Question Number	Answer	Mark
10(a)	**The only correct answer is C** (**R** and **S** only) *A is incorrect because P has six peaks* *B is incorrect because Q has six peaks* *C is incorrect because Q has six peaks*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is A (P)** *B is incorrect because **Q** has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet* *C is incorrect because **R** has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet* *D is incorrect because **S** has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet*	**(1)**

Question Number	Answer	Mark
10(c)	**The only correct answer is A** (**Q** only) *B is incorrect because **R** does not have a chiral carbon* *C is incorrect because **R** and **S** do not have a chiral carbon* *D is incorrect because **R** and **S** do not have a chiral carbon*	**(1)**

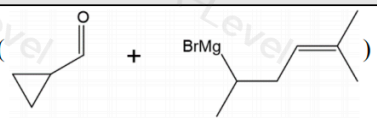
Question number	Answer	Mark
9	**The only correct answer is C** (525 (cm^3)) ***A*** *is incorrect because 225 cm^3 is the volume of oxygen needed to react with only 50 cm^3 propene* ***B*** *is incorrect because 300 cm^3 is the volume of oxygen needed to react with only 50 cm^3 but-1-ene* ***D*** *is incorrect because 700 cm^3 is the volume of oxygen needed to react with the whole mixture if the equations are balanced incorrectly by assuming that 1 mol of O_2 is needed to form 1 mol of H_2O*	**(1)**

Question number	Answer	Mark
10	**The only correct answer is C** (0.1 (cm^3)) ***A*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3* ***B*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3* ***D*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3*	**(1)**

Question number	Answer	Mark
16	**The only correct answer is D** (8 (cm^3)) ***A*** *is incorrect because 2 cm^3 of methane reacts with 4 cm^3 of oxygen* ***B*** *is incorrect because 4 cm^3 of methane would react with 4 cm^3 of oxygen if they reacted in a 1:1 mole ratio* ***C*** *is incorrect because 6 cm^3 would be the volume of argon if methane reacted with oxygen in a 1:1 mole ratio*	**(1)**

Question number	Answer	Mark
12(a)	**The only correct answer is D** (nucleophilic addition) ***A*** *is incorrect because electrophiles attack electron rich regions but the carbon atom attached to the magnesium is δ−* ***B*** *is incorrect because the Grignard reagent is not a source of free radicals* ***C*** *is incorrect because increasing the length of the carbon chain is not oxidation*	**(1)**

Question number	Answer	Mark
12(b)	**The only correct answer is B** ($CH_3CH_2CH(CH_3)MgBr$) ***A*** *is incorrect because this would form 1-phenylpentan-1-ol* ***C*** *is incorrect because this would form 1-phenyl-3-methylbutan-1-ol* ***D*** *is incorrect because this would form 1-phenyl-2,2-dimethylpropan-1-ol*	**(1)**

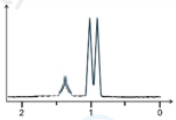
Question Number	Answer	Mark
20	**The only correct answer is A** () ***B*** *is not correct because these reagents would lead to the formation of compound* ***B*** ***C*** *is not correct because these reagents would lead to the formation of compound* ***B*** ***D*** *is not correct because these reagents would lead to the formation of compound* ***B***	**(1)** **Computer**

Question number	Answer	Mark
11(b)	**The only correct answer is A** (doublet and octet) ***B*** *is incorrect because the peak corresponding to the H attached to C with 2 CH_3 groups and CH will be an octet as there are 7 protons on the neighbouring carbons* ***C*** *is incorrect because the peak corresponding to the 2 CH_3 groups will be a doublet as there is 1 proton on the neighbouring carbon* ***D*** *is incorrect because the peak corresponding to the 2 CH_3 groups will be a doublet as there is 1 proton on the neighbouring carbon and the H attached to C with 2 CH_3 groups and CH will be an octet as there are 7 protons on the neighbouring carbons*	**(1)**

Question number	Answer	Mark
11(a)	**The only correct answer is B** (3095 – 3010 cm^{-1}) ***A*** *is incorrect because 3500 – 3300 cm^{-1} shows the presence of N-H in an amine which is present in valine* ***C*** *is incorrect because 2962 – 2853 cm^{-1} shows the presence of C-H in an alkane which is present in valine* ***D*** *is incorrect because 1725 – 1720 cm^{-1} shows the presence of C=O in an carboxylic acid which is present in valine*	**(1)**

Question number	Answer	Mark
17	**The only correct answer is A** (x is 30 and y is 40) ***B*** *is incorrect because water is a liquid at room temperature* ***C*** *is incorrect because 10 cm^3 of but-1-ene reacts with 60 cm^3 of oxygen to form 40 cm^3 of carbon dioxide so there is an initial decrease of 30 cm^3* ***D*** *is incorrect because 10 cm^3 of but-1-ene reacts with 60 cm^3 of oxygen to form 40 cm^3 of carbon dioxide so there is an initial decrease of 30 cm^3 and water is a liquid at room temperature*	**(1)**

Question Number	Answer	Mark
13(a)	**The only correct answer is B** (Two) ***A*** *is incorrect because there are two carbon environments* ***C*** *is incorrect because there are two carbon environments* ***D*** *is incorrect because there are two carbon environments*	**(1)**

Question Number	Answer	Mark
13(b)	**The only correct answer is B** () ***A*** *is incorrect because this is the spectrum for 2,3-dimethylbut-2-ene* ***C*** *is incorrect because this is the spectrum for propane* ***D*** *is incorrect because this is the spectrum for 2-methylbutane*	**(1)**

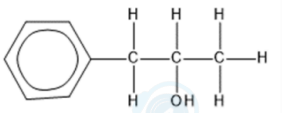
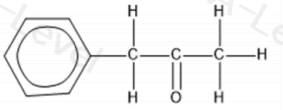
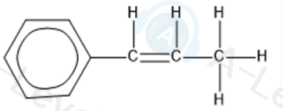
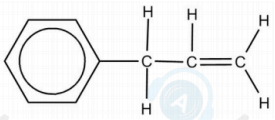
TOTAL FOR SECTION A = 20 MARKS

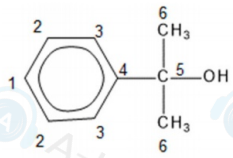
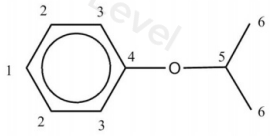
Question number	Answer	Mark
14	**The only correct answer is A** (CH_2=CHCOOH) ***B*** *is incorrect because phenol does not react with ethanol* ***C*** *is incorrect because 2-propen-1-ol does not react with sodium hydroxide or ethanol* ***D*** *is incorrect because ethanoic acid does not react with hydrogen in the presence of a nickel catalyst*	**(1)**

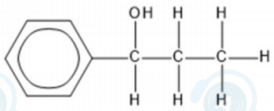
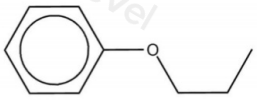
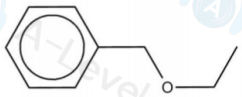
Question number	Answer	Mark
13	**The only correct answer is C** (0.6) ***A*** *is incorrect because the amino acid in the lower spot will have an R_f value of about 0.2* ***B*** *is incorrect because the distance moved by X is measured from the solvent front instead of from the baseline* ***D*** *is incorrect because the amino acid in the higher spot will have an R_f value of about 0.8*	**(1)**

Question Number	Answer
10	**The only correct answer is C** (dissolve in the minimum volume of hot solvent, filter to remove the insoluble impurities, then cool and filter to remove the soluble impurities) ***A** is incorrect because the hot solvent should be used first* ***B** incorrect because there is no cold filtering* ***D** is incorrect because the first filtration removes the insoluble impurities and the second filtration removes the soluble impurities*

Question Number	Answer	Additional Guidance	Mark
17(a)	• calculation of mol C / CO_2 **(1)** • calculation of mol H **(1)** • calculation of mol of O **(1)** • formula **(1)** **Comment** – alternative method via moles of A • M1 calculate moles of A : 5.26÷136 =0.0387 (mol) • M2 calculate moles of CO_2 and H_2O • M3 use combustion equation to show A forms $9CO_2$ and $6H_2O$, so C=9 and H=12 • M4 use of Mr to show mass due to O = 16, so number of O atoms = 1 If candidate does not score 4 marks, mark using method that gives best score	Example of calculation: mol CO_2 = 15.3/44 = 0.34773 = mol C or mass C = 15.3 x 12/44 = 4.1727 (g) **and** mol C = 4.1727/12 = 0.34773 mol H_2O = 4.18/18 = 0.23222 **and** mol H = 2 x 0.23222 = 0.46444 or mass H = 4.18 x 2/18 = 0.46444 (g) **and** mol H = 0.46444 mass O = 5.26 – 4.1727 – 0.46444 = 0.62286 (g) **and** mol O = 0.62286/16 = 0.038929 **or** moles of O = 5.26/136 = 0.03876 (mol) TE on mass C and H ratio mol $\frac{0.34773}{0.038929}$ C : $\frac{0.46444}{0.038929}$ H : $\frac{0.038929}{0.038929}$ O 9 : 12 : 1 So formula is $C_9H_{12}O$ (and this is the same as the molecular formula as M_r = (9 x 12) + (12 x 1) + 16 = 136) No TE on incorrect mol Ignore SF except 1 SF at each stage Comment : Ignore minor rounding errors e.g. 4.172 is acceptable for mass of C Allow masses of C, H and O to be determined and expressed as percentages e.g. C = 79.4%, H = 8.8%, so O = 11.8% Allow alternative methods	**(4)**

Question Number	Answer	Additional Guidance	Mark
17(b)	• structure of **A** **(1)** • structure of **B** **(1)** • structure of **C** **(1)** • structure of **D** **(1)** • structure of **E** **(1)**	Examples of structures  Ignore connectivity of OH  CHI_3 (standalone mark)  Allow *E* or *Z* isomer or both isomers  Allow displayed / structural formulae or any combination of these / skeletal formulae Allow Kekule Structures Allow **D** TE on incorrect 2° alcohol **A** e.g. if A is C_6H_5 $CH(OH)C_2H_5$ Allow **E** as TE on incorrect 1° alcohol **A** e.g. if A is $C_6H_5CH_2CH_2CH_2OH$ If **D** and **E** are the wrong way around, allow (1) for M4 and M5	**(5)**

Question Number	Answer	Additional Guidance	Mark
17(c)	An explanation that makes reference to the following points: • structure of **F** **(1)** • carbon atoms labelled **(1)**	Example of structure:  Allow displayed / structural formulae or any combination of these / skeletal formulae Allow alternative clear ways of identifying carbon atoms Allow  M2 dependent on M1, unless very near miss (e.g. accidental omitting H on OH group)	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(d)	An answer that makes reference to the following points: • structure of G **(1)** • *m*/*z* corresponds to $C_7H_7O^+$ / $C_6H_5CHOH^+$ / $C_6H_5OCH_2^+$ / $C_6H_5CH_2O^+$ / loss of C_2H_5 **(1)**	Example of structure  OR  OR  Allow any combination of structural and displayed formula / skeletal formula – if 2 structures are shown both must be incorrect Ignore missing + M1 and M2 are standalone marks No TE from incorrect structure	**(2)**

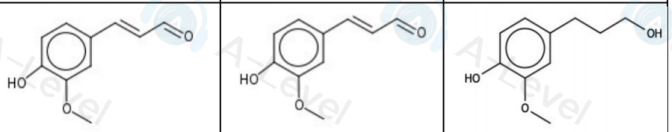
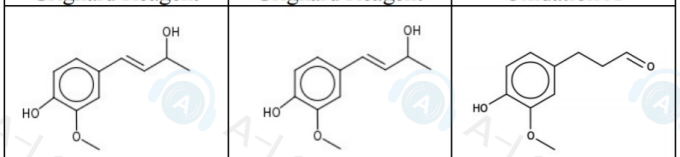
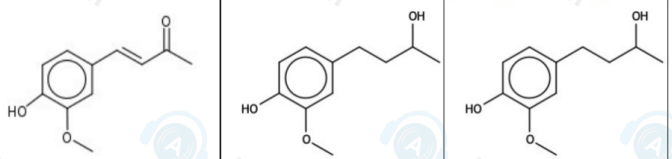
(Total for Question 17 = 13 marks)

Question Number	Answer		Additional Guidance
19	An explanation that makes reference to the following points:		
	• Step **1** $LiAlH_4$/lithium aluminium hydride/ lithium tetrahydridoaluminate **and** (dry) ether	**(1)**	Allow lithal Do not award $NaBH_4$
	• Step **2** KBr and conc H_2SO_4 or HBr or PBr_3 / I_2 and (red) P or PI_3 or HI / PCl_5 or PCl_3	**(1)**	Accept phosphoric(V) acid for sulfuric acid Allow ≥ 50% for conc Allow HCl
	• compound X bromoethane / C_2H_5Br iodoethane / C_2H_5I chloroethane / C_2H_5Cl	**(1)**	Dependent on the reagent used in step 2. Allow any type of formula
	• Step **3** magnesium **and** (dry) ether	**(1)**	Do not award if other reagents are added
	• Grignard reagent	**(1)**	CH_3CH_2MgX/ CH_3CH_2-Mg-X Do not award CH_3CH_2XMg Dependent on compound **X**
	• Step 4 dry ice/carbon dioxide/CO_2 (and then hydrolyse using an acid/water)	**(1)**	Allow CO_2 and H^+/acid
			No TE Ignore refluxing/any temperature throughout

Question Number	Answer		Additional Guidance
19	An explanation that makes reference to the following points:		
	• Step **1** $LiAlH_4$/lithium aluminium hydride/ lithium tetrahydridoaluminate **and** (dry) ether	**(1)**	Allow lithal Do not award $NaBH_4$
	• Step **2** KBr and conc H_2SO_4 or HBr or PBr_3 / I_2 and (red) P or PI_3 or HI / PCl_5 or PCl_3	**(1)**	Accept phosphoric(V) acid for sulfuric acid Allow ≥ 50% for conc Allow HCl
	• compound X bromoethane / C_2H_5Br iodoethane / C_2H_5I chloroethane / C_2H_5Cl	**(1)**	Dependent on the reagent used in step 2. Allow any type of formula
	• Step **3** magnesium **and** (dry) ether	**(1)**	Do not award if other reagents are added
	• Grignard reagent	**(1)**	CH_3CH_2MgX/ CH_3CH_2-Mg-X Do not award CH_3CH_2XMg Dependent on compound **X**
	• Step 4 dry ice/carbon dioxide/CO_2 (and then hydrolyse using an acid/water)	**(1)**	Allow CO_2 and H^+/acid
			No TE Ignore refluxing/any temperature throughout

Question Number	Answer	Additional Guidance	Mark
15(a)(i)	An answer that makes reference to the following points: • $C_{17}H_{26}O_4$		(1)

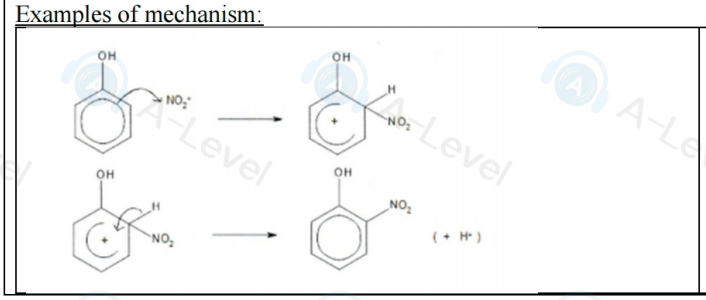
Question Number	Answer	Additional Guidance	Mark
15(a)(ii)	An answer that makes reference to the following points: • the OH is attached to a chiral carbon / gingerol exists as optical isomers (1) • The wedge shows the stereochemical arrangement / shows the shape of the molecule at the carbon (it is attached to) (1)	Ignore arguments about repulsion of the electrons Allow it shows the 3d arrangement of the C-OH bond Allow because the molecule is tetrahedral at the carbon Ignore just the molecule/shape is tetrahedral Ignore the molecule is not planar at the carbon Do not award the molecule is trigonal planar at the carbon Award (a wedged shaped bond) indicates the bond / OH group is in front of the plane of the paper / in the foreground Allow the wedge shaped bond shows the -OH group is in a different plane (to the carbon chain) Do not award a wedge shaped bond indicates the bond is behind the plane of the paper / in the background	(2)

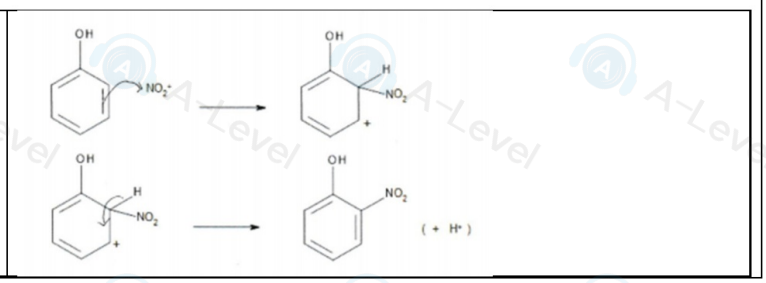
Question Number	Answer	Additional Guidance	Mark
15(b)	An answer that makes reference to the following points: • Reagents and conditions for Step 1 (1) • structure of intermediate 1 (1) • reagents and conditions for Step 2 (1) • structure of intermediate 2 (1) • reagents and conditions for Step 3 (1) • structure of intermediate 3 (1) • reagents and conditions for Step 4 (1)	Look for any of the given reagents and conditions and intermediates, but use only one Route (the one scoring the most marks). Allow the intermediates even if they would not be formed from the reagents and conditions stated. Route 1 / Route 2 / Route 3 Oxidation A / Oxidation A / Reduction  Grignard Reagent / Grignard Reagent / Oxidation A  Oxidation B / Reduction / Grignard Reagent  Reduction / Oxidation B / Oxidation B Allow any type of structural diagram / skeletal diagram Penalise lack of sulfuric acid / H^+ and/or use of HCl in oxidation steps	(7)

		once only Oxidation A $K_2Cr_2O_7$ and H_2SO_4 / H^+ (with distillation) Or acidified $K_2Cr_2O_7$ Allow acidified $KMnO_4$ / $KMnO_4$ and H_2SO_4 Do not award reflux Oxidation B	

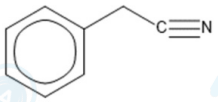
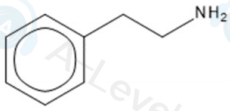
Question Number	Answer	Additional Guidance	Mark
19(a)(i)	• curly arrow from on or within the circle to anywhere towards or on NO_2^+ **(1)** • intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon atom **and** some part of the positive charge must be within the horseshoe **(1)** • curly arrow from **C–H bond** to anywhere in the hexagon, and final organic product shown **(1)**	Allow arrow that starts from anywhere within the hexagon Do not award curly arrow starting on or outside the hexagon Do not award missing + on electrophile Do not award missing OH in M1 only Do not award dotted bonds to H and NO_2 unless they are part of a 3D structure Do not award formation of 4-nitrophenol / 3-nitrophenol in M2 only Comment – some part of the 'horseshoe' opening must be opposite the tetrahedral carbon, so only penalise if the line of the circle extends level with or past the tetrahedral C Ignore missing H^+ Ignore additional equations to generate NO_2^+ and reform catalysts	**(3)**

Examples of mechanism:

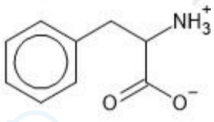


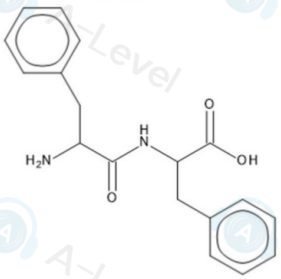


Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An explanation that makes reference to the following points: Phenol is more reactive than benzene / requires milder conditions because: • the **lone pair** (of electrons) on oxygen overlaps with the pi cloud / delocalised electrons / ring **(1)** • so increases the electron density of the (benzene) ring **(1)**	Allow reverse argument for why benzene is less reactive / requires harsher conditions Allow lone pair on OH group Ignore just lone pair Allow spreads into the pi cloud / delocalised electrons / ring (of electrons) Allow interacts with the pi cloud / delocalised electrons / ring (of electrons) Allow donated to the pi cloud / delocalised electrons / ring (of electrons) Allow the (benzene) ring is more susceptible to electrophilic attack Allow makes the (benzene) ring more nucleophilic Do not award 'makes the ring more electronegative'	**(2)**

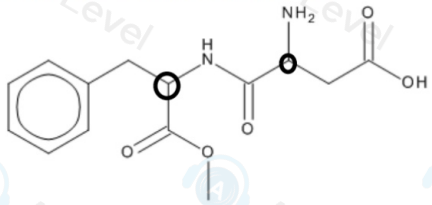
Question Number	Answer	Additional Guidance	Mark
19(b)	An answer that makes reference to the following points: • Reagent for step 1: potassium cyanide and (aqueous) ethanol **(1)** • First intermediate: 2-phenylethanenitrile **(1)**  • Reagent for step 2: lithium tetrahydridoaluminate(III) / $LiAlH_4$ in (dry) ether (followed by (hydrolysis with) dilute acid / H^+) **(1)** • Second intermediate: 2-phenylethylamine **(1)**  • Reagent for step 3: ethanoyl chloride / CH_3COCl / ethanoic anhydride / $(CH_3CO)_2O$ **(1)**	Allow displayed / structural formulae or any combination of these / skeletal formulae for intermediates Ignore any references to heat / reflux throughout Ignore HCN Allow NaCN Stand alone mark Allow -CN (i.e.triple bond not displayed) Do not award H_2 and Ni / Pt / Pd Stand alone mark Allow TE from M2, if extra C shown in nitrile Do not award ethanoic acid / CH_3COOH Ignore $AlCl_3$	**(5)**

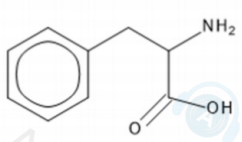
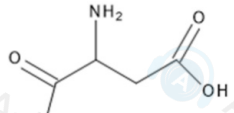
		Comment – allow (3) for use of Grignard reagent ; M1 –formation of Grignard, then reaction with HCHO to form $C_6H_5CH_2CH_2OH$, then reaction with KBr / H_2SO_4 to form $C_6H_5CH_2CH_2Br$, then reaction with NH_3 M2 structure of $C_6H_5CH_2CH_2NH_2$ M3 reaction of $C_6H_5CH_2CH_2NH_2$ with CH_3COCl	

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	• structure of zwitterion	Example of zwitterion:  Allow '+' anywhere on NH_3 group Allow carboxylate ion shown with charge delocalised across two oxygen atoms Allow displayed / structural / skeletal formulae or any combination of these Ignore bond lengths and bond angles	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	• structure of dipeptide	Example of dipeptide:  Allow displayed / structural / skeletal formulae or any combination of these Allow C_6H_5 for the phenyl groups Ignore bond lengths and bond angles Ignore connectivity of OH unless displayed as C-H-O (i.e. a bond shown from C to H then to O)	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(iii)	• $C_{14}H_{18}N_2O_5$	Allow symbols in any order e.g. $C_{14}H_{18}O_5N_2$	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(iv)	• two chiral carbon atoms circled	Example of circled chiral carbons:  Allow other ways of representing the two carbon atoms e.g. asterisk * If more than two carbons are circled then do not award	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(v)	• structure of methanol (1) • structure of 2-amino-3-phenylpropanoic acid (1) • structure of 2-aminobutanedioic acid (1)	Examples of structures: CH_3OH / —OH  	(3)

Question Number	Answer	Additional Guidance	Mark
21(a)	• 2-hydroxybenzoic acid	Accept 2-hydroxybenzenecarboxylic acid Allow minor misspellings such as 2-hydroxylbenzenoic acid Ignore missing hyphen or comma instead of hyphen	(1)

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	• carboxylic acid **and** ester **and** benzene / arene	Accept names given in any order Allow just 'carboxyl' for carboxylic acid Allow just 'carboxylic' Allow phen**y**l for benzene/arene Allow aromatic ring for benzene/arene Ignore formulae of groups Do not award phenol Do not award carbo**n**yl	(1)

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	• correct equation	Example of equation:  Accept displayed / skeletal formulae Allow use of C_6H_4 for the benzene ring Do not award molecular formulae	(1)

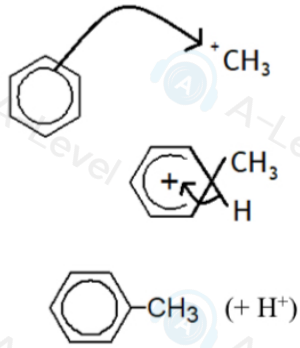
Question Number	Answer	Additional Guidance	Mark
21(b)(iii)	• calculation of amount of salicylic acid **(1)** • calculation of theoretical mass of acetyl salicylic acid **(1)** • calculation of actual mass of acetyl salicylic acid **(1)**	Example of calculation: mol salicylic acid used = $\frac{2.00}{138}$ = 0.014493 (mol) theoretical mass of acetyl salicylic acid = 0.014493 × 180 = 2.6087 (g) TE on M1 actual mass of acetyl salicylic acid = $\frac{2.6087 \times 74.8}{100}$ = 1.9513 (g) TE on M2 provided answer ≤ 5.00 (g) OR mass salicylic acid converted = 2.00 × 0.748 = 1.496 (g) (1) mol salicylic acid converted = $\frac{1.496}{138}$ = 0.01084 (mol) (1) mass acetyl salicylic acid formed = 0.01084 × 180 = 1.9513 (g) Ignore SF except 1 SF Correct answer scores without working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
21(c)(i)	• completed equation	Example of equation:  	(1)

Question Number	Answer	Additional Guidance	Mark
21(d)	• methanol / CH_3OH	Allow displayed formula / combination of structural and displayed formula If name and formula are given then both must be correct Allow methyl alcohol Ignore reference to acid catalyst/ H_2SO_4/ HCl/ heat Do not award methan**a**l Do not award CH_4O	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(e)	• chemical shift ranges for OH and CH_3 in acetylsalicylic acid **(1)** • chemical shift ranges for OH and CH_3 in methyl salicylate **(1)**	Example of table: Acetylsalicylic acid: Type of proton: OH; Chemical shift / ppm: 10.0 – 12.0 Acetylsalicylic acid: Type of proton: CH_3; Chemical shift / ppm: 1.6 – 2.8 Methyl salicylate: Type of proton: OH; Chemical shift / ppm: 3.8 – 7.6 Methyl salicylate: Type of proton: CH_3; Chemical shift / ppm: 2.8 – 4.3 Allow ranges in reverse order e.g. 12.0 – 10.0 Allow any range within these ranges 11.8 – 10.2 If no other mark is awarded, allow **(1)** for any two correct ranges If no other mark awarded, allow **(1)** for any three single values within the correct ranges or two single values with one acceptable range	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(f)	• **(M1)** calculation of mol NaOH added at start **(1)** • **(M2)** calculation of mol HCl used in titration **(1)** • **(M3)** calculation of mol NaOH remaining in 250 cm^3 **(1)** • **(M4)** calculation of mol acetylsalicylic acid reacted **(1)** • **(M5)** calculation of acetylsalicylic acid mass **(1)** • **(M6)** calculation of percentage of acetylsalicylic acid **and** deduction of Brand of tablet **(1)**	Example of calculation: mol NaOH = $\frac{25.0 \times 1.00}{1000}$ = 0.025 / 2.5×10^{-2} (mol) mol HCl = $\frac{16.95 \times 0.100}{1000}$ = 0.001695 / 1.695×10^{-3} (mol) (mol NaOH remaining in 25.0 cm^3 = 0.001695 / 1.695×10^{-3} (mol)) mol NaOH remaining in 250 cm^3 = 0.01695 / 1.695×10^{-2} (mol) mol NaOH = 0.025 – 0.01695 = 0.00805 / 8.05×10^{-3} (mol) mol acetylsalicylic acid = $\frac{0.00805}{2}$ = 0.004025 mass acetylsalicylic acid = 0.004025×180 = 0.7245 (g) percentage of acetylsalicylic acid = $\frac{0.7245 \times 100}{0.760}$ = 95.329 (%) **and** Brand B Allow TE at each stage Brand / percentage with no working scores (0) Ignore SF except 1 SF in the final mass calculated Ignore incorrect intermediate units Do not credit a division of moles by 2 if carried out before the subtraction	**(6)**

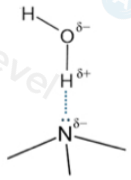
Question number	Answer	Additional guidance	Mark
17(a)	An answer that makes reference to the following points: • curly arrow from, on or within circle to C of CH_3^+ (1) • structure of intermediate ion including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **and** with some part of the positive charge within the horseshoe (1) • curly arrow from C–H bond to anywhere in the ring reforming the delocalised structure **and** correct organic product (1)	An example of a mechanism:  Allow from within the hexagon Allow halogen carrier with $CH_3^{\delta+}$ TE from M1 on incorrect electrophile Accept skeletal structure	3

Question number	Answer	Additional guidance	Mark
17(b)	An explanation that makes reference to the following points: • this reaction produces (a pair of) enantiomers / a racemic mixture / racemate (1) • the molecule is planar around the C=N bond (1) • the CN^-/nucleophile can attack from either side / both sides / above or below (the double bond) (1)	 Allow optical(ly active) isomers Allow "molecules that are (non-superimposable) mirror images" Do not award optically active solution Ignore "different" isomers Ignore chiral carbon Allow planar around reaction site Allow (trigonal) planar around the $^{\delta+}C$ Do not award "planar carbocation" Ignore left and right Marks are independent	3

Question number	Answer	Additional guidance	Mark
17(c)	An answer that makes reference to the following points: • hydrolysis (1) • aqueous acid solution / H^+(aq) (1) • reflux (1)	 Ignore modifiers Allow specific aqueous named strong acids or formulae Allow aqueous alkali solution followed by neutralisation with acid Do not award concentrated acid Further reagents negate M2 Allow heat M3 dependent on M1 or M2	3

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	• skeletal structure	Example of a diagram: N Ignore non-skeletal structures Ignore bond angles	(1)

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	• tertiary / 3°	No TE from (a)(i)	(1)

Question Number	Answer	Additional Guidance	Mark
17(a)(iii)	An answer that makes reference to the following points: • diagram showing one water molecule correctly aligned to H−bond with an angle 170-190° • lone pair on nitrogen atom lined up with hydrogen bond • one dipole on water (showing both δ+ and δ−) • δ− charge on nitrogen	Example of a diagram:  Allow any depiction of H−bond dashes/dots etc. Ignore $H^{\delta+}$ / $C^{\delta+}$ in TMA TE on structure in 17(a)(i), if a primary or secondary amine is drawn then the H−bond may be from the amine hydrogen to the water oxygen lone pair. Ignore bond lengths and angles of other bonds 4 points scores 2 marks 2 or 3 points score 1 mark	(2)

Question Number	Answer	Additional Guidance	Mark
17(a)(iv)	• balanced ionic equation	$(CH_3)_3N + H^+ \rightarrow (CH_3)_3NH^+$ $(CH_3)_3N + H_2O \rightarrow (CH_3)_3NH^+ + OH^-$ Allow molecular formula: $C_3H_9N + H^+ \rightarrow C_3H_9NH^+ / C_3H_{10}N^+$ $C_3H_9N + H_2O \rightarrow C_3H_9NH^+ / C_3H_{10}N^+ + OH^-$ TE on structure in 17a(i) Allow equilibria equations	(1)

Question Number	Answer	Additional Guidance	Mark
17(b)	• calculation of M_r (1) • mass calculated with answer to 2 or 3 SF (1) Alternative method: • calculation of moles (1) • multiplication by M_r and answer to 2 or 3 SF (1)	Example of a calculation: $M_r = 75$ $3.90 \times 10^{-6} \times 5.00 \times 75 = 0.0014625$ $= 1.5 \times 10^{-3}$ / 0.0015 (g) Accept 1.46×10^{-3} / 0.00146 (g) TE on M1 calculation $3.90 \times 10^{-6} \times 5.00 = 1.95 \times 10^{-5}$ $1.95 \times 10^{-5} \times 75 = 1.5 \times 10^{-3}$ / 0.0015 (g) Correct answer to 2 or 3 SF scores 2 Units, if given, should match the value	(2) Expert

Question Number	Answer	Additional Guidance	Mark
17(c)(i)	An explanation that makes reference to the following points: • (inert) gas carries samples through the column / the gas is a mobile phase **and** compounds are attracted to the contents of the column / the contents in the column are the stationary phase • compounds that are strongly attracted to the stationary phase take longer to pass through the column / compounds that are not attracted to the stationary phase take less time to pass through the column	Ignore the temperature of the oven can affect the separation Ignore affinity to the mobile phase / carrier gas Do not award reaction with the gas Accept adsorbed / absorbed to the contents of the column Allow dissolves in the stationary phase Ignore references to the nature of the stationary phase Accept references to being adsorbed / absorbed to the contents of the column Ignore different attractions leads to different/longer retention time	(2)

Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	• (retention) time	Ignore units of time	(1)

Question Number	Answer	Additional Guidance	Mark
17(c)(iii)	• mass spectrometry	Allow mass spectroscopy Allow MS	(1)

(Total Question 17 = 11 marks)