ribbon. [2]

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(iv) The data book value for this molar enthalpy change is –93.1 kJ mol^{-1}. (If you do not have an answer in (iii) assume that the molar enthalpy change is –65 kJ mol^{-1}, although this is not the correct answer).

Suggest **one** reason for Lisa's low value in this experiment and suggest **one** change to the method that would improve her result. [2]

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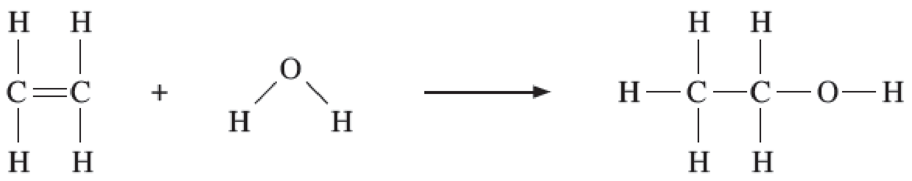
(b) Use the average bond enthalpy values in the table below and the enthalpy change for the direct hydration of ethene to calculate the average bond enthalpy of an O—H bond. [3]



$\Delta H = -45\,kJ\,mol^{-1}$

Bond	Average bond enthalpy / kJ mol^{-1}
C – C	348
C = C	612
C – H	412
C – O	360
O – H	?

Average bond enthalpy of an O—H bond = ………………………….. kJ mol^{-1}

12

10. *(a)* Petroleum (crude oil) is one of the most important resources in the world. It is a mixture of saturated hydrocarbons. These are separated into fractions by fractional distillation. Some fractions are used to make important chemicals such as propene while others are used as fuels.

Explain why hydrocarbons containing few carbon atoms distil at lower temperatures than hydrocarbons with many carbon atoms. [2]

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(b) Propene and two other hydrocarbon products are formed by cracking dodecane, $C_{12}H_{26}$.

$$C_{12}H_{26} \rightarrow C_3H_6 + \text{product } \mathbf{X} + \text{product } \mathbf{Y}$$

Suggest displayed formulae for products **X** and **Y**. [2]

(c) Propene and cyclopropane are isomers of formula C_3H_6. Name an instrumental technique that can be used to distinguish between these isomers. Explain your answer. [2]

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(d) (i) Draw the structural formula representing the saturated secondary alcohol containing four carbon atoms. [1]

(ii) Quantitative analysis of an alcohol shows that it contains 67.9 % carbon and 13.7 % hydrogen. The remainder is oxygen.
Calculate its empirical formula. [3]

Empirical formula ....

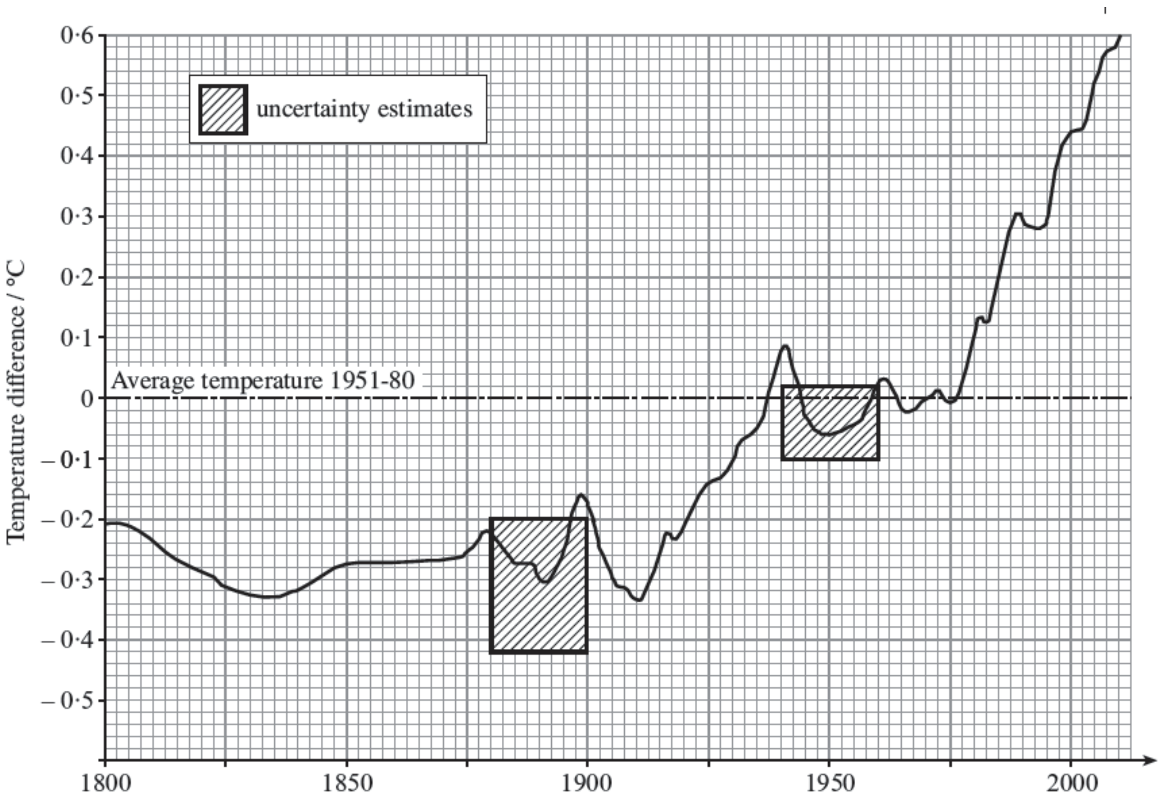
10

11. During the last 200 years, the average temperature of the Earth has risen.

The table below shows the concentration of carbon dioxide in the atmosphere.

	Year				
	1800	1850	1900	1950	2000
Concentration of carbon dioxide in the atmosphere (% by volume)	0.0282	0.0288	0.0297	0.0310	0.0368

The graph below shows the annual global temperature relative to the average temperature between 1951 and 1980. It is based on data from NASA research.



One hypothesis put forward by many scientists is that the increase in annual global temperature is due to the increased concentrations of carbon dioxide and other greenhouse gases in the atmosphere.

(a) Suggest **two** reasons why the uncertainty in the measurements is greater during the period from 1880-1900 than it is from 1940-1960. [2]

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(b) Give **two** reasons for the significant change in carbon dioxide concentration after 1900. [2]

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(c) Ozone is another greenhouse gas. 47 kg of ozone occupies 24 m^3 at 298 K and 101000 Pa. Use this information to show that the formula of ozone is O_3. [3]

(gas constant, R = 8.31 J K^{-1} mol^{-1})

7

12. Chloromethane can be produced by the radical chlorination of methane gas.

(a) Write the equation(s) for the propagation stage(s) to produce chloromethane starting with methane and a chlorine radical. [2]

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(b) Apart from chloromethane, a range of other compounds are produced in small amounts during the reaction.

Show how ethane is formed. [1]

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(c) Chloromethane can be converted into methanol by reaction with hydroxide ions.

(i) Write a balanced equation for this reaction. [1]

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(ii) Classify the mechanism of this reaction. [1]

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(iii) Explain why the boiling temperature of methanol is higher than the boiling temperature of chloromethane. [3]

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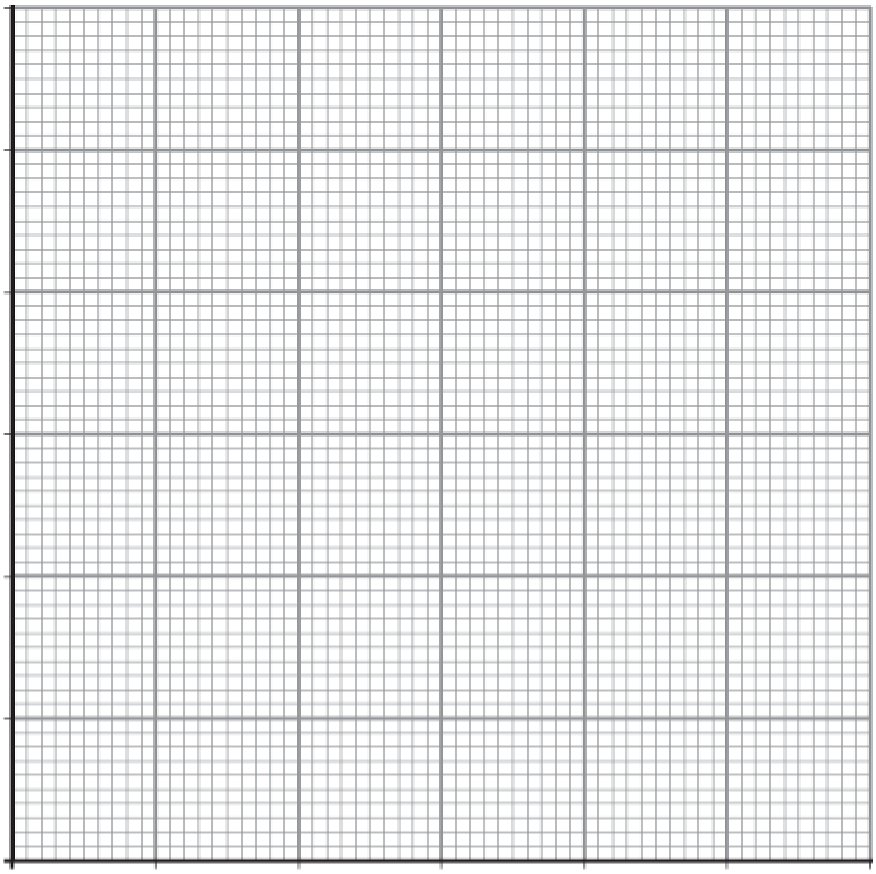
13. *(a)* The following results were obtained in an experiment to measure the rate of oxidation of iodide ions by hydrogen peroxide in acid solution as shown in the equation. The reaction was carried out at a temperature of 20 °C.

$$H_2O_2 \;+\; 2H^+ \;+\; 2I^- \;\rightarrow\; I_2\text{(brown)} \;+\; 2H_2O$$

Time (s)	0	100	200	300	400	500
Concentration of I_2 (mol dm^{-3})	0	0.0115	0.0228	0.0347	0.0420	0.0509

(i) Plot these results on the grid below, labelling the axes and selecting a suitable scale. Draw the line of best fit. [3]



(ii) Use the graph to calculate the initial rate of reaction and give the units. [2]

Rate = ...

Units ....

(iii) Describe briefly the key features of the method that would have been used to obtain these results. [3]

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(iv) A similar experiment was carried out using hydrogen peroxide and iodide solutions of different concentrations. The initial rates calculated for each reaction are shown in the table.

Concentration of H_2O_2 (relative units)	Concentration of I^- (relative units)	Initial rate (relative units)
0.60	0.050	4.1×10^{-4}
1.2	0.050	7.9×10^{-4}
1.2	0.10	1.6×10^{-3}

Analyse the data and state the relationship between the concentration of hydrogen peroxide and iodide ions and the initial rate of reaction. [2]

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(b) The rate of a chemical reaction varies with temperature. Draw the Boltzmann energy distribution curve and use this to explain why the rate of the reaction in part *(a)* would increase if it were carried out at a higher temperature. [4]

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14

14. *(a)* In an experiment, 1-chlorobutane and 1-bromobutane are separately heated with aqueous sodium hydroxide and the resulting solutions acidified. Aqueous silver nitrate is added to both.

Describe and explain what is observed in each case and illustrate your answer with relevant equations. [4]

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(b) The following table shows the formulae of some halogenoalkanes including various halogen atoms. Many of these cause significant damage to the ozone layer.

The amount of damage caused by each compound is expressed as its relative ozone depletion potential (RODP). The higher its value the more destructive its effect. CCl_3F is given a value of 1.00.

Compound	Relative ozone depletion potential (RODP)
CHF_3	0.01
$CHClF_2$	0.05
CCl_2F_2	0.86
CCl_3F	1.00
$CBrClF_2$	10.0

(i) Give the systematic name for the compound with an RODP value of 0.86. [1]

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(ii) Use the information given in the table to describe how the number and type of halogen atoms per molecule are related to the destructive effects of these compounds on ozone. [2]

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15. *(a)* Describe the mechanism of the reaction that occurs between propene and hydrogen bromide and use this to explain the products formed. [6]

(Your ability to construct an extended response will be assessed in this question.)

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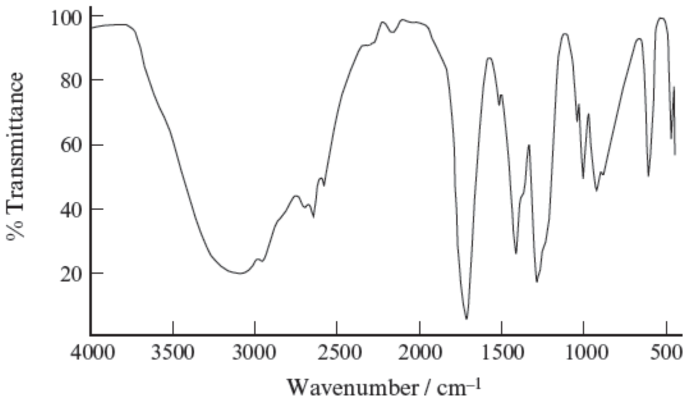
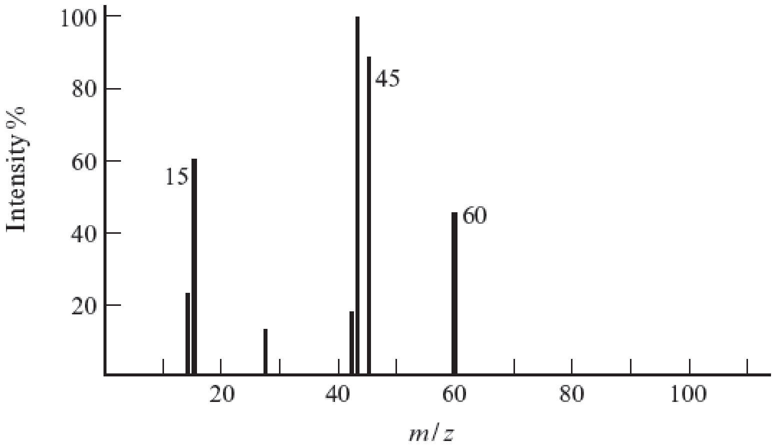
(b) A reaction of ethanol gives a product that is analysed in an IR spectrometer and a mass spectrometer. The following spectra are recorded.





(i) Use **all** the information to suggest the identity of the product formed. Explain your reasoning. [4]

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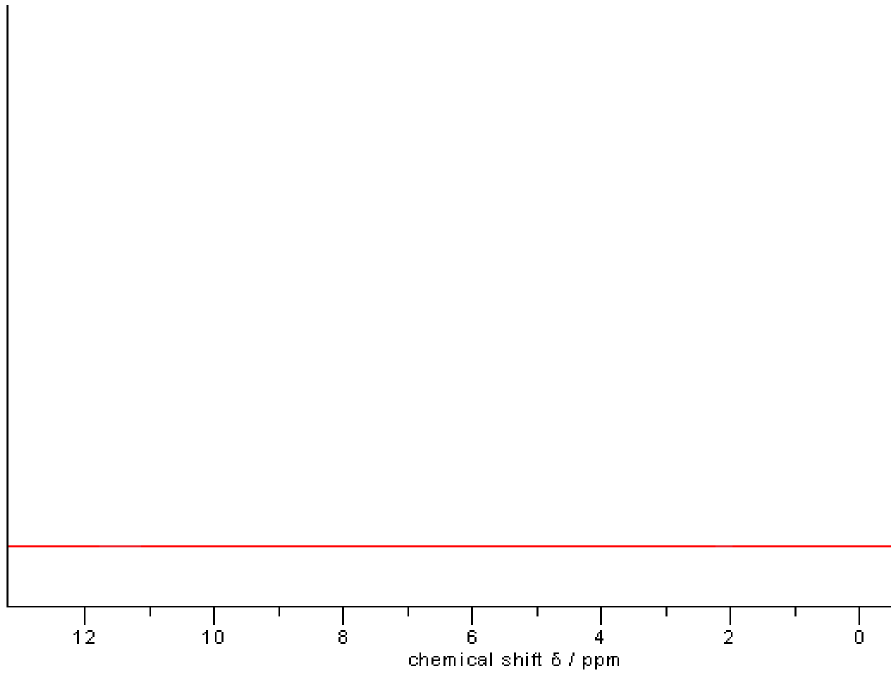
(ii) Predict what the ^{1}H NMR spectrum of the product identified in part (i) would look like. Draw the signals corresponding to its hydrogen atoms on the spectrum below. [2]



12

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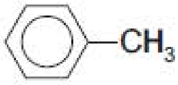
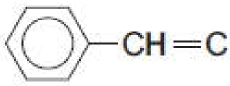
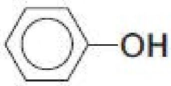
Data Booklet

Infrared absorption values

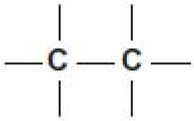
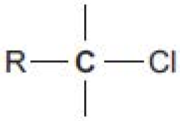
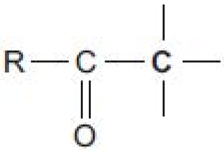
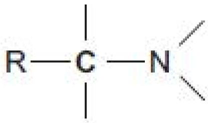
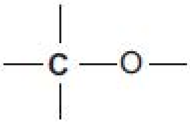
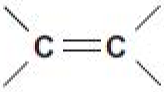
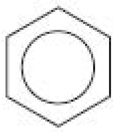
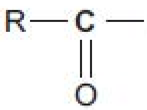
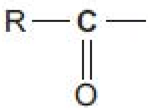
Bond	Wavenumber (cm^{-1})
C—Br	500 to 600
C—Cl	650 to 800
C—O	1000 to 1300
C=C	1620 to 1670
C=O	1650 to 1750
C≡N	2100 to 2250
C—H	2800 to 3100
O—H (carboxylic acid)	2500 to 3200 (very broad)
O—H (alcohol/ phenol)	3200 to 3550 (broad)
N—H	3300 to 3500

[1]H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
$CH_3-C(=O)-$	2.0 to 2.5
$-CH_2-C(=O)-$	2.0 to 3.0
	2.2 to 2.3
$R-CH_2Cl$	3.3 to 4.3
$R-OH$	4.5 *
$-C=CH-CO$	5.8 to 6.5
	6.5 to 7.5
	7.0 *
$R-C(=O)-H$	9.8 *
$R-C(=O)-OH$	11.0 *

*variable figure dependent on concentration and solvent

^{13}C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
	5 to 40
	10 to 70
	20 to 50
	25 to 60
	50 to 90
	90 to 150
	110 to 125
	110 to 160
 (carboxylic acid / ester)	160 to 185
 (aldehyde / ketone)	190 to 220

THE PERIODIC TABLE

Key

A_r (relative atomic mass) Symbol Name Z (atomic number)

Group — s Block (groups 1–2), d Block, p Block (groups 3–7, 0)

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 Be Beryllium 4											10.8 B Boron 5	12.0 C Carbon 6	14.0 N Nitrogen 7	16.0 O Oxygen 8	19.0 F Fluorine 9	20.2 Ne Neon 10
3	23.0 Na Sodium 11	24.3 Mg Magnesium 12											27.0 Al Aluminium 13	28.1 Si Silicon 14	31.0 P Phosphorus 15	32.1 S Sulfur 16	35.5 Cl Chlorine 17	40.0 Ar Argon 18
4	39.1 K Potassium 19	40.1 Ca Calcium 20	45.0 Sc Scandium 21	47.9 Ti Titanium 22	50.9 V Vanadium 23	52.0 Cr Chromium 24	54.9 Mn Manganese 25	55.8 Fe Iron 26	58.9 Co Cobalt 27	58.7 Ni Nickel 28	63.5 Cu Copper 29	65.4 Zn Zinc 30	69.7 Ga Gallium 31	72.6 Ge Germanium 32	74.9 As Arsenic 33	79.0 Se Selenium 34	79.9 Br Bromine 35	83.8 Kr Krypton 36
5	85.5 Rb Rubidium 37	87.6 Sr Strontium 38	88.9 Y Yttrium 39	91.2 Zr Zirconium 40	92.9 Nb Niobium 41	95.9 Mo Molybdenum 42	98.9 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 La ▸ Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(210) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) Ac ▸▸ Actinium 89															

f Block

▸ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
▸▸ Actinoid elements	232 Th Thorium 90	(231) Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(242) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(245) Bk Berkelium 97	(251) Cf Californium 98	(254) Es Einsteinium 99	(253) Fm Fermium 100	(256) Md Mendelevium 101	(254) No Nobelium 102	(257) Lr Lawrencium 103