Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Thursday 21 May 2020

Morning (Time: 1 hour 30 minutes) | Paper Reference **WCH12/01**

Chemistry

International Advanced Subsidiary / Advanced Level

Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

Candidates must have: Scientific calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- There is a Periodic Table on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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P 6 2 5 8 8 A 0 1 2 4

Pearson

SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The bond enthalpy for the Cl—Cl bond is +243.0 kJ mol^{-1}.

What is the enthalpy change of atomisation of chlorine in kJ mol^{-1}?

☒ **A** +243.0

☒ **B** –243.0

☒ **C** +121.5

☒ **D** –121.5

(Total for Question 1 = 1 mark)

2 The standard enthalpy change of neutralisation for the reaction between sodium hydroxide solution and hydrochloric acid is –56 kJ mol^{-1}.

Which row in the table is correct for this neutralisation?

	Reaction type	Temperature
☒ **A**	exothermic	increases
☒ **B**	exothermic	decreases
☒ **C**	endothermic	increases
☒ **D**	endothermic	decreases

(Total for Question 2 = 1 mark)

3 Which of the following statements about water is **not** due to hydrogen bonding?

☒ **A** water has a less open structure than ice

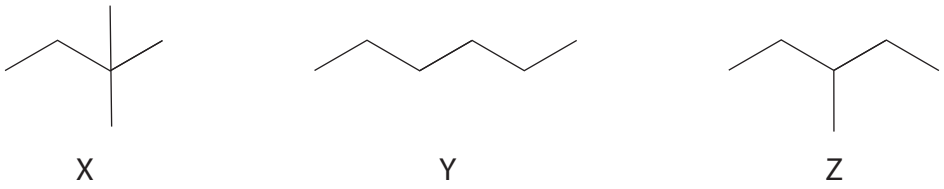
☒ **B** ice cubes float in a glass of iced water

☒ **C** when water freezes its volume increases

☒ **D** water is a good solvent for ionic compounds

(Total for Question 3 = 1 mark)

4 The skeletal formulae of three isomers are shown.



X Y Z

Which series shows the correct order of **increasing** boiling temperatures?

☒ **A** Y, X, Z

☒ **B** X, Y, Z

☒ **C** Y, Z, X

☒ **D** X, Z, Y

(Total for Question 4 = 1 mark)

5 Hydrogen peroxide decomposes in the presence of a catalyst.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

(a) What type of reaction occurs?

(1)

☒ **A** displacement

☒ **B** disproportionation

☒ **C** elimination

☒ **D** hydrolysis

(b) In an experiment, the volume of oxygen produced by the decomposition of hydrogen peroxide was measured at various times as the reaction progressed and a graph was plotted.

The initial gradient of the graph was $0.50\,cm^3\,s^{-1}$.

What is the initial rate of decomposition of hydrogen peroxide in $mol\,s^{-1}$?

[Molar volume of a gas at r.t.p. = $24\,dm^3\,mol^{-1}$]

(1)

☒ **A** $2.1 \times 10^{-2}\,mol\,s^{-1}$

☒ **B** $4.2 \times 10^{-5}\,mol\,s^{-1}$

☒ **C** $2.1 \times 10^{-5}\,mol\,s^{-1}$

☒ **D** $1.0 \times 10^{-5}\,mol\,s^{-1}$

(Total for Question 5 = 2 marks)

6 Dichromate(VI) ions may be reduced in acidic solution.

$$Cr_2O_7^{2-}(aq) + x\,H^+(aq) + y\,e^- \rightarrow 2Cr^{3+}(aq) + z\,H_2O(l)$$

The coefficients in this half-equation are

	x	y	z
☒ **A**	14	6	7
☒ **B**	14	3	7
☒ **C**	7	6	3.5
☒ **D**	7	3	3.5

(Total for Question 6 = 1 mark)

7 In an oxide of potassium, the oxidation number of oxygen is –½.

What is the formula of this oxide?

☒ **A** K_2O

☒ **B** K_2O_2

☒ **C** K_2O_3

☒ **D** KO_2

(Total for Question 7 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

8 Compound **Q** gives off nitrogen dioxide when heated, and produces a red colour in a flame test.

(a) Which of these compounds could be **Q**?

(1)

☒ **A** barium nitrate

☒ **B** lithium nitrate

☒ **C** magnesium nitrate

☒ **D** rubidium nitrate

(b) Which colour and test results are correct for nitrogen dioxide gas?

(1)

	Colour of nitrogen dioxide	Colour change of damp litmus paper
☒ **A**	brown	blue to red
☒ **B**	brown	red to blue
☒ **C**	colourless	blue to red
☒ **D**	colourless	red to blue

(Total for Question 8 = 2 marks)

9 The products of the reaction of sodium fluoride with concentrated sulfuric acid can be predicted by considering the trends for the other sodium halides.

Which gas or gases form when sodium fluoride reacts with concentrated sulfuric acid?

☒ **A** hydrogen fluoride only

☒ **B** hydrogen fluoride and fluorine only

☒ **C** hydrogen fluoride and sulfur dioxide only

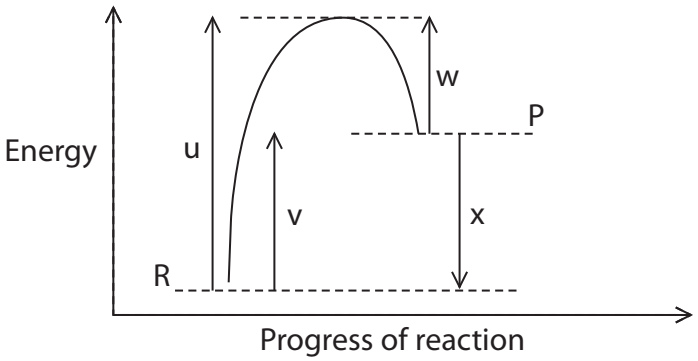
☒ **D** hydrogen fluoride, fluorine and sulfur dioxide only

(Total for Question 9 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

10 The diagram shows a reaction profile for a reversible reaction.

$$R \rightleftharpoons P$$



(a) Which symbol represents the enthalpy change for the reaction R → P?

(1)

☒ **A** u

☒ **B** v

☒ **C** w

☒ **D** x

(b) Which symbol represents the activation energy of the reaction P → R?

(1)

☒ **A** u

☒ **B** v

☒ **C** w

☒ **D** x

(c) Hess's Law can be applied to this system.

Which expression is correct?

(1)

☒ **A** v + x = u + w

☒ **B** w + x = u

☒ **C** u – w = v

☒ **D** u – v = x

(Total for Question 10 = 3 marks)

11 A solution containing 0.100 mol of hydrochloric acid is added to 8.43 g of magnesium carbonate.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) What is the total volume (at r.t.p.) of carbon dioxide formed?

[$M_r(MgCO_3) = 84.3$ Molar volume of a gas at r.t.p. = 24.0 $dm^3\,mol^{-1}$]

(1)

☒ **A** 2.40 dm^3

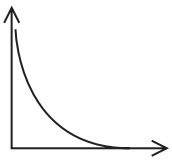
☒ **B** 1.20 dm^3

☒ **C** 2400 dm^3

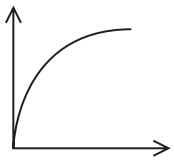
☒ **D** 1200 dm^3

(b) Which sketch graph shows the volume of carbon dioxide (*y*-axis) plotted against time (*x*-axis) during the reaction?

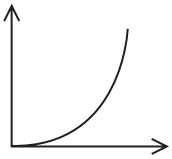
(1)



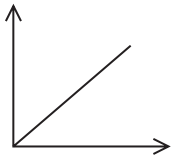
☒ **A**



☒ **B**



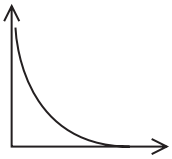
☒ **C**



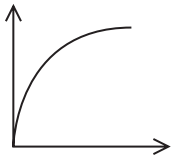
☒ **D**

(c) Which sketch graph shows the rate of the reaction (*y*-axis) plotted against time (*x*-axis) during the reaction?

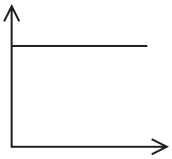
(1)



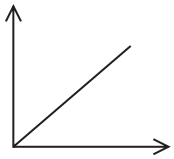
☒ **A**



☒ **B**



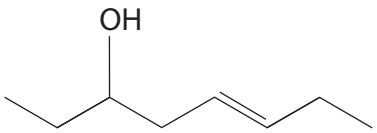
☒ **C**



☒ **D**

(Total for Question 11 = 3 marks)

12 (a) What is the name of compound L?



L

(1)

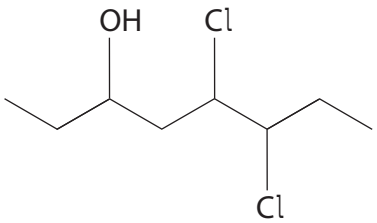
☒ **A** *Z*-oct-3-en-3-ol

☒ **B** *E*-oct-3-en-3-ol

☒ **C** *Z*-oct-5-en-3-ol

☒ **D** *E*-oct-5-en-3-ol

(b) Compound L can be converted into compound M.



M

Which reagent should be used?

(1)

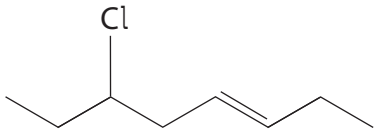
☒ **A** $Cl_2(g)$

☒ **B** HCl(g)

☒ **C** $PCl_5(s)$

☒ **D** KCl(aq)

(c) Compound L can also be converted into compound N.



N

Which reagent should be used?

(1)

☒ **A** $Cl_2(g)$

☒ **B** HCl(g)

☒ **C** $PCl_5(s)$

☒ **D** KCl(aq)

(Total for Question 12 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 Enthalpy changes of formation are often difficult to determine directly.

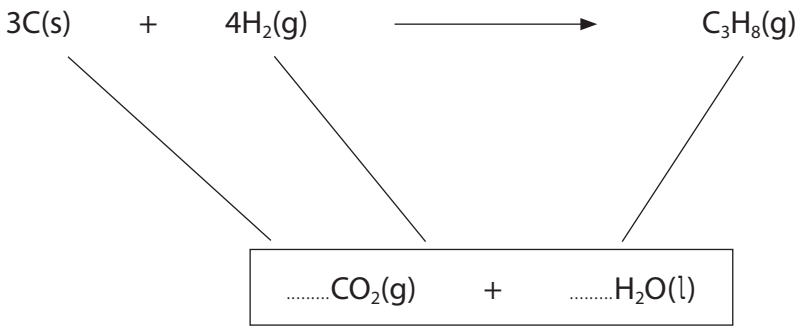
Some enthalpy data are shown.

Compound	Standard enthalpy change of formation, $\Delta_f H^{\ominus}$ / kJ mol^{-1}
$H_2O(l)$	–285.8
$CO_2(g)$	–393.5

Standard enthalpy change of combustion of propane ($\Delta_c H^{\ominus}$ (C_3H_8)) = –2219 kJ mol^{-1}.

(a) (i) Add arrowheads and stoichiometric coefficients to the Hess's Law diagram.

(1)



(ii) Use the data at the start of the question and your Hess's Law diagram to calculate the standard enthalpy change of formation of propane.
Include a sign and units in your answer.

(2)

(b) The values for the boiling temperatures and the standard enthalpies of combustion of a series of straight-chain alkanes are shown in the table.

Alkane	Boiling temperature / °C	Standard enthalpy change of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}	Increase in $\Delta_c H^{\ominus}$ / kJ mol^{-1}
C_2H_6	–88.5	–1560	–
C_3H_8	–42.0	–2219	659
C_4H_{10}	–0.5	–2877	658
C_5H_{12}	36.1	–3509	632
C_6H_{14}	68.8	–4163	654
C_7H_{16}	98.4	–4817	654

(i) Explain why the increases in the values of $\Delta_c H^{\ominus}$ are similar.

(2)

(ii) The increase in the value of $\Delta_c H^{\ominus}$ from butane to pentane is smaller than any other increase.

Suggest an explanation for this.

(2)

(iii) Explain, with reference to their intermolecular forces, why the boiling temperatures of **alkanes** increase as the number of carbon atoms increases. A detailed description of the intermolecular forces is not required.

(3)

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(Total for Question 13 = 10 marks)

14 Limewater is a solution of calcium hydroxide used in the laboratory to test for carbon dioxide.

(a) Write the equation for the formation of the white precipitate in this test. Include state symbols.

(2)

(b) The concentration of a saturated solution of calcium hydroxide can be determined by titration.

$25.0\,cm^3$ portions of a saturated solution of calcium hydroxide were titrated with $0.0500\,mol\,dm^{-3}$ hydrochloric acid using phenolphthalein indicator.
The mean titre was $23.40\,cm^3$.

Calculate the concentration of calcium hydroxide in $g\,dm^{-3}$.
Give your answer to an appropriate number of significant figures.

[$M_r(Ca(OH)_2) = 74.1$]

(4)

(c) The experiment was repeated using the same hydrochloric acid with a saturated solution of magnesium hydroxide.

Explain the difference (if any) in the mean titre.

(2)

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(Total for Question 14 = 8 marks)

15 (a) Silver ions have anti-microbial properties and are used in some wound dressings. Silver nitrate can be made by warming a mixture of silver metal and concentrated nitric acid.

$$Ag(s) + 2HNO_3(aq) \rightarrow AgNO_3(aq) + NO_2(g) + H_2O(l)$$

Show, by reference to oxidation numbers, that this is a redox reaction.

(2)

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(b) Two students used different methods to determine the concentration of a silver nitrate solution.

(i) Student A used a calorimetric method, reacting a 50.0 cm^3 sample of the solution with excess powdered zinc.

$$AgNO_3(aq) + \tfrac{1}{2}Zn(s) \rightarrow \tfrac{1}{2}Zn(NO_3)_2(aq) + Ag(s) \qquad \Delta_r H = -36.1\ kJ\ mol^{-1}$$

The student recorded a maximum rise in temperature of 5.2 °C.

Calculate the concentration of the silver nitrate solution in mol dm^{-3}.

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

(3)

(ii) Student B used a gravimetric method, which involved weighing a product of a reaction.

A 50.0 cm^3 sample of the same silver nitrate solution was mixed with excess potassium bromide solution. The precipitate was filtered and weighed.

$$AgNO_3(aq) + KBr(aq) \rightarrow AgBr(s) + KNO_3(aq)$$

The mass of the precipitate was found to be 5.96 g.

Calculate the concentration of the silver nitrate solution, in mol dm^{-3}, from this gravimetric method.

(2)

(iii) The students' values were different from the data book value.
Student A's value was lower and student B's value was higher.
Give a possible reason for each difference.

(2)

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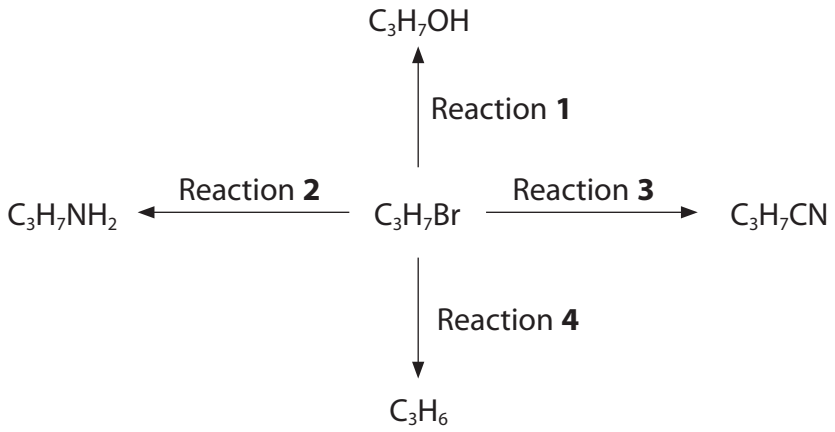
(Total for Question 15 = 9 marks)

16 Halogenoalkanes are useful reagents in organic synthesis.

Some reactions of 1-bromopropane are shown.



(a) Complete the table about these reactions.

(4)

Reaction	Reagent	Solvent	Type of reaction
1	potassium hydroxide		
2	ammonia		
3		ethanol	
4			elimination

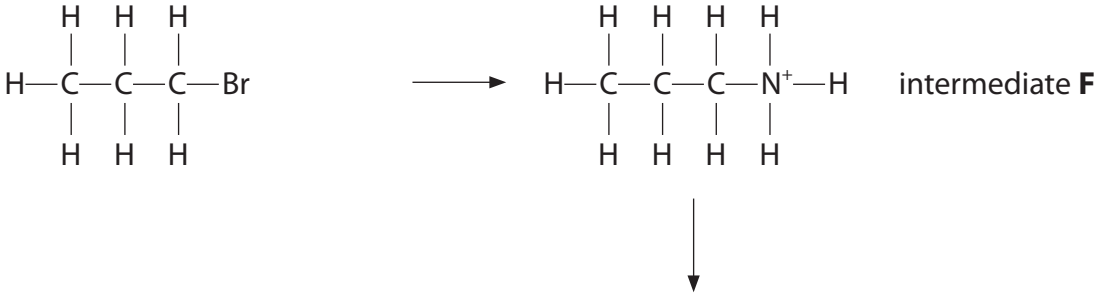
(b) Give the IUPAC name of the product of Reaction **3**.

(1)

.....

(c) Complete the mechanism for Reaction **2**.
Show the formation of the intermediate **F** and of the product.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)



*(d) The relative rates of hydrolysis of a series of halogenoalkanes were determined using the following method:

- five test tubes, each containing 2 cm^3 of ethanol and 2 cm^3 of aqueous silver nitrate, were placed in a water bath at 50 °C
- four drops of a different halogenoalkane were added to each test tube
- the time taken for a precipitate to appear in each test tube was recorded.

The results are shown.

Halogenoalkane	Time for ppt to appear / s
2-bromobutane	29
2-chlorobutane	75
2-iodobutane	<1
1-bromobutane	41
2-bromo-2-methylbutane	13

Explain these results by considering:

- the chemical reaction occurring
- the structures of the halogenoalkanes
- the strengths of the carbon-halogen bonds.

(6)

(Total for Question 16 = 14 marks)

TOTAL FOR SECTION B = 41 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

17 (a) The concentration of atmospheric carbon dioxide is at its highest level for 800 000 years. Carbon Capture and Utilisation (CCU) uses waste carbon dioxide from industrial processes to make green fuels, methanol, plastics or pharmaceuticals.
One method uses the reaction between carbon dioxide and hydrogen to make methanol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta_r H = -49.5\,kJ\,mol^{-1}$$

The conditions for this industrial reaction are a pressure of 50 atm, a temperature of 250 °C and a copper catalyst.

(i) Explain why high pressure is used.

(2)

(ii) Discuss the factors leading to a choice of 250 °C in this process.

(3)

(iii) Give a reason why using a catalyst to increase the rate makes the process more sustainable.

(1)

(b) Methanol can be oxidised to produce methanoic acid.

(i) State the reagents and reaction conditions for this oxidation in the laboratory.

(2)

(ii) Complete the equation to show the products of this oxidation.
State symbols are not required.

(1)

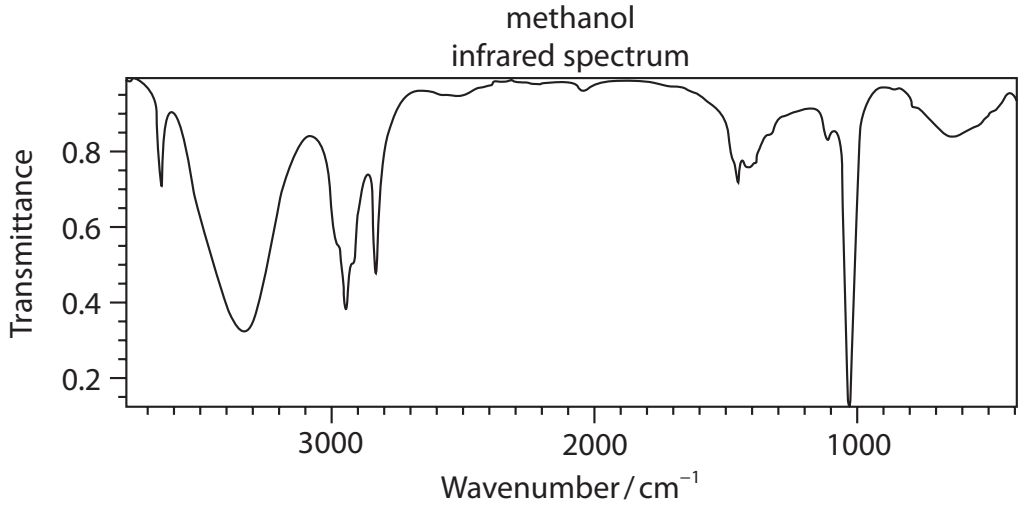
$$CH_3OH + \text{.....} [O] \rightarrow$$

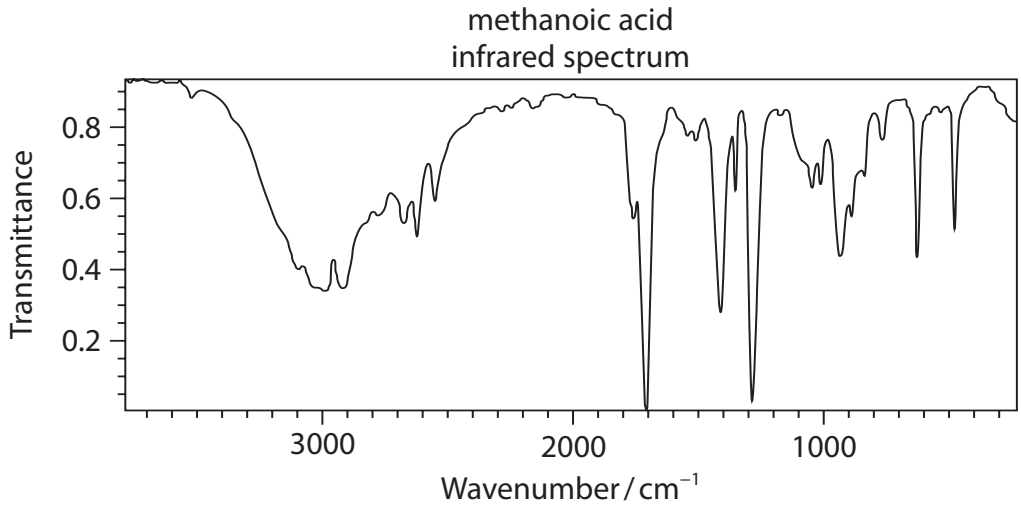
(iii) Give a chemical test, and its positive result, that could be used to confirm the functional group in methanoic acid.

(2)

(iv) The infrared spectra of methanol and methanoic acid are shown.
Explain how these could be used to show that **all** the methanol has been converted to methanoic acid, quoting relevant bonds and wavenumbers.
Use your Data Booklet.

(3)





(c) (i) Methanol produced from petrol by CCU may be mixed with petrol derived from fossil fuels. A concentration of 5% by mass of methanol is used.

Explain how the use of this fuel would affect the increase in global temperatures.

(2)

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(ii) Calculate the mass of carbon dioxide released when 1 mol of octane (C_8H_{18}) is burned completely.

(1)

(iii) A motorist who uses 1200 kg of fuel each year in a car changes to a fuel with 5% of the mass of petrol replaced by methanol produced by CCU.

Calculate the annual reduction, in kg, of carbon dioxide released by the car.

[Assume petrol has the same molecular formula as octane and the added methanol does not contribute any additional carbon dioxide when burned.]

(2)

(Total for Question 17 = 19 marks)

TOTAL FOR SECTION C = 19 MARKS

TOTAL FOR PAPER = 80 MARKS

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(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	39.9 Ar argon 18
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
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] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 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
* Actinide series	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