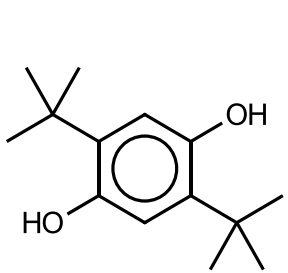
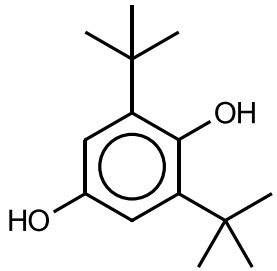
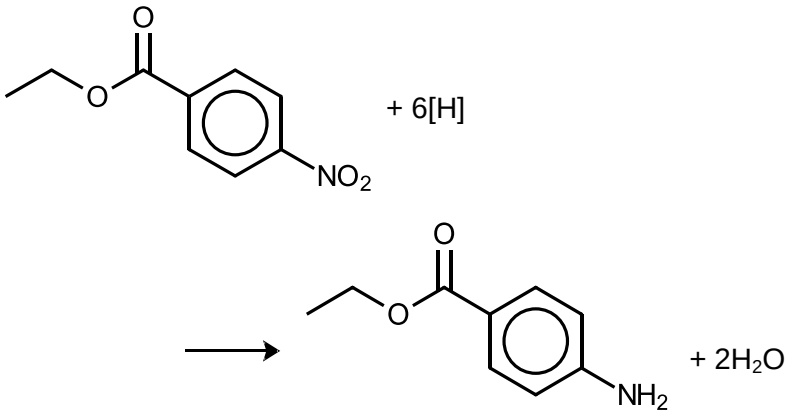
Mark Scheme

Question	Key	Marks	Guidance
1	B	**1**	
2	C	**1**	
3	C	**1**	
4	D	**1**	

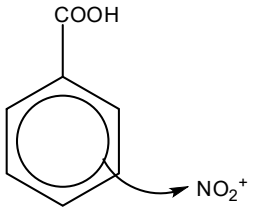
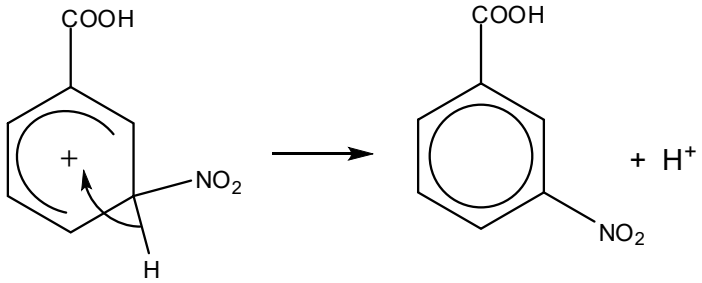
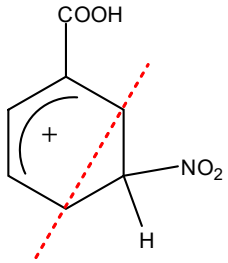
Mark Scheme

Question			Answer	Marks	Guidance
5	(a)	(i)	 **OR**  ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** disubstituted compound with *tert*-butyl groups adjacent
		(ii)	(The student's friend is correct because) the lone pair of electrons on the oxygen atom(s) ✓ is donated to/partially delocalised into the π system ✓ making quinol more susceptible to electrophilic attack ✓	**3**	**ALLOW** "the oxygen p-orbital overlaps with " **ALLOW** diagrammatic answer for 1st and 2nd marks: 1st mark: π system **OR** 6×p orbitals shown 2nd mark: O lone pair **OR** O p-orbital **AND** interaction **ALLOW** undergoes electrophilic substitution more easily if 1st and 2nd marks achieved through diagram, conclusion **must** refer to diagram for 3rd mark
	(b)	**(i)**	step **1** = (conc.) H_2SO_4 **AND** CH_3CH_2OH ✓	**1**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous

Mark Scheme

Question			Answer	Marks	Guidance
		(ii)	 **BOTH** organic structures ✓ balanced equation ✓	**2**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous
			Total	**7**	

Mark Scheme

Question			Answer	Marks	Guidance
6	(a)	(i)	**Generation of electrophile** $HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+$ ✓ **Electrophilic substitution** Curly arrow from π-bond to NO_2^+ ✓  --- Correct intermediate ✓ Curly arrow back from C-H bond to reform π-ring **AND** H^+ as product ✓  **Regeneration of catalyst** $H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$ **ALLOW** $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ then $H_2NO_3^+ \rightarrow H_2O + NO_2^+$ **ALLOW** $^+NO_2$ **OR** NO_2^+ First curly arrow must come from the ring to NO_2^+ **DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure **AND** the correct orientation, *i.e.* gap towards C with NO_2 **ALLOW** + sign anywhere inside the 'hexagon' of intermediate

Mark Scheme

Question	Answer	Marks	Guidance
(ii)*	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Outlines the main steps of recrystallisation to produce a pure sample of 3-nitrobenzoic acid from the impure solid. **AND** Calculates correct percentage yield of 3-nitrobenzoic acid. **AND** Method of checking purity to include comparison to relevant data. *A well-structured response with the steps for recrystallisation and the determination of purity being given in the correct order. Correct use of terminology throughout.* **Level 2 (3–4 marks)** Attempts all three scientific points but explanations may be incomplete. **OR** Explains two scientific points thoroughly with very few omissions. *The description of checking for purity or recrystallisation is clear and any calculations structured. Key terminology used appropriately.* **Level 1 (1–2 marks)** A simple explanation based on at least two of the main scientific points. **OR**	6	**Indicative scientific points, with bulleted elements, may include:** **1. Purification** • Recrystallisation • Dissolve impure solid in minimum volume of hot water/solvent • Cool solution and filter solid • Wash with cold water/solvent and dry **2. Percentage yield** • n(benzoic acid) used = $\frac{4.97}{122}$ = 0.0407 (mol) • n(3-nitrobenzoic acid) made = $\frac{4.85}{167}$ = 0.0290 (mol) • percentage yield = $\frac{0.0290}{0.0407} \times 100$ = 71.3 (%) **ALLOW** 71 to calculator value of 71.29001554 correctly rounded. **CHECK** for extent of errors by **ECF** Alternative correct calculation may calculate theoretical mass of 3-nitrobenzoic acid that can be produced as 0.0407 × 167 = 6.80 (g) followed by: percentage yield = $\frac{4.85}{6.80} \times 100$ = 71.3 (%) Calculation **must** attempt to calculate n(benzoic acid) in mol. **3. Checking purity**

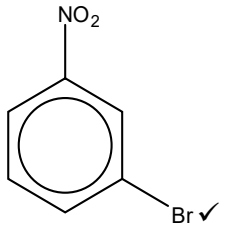
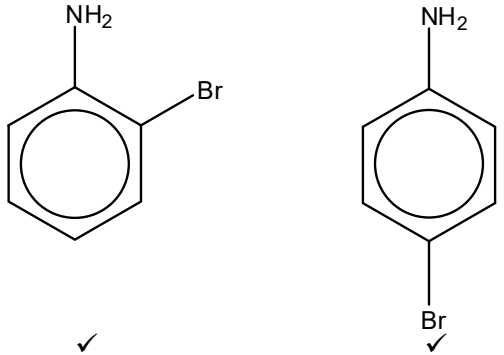
Mark Scheme

Question			Answer	Marks	Guidance
			Explains one scientific point thoroughly with few omissions. *There is an attempt at a logical structure. The description of the practical techniques provides some detail but may not be in the correct order.* • *Purification step is unclear with few scientific terms and little detail, e.g. just 'recrystallise'.* • *Calculation is difficult to follow, may just include a calculation of moles of reactants and/or products.* • *Purity check specifies a method but this is unclear with little detail, e.g. take melting point.* **0 marks** No response or no response worthy of credit.		• Obtain melting point • Compare to known values • Pure sample will have a (sharp) melting point very close to data book value **ALLOW** alternative approach based on spectroscopy or TLC **Spectroscopy** • Run an NMR/IR spectrum • Compare to (spectral) database • Spectrum of pure sample will contain same peaks and not others **TLC** • Run a TLC • Compare (R_f value) to known data • Pure sample will have a very similar R_f
	(b)	**(i)**	Phenol is the most easily nitrated/ most reactive **AND** Benzoic acid is the least easily nitrated /least reactive ✓	**1**	Response **must** give rank order of reactivity e.g. nitration becomes more difficult from phenol (to benzene) to benzoic acid **OR** nitration becomes easier from right to left in the table
		(ii)	**Reactivity of phenol** a (lone) pair of electrons on O is (partially) **delocalised/donated** into the π-system / ring ✓	**3**	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** the electron pair in the p orbitals of the O atom becomes part of the π-system / ring **ALLOW** diagram to show movement of lone pair into ring

Mark Scheme

Question			Answer	Marks	Guidance
			Reactivity of benzoic acid The –COOH group on benzoic acid is an electron withdrawing group ✓ **Links electron density in π-bond to reactivity** In phenol electron density is higher **AND** The ring is more susceptible to attack **OR** In benzoic acid electron density is lower **AND** The ring is less susceptible to attack ✓		**ALLOW** lone pair of electrons on O is (partially) drawn/attracted/pulled into π-system / ring **IGNORE** activating and deactivating. **ALLOW** the following alternatives for susceptibility to attack: • phenol attracts electrophiles / NO_2^+ **more** • phenol polarises electrophiles / NO_2^+ **more** • benzoic acid attracts electrophiles / NO_2^+ **less** • benzoic acid polarises electrophiles / NO_2^+ **less**
	(c)	**(i)**	**Bromination**: Br_2 **AND** $AlBr_3$/$FeBr_3$/Fe ✓ **Intermediate**	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any suitable halogen carrier catalyst

Mark Scheme

Question			Answer	Marks	Guidance
			 Br ✓ **Reduction**: Sn **AND** (concentrated) HC*l* ✓		**ALLOW** Kekulé structure **IGNORE** names *(question asks for formulae)* **IGNORE** reaction conditions even if incorrect **IGNORE** 'dilute' for HC*l* **IGNORE** H_2 **IGNORE** NaOH if seen as a reagent to convert nitro group into amine e.g 'Sn/(concentrated) HC*l* then NaOH' scores the mark
		(ii)	NH_2 is 2,4 directing ✓ Products (1 mark for each):  ✓ ✓	**3**	**IGNORE** references to electron donating/withdrawing groups **ALLOW** $-NH_2$ activates the ring causing the new group to join at positions 2 and 4. **ALLOW** ortho and para directing for 2,4 directing **IGNORE** 6-directing **ALLOW** Kekulé structure **IGNORE** names
			Total	**21**	

OCR (A) Chemistry A-Level - Aromatic Compounds

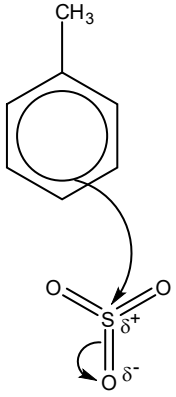
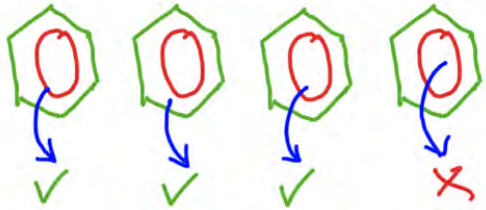
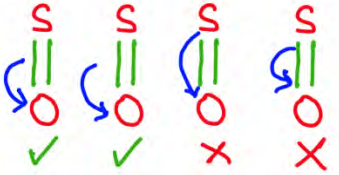
Mark Scheme

Question	Answer	Marks	Guidance
7	C	1	
8	A	1	

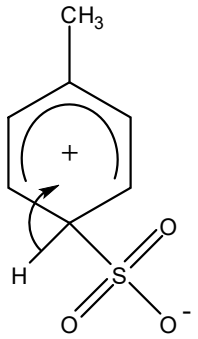
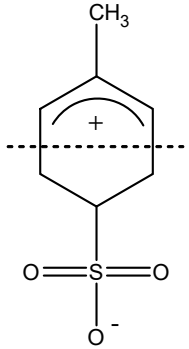
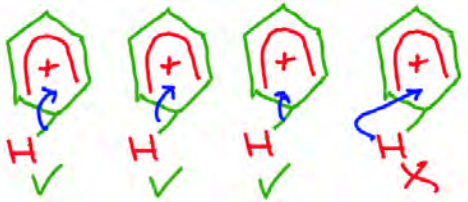
Mark Scheme

Question			Answer	Marks	Guidance
9	(a)	(i)	**Number of peaks** **2 marks** 2-nitrophenol **AND** 3-nitrophenol have **six** peaks/environments/types of carbon ✓ 4-nitrophenol has **four** peaks/environments/types of carbon ✓ **Statement** **1 mark** 4-nitrophenol can be distinguished **OR** 2-nitrophenol and 3-nitrophenol cannot be distinguished ✓	3	**IGNORE** any numbers shown on structures **ALLOW** 1 mark only **IF** a response identifies that all the compounds have 6 peaks/environments/types of C **OR** all the compounds have 4 peaks/environments/ types of carbon **IGNORE** chemical shifts **DO NOT ALLOW ECF** from an incorrect number of peaks/environments/types of carbon
		(ii)	(In phenol) a (lone) pair of electrons on O is(partially) delocalised/donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenol) is more susceptible to electrophilic attack **OR** (phenol) attracts/accepts electrophile/HNO_3 more **OR** (phenol) polarises electrophile/HNO_3 more ✓ **ORA**	3	**ALLOW** the electron pair in the p-orbitals of the O atom becomes part of the π-system / ring **ALLOW** diagram to show movement of lone pair into ring **ALLOW** lone pair of electrons on O is (partially) drawn/attracted/pulled/ into π-system / ring **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenol reacts more readily *(no reference to electrophile)* **ALLOW** NO_2^+ for electrophile

Mark Scheme

Question	Answer	Marks	Guidance
(b)	Curly arrow from π-bond to S in SO_3 **AND** curly arrow from the S=O bond to O atom ✓  	3	**ANNOTATE WITH TICKS AND CROSSES** **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the S of SO_3 **AND** • start from, **OR** close to **circle of benzene ring**  **2nd curly arrow** must start from, **OR** be traced back to, **any part of** S=O bond and go to O  **ALLOW 2nd** curly arrow from S=O to any O in SO_3 Intermediate must have correct SO_3^- structure fully displayed

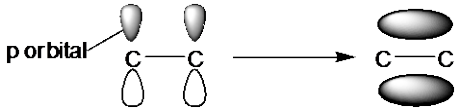
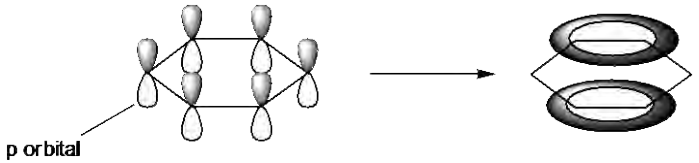
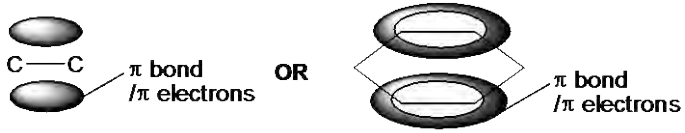
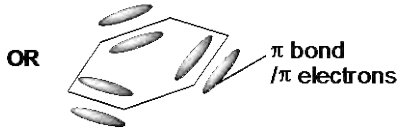
Mark Scheme

Question	Answer	Marks	Guidance
	Correct intermediate ✓ Curly arrow from C-H bond to reform π-ring ✓ 		**DO NOT ALLOW** the following intermediate:  π-ring must cover more than half of the benzene ring structure **AND** the correct orientation, *i.e.* gap towards C with SO_3^- **ALLOW** + sign anywhere inside the 'hexagon' of the intermediate. **DO NOT ALLOW** mark for intermediate if CH_3 is missing **curly arrow** must start from, **OR** be traced back to, **any part of** C-H bond and go inside the 'hexagon' 
	Total	**9**	

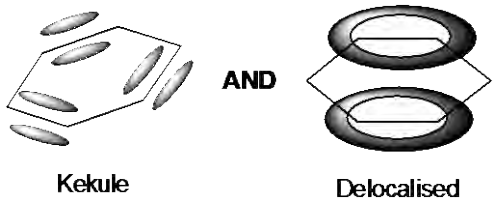
Mark Scheme

Question	Answer	Marks	AO element	Guidance
10	**C**	**1**	AO1.2	
11	**A**	**1**	AO1.1	

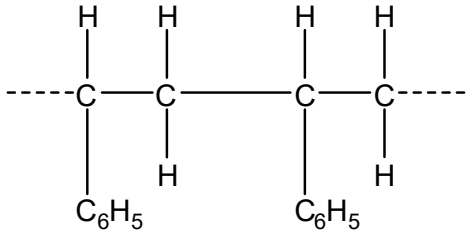
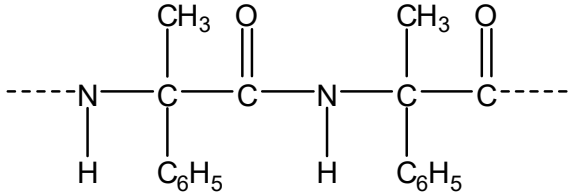
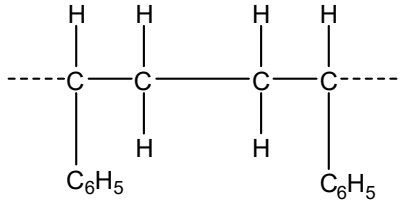
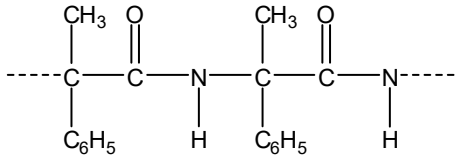
Mark Scheme

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

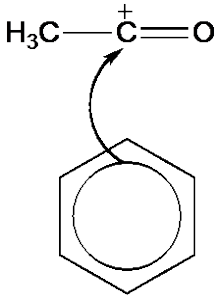
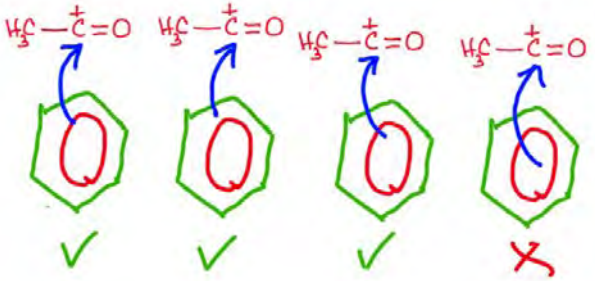
Mark Scheme

Question			Answer	Marks	AO element	Guidance
			Difference Kekule has: alternating π bonds OR 3 π bonds / localised (π electrons) / overlap in one direction / 2 electrons in π bond **AND** Delocalised has: π ring (system) / all p orbitals overlap OR (π electrons) spread around ring / overlap in both directions / 6 electrons in π bond /			---------- **ALLOW** diagram showing π bond in **both** Kekule **AND** delocalised models e.g  Kekule AND Delocalised π bond labels **not** required for third mark
		(ii)	**Any 2 pieces of evidence from** (✓ ✓) **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 **Δ*H* hydrogenation** Δ*H* hydrogenation less (exothermic) than expected **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	**2**	AO1.1 ×2	**ALLOW (**C–C) bond enthalpy is between single (C–C) and double bond (C=C) **OR** all (C–C) bond enthalpies are the same **IGNORE** enthalpy of hydration Benzene is unreactive is **not** sufficient *(no comparison to alkene)* For halogen carrier, **ALLOW** name or formula of suitable catalyst e.g. Fe, $AlCl_3$, $FeBr_3$

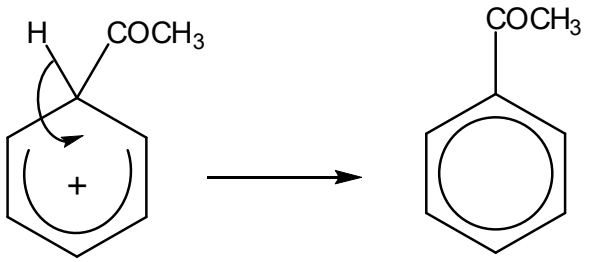
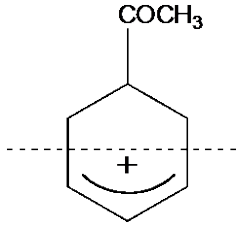
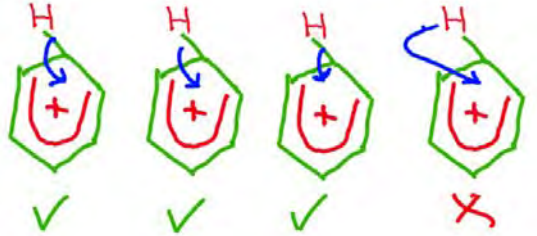
Mark Scheme

Question	Answer	Marks	AO element	Guidance
(b) (i)	**Polymer from D**  ✓ **Polymer from E**  Amide link ✓ 2 repeat units of correct polymer ✓	3	AO2.5 AO1.2 AO2.5	--- For **BOTH** structures, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown **BUT ALLOW ECF IF** end bonds omitted in both structures **DO NOT ALLOW** more than 2 repeat units **BUT ALLOW ECF** in subsequent structure **IGNORE** connectivity of C_6H_5 --- **CARE**: **ALLOW** any consistent repeat unit: C_6H_5 and H groups can alternate or be on opposite sides of chain e.g.  end –NH– may be at either side e.g.  **IGNORE** brackets **IGNORE** *n*

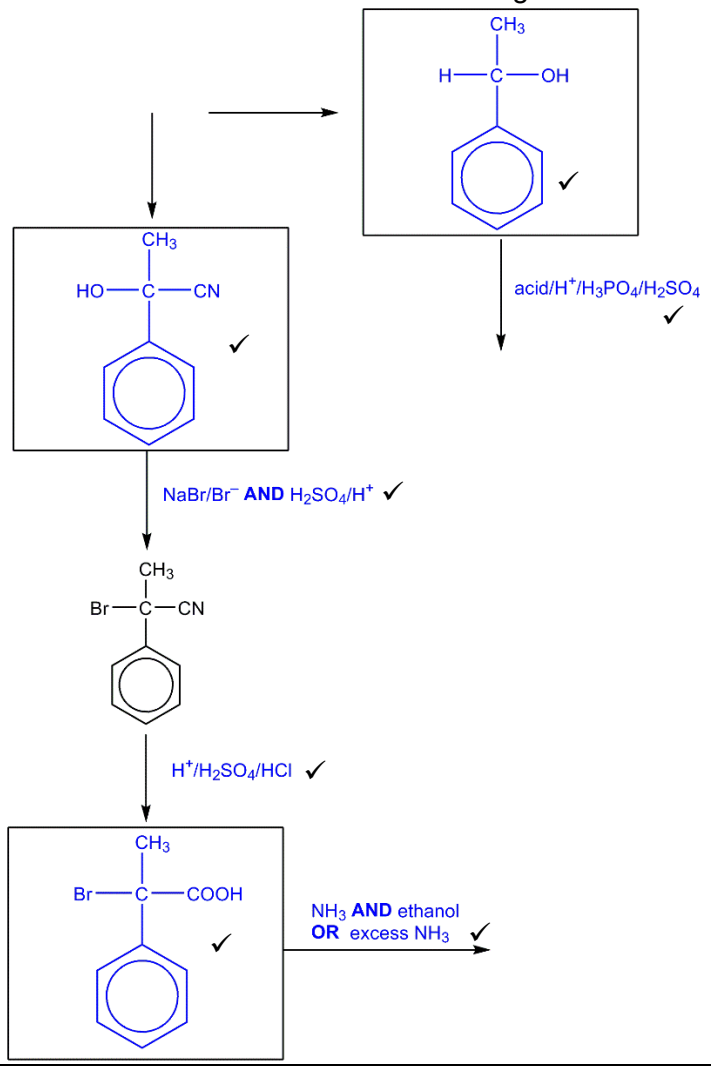
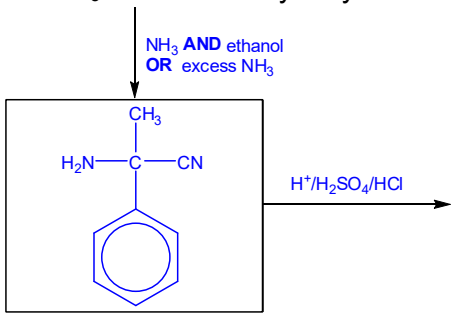
Mark Scheme

Question			Answer	Marks	AO element	Guidance
		(ii)	**D** Addition / polyalkene **AND** **E**: Condensation / polyamide ✓	1	AO1.1	**DO NOT ALLOW** 'additional'
		(iii)	**Formation of electrophile** $CH_3COCl + AlCl_3 \rightarrow CH_3–C^+=O + AlCl_4^-$ ✓ **Mechanism** Curly arrow from π-bond to $CH_3C^+=O$ ✓  ----------	5	AO2.5 AO2.5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** '+' charge anywhere on CH_3C^+O *i.e.* CH_3CO^+ **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the C of C=O **AND** • start from, **OR** close to **circle of benzene ring**  **IGNORE** curly arrow shown on C=O

Mark Scheme

Question	Answer	Marks	AO element	Guidance
	Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring ✓  **Regeneration of catalyst** $H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl$ ✓		AO3.1 AO2.5 AO1.2	**DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure **AND** the correct orientation, *i.e.* gap towards C with $COCH_3$ **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **curly arrow** must start from, **OR** be traced back to, **any part of** C-H bond and go inside the 'hexagon' 

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(iv)	**one** mark for each correct structure/reagent  	7	AO2.5 ×7	**ALLOW** any vertical bond to the OH **OR** NH_2 groups e.g. **ALLOW**  **DO NOT ALLOW** OH–, **OR** NH_2– but **ALLOW ECF** for subsequent use in this part For elimination, **IGNORE** 'concentrated', 'dilute' with acids **BUT DO NOT ALLOW** H_2O/steam/(aq) **ALLOW** HBr for $NaBr/H_2SO_4$ For hydrolysis. **IGNORE** missing (aq) **ALLOW** HNO_3 for hydrolysis but **DO NOT ALLOW** 'HNO_3 and H_2SO_4' **ALLOW** final 2 stages in opposite order i.e. NH_3 before acid hydrolysis 
	Total	**23**		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
13	(a)		$CO_3^{2-} + H_2O \rightarrow OH^- + HCO_3^-$ **OR** $CO_3^{2-} + H_2O \rightarrow 2OH^- + CO_2$ ✓	1	AO1.2	**ALLOW** $CO_3^{2-} + 2H_2O \rightarrow 2OH^- + H_2CO_3$ **IGNORE** state symbols **ALLOW** inclusion of Na^+ as spectator ion, e.g. $2Na^+ + CO_3^{2-} + H_2O \rightarrow 2OH^- + 2Na^+ + CO_2$ **IGNORE** $Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$ *Ionic equation required* **IGNORE** equation with H^+ or H_3O^+ e.g. $CO_3^{2-} + H^+ \rightarrow OH^- + CO_2$ *Question asks for reaction with H_2O*
	(b)		Acid/H^+/HCl reacts with **OR** protonates • benzoate / $C_6H_5COO^-$ • carboxylate / salt (to form benzoic acid) ✓	1	AO2.3	**ALLOW** suitable equation, e.g. $C_6H_5COO^- + H^+ \rightarrow C_6H_5COOH$ **IGNORE** responses purely in terms of neutralisation of alkali, e.g. Acid/H^+/HCl **neutralises** / reacts with/removes alkali **/** OH^- / CO_3^{2-} / Na_2CO_3
	(c)		$C_6H_5CH_2OH + 2[O] \rightarrow C_6H_5COOH + H_2O$ ✓	1	AO2.6	**ALLOW** molecular, structural, displayed formulae, etc e.g. molecular: $C_7H_8O + 2[O] \rightarrow C_7H_6O_2 + H_2O$

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(d)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 33.8 OR 33.9 (%) award 3 marks** --- **Theoretical moles** $n(C_6H_5COOH)$ **OR** $n(C_6H_5CH_2OH)$ $= \frac{4.00 \times 1.04}{108.0}$ **OR** 0.0385….. (mol) ✓ **Actual moles** $n(C_6H_5COOH) = \frac{1.59}{122.0}$ **OR** 0.013(0)…. (mol) ✓ % yield = $\frac{0.0130\ldots}{0.0385\ldots.} \times 100$ = 33.8% **OR** 33.9 (3 sig fig) ✓ *Answer depends on some intermediate roundings to 3SF*	3	AO2.8 ×1 AO2.8 ×1 AO1.2	**ALLOW ECF** for each step Calculator = 0.03851851852 Calculator = 0.01303278689 --- **Alternative method using mass** 1. Theoretical moles = 0.0385 mol 2. Mass = 0.0385 × 122.0 = 4.70 g 3. % yield = $\frac{1.59}{4.70} \times 100$ = 33.8% --- **Common errors** 35.2% → 2 marks • From $\frac{4.00}{108}$ = 0.0370 *(no use of density)* 36.5 **OR** 36.6% → 2 marks • $\frac{4.00/1.04}{108} = \frac{3.846}{108}$ = 0.0356 *(÷ density instead of × density)*

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(e)		Dissolve in the **minimum** quantity of **hot** water/solvent ✓ Cool **AND** Filter **AND** (leave to) dry ✓ *All three needed*	**2**	AO3.3 ×2	**ALLOW** any solvent **DO NOT ALLOW** use of drying agent (e.g. $MgSO_4$) **IGNORE** • Initial filtering • hot filtration to remove insoluble impurities
			Total	**8**		

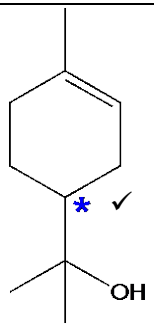
Mark Scheme

Question			Answer	Marks	AO element	Guidance
14	(a)	(i)	4-chloro-3,5-dimethylphenol ✓ **CARE**: Look for **di**methyl	1	AO1.2	**ALLOW** 3,5-dimethyl-4-chlorophenol **ALLOW** absence of hyphens or extra hyphen or space, e.g. 4 chloro 3,5 dimethylphenol **ALLOW** full stops or spaces between numbers e.g. 4-chloro-3.5-dimethylphenol **ALLOW** name based on benzene, if unambiguous e.g.1-chloro-4-hydroxy-2,6-dimethylbenzene **DO NOT ALLOW** meth **OR** methy
		(ii)	5 ✓	1	AO2.5	
		(iii)	**Functional group** Phenol ✓ **Test** Indicator/pH paper turns red / orange **OR** pH < 7 **OR** pH meter < 7 **AND** No reaction with Na_2CO_3/CO_3^{2-}/carbonate ✓	2	AO1.2 AO2.3	**DO NOT ALLOW** alcohol **OR** hydroxide **IGNORE** hydroxyl **OR** hydroxy **IGNORE** OH (*name asked for*) **ALLOW** Add bromine **AND** white precipitate **ALLOW** $FeCl_3$ **AND** violet/blue colour

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 1.71×10^{-10}, award **FOUR calculation marks** **CARE Separate mark for equation** --- **Equation (1 mark)** $C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$ ✓ *Molecular formulae required (atoms in any order)* **[C_8H_9ClO] calculation (2 marks)** Molar mass C_8H_9ClO = 156.5 (g mol^{-1}) ✓ **ONLY** correct answer $[C_8H_9ClO] = \frac{4.8 \times 10}{156.5}$ **OR** 0.3067….. (mol dm^{-3}) ✓ *Subsumes mark for molar mass = 156.5* **K_a calculation (2 marks)** $[H^+] = 10^{-5.14} = 7.244….. \times 10^{-6}$ (mol dm^{-3}) ✓ $K_a = \frac{(7.244…. \times 10^{-6})^2}{0.3067…..} = 1.71 \times 10^{-10}$ (mol dm^{-3}) ✓	**5**	AO1.2 ×1 AO2.8 ×4	**ALLOW** → for ⇌ **DO NOT ALLOW** C_8H_8ClOH in equation i.e. $C_8H_8ClOH \rightleftharpoons H^+ + C_8H_8ClO^-$ If equation is omitted, **ALLOW** equation mark for a correct K_a expression with molecular formula i.e. $\frac{[H^+]\,[C_8H_8ClO^-]}{[C_8H_9ClO]}$ **NO ECF** from an incorrect formula in equation **ALLOW ECF** from incorrect molar mass **ALLOW** 0.307 up to calculator value: 0.306709265 correctly rounded **ALLOW** 7.24×10^{-6} up to calculator value: $7.244359601 \times 10^{-6}$ correctly rounded **ALLOW 2 SF** ($1.7…. \times 10^{-10}$) up to calculator value, correctly rounded (but take care from acceptable intermediate rounding) **COMMON ERRORS** $2.36….. \times 10^{-5}$ 3/4 calculation marks *No squaring of 7.24×10^{-6}*

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(b)	(i)		1	AO2.5	**DO NOT ALLOW** more than one * **ALLOW** a circle for *
		(ii)	**MAXIMUM OF 4 MARKS FROM 5 MARKING POINTS** **Requirement for *E*/*Z* isomerism** ***2 marks*** C=C/double bond ✓ Each C (in C=C) is attached to (two) different groups/atoms ✓ **Identification as *E*- or *Z*- isomer** ***2 marks*** *E/Z* isomerism linked to (high) **priority groups** ✓ ***Z*- isomer AND** groups are on **same side** **OR** the ring carbons ✓ **Reason why other *E*/*Z* isomer does not exist** ***1 mark*** **ring** would be strained **OR ring** would break/deform **OR** Cannot form **ring** if high priority groups are on opposite sides **OR** ring locks groups on one side of C=C bond ✓	4	AO1.2 ×2 AO2.5 ×2	**IGNORE** no H attached to C=C **IGNORE** functional', i.e. **ALLOW** different functional groups **ALLOW** in context of groups with largest atomic number ***ORA*** ***Award BOTH identification marks for:*** ***Z*-** isomer **AND** (high) **priority groups** on **same side** Mark independently of previous part Response **MUST** be linked to the **ring**/cyclic structure **IGNORE** just '*E* isomer is impossible' **IGNORE** C=C bond cannot rotate **IGNORE** Groups can't swap sides

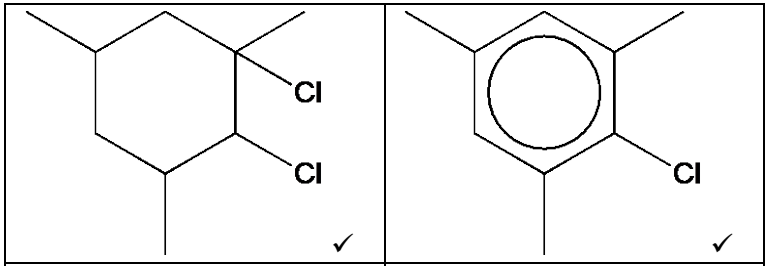
Mark Scheme

Question			Answer	Marks	AO element	Guidance
		(iii)	**First group**: **Reagent** **AND** **Functional group**: Alkene **OR** cycloalkene ✓ ***Examples of reagents*** Br_2 or other halogen, HBr, H_2 **AND** Ni (catalyst), H_2O(**g**)/steam **AND** H^+ (catalyst) **Organic product** for reagent with **C=C** in α-terpineol ✓ ***ALLOW*** *product from H_2 or H_2O if H^+ catalyst has been omitted from reagent.* --- **Second group** **Reagent** **AND** **Functional group**: (Tertiary) alcohol ✓ ***Examples of reagents*** NaBr/KBr/Br^- **AND** acid/H^+ (substitution), **OR** HBr Acid/H^+ (catalyst) (elimination), CH_3COOH **AND** acid/H^+ (catalyst) (esterification) $CH_3COOCOCH_3$ (esterification) CH_3COCl (esterification) **Organic product** for reagent with **OH** in α-terpineol ✓ ***ALLOW*** *product if catalyst omitted from reagent*	**4**	AO3.2 ×4	**CONTACT TEAM LEADER FOR OTHER REACTIONS** --- **ALLOW GROUPS EITHER WAY ROUND IN BOXES** Functional group **MUST** be **named** **DO NOT ALLOW** UV with halogens **ALLOW** H_2SO_4/H_3PO_4/acid for H^+ **ALLOW** addition of HBr/ H_2O either way across C=C **ALLOW ANY HALIDE**, i.e. Cl^-, Br^-, I^- **ALLOW** H_2SO_4/H_3PO_4/acid for H^+ **ALLOW** HBr for H^+ and Br^- **ALLOW** name or formula of any carboxylic acid or acyl chloride for esterification **ALLOW** Na → product with –ONa **OR** $–O^-$ **DO NOT ALLOW** $Cr_2O_7^{2-}/H^+$ (tertiary alcohol)
			Total	**18**		

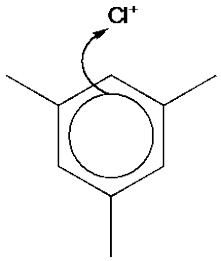
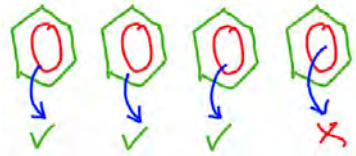
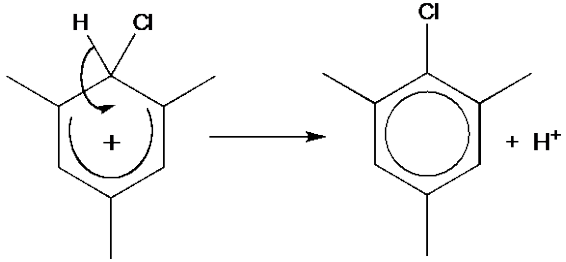
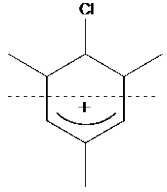
Mark Scheme

Question	Answer	Marks	AO element	Guidance
15	A	1	1.1	
16	C	1	1.2	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
17	(a)	(i)	 ✓ Organic product with **B** ✓ Organic product with **C**	2	2.5×2	
		(ii)	**Reactivity of B** in B electrons are localised OR in B π-bond is localised ✓ **Reactivity of C** in C electrons are delocalised OR In C π-system / ring is delocalised In **B**, electron density is higher **AND** B is more susceptible to electrophilic attack **OR** B attracts/accepts the electrophile/Cl_2 more **OR** B polarises the electrophile/Cl_2 more ✓ **ORA**	3	1.1×3	**ALLOW** labelled diagram to show delocalised system **IGNORE** charge density **IGNORE** electronegativity **IGNORE** B is more reactive/reacts more readily (no reference to electrophile) **IGNORE** references to electron density spread around the π–ring **ALLOW** chlorine

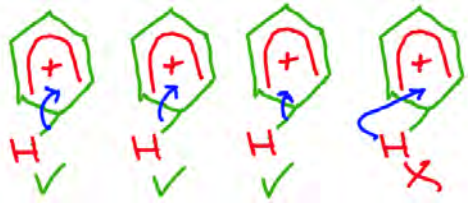
Mark Scheme

Question	Answer	Marks	AO element	Guidance
(iii)	**Generation of electrophile** $AlCl_3 + Cl_2 \rightarrow AlCl_4^- + Cl^+$ ✓	5	1.2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $FeCl_3 + Cl_2 \rightarrow FeCl_4^- + Cl^+$ **ALLOW** use of Fe
	Attack of Cl^+  Curly arrow from π-bond to Cl^+ ✓		1.2	**NOTE**: curly arrows can be straight, snake-like, etc. …….. but **NOT** double-headed or half-headed arrows **1st curly arrow** must • start from, **OR** close to, **circle of benzene ring** 
	--- **Intermediate and organic product**  Correct intermediate ✓		2.5	**DO NOT ALLOW** following intermediate: 
	Curly arrow from C–H bond to reform π-ring ✓		1.2	π-ring must cover 4 of the 6 sides of the benzene ring **AND** correct orientation, *i.e.* gap towards C–Cl
	--- **Regeneration of catalyst** $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓		1.2	**ALLOW** + sign anywhere inside the 'hexagon' of the intermediate.

Mark Scheme

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>IGNORE partial charges on the chlorine in the intermediate

DO NOT ALLOW mark for intermediate if any CH_3 is missing

Curly arrow must start from, OR be traced back to, any part of C-H bond and go inside the ‘hexagon’
 

ALLOW use of $AlCl_4^-$ in the mechanism

ALLOW ECF for regeneration of an incorrect metal chloride catalyst e.g. $AgCl_3$</td></tr>
<tr><td></td><td>(b)</td><td></td><td>$3C_3H_6O \rightarrow C_9H_{12} + 3H_2O$

molecular formulae of C_3H_6O AND C_9H_{12} ✓

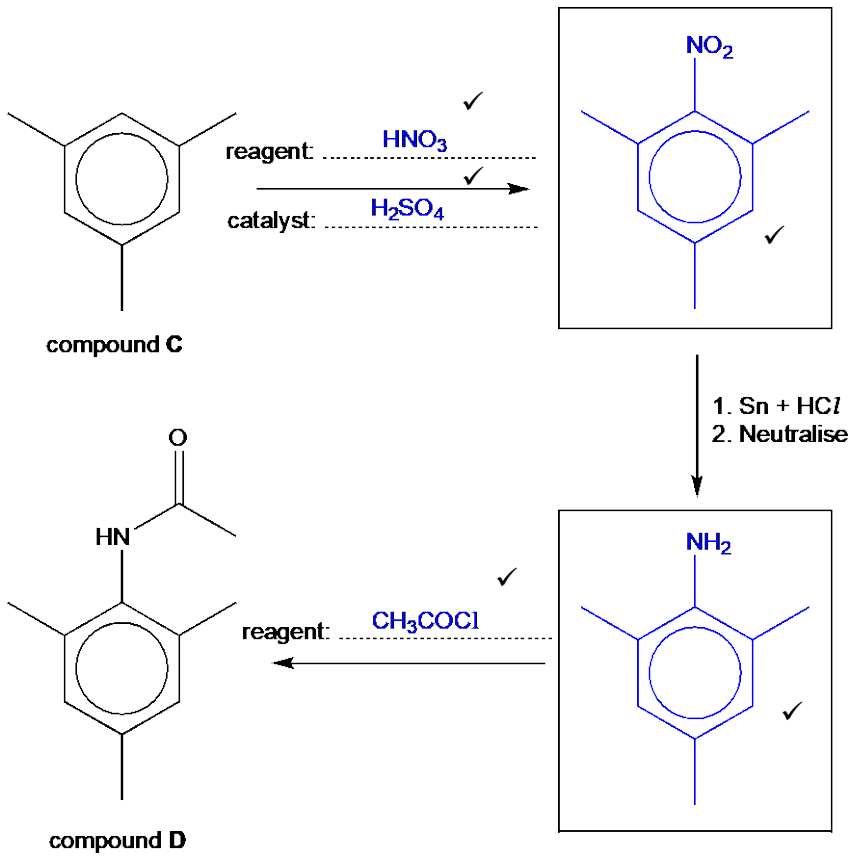
H_2O as by-product ✓

correct balanced equation ✓</td><td>3</td><td>2.6

2.5

2.6</td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td><table><tr><td></td><td>Compound C</td><td>Compound D</td></tr><tr><td>Number of peaks</td><td>3 ✓</td><td>8 ✓</td></tr></table></td><td>2</td><td>3.2</td><td></td></tr>
</table>

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(ii)		5	3.2×5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names for organic intermediates (question asks for structures **ALLOW** names of reagents and catalyst Around top arrow, **ALLOW** 1 of 2 marks if HNO_3 and H_2SO_4 swapped. i.e. reagent: H_2SO_4 catalyst: HNO_3 **IGNORE** references to concentration **ALLOW** $(CH_3CO)_2O$ for left arrow **IGNORE** CH_3COOH **IGNORE** acyl chloride **DO NOT ALLOW** $AlCl_3/FeCl_3$/Fe4