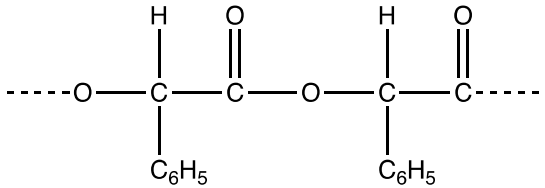
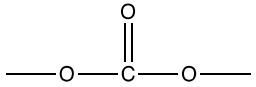
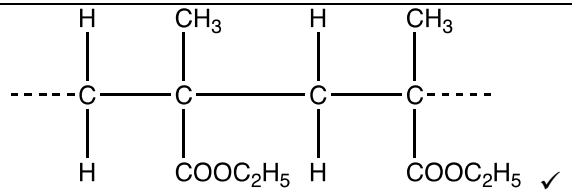
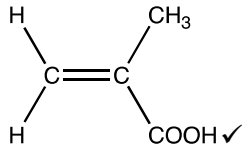
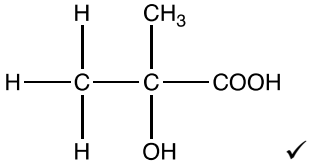
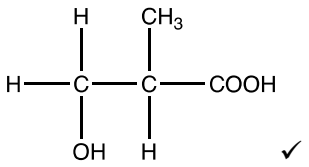
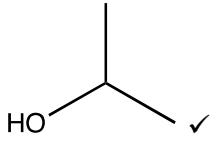
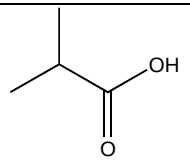
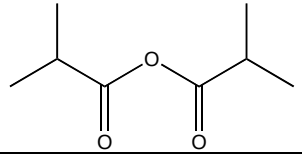
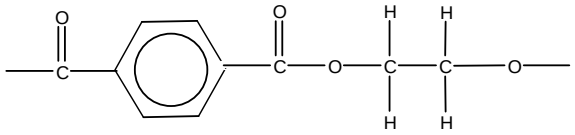
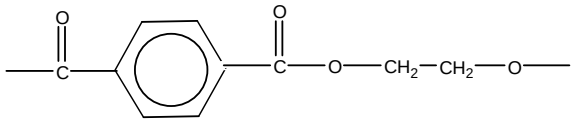
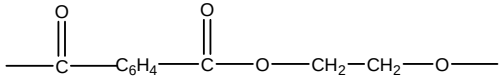
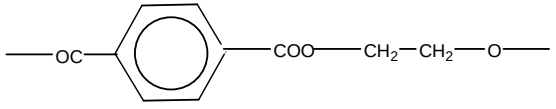
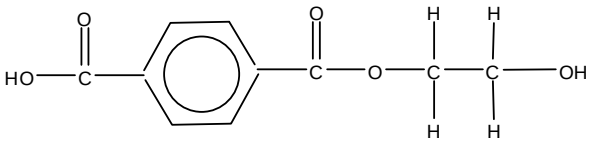
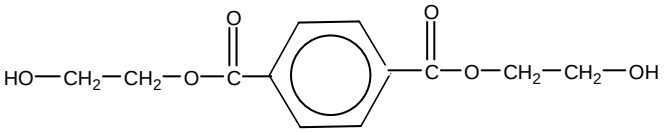
Question			Answer	Mark	Guidance
1	(a)		**monomers** join/bond/add/react/form polymer/form chain **AND** another product/small molecule e.g. H_2O/HCl ✓ **QWC** must spell **AND** use 'monomer(s)' correctly throughout	1	**IGNORE** 'two' when referring to monomers, ie (two) monomers ……..
	(b)	(i)	 ester link ✓ **Note**: Any ester link shown **must** be correct rest of the structure ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** benzene ring for C_6H_5 'End bonds' **MUST** be shown (do not have to be dotted) **ALLOW one** or more repeat units but has to have a whole number of repeat units (*ie* does not have to be two) For ester, **DO NOT ALLOW**  **ALLOW** structure with no O at left end and COO at right end **IGNORE** brackets **IGNORE** *n*
		(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW one** or more repeat units but has to have a whole number of repeat units (*ie* does not have to be two) 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*

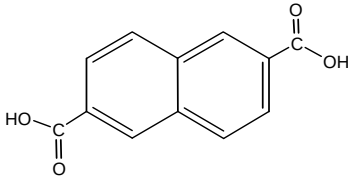
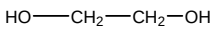
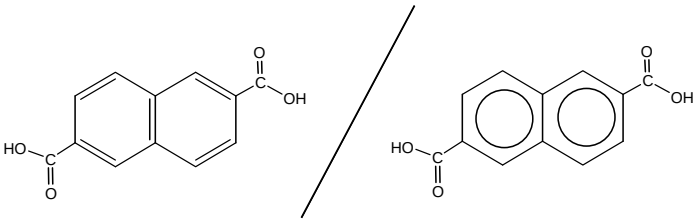
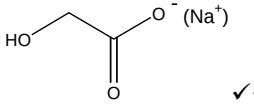
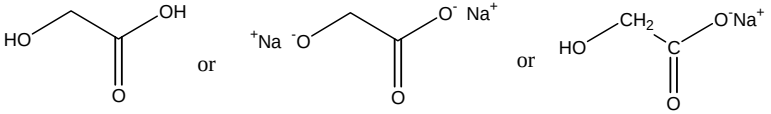
Question			Answer	Mark	Guidance
	(c)		compound **C**  ✓ compound **D** and compound **E**  ✓  ✓	**3**	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $CH_2C(CH_3)COOH$ **ALLOW D** and **E** by **ECF** from an incorrect structure of **C** provided that **C** contains a double bond and molecular formulae of **D** and **E** is $C_4H_8O_3$ with H_2O added across double bond
	(d)	(i)	 ✓	**1**	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) e.g. $(CH_3)_2CHOH$ **DO NOT ALLOW** –HO **IGNORE** working (*ie* other structures) provided correct structure of propan-2-ol is shown **IGNORE** name (even if wrong)

Question			er	Mark	Guidance
	(d)	(ii)	 ✓ **OR** acid anhydride: 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **OR** (2-)methylpropanoic acid **DO NOT ALLOW** incorrect name (will CON a correct structure) **ALLOW** acyl chloride: $(CH_3)_2CHCOCl$ **IGNORE** working provided correct structure of propan-2-ol is shown
		(iii)	Hydrogen bonds form **with** water ✓ **Note**: Can be shown in diagram as dashed line, *ie* ---- (no label required) **DO NOT CON** 'hydrogen bond' from an incorrect hydrogen bond in diagram Mandelic acid forms more hydrogen bonds (with water) ✓ **ORA** Mandelic acid has an extra OH **OR** 2 OH groups **OR** has a COOH group ✓ **ORA**	3	***ANNOTATIONS MUST BE USED*** **ALLOW** a diagram showing hydrogen bonds with water, dipole and lone pair are not required **ALLOW** a hydrogen bond to C=O, ie C=O---H–O **IGNORE** bond angles Diagram does **not** need to show all of mandelic acid (**IGNORE** if wrong) **ALLOW** any comparison of numbers of hydrogen bonds provided that mandelic acid has more hydrogen bonds **DO NOT ALLOW** 'No –OH groups in ester (as there are)' **DO NOT ALLOW** reference to $–OH^-$ / hydroxide **IGNORE** reference to carbon chain and van der Waals' forces **Note**: If a response compares **Ester 1** with **Ester 2** rather than with mandelic acid, maximum of 2 marks: **1st mark** hydrogen bonds **2nd mark** **Ester 2** has more Os/oxygens **OR** **Ester 2** forms more hydrogen bonds

Question			Answer	Mark	Guidance
	(d)	(iv)	To test for (adverse) side effects **OR** to test toxicity **OR** to test for irritation ✓	1	**ALLOW** a stated adverse side effect, *eg* allergy, carcinogenic, etc **IGNORE** references to optical isomers, chirality, etc **IGNORE** vague statements such as harmful to skin, dangerous to skin, corrosive to skin, reacts with skin **ALLOW** company liable to litigation/damages
			Total	13	

2			**Equations** $CH_3COCHO + 4[H] \longrightarrow CH_3CHOHCH_2OH$ ✓ $CH_3COCHO + [O] \longrightarrow CH_3COCOOH$ ✓ **Reduction reagents and observation** Methylglyoxal is **reduced** by $NaBH_4$ ✓ **Oxidation reagents and observation** Methylglyoxal is **oxidised** by H_2SO_4 **AND** $K_2Cr_2O_7$ ✓ Observation: turns green **OR** blue ✓ **OR** Methylglyoxal is **oxidised** by Tollens' reagent ✓ Observation: Silver (mirror) ✓	**1** **1** **1** **2**	***ANNOTATIONS MUST BE USED*** Throughout question, **ALLOW** correct structural **OR** displayed **OR** skeletal formula **DO NOT ALLOW** molecular formulae **ALLOW** partial reduction (ie reduction of either C=O group) [H] implies reduct [O] implies oxidat reduced **AND** reagent are **both** required for the mark **ALLOW** link to equation with [H] for reduction **ALLOW** $LiAlH_4$ as alternative for $NaBH_4$ **ALLOW** any recognisable attempt at name **IGNORE** any reference to acids oxidised **AND** reagent are **both** required for the mark **ALLOW** link to equation with [O] for oxidation **ALLOW** $Na_2Cr_2O_7$ instead of $K_2Cr_2O_7$ **ALLOW** H^+ **AND** $Cr_2O_7^{2-}$ **OR** H^+ **AND** CrO_4^{2-} If name given, **ALLOW** dichromate **OR** dichromate(VI) **ALLOW** acidified dichromate **ALLOW** any strong acid If formulae used, formulae must be correct **ALLOW** $AgNO_3$ in ammonia **OR** ammoniacal $AgNO_3$ **ALLOW oxidised** by manganate Observation: decolourised **Note**: If one reaction is identified as oxidation, assume the other is reduction (and vice versa)
			Total	**5**	

Question			Expected Answers	Marks	Additional Guidance
3	a	i	 ✓✓ Ester group must be displayed to get both marks and must contain 4 Os	2	**ALLOW** for both marks  **ALLOW** for one mark  **ALLOW** for one mark  **ALLOW** Kekulé structure / $(CH_2)_2$ **ALLOW** one mark if end bonds missing **ALLOW** 1 mark if the CH_2CH_2 is drawn skeletally **ALLOW** for  **ALLOW** <u>1 mark</u> if repeat unit shows a displayed ester group and contains a benzene ring and two other carbons **DO NOT ALLOW** $–OCC_6H_4COOCH_2CH_2O–$
		ii	 ✓	1	**ALLOW** Kekulé structure/ $(CH_2)_2$ CO_2 for ester groups C_6H_4 if already penalised in **a(i)**

Question			Expected Answers	Marks	Additional Guidance
	b	**i**	$C_7H_5O_2$	1	**ALLOW** any order of elements **ALLOW** $C_{14}H_{10}O_4 \rightarrow C_7H_5O_2$ or $C_{14}H_{10}O_4 = C_7H_5O_2$
		ii	  ✓ ✓ **Penalise incorrect bond linkage in 2b(ii) only. Do not penalise elsewhere on the paper**	2	**ALLOW** $COOH/CO_2H$ **ALLOW**  **ALLOW** $HO(CH_2)_2OH$
	c	**i**	 ✓✓	2	**ALLOW** any of the following for 1 mark  **DO NOT ALLOW** any other response
		ii	(PGA is) (bio)degradable **OR** photodegradable **OR** hydrolysed (but hydrocarbon based polymers are non-biodegradable) ✓ One of (bio)degradable **OR** photodegradable **OR** hydrolysed must be spelt correctly – if one spelt correctly and another incorrectly spelt – **ALLOW** mark	1	**ALLOW** broken down by bacteria (must be spelt correctly) **ALLOW** degrade as alternative to degradable **ALLOW** undergoes hydrolysis as alternative to hydrolysed **IGNORE** any additional information if the additional information is correct e.g. biodegradable and doesn't produce toxic gases **DO NOT ALLOW** any additional information if the additional information is incorrect e.g. biodegradable and can be recycled
			Total	**9**	

<table>
<tr><th colspan="3">Question</th><th>Expected Answers</th><th>Marks</th><th>Additional Guidance</th></tr>
<tr><td>4</td><td>a</td><td></td><td colspan="2">Alternative approaches</td><td rowspan="3">4</td><td rowspan="3">ALLOW ammoniacal $AgNO_3$/ $Ag^+(NH_3)_2$ / $Ag^+(NH_3)$
ALLOW acidified dichromate OR Fehlings as an alternative to Tollens – observation ‘turn green’ OR ‘red precipitate’ respectively
ALLOW acidified manganagate(VII) and observation as either brown precipitate/decolourised/pale pink
ALLOW Brady’s (reagent)
ALLOW orange/red/yellow for colour of the 2,4-DNP(H) precipitate
ALLOW solid/crystals in place of precipitate
IGNORE any reference to melting points
ALLOW PCl_5 as a test for the acid – observation would be ‘white fumes (of HCl)’

ALLOW detection of (carboxylic) acid by reacting with an alcohol to make an ester but no mark for the observation.

DO NOT ALLOW detection of (carboxylic) acid by pH or indicator

Please annotate, use ticks to show where marks are awarded</td></tr>
<tr><td></td><td></td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

react with 2,4-DNP(H) and ‘orange precipitate’ ✓

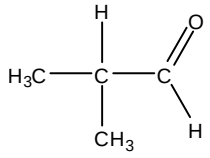
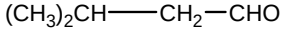
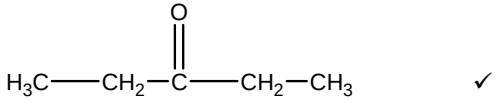
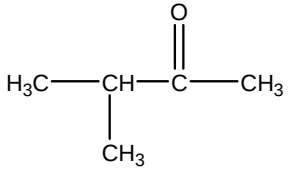
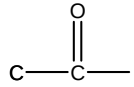
must be the ketone ✓</td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

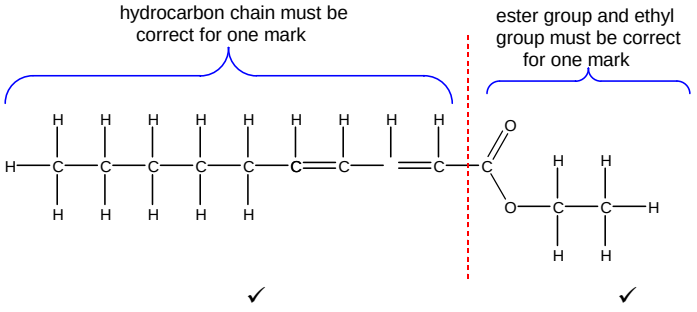
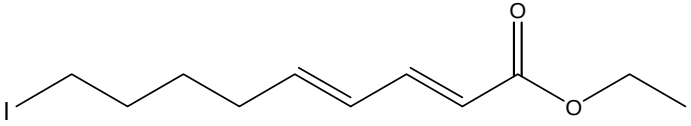
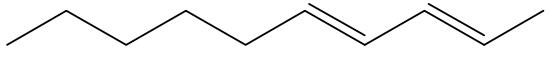
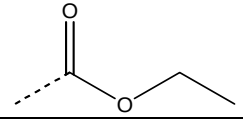
react with carbonate/ hydrogencarbonate/ Na/Mg and ‘fizzes/ bubbles/ effervesces/ gas evolved ✓

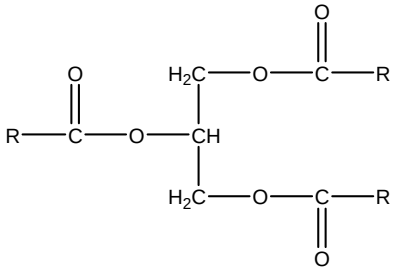
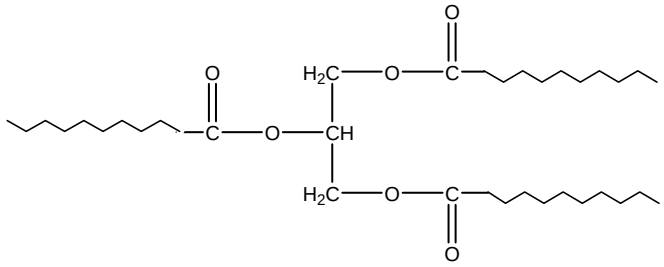
must be the (carboxylic) acid ✓</td></tr>
<tr><td></td><td></td><td>2,4-DNP(H) AND orange precipitate ✓
is either aldehyde OR ketone ALLOW carbonyl OR C=O✓

Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td><td>2,4-DNP(H) and no orange precipitate ✓
is the (carboxylic) acid ✓

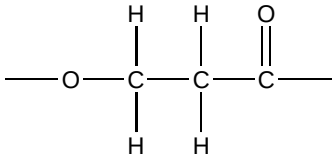
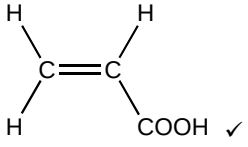
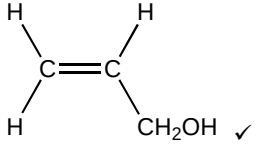
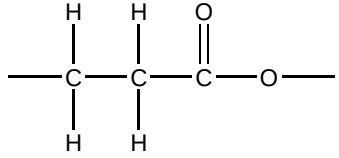
Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td></tr>
<tr><td></td><td>b</td><td></td><td colspan="2">Peak in range 2500–3300 (cm^{-1}) or (around) 3000 shows O–H ✓
[need wavenumber (or range) <u>and</u> O–H bond]</td><td>1</td><td>DO NOT ALLOW single peak quoted within range 2500–3300 other than 3000 (cm^{-1}) for OH
DO NOT ALLOWrange 3200–3550 (cm^{-1})
IGNORE any reference to C-O or C=O</td></tr>
</table>

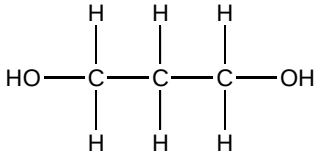
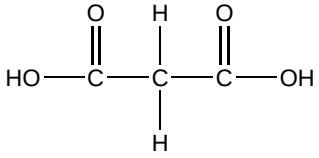
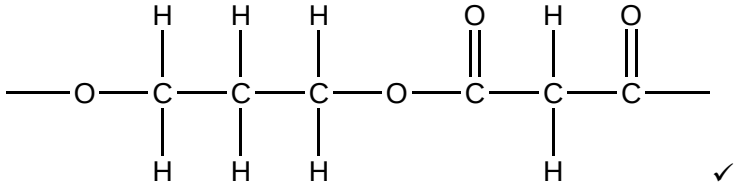
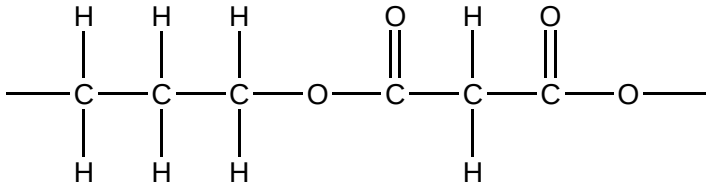
Question			Expected Answers		Marks	Additional Guidance
	c		**Alternative approaches depending on whether or not the aldehyde is correct**			**ALLOW** 3-methylbutanal , any correct unambiguous structure **ALLOW** two marks for correct aldehyde with no explanation **ALLOW** doublet/peak at 0.9ppm due to R–CH **ALLOW** the splitting shows adjacent to CH/environment that contains 1 H/proton **ALLOW** 6 Hs/ protons in same environment **DO NOT ALLOW** 6 Hs in same environment next to CHO e.g.  would score two marks if the doublet and the peak areas were correctly explained
			Doublet indicates adjacent C is bonded to only 1H **OR** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde is correct  ✓ ✓ *If aldehyde is correct **only** need to explain doublet **OR** peak areas*	Doublet indicates adjacent C is bonded to only 1H✓ **AND** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde identified is incorrect × *if aldehyde is incorrect **must** explain both doublet or peak areas*		
	d	i	 ✓ ketone **3**		1	**ALLOW** displayed/skeletal formulae
		ii	There are 4 (different C) environments ✓ (therefore) it is ketone **2 *I***  ✓ (C responsible for peak at δ = 210 ppm) is C=O/carbonyl carbon ✓		3	**ALLOW** 2 Cs are in same environment/equivalent **ALLOW** 3-methylbutan(-2-)one/ any correct unambiguous structure **ALLOW** 2-methylbutan-3-one **ALLOW** 
			Total		**12**	

Question			Expected Answers	Marks	Additional Guidance
5	a	i	The time (from the injection of the sample) for the component to leave the column ✓	1	**ALLOW** time from injection to detection **ALLOW** time spent in column **ALLOW** time taken to reach detector
		ii	They have similar retention times ✓	1	**ALLOW** both are esters therefore partition/adsorption/retention times will be very similar **ALLOW ECF** if they describe R_f values in part **a(i)** **ALLOW** same retention times
		iii	Butylbutanoate ✓	1	**ALLOW** butyl butanoate **ALLOW** but-1-yl butanoate **DO NOT ALLOW** butanyl butanoate
	b	i	 ✓ ✓	2	**ALLOW** any correct unambiguous structure/ $CH_3(CH_2)_4CHCHCHCHCOOCH_2CH_3$ / $CH_3(CH_2)_4CHCHCHCHCOOC_2H_5$ $CH_3(CH_2)_4(CH)_4COOCH_2CH_3$ **DO NOT ALLOW** $C_5H_{11}CHCHCHCHCOOCH_2CH_3$ etc **ALLOW** CO_2 for ester  **ALLOW** 1 mark for correct 2,4-decadiene structure e.  **ALLOW** 1 mark for correct ethyl … oate structure e.  or —$CO_2C_2H_5$ or —$COOC_2H_5$

Question	Expected Answers	Marks	Additional Guidance
ii		1	**ALLOW**  any orientation of the three fatty acids
c	**1.** react phenylethanal with $H_2SO_4/K_2Cr_2O_7$ ✓ **2.** to get phenylethanoic acid/$C_6H_5CH_2COOH$ ✓ mark **2** can be scored if dichromate is used without being acidified **3.** react phenylethanal with $NaBH_4$ ✓ **4.** to get 2-phenylethanol/$C_6H_5CH_2CH_2OH$ ✓ mark **3** must be correct to score mark **4** **5.** react phenylethanoic acid with 2-phenylethanol. If both already correctly named **ALLOW** acid and alcohol✓ **6.** H_2SO_4 if linked to the reaction of an alcohol and acid✓ **7.** reflux in either **(1)** or **(5)** or catalyst used in **(5)** ✓ QWC must spell catalyst or reflux correctly if either phenylethanoic acid or 2-phenyethanol not prepared – automatically lose two marks	7	**ALLOW** H^+ & $Cr_2O_7^{2-}$ or $H_2SO_4/Na_2Cr_2O_7$ - any other oxidising agent or other named acid – please consult with TL **ALLOW** $LiAlH_4$ as alternative to $NaBH_4$ phenylethanoic acid & phenylethanol must be unambiguously identified by either name or formula **DO NOT ALLOW** or oxidised to form(a carboxylic) acid or reduced to form alcohol for marks 2 and 4 **ALLOW** conc H_2SO_4 **DO NOT ALLOW** dilute or H_2SO_4(aq) **DO NOT ALLOW** just acid catalyst **DO NOT ALLOW** HCl, HNO_3 **Please annotate, use ticks to show where marks are awarded**
	Total	**13**	

Question			er	Mark	Guidance
6	(a)	(i)	One mark is for positive carbonyl test (Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ One mark is for negative aldehyde test **EITHER** (Add) Tollens' reagent/Tollens' test **AND** **no** change **OR no** reaction **OR no** silver (mirror) **OR** (Add) H_2SO_4 **AND** $K_2Cr_2O_7$ **AND** **no** change **OR no** reaction **OR no** green colour ✓	2	**ALLOW** errors in spelling **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **ALLOW** $AgNO_3/NH_3$ (Formulae must be correct) **OR** ammoniacal silver nitrate **ALLOW** Fehling's solution **OR** Benedict's solution **AND no** (brick-red) precipitate **ALLOW** any response that implies that nothing happens **ie no** change **OR no** reaction **OR no** silver (mirror) **ALLOW** 'the aldehyde/pentanal gives a silver mirror' **ALLOW** H^+ **AND** $Cr_2O_7^{2-}$ (Formulae must be correct) **ALLOW** any response that implies that nothing happens **IGNORE** responses using $NaBH_4$ (as no observations)
		(ii)	**1st mark** Take melting point of orange crystals/derivative/product from 2,4-DNP ✓ **2nd mark** Compare melting point with known values **OR** compare melting point with value in database/reference book ✓	2	**NOTE**: **a(ii)** is marked completely independently of **a(i)** **Mark independently of response for 1st mark** **DO NOT ALLOW** 1st or 2nd marks for taking and comparing boiling points **OR** chromatograms

Question			er	Mark	Guidance
	(b)	(	**Synthesis 1**  ✓ Ester linkage **must** be fully displayed **Synthesis 2**  ✓  ✓	6	**NOTE: ALL** Structures **MUST** have Hs shown **IGNORE** bond angles **DO NOT ALLOW** more than one repeat unit **IGNORE** brackets and '*n*' **ALLOW** terminal O— on right (**OR** C=O on left), i.e.  **ALLOW** end bonds shown as ----- **DO NOT ALLOW** if structure has **no** end bonds

Question			er	Mark	Guidance
			Synthesis 3  ✓  ✓  ✓		**Mark each structure independently** HO– **must** be connected correctly on **BOTH** structures **DO NOT ALLOW** more repeat units **IGNORE** brackets and '*n*' **ALLOW** terminal O— on right (**OR** C=O on left), i.  **ALLOW** end bonds shown as ----- **DO NOT ALLOW** if structure has **no** end bonds **DO NOT ALLOW ECF** from wrong structure in previous boxes
	(b)	(i	**Synthesis 1**: condensation **AND** **Synthesis 2**: addition **AND** **Synthesis 3**: condensation ✓	1	**All** three correct responses required for the mark
			Total	**11**	