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 Which of the following interacts with the nuclei of hydrogen atoms in a nuclear magnetic resonance spectrometer?

☒ **A** Gamma rays

☒ **B** X-rays

☒ **C** Microwaves

☒ **D** Radio waves

(Total for Question 1 = 1 mark)

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2 HPLC stands for

☒ **A** high pressure liquid column.

☒ **B** high performance liquid chromatography.

☒ **C** heterogeneous phase liquid chromatography.

☒ **D** homogenous phase liquid column.

(Total for Question 2 = 1 mark)

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

Question 3 : N/A

4 Which of these will **not** improve the **overall** yield of the Haber process?

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

☒ **A** Increasing the pressure.

☒ **B** Liquefying then removing the ammonia from the reaction.

☒ **C** Increasing the temperature.

☒ **D** Recycling unreacted nitrogen and hydrogen.

(Total for Question 4 = 1 mark)

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5 The equation for the reaction between ethanoic acid and phosphorus(V) chloride is

☒ **A** $CH_3COOH + PCl_5 \rightarrow CH_3COCl + POCl_3 + HCl$

☒ **B** $CH_3COOH + PCl_5 \rightarrow CH_3COOCl + PCl_3 + HCl$

☒ **C** $CH_3COOH + PCl_5 \rightarrow CH_3COCl + PCl_3 + HOCl$

☒ **D** $2CH_3COOH + PCl_5 \rightarrow (CH_3CO)_2O + PCl_3 + H_2O + Cl_2$

(Total for Question 5 = 1 mark)

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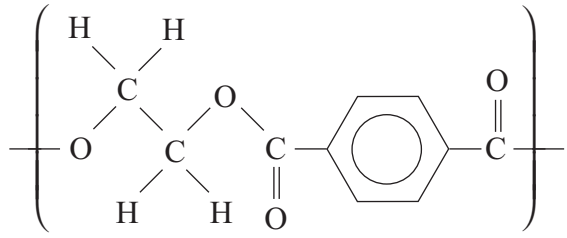
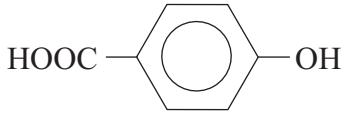
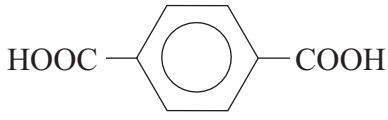
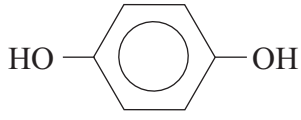
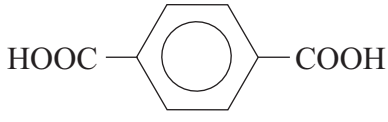
6 An example of a polyester is



(a) The two monomers needed to form this polymer are

(1)

	Monomer One	Monomer Two
☒ **A**		$HO(CH_2)_2OH$
☒ **B**		$HO(CH_2)_2OH$
☒ **C**		$HOOC(CH_2)_2COOH$
☒ **D**		$HOOC(CH_2)_2COOH$

(b) The type of reaction to form this polymer is

(1)

☒ **A** addition.

☒ **B** substitution.

☒ **C** condensation.

☒ **D** hydrolysis.

(Total for Question 6 = 2 marks)

Question 7: N/A

Question 8: N/A

Question 9: N/A

Question 10: N/A

Question 11: N/A

Question 12: N/A

13 In order to make $CH_3CH_2CONHCH_3$, you could use

☒ **A** $CH_3CH_2COOCH_3 + NH_3$

☒ **B** $CH_3CH_2COCl + CH_3NH_2$

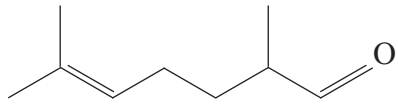
☒ **C** $CH_3CH_2COO^-Na^+ + CH_3NH_2$

☒ **D** $CH_3CH_2CONH_2 + CH_3NH_2$

(Total for Question 13 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

Question 14: N/A

15 The molecule  is sometimes known as melonal as it smells similar to watermelon.

(a) Give the systematic name for melonal.

(2)

.....

(b) (i) Melonal can be prepared by the oxidation of a compound, **X**. Suggest the formula of compound **X** and the names or formulae of the reagents needed to oxidize **X**.

(3)

Compound **X**

Reagents needed for oxidation .....

.....

(ii) Briefly suggest a practical measure to maximise the yield of melonal in (b)(i). Justify your answer.

(2)

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.....

(c) Infrared spectra can be used to confirm the presence of functional groups in a molecule. Use page 5 of the data booklet to suggest the position of two absorptions and the identity of the bonds responsible which can confirm the presence of the two functional groups in melonal.

(2)

Wavenumber range / cm^{-1}	Bond	Functional group present in melonal

(d) The mass spectrum of melonal shows small peaks at *m/e* = 57 and *m/e* = 83.

Give the formula of each of the fragments most likely to have caused these peaks.

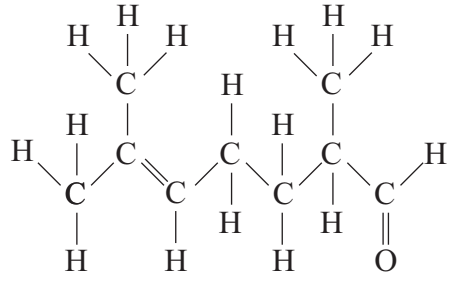
(2)

m/e = 57.....

m/e = 83.....

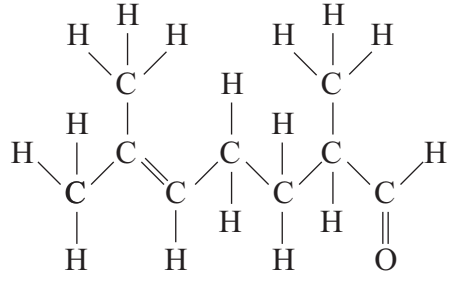
(e) (i) On the displayed formula below, circle the hydrogen atom that has a triplet peak in the proton nmr spectrum of melonal.

(1)



(ii) On the displayed formula below, circle the atom that gives rise to a peak at a chemical shift of δ = 9.65 ppm in the proton nmr spectrum of melonal. Refer to page 7 of the data booklet.

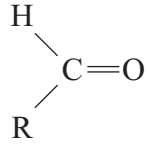
(1)



(f) Aldehydes react with HCN in the presence of CN^- ions.

(i) Give the mechanism for this reaction, using the simplified displayed formula below.

(3)



(ii) The product of this reaction has a chiral centre. Would you expect the reaction to produce a solution that rotates the plane of plane-polarized light? Explain your answer.

(3)

(Total for Question 15 = 19 marks)

Question 16 : N/A

17 The ester $CH_3CH_2COOCH_3$ can be formed from the reaction between propanoic acid and methanol with an acid catalyst.

$$CH_3CH_2COOH + CH_3OH \rightleftharpoons CH_3CH_2COOCH_3 + H_2O$$

(a) (i) Name the ester.

(1)

.....

(ii) The same product can be made using propanoyl chloride instead of propanoic acid. Suggest an additional hazard that could occur using this reagent and describe how you would minimise this risk.

(2)

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.....

.....

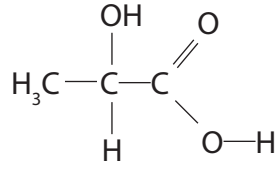
(b) Complete the table below to show the amounts of each substance present at equilibrium. Use your values to calculate the equilibrium constant, K_c, for the reaction.

(3)

	CH_3CH_2COOH	CH_3OH	$CH_3CH_2COOCH_3$	H_2O
Initial amounts / mol	0.52	0.37	0	1.2
Equilibrium amounts / mol			0.21	

(Total for Question 17 = 6 marks)

18 Ethanal, CH_3CHO, can be converted by a two-step synthesis into 2-hydroxypropanoic acid.



2-hydroxypropanoic acid

The reagents and conditions are

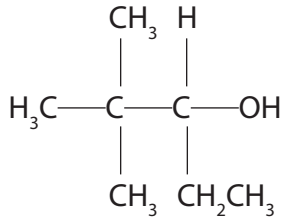
	1st step	2nd step
☒ **A**	$Na_2Cr_2O_7$ and dilute H_2SO_4, heat under reflux	NaOH(aq), heat under reflux
☒ **B**	Cl_2, UV light	NaOH(aq), heat under reflux
☒ **C**	$LiAlH_4$ in dry ether	CO_2, room temperature
☒ **D**	HCN, in presence of KCN(aq)	dilute HCl(aq), heat under reflux

(Total for Question 18 = 1 mark)

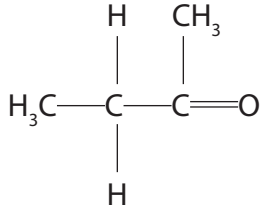
Use this space for any rough working. Anything you write in this space will gain no credit.

19 Questions (a) to (d) concern the following organic compounds.

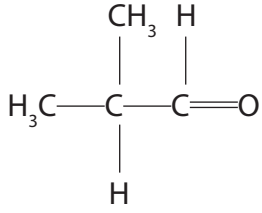
Compound A



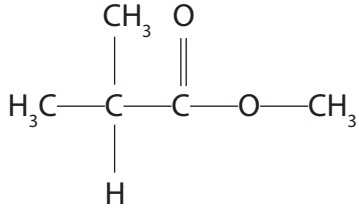
Compound B



Compound C



Compound D



Select from **A** to **D** the compound that

(a) forms iodoform with iodine in the presence of alkali.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(b) is chiral.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(c) reacts with Tollens' reagent.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(d) can be oxidized to form a ketone.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 19 = 4 marks)

20 Ethanoic acid, CH_3COOH, can be converted into ethanoyl chloride, CH_3COCl, by the action of

- ☒ **A** phosphorus(V) chloride.
- ☒ **B** chlorine.
- ☒ **C** dilute hydrochloric acid.
- ☒ **D** concentrated hydrochloric acid.

(Total for Question = 1 mark)

21 A compound, **Q**, gives an orange precipitate with 2,4-dinitrophenylhydrazine.
Compound **Q** is resistant to oxidation.
On reduction, **Q** gives a product made up of a pair of optical isomers.

Which of the following compounds could be compound **Q**?

- ☒ **A** $CH_3CH_2CH_2COCH_3$
- ☒ **B** $CH_3CH{=}CHCH(OH)CH_3$
- ☒ **C** $CH_3CH_2CH_2CH_2CHO$
- ☒ **D** $CH_3CH_2COCH_2CH_3$

(Total for Question = 1 mark)

SECTION C

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

22 An organic compound, **X**, was analyzed in a laboratory.

(a) Compound **X** was found to have the following percentage composition by mass:

carbon, C = 54.5%

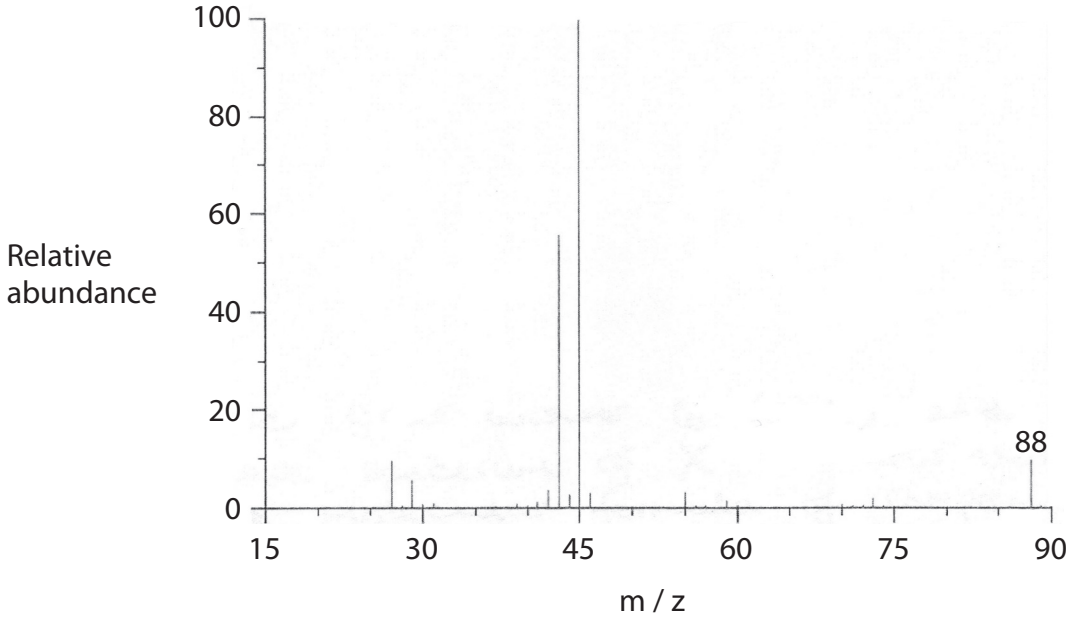
hydrogen, H = 9.1%

oxygen, O = 36.4%

(i) Use these data to calculate the empirical formula of compound **X**, showing your working.

(2)

(ii) The mass spectrum of **X** is shown below.



Use your answer to (a)(i), and the mass spectrum of **X**, to show that the molecular formula of compound **X** is $C_4H_8O_2$.

(2)

(b) The infrared spectrum of **X** has a broad peak at approximately 3500 cm^{-1} and a sharp peak at approximately 1700 cm^{-1}. Identify the **bond** responsible for the peak at

(2)

3500 cm^{-1}

1700 cm^{-1}

(c) (i) Some chemical information about compound **X** is given below.

- **X** is a neutral organic compound.
- **X** has no effect on Tollens' reagent.
- **X** turns hot acidified potassium dichromate(VI) solution from orange to green.

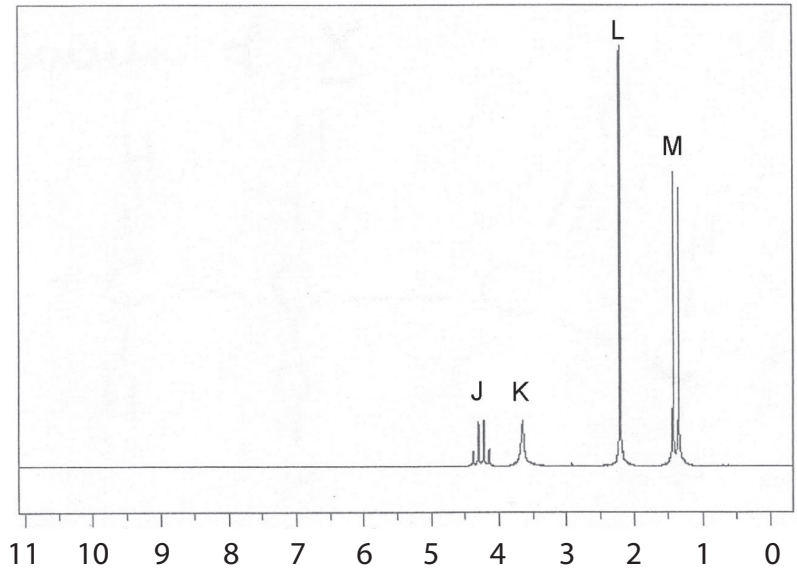
What does each of these three pieces of information suggest about the nature of **X**?

(4)

(ii) Use your answers to parts (b) and (c)(i) to name the two functional groups present in **X**.

(1)

*(d) The high resolution proton nmr spectrum of **X** is shown below.



The relative number of protons causing the peaks shown are: J = 1, K = 1, L = 3 and M = 3.

Use the information above to determine the structural formula of **X**.

In your answer, you should refer to the number of peaks, their relative sizes and their splitting patterns.

(7)

(Total for Question 22 = 18 marks)

23 Select the word that best describes the effect of a chiral molecule on the plane of plane-polarized light. The plane of polarization of light is

- ☒ **A** reflected.
- ☒ **B** refracted.
- ☒ **C** resolved.
- ☒ **D** rotated.

(Total for Question = 1 mark)

24 An organic compound reacts with **both** acidified potassium dichromate(VI) **and** lithium tetrahydridoaluminate (lithium aluminium hydride). The organic compound could be

- ☒ **A** a primary alcohol.
- ☒ **B** an aldehyde.
- ☒ **C** a ketone.
- ☒ **D** a carboxylic acid.

(Total for Question = 1 mark)

25 Ketones react with

- ☒ **A** both 2,4-dinitrophenylhydrazine solution and Tollens' reagent.
- ☒ **B** 2,4-dinitrophenylhydrazine solution but not with Tollens' reagent.
- ☒ **C** Tollens' reagent but not with 2,4-dinitrophenylhydrazine solution.
- ☒ **D** neither Tollens' reagent nor 2,4-dinitrophenylhydrazine solution.

(Total for Question = 1 mark)

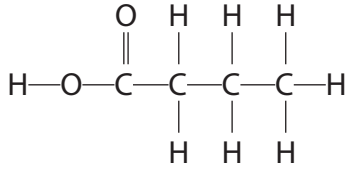
26 Ethanoic acid, CH_3COOH, may be prepared from ethanenitrile, CH_3CN. This reaction is best described as

- ☒ **A** reduction.
- ☒ **B** oxidation.
- ☒ **C** hydrolysis.
- ☒ **D** condensation.

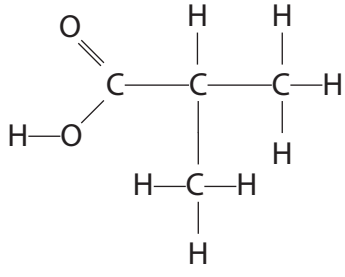
(Total for Question = 1 mark)

27 Propanoic acid reacts with methanol to form an ester. The structure of the ester is

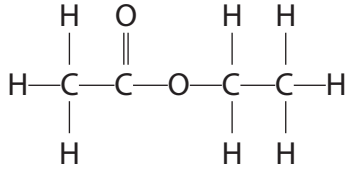
☒ **A**



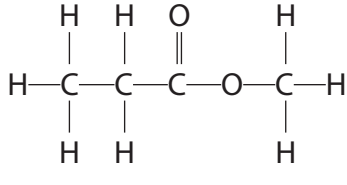
☒ **B**



☒ **C**



☒ **D**



(Total for Question = 1 mark)

28 The boiling temperature of ethanoic acid is very much higher than that of butane although these molecules have similar numbers of electrons. This is because ethanoic acid has

☒ **A** stronger covalent bonds.

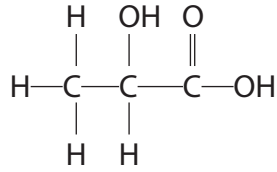
☒ **B** stronger ionic bonds.

☒ **C** greater London forces.

☒ **D** hydrogen bonding.

(Total for Question = 1 mark)

29 2-hydroxypropanoic acid, lactic acid, is a chiral molecule which is found in muscles and in sour milk. The 2-hydroxypropanoic acid formed in muscles is optically active but that in sour milk is not.



2-hydroxypropanoic acid

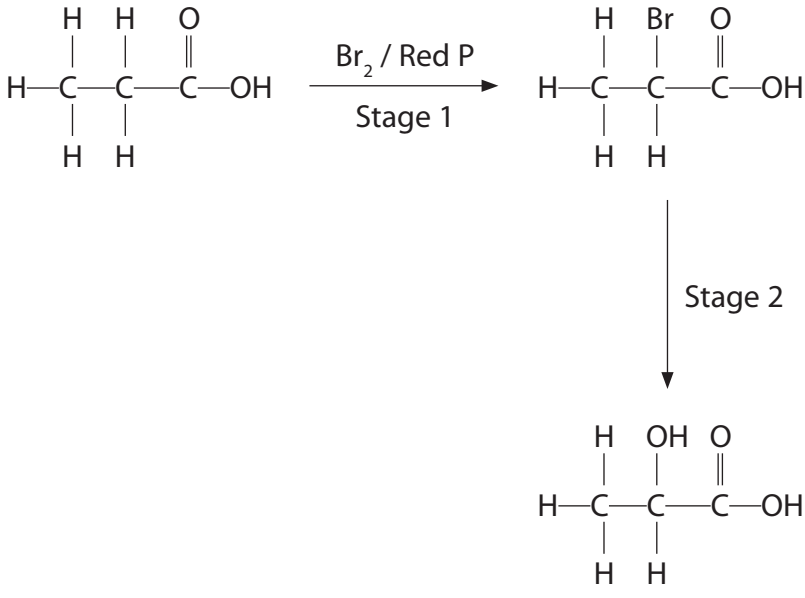
(a) (i) Explain the term **chiral**, stating the feature of 2-hydroxypropanoic acid that makes it chiral. Label this feature on the formula above.

(3)

(ii) What is the difference between the 2-hydroxypropanoic acid formed in muscles and that found in sour milk which gives rise to the difference in optical activity?

(2)

(b) 2-hydroxypropanoic acid may be prepared in the laboratory from propanoic acid in a two-stage sequence in which 2-bromopropanoic acid is formed as an intermediate:



(i) Stage 2 of this sequence was carried out in two steps. Identify the reagent required for each step in Stage 2.

(2)

First step .....

Second step .....

(ii) When an optically active isomer of 2-bromopropanoic acid is used in Stage 2, the resulting 2-hydroxypropanoic acid is also optically active. State and explain what this indicates about the mechanism of the first reaction in Stage 2.

(3)

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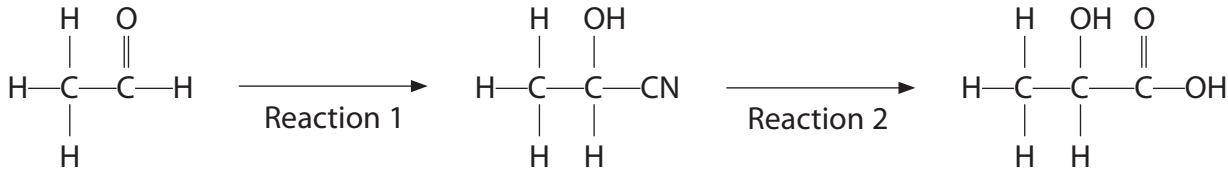
(c) 2-hydroxypropanoic acid may also be prepared from ethanal in the following sequence:



(i) Name the mechanism and type of reaction occurring in Reaction 1.

(2)

(ii) Identify the attacking species in Reaction 1.

(1)

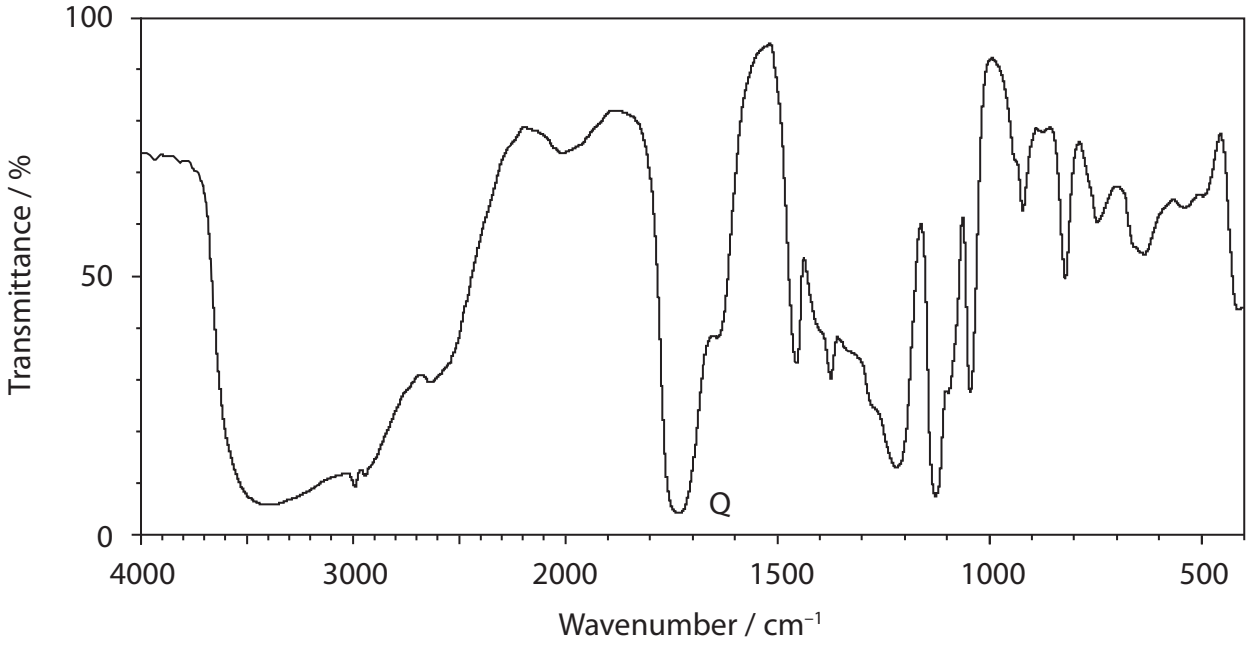
(iii) Give the first step of the mechanism of Reaction 1, showing the formation of the intermediate.

(2)

*(iv) Explain, by referring to the mechanism in (c)(iii), why the 2-hydroxypropanoic acid formed from ethanal shows no optical activity.

(3)

(d) The infrared spectrum of 2-hydroxypropanoic acid is shown below.



(i) Give the wavenumber of the peak that is present in the infrared spectrum of 2-hydroxypropanoic acid but will not be present in the infrared spectrum of ethanal, identifying the group most likely to be responsible for this peak. Use the data on pages 5 and 6 of the data booklet.

(1)

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*(ii) Identify the bond responsible for absorption peak Q in the spectrum. By considering the wavenumber of this peak, and the data on pages 5 and 6 of the data booklet, explain whether this peak **alone** can be used to distinguish between ethanal and 2-hydroxypropanoic acid.

(3)

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(e) Ethanal and 2-hydroxypropanoic acid can be distinguished by the use of chemical tests. Give two suitable tests **not** involving indicators. For each test, state the observation associated with a positive result.

(4)

Test which is positive for ethanal but not for 2-hydroxypropanoic acid.

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Test which is positive for 2-hydroxypropanoic acid but not for ethanal.

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(Total for Question 29 = 26 marks)