Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	D		**1**
2	B		**1**

Q. 3: N/A

4	C		**1**
5	A		**1**
6 a	B		**1**
6 b	C		**1**

Q7 - 12: N/A

13	B		**1**
		Total for Section A	**marks**

Q14 : N/A

Question Number	Acceptable Answers	Reject	Mark
15(a)	2,6-dimethylhept-5-enal **(2)** Either part scores **(1)** e.g. 2,6-dimethyl **(1)** hept-5-enal **(1)** IGNORE missing/misplaced/misused hyphens or commas ALLOW ene for en ALLOW methy or methly for methyl		**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(i)	$CH_3C(CH_3)=CHCH_2CH_2CH(CH_3)CH_2OH$ **(1)** OR $CH_3C(CH_3)CHCH_2CH_2CH(CH_3)CH_2OH$ OR $CH_3C(CH_3)=CHCH_2CH_2C\ (CH_3)\ HCH_2OH$ ALLOW displayed or skeletal formulae $K_2Cr_2O_7$/$Na_2Cr_2O_7$/name (oxidation state must be correct if given (VI)) **(1)** This is a stand alone mark H_2SO_4/name (ignore any references to concentration) **(1)** ALLOW H^+ and $Cr_2O_7^{2-}$ **(2)** 'Acidified dichromate' **(1)**	$C_9H_{18}O$ $KMnO_4$ (0) for last 2 marks HCl (0) for 3rd mark	**3**

Question Number	Acceptable Answers	Reject	Mark
15(b)(ii)	(Steam) **distil** off melonal (as it forms) Allow add a limited amount of oxidizing agent/excess alcohol/excess X **(1)** To prevent further oxidation/To prevent carboxylic acid forming **(1)** Stand alone marks		**2**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>15(c)</td><td>
<table>
<tr><th>Wavenumber range / cm^{-1}</th><th>Bond</th><th>Functional group present in melonal</th></tr>
<tr><td>1740 – 1720
OR
2900 – 2820
/
2775 – 2700</td><td>C=O

C-H</td><td>(saturated) Aldehyde/CHO</td></tr>
<tr><td>1669 – 1645
OR
3095 - 3010</td><td>C=C

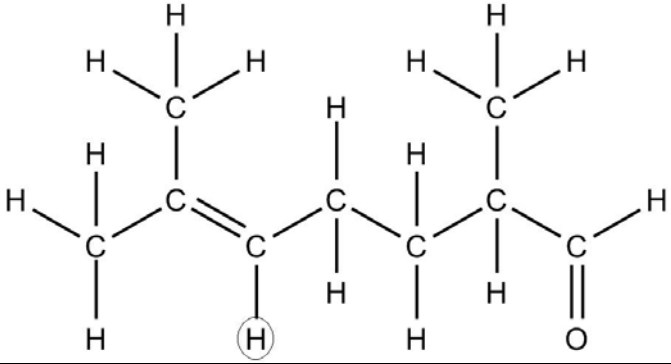
C-H</td><td>Alkene
ALLOW
‘carbon to carbon double bond’</td></tr>
</table>
(1)

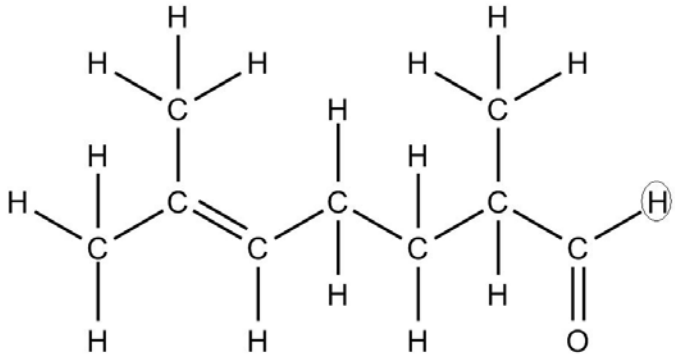
(1)</br>
ALLOW any single value or range within the ranges above

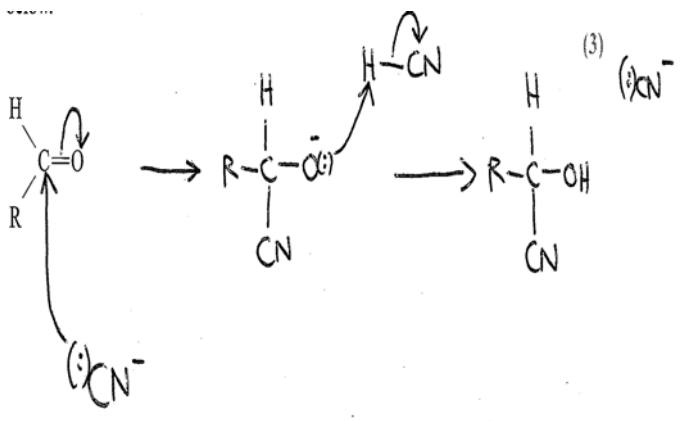
ALLOW one mark if both wavenumber ranges and bond columns are correct but neither bond identified</td><td>Just carbonyl

Just C=C in 3rd column</td><td>2</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
15(d)	$C_3H_5O^+$/CH_3CHCHO^+ **(1)** $C_6H_{11}^+$ **(1)** [ALLOW Structural, skeletal or displayed formulae] Penalise omission of + charge once only ALLOW any order of atoms if correct totals.	$C_4H_9^+$ $C_5H_7O^+$	**2**

Question Number	Acceptable Answers	Reject	Mark
15(e)(i)		Circle around any other additional atoms	**1**

Question Number	Acceptable Answers	Reject	Mark
15(e)(ii)		Circle around any other additional atoms	**1**

Question Number	Acceptable Answers	Reject	Mark
15(f)(i)	 Arrow from anywhere on the cyanide ion to the carbon of the carbonyl. Arrow to the O must come from the carbonyl bond **(1)** Formula of intermediate **(1)** Arrow from oxygen to H and from H-CN bond to CN **(1)** ALLOW arrow from O^- to H^+ or to H_2O	Starting from HCN/ $CN^{\partial-}$ Single headed arrows	**3**

Question Number	Acceptable Answers	Reject	Mark
15(f)(ii)	**These marks are stand alone** **EITHER** No **First mark:** Reaction site/carbonyl/aldehyde/molecule is planar **(1)** **Second mark:** Attack (equally likely) from both sides OR Attack (equally likely) from above and below **(1)** **Third mark:** (gives) racemic mixture/(gives) equal amounts of each isomer/(gives) equal amounts of each enantiomer **(1)** OR Yes Melonal has a chiral carbon atom **(1)** Correct identification of chiral centre **(1)** This chiral centre unaffected by reaction **(1)**	attack on a (planar) carbocation OR attack on a (planar) intermediate OR S_N1 OR S_N2 OR "planar product" Any/either direction or any/either angle	**3**

Q16 : N/A

Question Number	Correct Answer	Reject	Mark
17 (a)(i)	Methyl propanoate ALLOW methy or methly for methyl		**1**

Question Number	Acceptable Answers	Reject	Mark
17(a)(ii)	Toxic (steamy/misty) fumes/ toxic HCl(gas)/corrosive HCl(gas)/toxic propanoyl chloride/lachrymatory propanoyl chloride **(1)** So use in a fume cupboard **(1)** OR Corrosive Propanoyl chloride is **(1)** So wear gloves when handling **(1)**	HCl(aq)/ hydrochloric acid Just harmful/irritant Just harmful/irritant	**2**

Question Number	Acceptable Answers	Reject	Mark
17(b)	Table 0.31, 0.16, 1.41 all 3 scores 2, 2 out of 3 scores 1, 1 or 0 out of 3 scores 0 **(2)** $K_c = \frac{(0.21/V) \times (1.41/V)}{(0.16/V) \times (0.31/V)}$ $K_c = 5.969758$ $K_c = 5.97$ **(1)** IGNORE sf except 1 IGNORE any units ALLOW TE from incorrect values in table.		**3**

Question Number	Correct Answer	Mark
18	D	**1**

Question Number	Correct Answer	Mark
19(a)	B	**1**

Question Number	Correct Answer	Mark
19(b)	A	**1**

Question Number	Correct Answer	Mark
19(c)	C	**1**

Question Number	Correct Answer	Mark
19(d)	A	**1**

Question Number	Correct Answer	Mark
20	A	**1**

Question Number	Correct Answer	Mark
21	A	**1**

SECTION C

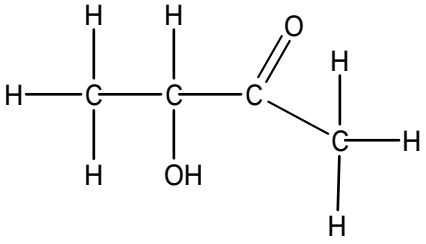
Question Number	Acceptable Answers	Reject	Mark
22 (a)(i)	C : H : O Mole ratio / mol $\frac{54.5}{12}$: $\frac{9.1}{1}$: $\frac{36.4}{16}$ **(1)** = 4.5417 : 9.1 : 2.275 = 1.996 : 4 : 1 = 2 : 4 : 1 C_2H_4O **(1)** Correct empirical formula of C_2H_4O, with or without working, scores **(2)**		**2**

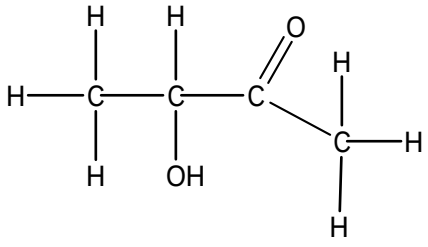
Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	**First mark:** Any mention of **44** or of doubling C_2H_4O **(1)** **Second mark:** Any mention of **88 in the context of the mass spectrum** eg mentions 'molecular ion' / M^+ / heaviest peak / peak furthest to the right / annotation at 88 on the mass spectrum itself / highest $\frac{m}{z}$ value **(1)**	**88** obtained **just** by adding up the relative atomic masses in $C_4H_8O_2$ scores **(0)** for 2nd scoring point	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	(Peak at 3500 cm^{-1}) **O—H** **(1)** Allow OH (Peak at 1700 cm^{-1}) **C=O** **(1)** **Penalise extra extension bond on an otherwise correct answer once only** (eg —O—H **and** —C=O scores (1)) **IGNORE** any names for the bonds suggested even if incorrect	—O—H / —OH C—O / —C=O / CO	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**First mark:** (**X** is neutral) so not a (carboxylic) acid **(1)** **IGNORE** **"X** doesn't have a charge as it is neutral" / "**X** is not an alkali" / "**X** is not a base" **Second mark:** **(X** does not react with Tollens') so is **not** an aldehyde / is a ketone **(1)** **Third mark:** (**X** reacts with H^+ / $Cr_2O_7^{2-}$ so) is an alcohol /contains an OH (group) / contains R—OH / contains hydroxyl (group) **(1)** **IGNORE** 'not an acid' if this is deduced **solely** from the H^+ / $Cr_2O_7^{2-}$ information **Fourth mark:** a primary or a secondary (alcohol) **both needed** **OR** (**X** is) not tertiary (alcohol) **(1)** **Mark each point separately** **NOTE:** **'X** is a primary or a secondary alcohol' scores both the third and fourth marks **ALLOW** Correct formulae for the functional groups, instead of their names	**X** is an aldehyde scores **(0)** for this scoring point / **X** is not a ketone scores **(0)** for this scoring point	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(primary or secondary) alcohol **and** ketone **NOTE** **BOTH names** are required here	Just 'hydroxyl for 'alcohol' and/or 'C=O /carbonyl' for ketone/	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)	**MARKING ADVICE** Check answer for the suggested structure of X. If the correct structure is shown  Mark answer according to the following. However if no structure for **X** is shown or an incorrect structure for **X** is proposed, mark answer according to "COMMENTS" scheme below **MARKS CAN BE AWARDED FROM SUITABLY ANNOTATED FORMULAE FOR X.** **<u>First mark:</u>** Four different H / hydrogen / proton environments **(1)** **<u>Any five from following seven points</u>:** **Either** Application of the (n+1) rule to peak **J** (which is a quartet / splits into **four**) **or** application of the (n+1) rule peak **M** (which is a doublet / splits into **two**) **(1)** Any mention to explain **no** splitting for peak **L** as there is no H is attached to the adjacent carbon **(1)** Peak **L** (C**H**$_3$) next to C=O **(1)** Peak **M** (C**H**$_3$) next to CH **(1)** Peak **K** O**H** **(1)** Peak **J** (C**H**) next to CH_3 **(1)** Any **one** correct δ value quoted within ± 0.2 of the following chemical shifts: 1.4(**M**) or 2.2 (**L**) or 3.7(**K**) or 4.2 (**J**) (ppm) **(1)**	**Just** 'four different **chemical** environments' If any incorrect chemical shift **OR A RANGE** of chemical shifts is quoted, this scoring point is not available	**7**

	Final mark (Compound **X** is) $CH_3CH(OH)COCH_3$ **NO** other compound allowed. **ACCEPT** any unambiguous formula, e.g. displayed formula **Peak J**  **Peak M** **Peak K** **Peak L** **ACCEPT** 3-hydroxybutan-2-one **(1)**		

(Total 22 marks)

Question Number	Correct Answer	Reject	Mark
23	D		**1**

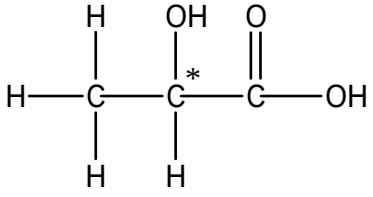
Question Number	Correct Answer	Reject	Mark
24	B		**1**

Question Number	Correct Answer	Reject	Mark
25	B		**1**

Question Number	Correct Answer	Reject	Mark
26	C		**1**

Question Number	Correct Answer	Reject	Mark
27	D		**1**

Question Number	Correct Answer	Reject	Mark
28	D		**1**

Question Number	Acceptable Answers	Reject	Mark
29(a)(i)	A chiral molecule is non-superimposable on its mirror image / 3D molecule with no plane of symmetry **(1)** 2-hydroxypropanoic acid has a carbon atom which is asymmetric / has **four** different groups attached **(1)** **Middle** carbon labelled in any clear way **(1)** e.g.  ALLOW asymmetric C described but not labelled IGNORE references to rotation of plane polarized light	just 'non-superimposable' just 'no plane of symmetry' Molecules for groups	**3**

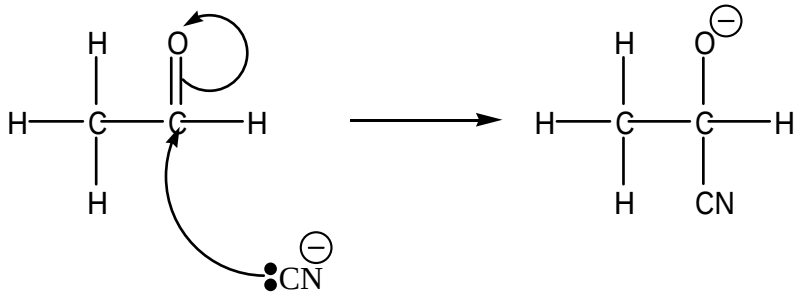
Question Number	Acceptable Answers	Reject	Mark
29(a)(ii)	2-hydroxypropanoic acid formed in muscles is a single (allow pure) enantiomer /(optical) isomer ALLOW Unequal mixture of enantiomers /(optical) isomers **(1)** 2-hydroxypropanoic acid formed in milk is a racemic mixture / equimolar mixture of the two enantiomers / racemate **(1)** If milk and muscles are reversed but the rest is correct, one mark is awarded	Just "not a racemic mixture" Just 'a mixture of enantiomers'	**2**

Question Number	Acceptable Answers	Reject	Mark
29(b)(i)	**First step** NaOH(aq) / KOH(aq) or names **(1)** Second mark dependent on first being correct **Second step** HCl(aq) / hydrochloric acid / H_2SO_4(aq) / sulfuric acid ALLOW HNO_3 / nitric acid /dil HCl /(dil) H_2SO4 /(dil) HNO_3 or any strong acid (name or formula) including HBr((aq)) and HI((aq)) **(1)** IGNORE Omission of (aq) and references to temperature Ethanolic /alcoholic solutions ALLOW One mark for correct two reagents in the wrong order One mark for 'alkali / OH^- followed by acid / H^+ /H_3O^+'	OH^- / alkali H^+ / H_3O^+ /acid	**2**

Question Number	Acceptable Answers	Reject	Mark
29(b)(ii)	**First mark** (Stand alone) A racemic mixture is not formed OR More of one enantiomer /(optical) isomer is formed OR Only one enantiomer /(optical) isomer is formed **(1)** **Second mark** (Stand alone) (Some of the) reaction is S_N2 **(1)** **Third mark** (Stand alone) Nucleophile / OH^- only attacks from one side of the molecule / from the opposite side to leaving group **(1)** ALLOW Use of 'intermediate' for 'transition state' in description of S_N2 Reverse argument based on S_N1 forming a racemic mixture	Carbocation (for molecule)	**3**

Question Number	Acceptable Answers	Reject	Mark
29(c)(i)	Nucleophilic **(1)** Addition **(1)**	 S_N1/S_N2	**2**

Question Number	Acceptable Answers	Reject	Mark
29(c)(ii)	Cyanide (ion) / CN^- /$C\equiv N^-$/ $:C\equiv N^-$/ ^-CN	HCN/ $C\equiv N$	**1**

Question Number	Acceptable Answers	Reject	Mark
29 (c) (iii)	 Both curly arrows **(1)** Intermediate **(1)** ALLOW Omission of lone pair Curly arrow from anywhere on nucleophile including from charge or nitrogen Formation of charged canonical form followed by attack of cyanide ion IGNORE $\delta+/\delta-$ even if unbalanced	Omission of charges (penalise once only) Full charges on ethanal —C—NC in intermediate	**2**

Question Number	Acceptable Answers	Reject	Mark
29 (c) (iv)	Racemic mixture / equal amounts of the two enantiomers / racemate formed **(1)** Stand alone mark CHO / aldehyde group is (trigonal) planar **(1)** ALLOW ethanal / molecule is (trigonal) planar Cyanide (ion) / CN^- /nucleophile attacks (equally) from above or below / either side (of the molecule) **(1)** Penalise use of intermediate / ion for aldehyde group **once** only Third mark cannot be awarded if the reaction is described as a nucleophilic substitution	Intermediate / carbonyl group /C_O is planar two positions Intermediate	**3**

Question Number	Acceptable Answers	Reject	Mark
29(d)(i)	Any value /range within the range 3750—2500 cm^{-1} due to O—H / OH / —OH IGNORE COOH / CO_2H / carboxylic acid	Wavenumbers alone OH in alcohol	**1**

Question Number	Acceptable Answers	Reject	Mark
29(d)(ii)	These three marks are stand alone Q is due to C═O **(1)** The (C═O) aldehyde range is 1740—1720 cm^{-1} **and** (C═O) carboxylic acid range is 1725—1700 cm^{-1} **(1)** So the peaks / absorptions cannot be used to distinguish these two compounds because they overlap. OR The (broad) absorption Q covers both the aldehyde and the carboxylic acid ranges **(1)** ALLOW 'too close'/'quite similar' for 'overlap'	Carboxylic acid / COOH group Just 'cannot be used to distinguish the compounds'	**3**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>29(e)</td><td>
If reagent incorrect, observation mark can only be awarded for a near miss

Test positive for ethanal
<table>
<tr><th>Reagent (1)</th><th>Observation (1)</th></tr>
<tr><td>Tollens’</td><td>Silver mirror / black / grey ppt</td></tr>
<tr><td>Fehling’s / Benedict’s</td><td>Red-brown ppt</td></tr>
<tr><td>2,4-DNP(H) / Brady’s reagent</td><td>Orange / red / yellow ppt
ALLOW brick-red ppt</td></tr>
</table>
Test positive for 2-hydroxypropanoic acid
<table>
<tr><th>Reagent (1)</th><th>Observation (1)</th></tr>
<tr><td>PCl_5 / Phosphorus (V)chloride / phosphorus pentachloride</td><td>Steamy fumes*
ALLOW gas evolved turns (blue) litmus / UI red</td></tr>
<tr><td>Named metal carbonate (solution)</td><td>Effervescence
ALLOW gas / CO_2 evolved turns lime water cloudy</td></tr>
<tr><td>Sodium hydrogencarbonate (solution)</td><td>Effervescence
ALLOW gas / CO_2 evolved turns lime water cloudy</td></tr>
<tr><td>Magnesium (& water)</td><td>Effervescence</td></tr>
<tr><td>Ethanol & H_2SO_4/named strong acid</td><td>Sweet / fruity / pear drops / glue smell</td></tr>
<tr><td>Ethanoic acid & H_2SO_4/named strong acid</td><td>Sweet / fruity / pear drops / glue smell</td></tr>
</table>
ALLOW
Na and effervescence / gas evolved pops with a lighted splint for2-hydroxypropanoic acid
(2)

ALLOW
fizzing / bubbling for effervescence

IGNORE
names of product

IF two tests given for one substance both must be correct for full marks

*misty fumes / white fumes / gas for fumes
</td><td>Iodine in alkali / iodoform test
Acidified potassium dichromate

Smoke
Just ‘fumes’

Any indicator as sole test

incorrect formulae of reagents</td><td>4</td></tr>
</table>

Total for Question 29 = 26 Marks