PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 18: ORGANIC CHEMISTRY III

SCORE	PERCENTAGE
/585	%

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Q59.

Benzene reacts with chlorine to produce 1,2,3,4,5,6-hexachlorocyclohexane, $C_6H_6Cl_6$, by

☒ **A** free radical addition.

☒ **B** free radical substitution.

☒ **C** electrophilic addition.

☒ **D** electrophilic substitution.

(Total for question = 1 mark)

Q60.

Which of the following reacts with benzene under suitable conditions to form $C_6H_5COC_6H_5$?

☒ **A** C_6H_5CHO

☒ **B** C_6H_5COOH

☒ **C** $C_6H_5CH_2OH$

☒ **D** C_6H_5COCl

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Reject	Mark
	C		**1**

Q2.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q3.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to • (similarity) both are reduction reactions **(1)** • (difference 1) reagents for preparation of phenylamine are tin and (conc.) hydrochloric acid **(1)** • (difference 2) reagents for preparation of butylamine are either Hydrogen gas **and** nickel catalyst **or** lithium tetrahydridoaluminate(III) **and** (dry) ether **(1)**	Ignore both require hydrogen Allow Iron for tin Do not award dilute hydrochloric acid/ sulfuric acid Lithium aluminium hydride / Lithal / $LiAlH_4$	**(3)**

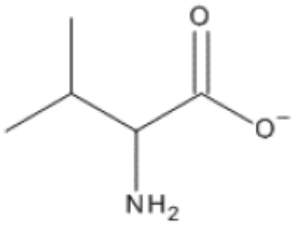
Q4.

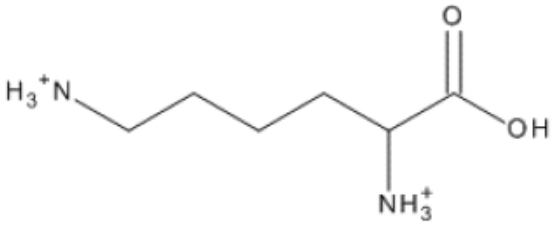
Question Number	Answer	Additional Guidance	Mark
(a)	• reacts with acids to form a salt/proton acceptor	Allow electron pair donor	**1**
(b)	B		**1**

Q5.

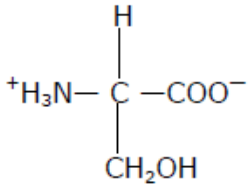
Question Number	Correct Answer	Reject	Mark
	B		1

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)		Do not award displayed or structural formulae	**1**

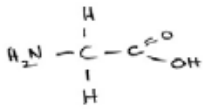
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	 **both** NH_2 groups must be protonated for the mark	Do not award displayed or structural formulae	**1**

Q7.

Question Number	Acceptable Answers	Reject	Mark
(a) (i)	 OR $HOCH_2CH(NH_3^+)CO_2^-$ ALLOW Charge on NH_3 shown on N atom		1

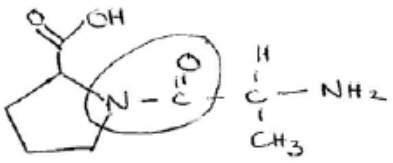
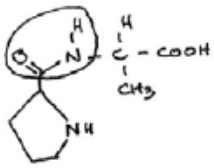
Question Number	Acceptable Answers	Reject	Mark
* (a) (ii)	**EITHER** At pH 5.68 both NH_2 groups on lysine will be NH_3^+ / lysine has an overall positive charge while serine has no overall charge (1) So only lysine will move to negative terminal / in an electric field (1) **OR** lysine has a greater positive charge (than serine) (1) Lysine will move faster / further in an electric field (1) ALLOW They have different charges so will move different distances/ at different speeds 1 mark max IGNORE Answers based on molecular mass		2

Question Number	Acceptable Answers	Reject	Mark
* (b)	**COMMENT** Ignore references to H bonds from amino and carboxyl groups and assume that "phenylalanine cannot form H bonds" refers to R group in the compound. Serine has an OH (alcoholic) group which can form H bonds with water (1) Benzene ring in phenylalanine is bulky /is large and non-polar / is hydrophobic / London forces between phenylalanine molecules are significant ALLOW van der Waals etc for London ALLOW If MP1 is not scored, 'phenylalanine cannot form H bonds with water' can score MP2 (1)	VdW / id-id	2

Question Number	Acceptable Answers	Reject	Mark
(c)	H, -H, H- ALLOW $NH_2CH_2CO_2H$ / NH_2CH_2COOH 		1

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	(Measure) the amount of / angle of / degree of /extent of rotation (of plane of polarization/ plane polarized light) IGNORE direction they rotate the light	Just "polarimetry"	1

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	(Leu has 1 chiral C but) Ile has 2 chiral C / 2 asymmetric C atoms OR The R group in Ile contains a chiral C (Leu has 2 optical isomers but Ile has 4 optical isomers) ALLOW Ile has (1) more chiral C (than leu) Chiral centres shown on formulae	Leu has no chiral C	1

Question Number	Acceptable Answers	Reject	Mark
(e)	 CON circled with N as part of ring (1) Fully correct structure (1) ALLOW $-CH(CH_3)NH_2$ shown skeletally **OR** Dipeptide using NH_2 from alanine and COOH from proline, with correct structure and CONH circled **This scores max (1)** 	Just N-C circled .	2

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	CH_3CHO / CH_2CHOH ALLOW Displayed or semi-displayed formula C_2H_4O	CH_3COH (unless with correct structure)	1

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	$C_{18}H_9NO_4$		1

Question Number	Acceptable Answers	Reject	Mark
(f)(iii)	**Several methods are possible.** **Amount of O should have been calculated and final answer should be consistent with masses/mols in calculation. There should be evidence of working at each stage for 4 marks** **MP1** 2.614 g CO_2 contain 0.7129 g C 0.2673 g H_2O contain 0.0297 g H OR 2.614 g CO_2 contain 0.059409 mol CO_2 0.2673 g H_2O contain 0.01485 mol H_2O (1) **MP2** Mass O in Q = (1.00 – 0.7129- 0.0297 -0.04620) = **0.2112** g (1) % mol/100g ratio C 71.29 5.94 18 H 2.97 2.97 9 N 4.62 0.33 1 O 21.12 1.32 4 **MP3** Number of moles of each element OR Number of mol in 100g Allow TE for incorrect mol of H – see calculation below (1)		4

	MP4 Ratio stated must follow from numbers in calculation (so empirical formula is consistent with the molecular formula of **Q**) (1) **OR** **Calculation following error in H scores max (3)** If mass H is wrongly calculated as 0.01485 g, then mass O will be 0.22605 (TE for MP2) (1) % mol/100g ratio C 71.29 5.94 18 H 1.48 1.48 4.5 N 4.62 0.33 1 O 22.60 1.41 4.27 Number of moles of each element (TE for MP3) (1) Ratio stated and empirical formula said not to be consistent (TE for MP4) (1)		

Question Number	Acceptable Answers	Reject	Mark
(f)(iv)	Mass of molecular ion in mass spectrum = 303 / any sensible fragment with mass eg 302 / 158 / 145 or smaller fragment (1) ALLOW Molecular ion based on formula in f(i) Number of peaks in nmr = 2 / 3 ALLOW 5 (1)	4	2

Q8.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q9.

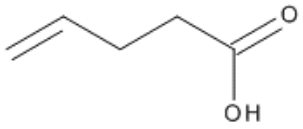
Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • peak at 1720 (cm^{-1}) **(1)** • shows presence of a C=O bond / carbonyl **(1)**	 Allow any absorbance between 1720 to 1700 (cm^{-1}) Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H Ignore references to alkane C-H bonds / fingerprint region Do not award just 'ketone' for MP2	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • peak between 3750 and 3200 (cm^{-1}) will disappear / will be absent from the spectrum OR Peak(s) above 3000(cm^{-1}) will disappear / will be absent from the spectrum **(1)** • (because) 3-methylbutan-2-ol / the alcohol / O-H has now been removed **(1)**	 Allow any absorbance between 3750 to 3200 (cm^{-1}) Ignore references to fingerprint region	**(2)**

Q10.

Question number	Answer	Mark
(i)	**The only correct answer is D** ($C_5H_8O_2$) ***A*** *is incorrect because C_7H_{16} has a molecular ion m / z = 100.1248* ***B*** *is incorrect because $C_6H_{12}O$ has a molecular ion m / z = 100.0885* ***C*** *is incorrect because $C_6H_{14}N$ has a molecular ion m / z = 100.1123*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• alkene / C=C **(1)** • carboxylic acid / COOH **(1)**	The functional groups can be in any order Ignore just 'double bond' Ignore just C=O and OH	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• skeletal formula of **X**	Example of skeletal formula  Ignore bond lengths and bond angles	(1)

Q11.

Question Number	Answer	Additional Guidance		Mark
	• correct formula (phenol) **(1)** • balanced equation **(1)**	Example of equation $C_6H_5OH + 7O_2 \rightarrow 6CO_2 + 3H_2O$ Allow C_6H_6O Do not award [O] Ignore state symbols even if incorrect		(2)

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• mass of carbon in both substances **(1)** • molar masses of both substances **(1)** • calculation of percentages by mass of carbon **(1)**	Example of calculation (12 x 7 =) 84 Phenylmethanol 108 and Benzoic acid 122 Phenylmethanol (84 ÷ 108) x100 = 78%/ 77.8%/ 77.78% / 77.7 % Benzoic acid (84 ÷ 122) x 100 = 68.85%/ 68.9%/69% Ignore sf except 1 Allow TE on incorrect M_r values Allow (2) for 11.1% and 9.8% calculated using 12 not 84 Allow 'rescue' (1) for one substance completely correct	(3)

Question Number	Answer	Additional Guidance	Mark
(ii)	A description that makes reference to: • black smoke	Allow Black fumes/soot/(yellow) smoky flame / grey smoke Ignore carbon particulates Do not award carbon monoxide/yellow flame	(1)

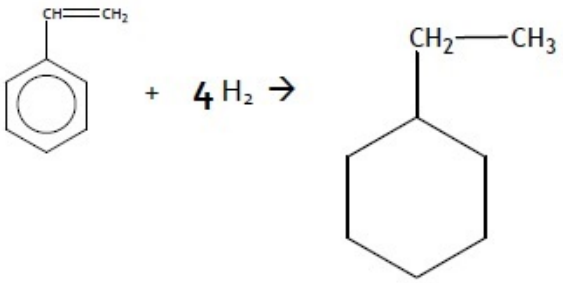
Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to • Alkenes	Allow Cycloalkenes/cycloalkanes/alkynes/ carbon-carbon double bonds Ignore Ethene/named alkenes/named alkynes Do not award benzene/arenes	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to • (window) above the safety line means the exhaust system is not strong enough to draw in the fumes **(1)** • so the toxic fumes will escape (into the laboratory) **(1)**	Allow reverse argument Allow reference to exhaust/fan not able to prevent gas escaping Allow poisonous/harmful/irritant/ carbon monoxide/soot for 'toxic fumes' Ignore reference to protection from splashing etc	(2)

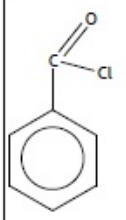
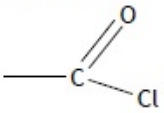
Q13.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	Addition / reduction / free-radical addition IGNORE references to 'hydrogenation'	'redox' 'electrophilic addition' 'nucleophilic addition'	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	**First mark:** **Delocalization** (of π/p electrons in benzene ring) **(1)** IGNORE reference to 'resonance' **Second mark:** Results in more **energy** needed to **break** the **bonds** in benzene (compared with three separate π bonds) **(1)** ALLOW confers **stability** on the molecule / makes benzene **more stable** (than expected) IGNORE Reference to carbon-carbon bond lengths Values of any enthalpy changes Mark the two points independently		**2**

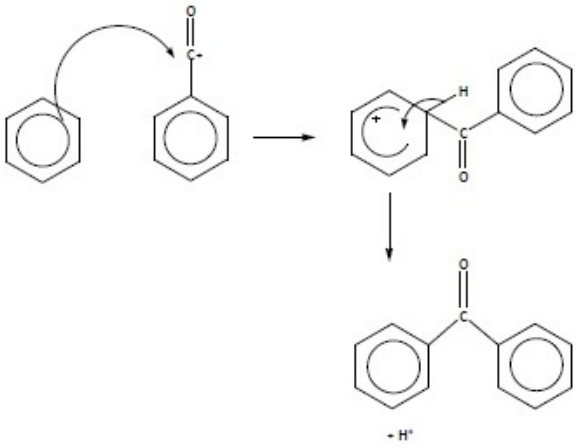
Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	 (ΔH =) **— 328** (kJ mol^{-1}) **First mark**: For "4" **Second mark**: Product as above / correct skeletal formula of product ALLOW Side chain written as $-C_2H_5$ **Third mark**: —328 (kJ mol^{-1}) **NOTE** **One** H_2 added showing a CQ correct product with only side chain reduced and cq ΔH = —120 (kJ mol^{-1}) scores **(2)** **Three** H_2 added showing a CQ correct product with only the benzene ring reduced and cq ΔH = —208 (kJ mol^{-1}) scores **(2)** **Five** H_2 added with fully correct product drawn and ΔH = —448 (kJ mol^{-1}) scores **(2)** **Three and a half** H_2 added showing a fully correct product and ΔH = —268/—293(.3)(kJ mol^{-1}) scores **(2)** **NOTE** Mark scoring points independently		**3**

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Question Number	Acceptable Answers	Reject	Mark
(b)(i)	 Mark awarded for displaying 		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Electrophilic substitution **BOTH** words needed IGNORE references to 'acylation' and /or 'Friedel-Crafts'		**1**

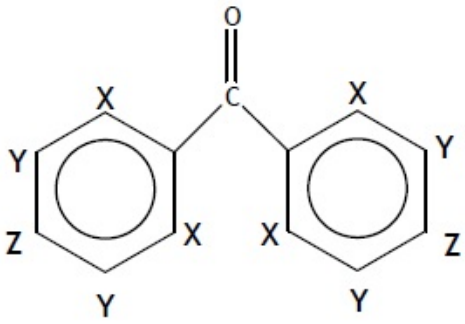
Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	Friedel **and** Crafts **BOTH** names are needed for this mark		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	**First mark:** $\mathbf{C_6H_5COCl}$ + $AlCl_3$ → $\mathbf{C_6H_5CO^+}$ + $AlCl_4^-$ **(1)** **+** can be anywhere on the C_6H_5CO in the equation for the first mark  ($AlCl_4^- + H^+ \rightarrow HCl + AlCl_3$) **NOTE:** If ethanoyl chloride or any other acid chloride or the generic RCOCl is used **instead** of benzoyl chloride, no first mark can be awarded but the 2nd, 3rd and 4th marks can be awarded consequentially **Second mark**: First curly arrow, as shown, to start from inside the hexagon to the correct C+ carbon (i.e. not to the benzene ring) Note the + must be on the C of the C=O/CO for this mark **(1)** **Third mark:** Intermediate correctly drawn **(1)** **NOTE** + can be shown anywhere in the ring or at the C atom where electrophile is bonded. The 'horseshoe' in the intermediate to cover at least three carbon atoms **Fourth mark:** Second curly arrow as shown from C—H bond to reform the ring, not from the H atom in this bond **(1)** **NOTE** Products do not have to be shown nor the equation for regeneration of the catalyst given		**4**

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Question Number	Acceptable Answers	Reject	Mark
(b)(v)	Absorbs / reflects / blocks / protects from / shields against / **uv** (light/ radiation) IGNORE 'non-toxic' / references to IR	**adsorbs** uv light	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Any **TWO** of the following (1) for identifying the bond by formula as shown and (1) for wavenumber in each matching pair **UNITS** are not required Bond / Wavenumber range/wavenumber (cm^{-1}) C=C / 1600 / 1580 / 1500 / 1450 **All four values needed** C=O / 1700 – 1680 C-H / 3030 C-H / 750 / 700 **Both values needed** **NOTE** ALLOW Correct wavenumber range, or any number within the correct range, **for C=O** Mark identification of the bond and the wavenumber independently (eg a correct bond with a wrong wavenumber, or vice-versa, scores one of the two marks in each case) IGNORE nmr values / chemical shifts		**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	 **First mark** **EITHER** Identifies correctly the **three** different proton environments ALLOW If the three different proton environments are only shown on one of the benzene rings **NOTE** On right-hand ring, clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments and /or On left-hand ring, anti-clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments **OR** Identifies proton Z correctly on both benzene rings **(1)** **Second mark** Fully correct labelling both rings using the letters **X**, **Y** and **Z** **NOTE** **X** and **Y** labels are interchangeable, **Z** is not **(1)**		**2**

Q14.

Question Number	Correct Answer	Mark
	B	**1**

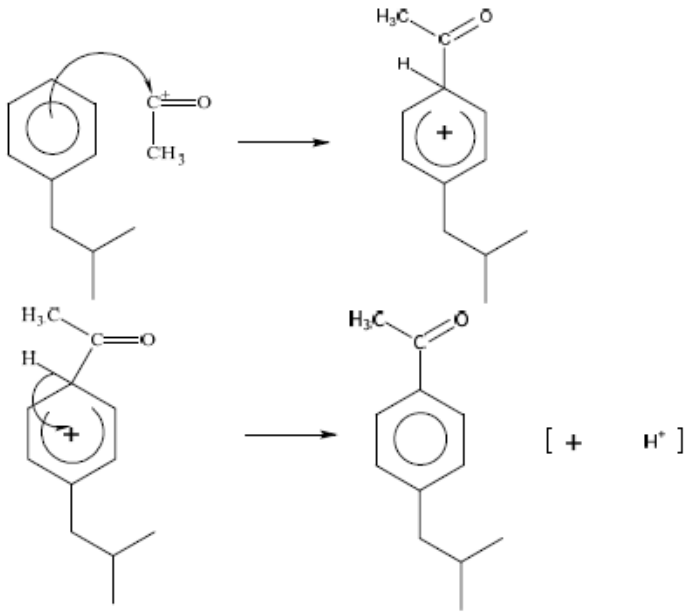
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Q15.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	Overall **yield** higher OR Reduces use of solvents (ALLOW chemicals / reactants) OR Less loss of chemicals OR Less waste products IGNORE References to Energy / fuel / CO_2 References to atom economy More efficient conversion Fewer side products		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Lowers (operating) temperature / energy (requirements) OR Less fuel needed IGNORE References to catalyst properties such as 'lowers E_a', 'can be re-used' Atom economy		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$ Structural formulae not required Positive charge may be anywhere on the electrophile. IGNORE Curly arrows even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	 TE on incorrect electrophile in (b)(i) If benzene used instead of substituted benzene OR If final product is not 1,4 only MP 1 and 2 can be scored Curly arrow from on or within the circle to positively charged carbon		**3**
	ALLOW Curly arrow from anywhere within the hexagon Arrow to **any** part of the electrophile including to the + charge (which can be anywhere on the electrophile) **(1)** Intermediate structure 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 ALLOW dotted horseshoe **(1)** Curly arrow from C—H bond to anywhere in the benzene ring reforming delocalized structure of a stable molecule **(1)** Correct Kekulé structures score full marks Ignore any involvement of $AlCl_4^-$ in the final step	Curly arrow on or outside the hexagon Partial bonds to H and CH_3 unless part of a 3D with a wedge bond	

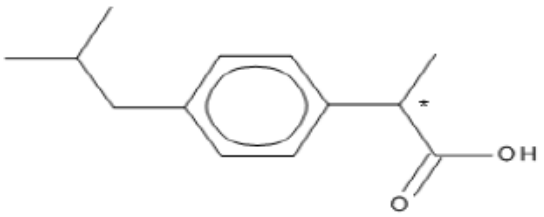
Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	No HCl formed (as a by-product) OR Ethanoic acid easier to recover ALLOW Reverse arguments IGNORE Chlorine containing product References to ozone layer, acid rain, global warming Atom economy	Chlorine	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Catalyst (more) easily recovered / separated OR can be filtered OR Facilitates the use of flow (rather than batch) systems IGNORE references to properties of catalysts		**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	**Reaction 1** (red) phosphorus / P / P_4 and iodine / I_2 ALLOW PI_3 / HI **(1)** **Reaction 3** Hydrochloric acid / HCl(aq) or sulfuric acid / H_2SO_4 (aq) **(1)** **and** reflux / heat **(1)** Award second mark for Acid / H^+ / H_3O^+ **and** reflux OR NaOH(aq) / KOH(aq) **(1)** (reflux) **then** acidify with HCl(aq) or H_2SO_4 (aq) **(1)** IGNORE Omission of states throughout	NaI + H_2SO_4 PI_5 Just H^+ / H_3O^+ reflux / heat without acid or with warm or <50°C	

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	C=O / carbonyl group (only) in carboxylic acid / ibuprofen **(1)** Absorption / peak at 1725 - 1700 (cm^{-1}) **(1)** If no other mark has been awarded, then ALLOW (for 1 mark) OH in both but in alcohol 3750 - 3200 (cm^{-1}) but in carboxylic acids 3300 to 2500 (cm^{-1})	ketone 1700 - 1680 (cm^{-1}) Single values rather than ranges	**2**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	(A chiral molecule is) non-superimposable on its mirror image. ALLOW Asymmetric (tetrahedral) carbon atom / has a carbon atom bonded to **four** different groups / atoms IGNORE Has two enantiomers Functional (as in functional groups) Reference to rotation of plane polarized light	molecules / species (for groups)	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	 ALLOW any clear indication of chiral carbon		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	(A racemic mixture is) an equimolar mixture of the two enantiomers / (optical) isomers ALLOW (for equimolar mixture) equal amounts / concentrations / volumes / proportions OR 50:50 mixture	Just 'no effect on plane polarised light'	**1**

Q16.

Question Number	Acceptable Answers	Reject	Mark
	B		**1**

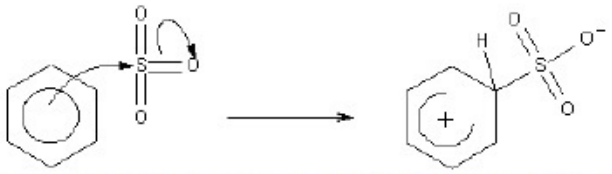
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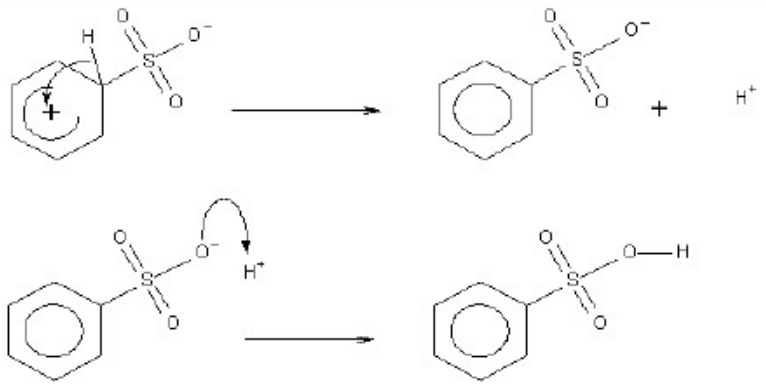
Question Number	Acceptable Answers	Reject	Mark
(a)(i)	**Fuming** sulfuric acid / **fuming** H_2SO_4 / oleum / $H_2S_2O_7$	Conc. (for fuming) Fuming dilute sulfuric acid **Just** sulfuric acid **Just** H_2SO_4	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Sulfur is δ+ and on at least one oxygen δ- **(1)** Oxygen is (much) more electronegative than sulfur ALLOW Oxygen is very electronegative **(1)**	Full + or – charge(s) 1/3 – on each oxygen	**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	The sulfur trioxide can accept a pair of electrons OR (Three oxygen atoms so) sulfur has a large δ or partial / slight positive charge OR π bonds allow S—O bonds to be polarized more easily ALLOW Electron-deficient sulfur	An electron	**1**

Marks for (b)(i) and (b)(ii) can be awarded from either of the two annotated diagrams on item

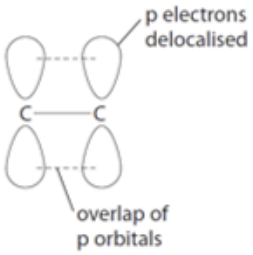
Question Number	Acceptable Answers	Reject	Mark
(b)(i)	 First curly arrow as shown to start inside the hexagon to the S atom **(1)** Second curly arrow from bond to O (i.e. not from the S atom itself) **(1)** ALLOW Second curly arrow to any of the three O atoms in SO_3 IGNORE A full + charge on S		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	 Curly arrow as shown from the C-H bond to reform the ring in first line, not from the H atom in this bond **(1)** Intermediate anion formed in first line (H^+ does not have to be shown) **(1)** Last line with curly arrow and correct structure of benzenesulfonic acid **(1)** ALLOW Use of H_2SO_4 for H^+ with HSO_4^- as other product in final step The marks for (b)(ii) may be awarded from annotations on the right hand structure given in question in (b)(i) If contradictory arrows drawn on structure in question (b)(ii), then penalise any such inconsistency The three marks for the two steps in (b)(ii) can be shown in one step / diagram / structure ALLOW $-SO_3H$ undisplayed	Use of H_2O for H^+ $-HSO_3$	**3**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	$C_6H_5SO_3H + 3NaOH \rightarrow C_6H_5ONa + Na_2SO_3 + 2H_2O$ **(1)** ALLOW Charges on $C_6H_5O^-Na^+$ $C_6H_5ONa + HCl \rightarrow C_6H_5OH + NaCl$ **(1)** ALLOW $C_6H_5O^- + HCl \rightarrow C_6H_5OH + Cl^-$ OR $C_6H_5O^- + H^+ \rightarrow C_6H_5OH$	Charges on $C_6H_5SO_3H$	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	**Any two from:** (Both) products useful / both are useful / propanone is useful So less waste / high(er) atom economy Fewer steps / one step / does not require many steps (in Hock synthesis) Continuous rather than a batch process **(2)** IGNORE "Only one waste product in Hock" Comments relating to hazardousness of reactants / safety / energy requirements References to yield References to efficiency References to rate	Cheaper	**2**

Q18.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to: • (head on) overlap between orbitals from neighbouring carbon atoms to form a sigma bond (1) • (the remaining) p orbitals overlap sideways (1) • and so electrons delocalise (around the ring) (1) Example of a possible diagram scoring 2 marks (marking points 2 and 3)  	Allow sp^2 hybrid orbitals overlap to form a sigma bond	3

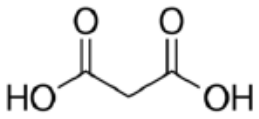
Q19.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • **lone pair** (of electrons) from the **oxygen** **and** will interact with the delocalised ring of electrons / increase the (pi/π) electron density of the benzene ring **(1)** • which increases the reactivity toward electrophiles (such as bromine)/ which means that the bromine is more easily polarised **(1)**	Allow reference to the **lone pair** (of electrons) from the **nitrogen** Ignore activation of ring Do not award charge density Allow $Br^+/Br^{\delta+}$ for electrophile Allow reference to benzene as being a stronger nucleophile Do not award references to electrophilic addition	**(2)**

Q20.

Question Number	Answer	Additional Guidance	Mark
	• calculation of mass of C and H in CO_2 and H_2O (1) • calculation of mass of O in acid (1) • calculation of moles of C, H and O (1) • deduction of empirical formula (1)	<u>Example of calculation</u> 0.68455 g C and 0.076667 g H 1.21878 g of O Amount of C = 0.68455/12 = 0.05705 mol Amount of H = 0.076667/1 = 0.076667 mol Amount of O = 1.21878/16 = 0.076174 mol 1 : 1.34 : 1.34 = 3:4:4 $C_3H_4O_4$ Allow TE throughout Ignore SF Ignore minor rounding errors e.g. 0.684 g of C NOTE do not award (2.51 + 0.69) – 1.98 = 1.22 g for M2 as this is molecular oxygen from combustion NOT oxygen from compound Y	(4)

Q21.

Question Number	Answer	Additional Guidance	Mark
	• calculation of amount of sodium hydroxide (1) • calculation of amount of **Y** in 25.0 cm^3 (1) • calculation of amount of **Y** in 250 cm^3 (1) • calculation of molar mass of **Y** (1) • deduction of structure of **Y** (1)	Example of calculation $26.10/1000 \times 0.320 = 8.352 \times 10^{-3}$ (mol) $8.352 \times 10^{-3} / 2 = 4.176 \times 10^{-3}$ (mol) $4.176 \times 10^{-3} \times (250/25) = 4.176 \times 10^{-2}$ (mol) $4.34 / 4.176 \times 10^{-2} = 103.9 / 104$ (g mol^{-1})  Allow structural / displayed / skeletal or any combination Allow TE throughout M1-M4 Penalise 1 SF in M1	(5)

Q22.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Ti **reduced** as oxidation number decreases from **+4 to 0**/ changes from **+4 to 0** **(1)** Na **oxidized** as oxidation number increases from **0 to +1** /changes from **0 to +1** **(1)** ALLOW Correct oxidation numbers only for one mark **NOTE** Max (1) if no + sign included ALLOW **'4+'** and/or **'1+'** given instead of **+4** and **+1** **NOTE** If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases **AND** during reduction the oxidation number decreases IGNORE References to loss and /or gain of electrons		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	(Ti [Ar]) $3d^2\ 4s^2$ / $4s^2\ 3d^2$ **(1)** (Ti^{3+} [Ar]) $3d^1$ / $3d^1\ 4s^0$ (Ti^{4+} [Ar]) 'nil' / $3d^0\ 4s^0$ /$3d^0$ space left blank by candidate BOTH Ti^{3+} and Ti^{4+} correct for second mark **(1)** Mark CQ on Ti electron configuration for the second mark ALLOW Upper case (e.g. 'D' for 'd' in electronic configurations) Subscripts for numbers of electrons Full correct electronic configurations $1s^2$, $2s^2$.....		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**(d-block element)** **EITHER** Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital **OR** (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital	**Outer / highest energy** electrons are in a d-orbital / **Outer / highest energy** electrons are in a d-subshell Electrons in the 'd-block'/ 'electrons in the d-shell'	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(transition element) Forms one (or more stable) **ions** / forms **Ti^{3+}** (ions) which have incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron IGNORE References to variable oxidation states		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	**First mark:** d-subshell splits /d-orbital**s** split (in energy by ligands) /d energy level(s) split(s) **(1)** **Second mark:** **absorbs light** (in visible region) **(1)** **Third mark:** Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy OR Electron(s) promoted (within d) **(1)** Mark independently **NOTE** Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again	d-**orbital /** d-**shell** splits absorbs **purple** light	**3**

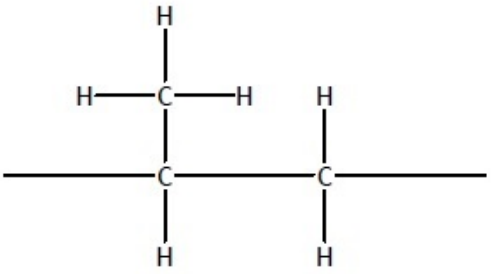
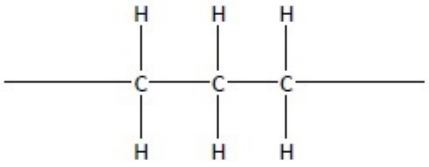
Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	No d-electrons / empty d-subshell		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(i)	**TiO_2** **'Structure' mark** **EITHER** Giant (structure) **OR** Lattice (structure) IGNORE Whether stated as ionic or covalent for this mark **(1)** **TiO_2** **'Bonding' mark** EITHER **Strong** (electrostatic) attraction between ions ALLOW **Strong** ionic bonds / ionic bonds require a lot of energy to break **OR** **Strong** covalent bonds/covalent bonds require a lot of energy to break **(1)** **$TiCl_4$** **'Structure' mark** (Simple) molecules / (small) molecules **/**molecular **(1)** **$TiCl_4$** **'Bonding' mark** **Weak** London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break	TiO_2 (small) molecule**s** / simple molecular For TiO_2 mention of any type of intermolecular forces between molecules of TiO_2 $TiCl_4$ giant structure Covalent bonds broken (on melting) in $TiCl_4$ Ionic bonding in $TiCl_4$ Hydrogen bonding **(0)** for this mark	**4**

	NOTE If candidates assumes TiO_2 and $TiCl_4$ are both simple molecular, can score last mark for saying that the **named** intermolecular forces in TiO_2 are stronger that those in $TiCl_4$ IGNORE (Permanent) dipole-dipole forces **(1)** Mark the four scoring points independently		

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	Amphoteric ALLOW Recognisable spellings		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	$TiO_2 + 2H_2O + 2KOH \rightarrow K_2Ti(OH)_6$ OR $TiO_2 + 2H_2O + 2OH^- \rightarrow Ti(OH)_6^{2-}$ IGNORE state symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iv)	 **MUST** have continuation bonds at each end ALLOW CH_3 IGNORE n and any brackets	 **Two** (or more) repeat units shown	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	$(H_2O_2 + 2H^+ +)$ **$2e^{(-)} \rightarrow 2H_2O$** **BOTH** $2e^{(-)}$ **and** **2**H_2O needed for the mark		**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	(Moles H_2O_2 = $\frac{0.0200 \times 22.50}{1000}$ =) 4.5×10^{-4} mol H_2O_2 **(1)** (Moles Ti^{3+} reacting in 25.0 cm^3) = 9.0×10^{-4} mol Ti^{3+} (Moles Ti^{3+} in 250 cm^3) = 9.0×10^{-3} mol Ti^{3+} **(1)** (Original concentration of Ti^{3+} = $\frac{9.0 \times 10^{-3}}{0.00500}$ =) 1.8 (mol dm^{-3}) **(1)** 1.8 (mol dm^{-3}) with or without working scores **(3)** **NOTES:** If mole ratio H_2O_2 : Ti^{3+} is 1:1 final answer for concentration of Ti^{3+} is 0.9 (mol dm^{-3}) scores **(2)** overall If mole ratio H_2O_2 : Ti^{3+} is 2:1 final answer for concentration of Ti^{3+} is 0.45 (mol dm^{-3}) scores **(2)** overall If candidate forgets to multiply no. of moles of Ti^{3+} by 10 then answer is 0.18 (moldm-3) this scores **(2)** If volume of H_2O_2 used is 25.0 no first mark, but can score **(2)** if final answer CQ is 2(.0) (mol dm^{-3})		**3**

Question Number	Acceptable Answers	Reject	Mark
(f)(iii)	(It/titanium(III)/Ti^{3+}) **oxidized** (by oxygen in the air) ALLOW 'It is a **strong** reducing agent'	Hydrolysis	**1**

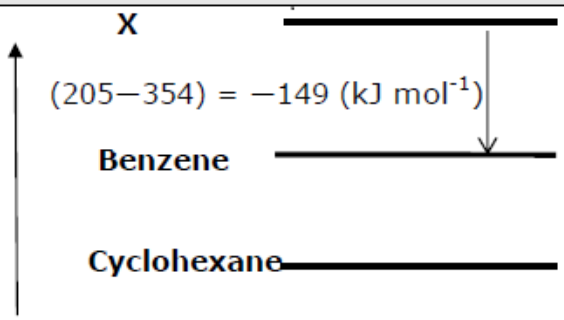
Q23.

Question Number	Answer	Additional Guidance	Mark
	• calculation of mass of C from CO_2 (1) • calculation of mass of H from H_2O (1) • subtraction to find mass of O, and evaluation of number of moles of C, H and O (1) • confirm whole number ratio (1)	Example of calculation Mass of C = 4.26 x 12/44 = 1.1618 g Mass of H = 1.1 x 2/18 = 0.12222 g So mass O = 1.56 – (1.1618 + 0.1222) = 0.27598 g Moles C = 1.1618/12 = 0.096817 Moles H = 0.12222/1 = 0.12222 Moles O = 0.27598/16 = 0.017249 Ratio = 5.6 : 7.1 : 1 = 11 : 14 : 2 Allow alternative correct methods	4

Q24.

Question Number	Acceptable Answers	Reject	Mark
(a)	All carbon to carbon bonds same length/ longer C-C and shorter C=C not present IGNORE Just "benzene has a delocalised ring" Benzene does not have C=C double bonds Any references to shape/ bond angles		1

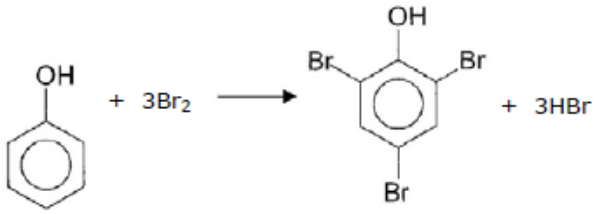
Question Number	Acceptable Answers	Reject	Mark
(b)(i)	(3 x -118) = -354 (kJ mol^{-1})		1

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	 **First mark** Relative levels with names or formulae (1) **Second mark** Value −149 (kJ mol^{-1}) + arrow in correct direction ALLOW double-headed arrow (1) TE from value in (b)(ii) IGNORE $3H_2$ if shown / cyclohexene / other arrows/values	Diagram inverted scores 0 +149	2

Question Number	Acceptable Answers	Reject	Mark
***(b)(iii)**	The p/pi-/Π/6 electrons (of carbon) (1) are delocalised in benzene (but not in **X**) (1)		2

Q25.

Question Number	Acceptable Answers	Reject	Mark
(i)	Bromine goes colourless OR It/the mixture goes from brown to colourless ALLOW Red-brown/ Orange/ yellow/ combinations of these colours Bromine is decolorised (1) White precipitate/solid forms / Steamy fumes (1) IGNORE Antiseptic smell Gets hot	Goes clear Red to colourless Bromine is discoloured Effervescence	2

Question Number	Acceptable Answers	Reject	Mark
(ii)	 Organic product with structure shown (1) Rest of equation correct ALLOW C_6H_5OH or Kekule for phenol (1) $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ Scores MP2 only Substitution of 1Br or 2Br in any position in balanced equation scores MP2 only.		2

Question Number	Acceptable Answers	Reject	Mark
* (iii)	**Lone pair of electrons on oxygen** (may be shown on a diagram) **and** EITHER overlaps with pi cloud OR Feeds into / donates into / interacts with benzene ring (1) Activating benzene ring / increasing electron density of ring / making attack by **electrophiles** easier (1) COMMENT 'Lone pair of electrons on oxygen increases electron density of ring' scores (2) ALLOW benzene becomes a better nucleophile for MP2	OH group overlaps Just 'making it more reactive'.	2

Q26.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q27.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (a)</td><td>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.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<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>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.

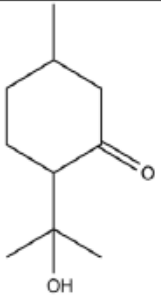
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Indicative Content:

• technique A allows heating for a longer time period / technique B is suitable for a shorter time period

• technique A ensures oxidation / technique B may result in loss of reactant before oxidation</td><td>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 which 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).</td><td>6</td></tr>
</table>

	• technique A minimises release of flammable **or** harmful vapours / technique B allows release of flammable **or** harmful vapours, unless carried out in fume cupboard • technique A involves more expensive equipment **or** is more complex to set up / technique B is simpler to set up **or** uses less expensive equipment • as complete oxidation is not necessary to qualitatively show it is an alcohol that can be oxidised • technique B is most appropriate as simpler / technique A is most appropriate as oxidation is guaranteed		

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	An explanation that makes reference to the following pairs: **either** • no, as chloride ions could be oxidised by dichromate(VI) ions (reducing amount of oxidant / producing toxic chlorine) (1) • $E^{\ominus}$ values for dichromate(VI) and chloride ions being oxidised to chlorine are sufficiently close (even though $E^{\ominus}$ is negative = -0.03 V) for chlorine to be formed (1) **or** • yes, as reaction is dependent on H^+ ions (not anions) (1) • $E^{\ominus}$ value is negative (-0.03 V) (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)			**1**

Q28.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (the increase in mass of) **X** will increase **and** (the increase in mass of) **Y** will stay the same **(1)** • because **X** will also absorb the water / moisture in the oxygen **(1)** • (**Y** stays the same) because the water / moisture has already been absorbed by **X** **(1)**	Allow greater change in mass or **X** if it is clear that it is an increase Allow **X** reacts with the water in oxygen Do not award **X** absorbs oxygen Allow because **Y** only absorbs carbon dioxide / CO_2 Allow because **Y** does not absorb water Allow because the amount of carbon dioxide / CO_2 does not change	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• calculation of mol C/ CO_2 **(1)**	Example of calculation mol CO_2 = 5.28/44 = 0.12 = mol C **or** mass C = 5.28 x 12/44 = 1.44 (g) mol C = 1.44/12 = 0.12	(5)
	• calculation of mol H **(1)**	mol H_2O = 0.72/18 = 0.04 mol H = 2 x mol H_2O = 0.08 **or** mass H = 0.72 x 2/18 = 0.08 mol H = 0.08 x 1 = 0.08	
	• calculation of mol N **(1)**	mol N_2 = 0.56/28 = 0.02 mol N = 2 x mol N_2 = 0.04 **or** mass N = 0.56 mol N = 0.56/14 = 0.04	
	• calculation of mol O **(1)**	mass O = 3.36 – (12 x 0.12 + 1 x 0.08 + 14 x 0.04) = 1.28 (g) mol O = 1.28/16 = 0.08 TE on masses of C, H and N	
	• empirical formula **(1)**	(0.12 C : 0.08 H : 0.04 N : 0.08 O) $C_3H_2NO_2$ Allow symbols in any order TE on incorrect moles but the ratio must be a whole number and include C, H, N and O if no O, only M1, M2 and M3 can be awarded Ignore use of O_2 / O / N_2 / N in the 'words' Correct empirical formula with some working at each stage scores (5) but correct empirical formula with no working scores M5 only	

Q29.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points • amino acids exist as zwitterions (1) • so ionic bonds form between the zwitterions / amino acids (1)	maybe shown on a diagram allow (a single molecule of an amino acid) forms positive and negative ions Allow 'strong electrostatic forces' if ions clearly referenced in response Ignore reference to hydrogen bonds	(2)

Q30.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(a)</td><td>• mass of C (1)

• mass of H (1)

• mass of oxygen <u>and</u> mols of C, H and O (1)

• ratio (1)

• empirical and use of molar mass to determine molecular formula (1)</td><td><u>Example of calculation</u>

mass of C = 2.83 x 12/44 = 0.772 g

mass of H = 0.693 x 2/18 = 0.077 g

mass of oxygen = 0.952 – (0.772 + 0.077) = 0.103 g

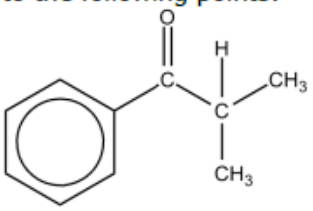
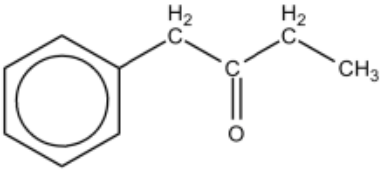
<table><tr><td></td><td>C</td><td>H</td><td>O</td></tr><tr><td>Moles</td><td>0.772/12=0.0643</td><td>0.077/1=0.077</td><td>0.103/16=0.0064</td></tr><tr><td>ratio</td><td>0.0643/0.0063=10</td><td>0.077/0.00643=12</td><td>0.0064/0.0064=1</td></tr></table>
Empirical formula = $C_{10}H_{12}O$, this has mass =148
so molecular formula = $C_{10}H_{12}O$</td><td>5</td></tr>
</table>

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • contains benzene ring / arene	Ignore comments about alkenes / unsaturated	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• is an aldehyde or ketone / is a carbonyl compound	Both aldehyde and ketone required for first alternative	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• (**Q** is a) ketone	Allow 'not an aldehyde' if first alternative given in (b)(ii)	**1**

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Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points:  (2) • **Chemical shift** (1) peak at 7.5 ppm indicates a benzene ring <u>and</u> peak at 2.55 ppm indicates H on carbon adjacent to C=O <u>and</u> peak at 1.25 ppm indicates alkyl hydrogens • **Splitting pattern** (2) Any 2 from 3: – complex multiplet indicates a benzene ring – septuplet indicates 6 equivalent protons on adjacent carbons – doublet indicates one hydrogen on adjacent carbon • **Area under peak** (2) Any 2 from 3: – five H's indicate C_6H_5 / monosubstituted benzene ring – one H indicates one H on C next to carbonyl group – six H's indicates six H's on two methyl groups	Award 1 mark for any structure of $C_{10}H_{12}O$ which includes a benzene ring and a ketone e.g. 	**7**

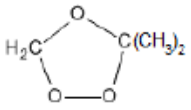
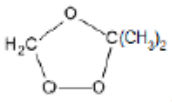
Q31.

Question Number	Correct Answer	Mark
	B	**1**

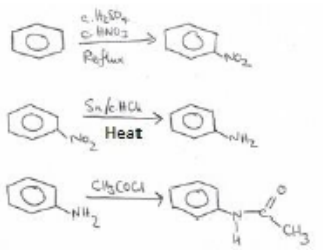
Q32.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• calculates mol of CO_2 and H_2O / mol C and H (1)	Example of calculation mol CO_2 / mol C = 0.88/44 = 0.02 and mol H_2O = 0.36/18 = 0.02 / mol H = 0.04	
	• deduces empirical formula (1)	ratio C : H = 1 : 2 and empirical formula is CH_2	
	• calculates mol **J** (1)	n = pV/RT mol **J** = 101 x 10^3 x 123 x 10^{-6}/(8.31 x 298) = 5.0166 x 10^{-3}	
	• calculates M_r of **J** and hence molecular formula (1)	M_r of **J** = 0.28/5.0166 x 10^{-3} = 55.8 so molecular formula is C_4H_8	**4**

Q33.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • **K** is HCHO/methanal because it is the (only) carbonyl with M_r 30 (1) • the M_r of **L** is 58 so it could be CH_3COCH_3/propanone or CH_3CH_2CHO/propanal **or** • a carbonyl compound with 3 carbon atoms (1) • 2 peaks on the ^{13}C NMR spectrum show 2 different carbon environments so it must be propanone (as propanal would have 3 different carbon environments (1)		**5**
	• **J** is methylpropene/$CH_2=C(CH_3)_2$ /  (1) • $CH_2=C(CH_3)_2 + O_3 \rightarrow$   $+ H_2O \rightarrow HCHO + O=C(CH_3)_2 + H_2O_2$ **both** equations correct (1)		

Q34.

Question Number	Answer	Additional Guidance	Mark
		Example of synthetic pathway  The compounds used can be stated or given within equations. Ignore any unbalanced, incorrect equations or reaction mechanisms	**(5)**
	A synthetic pathway that consists of:		
	• (reagents and conditions for the nitration of benzene) conc. Nitric (HNO_3) and sulfuric acids (H_2SO_4) **and** 55°C/heat/reflux **(1)**	Allow any single value or range between 50-60°C/warm/ <55 °C	
	• structure of nitrobenzene **(1)**	Intermediate marks are standalone	
	• (reduction of nitrobenzene) tin and conc. hydrochloric acid and heat/reflux **(1)**	Allow iron & c.HCl Do not award dilute Ignore subsequent addition of NaOH Penalise lack of heat once only in M1 and M3	
	• structure of phenylamine **(1)**	Penalise just the names of intermediates once only	
	• (reaction of phenylamine with) ethanoyl chloride **(1)**	Ignore heat Do not award use of $AlCl_3$	

Q35.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>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.
<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><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></table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
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Indicative content
• convert some ethanol into bromoethane or iodoethane / CH_3CH_2Br / CH_3CH_2I

• reagents and conditions: potassium bromide / KBr <u>and</u> concentrated sulfuric acid /</td><td>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).</td><td></td></tr>
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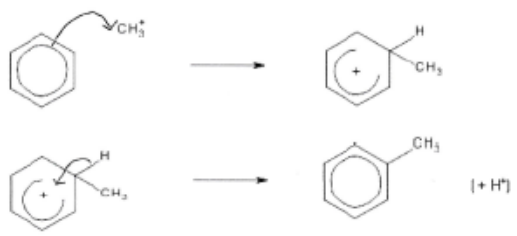
STEMUP.CO.UK

	H_2SO_4 or red phosphorus / P_4 and iodine / I_2 • convert bromoethane / iodoethane into ethylmagnesium bromide / iodide CH_3CH_2MgBr / CH_3CH_2MgI and using magnesium / Mg in dry ether • convert some ethanol into ethanal / CH_3CHO • reagents and conditions: potassium dichromate(VI) in dilute sulfuric acid and distil product immediately • react ethylmagnesium bromide / iodide with ethanal (in dry ether) and hydrolyse the product (with dilute acid)		**6**

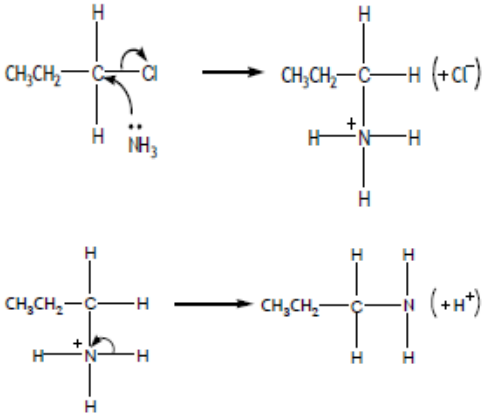
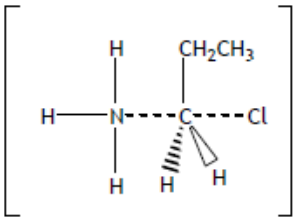
Q36.

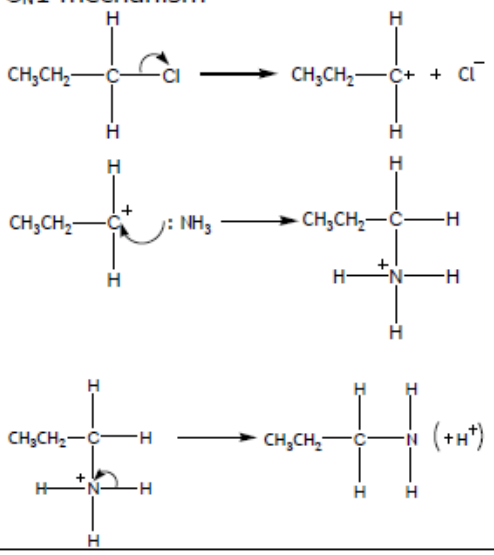
Question Number	Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram	Example of diagram  Allow electrons in overlapping circles Allow all dots / all crosses Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x • Do not award diagram with lone pair on Al	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • shape – trigonal planar (1) • bond angle - 120° (1)	Mark independently Both words needed Allow triangular for trigonal – but not just tri Allow marks for labelled diagram **Note** If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape	(2)

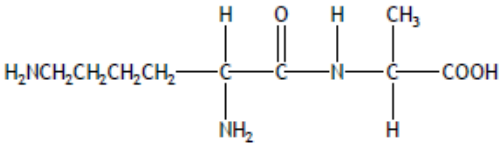
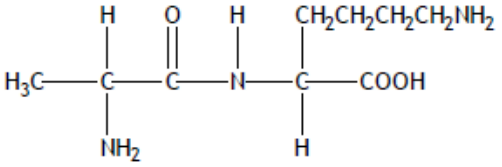
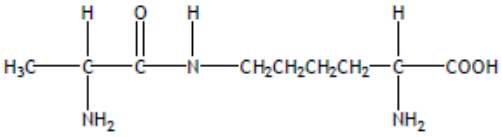
Question Number	Answer	Additional Guidance	Mark
(iii)	• equation for the formation of the electrophile (1) • curly arrow from on or within the circle to CH_3^+ (1) • structure of intermediate including charge with some part of the charge within the horseshoe **and** horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon (1) • curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure (1)	<u>Example of mechanism</u> $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + [AlCl_4]^-$  Allow $AlCl_4^-$ / $^{\delta+}CH_3\text{-}AlCl_4^{\delta-}$ Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of CH_3^+, including the + charge Do not award curly arrow from outside the hexagon Allow dotted / dashed lines for horseshoe Do not award dotted bonds to H and CH_3 unless clearly part of a 3D structure Ignore any involvement of $AlCl_4^-$ in the final step /HCl **Note** Correct Kekulé structures score full marks	(4)

Q37.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including positive charge **(1)** • third curly arrow and formation of final organic product **(1)**	Ignore correct dipoles Allow non-displayed NH_3^+ for MP2 Ignore involvement of Cl^- / NH_3 or wrong inorganic products for MP3 EITHER  Ignore depiction of transition state e.g. 	**(3)**

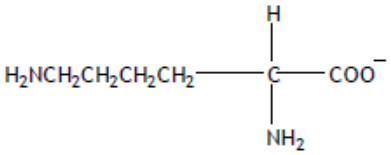
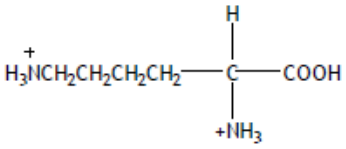
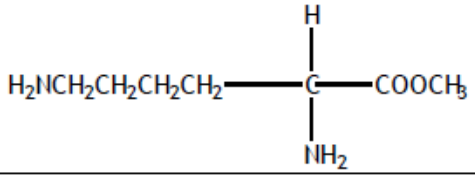
	OR • fission of C-Cl bond curly arrow **and** curly arrow from nitrogen in NH_3 with lone pair shown on N atom to correct carbocation **(1)** • structure of resulting nitrogen-containing intermediate including positive charge **(1)** • curly arrow resulting in breaking of an N-H bond and structure of the final organic product **(1)**	OR AWARD S_N1 mechanism 	

Q38.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	Any one of:  OR  OR 	Must be the dipeptide and not the repeat unit Allow $-CO_2H$ Allow $-H_2N$ Allow –CONH– / -COHN- unless C-H-N Allow zwitterions or cyclic dipeptides Allow skeletal / part-skeletal formulae	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • (In acidic conditions) lysine (ion) has two positive charges (whereas alanine has only one) **(1)** • (So lysine ion has) has greater attraction for the stationary phase **(1)**	Ignore comments on retention time, solubility, polarity, dipoles or intermolecular forces Allow 'greater positive charge' Allow lysine has 2 NH_2 groups that can be protonated Allow 'greater affinity for stationary phase' 'adheres better to stationary phase' 'better adsorption onto stationary phase' Allow 'polar phase' for 'stationary phase' Allow reverse argument for alanine Mark points M1 and M2 independently	(2)

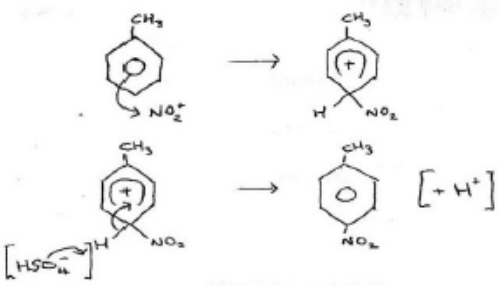
Q39.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Deprotonated structure **(1)**  (Na^+)	Allow displayed /structural /condensed formulae Allow NH_2- Allow $-CO_2^-$ Allow –COONa but penalise if O–Na covalent bond is shown	**(3)**
	• Protonated structure **(1)**  ($2Cl^-$)	**Both** NH_2 groups must be protonated Allow NH_3^+- / $^+H_3N-$ Allow $-CO_2H$	
	• Ester structure **(1)** 	Allow CO_2CH_3 Allow NH_3^+- or NH_2- for each amine group Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded	

Q40.

Question Number	Correct Answer	Reject	Mark
	B		1

Q41.

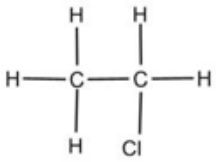
Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ **OR** $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_2O + HSO_4^-$ **OR** $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ (1)  • curly arrow from on or within the circle to the N of NO_2^+ (1) • intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **and** some part of the positive charge must be within the horseshoe (1) • curly arrow from C—H bond to anywhere in the hexagon, reforming the delocalized structure (1)	**IGNORE** state symbols, even if incorrect Correct Kekulé structures score full marks If final product is not 1-methyl-4-nitrobenzene, maximum 3 marks Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of the NO_2^+ including to the + charge Ignore any involvement of HSO_4^- in the final step	**4**

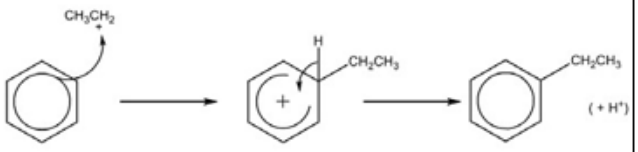
Q42.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A synthetic pathway that includes: **Conversion to alcohol** • (aqueous ethanolic) potassium / sodium hydroxide **(1)** • name or structure of propan-1-ol **(1)** **EITHER ROUTE 1** **Conversion to carboxylic acid** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **(1)** • name or structure of propanoic acid **(1)** **Formation of ester** • react propan-1-ol and propanoic acid together **and** using (concentrated) sulfuric acid (catalyst) **(1)** **PTO for ROUTE 2**	Allow names or formulae for reagents but if both are given, both must be correct Allow correct species in unbalanced equations Allow any combination of structural, displayed or skeletal formulae for the intermediates Penalise missing H once only Ignore conditions e.g. heat / reflux Allow hydroxide ions / OH^- Ignore concentration Do not award just ethanol / ethanolic Stand alone mark e.g. $CH_3CH_2CH_2OH$ Allow propanol if correct structure shown somewhere Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COOH Stand alone mark for C_3 compounds Allow (concentrated hydrochloric) acid / H^+ / H_3O^+ instead of sulfuric acid Ignore concentration of acid Ignore incorrect structure of ester e.g. with H or O missing	**(5)**

	OR ROUTE 2 **Conversion to acyl chloride** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **and** add phosphorus(V) chloride to propanoic acid **(1)** • name or structure of propanoyl chloride **(1)** **Formation of ester** • react propan-1-ol and propanoyl chloride together **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COCl Stand alone mark for C_3 compounds Ignore incorrect structure of ester e.g. with H or O missing	

Q43.

Question Number	Answer	Additional Guidance	Mark
(i)		Do not award skeletal or structural formulae	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• **M1 equation** to show formation of electrophile (1) • **M2** curly arrow from anywhere on the central ring to positive carbon (1) • **M3** structure of intermediate (1) • **M4** curly arrow from C-H bond to reform the ring (1) • **M5 equation** showing regeneration of catalyst (1)	Example of mechanism Penalise incorrect halogenoalkane in (a)(i) only $CH_3CH_2Cl + AlCl_3 \rightarrow CH_3CH_2^+ + AlCl_4^-$ Ignore any curly arrows given in the equation Allow curly arrow from anywhere within the hexagon Do not award if curly arrow to CH_3 carbon in $CH_3CH_2^+$ Do not award if curly arrow to $C_2H_5^+$ Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms Some part of the positive charge in the horseshoe Do not award dotted lines unless clearly part of a 3D structure $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$ Ignore regeneration step if part of the mechanism **Mechanism**  Allow TE from (a)(i)	(5)

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: Phenol is likely to be more reactive because • **M1 lone pair** on **oxygen** (atom of –OH group) delocalises / is incorporated into the (benzene) ring / donated to the ring (1) • **M2** which increases the electron density (of the ring) (1) • **M3** making the ring / phenol more susceptible to electrophilic attack (1)	Do not award M2 if mention of "charge density" / "electronegativity" Ignore references to "the ring becomes more negative" Award "making the ring more nucleophilic" / "making the ring more susceptible to attack by a positive ion" Ignore references to "activation of the ring"	(3)

Q44.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to: • invert the funnel **and** then open the tap	Allow Just removal of stopper/bung/lid/top Ignore shaking	**(1)**

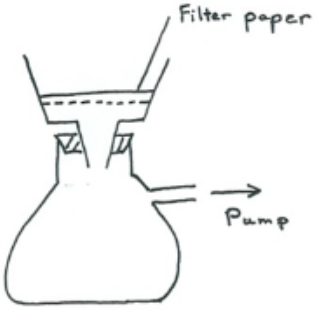
Q45.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to • (Water is) more dense (than ether/than the organic layer)	Accept reverse argument Ignore references to immiscibility Do not award references to water being insoluble	**(1)**

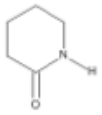
Q46.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to: • some sodium benzoate has dissolved in the ether (instead of the aqueous sodium carbonate)	Ignore to increase the yield of sodium benzoate Ignore to remove the product from the ether	**(1)**

Q47.

Question Number	Answer	Additional Guidance	Mark
	A labelled diagram that includes • Buchner/side-armed flask connected to vacuum/ pump/ water aspirator **(1)** • funnel with flat filter paper **(1)**	Example of diagram  Do not award fluted filter paper Do not award water flow into the flask	**(2)**

Q48.

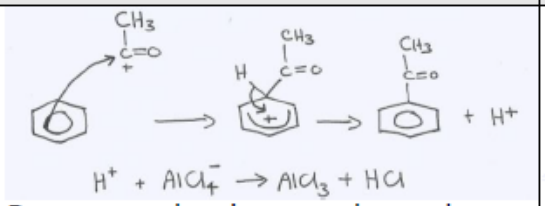
Question Number	Answer	Additional Guidance	Mark
	$H_2N - (CH_2)_4 - COOH$	Accept skeletal, structural or displayed formulae Allow $H_2N - (CH_2)_4 - COCl$ Ignore connectivity Allow  Allow use of C_4H_8 here only Penalise missing hydrogens	**(1)**

Q49.

Question Number	Answer	Additional Guidance	Mark
	• $HOOC - (CH_2)_4 - COOH$ or $ClOC - (CH_2)_4 - COCl$ **(1)** • $H_2N - (CH_2)_4 - NH_2$ **(1)**	Accept skeletal, structural or displayed formulae Penalise use of C_4H_8 once only Penalise missing H's once only The monomers can be in either order Do not award monofunctionality	**(2)**

Q50.

Question Number	Answer	Additional Guidance	Mark
(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	Accept use of $FeCl_3/Fe + Cl_2$ Allow displayed formulae Do not award C_2H_3OCl Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	 • electron pair movement from ring to electrophile **(1)** • formula of intermediate ion **(1)** • curly arrow from C–H bond to reform delocalised ring **(1)** • correct product and equation to show regeneration of catalyst and HCl **(1)**	Do not award curly arrow that ends at the CH_3 Allow arrow starting anywhere within the hexagon 'Horseshoe' to cover at least three carbon atoms and face the tetrahedral carbon and with some part of the plus sign inside 'horseshoe' Allow Kekulé diagrams Do not award dotted bonds unless part of a 3D structure Could be shown in reaction mechanism Ignore curly arrows	**(4)**

Q51.

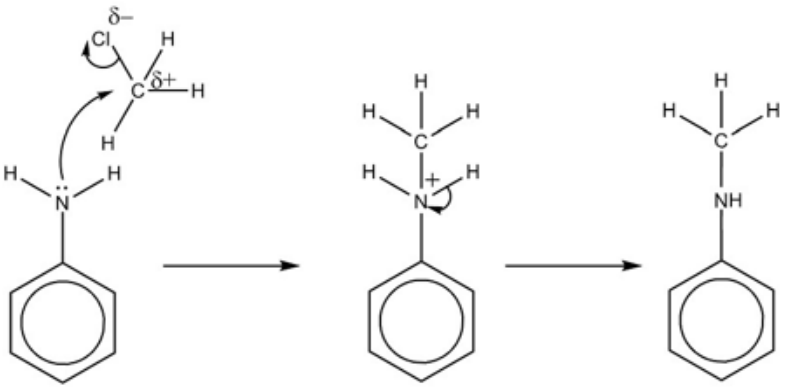
Question Number	Correct Answer	Reject	Mark
	B		**1**

Q52.

Question Number	Acceptable Answers	Reject	Mark
	D		**1**

Q53.

Question Number	Answer	Mark
(i)	**The only correct answer is D** (nucleophilic substitution) **A** *is not correct because it is not electrophilic or addition* **B** *is not correct because it is not electrophilic* **C** *is not correct because it is not addition*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• **M1** arrow from lone pair on nitrogen atom to carbon atom (1) • **M2** dipole shown **and** arrow from C–Cl bond to Cl or just beyond (1) • **M3** formula of including intermediate the + charge on the N atom (1) • **M4** arrow from N-H bond to N^+ and formula of organic product (1)	Example of mechanism  (+ H^+ / HCl) **Comment** M2 is a stand alone mark Allow access to full marks for correct use of other halogenomethanes Ignore any SN2 transition states Ignore use of a second molecule of phenylamine behaving as a base	**(4)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • **M1** dissolve (impure product) in a **minimum** volume of **hot** solvent (1) • **M2** cool (in ice) **or** leave to recrystallise (1) • **M3** filter using vacuum filtration / Buchner filtration / filter under suction (1) • **M4** dry solid in desiccator / between filter papers (1)	Allow any named solvent Ignore hot filtration after M1 Allow dry in a **warm** oven Ignore references to rinsing Do not award M4 if drying agent added to the crystals / solution	(4)

Q54.

Question Number	Correct Answer	Reject	Mark
	B		1

Q55.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• 2,6-diaminohexanoic acid	Allow 2,6-diaminehexanoic acid Ignore any additional commas or hyphens or spaces Do not award 2,6-diammminohexanoic acid	(1)

Q56.

<table>
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</table>
</td>
<td>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.</td>
<td></td>
</tr>
</table>

	Indicative content • **IP1 - Reagents and conditions** magnesium **and** dry ether / dry ethoxyethane / dry $(CH_3CH_2)_2O$ • **IP2 - Hydrolysis of product** add dilute (hydrochloric) acid / $H^+(aq)$ /HCl(aq) (to hydrolyse the intermediate / protonate …O–) • **IP3 – Primary alcohol** react with methanal to form butan-1-ol / $CH_3CH_2CH_2CH_2OH$ • **IP4 – Secondary alcohol** react with ethanal to form pentan-2-ol / $CH_3CH_2CH_2CH(OH)CH_3$ • **IP5 – Tertiary alcohol** react with propanone to form 2-methylpentan-2-ol / $CH_3CH_2CH_2C(CH_3)(OH)CH_3$ • **IP6 – Carboxylic acid** react with carbon dioxide to form butanoic acid / $CH_3CH_2CH_2COOH$	This may be shown as part of any specific reaction. Ignore errors in an equation to make the Grignard. 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 Allow other specific aldehydes with corresponding product Allow other specific ketones with corresponding product	

Q57.

Question Number	Correct Answer	Mark
	B	**1**

Q58.

Question Number	Correct Answer	Reject	Mark
	B		1

Q59.

Question Number	Correct Answer	Reject	Mark
	A		1

Q60.

Question Number	Correct Answer	Reject	Mark
	D		1

.....

.....

(Total for question = 20 marks)

Q60.

This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

Lactic acid can be made in a two-step synthesis starting from ethanal, CH_3CHO.

Devise a reaction scheme for a two-step synthesis.

Include in your answer all reagents and conditions, the type of reaction occurring at each step, and a balanced equation for each reaction.
State symbols are **not** required.

(7)

(Total for question = 7 marks)

Q61.

Ninhydrin is used in thin-layer chromatography to help with the identification of amino acids.
This is because the ninhydrin

☒ **A** reacts with amino acids to form a compound which has an intense colour.

☒ **B** reacts with amino acids to form compounds each of which has a characteristic colour.

☒ **C** increases the separation of the amino acids on the chromatogram.

☒ **D** ensures that the mobile phase maintains a nearly constant pH for all the amino acids.

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	• (The cation in **X** is) Fe^{2+} / iron(II) / Fe(II) (1) • (The anion in **X** is) SO_4^{2-} / sulfate(VI) (1)	Allow Fe^{+2} Allow sulfate / SO_4^{-2} Do not award sulfite / sulfate(IV)	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• species and balancing (1) • state symbols (1)	Examples of equation $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ **or** $[Fe(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s) + 6H_2O(l)$ **or** $[Fe(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(H_2O)_4(s) + 2H_2O(l)$ Ignore missing square brackets TE on cation that forms an insoluble hydroxide in **Test 1** State symbols conditional on correct species or 'near miss' / non-ionic equation	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • Fe^{2+} is oxidised (to Fe^{3+}) by oxygen / air	Allow iron(III) hydroxide / iron(III) (ions) are formed by reaction with oxygen / air TE on cation in **Test 1** Allow just 'the precipitate / it is oxidised by oxygen / air'	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that makes reference to the following point: • to react with / remove any carbonate / sulfite / sulfate(IV) ions **or** to eliminate the possibility of carbonate / sulfite / sulfate(IV) ions	Allow to prevent any other ions forming a precipitate with barium ions / Ba^{2+}	(1)

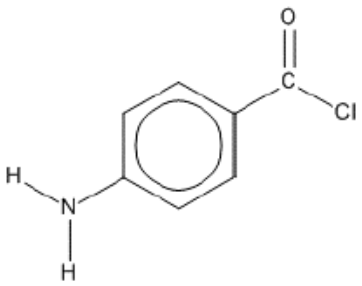
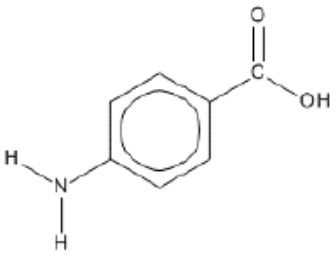
Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following: synthetic pathway that consists of: (Step 1) • (acylation of benzene) using ethanoyl chloride **(1)** • use of aluminium chloride (and heat) **(1)** (Step 2) • (reduction of) **A** with $LiAlH_4$ in ether (dry) **(1)** (Step 3) • (dehydration of) **B** with (conc.) phosphoric acid/H_3PO_4 **(1)** (Intermediates) • identification of **A** as phenylethanone and **B** as (1-)phenylethanol	The compounds used can be stated or given within equations. Only award if part of a Friedel-Crafts reaction Only award if given to reduce an aromatic carbonyl or carboxylic acid Allow (conc.) sulfuric acid/ H_2SO_4 Only award if given to dehydrate an aromatic alcohol Accept formulae for names, but if both given, then both must be correct This also applies to reagents	**(5)**
	 **(1)**	Do not award use of other reagents not in the table.	

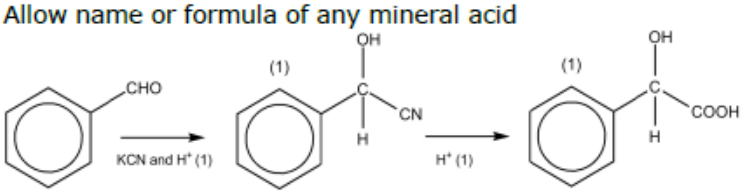
Q3.

Question Number	Answer	Additional Guidance	Mark
	A comparison that makes reference to • (melting temperature) is a (wide) range/ not sharp **(1)** • (it is lower) because impurities are present **(1)**	Ignore just lower for M1 Allow water/phenol is present Allow 'it is not pure'	**(2)**

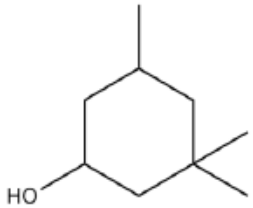
Q4.

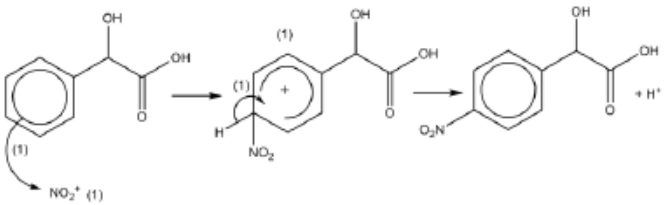
Question Number	Acceptable Answer	Additional Guidance	Mark
	 **or** 	Allow skeletal formula Allow NH_2 Allow COOH / CO_2H / COCl Allow O-H	**1**

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• reagent for step 1 (1) • product of step 1 (1) • reagent for step 2 (1)	KCN and HCN **or** KCN and H^+ **or** HCN Allow structural or displayed formulae Allow name or formula of any mineral acid 	**3**

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Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	 (1) • esterification (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• NO_2^+ ion (1)	Ignore equation to produce electrophile	**4**
	• curly arrow from ring to electrophile (1)	To any part of the electrophile including the plus sign	
	• formula of intermediate (1)	The horseshoe must cover at least three carbon atoms, opening towards the carbon atom approached by the electrophile and at least part of the plus charge within the horseshoe	
	• curly arrow from CH bond to ring and formation of H^+ (1)		

Q6.

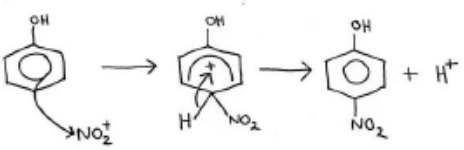
Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	**Test 1** • (gas is) ammonia / NH_3 **(1)** • (cation is) ammonium / NH_4^+ **(1)** **Test 2** • (cation is) cobalt(II) / Co^{2+} / $[Co(H_2O)_6]^{2+}$ **(1)** • (complex ion is) $[CoCl_4]^{2-}$ **(1)** **Test 3** • (precipitate is) barium sulfate / $BaSO_4$ **(1)** • (anion is) sulfate((VI)) / SO_4^{2-} **(1)**	If name and formula are given, both must be correct Mark independently Do not award gas is ammonium / NH_4 Do not award cation is ammonia / NH_3^+ Oxidation number of cobalt is needed in the name but allow cobalt **with** Co^{2+} Charge is needed on the ion Allow +2 and −2 for the charges on the ions Allow brackets around Cl Ignore missing square brackets in complex ions Do not award $[CoCl_6]^{4-}$ **Note** If cation in Test 2 is identified as copper(II) / Cu^{2+}, do not award M3 but M4 can be awarded as TE for $[CuCl_4]^{2-}$ Oxidation number of sulfate is not needed but if given must be correct e.g. do not award sulfate(IV)	**(6)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• correct formula	Examples of correct formula $(NH_4)_2Co(SO_4)_2$ $(NH_4)_2SO_4.CoSO_4$ Allow NH_4, Co and SO_4 in any order Allow multiples Allow any combination of Co^{2+} / NH_4^+ / SO_4^{2-} that gives a neutral complex TE on the **three** ions identified in (a)(i) Ignore missing dot in second formula Ignore any amount of water of crystallisation	**(1)**

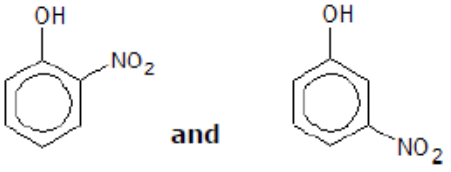
Q7.

Question Number	Acceptable Answers	Reject	Mark
	C		**1**

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to • Electron pair movement from ring to electrophile **(1)** • Formula of intermediate ion **(1)** • Curly arrow from C-H bond to reform delocalised ring and correct final structure with H^+ also formed **(1)**	Allow arrow that starts from anywhere within the hexagon but it must go to the nitrogen of the ion 'Horseshoe' to cover at least three carbon atoms, facing the tetrahedral carbon and part of the + sign to be inside the 'horseshoe' Do not award '+' charge on the tetrahedral carbon Do not award dotted bonds unless part of a 3D structure Curly arrow to go from the bond to anywhere inside the ring Accept the drawing of HSO_4^- to remove the H from the ring as long as H_2SO_4 is given as the product instead of H^+ Exemplar mechanism  Do not penalise attachment of OH/NO_2 to benzene ring Penalise incorrect product: 1 mark	**(3)**

Question Number	Acceptable Answer	Mark
(ii)	The only correct answer is **B** ***A*** *is incorrect because this is 15% of the mass of the starting material* ***C*** *is incorrect because this is the percentage of the starting mass over the max mass of product* ***D*** *is incorrect because this is 100% yield and not 15%*	**(1)**

Question Number		Additional Guidance	Mark
(iii)		Ignore connectivity of OH/NO_2	**(1)**

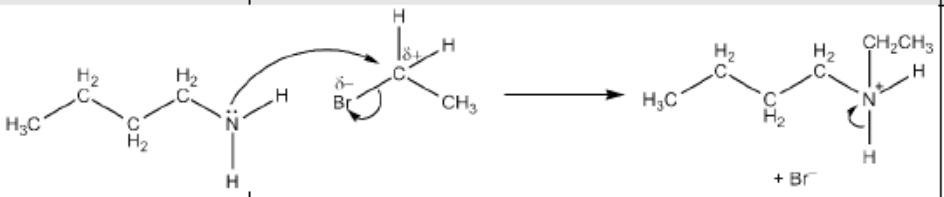
Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the lone pair of electrons on the O overlap with the π/delocalised electrons in the benzene ring (1) • so (increased electron density) makes the ring more susceptible to electrophilic attack (1)	second mark is conditional on a reasonable explanation	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • 2-nitrophenol forms intramolecular hydrogen bonding <u>and</u> 4-nitrophenol only forms intermolecular hydrogen bonding **(1)** • so the hydrogen in the 2-nitrophenol cannot form hydrogen bonds with water (so less soluble) **(1)**		**2**

Q10.

Question Number	Answer	Mark
(i)	**The only correct answer is D** (nucleophilic substitution) *A is incorrect because the reaction is not an addition or electrophilic* *B is incorrect because the attacking species is not an electrophile* *C is incorrect because the reaction is not an addition*	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	 • arrow from lone pair on nitrogen atom to carbon atom **(1)** • dipole shown **and** arrow from C-Br bond to Br or just beyond **(1)** • formula of intermediate including + charge on the N atom and Br^- **(1)** • arrow from N-H bond to N^+ **(1)**	Ignore transition state Ignore arrow from Br^- ion to H in intermediate	(4)

Q11.

Question Number	Correct Answer	Mark
	B	**1**

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • glycinate ions / they do not contain a carbon atom with four different atoms / groups attached **or** the glycinate ion is superimposable on its mirror image **(1)** • so there will be no effect (on plane-polarised monochromatic light) **(1)**	An answer that states there will be an effect scores (0) Allow not chiral / achiral / has no enantiomers / has no asymmetric carbon atom Allow the carbon atom attached to NH_2 is only attached to 3 different atoms / groups / is not attached to 4 different atoms / groups Ignore glycinate ions are not optically active / do not exhibit optical isomerism Do not award it is a racemic mixture / there are equal amounts of the two isomers / four different molecules attached M2 is conditional on M1 Do not award the (monochromatic) light will not be polarised	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• correct formula of one of the copper species **(1)** • rest of equation correct **(1)**	Example of equation $(CH_3COO)_2Cu + 2\ NH_2CH_2COOH \rightarrow (NH_2CH_2COO)_2Cu + 2CH_3COOH$ Allow $Cu(CH_3COO)_2$ / $Cu(NH_2CH_2COO)_2$ Allow both charges shown e.g. $(CH_3COO^-)_2Cu^{2+}$ Allow displayed / skeletal formulae for organic substances but not molecular formulae Ignore state symbols, even if incorrect Do not award M1 if covalent bond between Cu and O in any species but M2 can still score	**(2)**

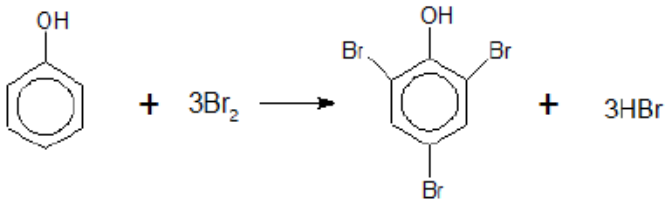
Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	An answer that makes reference to any **four** of the following points: Student **1** / higher yield • the crystals were not dry / still damp when they were weighed **(1)** • there are impurities in the crystals **(1)** Student **2** / lower yield • reaction was incomplete **(1)** • not all of the copper(II) glycinate had crystallised / some is left in solution **(1)** • description of a specific handling loss **(1)**	Ignore reference to weighing errors for both students Allow the student did not subtract the mass of filter paper / product container Do not award the crystals contain water of crystallisation / are (partially) hydrated Allow a specific impurity e.g. glycine Allow the reaction reached equilibrium / side reactions occur / by-products form Ignore just 'the solution has not cooled enough' Allow any specific example e.g. some crystals left on the walls of the container / beaker / flask / lost during filtration / lost during transfer Ignore just 'transfer error' / lost when handling	**(4)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	• $C_8H_9NO_2$	Allow the symbols, with subscripts, in any order e.g. $C_8H_9O_2N$ Allow large numbers but not superscripts Ignore any other formulae as working	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of amount of Ce^{4+} (1) • calculation of amount of paracetamol in 25.0 cm^3 (1) • calculation of amount of paracetamol in 100.0 cm^3 (1) • calculation of molar mass of paracetamol **and** mass of paracetamol in 1 tablet (1) • calculation of percentage of paracetamol in 1 tablet **and** conclusion	Example of calculation amount Ce^{4+} used = $\frac{16.5 \times 0.100}{1000}$ = 0.00165 / 1.65 x 10^{-3} (mol) amount paracetamol in 25.0 cm^3 = $\frac{0.00165}{2}$ = 0.000825 / 8.25 x 10^{-4} (mol) TE on M1 amount paracetamol in 100.0 cm^3 = 4 x 0.000825 = 0.00330 / 3.30 x 10^{-3} (mol) TE on M2 molar mass of paracetamol, $C_8H_9NO_2$ = (8 x 12) + (9 x 1) + 14 + (2 x 16) = 151 **and** mass of paracetamol in 1 tablet = 0.00330 x 151 = 0.4983 g TE on M3 and (d)(i) percentage of paracetamol = $\frac{0.4983}{0.500}$ x 100 = 99.66 (%) **and** the tablet was from Brand **R** TE on M4 provided M4 < 0.500 g Ignore SF except 1 SF	(5)

Q14.

Question Number		Additional Guidance	Mark
(i)	 • Structure of 2,4,6-tribromophenol **(1)** • Balanced equation **(1)**	Ignore state symbols even if incorrect Do not award $C_6H_3OBr_3$ M2 dependent on M1	**(2)**

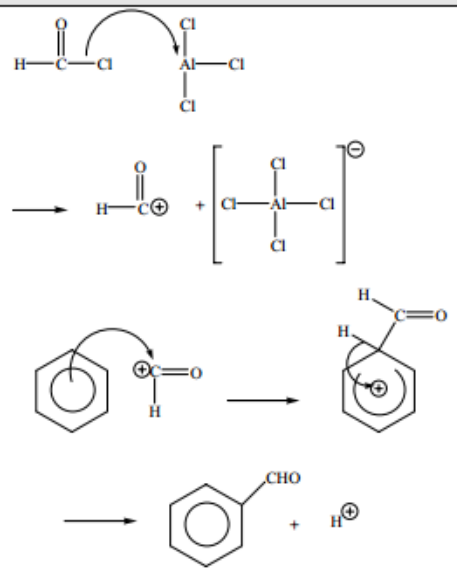
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following: Similarity • Both electrophilic substitution **(1)** Any two from: Contrast • No need of a halogen carrier with phenol **(1)** • oxygen's lone pair of electrons interacts with the benzene ring of delocalised electrons so electrophilic attack more likely **(1)** • Tri-substitution of phenol compared to mono for benzene **(1)** • Bromination of phenol requires bromine in aqueous solution but benzene requires liquid bromine **(1)** • Bromination of phenol requires room temperature but benzene requires heating (under reflux) / reflux **(1)**	Ignore comments of ease of reaction Should be stated clearly as a similarity Accept reverse argument Allow $Fe/FeBr_3/AlBr_3$ with benzene Do not award just 'catalyst' Allow reference to OH group Allow 'bromine' for 'electrophilic' Do not award for nucleophilic attack Allow "multiple-" for "tri-"	**(3)**

Q15.

Question Number	Acceptable Answers	Reject	Mark
(a)	D		**1**
(b)	B		**1**
(c)	A		**1**

Q16.

Question Number	Acceptable Answers	Reject	Mark
16(a)(i)	The delocalization of the (π) electrons of the ring make benzene more stable (than 1,3,5-cyclohexatriene) **(1)** IGNORE bonding in benzene is strong Substitution retains this (stable) arrangement OR Addition removes this (stable) arrangement **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
16(a)(ii)	 Formation of electrophile (curly arrow, structural formulae not required). Positive charge may be anywhere on the electrophile ALLOW HCl + CO for HCOCl ALLOW Non-displayed electrophile **(1)** Curly arrow from benzene ring to electrophile **(1)**		**4**

	Wheland structure with gap opposite tetrahedral carbon **(1)** Curly arrow from C—H bond into ring and formation of **correct** organic product OR Kekulé structures **(1)** IGNORE Use of $AlCl_4^-$ to pick off proton Proton product First curly arrow may come from any part of the delocalisation circle Second curly arrow may come from any part of the C–H bond Positive charge on the Wheland structure may be in any part of the horseshoe	-COH /-HCO Positive charge on the tetrahedral carbon	

Question Number	Acceptable Answers	Reject	Mark
16(a)(iii)	In each step the second mark is dependent on the first **Step 2** Potassium dichromate((VI)) / $K_2Cr_2O_7$ / sodium dichromate((VI)) / $Na_2Cr_2O_7$ ALLOW Potassium manganate ((VII)) / $KMnO_4$ Sodium manganate ((VII)) / $NaMnO_4$ **(1)** Stand alone mark Sulfuric acid / H_2SO_4 (ALLOW nitric acid) **(1)** Ignore 'concentrated' ALLOW Acidified potassium (/ sodium) dichromate((VI)) OR Acid and potassium (/ sodium) dichromate((VI)) **(2)** $Cr_2O_7^{2-}$ and H^+ OR acidified dichromate((VI)) **(1)**	Incorrect oxidation number Hydrochloric acid	**4**
	Step 3 Lithium tetrahydridoaluminate((III)) / $LiAlH_4$ OR Lithium aluminium hydride **(1)** Stand alone mark (Dry) ether / ethoxyethane / (di)ethyl ether **(1)** Sodium borohydride / $NaBH_4$ in ethanol, alkali or water scores 1/2 **(1)**	Hydrogen and catalyst / Tin and HCl	

Question Number	Acceptable Answers	Reject	Mark
16(b)	**Marking Point 1** Electron density of the ring increased **(1)** Stand alone mark **Marking Point 2** Due to donation of oxygen / OH group lone pair to the ring **(1)** **Marking Point 3 and 4** Any two from in phenol oxygen / OH group attached directly to ring Oxygen / OH group in phenylmethanol too far away / not attached directly to ring (In phenol) lone pair overlaps with the π electrons / delocalised electrons (of the ring) ALLOW p orbital for lone pair for this mark **(2)**		**4**

Q17.

Question Number	Answer	Additional Guidance	**Mark**
	• amine monomer structure or name	$H_2N(CH_2)_6NH_2$ / 1,6-diaminohexane Accept any mixture of displayed, structural or skeletal formulae Do not award molecular formulae or $H_2N\ C_6H_{12}\ NH_2$ If name and formula given then both must be correct	**(1)**

Q18.

Question Number	Correct Answer	Mark
	D	**1**

Q19.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
This question assesses the 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.

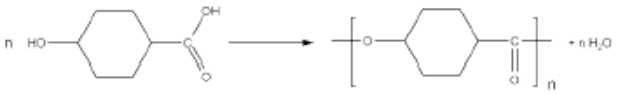
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>
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, a response with four 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).
</td><td>(6)</td></tr>
<tr><td></td><td>
Indicative content
• IP1 in both cases many monomers join (by covalent bonds to form polymers)

• IP2 cyclohexene forms an addition polymer / the polymer is formed by an addition reaction

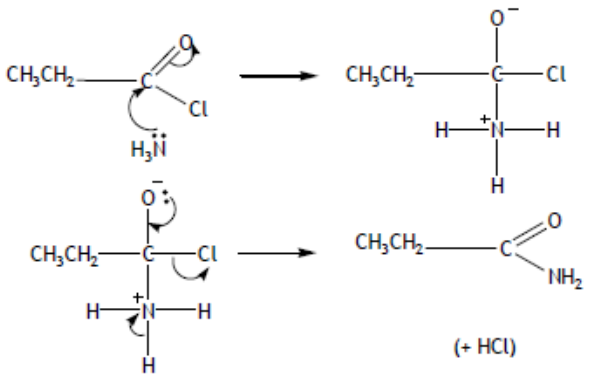
• IP3 4-hydroxycyclohexanecarboxylic acid forms a condensation polymer / the polymer is formed by a condensation reaction

• IP4 no additional products from when cyclohexene polymerises, but water is also
</td><td>
Allow both polymerisations require a catalyst
Allow both polymers are formed from a single type of monomer

Allow unsaturated monomer forms saturated polymer
</td><td></td></tr>
</table>

	formed when 4-hydroxycyclohexanecarboxylic acid polymerises • **IP5** • **IP6**  	Allow 'only 1 product in addition but two products in condensation' Allow only one functional group is needed for addition polymerisation but two different functional groups are needed for condensation polymerisation Allow cyclohexene polymerisation has 100% atom economy, 4-hydroxycyclohexanecarboxylic polymerisation has less than 100% atom economy Ignore omitted or misplaced n in **IP5** and **IP6** Allow 1 IP for IP5 and IP6 if both correct repeat units shown Allow 2 oxygen atoms on RHS and none on LHS for IP6 repeat unit	

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including both charges **(1)** • three curly arrows and structure of final organic product **(1)**		**(3)**

Q21.

Question Number	Answer	Additional Guidance	Mark
	• Prediction: 7/neutral (1) • Justification: Amino group accepts one proton released from acid /B exists as a zwitterion (so it is not acidic or alkaline) (1)	Allow 6.5 to 7.5 Allow proton from acid accepted by amine	2

Q22.

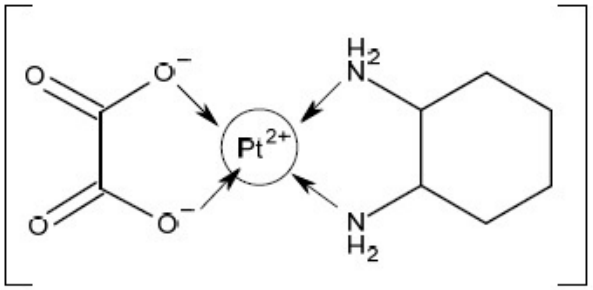
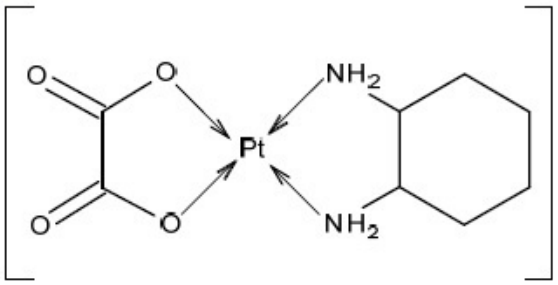
Question Number	Acceptable Answers	Reject	Mark
(a)(i)	The electron withdrawing effect of the (extra) COOH group / oxygen atoms **(1)** Increases the stability of the (hydrogenethanedioate) ion ALLOW Weakens the OH bond **(1)** IGNORE Reference to OH bond becoming more polar		**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	H^+ ions formed (in first dissociation) shifts (second equilibrium) to the left ALLOW H^+ formed suppresses (second) ionization		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	Colourless to (pale) pink ALLOW purple for pink	Clear for colourless	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Amount of MnO_4^- = $28.55 \times 10^{-3} \times 0.0200$ (= 5.71×10^{-4} mol) **(1)** Amount of $C_2O_4^{2-}$ = $5.71 \times 10^{-4} \times \frac{5}{2}$ **(1)** = 1.4275×10^{-3} (mol) Amount of $C_2O_4^{2-}$ in 250 cm^3 / rhubarb leaves = $1.4275 \times 10^{-3} \times 10 = 1.4275 \times 10^{-2}$ (mol) **(1)** Mass $H_2C_2O_4$ in 250 cm^3 = $1.4275 \times 10^{-2} \times 90$ **(1)** = 1.28475 g % $H_2C_2O_4$ in rhubarb = $\frac{1.28475}{250} \times 100$ = 0.5139 % **(1)** IGNORE SF except 1 SF Correct answer with no working scores 5 TE on all parts of calculation If M_r = 88 used then final answer is 0.50248%		**5**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	(Ligand that) Has two lone pairs that can bond (separately) (to the central ion / atom) OR Occupies two coordination positions (around a central ion / atom) OR Two points of attachment (to the central ion / atom) OR Forms two **dative** bonds (to the central ion / atom) OR Two atoms of the same ion / molecule that bond with central metal ion / atom	Two ligands **Just** two lone pairs	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	 Or  Square planar shape around Pt drawn as above and zero net charge NOTE The structure of each ligand must be totally correct **(1)** Both nitrogen atoms attached **and** both C-O oxygen atoms attached from separate COO^- groups **(1)** **Dative** covalent bonds **(1)** **Mark each point separately**	Different oxygen atoms from the same carboxyl group attached to different coordination positions. If O attached from a C=O oxygen	3

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Question Number	Acceptable Answers	Reject	Mark
(d)(i)	(Alkaline or neutral or acidified) potassium manganate(VII) / $KMnO_4$ / MnO_4^- **(1)** Forms ethane-1,2-diol (name or structural / skeletal / displayed formula) **(1)** NOTE It does not matter how the ethane-1,2-diol has been formed (Oxidized by) (refluxing with) acidified potassium dichromate(VI) / $Cr_2O_7^{2-}$ and H^+ OR Acidified/alkaline potassium manganate(VII) / MnO_4^- with either H^+ or OH^- OR (Oxidized by) nitric acid (c.f. passage) **(1)** **Mark each point separately** Max 2 for a three step synthesis e.g. bromine followed by NaOH then oxidation ALLOW correct formulae instead of names	Molecular formula $C_2H_6O_2$ Air catalyzed by V_2O_5	**3**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	Carbohydrates and / or glucose are obtained from renewable / sustainable resources (whereas ethene is obtained from crude oil) ALLOW Reverse argument for ethene		**1**

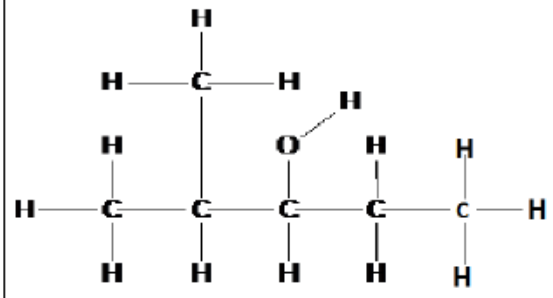
Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	**Ethanedioic acid** Will have one (singlet) peak / hydrogen environment (due to the COOH protons) **(1)** **Propanoic acid** Will have three peaks / three hydrogen environments **(1)** Triplet, quartet / quadruplet & singlet in any order OR Split(ting) pattern 3,4,1 in any order **(1)** NOTE If first mark for **propanoic acid** hasn't been awarded "triplet, quartet / quadruplet & singlet" **scores 2** Intensity in ratio 3:2:1 in any order **(1)** ALLOW labelled and annotated diagrams Max. 3 if not clear that hydrogens/protons give rise to the peaks		**4**

Q23.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q24.

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)	• 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)	• ✓ 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)	• propane / C_3H_8	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)

Q25.

Question Number	Answer	Additional guidance	Mark
(a)	An answer that makes reference to the following points: • step 2: insoluble impurities are removed by filtration of the hot solution (1) • step 4: soluble impurities remain in the solvent left after filtering the cooled mixture (1) • step 5: the solid product is washed so that no soluble impurities form on the product as it dries (1)		3
(b)	A description that makes reference to the following points: • the melting temperature is over a larger range / is not sharp (1) • the measured melting temperature is less than for the pure solid (1)		2

Q26.

Question Number	Answer	Additional Guidance	Mark
	Any **two** of the following points: • the nucleophile does not have an unpaired electron, it has a lone pair of electrons (1) • the slightly positive carbon is not attached to an electropositive chlorine atom, it is attached to an electronegative chlorine atom (1) • the product is not an amide, it is a (secondary) amine (1)		2

Q27.

Question Number	Correct Answer	Reject	Mark
	A		**1**

Q28.

Question Number	Answer	Mark
	The only correct answer is A (blue solution) **B** *is incorrect because the product is not a precipitate* **C** *is incorrect because the product is not yellow* **D** *is incorrect because the product is neither yellow nor a precipitate*	(1)

Q29.

Question Number	Correct Answer	Reject	Mark
	A		**1**

Q30.

Question Number	Correct Answer	Reject	Mark
	B		1

Q31.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q32.

Question Number	Correct Answer	Reject	Mark
	D		1

Q33.

Question Number	Answer	Additional Guidance	Mark
(i)	• (The cation in **Y** is) Cu^{2+} / copper(II) (1) • (The anion in **Y** is) Cl^- / chloride (1)	Allow Cu^{+2} Ignore water ligands Do not award just copper / Cu Do not award just 'chlorine' / Cl	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• $[Cu(NH_3)_4(H_2O)_2]^{2+}$	Allow $[Cu(NH_3)_4]^{2+}$ Allow $[Co(NH_3)_6]^{2+}$ if Co^{2+} in (i) Ignore missing square brackets	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	A description that makes reference to the following points: • add dilute (aqueous) ammonia (and stir the mixture) (1) • the precipitate dissolves (1)	If Cl^- / chloride / chlorine ion: Allow add aqueous ammonia / $NH_3(aq)$ Do not award concentrated ammonia Conditional on use of ammonia Ignore colourless solution If Br^- / bromide / bromine ion identified in Test 4: precipitate is insoluble in dilute ammonia (1) but soluble in concentrated ammonia (1) If I^- / iodide / iodine ion identified in test 4: precipitate is insoluble (1) in dilute and concentrated ammonia (1) Do not award addition of concentrated sulfuric acid	(2)

Q34.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	Lone pair(s) (of electrons on the nitrogen) ALLOW Non-bonded pair(s)	Spare pair	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	$CH_3CH_2CH_2CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+ + OH^-$ ALLOW → for ⇌ IGNORE state symbols even if incorrect Right hand ions must be shown separately ALLOW $C_4H_9NH_2$	Reject near misses	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	**Any two of:** Butyl / alkyl groups are electron donating / are electron pushing / are electron releasing Two (alkyl) groups in dibutylamine (but only one in butylamine) **Lone pair** (of electrons) on the nitrogen more readily available / higher electron density on the nitrogen or NH_2 or amine group / N more delta negative / N or NH_2 accepts a proton more readily **(2)** Stand alone marks Accept reverse argument for butylamine IGNORE 'electronegativity of nitrogen increasing'		**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	**First mark** For the idea of the **lone pair** being withdrawn towards the ring e.g. Lone pair pulled into the ring Lone pair (of electrons) on the nitrogen overlap Lone pair interacts with π electrons / lone pair interacts with delocalized electrons of the (benzene) ring Lone pair (of electrons) on the nitrogen donated to the (benzene) ring **(1)** NOTE The reference to the lone pair may be found in a later part of the answer and credited **Second mark** EITHER For the idea of the **lone pair** being less available OR The **nitrogen** (atom) must be specified as below e.g. Lone pair is less readily available Nitrogen (atom) has lower electron density N (atom) or lone pair is less able to accept protons / H^+ **(1)** ALLOW N is less δ^- for second mark		**2**

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Question Number	Acceptable Answers		Mark
(b)	I $(Cu(H_2O)_6^{2+} + 2C_4H_9NH_2) \rightarrow Cu(H_2O)_4(OH)_2 + 2C_4H_9NH_3^+$ ALLOW I $(Cu(H_2O)_6^{2+} + 2C_4H_9NH_2) \rightarrow Cu(OH)_2 + 2C_4H_9NH_3^+ + 4H_2O$ **(2)** II $(Cu(H_2O)_6^{2+} + 4C_4H_9NH_2) \rightarrow Cu(H_2O)_2(C_4H_9NH_2)_4^{2+} + 4H_2O$ ALLOW II $(Cu(H_2O)_6^{2+} + 4C_4H_9NH_2) \rightarrow Cu(C_4H_9NH_2)_4^{2+} + 6H_2O$ **(2)** Each correct equation scores 2 marks: 1 mark for the formula of the copper complex ion and 1 mark for the rest of the equation being correct Ligands can be in either order IGNORE state symbols even if incorrect IGNORE (lack of) square brackets around complex ions		**4**

Question Number	Acceptable Answers	Reject	Mark
(c)	Reaction is a nucleophilic substitution **(1)** It is unusual because benzene normally reacts with electrophiles / by electrophilic substitution OR Positive charge withdraws electrons from the ring (making it susceptible to nucleophilic attack) OR Expect nucleophiles to be repelled by the electron density of the ring **(1)**		**2**

Q35.

Question Number	Answer	Additional Guidance	Mark
(i)	• balanced equation	Example of equation $C_4H_9NH_2 + H_2O \rightleftharpoons C_4H_9NH_3^+ + OH^-$ + sign can be on N Product ions must be shown as 2 species Allow arrow for ⇌ Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points • lone pair of electrons on the nitrogen atom (1) • the interaction of the lone pair and the pi electrons of the ring (1) • so less able to accept a proton (1) allow 2 possible marking points for reverse argument • butyl group pushes electrons towards lone pair on nitrogen • so it is more able to accept a proton	Allow the lone pair delocalises into the benzene ring	(3)

Q36.

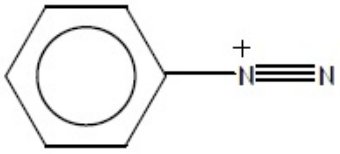
Question Number	Answer	Additional Guidance	Mark
	• correct name (1) • correct formula (1)	Propanoyl chloride Allow propanoic anhydride CH_3CH_2COCl Allow $(CH_3CH_2CO)_2O$ Allow displayed or skeletal formula Allow 1 mark for correct name **and** formula for propanoic acid Allow 1 mark for name and formulae of acyl chloride / acid anhydride with incorrect number of carbon atoms	(2)

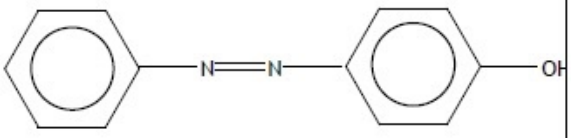
Q37.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	**Lone pair** (of electrons on the nitrogen atom) ALLOW non-bonded pair (of electrons on the nitrogen atom)	**Lone pairs** **Spare pair**	**1**

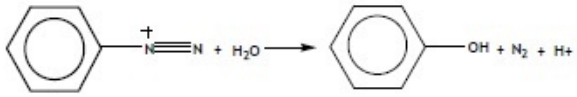
Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	**(with H_2SO_4)** $(C_4H_9NH_3^+)_2SO_4^{2-}$ **(1)** ALLOW $C_4H_9NH_3^+HSO_4^-$ **(with CH_3COOH)** $C_4H_9NH_3^+CH_3COO^-$ **(1)** **CHARGES** not essential Cation and anion can be in either order Max **(1)** if formula of the amine is incorrect in either case ALLOW (1) if only the correct cation is given in each case (i.e. the anion has been omitted in both cases) **NOTE** The correct ions can be shown separately Eg $(C_4H_9NH_3^+)_2$ **+** SO_4^{2-}		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	Tin / Sn ALLOW Iron / Fe **(1)** (concentrated) **hydrochloric acid** **NOTE** If they write 'HCl', there must be some indication of concentrated Eg 'conc HCl' / 'concentrated HCl' ALLOW HCl(aq) (Followed by addition of alkali to liberate the free amine) **(1)** Mark the two points independently **NOTE** Do not allow 2nd mark if there is a suggestion that the acid and alkali are added together simultaneously	$LiAlH_4$ **Just 'HCl'** **'dilute'** hydrochloric acid / sulfuric acid	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	 **NOTE** If the above structure is drawn, the + charge must be on the N connected directly to the benzene ring ALLOW $-N=N^+$ on ring IGNORE Cl^-	N_2^+ on ring	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)			**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	**(Conditions)** (Presence of) NaOH / KOH / alkali /OH^- **(1)** ALLOW 'Alkaline (conditions)' or 'base' or 'high pH' IGNORE Any references to temperature **(Use)** Dye / pigment / colouring / indicator / in foodstuff / in paint / methyl orange **(1)** IGNORE Any reference to medicines		**2**

Question Number	Acceptable Answers	Reject	Mark
(d)	 ALLOW The +sign to be on either N atom in the benezenediazonium ion OR $C_6H_5N_2^+ + H_2O \rightarrow C_6H_5OH + N_2 + H^+$ OR $C_6H_5N_2Cl + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ OR $C_6H_5N_2^+ + 2H_2O \rightarrow C_6H_5OH + N_2 + H_3O^+$ OR $C_6H_5N_2^+Cl^- + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ **NOTE** $-C_6H_5$ can be written or drawn **First mark** for **N_2** **(1)** **Second mark** for rest of the equation correct **(1)** IGNORE State symbols, even if incorrect		**2**

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Question Number	Acceptable Answers	Reject	Mark
(e)(i)	(Otherwise) too much (product) remains in solution OR If excess (solvent) is used, crystals might not form ALLOW To avoid losing (too much) product (in the filtrate when crystallization occurs) / 'to maximize the yield'/ 'will crystallize better from a concentrated solution'/ 'will recrystallize (better) when cold' IGNORE References to a 'saturated solution' or references to 'dilution' or references to the time taken for crystals to form		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	**(Insoluble impurities removed)** By **hot** filtration / During the **first** filtration / During the **second** step in the process **(1)** **(Soluble impurities removed)** By remaining in solution / Left in filtrate / Removed when washed (with cold solvent) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	Measure the melting temperature / melting point **and** compare with data / known value (from a data book / literature / Internet /data base) (BOTH points needed for the mark) OR The melting point is sharp (Just this statement is needed for the mark) ALLOW Any form of chromatography IGNORE References to any types of spectroscopy	**(0)** if reference to determination of the boiling point is made	**1**

Q38.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the electron density of the (benzene) ring is greater in phenol (than in benzene) (1) • because the lone pair (of electrons) on oxygen **and** (1) overlaps with the pi cloud / delocalised electrons / delocalised system	Allow lone pair (of electrons) on oxygen feeds into / donates into / interacts with the delocalised electrons / system Ignore electron pushing effect of OH	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • they both form hydrogen bonds (1) • in 4-nitrophenol the hydrogen bonds join molecules in a straight chain / at both ends / at opposite ends (of the molecule so are stronger) or 2-nitrophenol forms intramolecular hydrogen bonds / forces / interactions (so fewer intermolecular hydrogen bonds) (1)	Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces Allow 4-nitrophenol forms stronger intermolecular hydrogen bonds / forces / interactions Allow in 2-nitrophenol the hydrogen bonds join 2 molecules together / form a dimer (so there are fewer / weaker hydrogen bonds) Allow in 2-nitrophenol the hydrogen bonds are on the same side (of the molecule)	(2)

Q39.

Question Number	Answer	Additional Guidance	Mark
	• reducing agent / reductant	Ignore tin and concentrated hydrochloric acid Do not award any other named reducing agent	(1)

Q40.

Question Number	Answer	Additional Guidance	Mark
	C		1

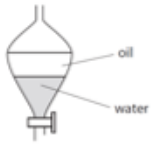
Q41.

Question Number	Correct Answer	Mark
	B	**1**

Q42.

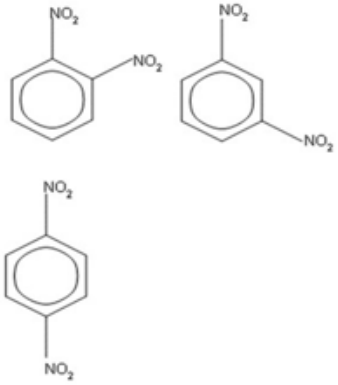
Question Number	Correct Answer	Reject	Mark
	A		**1**

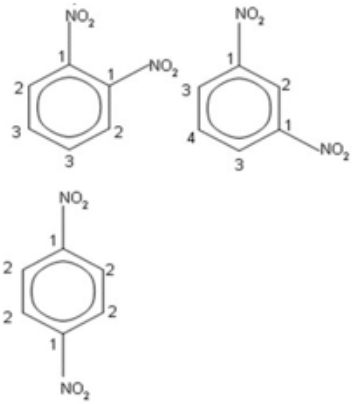
Q43.

Question Number	Answer	Additional guidance	Mark
(i)	 • separating funnel (1) • cinnamon oil upper layer (1)	Funnel must be suitable for a stopper	**2**
(ii)	• addition of (anhydrous) sodium sulfate / calcium chloride / magnesium sulfate		**1**
(iii)	• from cloudy to clear	Do not accept colourless in place of clear	**1**

Q44.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	$C_6H_4^{+}$	Allow $H_4C_6^{+}$ Do not award just C_6H_4	**(1)**

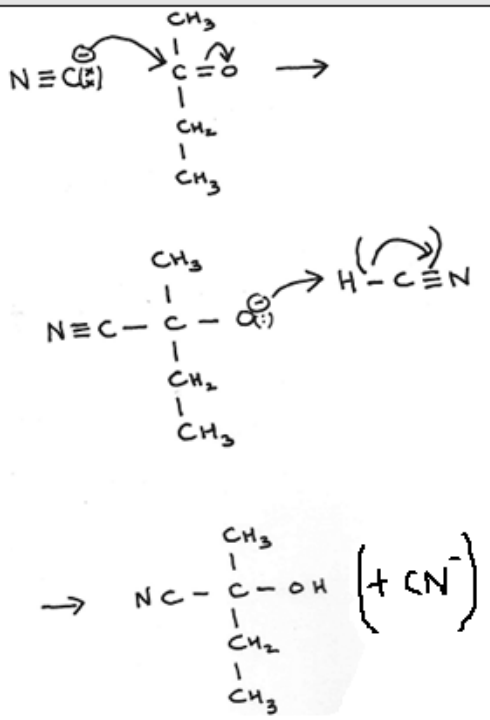
Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• 3 correct formulae **(2)**	Examples of formulae  Allow (1) for any 2 correct formulae Allow (2) for three disubstituted benzenes with incorrect substituents / (1) for any two disubstituted benzenes with incorrect substituents Allow incorrectly displayed formulae of NO_2 groups **In (c)(ii) and (iii):** Allow Kekule structures Allow hydrogen atoms shown on benzene Ignore connectivity of NO_2 groups Penalise missing circle in benzene once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• **D** identified as 1,3-dinitrobenzene **and** 4 different carbon environments labelled **(1)** • 3 different carbon environments labelled on 1,2-dinitrobenzene **(1)** • 2 different carbon environments labelled on 1,4-dinitrobenzene **(1)**	 <u>Examples of identification</u> These labels may be shown on the structures in (c)(ii) The identification of **D** can be assumed if it is the only structure with 4 carbon environments labelled Allow any form of identification of the carbon environments e.g. numbers, letters, equivalent carbon environments circled TE on disubstituted benzene substituents in (ii) Penalise only half the carbon environments labelled once only	**(3)**

Q45.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Sodium/potassium dichromate ((VI)) **and** (Dilute/concentrated) sulfuric acid OR correct formulae / H^+ **and** $Cr_2O_7^{2-}$ ALLOW H^+ **and** $Cr_2O_7^{2-}$/acidified dichromate((VI)) **(1)** Reflux/distil Ignore 'heat', 'warm', and 'boil' alone. ALLOW Just 'under reflux' Just 'under distillation' **(1)** Second mark depends on mention of dichromate/$Cr_2O_7^{2-}$ in first part OR $KMnO_4$ and acid with heat **(1)**	Hydrochloric acid	**2**

Question Number	Correct Answer	Reject	Mark
(a)(ii)	Carbonyl group – addition of 2,4-dinitrophenylhydrazine / 2,4-DNP(H) / Brady's reagent **(1)** to give yellow/orange/red precipitate/ppt/ppte/solid/crystals ALLOW recognisable spelling e.g., percepitate **(1)** $CH_3C{=}O$ reaction with iodine in alkali/NaOH/KOH/OH^- ALLOW Iodoform/tri-iodomethane/haloform AND reaction/test **(1)** to form (pale) yellow / cloudy precipitate/solid/crystals **(1)**	2-DNP/4DNP Just DNP Brick red ppt	**4**
	Ignore references to smell Ignore heat in either part **Note** • In both cases result mark depends on test being recognisably correct even if it did not score a mark Examples: DNP gives yellow ppt Iodine test gives yellow ppt • Tests for aldehydes with correct results, no marks		

Question Number	Correct Answer	Reject	Mark
(b)(i)	 Arrow (from carbon) of CN^- to carbon of C=O AND Arrow from part of C=O double bond to oxygen ALLOW	CN without negative charge	**3**
	Two steps via a charged canonical form **(1)** Intermediate anion with C-CN bond. **(1)** Arrow from resulting O^- to hydrogen of $HCN/H^+/H_2O$ **(1)** **Note** Arrow directions must be correct to score each mark Penalise half-headed arrows each time in both parts ALLOW skeletal formulae.	...C-NC bond	

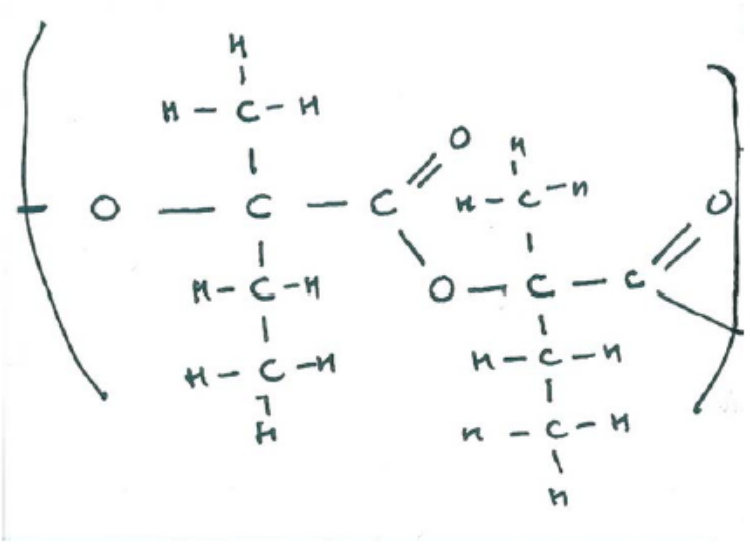
Question Number	Correct Answer	Reject	Mark
(b)(ii)	Forms a racemic mixture **(1)** Because bonds around C=O are planar OR Carbonyl group/reaction site is (trigonal) planar OR Bonds around carbonyl carbon are planar **(1)** Cyanide can attack from either side / above or below **(1)**	Butanone/molecule/it is planar C=O is planar Carbonyl bond is planar Intermediate is planar	**3**

Question Number	Correct Answer	Reject	Mark
(c)(i)	(Acid) hydrolysis OR Alkaline hydrolysis followed by acidification	Hydration	**1**

Question Number	Correct Answer	Reject	Mark
(c)(ii)	The O-H absorptions for alcohol and carboxylic acid overlap. OR OH absorption for an acid is very broad OR Quote data booklet values which must show some overlap, to include 3300 to 3200. ALLOW OH absorptions similar/the same.	Just 'both have OH groups' Just 'two OH groups present'	**1**

Question Number	Correct Answer	Reject	Mark
(c)(iii)	(Chemical shift δ) 2.0 - 4.0 (ppm) / any value within this range ALLOW Correct number followed by δ, eg 3δ		**1**

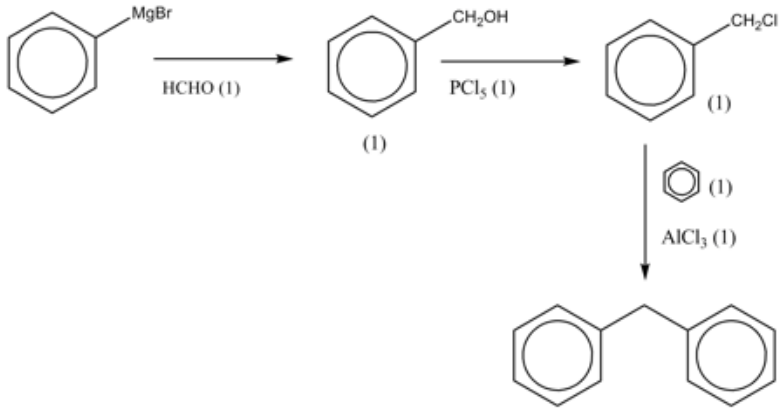
Question Number	Correct Answer	Reject	Mark
(c)(iv)	There is no hydrogen atom/proton on the adjacent/neighbouring carbon atom ALLOW No adjacent/neighbouring hydrogens/protons		**1**

Question Number	Correct Answer	Reject	Mark
(d)	 Ester linkage **(1)** Rest of molecule **(1)** ALLOW Attached chains as structural formulae Ignore n or other numbers outside bracket		**2**

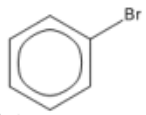
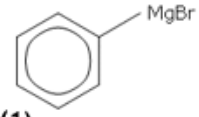
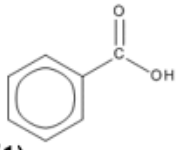
Q46.

Question Number	Answer	Additional Guidance	Mark
	• 2-bromo-2-methylbutane reacts with Mg **(1)** • Dry ether **(1)** • $CH_3CH_2C(MgBr)(CH_3)CH_3$ **(1)** • react Grignard reagent with HCHO **(1)** • $CH_3CH_2C(CH_3)_2CH_2OMgBr$ **(1)** • (hydrolyse) with (dilute) acid **(1)** OR • 2-bromo-2-methylbutane reacts with KCN **(1)** • ethanol (as solvent) **(1)** • $CH_3CH_2C(CN)(CH_3)CH_3$ **(1)** • nitrile (hydrolysed) with (dilute) acid **(1)** • $CH_3CH_2C(COOH)(CH_3)CH_3$ **(1)** • carboxylic acid (reduced) with $LiAlH_4$ (in dry ether) **(1)**	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 do not award HCOH Allow with water / H^+ Ignore HCN Allow methanol Allow H^+	(6)

Q47.

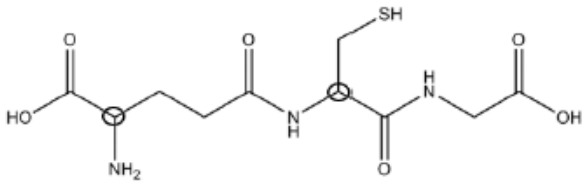
Question Number	Answer	Additional guidance	Mark
(i)	Iron / iron(III) bromide	Allow aluminium / aluminium bromide Allow correct formulae	1
(ii)	• reagent for step 1 (1) • product of step 1 (1) • reagent for step 2 (1) • product of step 2 (1) • reagent for step 3 (1) • catalyst for step 3 (1) Example of synthesis:  		6

Q48.

Question Number	Answer	Additional Guidance	Mark
	Step 1 • bromine **and** iron / iron(III) bromide **or** chlorine and aluminium chloride **(1)** •  **(1)** **Step 2** • magnesium **and** dry ether **(1)** •  **(1)** **Step 3** • carbon dioxide followed by a dilute acid **(1)** •  **(1)** **Step 4** • phosphorus(V) chloride / phosphorus pentachloride **(1)**	Allow names or formulae for reagents but if both are given, both must be correct Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations The marks for the intermediate structures are stand-alone Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water	**(7)**

Q49.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (oxidation) *A is incorrect as there is no evidence the species have added to the benzene ring* *B is incorrect as there is no evidence of chemical breakdown due to reaction with water* *D is incorrect as the -NH group and -OH group have lost hydrogen atoms*	(1)

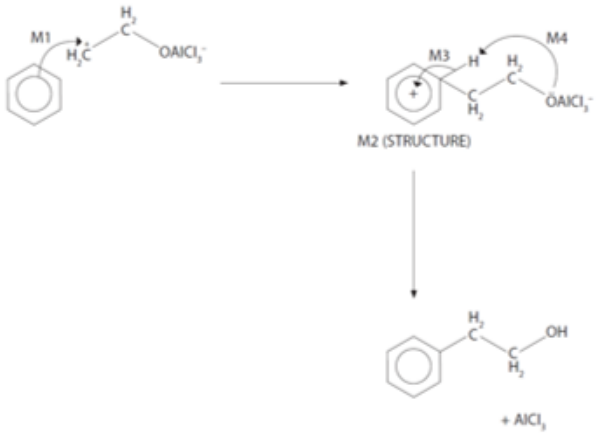
Question Number	Answer	Additional guidance	Mark
(ii)	• both carbon atoms circled	 Allow any other labelling e.g. asterisk / arrow Do not award additional incorrect carbon atoms	(1)

Question Number	Answer	Mark
(iii)	**The only correct answer is B** (glutamic acid and cysteine) ***A*** *is incorrect as aspartic acid has only 4 carbon atoms* ***C*** *is incorrect as the sulfur atom in methionine has a methyl group attached* ***D*** *is incorrect as the sulfur atom in methionine has a methyl group attached and aspartic acid has only 4 carbon atoms*	(1)

Q50.

Question Number	Answer	Additional Guidance	Mark
(a)	Any **one** from: • $C_3H_6 + C_7H_{16}$ (1) • $2C_3H_6 + C_4H_{10}$ (1) • $3C_3H_6 + CH_4$ (1)		**1**
(b)(i)	• **X** is propan-1-ol (1) Step 2 • reaction with aqueous NaOH (and heat) (1) Step 3 • oxidation to acid using acidified $K_2Cr_2O_7$ (1) • with excess oxidising agent / heated under reflux (1)	Allow 'H^+ and $Cr_2O_7^{2-}$'	**4**
(b)(ii)	An explanation that makes reference to **two** of the following points: • main product from reaction with HBr will be 2-bromopropane (1) • as secondary carbocation (formed in mechanism) is more stable (than primary) (1)	Allow reverse argument e.g. • 1-bromopropane is the minor product (1) • as primary carbocation (formed in mechanism) is less stable (than secondary)	**2**

Q51.

Question Number	Answer	Additional Guidance	Mark
(i)	A		1
(ii)	 • electron pair movement from ring to electrophile (1) • formula of intermediate ion (1) • movement of bond pair to reinstate delocalised ring (1) • movement of lone pair from oxygen to hydrogen (1)	Can show H^+ ion forming and reacting with lone pair from oxygen Can show O-Al bond breaking	4
(iii)	B		1
(iv)	• (concentrated) sulfuric acid / H_2SO_4 **or** • (concentrated) hydrochloric acid/HCl	Do not award dilute sulfuric acid	1

Q52.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to: • (similarity) both are basic because they have a lone pair of electrons on the nitrogen atom which accepts a proton **(1)** • (difference 1)in $C_6H_5NH_2$ the lone pair of electrons of the nitrogen atom becomes incorporated with the delocalised ring of electrons and so is less able to accept a proton hence a weaker base **(1)** • (difference 2) the alkyl group/ C_4H_9 is electron-releasing / positively inductive and means the lone pair of electrons of the nitrogen atom are more able to accept a proton hence a stronger base **(1)**	Diagrams can be used to score Comparison of basicity/nitrogen's lone pair of electrons/proton acceptance only need to be mentioned once.	**(3)**

Q53.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to • **(M1)** (similarity) all have arene C–H absorptions Either 3030 (cm^{-1}) **or** 750 and/or 700 (cm^{-1}) **(1)** • **(M2)** only phenol and phenylmethanol have O–H 3750 - 3200 (cm^{-1}) **(1)** • **(M3)** only benzoic acid has O–H 3300 - 2500 (cm^{-1}) **(1)** • **(M4)** only benzoic acid has C=O 1700 - 1680 (cm^{-1}) **(1)** • **(M5)** only phenylmethanol has alkane C–H absorptions either 2962 - 2853 (cm^{-1}) or 1485 - 1365 (cm^{-1}) **(1)**	Bond and wavenumber ranges necessary for each mark Do not award 880/830/780 (cm^{-1}) Do not award –OH / C–OH by penalising once only in M2 and M3 All 5 correct bonds with no wavenumber ranges scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) All 5 correct wavenumber ranges with no bonds or incorrect bonds scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) Penalise any additional peaks once only Ignore references to different fingerprint regions	**(5)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to • five peaks (in the ^{13}C NMR spectrum) **(1)** • (four) aromatic peaks within the chemical shift range of 165 - 105 (ppm) **(1)** • (one) peak (for the C-OH) within the chemical shift range of 75 - 55 (ppm) **(1)**	Allow any range within the stated ranges Penalise single values as opposed to ranges once only Accept annotations on diagram Penalise additional peaks once only when three or more types of peak are stated	**(3)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to • suitable formula of fragment ion **(1)** • matching *m*/*z* value **(1)**	Example of a suitable formula $C_6H_5COO^+$ or $C_6H_5CO^+$ Do not award $C_7H_5O_2^+$ or $C_7H_5O^+$ *m*/*z* = 121 or 105 Allow $COOH^+$ (1) Do not award bond to the fragment, e.g. $–COOH^+$ *m*/*z* = 45 (1) No TE on incorrect fragment ions such as CH_3^+	**(2)**

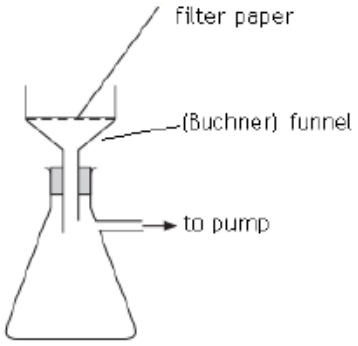
Q54.

Question Number	Answer	Additional Guidance	Mark
(i)	 • formulae (1) • balancing and brackets (1) (2nd mark dependent on use of correct formulae)	Ignore type of brackets	**2**
(ii)	A description that makes reference to: • nylon is formed by a condensation reaction / releases HCl when polymers forms (1) • nylon is formed from two different monomers (1) OR • poly(propene) is formed by an addition reaction / forms only one product (1) • poly(propene) is formed from only one type of monomer (1)		**2**
(iii)	An answer that makes reference to **two** of the following points: • reprocessing of polymers into simpler compounds for use as feedstock in the chemical industry (1) • capture and use of energy from incineration (1) • sorting (Using IR) **and** recycling of polymers (1) • removal of harmful/toxic/corrosive products formed during incineration (1)		**2**

Q55.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to: • The benzoate ion is protonated by the hydrochloric acid **(1)** • benzoic acid is less soluble (in water) than the sodium salt **(1)**	 Allow HCl/acid reacts to form benzoic acid Allow benzoic acid is insoluble	**(2)**

Q56.

Question Number	Answer	Additional Guidance	Mark
(i)	• side-arm flask with label 'to pump' / drawing of pump **(1)** • (Buchner) funnel with perforations **and** bung around neck of funnel **(1)** • **flat** filter paper (over perforations)	Example of diagram  Ignore just 'suction' Allow funnel joined to flask with 'Quickfit' joint / no gap Do not award fluted filter paper / filter paper that extends up the sides of the funnel	**(3)**

Question Number	Answer	Additional Guidance	Mark
(ii)	A description that makes reference to the following points: • dissolve crystals in the **minimum** (amount / volume) (1) • of hot water / solvent (1) • filter hot **and** allow to cool (1) • filter **and** wash with a small amount of (cold) solvent (1) (1) • dry crystals between filter papers / in a desiccator / in a warm oven	Allow add / put for dissolve Do not award wash for dissolve Penalise use of incorrect solvent once only Allow M3 if hot is omitted and is mentioned in M2 Do not award filter to remove soluble impurities Stand alone mark Allow other suitable methods of drying Do not award reference to crystals mixed with a drying agent	(5)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: (1) • melting temperature is lower • it melts over a range of temperatures (1) **or** the melting temperature is not sharp	Allow a specified range of temperatures	(2)

Q57.

Answer	Additional Guidance	Mark
• equation **(1)** • name **(1)**	$C_2H_5COCl + C_5H_{11}NH_2 \rightarrow C_2H_5CONHC_5H_{11} + HCl$ or  Allow skeletal/structural/combination of formulae Allow $C_2H_5COCl + 2C_5H_{11}NH_2 \rightarrow C_2H_5CONHC_5H_{11} + HCl + C_5H_{11}NH_3Cl$ Do not award molecular formulae N-pentylpropanamide Do not award N-pentylpropylamine	**(2)**

Q58.

Question Number	Acceptable Answer	Additional guidance	Mark
(i)	• Answer to 2 SF	Example of calculation: R_f= 1.5 = 0.15 10 Allow 0.14 – 0.16 Do not award 3SF, e.g. 0.140/0.150/0.160 Do not award an answer with units	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
(ii)	An answer that makes reference to the following: • serine (1) • methionine (1) • (reason) one amino acid is present twice (in the tripeptide) OR Another amino acid has the same R_f value as either serine or methionine (1)	 Allow for 1 mark out of the first two for F and B Allow 'there are two serine amino acids/ there are two methionine amino acids' Do not award if given with any other amino acid stated in the question Ignore reference to another amino acid not given in the table	(3)

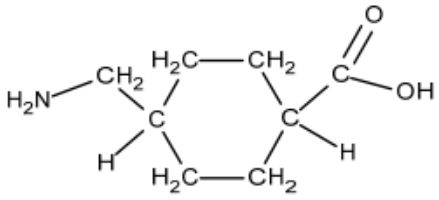
Question Number	Acceptable Answer	Additional guidance	Mark
(iii)	An answer that makes reference to the following: • amino acids have different solubility / adsorption to the stationary phase (1) • amino acids have different solubility in the mobile phase (1)	Allow reverse arguments Do not award react with the stationary phase Allow "TLC plate" for stationary phase Allow interact with/affinity for/form different intermolecular forces with the stationary or mobile phase Allow "solvent" for mobile phase Ignore references to molecular mass/size	(2)

Question Number	Answer	Mark
(iv)	The only correct answer is **C** ***A*** *is incorrect because* this is a test for starch ***B*** *is incorrect because* this is a strong acid-weak base indicator ***D*** *is incorrect because* this is a weak acid-strong base indicator	**(1)**

Q59.

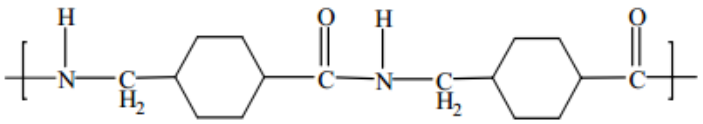
Question Number	Acceptable Answers	Reject	Mark
17(a)(i)	There is a barrier to rotation about a (C=C) bond **(1)** ALLOW restricted / limited / no rotation Each carbon atom (in the C=C double bond) has (two) different atoms / groups attached **(1)** IGNORE reference to priority groups	Just 'molecule cannot rotate'	**2**

Question Number	Acceptable Answers	Reject	Mark
17(a)(ii)	There is a barrier to / restricted rotation about the ring OR The ring behaves like a double bond	Reference to benzene ring Just 'molecule cannot rotate'	**1**

Question Number	Acceptable Answers	Reject	Mark
17(a)(iii)	 Any diagram of the correct molecule showing the groups (attached to the ring) on same side of the ring OR zwitterion ALLOW Amine group in skeletal form	Omission of amine CH_2	**1**

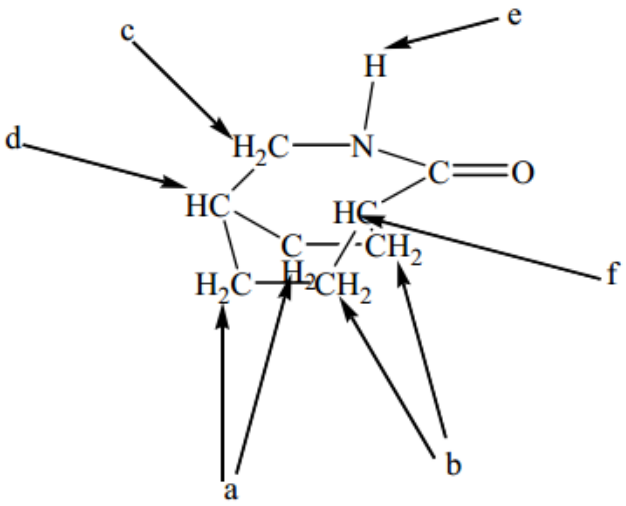
Question Number	Acceptable Answers	Reject	Mark
17(a)(iv)	Tranexamic acid exists as a zwitterion OR Diagram of zwitterion OR Description of zwitterion formation **(1)** So the (strongest) intermolecular forces are ionic (strong) ALLOW electrostatic for ionic **(1)** IGNORE H bonding in tranexamic acid if **either** of the first two marks scored. Otherwise... Hydrogen bonding in tranexamic acid scores 1/2 max Undecane has (only) (much weaker) London / dispersion / van der Waals / temporary induced dipole (-induced dipole) forces / interactions **(1)**		**3**

Question Number	Acceptable Answers	Reject	Mark
17(b)(i)	Phosphorus(v) chloride / PCl_5 ALLOW phosphorus pentachloride / phosphorus(III) chloride / PCl_3 / phosphorus trichloride Thionyl chloride (sulfur dichloride oxide) / $SOCl_2$	HCl	**1**

Question Number	Acceptable Answers	Reject	Mark
17(b)(ii)	 **First mark** amide linkage ALLOW CONH for amide linkage **(1)** **Second mark** Completion of structure (brackets not required) with displayed or skeletal formula **(1)** Second mark dependent on first Dimer scores amide linkage mark only		**2**

Question Number	Acceptable Answers	Reject	Mark
17(b)(iii)	Condensation / addition-elimination (polymerization)	Addition (polymerization) Elimination (polymerization) Polyamide formation	**1**

Question Number	Acceptable Answers	Reject	Mark
17(b)(iv)	Protein / proteins / polypeptide / polypeptides / peptide / peptides ALLOW Enzyme / Enzymes	Nylon Polyamide amino acids	1

Question Number	Acceptable Answers	Reject	Mark
17(c)(i)	Check sequence of letters. Candidates may have labelled the groups of hydrogen atoms with different letters, which is fine. **First mark** Unique N**H** (at e) **(1)** **Second mark** **(1)** Unique C$\mathbf{H_2}$ (at c) **Third mark** **(1)** C**H** (at d) and C**H** (at f) with different unique labels **Fourth mark** **(1)** 2C$\mathbf{H_2}$ (at a) and 2C$\mathbf{H_2}$ (at b) with different new labels 		4

Question Number	Acceptable Answers	Reject	Mark
17(c)(ii)	C=O amide (stretching vibrations are in the region) 1700-1630 cm^{-1} **(1)** N—H amide (stretching vibrations are in the region) 3500-3140 cm^{-1} **(1)** Amide only needs to be mentioned once but... These answers without mention of **amide** max 1 Amides have peaks in these regions max 1	Ketone Amine (for amide)	2

Question Number	Acceptable Answers	Reject	Mark
17(c)(iii)	**Any two from** In the trans isomer the (amine and acid chloride) groups are too far apart to react intramolecularly / to form **M** OR Because the groups are on opposite sides of the (plane of the) **ring** OR More likely to polymerize / react with adjacent molecules. **(2)** Marks may also be scored by a reverse argument: In the cis isomer the (amine and acid chloride) groups are on the same side of the (plane of the) **ring** **(1)** So close enough to react intramolecularly / to form **M (1)**	bond	2

Q60.

Question Number	Acceptable Answers	Additional Guidance	Mark
	An answer that makes reference to the following points: (1st Step) • HCN (and KCN) **(1)**	Ignore references to other conditions / solvent in step 1 Allow HCN and CN^- / H^+ and CN^- / H^+ and KCN **or** KCN and H_2SO_4 / KCN and HCl **or** HCN at pH 8 – 9 M1 can be scored for the appearance of HCN in M3	**(7)**
	• Nucleophilic addition **(1)**	Do not award additional incorrect reaction types e.g. nitrification Allow skeletal formulae in equations	
	• $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ **(1)**	M4, 5 & 6 dependent on the formation of any nitrile in step 1	
	(2nd Step)		
	• Any identified (dilute) strong acid / H^+ **(1)**	Allow sodium hydroxide followed by acid Do not award conc. acid / just "acidify" / just "acid" Allow warm	
	• Heat (under reflux) / reflux **(1)**		
	• Hydrolysis **(1)**	Do not award additional incorrect reaction types	
	• $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ **or** $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ **(1)**	Allow two equations involving NaOH and H^+ Allow $CH_3CH(OH)CN + 2H_2O + HCl \rightarrow CH_3CH(OH)COOH + NH_4Cl$	

Q61.

Question Number	Correct Answer	Reject	Mark
	A		1