## Mark Scheme

Q1.

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (i) | An answer that makes reference to the following points:<br>• 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<br>Do not award for –O–H where it is unclear which bond is stretching | (1) |

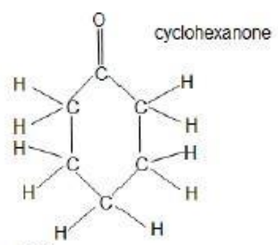
| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (ii) | An answer that makes reference to the following points:<br>• an advantage is the cost associated with the chemical test is small Or result is very rapid Or chemicals are readily available (1)<br>• a disadvantage is the chemical test is not so sensitive Or Uses some of the sample which cannot easily be recovered (1) | Allow reverse arguments for infrared spectroscopy<br>Ignore comments about quantities used<br>Allow can be in schools / anywhere<br>Allow infrared spectroscopes not available in schools / require special laboratories<br>Allow easy to access the chemicals<br>Ignore test is less accurate<br>Allow produces hazardous /corrosive HCl (from $PCl_5$)<br>Allow produces hazardous / flammable $H_2$ (from Na)<br>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:<br>• peak at 1720 ($cm^{-1}$) **(1)**<br>• shows presence of a C=O bond / carbonyl **(1)** | Allow any absorbance between 1720 to 1700 ($cm^{-1}$)<br>Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H<br>Ignore references to alkane C-H bonds / fingerprint region<br>Do not award just 'ketone' for MP2 | (2) |

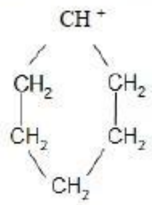
| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (ii) | An answer that makes reference to the following points:<br>• peak between 3750 and 3200 ($cm^{-1}$) will disappear / will be absent from the spectrum<br>OR<br>Peak(s) above 3000($cm^{-1}$) will disappear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

**Q3.**

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

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (ii) | An answer that makes reference to the following points:<br>• O-H bond (stretching) 3750 – 3200 $cm^{-1}$ in cyclohexanol is not present in cyclohexanone /disappears (when cyclohexanol reacts). (1)<br>• C=O bond (stretching) 1720 – 1700 $cm^{-1}$ appears in cyclohexanone (1) | Allow a range within the specified range<br>Allow 1725 – 1700 $cm^{-1}$<br>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<br>Do not accept just '98' with no supporting evidence<br>Allow peak furthest to the right / molecular ion peak is 98 | (1) |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (iv) | • fragment (1)<br>• charge (1) | Examples of fragment structure<br><br>$C_6H_{11}^+$<br>Allow charge anywhere on fragment, including outside brackets around the fragment<br>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>
<ul>
<li>absorbance for A (1)</li>
<li>absorbance for B (1)</li>
<li>absorbance for C (1)</li>
</ul>
</td>
<td>
<u>Example of table</u>
<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<br>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<br>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:<br>A 3300-2500 and C 2900-2820 / 2775-2700
</td>
<td>(3)</td>
</tr>
</table>

**Q5.**

| Question Number | Acceptable Answer | Additional Guidance | Mark |
|---|---|---|---|
| * | This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.<br><br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>The following table shows how the marks should be awarded for indicative content. | Guidance on how the mark scheme should be applied:<br><br>The mark for indicative content should be added to the mark for lines of reasoning.<br><br>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).<br><br>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). | (6) |

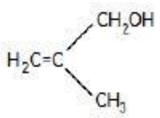
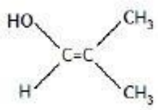
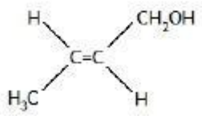
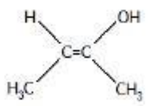
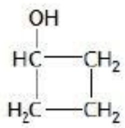
| Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points |
|---|---|
| 6 | 4 |
| 5–4 | 3 |
| 3–2 | 2 |
| 1 | 1 |
| 0 | 0 |

The following table shows how the marks should be awarded for structure and lines of reasoning.

| | Number of marks awarded for structure of answer and sustained line of reasoning |
|---|---|
| Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2 |
| Answer is partially structured with some linkages and lines of reasoning. | 1 |
| Answer has no linkages between points and is unstructured. | 0 |

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

| | |
|---|---|
| **Indicative content:** | |
| IP1<br>• 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<br>• B must have two different groups attached to each carbon of a double bond | Allow discussion of priority groups<br>Allow double bond must be in the middle |
| IP3<br>• C (has no double bond so) must be cyclic | Allow statement that C does not have a C=C<br>Do not award C has a C=O |
| IP4<br>• A is  or  | Allow 2-methyl-1-propen-1-ol / $CH_2 = C(CH_3)CH_2OH$ / skeletal formula<br>Allow enol isomer (as shown) |
| IP5<br>• B is  or  | Allow *E*-but-2-ene-1-ol / skeletal formula and enol isomers (as shown) but must be an *E*-isomer |
| IP6<br>• C is  | Allow cyclobutanol / skeletal formula<br><br>Allow methylcyclopropanol isomers with OH on any carbon |

**Q6.**

| Question Number | Answer | Mark |
|---|---|---|
| | **The only correct answer is A** (an amide)<br><br>***B*** *is not correct because the amine range does not include* 3220 $cm^{-1}$<br><br>***C*** *is not correct because the amine range does not include* 3220 $cm^{-1}$<br><br>***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<br><br>• (M1) (similarity) all have arene C–H absorptions<br>Either 3030 ($cm^{-1}$)<br>**or**<br>750 and/or 700 ($cm^{-1}$)<br>**(1)**<br><br>• (M2) only phenol and phenylmethanol have O–H<br>3750 - 3200 ($cm^{-1}$)<br>**(1)**<br><br>• (M3) only benzoic acid has O–H<br>3300 - 2500 ($cm^{-1}$)<br>**(1)**<br><br>• (M4) only benzoic acid has C=O 1700 - 1680 ($cm^{-1}$)<br>**(1)**<br><br>• (M5) only phenylmethanol has alkane C–H absorptions<br>either<br>2962 - 2853 ($cm^{-1}$)<br>or<br>1485 - 1365 ($cm^{-1}$)<br>**(1)** | Bond and wavenumber ranges necessary for each mark<br><br>Do not award 880/830/780 ($cm^{-1}$)<br><br>Do not award –OH / C–OH by penalising once only in M2 and M3<br><br>All 5 correct bonds with no wavenumber ranges scores (3) 4 correct etc scores (2) and 3 correct etc scores (1)<br><br>All 5 correct wavenumber ranges with no bonds or incorrect bonds scores (3) 4 correct etc scores (2) and 3 correct etc scores (1)<br><br>Penalise any additional peaks once only<br><br>Ignore references to different fingerprint regions | **(5)** |

| Question Number | Answer | Additional Guidance | Mark |
|---|---|---|---|
| (ii) | An answer that makes reference to<br><br>• five peaks (in the $^{13}C$ NMR spectrum)<br>**(1)**<br><br>• (four) aromatic peaks within the chemical shift range of 165 - 105 (ppm)<br>**(1)**<br><br>• (one) peak (for the C-OH) within the chemical shift range of 75 - 55 (ppm)<br>**(1)** | Allow any range within the stated ranges<br>Penalise single values as opposed to ranges once only<br>Accept annotations on diagram<br><br>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<br>• suitable formula of fragment ion **(1)**<br>• matching *m*/*z* value **(1)** | Example of a suitable formula<br>$C_6H_5COO^+$ or $C_6H_5CO^+$<br>Do not award $C_7H_5O_2^+$ or $C_7H_5O^+$<br>*m*/*z* = 121 or 105<br>Allow<br>$COOH^+$ (1)<br>Do not award bond to the fragment, e.g. $-COOH^+$<br>*m*/*z* = 45 (1)<br>No TE on incorrect fragment ions such as $CH_3^+$ | **(2)** |

**Q8.**

| Question Number | Answer Acceptable | Additional Guidance | Mark |
|---|---|---|---|
| (a) | alkene **and**<br>C=C **and**<br>(IR) peak between 1669 and 1645 ($cm^{-1}$)<br>OR<br>alkene **and**<br>C-H **and**<br>(IR) peak between 3095 and 3010 OR 3095 and 2995 ($cm^{-1}$)<br>**(1)**<br>alcohol **and**<br>O-H **and**<br>(IR) peak between 3750 and 3200 ($cm^{-1}$)<br>**(1)** | can be in either order<br>Allow CH (bond)<br>Ignore any qualification of the wavenumber range eg isolated alcohol or phenol<br>Allow Hydroxyl<br>Do not award Hydroxide<br>Allow OH (bond)<br>Do not award –OH /–O–H<br>If both bonds missing and everything else correct, award 1 mark<br>Ignore all references to alkanes<br>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:<br><br>Alkene<br>• bromine water/$Br_2$(aq)/bromine **(1)**<br>• decolorised or orange/yellow/brown to colourless **(1)**<br><br>Alcohol<br>• $PCl_5$/phosphorus pentachloride /phosphorus(V)chloride **(1)**<br>• Misty/steamy/white fumes **(1)** | Allow alkene and alcohol in either order.<br>No TE for other groups incorrectly identified in 4c or alkanes<br>Result dependent on correct test for both functional groups<br><br>allow acidified potassium manganate/$KMnO_4$.<br>Decolourised (from purple)<br><br>allow (warm with) acidified $Cr_2O_7^{2-}$ turns from orange to green / blue<br>If name and formula, both must be correct<br><br>sodium (metal) effervescence<br>OR<br>any other workable test<br>and correct result | **(4)** |

**Q9.**

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (a)(i) | An answer that makes reference to the following points:<br>• 3300 — 2500 ($cm^{-1}$) **and** O-H (bond) **(1)**<br>• 1725 — 1700 ($cm^{-1}$) **and** C=O (bond) **(1)** | Allow any value(s) within the range 3300 — 2500 ($cm^{-1}$)<br>Allow -OH<br><br>Allow any value(s) within the range 1725 — 1700 ($cm^{-1}$)<br><br>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:<br><br>• 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)**<br><br>• only structure 2 will have an absorption due to the presence of an alcohol / O—H at 3750 —3200 ($cm^{-1}$) **(1)**<br><br>• 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)**<br><br>• calculation of mass of NaOH **(1)** | Example of calculation:<br><br>(moles NaOH = 0.140 x 250)<br><br>1000<br>= 0.035(0) (mol)<br><br>= 40(.0) x 0.035(0) = 1.4(0) (g)<br><br>Correct answer with or without working scores 2 marks<br><br>Allow TE for M2 on moles of NaOH<br><br>Alternative route, allow M1 for conversion of concentration to 5.6 g $dm^{-3}$<br><br>Ignore SF | **(2)** |

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

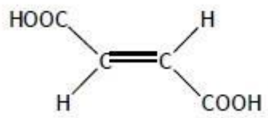
| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (c)(ii) | An explanation that makes reference to the following points:<br><br>M1 no effect (on the titre) **(1)**<br><br>M2 because the (number of) moles of sodium hydroxide is unaffected **(1)** | M2 depends on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

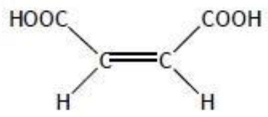
| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (c)(iii) | • calculation of percentage uncertainty in burette volume **(1)**<br><br>• calculation of percentage uncertainty in volumetric flask volume<br><br>**and**<br><br>in pipette volume **(1)**<br><br>• identification of volume with the lowest percentage uncertainty **(1)** | Example of calculation:<br><br>$\frac{2 \times (\pm)0.05}{10.20} \times 100\% = (\pm)0.980392156\%$<br><br>$\frac{(\pm)0.30}{250.0} \times 100\% = (\pm)0.12\%$<br><br>**and**<br><br>$\frac{(\pm)0.040}{10.0} \times 100\% = (\pm)0.4\%$<br><br>Volumetric flask has the lowest uncertainty<br><br>Allow TE for identification in M3<br><br>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)**<br><br>• right-hand side of equation correct **(1)** | Example of equation<br><br>HOOCCH=CHCOOH + 2NaOH → NaOOCCH=CHCOONa + $2H_2O$<br><br>ALLOW use of molecular formulae or ionic equation:<br><br>$C_4H_4O_4 + 2NaOH \rightarrow Na_2C_4H_2O_4 + 2H_2O$<br><br>HOOCCH=CHCOOH + $2OH^-$ (+ $2Na^+$) → $^-$OOCCH=CHCOO$^-$ + $2H_2O$ (+ $2Na^+$)<br><br>ALLOW<br>Multiples<br>Correct charges<br>Do not award if O–Na covalent bond drawn<br>IGNORE<br>State symbols, even if incorrect | **(2)** |

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

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(e)</td><td>
<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)<br>
Right hand column correct (1)
</td><td>3 correct ticks with no crosses scores 1<br><br>Ignore descriptions of result in terms of colour (changes) / reactions occurring</td><td>(2)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(f)(i)</td><td>
• E-isomer:<br>


(1)<br>
• Z-isomer:<br>


(1)
</td><td>ALLOW skeletal or displayed structures<br><br>ALLOW $-CO_2H$<br><br>IGNORE<br>Connectivity to the –COOH group<br><br>IGNORE<br>bond angles<br><br>Award one mark if correct structures are drawn, but E- and Z-isomers labelled the wrong way round<br><br>Award 1 mark if incorrect molecule used but E - and Z- isomers are correct</td><td>(2)</td></tr>
</table>

| Question Number | Acceptable Answers | Additional Guidance | Mark |
|---|---|---|---|
| (f)(ii) | An answer that makes reference to the following points:<br>• restricted / limited rotation (about the C=C double bond) **(1)**<br>• 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"<br>Do not award the carbons are attached to 2 "different molecules"<br>Mark points M1 and M2 independently | (2) |