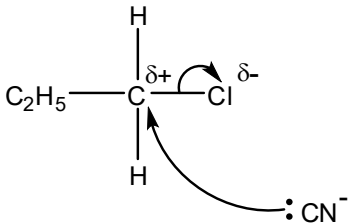
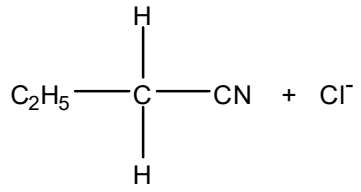
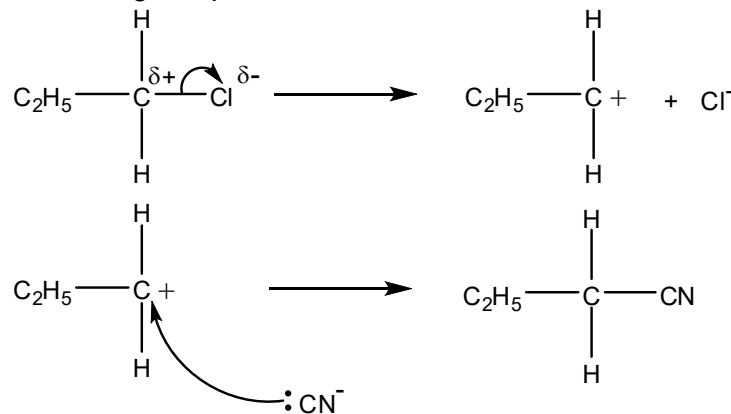
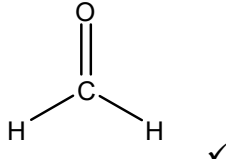
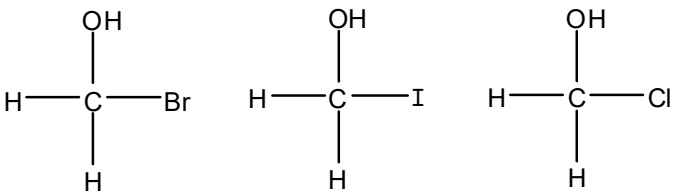


Mark Scheme

Question	Answer	Marks	Guidance
1	<p>(a) (i) curly arrow from CN^- to carbon atom of $\text{C}-\text{Cl}$ bond ✓</p> <p>Dipole shown on $\text{C}-\text{Cl}$ bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$, AND curly arrow from $\text{C}-\text{Cl}$ bond to Cl atom ✓</p>  <hr/> <p>correct organic product AND Cl^- ✓</p> 	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>Curly arrow must come from lone pair on C of CN^- OR CN^- OR from minus sign on C of CN^- ion (then lone pair on CN^- does not need to be shown)</p> <p>IGNORE NaCl</p> <p>-----</p> <p>ALLOW $\text{S}_{\text{N}}1$ mechanism:</p> <p>Dipole shown on $\text{C}-\text{Cl}$ bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$, AND curly arrow from $\text{C}-\text{Cl}$ bond to Cl atom ✓</p> <p>Correct carbocation AND curly arrow from CN^- to carbocation. Curly arrow must come from lone pair on C of CN^- OR CN^- OR from minus sign on C of CN^- ion (then lone pair on CN^- does not need to be shown) ✓</p> <p>correct organic product AND Cl^- ✓</p> 

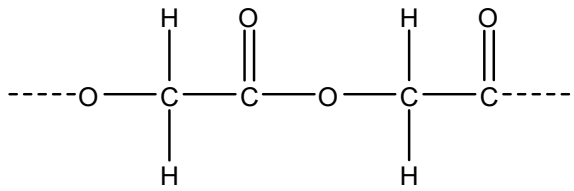
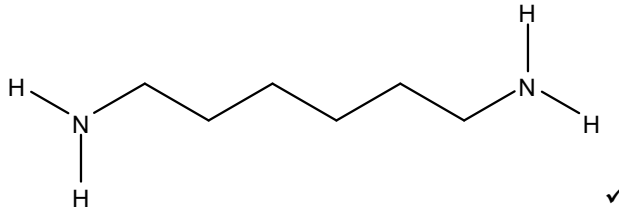
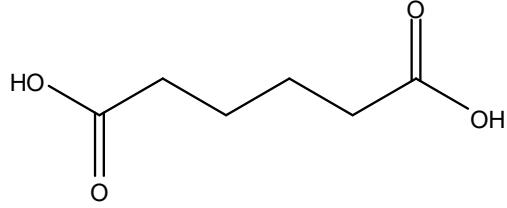
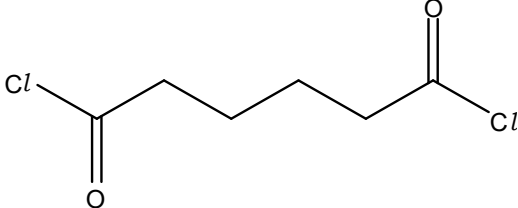
Mark Scheme

Question	Answer	Marks	Guidance
(ii)	<p>Compound G</p>  <p>Reagents</p> <p>Reaction 2: H₂ AND Ni ✓</p> <p>Reaction 3: Correct formula of an aqueous acid e.g. HCl(aq)/H₂SO₄(aq) ✓</p>	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>IGNORE name(s)</p> <p>ALLOW</p>  <p>ALLOW any suitable metal catalyst e.g. Pt ALLOW LiAlH₄ for reagent in reaction 2 DO NOT ALLOW NaBH₄ for reagent in reaction 2 IGNORE names (<i>question asks for formulae</i>)</p> <p>IGNORE references to temperature and/or pressure</p> <p>ALLOW H⁺(aq) IGNORE dilute ALLOW formula of an acid AND water e.g. HCl AND H₂O H₂SO₄ AND H₂O</p>

Mark Scheme

Question	Answer	Marks	Guidance
(iii)	<p>Explanation</p> <p>Nitrogen electron pair OR nitrogen lone pair AND accepts a proton/H⁺ ✓</p> <p>Structure of salt</p> $ \begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_3^+ \\ \quad \\ \text{H} \quad \text{H} \end{array} $ <p>AND Cl⁻ ✓</p>	2	<p>IGNORE NH₂ group donates electron pair</p> <p>ALLOW nitrogen donates an electron pair to H⁺ DO NOT ALLOW nitrogen donates lone pair to acid IGNORE comments about the O in the –OH group</p> <p>Compound H is a base is not sufficient (<i>role of lone pair required</i>)</p> <p>DO NOT ALLOW nitrogen/N lone pair accepts hydrogen (<i>proton/H⁺ required</i>)</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW</p> $ \begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_3\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array} $ <p><i>i.e.</i> charges not required</p> <p>IF charges are shown both need to be present</p> <p>ALLOW charge either on N atom or NH₃⁺</p> <p>IF displayed then + charge must be on the nitrogen</p>

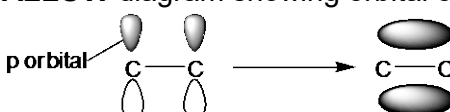
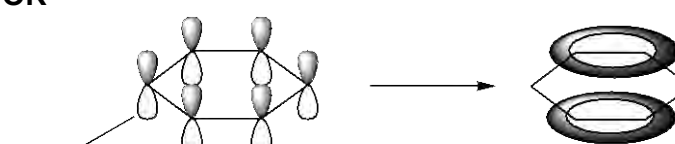
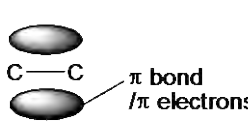
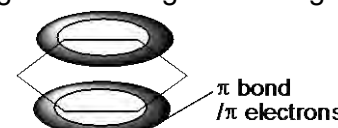
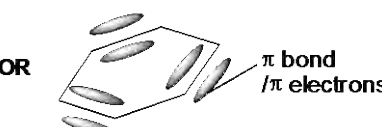
Mark Scheme

Question		Answer	Marks	Guidance
	(iv)	 <p>Ester link ✓</p> <p>Rest of structure ✓</p> <p>(polymer J is biodegradable because) the ester / ester bond / ester group / polyester can be hydrolysed ✓</p>	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>DO NOT ALLOW more than two repeat units for second marking point.</p> <p>'End bonds' MUST be shown (do not have to be dotted)</p> <p>IGNORE brackets</p> <p>IGNORE n</p> <p>Broken down by water is not sufficient</p> <p>IGNORE references to photodegradable</p>
(b)	(i)	 ✓  ✓	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW</p> 
	(ii)	$(n = \frac{21500}{226} =) 95$ (repeat units) ✓	1	<p>MUST be a whole number.</p> <p>DO NOT ALLOW an answer that uses an incorrect molar mass in the working.</p> <p>ALLOW 96</p>
Total			14	

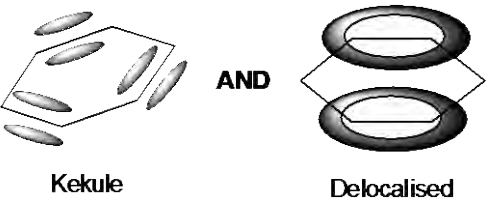
Mark Scheme

Question	Answer	Marks	AO element	Guidance
2	A	1	AO2.5	

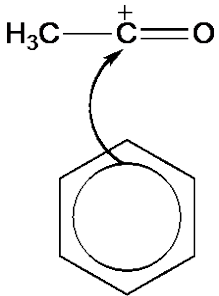
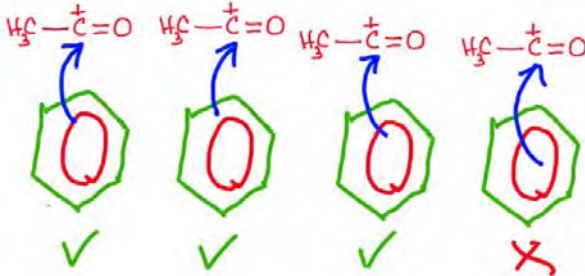
Mark Scheme

Question			Answer	Marks	AO element	Guidance
3	(a)	(i)	<p>Similarities</p> <p>Orbital overlap (sideways) overlap of p orbitals ✓</p> <p>π bond</p> <p>π bond/system/ring above and below (bonding (C) atoms/ring/plane) ✓</p>	3	AO1.1 × 3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>ALLOW diagram showing orbital overlap e.g.</p>  <p>OR</p>  <p>p orbital label is required for first mark</p> <p>IGNORE C=C in diagram showing π bond</p> <p>IGNORE reference to s orbital overlap/σ bonds</p> <p>-----</p> <p>ALLOW from labelled diagram showing π bond e.g.</p>  <p>OR</p>  <p>OR</p>  <p>π bond/π electrons label is required for second mark</p>

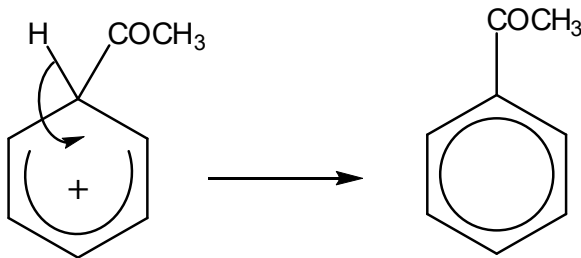
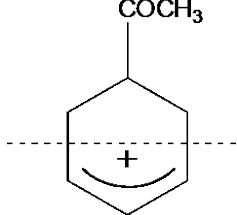
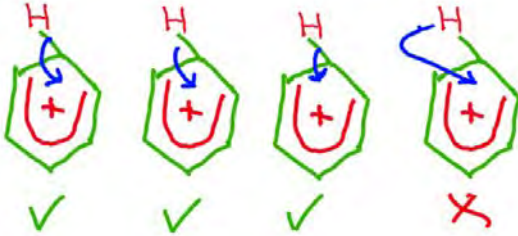
Mark Scheme

Question	Answer	Marks	AO element	Guidance
	<p>Difference</p> <p>Kekule has: alternating π bonds OR 3 π bonds / localised (π electrons) / overlap in one direction / 2 electrons in π bond</p> <p>AND</p> <p>Delocalised has: π ring (system) / all p orbitals overlap OR (π electrons) spread around ring / overlap in both directions / 6 electrons in π bond /</p>			<p>-----</p> <p>ALLOW diagram showing π bond in both Kekule AND delocalised models e.g</p> <div style="text-align: center;">  <p style="display: flex; justify-content: space-around; width: 100%;"> Kekule Delocalised </p> </div> <p>π bond labels not required for third mark</p>
(ii)	<p>Any 2 pieces of evidence from (✓ ✓)</p> <p>Bond length (C–C) bond length is between single (C–C) and double bond (C=C) OR all (C–C) bond lengths are the same</p> <p>ΔH hydrogenation ΔH hydrogenation less (exothermic) than expected</p> <p>Resistance to reaction Benzene is less reactive than alkenes OR bromination of benzene requires a catalyst/halogen carrier OR benzene does not react with/decolourise bromine (at room temperature) OR benzene reacts by substitution OR benzene does not (readily) react by addition</p>	2	AO1.1 ×2	<p>ALLOW (C–C) bond enthalpy is between single (C–C) and double bond (C=C) OR all (C–C) bond enthalpies are the same</p> <p>IGNORE enthalpy of hydration</p> <p>Benzene is unreactive is not sufficient (no comparison to alkene)</p> <p>For halogen carrier, ALLOW name or formula of suitable catalyst e.g. Fe, AlCl₃, FeBr₃</p>

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(ii)	<p>D Addition / polyalkene AND E: Condensation / polyamide ✓</p>	1	AO1.1	DO NOT ALLOW 'additional'
(iii)	<p>Formation of electrophile $\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{-C}^+=\text{O} + \text{AlCl}_4^-$ ✓</p> <p>Mechanism Curly arrow from π-bond to $\text{CH}_3\text{C}^+=\text{O}$ ✓</p>  <p>-----</p>	5	AO2.5 AO2.5	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW '+' charge anywhere on $\text{CH}_3\text{C}^+\text{O}$ <i>i.e.</i> CH_3CO^+</p> <p>NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows</p> <p>1st curly arrow must</p> <ul style="list-style-type: none"> go to the C of $\text{C}=\text{O}$ <p>AND</p> <ul style="list-style-type: none"> start from, OR close to circle of benzene ring  <p>IGNORE curly arrow shown on $\text{C}=\text{O}$</p>

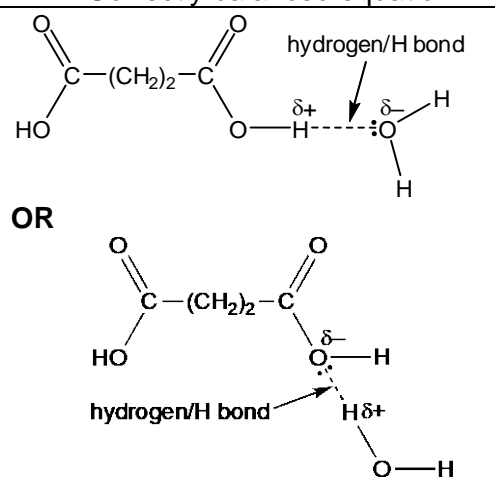
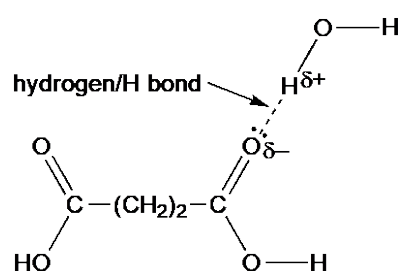
Mark Scheme

Question	Answer	Marks	AO element	Guidance
	<p data-bbox="365 272 663 304">Correct intermediate ✓</p> <p data-bbox="365 341 963 373">Curly arrow from C–H bond to reform π-ring ✓</p> <div data-bbox="365 410 943 668">  </div> <p data-bbox="365 979 707 1011">Regeneration of catalyst</p> $H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl \checkmark$		<p data-bbox="1216 272 1301 304">AO3.1</p> <p data-bbox="1216 341 1301 373">AO2.5</p> <p data-bbox="1216 1018 1301 1050">AO1.2</p>	<p data-bbox="1346 443 1921 475">DO NOT ALLOW the following intermediate:</p> <div data-bbox="1346 480 1581 695">  </div> <p data-bbox="1346 707 2024 770">π-ring should cover approximately 4 of the 6 sides of the benzene ring structure</p> <p data-bbox="1346 775 1939 871">AND the correct orientation, <i>i.e.</i> gap towards C with $COCH_3$</p> <p data-bbox="1346 898 1973 962">ALLOW + sign anywhere inside the 'hexagon' of intermediate</p> <p data-bbox="1346 1002 2007 1066">curly arrow must start from, OR be traced back to, any part of C-H bond and go inside the 'hexagon'</p> <div data-bbox="1429 1082 1944 1318">  </div>

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(iv)	<p>one mark for each correct structure/reagent</p> <p> CH_3 $\text{HO}-\text{C}-\text{COOH}$ $$ C_6H_5 </p> <p> NH_3 AND ethanol OR excess NH_3 </p> <p> CH_3 $\text{Br}-\text{C}-\text{COOH}$ $$ C_6H_5 </p> <p> $\text{H}^+/\text{H}_2\text{SO}_4/\text{HCl}$ </p> <p> CH_3 $\text{H}_2\text{N}-\text{C}-\text{COOH}$ $$ C_6H_5 </p> <p> HNO_3 </p> <p> CH_3 $\text{HO}-\text{C}-\text{COOH}$ $$ C_6H_5 </p> <p> NaBr/Br^- AND $\text{H}_2\text{SO}_4/\text{H}^+$ </p> <p> CH_3 $\text{HO}-\text{C}-\text{CN}$ $$ C_6H_5 </p> <p> $\text{acid}/\text{H}^+/\text{H}_3\text{PO}_4/\text{H}_2\text{SO}_4$ </p> <p> CH_3 $\text{H}-\text{C}-\text{OH}$ $$ C_6H_5 </p>	7	AO2.5 x7	<p>ALLOW any vertical bond to the OH OR NH_2 groups e.g. ALLOW</p> <p> $\begin{array}{c} \\ \text{OH} \end{array}$ OR $\begin{array}{c} \\ \text{HO} \end{array}$ AND $\begin{array}{c} \\ \text{NH}_2 \end{array}$ OR $\begin{array}{c} \\ \text{H}_2\text{N} \end{array}$ </p> <p>DO NOT ALLOW OH^-, OR NH_2^- but ALLOW ECF for subsequent use in this part</p> <p>For elimination, IGNORE 'concentrated', 'dilute' with acids BUT DO NOT ALLOW $\text{H}_2\text{O}/\text{steam}/(\text{aq})$</p> <p>ALLOW HBr for $\text{NaBr}/\text{H}_2\text{SO}_4$</p> <p>For hydrolysis. IGNORE missing (aq) ALLOW HNO_3 for hydrolysis but DO NOT ALLOW 'HNO_3 and H_2SO_4'</p> <p>ALLOW final 2 stages in opposite order i.e. NH_3 before acid hydrolysis</p> <p> CH_3 $\text{H}_2\text{N}-\text{C}-\text{CN}$ $$ C_6H_5 </p> <p> NH_3 AND ethanol OR excess NH_3 </p> <p> CH_3 $\text{H}_2\text{N}-\text{C}-\text{COOH}$ $$ C_6H_5 </p> <p> $\text{H}^+/\text{H}_2\text{SO}_4/\text{HCl}$ </p>
	Total	23		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
4	(a)	(i)	<p>Reagents $K_2Cr_2O_7$ AND acid AND reflux ✓</p> <p>Equation $HO(CH_2)_4OH + 4[O] \rightarrow HOOC(CH_2)_2COOH + 2H_2O$</p> <p>[O] AND H_2O ✓</p> <p>Correctly balanced equation ✓</p>	3	1.1 2.5 2.6	<p>ALLOW $Na_2Cr_2O_7$ OR $Cr_2O_7^{2-}$ ALLOW H_2SO_4 OR HCl OR H^+ ALLOW words. e.g. 'acidified dichromate' ALLOW a small slip in formula for dichromate e.g KCr_2O_7,</p>
		(ii)	 <p>Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓</p> <p>Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another AND Hydrogen bonding stated or labelled on diagram</p>	2	2.1x2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>DO NOT ALLOW $\delta+$ on H atoms of CH_2 group</p> <p>ALLOW H-bond for hydrogen bond</p> <p>ALLOW H bond between $C=O$ and H_2O, i.e.</p>  <p>IF diagram is not labelled, ALLOW hydrogen bond/H bond from text</p>

Mark Scheme

Question		Answer	Marks	AO element	Guidance
(b)	(i)	$\text{---}\overset{\text{O}}{\parallel}\text{C}-(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4-\text{O}\text{---}$ <p>Ester link (must be displayed) ✓</p> <p>Rest of structure ✓</p>	2		<p>ALLOW the 'O' or C=O at either end, e.g.</p> $\text{---}\overset{\text{O}}{\parallel}\text{C}-(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4\text{---}$ $\text{---}(\text{CH}_2)_2-\overset{\text{O}}{\parallel}\text{C}-\text{O}-(\text{CH}_2)_4-\text{O}-\overset{\text{O}}{\parallel}\text{C}\text{---}$ <p>1.2</p> <p>2.5</p> <p>IGNORE brackets</p> <p>IGNORE n</p> <p>End bonds' MUST be shown (solid or dotted)</p> <p>DO NOT ALLOW more than one repeat unit</p>
	(ii)	<p>the ester/ ester bond/ ester group /polyester can be broken down ✓</p> <p>OR</p> <p>It can be hydrolysed ✓</p>	1	3.2	<p>IGNORE references to photodegradable</p> <p>'Bond breaks' is not sufficient – no reference to ester bond</p>
	(iii)	$\begin{array}{c} \text{O} & & \text{O} \\ \parallel & & \parallel \\ \text{C}-(\text{CH}_2)_2-\text{C} \\ \text{HO} & & \text{OH} \end{array} + 2 \text{SOCl}_2 \longrightarrow \begin{array}{c} \text{O} & & \text{O} \\ \parallel & & \parallel \\ \text{C}-(\text{CH}_2)_2-\text{C} \\ \text{Cl} & & \text{Cl} \end{array} + 2 \text{SO}_2 + 2 \text{HCl}$ <p>SOCl₂ in equation ✓</p> <p>Structure of diacyl dichloride ✓</p> <p>Complete balanced equation ✓</p>	3		<p>ALLOW alternative approach using PCl₅ or PCl₃</p> <p>1.1</p> <p>1.2</p> <p>2.6</p>