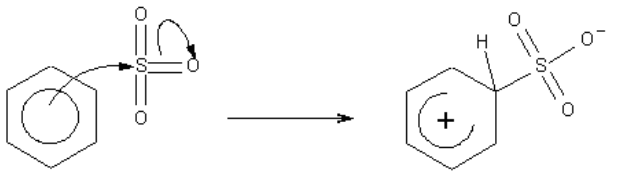
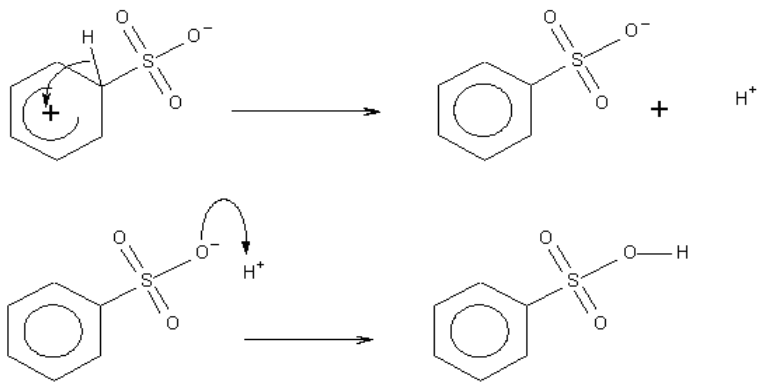
Question Number	Acceptable Answers	Reject	Mark
1(a)(i	sulfuric acid / **fuming** H_2SO_4 / oleum / $H_2S_2O_7$	Conc. (for fuming) Fuming dilute sulfuric acid **Just** sulfuric acid **Just** H_2SO_4	**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	Sulfur is δ+ and on at least one oxygen δ- **(1)** Oxygen is (much) more electronegative than sulfur ALLOW Oxygen is very electronegative **(1)**	Full + or – charge(s) 1/3 – on each oxygen	**2**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(iii)	The sulfur trioxide can accept a pair of electrons OR (Three oxygen atoms so) sulfur has a large δ or partial / slight positive charge OR π bonds allow S—O bonds to be polarized more easily ALLOW Electron-deficient sulfur	An electron	**1**

Marks for (b)(i) and (b)(ii) can be awarded from either of the two annotated diagrams on item

Question Number	Acceptable Answers	Reject	Mark
1(b)(i)	 First curly arrow as shown to start inside the hexagon to the S atom **(1)** Second curly arrow from bond to O (i.e. not from the S atom itself) **(1)** ALLOW Second curly arrow to any of the three O atoms in SO_3 IGNORE A full + charge on S		**2**

Question Number	Acceptable Answers	Reject	Mark
1 (b)(ii)	 Curly arrow as shown from the C-H bond to reform the ring in first line, not from the H atom in this bond **(1)** Intermediate anion formed in first line (H^+ does not have to be shown) **(1)** Last line with curly arrow and correct structure of benzenesulfonic acid **(1)** ALLOW Use of H_2SO_4 for H^+ with HSO_4^- as other product in final step The marks for (b)(ii) may be awarded from annotations on the right hand structure given in question in (b)(i) If contradictory arrows drawn on structure in question (b)(ii), then penalise any such inconsistency The three marks for the two steps in (b)(ii) can be shown in one step / diagram / structure ALLOW -SO_3H undisplayed	Use of H_2O for H^+ -HSO_3	**3**

Question Number	Acceptable Answers	Reject	Mark
1(c)(i)	$C_6H_5SO_3H + 3NaOH \rightarrow C_6H_5ONa + Na_2SO_3 + 2H_2O$ **(1)** ALLOW Charges on $C_6H_5O^-Na^+$ $C_6H_5ONa + HCl \rightarrow C_6H_5OH + NaCl$ **(1)** ALLOW $C_6H_5O^- + HCl \rightarrow C_6H_5OH + Cl^-$ OR $C_6H_5O^- + H^+ \rightarrow C_6H_5OH$	Charges on $C_6H_5SO_3H$	**2**

Question Number	Acceptable Answers	Reject	Mark
1(c)(ii)	**Any two from:** (Both) products useful / both are useful / propanone is useful So less waste / high(er) atom economy Fewer steps / one step / does not require many steps (in Hock synthesis) Continuous rather than a batch process **(2)** IGNORE "Only one waste product in Hock" Comments relating to hazardousness of reactants / safety / energy requirements References to yield References to efficiency References to rate	Cheaper	**2**

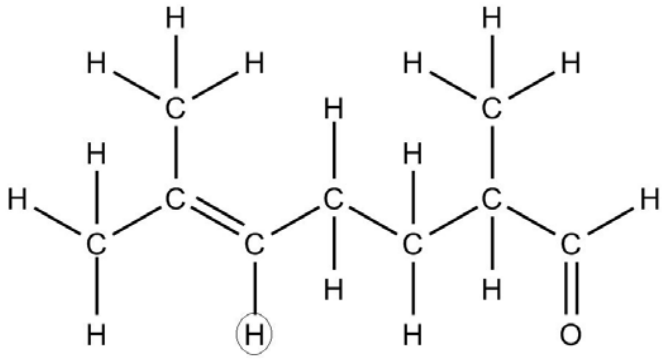
Question Number	Acceptable Answers	Reject	Mark
2(a)	2,6-dimethylhept-5-enal **(2)** Either part scores **(1)** e. 2,6-dimethyl **(1)** hept-5-enal **(1)** IGNORE missing/misplaced/misused hyphens or commas ALLOW ene for en ALLOW methy or methly for methyl		**2**

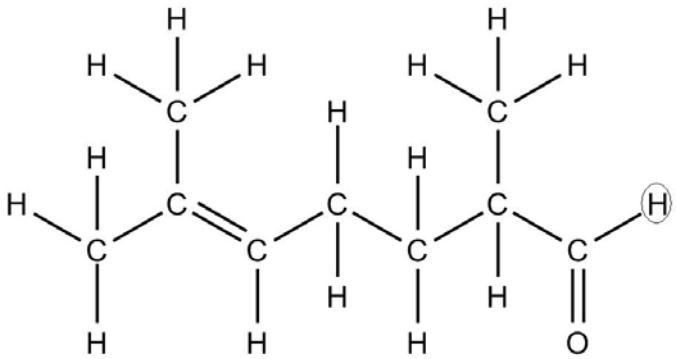
Question Number	Acceptable Answers	Reject	Mark
2(b)(i)	$CH_3C(CH_3)=CHCH_2CH_2CH(CH_3)CH_2OH$ **(1)** OR $CH_3C(CH_3)CHCH_2CH_2CH(CH_3)CH_2OH$ OR $CH_3C(CH_3)=CHCH_2CH_2C\ (CH_3)\ HCH_2OH$ ALLOW displayed or skeletal formulae $K_2Cr_2O_7$/$Na_2Cr_2O_7$/name (oxidation state must be correct if given (VI)) **(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**

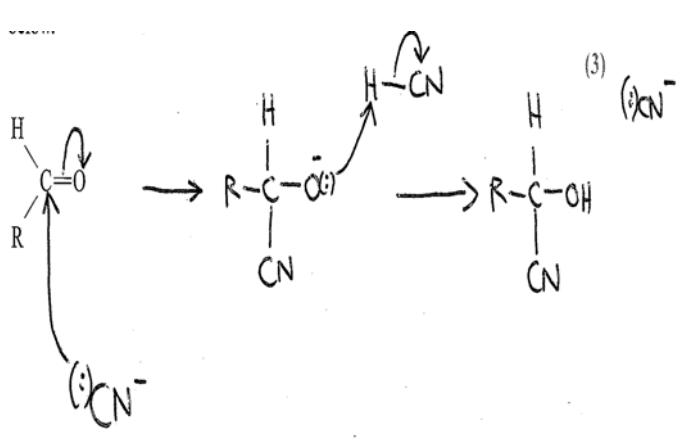
Question Number	Acceptable Answers	Reject	Mark
2(b)(ii)	(Steam) **distil** off melonal (as it forms) Allow add a limited amount of oxidizing agent/excess alcohol/excess X **(1)** To prevent further oxidation/To prevent carboxylic acid forming **(1)** Stand alone marks		**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)	<table><tr><th>Wavenumber range / cm^{-1}</th><th>Bond</th><th>Functio group present in melonal</th></tr><tr><td>1740 – 1720 OR 2900 – 2820 / 2775 – 2700</td><td>C=O C-</td><td>(saturated) Aldehyde/CHO</td></tr><tr><td>1669 – 1645 OR 3095 - 3010</td><td>C=C C-</td><td>Alkene ALLOW ‘carbon to carbon double bond’</td></tr></table> **(1)** **(1)** 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	Just carbonyl Just C=C in 3rd column	**2**

Question Number	Acceptable Answers	Reject	Mark
2(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
2(e)(i)		Circle around any other additional atoms	**1**

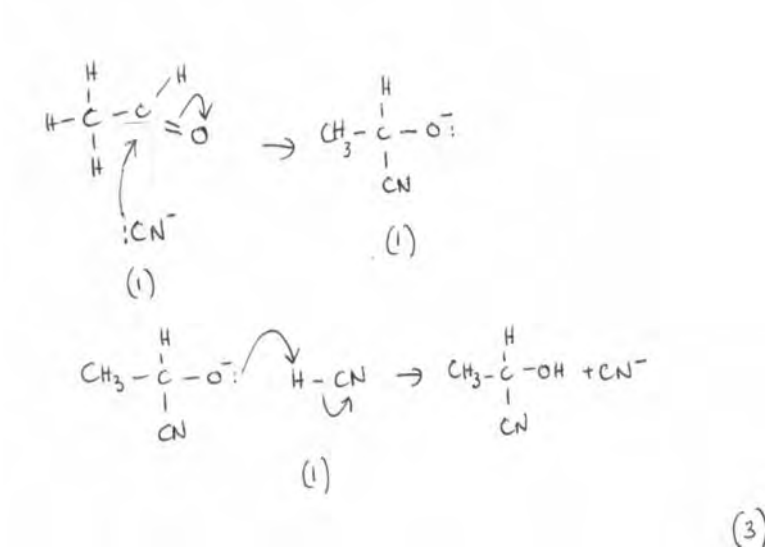
Question Number	Acceptable Answers	Reject	Mark
2(e)(ii)		Circle around any other additional atoms	**1**

Question Number	Acceptable Answers	Reject	Mark
2(f)(i)		Starting from HCN/ $CN^{\partial-}$	**3**
	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)**	Single headed arrows	
	ALLOW arrow from O^- to H^+ or to H_2O		

Question Number	Acceptable Answers	Reject	Mark
2(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**

Question Number	Acceptable Answers	Reject	Mark
3 (a)(i)	Addition **(1)** Nucleophilic **(1)** Either order	SN1 SN2	**2**

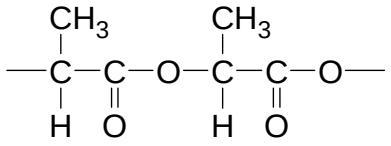
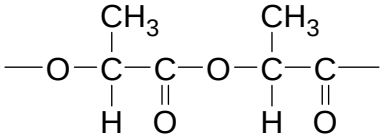
Question Number	Acceptable Answers	Reject	Mark
3 (a)(ii)	Hydrogen cyanide / HCN **(1)** Potassium cyanide / KCN/ sodium cyanide/ NaCN **(1)** OR Potassium cyanide / KCN **(1)** With hydrochloric acid / sulfuric acid (to generate HCN) **(1)** Ignore concentration of acids Mark for HCl etc is consequential on KCN OR Hydrogen cyanide / HCN **(1)** With sodium hydroxide / other base (to make cyanide ions) **(1)** Mark for NaOH etc is consequential on HCN	 Just CN^- Just CN^- Just acid/ H^+ any weak acid Just OH^-	**2**

Question Number	Acceptable Answers	Reject	Mark
3 (a)(iii)	 Both arrows in first step of mechanism above correctly drawn **(1)** Correct intermediate with charge **(1)** Both arrows in second step with correct organic product (CN^- is not required) **(1)** Use of HCN for first step max 2 marks Allow omission of lone pair on CN^- and O^- Allow curly arrow from negative charge or elsewhere on cyanide ion Allow arrow from O^- in 2nd step to H^+ (no other product or only one product) or H_2O (with OH^- formed)	C=O breaking before attack by CN^- Arrows from atoms when they should be from bonds and vice versa	**3**

Question Number	Acceptable Answers	Reject	Mark
***3(a) (iv)**	Attack (by nucleophile on the C) is from both sides (equally)/ above and below (at the planar reaction site in the aldehyde group) **(1)** So a mixture of two enantiomers/(optical)isomers **in equal proportions** forms OR racemic mixture forms **(1)** **First and second marks are independent**	Attack on **intermediate in reaction mechanism** is from both sides Attack from both ends/two angles Just "both enantiomers form"	**2**

Question Number	Acceptable Answers	Reject	Mark
3 (b)	Any named (aqueous) strong acid or its formula. Allow (aqueous) sodium hydroxide followed by named acid or formula Ignore references to concentration	Water H^+ Potassium dichromate + sulfuric acid Carboxylic acids	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(i)	2-hydroxypropanoic acid	2-hydroxylpropanoic acid 2-hydroxopropanoic acid 2-hydroxypropan-1-oic acid	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(ii)	 OR  All bonds in ester link must be shown More than 2 units may be shown but structure shown should be a repeat unit Ignore brackets/n	A dimer Missing H atoms Missing bonds at ends	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(iii)	**Ester** (link/bond) in PLA can be hydrolysed/broken down (by enzymes) **OR Ester** (link/bond) in PLA can be broken down	Just "it can be hydrolysed"	**1**

Question Number	Acceptable Answers	Reject	Mark
3 (c)(iv)	Ethene is (from crude oil so) non-renewable/ milk is from a renewable source/ energy required to make ethene is **high**/ high temperatures needed to make ethene/ energy requirements for process from sour milk **less**/ process from milk doesn't use toxic chemicals / process from milk doesn't use cyanide Allow process from ethene requires many steps **so** expensive/**so** loss of material occurs at each step /**so** more reagents needed Ignore references to cost, unless answer gives a reason for lower cost.	Milk is more readily available Greater atom economy No other chemicals needed in process from milk Just "process from ethene requires many steps" Just "cheaper"	**1**