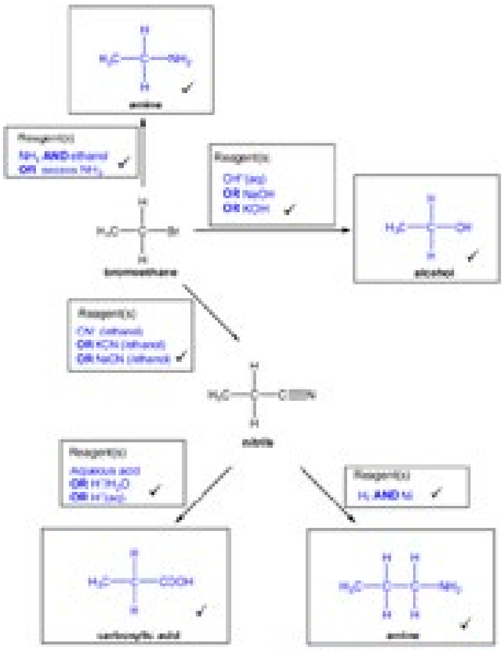
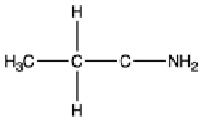
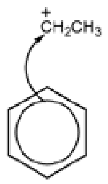
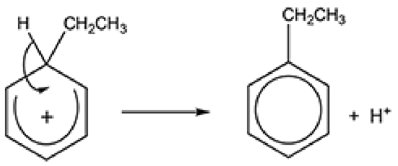
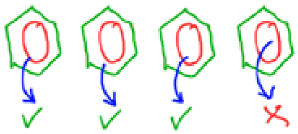
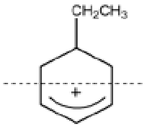
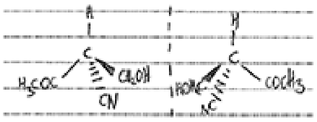
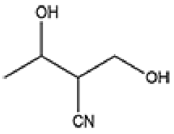
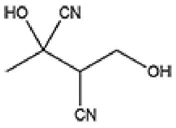
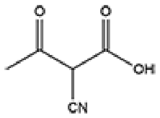
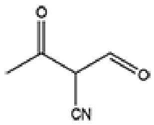
Mark scheme

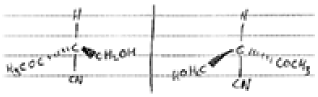
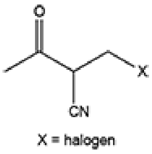
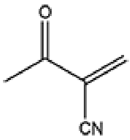
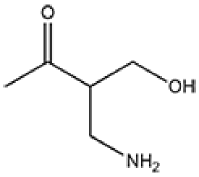
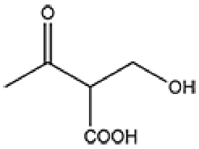
Question	Answer/Indicative content	Marks	Guidance
1	 Check has 3C not 2C	9	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** structure if H(s) are missing from **ONE** structural/displayed formula… **BUT ALLOW** any further omissions as **ECF** **ALLOW** any vertical bond to the OH **OR** NH_2  **DO NOT ALLOW** OH−, **OR** $NH_{2}-$ but **ALLOW ECF** for subsequent use in this part **ALLOW** names of reagents e.g. ethanolic ammonia, if no formulae given **DO NOT ALLOW** other additional reagents **IGNORE** Conditions **For bromoethane to amine:** **IF** a secondary / tertiary amine is given **ALLOW** one mark for a correct structure **AND** one mark for an appropriate reagent to produce the amine shown. **For bromoethane to alcohol:** **ALLOW** H_2O **IGNORE** ethanol (as a solvent) **For bromoethane to nitrile:** **DO NOT ALLOW** HCN **OR** CN^- / H^+ **DO NOT ALLOW** H_2O / (aq) **For nitrile to carboxylic acid:** **ALLOW** any mineral acid **IGNORE** dilute/concentrated **For nitrile to amine:** **ALLOW** suitable non-specification alternative e.g. $LiAlH_4$, H_2 with Pd or

						Pt **Examiner's Comments** This question was well-answered with around a half of candidates scoring 8 or 9 marks. The full range of marks was seen across the whole cohort. The most common reasons for losing marks were for the addition of extra, contradictory reagents or for missing hydrogens from structures. **Bromoethane to amine:** The amine structure was mostly correct with a few adding an extra hydrogen to the amine i.e. $CH_3CH_2NH_3$. Most gave the correct reagent as NH_3 but some omitted either ethanol or excess, so did not score here. **Bromoethane to alcohol:** The alcohol structure was usually correct. However, many lost the reagent mark here for the addition of acid/ H^+/H_2SO_4 alongside the hydroxide. **Bromoethane to nitrile:** A suitable cyanide was often used, but again many included an acid catalyst or aqueous conditions (aq) so lost the mark here. Ideally candidates would react in ethanol to prevent hydrolysis of the haloalkane. **Nitrile to carboxylic acid:** Most gave the correct carboxylic acid structure, while occasionally ethanoic acid was given instead of propanoic acid. Most identified the need for acid as a reagent but some omitted water or (aq). **Nitrile to amine:** H_2 was often seen as the reagent but sometimes without a catalyst. Many gave an incorrect structure here either with a missing C (i.e. ethylamine) or missing hydrogens on the first carbon i.e.

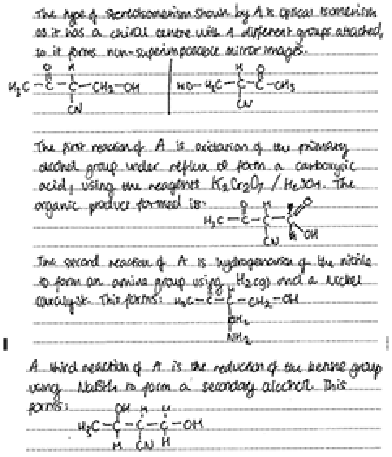
					 **OCR support** A useful resource for teaching about organic synthetic routes including functional groups, reagents and two-step processes can be found in the Topic Exploration pack on Teach Cambridge.
			Total	**9**	
2		i	**ALLOW correct Kekulé representation of benzene throughout question 21** An electron 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 $^+CH_2CH^3$ ✓ -- ---	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**

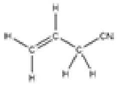
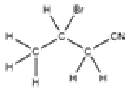
			 Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring **AND** H^+ as product ✓ **Regeneration of catalyst** $H^+ + AlCl_4^- \rightarrow AlCl^3 + HCl$ ✓		• go to anywhere on $^+CH_2CH^3$  **DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the 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.
			Total	**6**	
3			**Level 3 (5–6 marks)** Suggests **ALL** of the following • Reagents and conditions for **3** functional groups • Products for **3** functional groups	6 (AO 3.1 ×3) (AO 3.2 ×3)	**CHECK TOP OF QUESTION FOR RESPONSES** --- *Indicative scientific points may include:* **Stereoisomerism**

			• 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.* *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*		• 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** $H_2SO_4/K_2Cr_2O_7$ reflux  $H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ distil 

			 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		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** **Examiner's Comments** Overall, candidates performed well when answering this question. They were required to identify that compound **A** shows optical isomerism and to choose a reaction

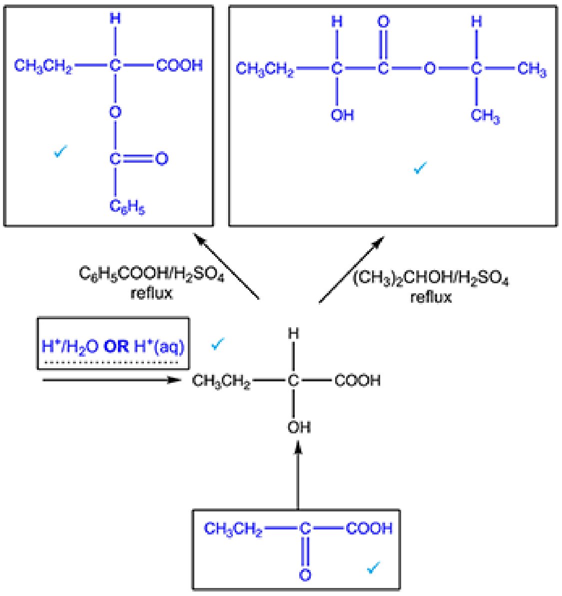
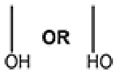
					for each of the three functional groups. Candidates were also expected to use structures for the organic products. To achieve the highest level of response, a description of optical isomerism should be accompanied by 3D diagrams of the optical isomers. Optical isomerism was usually identified, with associated 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

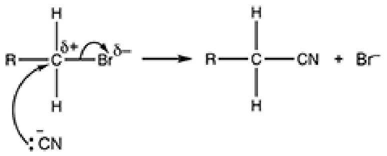
4					was a ketone from no reaction with Tollens' reagent. The question asked for the organic product and the 2,4- DNP product is beyond the demands of this specification (although this was seen very rarely). Candidates adopting this reaction were limiting the extent of their response and candidate should have considered this requirement before selecting 2.4-DNP. Exemplar 2  The type of stereoisomerism shown by A is optical isomerism as it has a chiral centre with 4 different groups attached, so it forms non-superimposable mirror images. The first reaction of A is oxidation of the primary alcohol group under reflux to form a carboxylic acid, using the reagents $K_2Cr_2O_7$ / H_2SO_4. The organic product formed is: The second reaction of A is hydrogenation of the nitrile to form an amine group using $H_2(g)$ and a nickel catalyst. This forms: A third reaction of A is the reduction of the ketone group using $NaBH_4$ to form a secondary alcohol. This forms: 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**	
4			**Level 3 (5–6 marks)** A **three** stage synthesis in the **correct** order **AND** Equations for each stage are mostly correct	6 (AO3.3 ×6)	**Mark second page as SEEN** **Indicative scientific points may include:** **IGNORE conditions**

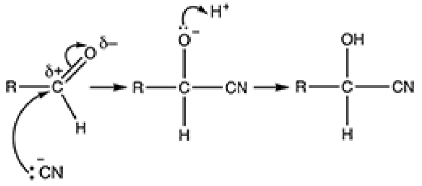
			AND Most reagents correct *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Synthesis includes at least **two** stages in **any** order **OR** uses NH_3 and HBr in the **correct** order (without chain extension) **AND** some of the reagents and some equations correct *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)** Planned synthesis includes reagents for **any** two stages **OR** Describes one stage with reagents and equation mostly correct *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.		***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C{=}CHCH_2Br + CN^- \rightarrow$ $H_2C{=}CHCH_2CN + Br^-$ **Intermediate 1**  ***Stage 2: Addition of HBr to C=C*** • Reagents**:** HBr • Equation: $H_2C{=}CHCH_2CN + HBr \rightarrow$ $CH_3CHBrCH_2CN$ **Intermediate 2**  ***Stage 3: Reduction of CN*** • Reagents: H_2 (with Ni) • Equation: $H_3CCHBrCH_2CN + 2H_2 \rightarrow$ $CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr*** ***– CN^- would react with both Br atoms*** ***Needs HBr before H_2*** ***– H_2 would react with C=C*** **Alternative three stage syntheses:** ***Alternative using $LiAlH_4$*** ***Caution - Can be done as stage 2 or 3*** • Reagents: LiAlH4 • Equation: $H_2C{=}CHCH_2CN + 4[H] \rightarrow$ $H_2C{=}CHCH_2CH_2NH_2$ **OR** $H_3CCHBrCH_2CN + 4[H] \rightarrow$

						$CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr and $LiAlH_4$*** ***Can have HBr and $LiAlH_4$ in any order*** ***Alternative using radical substitution:*** ***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C{=}CHCH_2Br + CN^- \rightarrow$ $H_2C{=}CHCH_2CN$ + Br– ***Stage 2: Reduction of CN and C=C*** • Reagents: H_2 (with Ni) • Equation: $H_2C{=}CHCH_2CN + 3H_2 \rightarrow$ $CH_3CH_2CH_2CH_2NH_2$ **Stage 3: Reaction with Br_2** • Reagents: Br_2 (with UV) • Equation: $CH_3CH_2CH_2CH_2NH_2 + Br_2 \rightarrow$ $CH_3CHBrCH_2CH_2NH_2 + HBr$ ***Needs CN^- before H_2*** ***Needs H_2 before Br_2*** ***Two stage synthesis using NH_3 and HBr forming product with no lengthening of carbon chain*** ***Stage 1: Reaction of NH_3*** • Reagents: NH_3 (in ethanol) • Equation: $H_2C{=}CHCH_2Br + NH_3 \rightarrow$ $H_2C{=}CHCH_2NH_2 + HBr$ ***OR*** *$2\ NH_3 \rightarrow NH_4Br$* ***Stage 2: Addition of HBr to C=C*** • Reagents: HBr • Equation:

					$H_2C{=}CHCH_2NH_2 + HBr \rightarrow CH_3CHBrCH_2NH_2$ ***Needs NH_3 before HBr*** ***– HBr would react with C=C*** **Examiner's Comments** This challenging level of response question was generally well attempted. Many candidates recognised the reagents required in this synthesis but fewer candidates were able to deduce three correct reagents in the right order with equations to achieve Level 3. Most candidates achieved Level 2 4 marks. Many correctly identified suitable reagents but carried out the stages in the wrong order. A common error was to carry out electrophilic addition with HBr first then react with cyanide ion, not realising both Br groups would react and the reaction would not be selective. Alternatively, having introduced the nitrile group then carried out the reduction first, not realising that the C=C would also be reduced. The lowest scoring responses were often incomplete and despite identifying some reagents did not give equations. Candidates are encouraged to read the questions carefully so they can make sure their response covers all the detail required. Many candidates used molecular formula in their equations. It is usually preferrable in organic chemistry to give structures. Some gave surplus information such as the mechanisms and reaction conditions for each reaction. The key to answering this question well was knowing reagents for different functional group interconversions as well as planning each step to make sure of a logical synthesis. Some candidates were seemingly confused by the term 'intermediate' and gave an

					intermediate as in a mechanism, e.g. carbocation. **OCR support** A useful resource for teaching how to identify functional groups and practice at devising synthetic routes is the Topic exploration pack on Organic synthesis. This should be used in conjunction with the reaction pathways summaries.
			Total	**6**	
5			**D**	1 (AO1.2)	**Examiner's Comments** The most common incorrect response seen here was B. Candidates understood that nitriles can be hydrolysed but did not realise that it would give pentanoic acid not butanoic. Those who drew out the structures of the products for each were more likely to give the correct answer, D.
			Total	**1**	
6				4 (AO2.5×4)	**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**  **IGNORE** connectivity of CH_3CH_2 group **IGNORE** inorganic by-products **ALLOW** HCl/H_2O, H_2SO_4/H_2O **IGNORE** dilute

					Examiner's Comments The majority of candidates were able to identify at least one of the structures. A significant number of candidates did not check the number of bonds of each atom in their structures and frequently had too many or too few hydrogen atoms attached. Most candidates identified that acidic conditions were required but some missed the aqueous condition that was also required for the mark.
			Total	**4**	
7			**Level 3 (5–6 marks)** Describes, in detail, reactions of **two** aliphatic compounds that form a C–C bond **AND** mechanisms for the **two** aliphatic reactions. *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)** Describes a reaction of **one** aliphatic compound that forms a C–C bond with few omissions/errors. **AND** mechanism for **one** aliphatic reaction. **OR** Describes reactions of **two** compounds that forms a C–C bond **AND** attempts a mechanism for **one** of the reactions *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)** Selects suitable reagents for reactions of **two** compounds that form a C–C bond. **OR** Attempts to describe a reaction and mechanism of **one** compound that forms a C–C bond, with omissions/errors.	6 (AO1.2×4) (AO2.5×2)	**Indicative scientific points may include:** **Reactions of aliphatic compounds and mechanisms** • Haloalkane, RX and CN^- → RCN + X^- Reagents: NaCN and ethanol Reaction: Nucleophilic substitution Mechanism:  • Aldehyde or ketone and HCN e.g. RCHO + HCN → RCH(OH)CN Reagents: NaCN and H^+ Reaction: Nucleophilic addition Mechanism:

			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.*		 OR H_2O instead of H^+ for 2nd stage **If alternative reactions are shown contact your TL e.g. radical substitution, polymerisation** **Examiner's Comments** This question differentiated well. Candidates who were given Level 3 (5-6 marks) understood the term aliphatic and were able to provide two different mechanisms that produced a C-C bond. The most common responses seen involved the nucleophilic substitution of a halogenoalkane and a cyanide ion and the nucleophilic addition of a carbonyl with a cyanide ion. Some candidates offered radical substitution mechanisms, detailing initiation, propagation and termination steps, with the termination step producing a C-C bond. Candidates who scored Level 2 (3-4 marks) frequently detailed a reaction involving aromatic compounds or polymerisation of alkenes for which they were unable to give a mechanism.
			Total	6	