Questions

Q1.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature /°C	Density /g cm^{-3}
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

The dried 2-chloro-2-methylpropane was transferred to the distillation apparatus.

11.6 cm^3 of 2-chloro-2-methylpropane was collected from 12.0 g of 2-methylpropan-2-ol.

Infrared spectroscopy can be used to determine the purity of a substance.

(i) State how infrared spectroscopy could be used to show that no 2-methylpropan-2-ol was present in the distillate.

(1)

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(ii) Give one advantage and one disadvantage of using a chemical test rather than infrared spectroscopy to determine whether any of the 2-methylpropan-2-ol remained.

(2)

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(Total for question = 3 marks)

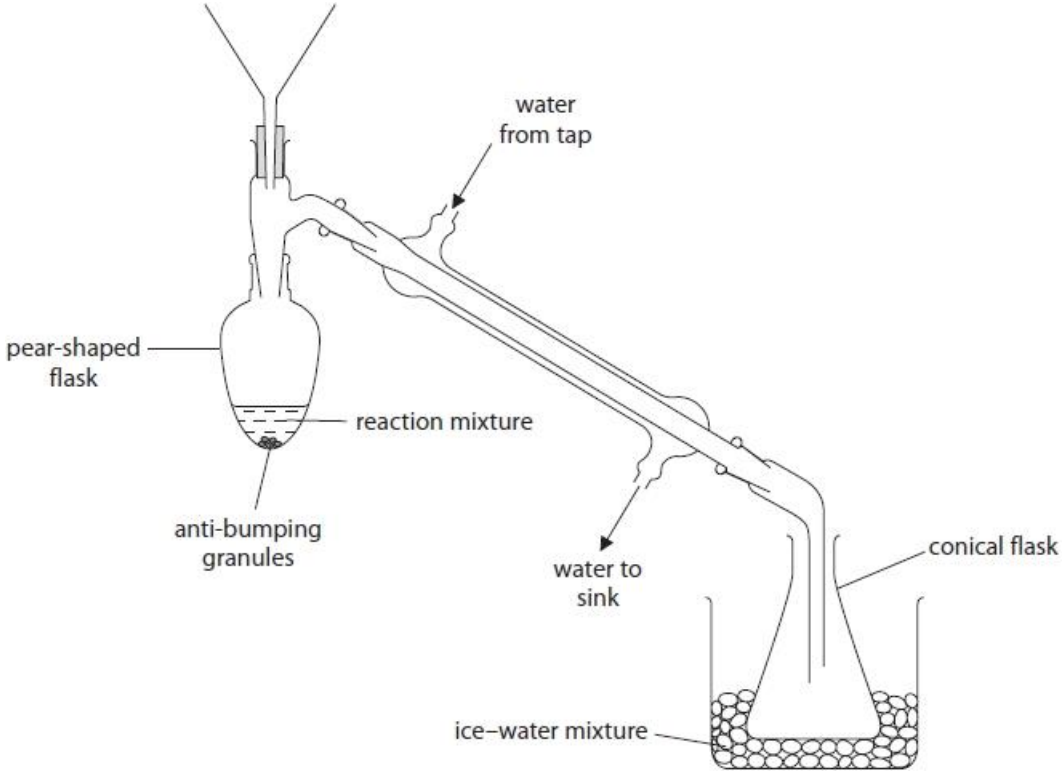
Q2.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

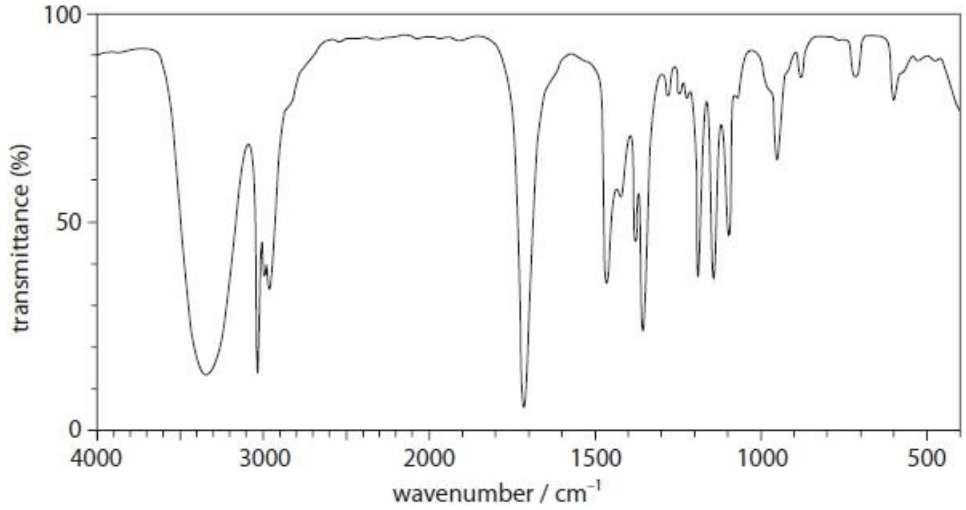
The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



The organic mixture was separated from the aqueous layer and dried.

The infrared spectrum of the organic mixture is shown.



(i) By reference to any relevant peak(s), deduce how the infrared spectrum shows that the mixture contains 3-methylbutan-2-one.

(2)

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(ii) From the infrared spectrum, the student concludes that the mixture contains another organic compound.

The mixture is redistilled and the fraction that boils in the range 93–95°C is collected. The boiling temperature of 3-methylbutan-2-one is 94°C.

Predict any change(s) you would see in the infrared spectrum after redistillation, justifying your answer.

(2)

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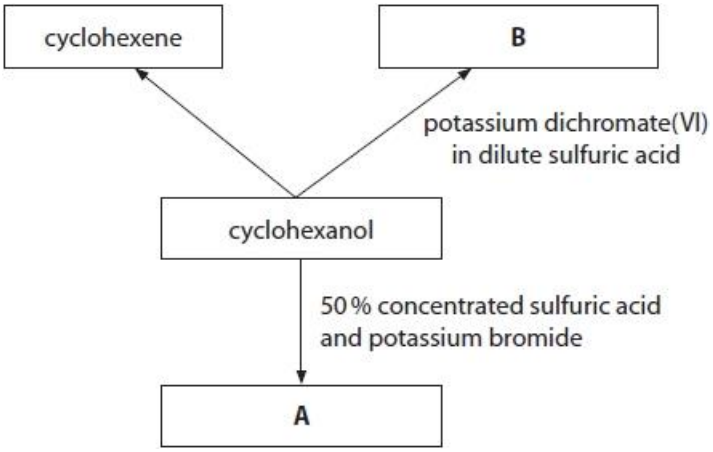
(Total for question = 4 marks)

Q3.

This question is about some reactions of cyclohexanol.

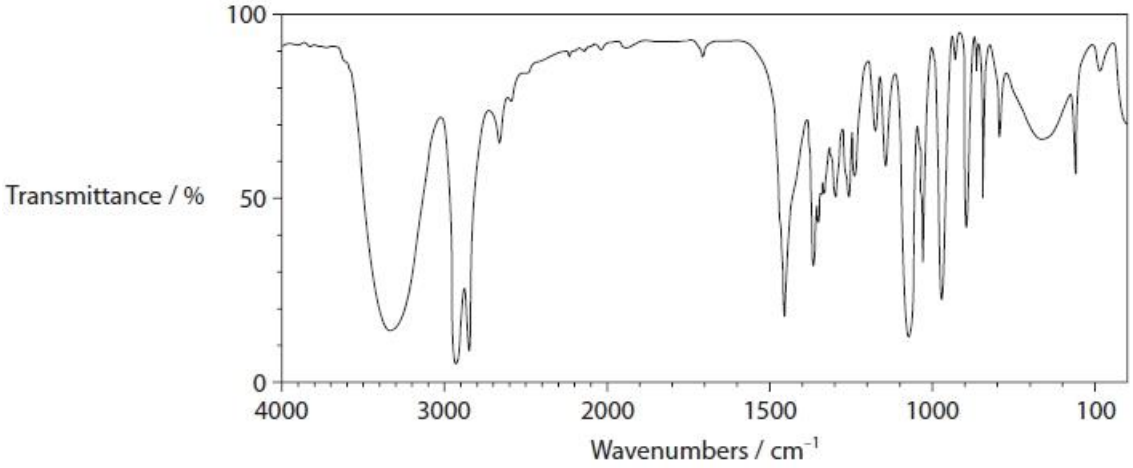


(i) Give the name **and** displayed formula of compound **B**.

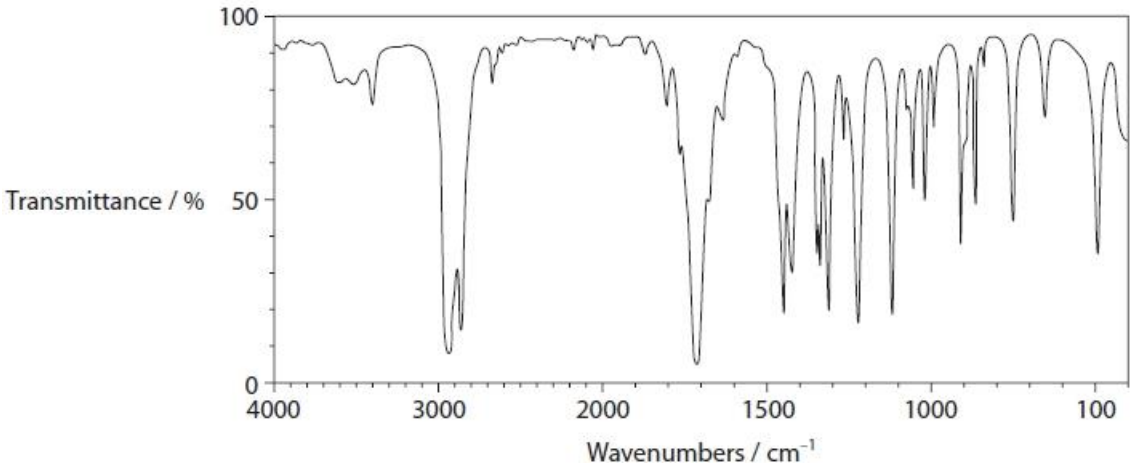
(2)

(ii) The infrared (IR) spectra of cyclohexanol and compound **B** are shown.

IR Spectrum of cyclohexanol



IR Spectrum of compound **B**



Identify the bonds, using **both** IR spectra, that help to confirm the reaction of cyclohexanol to produce compound **B**.
Your answer must include the wavenumber ranges of any relevant bonds.

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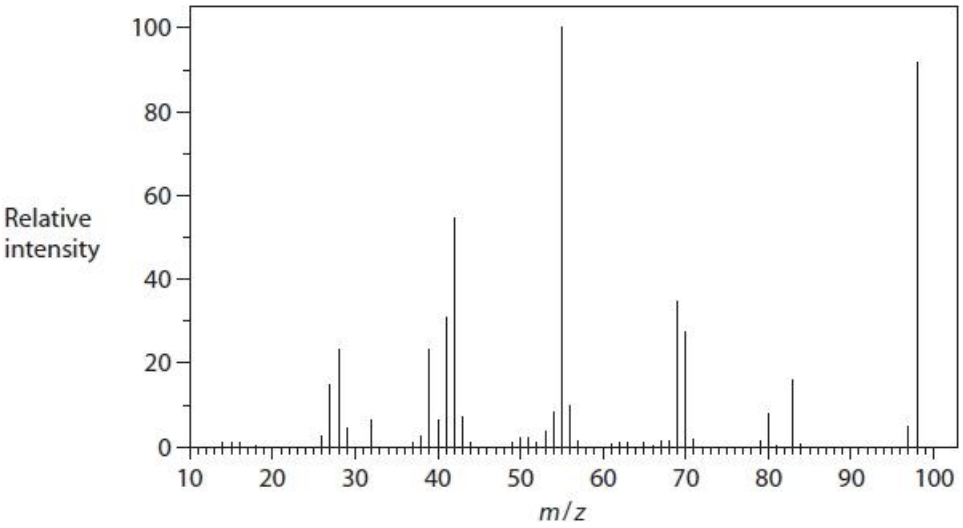
(iii) The mass spectrum of compound **B** is shown.



Deduce the relative molecular mass of compound **B** using the mass spectrum. Justify your answer.

(1)

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(iv) In the mass spectrum of cyclohexanol, there is a peak at *m*/*z* = 83.

Give the formula of a fragment that could be responsible for this peak.

(2)

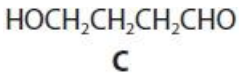
(Total for question = 7 marks)

Q4.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

Another student suggests that the compound could contain an aldehyde and an alcohol functional group, with structure **C**.



Complete the table to show how the infrared spectra of **A**, **B** and **C** would be expected to differ in the wavenumber range **1800-1600 cm^{-1}**.
Use information from the Data Booklet.

(3)

Absorbance	Wavenumber range / cm^{-1}
Absorbance expected in infrared spectrum of **A** but **not** in **B** or **C**	
Absorbance expected in infrared spectrum of **B** but **not** in **A** or **C**	
Absorbance expected in infrared spectrum of **C** but **not** in **A** or **B**	

(Total for question = 3 marks)

Q5.

* This question is about compounds with the molecular formula C_4H_8O.

Three different compounds, **A**, **B** and **C**, have the molecular formula C_4H_8O.

Information about these three compounds includes:

- all three compounds have infrared absorptions at about 3500 cm^{-1}
- the infrared spectra of **A** and **B** each contain a peak at about 1650 cm^{-1}, while that of **C** does not
- only **A** has a branched carbon chain
- **B** is the *E*-isomer of a pair of stereoisomers.

Deduce a possible **displayed** formula for each of the compounds **A**, **B** and **C**.

You must use **all** the information and the Data Booklet to fully justify each of your structures.

(6)

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(Total for question = 6 marks)

Q6.

Organic compounds containing nitrogen include amides, amines, amino acids and nitriles.

A compound produced a peak due to an N—H stretching vibration in its infrared spectrum with
a wavenumber of 3220 cm^{-1}.

This compound could be

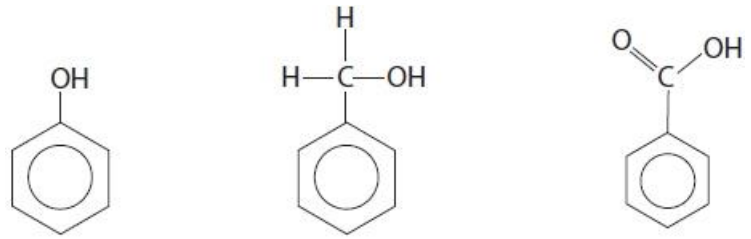
(1)

- ☒ **A** an amide
- ☒ **B** an amine
- ☒ **C** either an amide or an amine
- ☒ **D** neither an amide nor an amine

(Total for question = 1 mark)

Q7.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

Spectroscopy is an effective means of distinguishing between molecules.

(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid. Include relevant bonds and their wavenumber ranges using the Data Booklet.

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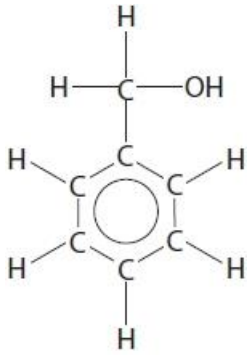
(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of
phenylmethanol.
Use the information in the Data Booklet to help you.

(3)



phenylmethanol

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(iii) Give the formula of a fragment ion, with its *m*/*z* value, that you would expect to be present in the mass spectrum of
benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of phenylmethanol.

(2)

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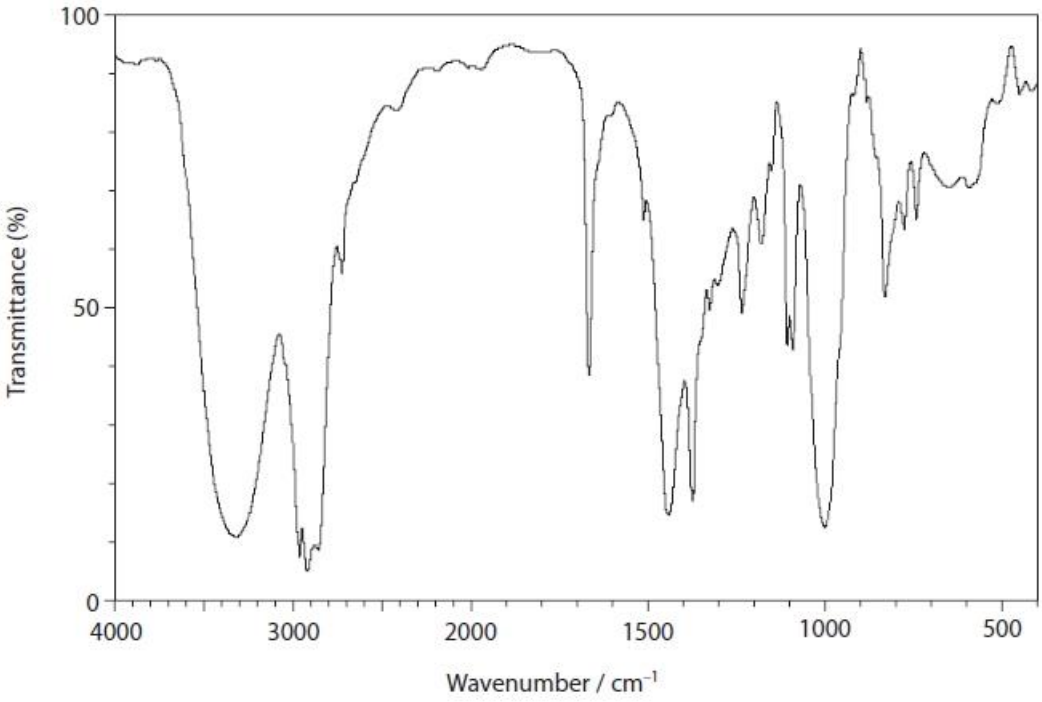
(Total for question = 10 marks)

Q8.

(a) The infrared spectrum of geraniol is shown.



Using the table of absorptions from the Data Booklet and the infrared spectrum, give the **names** of the two functional groups present in geraniol.To confirm these functional groups, give the wavenumber ranges and their corresponding bonds.

(2)

First functional group

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Second functional group

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(b) Give **one** chemical test that you could use to confirm the presence of each of the two functional groups suggested in part (a). Predict a result for each test.

(4)

Test and result for first functional group

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Test and result for second functional group

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(Total for question = 6 marks)

Q9.

(a) This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at $m / z = 116$.

The three students each propose a different structural formula for compound **X**.

Structure 1 HOOCCH==CHCOOH

Structure 2 $HOCH_2CH{=}{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

The students are given the infrared spectrum of **X**.

(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

(2)

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(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet **alone** could be used to identify which of the three proposed structures is **X**.

Show that this student's suggestion is correct. Include relevant infrared data in your answer.

(3)

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(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.

Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol dm^{-3}.
Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 cm^3 of a 0.140 mol dm^{-3} solution.

(2)

(c) Each of the students makes up 250.0 cm^3 of 0.140 mol dm^{-3} sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

Student A

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution and pipettes a volume of 10.0 cm^3 of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 cm^3.

Student B

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several cm^3 beyond the graduation mark
- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 cm^3 of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

Student C

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 cm^3 of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

(2)

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(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

(2)

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(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of ±0.05 cm^3 for each volume reading
- The volumetric flask has an uncertainty of ±0.30 cm^3 for the volume
- The pipette has an uncertainty of ±0.04 cm^3 for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

(3)

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 cm^3. The results indicate that **X** has **structure 1**.

Structure 1 HOOCCH==CHCOOH
Structure 2 $HOCH_2CH{=}{=}CHCH_2COOH$
Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

(2)

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.
Justify your answer.

(2)

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(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).
Use a tick (✓) if a reaction occurs.
Use a cross (✗) if no reaction occurs.

(2)

Structure	Test with bromine water	Test with acidified potassium dichromate(VI)
$HOOCCH{=}{=}CHCOOH$		
$HOCH_2CH{=}{=}CHCH_2COOH$		
$CH_3CH_2CH_2CH_2CH_2COOH$		

(f) The structure HOOCCH==CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

(2)

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH==CHCOOH has *E*/*Z* isomers.

(2)

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(Total for question = 24 marks)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • look for the absence of peaks in the infrared spectrum corresponding to the O-H (stretching absorption in alcohols) / in the range 3750 – 3200 / 3200 – 3750 (cm^{-1})	Ignore references to incorrect spectrometers, e.g. mass spectrometer Do not award for –O–H where it is unclear which bond is stretching	(1)

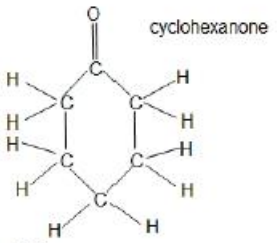
Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • an advantage is the cost associated with the chemical test is small Or result is very rapid Or chemicals are readily available (1) • a disadvantage is the chemical test is not so sensitive Or Uses some of the sample which cannot easily be recovered (1)	Allow reverse arguments for infrared spectroscopy Ignore comments about quantities used Allow can be in schools / anywhere Allow infrared spectroscopes not available in schools / require special laboratories Allow easy to access the chemicals Ignore test is less accurate Allow produces hazardous /corrosive HCl (from PCl_5) Allow produces hazardous / flammable H_2 (from Na) Ignore comments about identification of compounds using spectroscopy	(2)

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • peak at 1720 (cm^{-1}) **(1)** • shows presence of a C=O bond / carbonyl **(1)**	 Allow any absorbance between 1720 to 1700 (cm^{-1}) Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H Ignore references to alkane C-H bonds / fingerprint region Do not award just 'ketone' for MP2	**(2)**

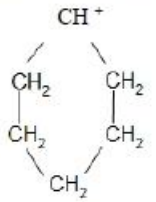
Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • peak between 3750 and 3200 (cm^{-1}) will disappear / will be absent from the spectrum OR Peak(s) above 3000(cm^{-1}) will disappear / will be absent from the spectrum **(1)** • (because) 3-methylbutan-2-ol / the alcohol / O-H has now been removed **(1)**	 Allow any absorbance between 3750 to 3200 (cm^{-1}) Ignore references to fingerprint region	**(2)**

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • name (1) • displayed formula (1)	Example of displayed formula  Allow CH_2 groups Allow skeletal formula Do not award molecular formula	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • O-H bond (stretching) 3750 – 3200 cm^{-1} in cyclohexanol is not present in cyclohexanone /disappears (when cyclohexanol reacts). (1) • C=O bond (stretching) 1720 – 1700 cm^{-1} appears in cyclohexanone (1)	Allow a range within the specified range Allow 1725 – 1700 cm^{-1} Do not allow 1740 – 1720 cm^{-1} (aldehyde)	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	• highest $m/z = M_r = 98$	Check, answer may be shown on mass spectrum Do not accept just '98' with no supporting evidence Allow peak furthest to the right / molecular ion peak is 98	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	• fragment (1) • charge (1)	Examples of fragment structure  $C_6H_{11}^+$ Allow charge anywhere on fragment, including outside brackets around the fragment Allow straight chain fragment provided it has the correct number of C and H atoms	(2)

Q4.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td></td><td>

- absorbance for **A** **(1)**
- absorbance for **B** **(1)**
- absorbance for **C** **(1)**

</td><td>

Example of table

<table>
<tr><th>Absorbance</th><th>Wavenumber range / cm^{-1}</th></tr>
<tr><td>Absorbance expected in infrared spectrum of A but not in B or C</td><td>1720 – 1700
Allow 1725 - 1700</td></tr>
<tr><td>Absorbance expected in infrared spectrum of B but not in A or C</td><td>1669 – 1645</td></tr>
<tr><td>Absorbance expected in infrared spectrum of C but not in A or B</td><td>1740 – 1725
Allow 1740 - 1720</td></tr>
</table>

Allow values in reverse order e.g. 1700 – 1720 for **A**

If single values are given instead of a range award (2) for 3 correct values within the ranges and (1) for 2 correct values

Do not award a single value that occurs in two ranges i.e 1720-1725

If no other mark is awarded, allow (1) for:
A 3300-2500 **and C** 2900-2820 / 2775-2700

</td><td>**(3)**</td></tr>
</table>

Q5.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

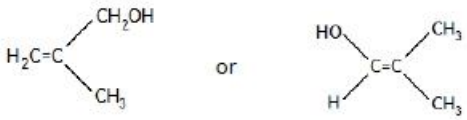
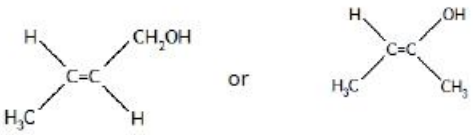
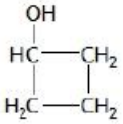
<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table></td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning.

For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>(6)</td></tr>
<tr><td colspan="2">The following table shows how the marks should be awarded for structure and lines of reasoning.
<table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table></td><td colspan="2">In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

Reasoning marks may be reduced for extra incorrect chemistry</td></tr>
</table>

Indicative content: IP1 • IR data shows that they all have an (alcohol) O−H and A and B have a C=C	Can be awarded as statements about all 3 together or separately
IP2 • B must have two different groups attached to each carbon of a double bond	Allow discussion of priority groups Allow double bond must be in the middle
IP3 • C (has no double bond so) must be cyclic	Allow statement that C does not have a C=C Do not award C has a C=O
IP4 • A is 	Allow 2-methyl-1-propen-1-ol / $CH_2 = C(CH_3)CH_2OH$ / skeletal formula Allow enol isomer (as shown)
IP5 • B is 	Allow *E*-but-2-ene-1-ol / skeletal formula and enol isomers (as shown) but must be an *E*-isomer
IP6 • C is 	Allow cyclobutanol / skeletal formula Allow methylcyclopropanol isomers with OH on any carbon

Q6.

Question Number	Answer	Mark
	The only correct answer is A (an amide) ***B*** *is not correct because the amine range does not include* 3220 cm^{-1} ***C*** *is not correct because the amine range does not include* 3220 cm^{-1} ***D*** *is not correct because the amide range does include* 3220 cm^{-1}	**(1)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to • (**M1**) (similarity) all have arene C–H absorptions Either 3030 (cm^{-1}) **or** 750 and/or 700 (cm^{-1}) **(1)** • (**M2**) only phenol and phenylmethanol have O–H 3750 - 3200 (cm^{-1}) **(1)** • (**M3**) only benzoic acid has O–H 3300 - 2500 (cm^{-1}) **(1)** • (**M4**) only benzoic acid has C=O 1700 - 1680 (cm^{-1}) **(1)** • (**M5**) only phenylmethanol has alkane C–H absorptions either 2962 - 2853 (cm^{-1}) or 1485 - 1365 (cm^{-1}) **(1)**	Bond and wavenumber ranges necessary for each mark Do not award 880/830/780 (cm^{-1}) Do not award –OH / C–OH by penalising once only in M2 and M3 All 5 correct bonds with no wavenumber ranges scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) All 5 correct wavenumber ranges with no bonds or incorrect bonds scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) Penalise any additional peaks once only Ignore references to different fingerprint regions	**(5)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to • five peaks (in the ^{13}C NMR spectrum) **(1)** • (four) aromatic peaks within the chemical shift range of 165 - 105 (ppm) **(1)** • (one) peak (for the C-OH) within the chemical shift range of 75 - 55 (ppm) **(1)**	Allow any range within the stated ranges Penalise single values as opposed to ranges once only Accept annotations on diagram Penalise additional peaks once only when three or more types of peak are stated	**(3)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to • suitable formula of fragment ion **(1)** • matching *m*/*z* value **(1)**	Example of a suitable formula $C_6H_5COO^+$ or $C_6H_5CO^+$ Do not award $C_7H_5O_2^+$ or $C_7H_5O^+$ *m*/*z* = 121 or 105 Allow $COOH^+$ (1) Do not award bond to the fragment, e.g. –$COOH^+$ *m*/*z* = 45 (1) No TE on incorrect fragment ions such as CH_3^+	**(2)**

Q8.

Question Number	Answer Acceptable	Additional Guidance	Mark
(a)	alkene **and** C=C **and** (IR) peak between 1669 and 1645 (cm^{-1}) OR alkene **and** C-H **and** (IR) peak between 3095 and 3010 OR 3095 and 2995 (cm^{-1}) **(1)** alcohol **and** O-H **and** (IR) peak between 3750 and 3200 (cm^{-1}) **(1)**	can be in either order Allow CH (bond) Ignore any qualification of the wavenumber range eg isolated alcohol or phenol Allow Hydroxyl Do not award Hydroxide Allow OH (bond) Do not award –OH /–O–H If both bonds missing and everything else correct, award 1 mark Ignore all references to alkanes Allow single IR value or range within the data book range	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: Alkene • bromine water/Br_2(aq)/bromine **(1)** • decolorised or orange/yellow/brown to colourless **(1)** Alcohol • PCl_5/phosphorus pentachloride /phosphorus(V)chloride **(1)** • Misty/steamy/white fumes **(1)**	Allow alkene and alcohol in either order. No TE for other groups incorrectly identified in 4c or alkanes Result dependent on correct test for both functional groups allow acidified potassium manganate/$KMnO_4$. Decolourised (from purple) allow (warm with) acidified $Cr_2O_7^{2-}$ turns from orange to green / blue If name and formula, both must be correct sodium (metal) effervescence OR any other workable test and correct result	**(4)**

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • 3300 — 2500 (cm^{-1}) **and** O-H (bond) **(1)** • 1725 — 1700 (cm^{-1}) **and** C=O (bond) **(1)**	Allow any value(s) within the range 3300 — 2500 (cm^{-1}) Allow -OH Allow any value(s) within the range 1725 — 1700 (cm^{-1}) Allow 1320 – 1210 (cm^{-1}) **and** C-O	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • structures 1 and 2 will have an absorption at Either C=C at 1669 — 1645 (cm^{-1}) **or** C—H in an alkene at 3095 — 3010 (cm^{-1}) **(1)** • only structure 2 will have an absorption due to the presence of an alcohol / O—H at 3750 —3200 (cm^{-1}) **(1)** • structure 3 will have none of these absorptions / will not show C=C absorption / C-H absorption for an alkene **(1)**	Reject C=C at 3010 (cm^{-1})	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculation of moles of NaOH **(1)** • calculation of mass of NaOH **(1)**	Example of calculation: (moles NaOH = 0.140 x 250) 1000 = 0.035(0) (mol) = 40(.0) x 0.035(0) = 1.4(0) (g) Correct answer with or without working scores 2 marks Allow TE for M2 on moles of NaOH Alternative route, allow M1 for conversion of concentration to 5.6 g dm^{-3} Ignore SF	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • (because the) sodium hydroxide has been diluted **(1)** • (the titre will be) smaller **(1)**	Allow Fewer moles of sodium hydroxide present / some sodium hydroxide will have been removed M2 dependent on M1	(2)

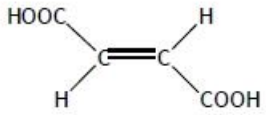
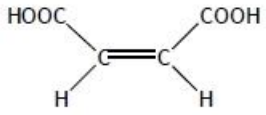
Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	An explanation that makes reference to the following points: M1 no effect (on the titre) **(1)** M2 because the (number of) moles of sodium hydroxide is unaffected **(1)**	 M2 depends on M1 Allow base / alkali / hydroxide (ions) Allow amount / mass of sodium hydroxide is unaffected	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(iii)	• calculation of percentage uncertainty in burette volume **(1)** • calculation of percentage uncertainty in volumetric flask volume **and** in pipette volume **(1)** • identification of volume with the lowest percentage uncertainty **(1)**	Example of calculation: $\frac{2 \times (\pm)0.05}{10.20} \times 100\% = (\pm)0.980392156\%$ $\frac{(\pm)0.30}{250.0} \times 100\% = (\pm)0.12\%$ **and** $\frac{(\pm)0.040}{10.0} \times 100\% = (\pm)0.4\%$ Volumetric flask has the lowest uncertainty Allow TE for identification in M3 Allow ANY number of SF in answer, from 1 SF up to calculator value	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	• left-hand side of equation correct **(1)** • right-hand side of equation correct **(1)**	Example of equation $HOOCCH=CHCOOH + 2NaOH \rightarrow NaOOCCH=CHCOONa + 2H_2O$ ALLOW use of molecular formulae or ionic equation: $C_4H_4O_4 + 2NaOH \rightarrow Na_2C_4H_2O_4 + 2H_2O$ $HOOCCH=CHCOOH + 2OH^- (+ 2Na^+) \rightarrow {}^-OOCCH=CHCOO^- + 2H_2O (+ 2Na^+)$ ALLOW Multiples Correct charges Do not award if O–Na covalent bond drawn IGNORE State symbols, even if incorrect	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following points: • (New mean titre) = 20.4(0) (cm^3) / double (the original value) **(1)** • For structure 2, mole ratio / reacting ratio is 1:1 (with NaOH) **(1)**	Mark M1 and M2 independently Allow structure 2 has 1 COOH / 1 acid group	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	<table><tr><th>Structure</th><th>Test with Br_2 water</th><th>Test with acidified $K_2Cr_2O_7$</th></tr><tr><td>HOOCCH=CHCOOH</td><td>✓</td><td>x</td></tr><tr><td>$HOCH_2CH=CHCH_2COOH$</td><td>✓</td><td>✓</td></tr><tr><td>$CH_3CH_2CH_2CH_2CH_2COOH$</td><td>x</td><td>x</td></tr></table> Left hand column correct **(1)** Right hand column correct **(1)**	3 correct ticks with no crosses scores 1 Ignore descriptions of result in terms of colour (changes) / reactions occurring	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)(i)	• *E*-isomer:  **(1)** • *Z*-isomer:  **(1)**	ALLOW skeletal or displayed structures ALLOW $-CO_2H$ IGNORE Connectivity to the –COOH group IGNORE bond angles Award one mark if correct structures are drawn, but *E*- and *Z*-isomers labelled the wrong way round Award 1 mark if incorrect molecule used but *E* - and *Z*- isomers are correct	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)(ii)	An answer that makes reference to the following points: • restricted / limited rotation (about the C=C double bond)**(1)** • each carbon atom in the double bond is attached to (two) different atoms / different groups (of atoms) / to a H (atom) and a COOH group **(1)**	Allow "no rotation" Do not award the carbons are attached to 2 "different molecules" Mark points M1 and M2 independently	**(2)**