Mark scheme

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>a</td><td></td><td>$C_5H_{12}O^+$ 7½ $O_2 \rightarrow$ 5 CO_2 + 6 H_2O

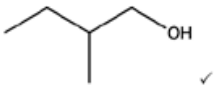
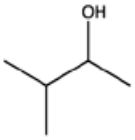
CO_2 AND H_2O products ✓

Complete equation balanced ✓</td><td>2</td><td>ALLOW multiples
e.g. 2 $C_5H_{12}O$ + 15 $O_2 \rightarrow$ 10 CO_2 + 12 H_2O

Watch for 15/2 OR 7.5 for 7½

<u>Examiner's Comments</u>

Most candidates identified the correct products of this combustion as CO_2 and H_2O. The second mark was available for a balanced equation but many balanced O_2 with an 8 rather than with 7½.

Candidates need to be very careful when writing equations for the combustion of alcohols as it is easy to miss the O atom within the alcohol formula.</td></tr>
<tr><td></td><td>b</td><td></td><td><table><tr><th>Alcohol</th><th>Structure</th></tr><tr><td>A</td><td>  ✓</td></tr><tr><td>B</td><td>  ✓</td></tr><tr><td>C</td><td>  ✓</td></tr></table></td><td>3</td><td>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

DO NOT ALLOW structure if H(s) are missing from ONE structural formula ..... BUT ALLOW any further omissions as ECF

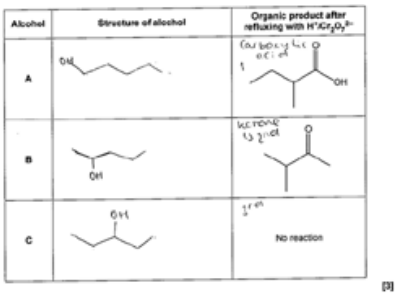
Take care with numbers of carbons, the branches and the position of branching .... especially for C

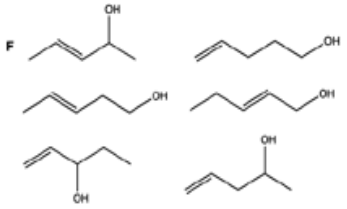
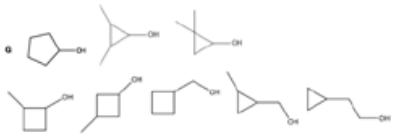
IGNORE connectivity,
e.g.
ALLOW 

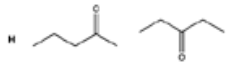
BUT DO NOT ALLOW −HO

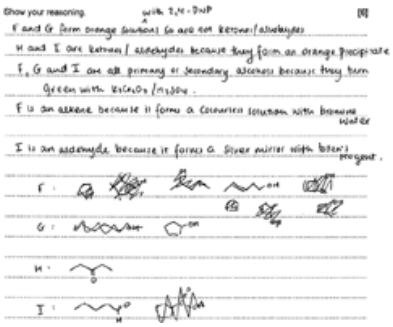
<u>Examiner's Comments</u>

This question appeared to be straightforward, but many candidates got into a muddle when drawing the alcohol structures. The best tactic is to copy the carbon skeletal and to then add the functional group.</td></tr>
</table>

					Many candidates drew displayed formulae and these often contained too many carbon atoms or missing H atoms. Great care is needed in drawing organic structures. Exemplar 3  [3] Exemplar 3 provides some useful lessons. The candidate draws their structures skeletally, but the skeletons do not match the product. Structure C must be a tertiary alcohol, but the candidate has drawn the structure of a secondary alcohol. It should be noted that, even with a correct carbon skeleton, structure A would be rejected. Incorrect connectivity of the OH group is always penalised.
			Total	**5**	
2		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 **Examiner's Comments** 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.*	6	Indicative scientific points may include: **Identity of F, G, H and I showing CORRECT structures**  **ALLOW** enols for F, e.g.  For **G**, **DO NOT ALLOW** tertiary -OH. e.g.  For **G, DO NOT ALLOW** tertiary -OH. e.g. 

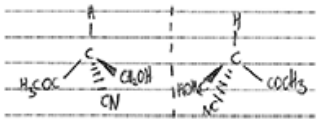
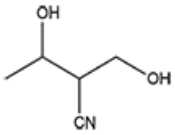
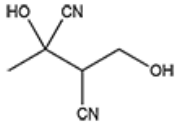
			0 marks *No response or no response worthy of credit.*		  **IGNORE** names, even if incorrect For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g. **2,4-DNP** **H** and **I** have carbonyl group/aldehyde or ketone **$H^+/Cr_2O_7^{2-}$** **F**, **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

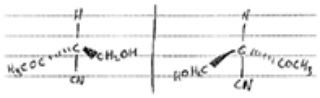
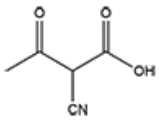
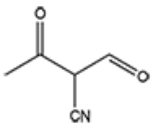
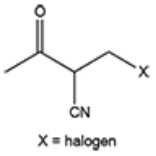
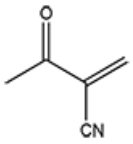
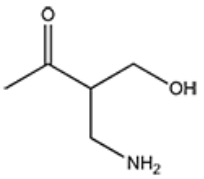
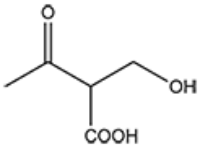
					skills. This question differentiated very well between well-prepared and less confident candidates. The latter often did not know how the results of these organic tests can be used to identify the functional groups present. It was common for such candidates to identify only one of the four compounds, 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	**8**	
3	a		**Reagent and/or catalyst:** H_2SO_4 **OR** H_3PO_4 **OR** H^+ **OR** acid (catalyst) ✓ **Organic product: (mark independently)** $CH_3CH_2CHCH_2$ ✓	2	**DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid as can be used for substitution reaction **DO NOT ALLOW** other additional reagents e.g. H_2O / steam, H_2 / hydrogen **ALLOW** suitable non-specification alternatives e.g. Al_2O_3 **OR** Pumice stone **ALLOW** names of reagents e.g. sulfuric or phosphoric acid, if no formulae given **IGNORE** concentration e.g. dilute/concentrated **IGNORE** (aq) state symbol **IGNORE** conditions e.g. temperature/pressure/reflux **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept but-1-ene **Examiner's Comments** More than half scored both marks here. Common reasons for losing marks included adding water or steam as a reagent, using an incorrect chain length (5 carbons not 4 carbons), missing or adding hydrogens on the structure, e.g. $CH_3CH_2CH_2{=}CH_2$ or giving butane as the product. **OCR support** Useful synthetic route maps for the

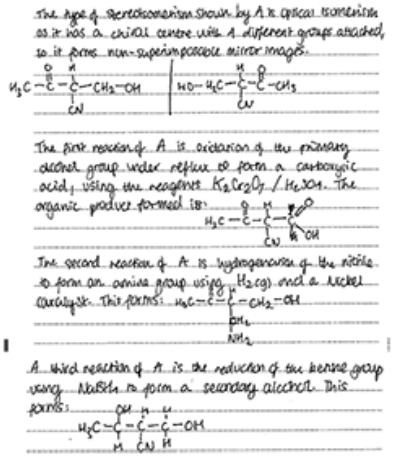
					whole specification, both with and without reagents, can be found on Teach Cambridge.
	b		**Reagent and/or catalyst:** $K_2Cr_2O_7$ **AND** H_2SO_4 **OR** $Cr_2O_7^{2-}/H^+$ ✓ **Organic product: (mark independently)** $CH_3CH_2COCH_3$ ✓	2	**ALLOW** $Na_2Cr_2O_7$ for $K_2Cr_2O_7$ **ALLOW** names for reagents e.g. acidified dichromate, if no formulae given **IGNORE** Roman numerals e.g. (VI), unless incorrect **IGNORE** [O] **DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid **DO NOT ALLOW** other additional reagents e.g. H_2O, steam **ALLOW** suitable non-specification alternative oxidising agents e.g. $KMnO_4/H^+$ **OR** CrO_3/H^+ **OR** H_2CrO_4 (chromic acid) **IGNORE** concentration e.g. dilute/concentrated **IGNORE** conditions e.g. reflux/distillation **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept butanone **Examiner's Comments** This was the most well-known out of the four reactions with more than three quarters of candidates getting both marks. The most common errors included omission of acid catalyst or adding an extra hydrogen on the carbonyl carbon of C=O. Candidates should be reminded to count the number of bonds around each carbon before moving on. A few attempted to oxidise this secondary alcohol to form a carboxylic acid.
	c		**Mark organic product first:** $(CH_3)_2CHCH_2X$ where X is identified as Cl, Br, I ✓ **Reagent and/or catalyst:** Reagent to match organic product	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept 1-halo-2-methylpropane, where halo is chloro, bromo or iodo (ignore alphabetical order for prefixes) **For 2 marks**, the reagent must be

			NaX / KX / X^- **AND** H_2SO_4 / H^+ / acid Where X is identified as Cl, Br, I ✓		consistent with the product given e.g. $(CH_3)_2CHCH_2Cl$ then correct reagent is NaCl / H_2SO_4 **ALLOW** 1 mark if correct reagents given but no or incorrect organic product shown **ALLOW** 1 mark if organic product is given with X i.e. $(CH_3)_2CHCH_2X$ **AND** reagent is consistent e.g. NaX / H^+ **OR** just states 'halide with acid' **ALLOW** HX where X is identified as Cl, Br, I **ALLOW** names of reagents e.g. sodium bromide and sulfuric acid, if no formulae given **DO NOT ALLOW** other additional reagents e.g. $AlCl_3$ **ALLOW** suitable non-specification alternative e.g. PCl_3, PCl_5, (red) phosphorus **AND** bromine **OR** iodine, $SOCl_2$ **IGNORE** concentration e.g. dilute/concentrated **IGNORE** conditions e.g. reflux/distillation **Examiner's Comments** Generally well-answered with very few gaining no marks. Some lost marks for correctly giving sodium halide but forgetting the acid. Some gave the halogen rather than the halide. A few added an additional CH_2 to structure. Some attempted to substitute directly with cyanide to give a nitrile product, e.g. $(CH_3)_2CHCH_2CN$.
			Total	**6**	
4			**D**	1	**Examiner's Comments** Most were able to correctly calculate the moles of alcohol using the mass

					and M_r provided and then multiply by 24 dm^3 mol^{-1} to give the correct answer D. All other distractors were seen as incorrect responses from calculations involving the incorrect molar ratio.
			Total	**1**	
5			**Level 3 (5–6 marks)** Suggests **ALL** of the following • Reagents and conditions for **3** functional groups • Products for **3** functional groups • Optical isomerism with description and 3D optical isomers shown *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)** Suggests **two** of the following • Reagents and conditions for **2** functional groups • Products for **2** functional groups • Optical isomerism with description **OR** an attempt to show 3D optical isomers *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)** Suggests **two** of the following • Reagents and conditions for **1** functional group • Products for **1** functional group • Identifies optical isomerism with description **OR** an attempt to show 3D optical isomers *There is an attempt at a logical structure with a line of reasoning.*	6 (AO 3.1 ×3) (AO 3.2 ×3)	**CHECK TOP OF QUESTION FOR RESPONSES** --- *Indicative scientific points may include:* **Stereoisomerism** • Optical isomerism identified with description: e.g. chiral centre /non-superimposable mirror images • 3D Optical isomers drawn, e.g.  *Description is subsumed in 3D diagrams* **Reactions of ketone/carbonyl e.g.** $NaBH_4$  HCN **OR** CN^-/H^+ (e.g. $NaCN/H^+$)  **Reactions of –OH, e.g.** $H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$

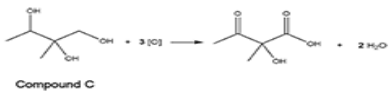
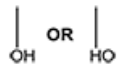
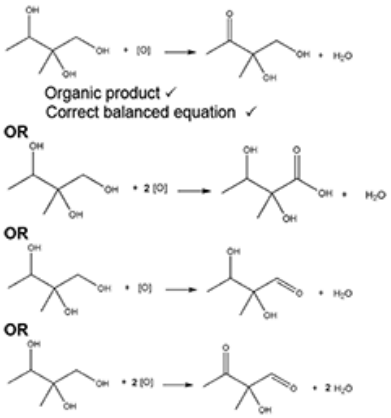
			The information is in the most part relevant. **0 mark** *No response or no response worthy of credit.* **Key points to check** *CHECK TOP OF QUESTION for responses* *IGNORE CONNECTIVITY* *in 3D isomer structures* • *IGNORE bond angles* • *Wedges needed* • *ALLOW*  Some responses will not fit into this exact pattern and a best-fit match may be needed **Clear communication** Focus on • Clear diagrams of 3D optical isomers • Diagrams of unambiguour structures • Reagents and functional group formed are linked • Communication is more a general feel for the quality of theresponses. **Slips and minor errors in structures** • Do not penalise the odd slip or omission, e.g. An extra C in a chain; a C short in a chain, C shown instead of CH_2 or skeletal • You need to judge the extent of any slip based on the whole response. Remember that each candidate		reflux  $H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ distil  NaBr/KBr/Br^- **AND** acid/H^+ **OR** HBr  Acid/H^+ (catalyst) (e.g. H_2SO_4)  **Reactions of C–CN, e.g.** H_2 **AND** metal catalyst e.g. Ni, Pt, Pd  H^+/H_2O e.g. HCl(aq) or H_2SO_4(aq) 

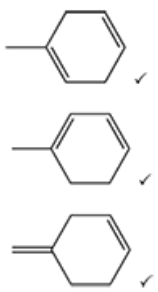
					OTHER REAGENTS, CONDITIONS AND PRODUCTS **e.g. $LiAlH_4$ as reagent** **Check with Team Leader** **<u>Examiner's Comments</u>** Overall, candidates performed well when answering this question. They were required to identify that compound **A** shows optical isomerism and to choose a reaction for each of the three functional groups. Candidates were also expected to use structures for the organic products. To achieve the highest level of response, a description of optical isomerism should be accompanied by 3D diagrams of the optical isomers. Optical isomerism was usually identified, with associated diagrams with almost all candidates identifying the chiral centre. Most attempted 3D diagrams but candidates do need to take care that the groups attached to the chiral C atom are those in compound A and that no parts of chains are omitted. Optical isomers do also require use bold and dashed wedges to be used. Most candidates showed good knowledge and understanding of reactions for the three functional groups. • For the primary alcohol, most chose $H^+/Cr_2O_7^{2-}$, with distil (→ aldehyde) or reflux (→ carboxylic acid); a significant number chose a concentrated acid (→ alkene) or Br–-/H+ (→ haloalkane) • For the ketone, most chose $NaBH_4$ (→ secondary alcohol)

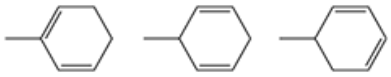
					• For the nitrile, most chose either H_2/Ni (→ amine) or H^+(aq) (→ carboxylic acid). Clear diagrams of the products were usually seen although many omitted a CH_2 from the amine branch for hydrolysis of the nitrile or an extra CH_2 in the aldehyde or carboxylic acid branch from oxidation of the primary alcohol. Some candidates chose 2,4-DNP for a reaction of the ketone and treated the question as one requiring tests, and then proving that the compound was a ketone from no reaction with Tollens' reagent. The question asked for the organic product and the 2,4-DNP product is beyond the demands of this specification (although this was seen very rarely). Candidates adopting this reaction were limiting the extent of their response and candidate should have considered this requirement before selecting 2.4-DNP. Exemplar 2  This exemplar shows a good response that lacks 3D diagrams for the optical isomers. The candidate has clearly given reagents and conditions and has shown the organic products. In the response, you can see that the candidate initially showed an extra CH_2 in the –COOH branch,

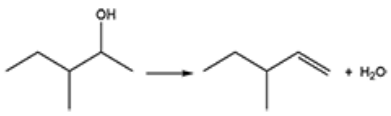
					and a mistake in the amine branch. The absence of 3D structures limits the response to Level 2 and 4 marks have been awarded for choosing correct and relevant reagents and conditions, and for the clear communication of the structures.
			Total	**6**	
6			**Correct structural isomers of C_3H_8O** *1 mark* $CH_3CH_2CH_2OH$ **AND** $CH_3CHOHCH_3$ ✓ **Reaction conditions** *1 mark* Distillation for aldehyde **AND** reflux for carboxylic acid **OR** ketone ✓ **Functional group of organic product** *2 marks* $CH_3CH_2CH_2OH$ → aldehyde **OR** → carboxylic acid ✓ $CH_3CHOHCH_3$ → ketone ✓ **One correct equation** *1 mark* $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ **OR** $CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ **OR** $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		**ANNOTATE WITH TICKS AND CROSSES** **Throughout,** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IF functional group is NOT given,** **ALLOW** propanal / RCHO **ALLOW** propanoic acid / RCOOH **ALLOW**propanone / ..... RCOR **IGNORE** small slips in formulae (assessed in equation) **Examiner's Comments** There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions required to produce the organic products. The equation

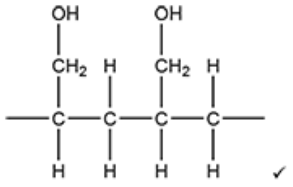
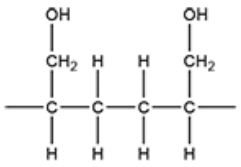
					proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead. A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.
			Total	**5**	
7			**A**	1 (AO 2.5)	**Examiner's Comments** Candidates had more success with this question with most obtaining the correct option, A.
			Total	**1**	
8	a		$C_6H_{11}OH$ ✓ Correct balanced equation $C_6H_{11}OH + 8½\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓	2 (AO2.6 ×2)	For $C_6H_{11}OH$, **ALLOW** $C_6H_{12}O$ **OR** any combination of skeletal **OR** structural **OR** displayed formula **ALLOW** multiples **IGNORE** state symbols **ALLOW** multiple OH groups in structure for both marks e.g. $C_6H_{12}O_2$ ✓ $C_6H_{12}O_2 + 8\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓ **Examiner's Comments** Approximately half the candidates gained both marks here but just over a third gained no credit. A very common error was $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$ missing the need for an alcohol group. Another common error

					was balancing with $9O_2$ i.e. not deducting O from alcohol from their count of O atoms. Some struggled to determine the correct number of Hs when a single C=C bond is introduced so gave $C_6H_{12}OH$ or $C_6H_{13}OH$ instead. Lower attaining candidates did not understand what happens during complete combustion. For example, they used [O] instead of molecular oxygen or didn't have CO_2 and water as the products. Some used structural formula which made it easier to get the correct formula of the reactant but often made it trickier to balance the equation.
	b		 Compound C Correct organic product ✓✓ Correct balanced equation ✓	3 (AO2.5 ×2) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the OH group e.g. **ALLOW**  **ALLOW** 1 mark for partially oxidised organic product and an additional mark for ECF for correct balanced equation for this product. i.e.  Organic product ✓ Correct balanced equation ✓ **OR** **OR** **OR** **Examiner's Comments** The higher attaining candidates scored well here, with many being

					able to identify both the primary alcohol being oxidised to the carboxylic acid and the secondary alcohol being oxidised to the ketone and obtaining correct balancing. A good strategy adopted by some candidates was labelling the three alcohol groups with their classification, i.e. primary, secondary, and tertiary. Some missed the water by-product or gave H_2 instead. Some gained credit for partial oxidation products as shown in the guidance on the mark scheme. However, more than a third gained no credit here with many attempting to oxidise the tertiary alcohol or removing it entirely. Some made a mistake by adding an extra CH_2 on to the product before COOH group - again demonstrating the importance of counting atoms when balancing equations. Oxidation of alcohols is typically taught in the first year with very simple examples, but candidates need to practise more complex examples. Candidates need to be reminded that every oxidation step requires an [O] and every OH group oxidised produces a water molecule.
	c	i		3 (AO2.5 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **<u>Examiner's Comments</u>** Lots struggled here with just under half of candidates gaining no credit. Only the strongest responses recognised that a carbon-carbon double bond could be formed external to the ring from the methyl branch. A common error was repeating one of the first two isomers as a mirror or rotated image and so lost a mark - candidates need to be able to recognise same structures (especially using skeletal formula) Lower scoring candidates didn't

					recognise this reaction would result in the elimination of water. So, it was common to see responses with three structures still containing the OH group or ketones (possible oxidation products), despite the molecular formula C_7H_{10} being provided twice in the question. Some candidates attempted to give structural isomers of C_7H_{10} that would not form from this reaction (see below) including those with smaller rings and even unsaturated straight chain compounds. Some even gave benzene structures.  This question was particularly problematic to mark if previous structures drawn were then rubbed out. **Drawing structures in exams** Please remind candidates to draw structures clearly in black ink. If incorrect cross them out and redraw them. Drawing in pencil then rubbing out often leads to extra lines showing when exam papers are scanned making it appear that structures are incorrect.
		ii	NaI / KI **AND** H_2SO_4 ✓	1 (AO1.2)	**ALLOW** HI **ALLOW** NaI / KI **AND** H_3PO_4 **OR** HNO_3 **IGNORE** Conc or dilute **Examiner's Comments** Many candidates were unable to provide reagents and conditions for this reaction. Iodo- seemed unfamiliar to some with responses including NaBr or HBr suggesting substitutions with Br are more familiar. The most common errors were to use iodide with no acid or to use iodine,

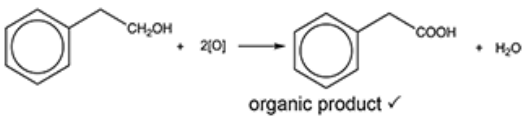
					sometimes in conjunction with other reagents such as AlI_3 or FeI_3.
			Total	**9**	
9	a	i	3-methylpentan-2-ol ✓	1 (AO 2.1)	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylpentane-2-ol **DO NOT ALLOW** 2-methylpentan-3-ol 3-methylpent-2-ol 3-methpentan-2-ol 3-methypentan-2-ol 3-methlypentan-2-ol **Examiner's Comments** A significant number of candidates lost the mark for missing -an- in their answer i.e. 3-methylpent-2-ol. Others lost the mark for incorrect spelling of methyl.
		ii	 Correct structure of organic product ✓ Balanced equation ✓	2 (AO 2.7 × 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** additional reactants such as H^+ or [O] in the equation. **ALLOW** incorrect isomer 3-methylpent-2-ene for balancing mark. **Examiner's Comments** Most candidates did not score either mark here, despite the structures for B and C being given in the table below for (iii). Many thought this was oxidation, showing [O] in equations and giving a carbonyl product. Many had alkenes but still with the -OH present. Some attempted to use structural or displayed formulae but errors were made in giving the correct number of H atoms. For those that did have the correct structure, they often did not give an equation, added the

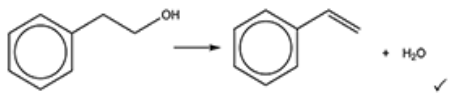
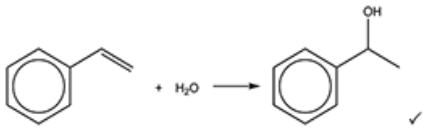
					acid as a reactant , or missed off the water as a product.
		iii	Priority groups on same side ✓ High(est) priority groups are CH_3CH_2 and CH_3 **OR** Low(est) priority groups are CH_3 and H ✓	2 (AO 3.1 × 2)	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic number or more important groups etc. **ALLOW** priority groups are both on the top **IGNORE** references to relative mass of groups, Ar, Mr, **ALLOW** identification by name e.g. ethyl and methyl, or by circling on the structure. **IF** 'priority' is not mentioned **ALLOW** 1 mark for CH_3CH_2 and CH_3 are on same side **OR** H and CH_3 are on same side **Examiner's Comments** Many responses made no reference to 'priority' and/or discussed alkene C, suggesting that they didn't read the question fully. Candidates often struggled to find the right language to express themselves, such as reference to 'functional groups' or 'molecules' rather than priority groups. Lots discussed using *M*r to assign priority with only a few stating correctly that it is atomic number that is used for CIP rules. Many, despite stating that priority groups are on the same side, didn't identify these groups so didn't get the second mark.
	b	i	**Section of polymer**  ✓	2 (AO 2.5) (AO 3.1)	**ALLOW** correct structural **OR** displayed **OR** skeletal formula. **ALLOW** alternating side chains i.e.  **IGNORE** brackets and use of 'n'

			- **Reason for solubility in water** <u>OH/alcohol</u> groups form hydrogen bonds <u>with water</u> ✓		**IGNORE** incorrect connectivity for -CH_2OH **DO NOT ALLOW** -HO End bonds **MUST** be shown (solid or dotted) **DO NOT ALLOW** one repeat unit *Question asks for 2 repeat units.* - **DO NOT ALLOW** 'it forms hydrogen bonds' **<u>Examiner's Comments</u>** Most candidates were able to gain credit for their structure, with only a few missing out by only drawing one repeat unit, keeping the C=C, having no end bonds or missing/extra Hs. Lots struggled to gain the second mark for the reason for solubility in water as they didn't refer to H-bonding. There were quite a few misconceptions highlighted in the responses to this question. These included the misunderstanding that a H-bond is an an intermolecular force between -OH on alcohol and water, rather than the covalent bond in the molecule. Some thought the -OH would behave as an alkali, even referring to ions, so would 'fully dissociate'. Some described a reaction with water and breaking apart, perhaps confusing with condensation polymers which can be hydrolysed.
		ii	Any two ✓✓ • Recycled (to make other plastic materials) • Combustion to generate energy / electricity • As (organic) feedstock	2 (AO 1.1 × 2)	**IGNORE** Reused **ALLOW** Used as a fuel to generate energy / electricity **<u>Examiner's Comments</u>** About a quarter of candidates didn't gain any credit here as they struggled

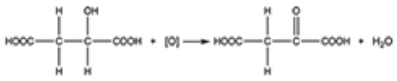
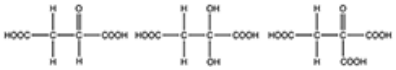
					to identify useful processes. Lots referred to cracking or breaking down into smaller chains, possibly thinking about fractional distillation of crude oil and how we make better use of larger fractions. Some identified possible use as a fuel but didn't say to generate energy/electricity. We also saw reference made to photodegradable/biodegradable polymers which isn't relevant to hydrocarbon polymers. There was evidence of the misunderstanding of the use as 'feedstock' with reference being made to animals (livestock or animal feed) or as food to eat.
			Total	**9**	
10			**Level 3 (5-6 marks**) Diagram showing reflux with most labels **AND** A **CORRECT** calculation of the % yield of 1-bromobutane **AND** A **detailed** description of most purification steps. *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)** Diagram showing reflux with some labels **AND** Calculates the % yield of 1-bromobutane with some errors **OR** Diagram showing reflux with most labels **AND** describes some purification steps, with some detail **OR** Calculates the % yield of 1-bromobutane with some errors **AND** describes some purification steps, with some detail *There is a line of reasoning presented with some structure. The information presented is relevant and supported by*	6 (AO2.8 ×2) (AO3.3 ×4)	**Indicative scientific points may include:** <u>Diagram</u> Diagram draw with condenser above flask Labels including • condenser • water in at bottom and out at top • pear-shaped or round-bottom flask ***<u>Calculation of % yield of 1-bromobutane</u>*** • $n(\text{butan-1-ol}) = \frac{9.25}{74.0} = 0.125\ (\text{mol})$ • mass 1-bromobutane = 6.10 × 1.268 = 7.7348 g • $n(\text{1-bromobutane}) = \frac{7.7348}{136.9} = 0.0565\ (\text{mol})$ • $\%\ \text{yield} = \frac{0.0565}{0.125} \times 100 = 45.2\%$ **ALLOW** 45.2 ± 0.2 for small slip/rounding **NOTE Use of 6.1 g (omission of density)** • $n(\text{1-bromobutane}) = \frac{6.10}{136.9} = 0.044558\ldots\ (\text{mol})$ • $\%\ \text{yield} = \frac{0.044558\ldots}{0.125} \times 100 = 35.6\%$ ***<u>Purification</u>***

			some evidence. **Level 1 (1-2 marks)** Diagram showing reflux **OR** Attempts to calculate the % yield of 1-bromobutane **OR** Describes few purification steps. *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.		• In separating funnel, **organic layer is on bottom** • Drying with an **anhydrous salt by formula or name**, e.g. $MgSO_4$, Na_2SO_4, $CaCl_2$ • Redistil **at 102°C** **Examples** of detail in **bold** (**NOT INCLUSIVE**) **NOTE**: 'Use a separating funnel', dry, and 'redistil' on their own are **NOT** detailed descriptions **<u>Examiner's Comments</u>** This question was assessed by level of response (LoR). Candidates were required to describe key features in a procedure to prepare a pure organic liquid, including a labelled diagram for reflux, a calculation of the percentage yield and the procedural steps for purification. Levels were determined using these three features. Marks within a level were determined by communication. This question discriminated extremely well. Level 3 candidates would draw a clear diagram with all key items labelled and the set up being capable of being used safely. The percentage yield calculation would be correct, producing a percentage yield close to 45.2%. The steps for the purification: use of a separating funnel, drying and redistillation would be described in the correct order and with some detail. Level 2 candidates would have obtained some of the features required for Level 3 but there would be some key omissions or errors. The diagram may have been drawn clearly but labelling may have been incomplete or a thermometer with bung may have been inserted into the top of the condenser, a very hazardous arrangement. The calculation would be attempted but with some errors, such as omitting to use the density, or using a mixture of

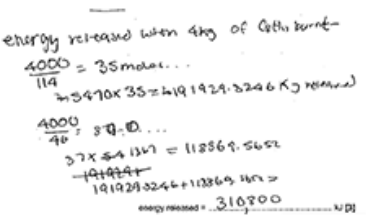
					moles and masses. The purification steps may have been described but in the wrong order. Purification steps would be incomplete, perhaps only including distillation. Level 1 candidates often drew a diagram resembling a tube above a flask, with water often flowing in the wrong direction. The percentage yield may have been a simple mass ratio with no moles being used. A significant number of candidates described the purification steps for an organic solid, including recrystallisation. The preparation of an organic liquid is a key practical procedure that will have been experienced by students during their A Level studies (PAG 5). The overall standard of drawing diagrams was poor, an area that needs improvement.
			Total	**6**	
11	a		 organic product ✓ Correct balanced equation ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_6H_5 for phenyl group **Examiner's Comments** Most candidates were able to score at least 1 mark for this question. Common errors included candidates producing two water molecules or failing to balance [O]. A significant proportion of candidates did not score any marks, frequently due to the organic product having too many carbon atoms in it.
	b		**Stage 1** *Reagents*: H_2SO_4 ✓	4 (AO3.1) (AO2.6) (AO3.1) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam

			 ✓ **Stage 2** *Reagents*: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓  ✓		For steam, **ALLOW** H_2O with temperature ≥100°C **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst **DO NOT ALLOW** HCl **IGNORE** pressure **Examiner's Comments** This question proved challenging with only the most able being given full marks. The reagents and conditions were not well known and candidates did not include water in their equations to make sure they were balanced.
			Total	**6**	
12		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 8.07 g award 3 marks** **CARE: Intermediate rounding may give 8.06 g which is acceptable for 3 marks** --- *n*(2-bromobutane) $= \frac{10.0}{136.9} = 0.073(0)\ldots.$ (mol) ✓ *n*($CH_3CH_2CHOHCH_3$) $= 0.0730\ldots. \times \frac{100}{67.0} = 0.109$ (mol) ✓ mass $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **3 SF** required	3 (AO 2.4 × 3)	**ALLOW ECF throughout** **IGNORE** trailing zeroes in intermediate working, e.g. 0.073 for 0.0730 **ALLOW** 3 SF or more, correctly rounded Calculator: 0.7304601899 Calculator: 0.1089552239 **ALLOW alternative method mass** • Theoretical mass of 2-bromobutane $= 100 \times \frac{10.0}{67.0} = 14.9\ldots.$ (g) Calculator: 14.925373 • Theoretical *n*($CH_3CH_2CHBrCH_3$) $= \frac{14.923373}{136.9} = 0.1902$ (mol)

					• Mass of $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **Common Errors for 2 marks** 5.41 g (no % yield) 3.62 g (inverted yield) **Examiner's Comments** The most common errors were omitting the yield or inverting the yield, as given on mark scheme, resulting in 2 marks. Clear working was vital here to help marks to be given even if the final answer was incorrect. Many candidates did not gain the final mark due to incorrect significant figures. As with other multi-step calculations, rounding of intermediate values could also cause marks to be lost.
		ii	Separating funnel (to separate aqueous and organic layers) ✓ Dry organic layer with anhydrous salt ✓ Distil and collect fraction at 91°C ✓	3 (AO 3.3 × 3)	**ALLOW** Use a drying agent **ALLOW** appropriate example of an anhydrous salt e.g. $MgSO_4$, $CaCl_2$ **Examiner's Comments** This question was not answered well with over half the candidates failing to score any marks. While some candidates seemed familiar with the techniques required, describing the process to separate the layers, they often struggled to name the separating funnel. Common approaches were to attempt to 'filter' the layers or to use heat (via evaporation or distillation) to drive off the water. Some attempted to use Na_2CO_3 or NaOH to dry the organic layer – perhaps confusing neutralisation of any remaining acid. Although distillation appeared frequently many did not give the temperature so did not gain marks. The order of the procedure was also not always clear with distillation

					before using a drying agent. Some described attempts to crystallise the organic layer. The range of answers suggests students may need more practical experience with separating organic liquids.
			Total	**6**	
13			 Correct structure of product ✓ Correctly balanced equation ✓	2 (AO 2.5) (AO 2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **<u>Examiner's Comments</u>** Despite oxidation of alcohols being a topic that has been assessed many times, candidates found this question very tricky with a majority failing to score any marks. Candidates needed to correctly identify this as a secondary alcohol which, when oxidised, will become a ketone. A wide range of errors were seen, including the following:  Other errors included forming C=C or removing COOH. Approximately half of those that got the correct structure were also able to balance the equation gaining both marks. Some forgot that another product was formed or gave H_2 instead. Candidates were given the structure and told to use [O] to represent the oxidising agent. However, some attempted to use structural or molecular formula and/or adding in dichromate to their answers.
			Total	**2**	
14		i	$C_8H_{18} + C_2H_5OH + 15½\ O_2 \rightarrow 10\ CO_2 + 12\ H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples e.g. $2\ C_8H_{18} + 2\ C_2H_5OH + 31\ O_2 \rightarrow 20$

					CO_2 + 24 H_2O **ALLOW** $C_{10}H_{24}O$ for C_8H_{18} + C_2H_5OH *Combining ethanol and octane!* **Examiner's Comments** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a 'mixture formula' of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using 15½O_2 was the hardest part of the equation and many different balancing numbers for O2 were seen (10CO_2 and 12H_2O where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** --- $M(C_8H_{18})$ = 114 **AND** $M(C_2H_5OH)$ = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark $m(C_8H_{18})$ = (114/160) × 8000 = 5700 g **AND** $m(C_2H_5OH)$ = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded --- **Common errors** **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**

					 **Examiner's Comments** This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**4**	
15	a		Number of optical isomers = 4 ✓	1 (AO2.1)	**Examiner's Comments** Most candidates added two asterisks to the diagram of vitamin C for the possible chiral centres. More successful responses usually realised that two chiral centres would give rise to $2^2 = 4$ optical isomers, with 2 optical isomers being the commonest error.
	b	i	Hydrogen bonding **AND** **Many** OH/hydroxyl / hydroxy / alcohol ✓	1 (AO2.1)	**ALLOW** 4 OH **DO NOT ALLOW** OH^- **Examiner's Comments** Most candidates realise that hydrogen bonds would be formed from the OH groups in vitamin C to water. Candidates are advised to read the question carefully as the word 'extremely' was a hint that 'many' OH groups would be needed in the explanation. The most successful responses quoted that hydrogen bonds would form between the 4 OH groups in vitamin C and water. Some candidates stated that O atoms in

					vitamin C would be involved. This was not given marks as not all O atoms in vitamin C are a part of OH groups and capable of hydrogen bonding.
		ii	x = 15 ✓ y = 31 ✓	1 (2 ×AO3.2)	**Examiner's Comments** More successful responses determined that *x* = 15 and *y* = 31. The key to success here was to subtract the formula of vitamin C from the formula of the ester and to add the formula of water: $C_{22}H_{38}O_7$ - $C_6H_8O_6$ + H_2O → $C_{16}H_{32}O_2$ → $C_{15}H_{31}COOH$. A significant number of candidates did obtain one of these values, with 15/16 and 29/30/32 being common incorrect answers. Omitting part(s) of sequence above would result in these incorrect numbers.
			Total	**4**	