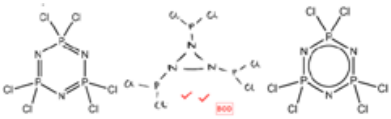
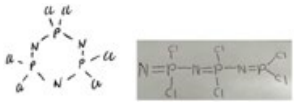
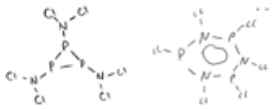
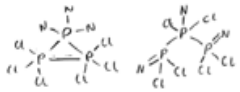
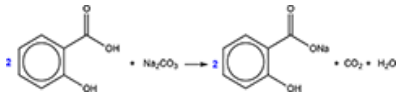
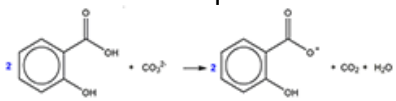
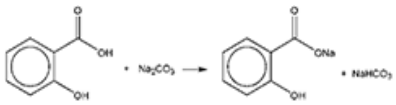
Mark scheme

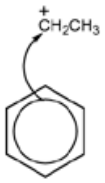
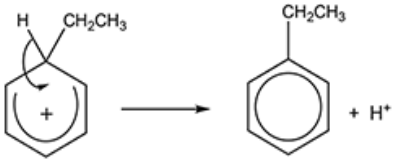
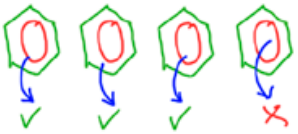
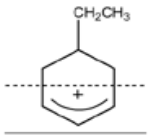
Question			Answer/Indicative content	Marks	Guidance
1		i	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong **Examiner's Comments** This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride. Candidates are expected to know that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report. As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course. **Assessment for learning** The specification states the following. ***Formulae and equations*** ***2.1.2(a)*** *the writing of formulae of ionic compounds from ionic charges, including:* i. *prediction of ionic charge from the position of an element in the periodic table*

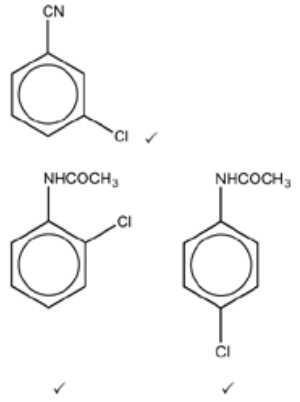
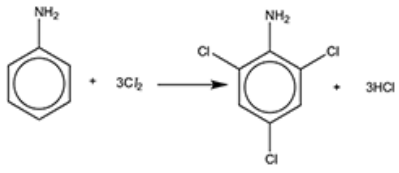
					ii. *recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+* This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE IF % by mass = 26.72, award 2 marks IF % by mass = 26.7, award 1 mark** ---------- ---------- M_r of $P_3N_3Cl_6$ = 348(.0) ✓ % by mass of P = $\frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓ **2 DP required**	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW** ECF from incorrect M_r **ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times 100 = 8.91$ **Examiner's Comments** In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72. Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).
		iii	(P-N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C-C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds **Examiner's Comments** About half the candidates suggested a range of creditworthy responses with 'different bond lengths' and 'decolorises bromine' being the most common.
		iv	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark**	2	1st mark *Meets criteria for 1st mark*

			• Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark (dependent on 1st mark)** • Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 		 **ZERO** marks  *N bonded to Cl*  *N atom(s) with 1 bond only* **Examiner's Comments** This was another question where valuable information: *'all N and Cl atoms are bonded to P atoms'* had been provided. Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds. Most structures contained 6 or 3-membered rings. This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark. The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules
			Total	**6**	
2		i	**Reaction with H_2SO_4** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓ **Reaction with excess G**	3	**ALLOW** multiples in both equations **IGNORE** state symbols **ALLOW** $Na_2CO_3 + 2H_2SO_4 \rightarrow 2NaHSO_4 + CO_2 + H_2O$ **ALLOW** ionic equation $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$

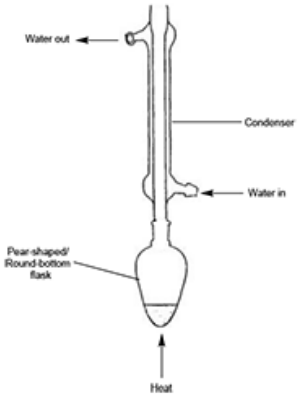
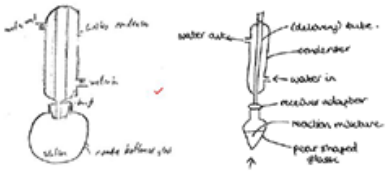
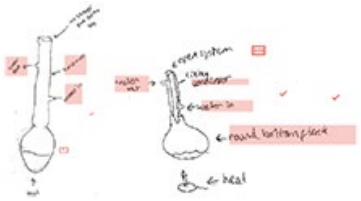
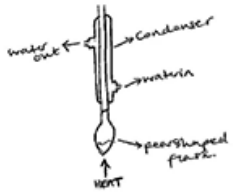
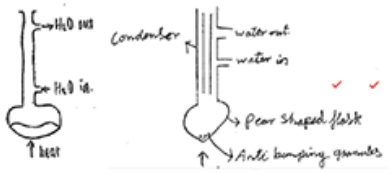
			 Correct organic product structure ✓ Correct balanced equation ✓		**ALLOW** $-COO^-$ (Na^+) for product structure mark **ALLOW** ionic equation  **ALLOW**  **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** correct Kekulé representation of benzene **Examiner's Comments** Another fairly challenging question, however most secured at least one mark for giving an equation for the reaction of sulfuric acid with sodium carbonate. Less confident candidates struggled to gain any marks as they were unable to give correct formula for sodium sulfate, giving $NaSO_4$ for example. Although many attempted the equation showing the reaction of compound **G** with sodium carbonate, only some correctly identified that only the carboxyl group would react, not the phenol. A small minority of students were able to balance the second equation gaining all 3 marks.
		ii	(NaOH) reacts with phenol / -OH (in compound G / H) **OR** (NaOH) would hydrolyse the ester / compound H	1	**IGNORE** comment about whether it improves or not **DO NOT ALLOW** (NaOH) reacts with alcohol **Examiner's Comments** The best responses correctly identified that using sodium hydroxide was not an improvement and explained this either bystating that it would react with the phenol group or hydrolyse the ester group in compound **H**. However, most candidates appeared not to consider a reaction with **H** in their answer. Many focused on the neutralisation of sulfuric acid in a similar way to sodium carbonate and gave responses such as: • stronger base • no effervescence so harder to see when completely reacted • no CO_2 produced so easier/safer/higher atom economy/less waste • requires double the moles compared to Na_2SO_4 to react

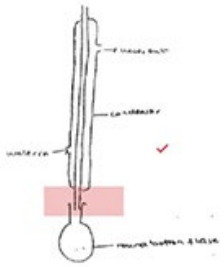
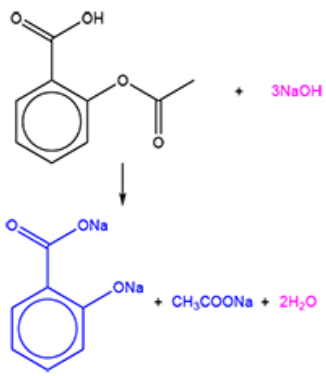
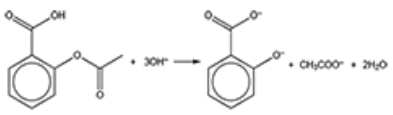
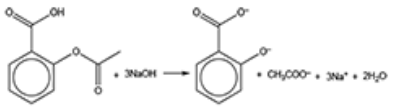
			Total	**4**	
3			1-ethyl-2,4-dimethylbenzene ✓	1	**ALLOW** other unambiguous names using smallest numbering. e.g. **ALLOW** 1,3-dimethyl-4-ethylbenzene 2,4-dimethylethylbenzene ethyl-2,4-dimethylbenzene 2,4-dimethyl-1-ethylbenzene **IGNORE** alphabetical order of methyl and ethyl **IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces **DO NOT ALLOW** 1,5-dimethyl-2-ethylbenzene **OR** 1,3-dimethyl-6-ethylbenzene *Needs smallest numbers* **DO NOT ALLOW** the following for dimethyl: dimethy, dimeth, dimethly, dimethanyl **DO NOT ALLOW** the following for ethyl: ethy, eth, ethly, ethanyl **Examiner's Comments** This question appeared to be equally challenging for candidates. Common errors included names without the lowest possible numbering. The methyl group was given on the top which could have influenced candidates to start counting from there – more practice is needed to help with naming simple aromatics. Other common errors included:1-ethyl-2,4-methylbenzene (missing di-) and 1-ethyl-2,3-dimethylbenzene (miss counting groups).
			Total	**1**	
4	a	i	**ALLOW correct Kekulé representation of benzene throughout question 21** An electron pair acceptor ✓	1	**ALLOW** gains an electron pair / lone pair **Examiner's Comments** Most candidates were able to give the correct definition here. A common error was omission of 'pair' of electrons. Manyalso described that electrophiles are 'species attracted to areas of high electron density'or words to that effect, either alongside the accepted definition gaining credit or as the sole definition not gaining a mark.

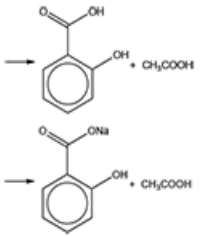
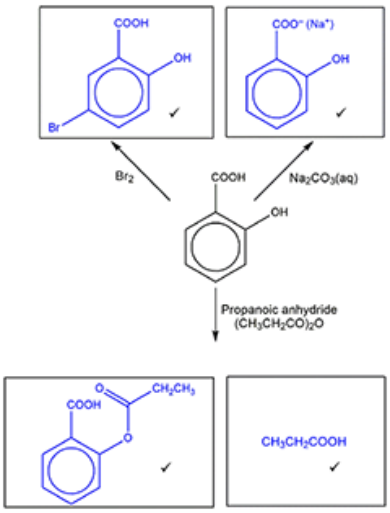
		ii	**Generation of electrophile** $AlCl_3 + CH_3CH_2Cl \rightarrow CH_3CH_2^+ + AlCl_4^-$ ✓ **Electrophilic substitution**  Curly arrow from π-bond to $^+CH_2CH^3$ ✓ ---  Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring **AND** H^+ as product ✓ **Regeneration of catalyst** $H^+ + AlCl_4^- \rightarrow AlCl^3 + HCl$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_2H_5Cl **AND** $C_2H_5^+$ **ALLOW** positive charge anywhere on CH_2CH_3 e.g. $CH_2CH_3^+$ **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 AND** • go to anywhere on $^+CH_2CH^3$  **DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure **AND** 'horseshoe' the right way, *i.e.* gap towards C with CH_2CH_3 **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **Examiner's Comments** Most candidates were well prepared for this question, with over half of candidates gaining all 5 marks. A significant number of candidates showed halogenation, generating Cl^+ as an electrophile, instead ofalkylation. Others attempted to substitute the ethylbenzene ring rather than benzene. Further commonerrors included incorrect connectivity in the ethyl group on the intermediate, curly arrows coming fromhydrogen atoms rather than C-H bond to reform the π-ring and omission of an H^+ ion at the end ofmechanism.

	b	i	 ✓ ✓ ✓	3	**IGNORE** additional copies of the same structures **IGNORE** connectivity to CN and $NHCOCH_3$ in products. **IGNORE** HCl / H^+ **IGNORE** multisubstituted products **ALLOW** protonation of $NHCOCH_3$ group i.e. $NH_2^+COCH_3$ **ALLOW ECF** small slips on $NHCOCH_3$ e.g. extra O or missing 3 on CH_3 **Examiner's Comments** Most candidates were able to correctly recognise the correct direction for substitution, with over half gaining all 3 marks. Marks were most often lost for giving multiple substitution products despite being asked for the monosubstituted products. Many unnecessarily drew the same structures but with differentorientations i.e. substituting on carbon-3 of a ring is the same as substituting on carbon-5. **Misconception** Ensure students understand the term 'monosubstituted' and practise naming compounds to give the lowest possible numbering. This will also help them to recognise the equivalent structures.
		ii	 Correct organic product ✓ Correct balanced equation ✓	2	**ALLOW** any trichlorophenyl amine structure **ALLOW** $C_6H_2Cl_3NH_2$ **OR** $C_6H_4Cl_3N$ (allow elements in any order) for correct organic product **IGNORE** incorrect structural or molecular formula **IF** correct structure is drawn **ALLOW** ammonium salt of trichloro product $C_6H_2NH_3Cl_4$ **ALLOW** multiples for balanced equation **ALLOW** 1 mark for use of Br_2 with a correctly balanced equation **Examiner's Comments**

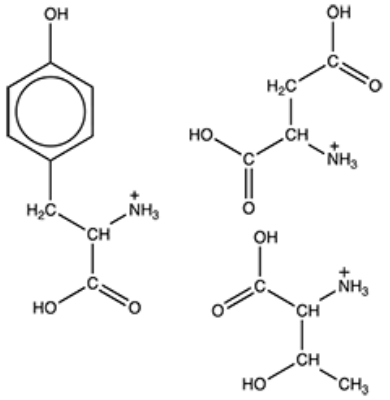
					The majority of candidates were able to give a suitable tri-substituted product, with many showing the structure although not asked for in the question. Many were also able to give a correct balancedequation too. Some were unsure how phenylamine would react showing the reaction with the aminegroup or only giving a monosubstituted product. Some didn't form HC*l* as another product, reacting phenyl amine with 1.5 Cl_2 instead. Others gave hydrogen as the product.
		iii	(In phenylamine) a (lone) pair of electrons on N is (partially) delocalised / donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenylamine is) **more** susceptible to electrophilic attack **OR** (phenylamine) attracts/accepts electrophile/Cl_2 **more** **OR** (phenylamine) polarises electrophile/Cl_2 **more** ✓ **ORA**	3	Must be clear that electrons come from N not just NH_2 **ALLOW** the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring **ALLOW** diagram to show movement of lone pair into ring from N **ALLOW** lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring **ALLOW** lone pair on N (i.e. no reference to electrons) **ALLOW** π-bond instead of π-system / ring **DO NOT ALLOW** (two) lone pair**s** are delocalised/donated into the π-system / ring **Responses must be comparative for 2nd and 3rd marking point.** **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenylamines react more readily with electrophiles/Cl_2 (*given in question*) **ALLOW** Cl^+ for electrophile **IGNORE** Cl for electrophile **ALLOW** Benzene can't polarise electrophile/Cl_2 but phenylamine can (polarise electrophile/Cl_2) **Examiner's Comments** Similar questions have been seen previously and many candidates were able to give clear and concise responses. The first marking point was the most frequently lost as although many described $-NH_2$ aselectron donating, they were not able to fully explain its role. Some understood that a lone pair wasdonated into the π-ring but did not specify that the lone pair was on the nitrogen. Other marks were lostby not making comparison to benzene,

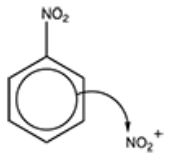
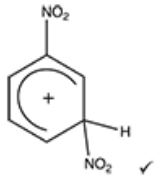
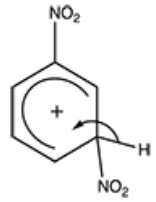
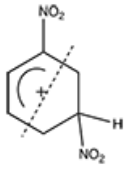
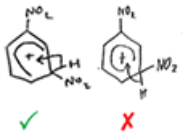
					e.g. high electron density, polarises Cl_2. Some repeated theinformation from the question regarding phenylamine being more reactive with electrophiles but notexplaining why. Lower attaining candidates often described the structure of the benzene ring or referredto phenylamine being more electronegative.
			Total	**14**	
5		i	 **Reaction apparatus (Labels NOT required)** flask **AND** upright condenser **AND** open system at top ✓ *(Could be labelled)* **Labels AND direction of water flow** Pear-shaped/round-bottom flask **AND** condenser **AND** water in at bottom and out at top ✓ Heat **NOT** required **DO NOT ALLOW** flask, conical flask, volumetric flask **DO NOT ALLOW** thermometer **DO NOT ALLOW** condensing tube as label	2 (AO 3.3 ×2)	For open system, **DO NOT ALLOW**  **For open system, ALLOW** label. e.g. ‘open at top’  **ALLOW** line across flask   **ALLOW small** gap between flask and condenser **BOD**, e.g.

					 **If in doubt, ask Team Leader** **Examiner's Comments** Most candidates drew a diagram that looked like a vertical condenser above a flask. The quality of the diagrams was not very good. Candidates then needed to label their diagram. Errors included a bung or thermometer inserted at the top of the condenser and water flowing the wrong way in the condenser. For labelling, candidates were expected to use scientific terminology. Responses such as 'condensation tube' and vague terms such as 'flask' were not credited. These labels were often omitted. A significant number drew a set up for distillation instead of reflux.
		ii	 Organic products ✓ ✓ ***2 marks*** 3NaOH AND $2H_2O$ ✓ ***1 mark*** NOTE: ALLOW O^-Na^+ for ONa throughout **SCROLL DOWN FOR PRODUCTS**	3 (AO 2.6 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** annotations of provided structure of aspirin at top left **ALLOW** equation with 3OH– **OR** 3NaOH giving anions for organic products, i.e.  **OR**  **ALLOW** 1 of the 2 organic products mark for BOTH structures as COOH and OH (or mixture) e.g

					 **Examiner's Comments** This question was the hardest part of Question 5 and about half the candidates were not given any marks. Some drew the sodium carboxylate salt of aspirin structure, leaving the ester link intact. A large number of candidates realised that the ester would be hydrolysed. Sometimes the sodium salts were often not shown and, even they were shown, the phenol group was often shown intact. The hardest mark was the formation of $2H_2O$ and a large number of candidates showed the more intuitive but incorrect '$3H_2O$' instead.
			Total	**5**	
6				4 (AO2.5 ×4)	**IGNORE** connectivity of phenol OH group and COOH group throughout *(marks are for correct conversions)* **Br_2** **ALLOW** Br substitution at any position on ring **ALLOW** up to 4 Br atoms onto ring **Na_2CO_3** **ALLOW** COO^- **OR** COONa **$(CH_3CH_2CO)_2O$** **IGNORE** reaction of COOH to form an acid anhydride

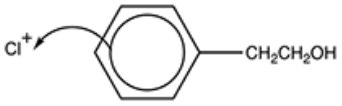
					ALLOW structures in bottom 2 boxes in either order **Examiner's Comments** Overall, this question discriminated well with most candidates gaining some credit. Most candidates were able to suggest a correct product for the reaction of salicylic acid with bromine, with just a few candidates replacing the OH group with a Br atom. Most candidates recognised that the carboxylate salt would be produced from the reaction with Na_2CO_3 but not all were able to recall that the phenolic OH group is too weak acid to react. Some missed an O on carboxylate i.e. -CO-Na^+. Some added Na or CO_3 directly to the ring. The reaction with the anhydride proved much more challenging. All sorts of weird and wonderful structures of the main 'ester' product were given including joining the CH_3 group of propanoic anhydride to the O of the phenol group. Some used the bottom two boxes to form esters with the COOH and OH groups in turn. Many did not identify propanoic acid as a by-product even if they had correctly identified the ester product. Water was a common incorrect product. Marks were also occasionally lost for missing the benzene ring on structures or missing the -OH or -COOH groups that were left unreacted.
			Total	**4**	
7		i	16 ✓	1 (AO2.6)	**Examiner's Comments** This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many identified the four chiral centres in compound E, often labelling these with an asterisk. However, only a small proportion were able to predict that there would be 16 possible optical isomers. Most provided an answer of four corresponding to the number of chiral centres or eight considering that each chiral centre would result in two optical isomers. They struggled to see that they needed 2^n in this case where n represents the number of chiral centres. Candidates have probably seen very few, if any, examples of chiral compounds with more than two chiral centres.

		ii	 **1 mark** for each **correct** structure with • **Either** NH_3^+ **OR** NH_2 ✓✓✓ **1 mark** for • **all 3 correct** structures with NH_3^+ ✓	4 (AO2.5 ×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity **ALLOW** + charge on H of NH_3 group, i.e. NH_3^+ If structures are shown with NH_3 groups (without the + charge) **OR** as NH_2^+ groups allow **ECF** for subsequent use. **ALLOW** structures shown as correctly balanced salts, e.g NH_3Cl **OR** $NH_3^+Cl^-$ all marks can be awarded. **Examiner's Comments** A significant number of candidates did not attempt this question despite similar questions appearing in previous exam series. However, approximately a quarter of candidates scored all 4 marks. Some lost the final mark for not protonating the amine groups as required as under acidic conditions. A very common error was to hydrolyse the amides to give acyl chlorides or even aldehydes rather than carboxylic acids. Lower scoring candidates often had incomplete hydrolysis or no hydrolysis at all with just changes to acid/amine/phenol functional groups, e.g. protonation of amine to form salts or swapping or OH groups for Cl. Candidates need to check their answers carefully for missing or extra Hs as this lost marks. It was much easier to mark candidates' work presented with structures with a similar arrangement to compound E.
			Total	**5**	
8			**Role of H_2SO_4 catalyst 2 marks** *Forming electrophile* $HNO_3 + H_2SO_4 \rightarrow H_2O + HSO_4^- + NO_2^+$ ✓ *Reforming catalyst*	5 (AO1.2) (AO1.2) (AO1.2) (AO2.5) (AO1.2)	**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^+

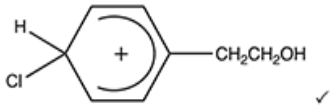
			$H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓ **Electrophilic attack 1 mark** Curly arrow from π-bond to NO_2^+ ✓  --- **Correct intermediate 1 mark**  --- **Reforming benzene ring 1 mark** Curly arrow from C–H bond to reform π-ring ✓  **Curly arrow** must start from, **OR** be traced back to, **any part of** C–H bond and go inside the 'hexagon'		**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** **AND** • go to anywhere on NO_2+  **DO NOT ALLOW** mark for intermediate if additional NO_2 is missing **IGNORE** connectivity to NO_2 groups *(mark is for correct substitution position and position of* π-ring*)* **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 and H  **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **Examiner's Comments** Many candidates knew this mechanism well with the majority gaining 4 or 5 marks here. The mark most frequently lost was for the incorrect drawing of the intermediate. Many candidates did not

					appreciate that two electrons are removed from the π ring in the first stage of the mechanism resulting in the partial delocalisation of electron density across four sides of the benzene ring in the intermediate. In addition, it must have the correct orientation with the opening at the three position where the nitro group is added. Some candidates nitrated the 2 or 4 position instead. Some also showed nitration of benzene then the second nitration. Other common errors included missing or extra charges, missing NO_2 group on intermediate, use of NO_3^+ or other incorrect electrophiles. Lower scoring responses were characterised by unclear diagrams and inaccurate use of curly arrows. Many were often able to score 1 mark for showing C-H bond on benzene ring breaking and electrons going back into the ring. Such responses often included errors in the equations showing the role of the sulfuric acid catalyst, e.g. formation of $H_3SO_4^-$, or omitted these steps entirely. Others evidently didn't know what a nitro group was with $-NO_3$ giving just -N and even $-NH_3$ instead. **Assessment for learning** Encourage candidates to look at more recent mark schemes to check for tips on how to correctly draw out mechanisms. An easy tip for ensuring the correct intermediate for electrophilic substitution is to place a dot inside the ring for each C without the new substituent attached and then connect the dots. Only four out of the six sides should be covered by the broken delocalised π ring (as two electrons have formed the new bond). Alternatively, some find it easier to redraw, so horseshoe ring opens upwards (like a smiley face), rather than at an angle.
			Total	**5**	
9			**A**	1 (AO1.2)	**Examiner's Comments** Fewer than a third of candidates gave the correct response, A. Most identified that compounds 1 and 2 contain a bond angle of approximately 120° and consequentially selected option B. Only the most able candidates were able to apply their understanding of shapes to deduce that the carbocation would also exhibit trigonal planar geometry.

			Total	**1**	
10			**B**	1 (AO1.1)	**Examiner's Comments** The answer to this question was generally well known. The most common incorrect response was A.
			Total	**1**	
11	a	i	Indicator **AND** observation of acidity **AND** No reaction with carbonate ✓	1 (AO1.2×1)	**ALLOW** (Add) bromine **AND** white precipitate ✓ **ALLOW** (Add) $FeCl_3$ **AND** violet/purple colour ✓
		ii	Compound **J** has **6** peaks/environments/types of carbon ✓ Compound **K** has **5** peaks/environments/types of carbon ✓ Compound **L** has **8** peaks/environments/types of carbon ✓	3 (AO3.2×3)	**IGNORE** any numbers shown on structures **IGNORE** chemical shifts
		iii	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Action of catalyst 1 mark** Formation of electrophile: $Cl_2 + AlCl_3 \rightarrow Cl^+ + AlCl_4^-$ **AND** Regeneration of catalyst: $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓ **----------** **Electrophilic attack 1 mark** Curly arrow from π-bond to Cl^+ ✓	4 (AO1.2×2) (AO2.5×2)	**ALLOW** use of $FeCl_3$ or other halogen carriers ($AlBr_3$) **----------** **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** ---------- **1st curly arrow** must • start from, **OR** close to **circle of benzene ring**

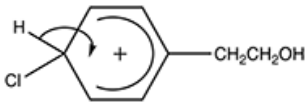


Correct intermediate only 1 mark



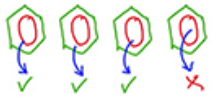
Reforming benzene ring 1 mark

Curly arrow from C–H bond to reform π-ring ✓

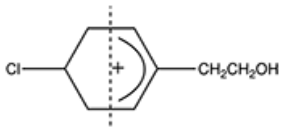


AND

• go to Cl^+



DO NOT ALLOW the following intermediate:

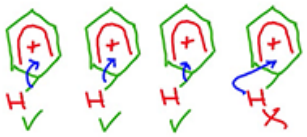


π-ring must cover more than half of benzene ring
AND
correct orientation, *i.e.* gap towards C with Cl

ALLOW + sign anywhere inside the 'hexagon' of intermediate

DO NOT ALLOW intermediates substituted at positions 3 or 5
IGNORE intermediates substituted at position 2
OR di-substituted at positions 2,4

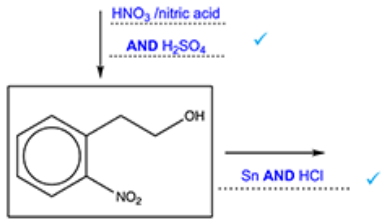
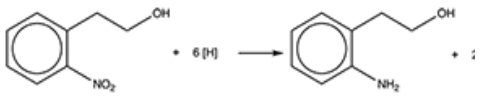
Curly arrow must start from, **OR** be traced back to, **any part of** C–H bond and go inside the 'hexagon'



Examiner's Comments

Few candidates knew the test for a phenol group. Frequent incorrect responses involved the production of a gas with a carbonate or stating that bromine water is decolourised but failing to state that a white precipitate is also formed. A significant number of candidates also stated that the reaction with sodium hydroxide confirms the presence of the phenol group.

					This question proved challenging to candidates with few scoring all 3 marks. Where no marks were given, this was frequently because candidates did not state the number of carbon environments in compounds J, K and L. Candidates who were given 1 or two marks frequently stated the incorrect number of peaks that would be observed. This question required candidates to apply their knowledge of the mechanism of electrophilic substitution. Examiners were encouraged by the number of excellent responses to this question, with the majority of candidates securing 3 out of 4 marks. Common errors included the omission of HCl as product from the regeneration of the catalyst or candidates attempting to substitute at the 2 position.
	b		(In phenols) a (lone) pair of electrons on O is (partially) **delocalised/donated** into the ring / π-system ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenols) are more susceptible to electrophilic attack **OR** (phenols) attract/accept electrophile/Cl_2 more **OR** (phenols) polarise electrophile/Cl_2 more ✓ **ORA**	3 (AO1.1 × 3)	**ALLOW** the electron pair in the p-orbitals of the atom becomes part of the ring / π-system **ALLOW** diagram to show movement of lone pair into ring **ALLOW** lone pair of electrons on O is (partially) drawn/attracted/pulled/ into ring / π-system **ALLOW** lone pair on O **DO NOT ALLOW** (two) lone pair**s** are delocalised/donated into the ring / π-system **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenols react more readily with electrophiles/Cl_2 (*given in question*) **ALLOW** Cl^+ for electrophile **IGNORE** Cl for electrophile **Examiner's Comments** The most able candidates scored well on what proved a difficult question for many. Although the vast majority of candidates knew about the reasons behind compounds K and L's increased reactivity many were unable to express themselves clearly to gain credit. Often answers lacked the specific detail about the lone pair on the oxygen atom in the –OH group being delocalised into the ring. Less

					successful answers discussed electrons being supplied to the ring, the -OH group providing the electrons to the ring or just that –OH is an activator. More successful answers expressed the increase in electron density and the subsequent increase in compound K and L's susceptibility to electrophilic attack. Exemplar 3 The lone pair from the OH group becomes delocalised into the ring / π bond, which makes K and L more electron dense than), so they are more susceptible to electrophilic attack. This response correctly states that the electron density is higher which result in K and L being more susceptible to electrophilic attack and receives 2 marks. To score the third mark, the candidate needed to identify that that the lone pair is on the oxygen of the OH group.
	c	i		2 (AO1.2× 2)	**IGNORE** references to concentration **IGNORE** 'dilute' for HCl **IGNORE** H_2 **IGNORE** NaOH if seen as a reagent to convert nitro group into amine e.g 'Sn/(concentrated) HCl then NaOH' scores the mark
		ii		1 (AO2.6)	**Examiner's Comments** Candidates were familiar with the reagents required in these two reactions. The most able candidates were able to identify the use of 6[H] as the reducing agent and the production of 2 water molecules. Incorrect responses commonly included the use of HCl and $NaBH_4$ as a reactant.
			Total	**14**	
12			D	1 (AO1.2)	**ALLOW** 15 (correct number of sigma bonds)

					Examiner's Comments This question discriminated well, with higher ability candidates correctly identifying D. Often students overlooked the sigma bonds in the aromatic ring and selected B.
			Total	**1**	