



Mark Scheme

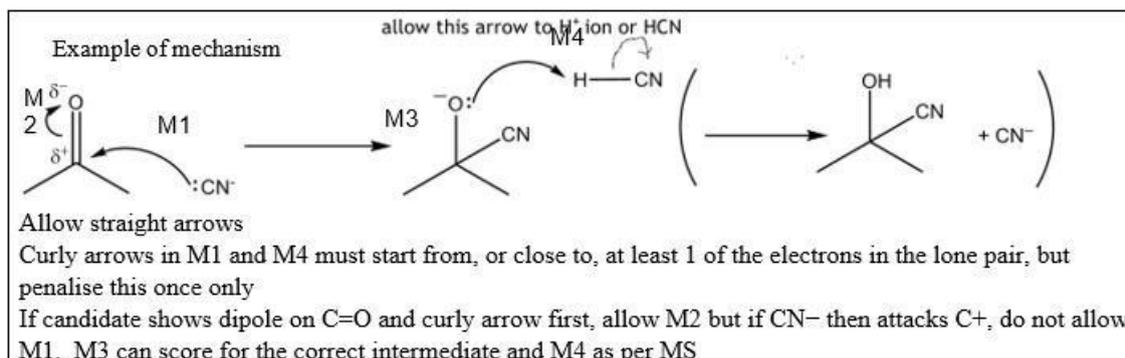
Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An explanation that makes reference to any two of the following points:</p> <ul style="list-style-type: none"> to make sure the solution doesn't cool down (significantly) (1) to prevent (premature) crystallization taking place (in funnel / on filter paper) (1) which would reduce yield (of product) (1) 	<p>Ignore general references to removing impurities Allow crystals / solid / precipitate forming for crystallisation</p> <p>Allow to keep the solution warm</p> <p>Accept to prevent crystals forming during filtration Allow to make sure the substance stays in solution</p>	(2)
Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to any two of the following points:</p> <ul style="list-style-type: none"> Step 4: product less soluble in cooler solvent (than hot solvent, so product crystallises out) (1) Step 4 : (soluble) impurities present (in small amount so) stay in solution / remain dissolved (while product crystallises) (1) Step 5: filtering under reduced pressure removes more of the soluble impurities / removes the soluble impurities faster / produces a drier product (1) 	<p>Allow crystals / solid / precipitate for product</p> <p>Allow product is insoluble in cold solvent</p> <p>Allow filtration removes the solution containing the impurities / separates the crystals from the soluble impurities Allow filtering under reduced pressure is faster (than gravity filtration) Ignore just 'use a Buchner funnel'</p>	(2)
Question Number	Answer	Additional Guidance	Mark
(iii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> (measure) melting temperature (of purified crystals) (1) compare to literature value (matched to original carbonyl compound) (1) 	<p>Allow compare to data book value / compare to value from (credible) internet source / compare to known melting temperature / compare to values in a database</p>	(2)



Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> curly arrow from lone pair on C of CN^- ion to C of $\text{C}=\text{O}$ (1) dipole on $\text{C}=\text{O}$ and curly arrow from $\text{C}=\text{O}$ bond to or just beyond O (1) intermediate structure (1) curly arrow from lone pair on O to H of HCN and curly arrow from $\text{H}-\text{C}$ bond to anywhere on CN (1) 	<p>Penalise omission of lone pair once in M1 and M4</p> <p>Penalise use of single-headed arrows only once</p> <p>Penalise use of incorrect nucleophile once only in M1 e.g. OH^-</p> <p>Allow skeletal, displayed or structural formulae</p> <p>Allow CN^- to attack from any angle</p> <p>Allow CN triple bond displayed</p> <p>Do not award curly arrow from lone pair on N</p> <p>Do not award $\text{CN}^{\delta-}$</p> <p>Ignore missing lone pair on O</p> <p>Ignore connectivity for vertical CN group if M1 awarded</p> <p>Do not award O^{2-}</p> <p>Allow curly arrow from lone pair on O^- to H^+</p> <p>Ignore dipole on HCN</p> <p>Ignore products, even if incorrect</p>	(4)





Question number	Answer	Additional Guidance	Mark												
(ii)	<table border="1"> <tr> <td>Reagent 2</td> <td>(conc) phosphoric acid / H_3PO_4 (conc) sulfuric acid / H_2SO_4 aluminium oxide / Al_2O_3 (1)</td> </tr> <tr> <td>Structure of compound A</td> <td> <chem>CC(C)(C)C#N</chem> (1) <chem>C=C(C)C#N</chem> </td> </tr> <tr> <td>Reaction type 3</td> <td>(acid) Hydrolysis (1)</td> </tr> <tr> <td>Structure of compound B</td> <td> <chem>CC(C)(C)C(=O)O</chem> (1) <chem>C=C(C)C(=O)O</chem> </td> </tr> <tr> <td>Reagent 4</td> <td>CH_3OH / methanol (1)</td> </tr> <tr> <td>Reaction type 4</td> <td>Esterification / condensation (1)</td> </tr> </table>	Reagent 2	(conc) phosphoric acid / H_3PO_4 (conc) sulfuric acid / H_2SO_4 aluminium oxide / Al_2O_3 (1)	Structure of compound A	 <chem>CC(C)(C)C#N</chem> (1) <chem>C=C(C)C#N</chem>	Reaction type 3	(acid) Hydrolysis (1)	Structure of compound B	 <chem>CC(C)(C)C(=O)O</chem> (1) <chem>C=C(C)C(=O)O</chem>	Reagent 4	CH_3OH / methanol (1)	Reaction type 4	Esterification / condensation (1)	<p>Ignore connectivity of groups All marks are stand alone Allow 'alumina' Do not award steam / water Do not award dilute for either acid</p> <p>Allow structural, displayed or any combination of structural, displayed or skeletal for Compounds A and B</p> <p>Do not award hydration / halogenation for M3</p> <p>Allow TE for M4 based on incorrect M2 structure provided the nitrile group has been hydrolysed correctly and no other changes</p> <p>Allow addition/elimination for condensation in M6</p>	(6)
Reagent 2	(conc) phosphoric acid / H_3PO_4 (conc) sulfuric acid / H_2SO_4 aluminium oxide / Al_2O_3 (1)														
Structure of compound A	 <chem>CC(C)(C)C#N</chem> (1) <chem>C=C(C)C#N</chem>														
Reaction type 3	(acid) Hydrolysis (1)														
Structure of compound B	 <chem>CC(C)(C)C(=O)O</chem> (1) <chem>C=C(C)C(=O)O</chem>														
Reagent 4	CH_3OH / methanol (1)														
Reaction type 4	Esterification / condensation (1)														

Question Number	Answer	Additional Guidance	Mark
(iii)	<ul style="list-style-type: none"> correct repeat unit shown (1) equation balanced (1) 	 <chem>CC(=C)C(=O)OC >> [CC(C)C(=O)OC]_n</chem> <p>Allow displayed or structural formulae or a combination of these e.g.</p> $\left[\begin{array}{c} H \\ \\ -C- \\ \\ H \end{array} - \begin{array}{c} COOCH_3 \\ \\ -C- \\ \\ CH_3 \end{array} \right]_n$ <p>Do not award 2 as the balancing number</p>	(2)



Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark												
	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.</p> <table border="1"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														

		Number of marks awarded for structure of answer and sustained line of reasoning		In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.	
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2			
	Answer is partially structured with some linkages and lines of reasoning.	1			
	Answer has no linkages between points and is unstructured.	0			



Indicative content			
<ul style="list-style-type: none"> IP1 - Reagents and conditions magnesium and dry ether / dry ethoxyethane / dry $(\text{CH}_3\text{CH}_2)_2\text{O}$ IP2 - Hydrolysis of product add dilute (hydrochloric acid / $\text{H}^+(\text{aq})$ / $\text{HCl}(\text{aq})$) (to hydrolyse the intermediate / protonate ...O^-) IP3 - Primary alcohol react with methanal to form butan-1-ol / $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ IP4 - Secondary alcohol react with ethanal to form pentan-2-ol / $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ IP5 - Tertiary alcohol react with propanone to form 2-methylpentan-2-ol / $\text{CH}_3\text{CH}_2\text{CH}_2\text{C}(\text{CH}_3)(\text{OH})\text{CH}_3$ IP6 - Carboxylic acid react with carbon dioxide to form butanoic acid / $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ 	<p>This may be shown as part of any specific reaction. Ignore errors in an equation to make the Grignard.</p> <p>This only needs to be mentioned once Do not award this point if acid is clearly added at the same time as magnesium / dry ether / a reactant</p> <p>Allow other specific aldehydes with corresponding product</p> <p>Allow other specific ketones with corresponding product</p>		

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	C atom of C-Mg bond labelled as δ^- and Mg labelled as δ^+	Do not award full + or - charge Ignore δ^- on Br	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)		Ignore other structures Allow non-displayed formula	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	<ul style="list-style-type: none"> 2-methylpentan-3-ol 	Allow 2-methyl-3-pentanol No TE on incorrect formula from 5(b)(i)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	<ul style="list-style-type: none"> ✓ next to nucleophile (1) ✓ next to reducing agent (1) 	If more than two boxes ticked scores (0)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	<ul style="list-style-type: none"> propane / C₃H₈ 	Accept name or formula or structural / skeletal / displayed formula Ignore additional inorganic products Do not award just 'alkane' If name and formula given then they both must be correct	(1)

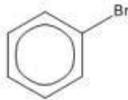
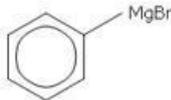
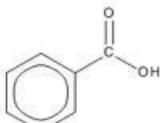


Q5.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> • 2-bromo-2-methylbutane reacts with Mg (1) • Dry ether (1) • $\text{CH}_3\text{CH}_2\text{C}(\text{MgBr})(\text{CH}_3)\text{CH}_3$ (1) • react Grignard reagent with HCHO (1) • $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{OMgBr}$ (1) • (hydrolyse) with (dilute) acid (1) <p>OR</p> <ul style="list-style-type: none"> • 2-bromo-2-methylbutane reacts with KCN (1) • ethanol (as solvent) (1) • $\text{CH}_3\text{CH}_2\text{C}(\text{CN})(\text{CH}_3)\text{CH}_3$ (1) • nitrile (hydrolysed) with (dilute) acid (1) • $\text{CH}_3\text{CH}_2\text{C}(\text{COOH})(\text{CH}_3)\text{CH}_3$ (1) • carboxylic acid (reduced) with LiAlH_4 (in dry ether) (1) 	<p>Note – award of reagent or solvent marks must be in context of attempt to carry out an appropriate reaction e.g. use of ethanolic KCN to react with a ketone would not score OR M2</p> <p>do not award HCOH</p> <p>Allow with water / H^+</p> <p>Ignore HCN</p> <p>Allow methanol</p> <p>Allow H^+</p>	(6)



Q6.

Question Number	Answer	Additional Guidance	Mark
	<p>Step 1</p> <ul style="list-style-type: none"> bromine and iron / iron(III) bromide or chlorine and aluminium chloride (1)  (1) <p>Step 2</p> <ul style="list-style-type: none"> magnesium and dry ether (1)  (1) <p>Step 3</p> <ul style="list-style-type: none"> carbon dioxide followed by a dilute acid (1)  (1) <p>Step 4</p> <ul style="list-style-type: none"> phosphorus(V) chloride / phosphorus pentachloride (1) 	<p>Allow names or formulae for reagents but if both are given, both must be correct</p> <p>Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations</p> <p>The marks for the intermediate structures are stand-alone</p> <p>Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water</p>	(7)



Q7.

Allow annotated equations to score these marks in both (i) and (ii) Allow any unambiguous formulae for the organic molecules in both (i) and (ii) such as C ₂ H ₅ CN for CH ₃ CH ₂ CN			
Question Number	Answer	Additional Guidance	Mark
(i)	A description which includes <ul style="list-style-type: none"> equation (1) LiAlH₄ in (dry) ether (followed by dilute acid) or H₂ with Ni / Pt / Pd (1) 	<u>Example of equation</u> $\text{CH}_3\text{CH}_2\text{CN} + 4[\text{H}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ $\text{CH}_3\text{CH}_2\text{CN} + 2\text{H}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ Allow names or formulae but both must be correct if given together Allow Lithal Allow hydrogen to be given in the equation or written over the arrow Ignore references to heat or a temperature	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	A description which includes <ul style="list-style-type: none"> equation from any halogenoalkane (1) ethanolic/alcoholic ammonia (1) heat and under pressure (1) 	<u>Example of equation</u> $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HBr}$ or $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$ Allow use of state symbol (alc)/(EtOH)/(eth) with NH ₃ Allow ammonia to be given in equation or written over the arrow Accept heat and in a sealed tube Ignore mechanisms If a contradictory chemical is stated then penalise once against M2 or M3	(3)



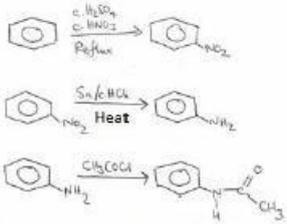
Q8.

Question Number	Answer	Additional Guidance	Mark
(i)	Any three of the following four structures		(3)
		<p>Accept formulae in any order</p> <p>Award (2) if 3 correct displayed/structural formulae given</p> <p>Award (1) if 2 correct displayed/structural formulae given</p>	

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An equation that has</p> <ul style="list-style-type: none"> • ethanoyl chloride (1) • alcohol and ester+ HCl product (1) 	<p><u>Example of equation</u></p> <p>Allow structural, displayed formulae in any combination Ignore connectivity to OH except horizontal Ignore state symbols even if incorrect If molecular formulae used then allow (1) for correct equation</p> <p>Allow (1) for a correct equation to form ester A from ethanoic acid e.g. $\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3 \rightleftharpoons \text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$</p>	(2)



Q9.

Question Number	Answer	Additional Guidance	Mark
	<p>A synthetic pathway that consists of:</p> <ul style="list-style-type: none"> • (reagents and conditions for the nitration of benzene) conc. Nitric (HNO₃) and sulfuric acids (H₂SO₄) and 55°C/heat/reflux (1) • structure of nitrobenzene (1) • (reduction of nitrobenzene) tin and conc. hydrochloric acid and heat/reflux (1) • structure of phenylamine (1) • (reaction of phenylamine with) ethanoyl chloride (1) 	<p>Example of synthetic pathway</p>  <p>The compounds used can be stated or given within equations. Ignore any unbalanced, incorrect equations or reaction mechanisms</p> <p>Allow any single value or range between 50-60°C/warm/<55 °C</p> <p>Intermediate marks are standalone</p> <p>Allow iron & c.HCl Do not award dilute Ignore subsequent addition of NaOH Penalise lack of heat once only in M1 and M3</p> <p>Penalise just the names of intermediates once only</p> <p>Ignore heat Do not award use of AlCl₃</p>	(5)



Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<p>A synthetic pathway that includes:</p> <p>Conversion to alcohol</p> <ul style="list-style-type: none"> (aqueous ethanolic) potassium / sodium hydroxide (1) name or structure of propan-1-ol (1) <p>EITHER ROUTE 1</p> <p>Conversion to carboxylic acid</p> <ul style="list-style-type: none"> (oxidise some of the propan-1-ol using) potassium dichromate(VI) and (dilute) sulfuric acid (1) name or structure of propanoic acid (1) <p>Formation of ester</p> <ul style="list-style-type: none"> react propan-1-ol and propanoic acid together and using (concentrated) sulfuric acid (catalyst) (1) <p>PTO for ROUTE 2</p>	<p>Allow names or formulae for reagents but if both are given, both must be correct</p> <p>Allow correct species in unbalanced equations</p> <p>Allow any combination of structural, displayed or skeletal formulae for the intermediates</p> <p>Penalise missing H once only</p> <p>Ignore conditions e.g. heat / reflux</p> <p>Allow hydroxide ions / OH⁻</p> <p>Ignore concentration</p> <p>Do not award just ethanol / ethanolic</p> <p>Stand alone mark e.g. CH₃CH₂CH₂OH</p> <p>Allow propanol if correct structure shown somewhere</p> <p>Allow acidified potassium dichromate(VI) / Cr₂O₇²⁻ and H⁺</p> <p>Allow acidified manganate(VII)</p> <p>Ignore concentration of acid / formation of aldehyde</p> <p>Do not award hydrochloric acid / HCl</p> <p>Stand alone mark e.g. CH₃CH₂COOH</p> <p>Stand alone mark for C₃ compounds</p> <p>Allow (concentrated hydrochloric) acid / H⁺ / H₃O⁺ instead of sulfuric acid</p> <p>Ignore concentration of acid</p> <p>Ignore incorrect structure of ester e.g. with H or O missing</p>	(5)

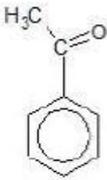
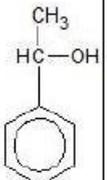


	<p>OR ROUTE 2</p> <p>Conversion to acyl chloride</p> <ul style="list-style-type: none"> (oxidise some of the propan-1-ol using) potassium dichromate(VI) and (dilute) sulfuric acid <p>and add phosphorus(V) chloride to propanoic acid (1)</p> <ul style="list-style-type: none"> name or structure of propanoyl chloride (1) <p>Formation of ester</p> <ul style="list-style-type: none"> react propan-1-ol and propanoyl chloride together (1) 	<p>Allow acidified potassium dichromate(VI) / $\text{Cr}_2\text{O}_7^{2-}$ and H^+</p> <p>Allow acidified manganate(VII)</p> <p>Ignore concentration of acid / formation of aldehyde</p> <p>Do not award hydrochloric acid / HCl</p> <p>Stand alone mark e.g. $\text{CH}_3\text{CH}_2\text{COCl}$</p> <p>Stand alone mark for C_3 compounds</p> <p>Ignore incorrect structure of ester e.g. with H or O missing</p>
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Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following:</p> <p>synthetic pathway that consists of:</p> <p>(Step 1)</p> <ul style="list-style-type: none"> (acylation of benzene) using ethanoyl chloride (1) use of aluminium chloride (and heat) (1) <p>(Step 2)</p> <ul style="list-style-type: none"> (reduction of) A with LiAlH_4 in ether (dry) (1) <p>(Step 3)</p> <ul style="list-style-type: none"> (dehydration of) B with (conc.) phosphoric acid/H_3PO_4 (1) <p>(Intermediates)</p> <ul style="list-style-type: none"> identification of A as phenylethanone and B as (1-phenylethanol 	<p>The compounds used can be stated or given within equations.</p> <p>Only award if part of a Friedel-Crafts reaction</p> <p>Only award if given to reduce an aromatic carbonyl or carboxylic acid</p> <p>Allow (conc.) sulfuric acid/H_2SO_4</p> <p>Only award if given to dehydrate an aromatic alcohol</p> <p>Accept formulae for names, but if both given, then both must be correct</p> <p>This also applies to reagents</p>	(5)



 (1)		Do not award use of other reagents not in the table.
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Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<p>An answer that makes reference to the following points: (1st Step)</p> <ul style="list-style-type: none"> HCN (and KCN) (1) Nucleophilic addition (1) $\text{CH}_3\text{CHO} + \text{HCN} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CN}$ (1) <p>(2nd Step)</p> <ul style="list-style-type: none"> Any identified (dilute) strong acid / H⁺ (1) Heat (under reflux) / reflux (1) Hydrolysis (1) $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_4^+$ or $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_3$ (1) 	<p>Ignore references to other conditions / solvent in step 1</p> <p>Allow HCN and CN⁻ / H⁺ and CN⁻ / H⁺ and KCN or KCN and H₂SO₄ / KCN and HCl or HCN at pH 8 – 9 M1 can be scored for the appearance of HCN in M3</p> <p>Do not award additional incorrect reaction types e.g. nitration Allow skeletal formulae in equations</p> <p>M4, 5 & 6 dependent on the formation of any nitrile in step 1</p> <p>Allow sodium hydroxide followed by acid Do not award conc. acid / just "acidify" / just "acid" Allow warm</p> <p>Do not award additional incorrect reaction types</p> <p>Allow two equations involving NaOH and H⁺</p> <p>Allow CH₃CH(OH)CN + 2H₂O + HCl → CH₃CH(OH)COOH + NH₄Cl</p>	(7)