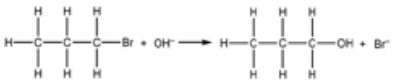
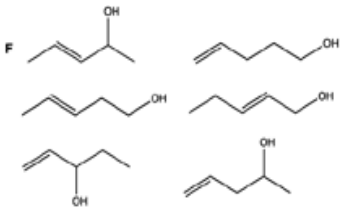
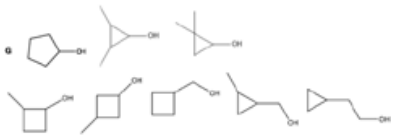
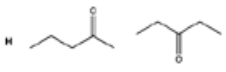
Mark scheme

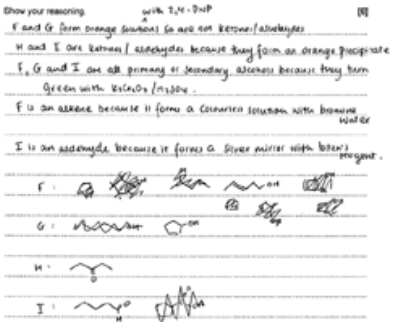
Question			Answer/Indicative content	Marks	Guidance
1	a	i	$R_f \sim \frac{1.4}{9.1}$ in cm **OR** $\frac{14}{91}$ in mm = **0.15** ✓ *Working required* ***Check for ~ 9.1 as denominator***  	1	**ALLOW** 0.12 - 0.18 (i.e. ±0.03) **DO NOT ALLOW** $\frac{1.4}{10.1} = 0.14$ ***10.1*** *measured from bottom of plate to solvent front*  **<u>Examiner's Comments</u>** Candidates are well versed with calculating an R_f value, with nearly all candidates obtaining a value in the acceptable range of 0.12-0.18.
		ii	 Correct balanced equation **ALLOW** OH- above the arrow **DO NOT ALLOW** if a **CON** reagent is present, e.g. an acid For OH- and Br- **ALLOW** KOH and KBr **OR** NaOH and NaBr **BUT DO NOT ALLOW** K-OH *implies covalent bond*	1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW Missing H atoms** **DO NOT ALLOW** H_2O and HBr *Question asks for **alkaline** hydrolysis* **DO NOT ALLOW** C_3H_7, i.e. C_3H_7Br **OR** C_3H_7OH *Structure asked for in Question* **IGNORE** connectivity, e.g. **ALLOW** | OH

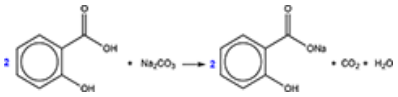
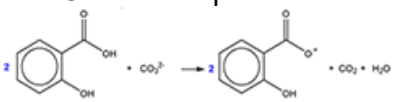
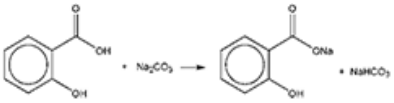
					BUT DO NOT ALLOW —HO **Examiner's Comments** This question was answered well by candidates, with most showing correct structures for the organic reactant and its product, propan-1-ol, and skeletal formulae mostly used. The question asked for an equation for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable answers would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given a mark, a common error for alkaline hydrolysis.
		iii	**Difference** propan-1-ol/product/bottom spot is smaller **OR** 1-chloropropane/reactant/top spot bigger ✓ **Reasons** propan-1-ol/product/bottom spot is smaller C-Cl bond is stronger than C-Br **AND** 1-chloropropane reacts slower/is less reactive ✓ **Use of propan-1-ol** shows **formation** of propan-1-ol **OR** shows when reaction has **finished** **OR** monitors **course/progress** of reaction ✓	3	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF and ORA throughout** **----------** **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide **DO NOT ALLOW** 1-chloropropane has larger bond enthalpy *C-Cl bond required* **IGNORE** 1-chloroproane has different R_f value **IGNORE** 'as a control' **OR** 'as a comparison' ..... with no further explanation **Examiner's Comments** This novel question assessed whether candidates realised why chemists used TLC when carrying out organic reactions. A good response would identify the following key features after 20 minutes:

					• The C-C*l* bond energy is greater than C-Br and so the reaction would be slower. • The haloalkane spot would be larger and the propan-1-ol spot smaller. • The propan-1-ol is spotted on the chromatogram to monitor the progress of the reaction. The question differentiated very well between candidates, but many did not seem to know where to start with many candidates not scoring any marks. This suggested that candidates recognised chromatography as a technique but did not appreciate its relevance in organic chemistry. Some candidates referred to pigments, recalling their early chromatography experiments in finding the colours in ink.
	b	i	Green solution Cr^{3+} **OR** $[Cr(H_2O)_6]^{3+}$ ✓ Orange solution $Cr_2O_7^{2-}$ ✓ Formulae **AND** charges must be correct	2	**Green solution** **IGNORE** H^+ **ALLOW** $Cr_2(SO_4)_3$ **OR** $CrCl_3$ **OR** Cr^{+3} Orange solution **IGNORE** H^+ **ALLOW** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **DO NOT ALLOW** Cr^{6+} **ALLOW** 1 mark for correct formulae but wrong way round **<u>Examiner's Comments</u>** Although high attaining candidates responded with the formulae of chromium-containing species, it was common to see organic compounds being suggested. Consequently, a large proportion of candidates did not score either of the 2 marks. Many candidates seem to expect to only give organic species in their

					responses on this paper and would benefit from understanding that inorganic species may also need to be provided.
		ii	**Level 3 (5-6 marks)** Reaches a comprehensive conclusion to determine possible correct structures for **ALL** of **F**, **G**, **H** and **I** **AND ALL** functional groups of **F**, **G**, **H** and **I** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Reaches a conclusion to determine possible **correct** structures for two of **F**, **G**, **H** and **I** **AND most** functional groups of **F**, **G**, **H** and **I** *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Reaches a simple conclusion to determine a possible correct structure for one of **F**, **G**, **H** and **I** **OR** some functional groups of **F**, **G**, **H** and **I** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	6	Indicative scientific points may include: **<u>Identity of F, G, H and I showing CORRECT structures</u>**  **ALLOW** enols for F, e.g.  For **G**, **DO NOT ALLOW** tertiary -OH. e.g.  For **G, DO NOT ALLOW** tertiary -OH. e.g.    **IGNORE** names, even if incorrect For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g.

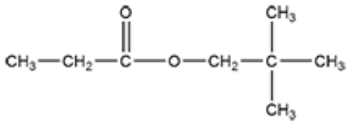
					2,4-DNP **H** and **I** have carbonyl group/aldehyde or ketone **$H^+/Cr_2O_7^{2-}$** **F**, **G** and **I** are primary or secondary alcohols or aldehydes **Bromine** **F** is unsaturated/has C=C **Tollens** **I** is aldehyde ***Correct functional groups may be shown in correct structures*** **Examiner's Comments** This Level of Response question was answered well with many candidates identifying compounds **F-I** correctly to reach Level 3. Structures were usually shown skeletally and this practice is to be recommended. Not only is it far quicker and clearer, it eliminates writing every atom in a displayed or structural formula. Some candidates were not given marks for missing hydrogen atoms or for 'sticks' being shown. In these structures, the chemical meaning of a stick is a terminal CH_3 group. Candidates were also asked to show how the results of the chemical tests helped the identification of the unknown compounds and this formed the basis of the communication strand of the LOR mark. Candidates answered this part of the analysis extremely well and most were given marks for their good communication skills. This question differentiated very well between well-prepared and less confident candidates. The latter often did not know how the results of these organic tests can be used to identify the functional groups present. It was common for such candidates to identify only one of the four compounds, scoring within Level 1 only.

					OCR Support To better prepare candidates, we recommend using either the digital multiple choice quizzes on Teach Cambridge or creating targeted practise materials using ExamBuilder. If you are unsure of how to access these or ways to make the most of them, get in touch via science@ocr.org.uk. Exemplar 3  This exemplar is concise and very clear. The candidate has clearly linked the result of each test to the functional groups that must be present. The candidate has drawn skeletal formulae and clearly has experimented with many possible structures before deciding on which must be correct. Notice that the candidate has crossed out the structures that they have rejected. This is an important exam technique - if two structures are drawn, with one correct and the other incorrect, the correct structure cannot be given marks. The response is clearly at Level 3 for the four correct structures and the good communication ensures that the communication strand can be given. This response received all 6 marks.
			Total	**13**	
2		i	**Reaction with H_2SO_4**	3	**ALLOW** multiples in both equations **IGNORE** state symbols

			$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓ **Reaction with excess G**  Correct organic product structure ✓ Correct balanced equation ✓		**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 $CO_2 + H_2O$ **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			**D**	1	**Examiner's Comments** Most correctly identified the colour of the precipitate as yellow, D. The most common incorrect response was brown, A, possibly linking to the colour of iodine.
			Total	**1**	
4			**C**	1	**Examiner's Comments** The majority of candidates were able to correctly identify the two functional groups and the correct corresponding test i.e. alkene using bromine water and primary alcohol using 2,4-dinitrophenylhydrazine. The most common incorrect response was B.
			Total	**1**	
5			**C**	1	**Examiner's Comments** More than half of candidates were able to give C as the correct answer recognising that Statements 2 and 3

					are correct. Some felt that Statement 1 was also correct giving A or B as the answer – relative peak area is not the same as the mass of 1 mole. Some were not able to relate the peak area to amount of compound present, so did not pick Statement 3 as one of the true statements, giving B or D.
			Total	**1**	
6			**Level 3 (5–6 marks)** Structure is either $CH_3CH_2COOCH_2C(CH_3)_3$ **OR** $(CH_3)_3CCH_2COOCH_2CH_3$ **AND** Most of the data analysed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Structure is an ester of $C_8H_{16}O_2$ with **some** key features present **AND** Analyses some of the data from at least 3 of the scientific points. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts analysis from at least 2 of the scientific points. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** No response or no response worthy of credit.	6 (AO1.2 × 2) (AO3.1 × 2) (AO3.2 × 2)	**Mark spectra page as SEEN** Indicative scientific points: **1. Empirical Formulae** • C : H : O = $\frac{66.63}{12.0} : \frac{11.18}{1.0} : \frac{22.19}{16.0}$ = 5.55 : 11.18 : 1.39 = 4 : 8 : 1 • Empirical formula = C_4H_8O **2. Molecular Formulae** • uses *m/z* = 144.0 to determine molecular formula as $C_8H_{16}O_2$ **3. Functional group** From IR, • → C=O from ~1740 cm^{-1} **IGNORE** references to C–O peaks No reaction with 2,4-DNP • → no carbonyl/no ketone and aldehyde • Likely to be an ester **4.** ^{1}H NMR analysis • δ = 0.9 ppm, singlet, 9H – $C(\mathbf{CH_3})_3$ • δ = 1.2 ppm, triplet, 3H $\mathbf{CH_3}CH_2$– • δ = 2.2 ppm, quartet, 2H $CH_3\mathbf{CH_2}CO$ • δ = 4.1 ppm, singlet, 2H – $\mathbf{OCH_2}$– **ALLOW** approximate values for

					chemical shifts. **Structure** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Key features consistent with chemical shift data and relative peak areas** • $O\text{-}CH_2$ • $C(CH_3)_3$ • $CH_3CH_2C{=}O$ **Correct Structure** • $CH_3CH_2COOCH_2C(CH_3)_3$  **Examiner's Comments** Most candidates were able to deduce the empirical and/or molecular formula of the organic compound. Analysis of the IR spectrum was also well attempted, but some candidates assumed the unknown was a carboxylic acid, attributing the sharp peak just below 3000 cm^{-1} to an OH group. Others misidentified the C=O peak as a C=C group suggesting alkene or arene structure. They were often led to this conclusion as they believed no precipitate with 2,4-DNP suggested no C=O rather than no aldehyde or ketone. Good analysis of the NMR data was crucial for deducing the correct ester. Some candidates opted to annotate the proton NMR spectrum, some produced tables and others gave

					written details for each peak. It was vital that they were able to interpret all information for each peak i.e. number of proton environments, the type of environment from chemical shift, the number of protons in each environment from relative peak areas and use of splitting patterns to find information about adjacent protons. Many tried to make the data fit their proposed structure rather than the other way round. Some suggested structures that were only partially consistent with the data such as $CH_3CH_2CH_2COOC(CH_3)_3$ and were awarded Level 2. Others did not take full note of all the information provided, for example omitting the 2,4-DNP observations, giving the ketone $(CH_3)_3COCH_2COCH_2CH_3$ or not checking it matched the molecular formula $CH_3CH_2COOC(CH_3)_3$ so only achieved Level 1. Candidates need to be encouraged to draw a structure as without they can only achieve a maximum of 2 marks despite some excellent analysis of the data. Conversely, it is not sufficient to just give a structure, candidates must give analysis of the data provided. Exemplar 3  (continues on back page)

					This is a good Level 3 6 mark response. As well as this clearly laid out analysis they also had details written on the question, e.g. no aldehyde or ketone due to no reaction with 2,4-DNP. This response has been selected due to the detailed analysis of NMR data that has been summarised in a table.
			Total	**6**	
7		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: $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓	4 (AO1.2×2) (AO2.5×2)	**ALLOW** use of $FeCl_3$ or other halogen carriers ($AlBr_3$) ----------

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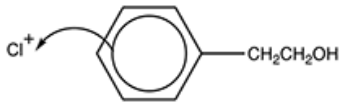
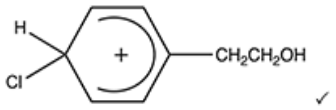
Electrophilic attack 1 mark

Curly arrow from π-bond to Cl^+ ✓

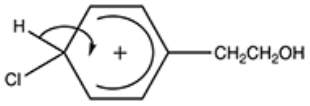


Correct intermediate only 1 mark



Reforming benzene ring 1 mark

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



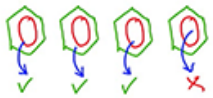
For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):

1st curly arrow must

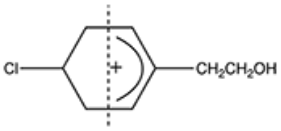
• start from, **OR** close to **circle of benzene ring**

AND

• go to Cl^+



DO NOT ALLOW the following intermediate:

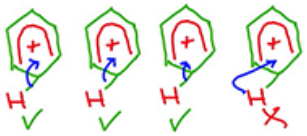


π-ring must cover more than half of benzene ring
AND
correct orientation, *i.e.* gap towards C with Cl

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.
			Total	**8**	