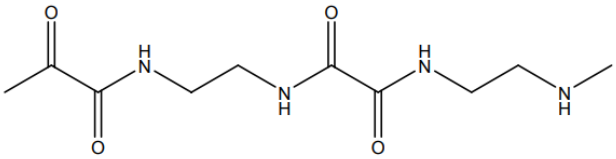
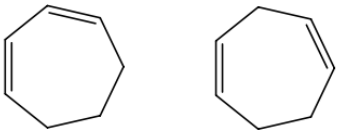
1. 9701/41/O/N/16 Q1e

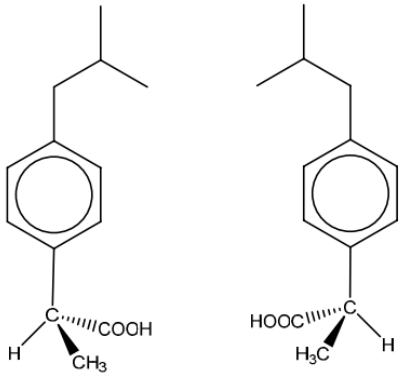
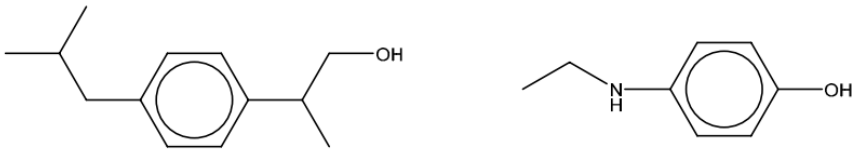
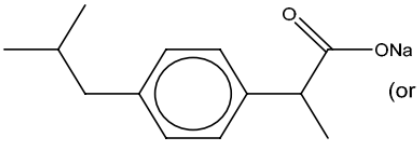
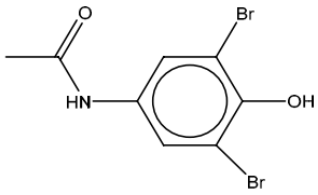
1(e)(ii)	$H_2NCH_2CH_2NH_2 + 2HCl \rightarrow ClH_3NCH_2CH_2NH_3Cl$ **OR** $H_2NCH_2CH_2NH_2 + 2H^+ \rightarrow H_3N^+CH_2CH_2N^+H_3$	1 **1**
1(f)(i)	amide bond, displayed or –CONH– rest of the molecule with continuation bonds 	1 1 **2**
1(f)(ii)	condensation / addition – elimination	1 **1**
1(f)(iii)	any named polyalkene / eg polyethene, PVC **allow** Bakelite or Kevlar	1 **1**

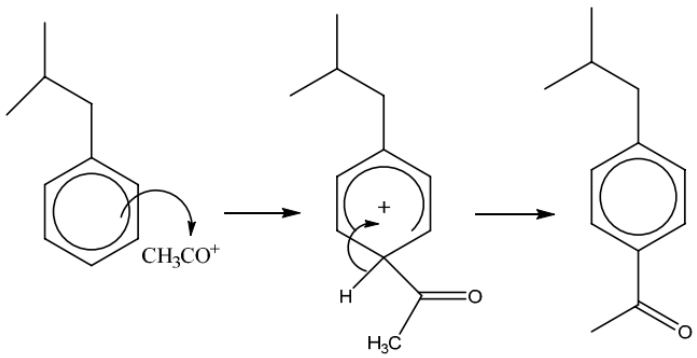
2. 9701/41/O/N/16 Q5d

5(d)(i)	 both required for 1 mark	1 **1**

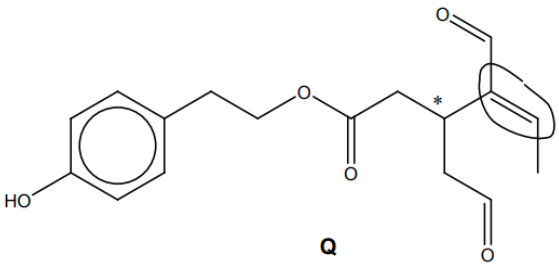
3. 9701/41/O/N/16 Q6

6(a)	ibuprofen: carboxylic acid / carboxyl paracetamol: phenol and amide any two = 1 mark all three = 2 marks	**2**
6(b)(i)	(chiral centre is a) carbon **OR** atom that has four different groups / atoms / species attached to it	1 **1**

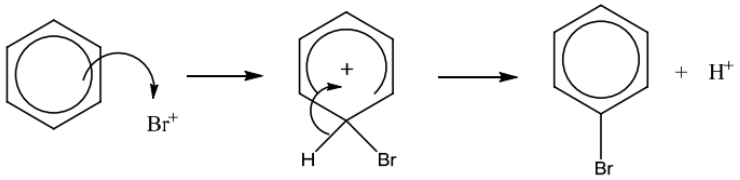
6(b)(ii)	 one correct isomer second diagram shows second isomer	1 1 **2**
6(c)	 with ibuprofen with paracetamol	1 1 **2**
6(d)(i)	(reagent **D**) Na_2CO_3 / any carbonate (reagent **E**) Cl_2 / Br_2	1 1 **2**
6(d)(ii)	 (or ionic)	1 **1**
6(d)(iii)		1 **1**
6(e)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	1 **1**

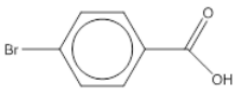
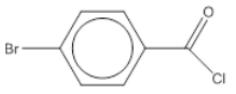
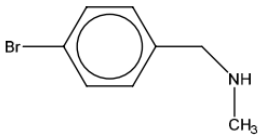
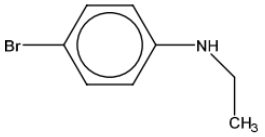
6(e)(ii)	 curly arrow from ring system to CH_3CO^+ correct intermediate curly arrow from C–H bond into ring	1 1 1 **3**
6(e)(iii)	electrophilic substitution	1 **1**

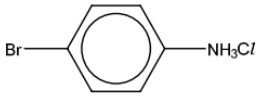
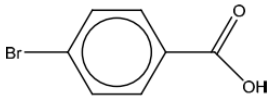
4. 9701/42/O/N/16 Q6a

6(a)	 **Q**	**1**

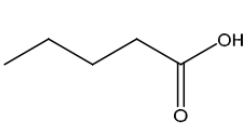
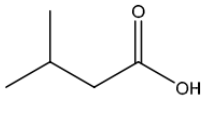
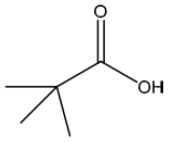
5. 9701/42/O/N/16 Q7

7(a)(i)	electrophilic substitution	1 **1**
7(a)(ii)	$(Br_2 + AlBr_3) \rightarrow Br^+ + AlBr_4^-$  curly arrow from ring system to Br^+ correct intermediate curly arrow from C–H bond into ring and loss of H^+	1 1 1 1 **4**
7(b)	**both** amide	1 **1**
7(c)(i)	step 1, $AlBr_3$ **and** CH_3Br **OR** other suitable halogen instead of Br step 2, $KMnO_4$ or potassium manganate(VII) step 3, conc. H_2SO_4 **and** conc. HNO_3 step 4. Sn **and** (conc.) HCl (heat)	1 1 1 1 **4**

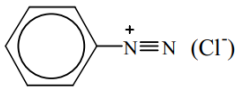
7(c)(ii)	 R  S  T 1 mark for each correct structure	3
7(d)(i)	  1 mark for each correct structure	2
7(d)(ii)	reduction	1 1

7(e)(i)	 CH_3COOH (or ionic) 1 mark for each correct structure	2
7(e)(ii)		1 1
7(e)(iii)	(precipitate) compound is less polar / more non-polar / non-ionic resulting in less hydrogen bonding to water	1 1

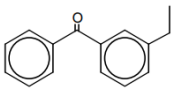
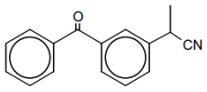
6. 9701/42/O/N/16 Q8b

8(b)(i)	   2 correct = 1 mark 3 correct = 2 marks	2
8(b)(ii)	2-methyl butanoic acid	1 1

7. 9701/41/M/J/16 Q6d

6	(a) (i)	$C_6H_5NO_2 + 6e^- + 6H^+ \longrightarrow C_6H_5NH_2 + 2H_2O$	[1]
	(ii)	$2C_6H_5NO_2 + 14HCl + 3Sn \rightarrow 2C_6H_5NH_3Cl + 3SnCl_4 + 4H_2O$	[2]
	(d)	phenylamine is less basic that ethylamine the lone pair on N is delocalised over the ring… …making it less available for reaction with a proton / δ+ H	[2]
	(e) (i)	step 1: HNO_2 OR ($NaNO_2$ + HCl) at $T \leqslant 10\,°C$ step 2: boil / heat in water	[1] [1]
	(ii)	**E** is 	[1]

8. 9701/41/M/J/16 Q9

9	(a)	**T** is  **U** is 	[1] [1]
	(b)	step 1: C_6H_5COCl + $AlCl_3$ (+ heat) step 2: CH_3CH_2Cl + $AlCl_3$ (+ heat) step 3: Br_2 + light (*or* heat) step 4: KCN + heat (in ethanol) step 5: H_3O^+ OR H^+ in H_2O OR HCl (aq) etc AND heat / boil / reflux	[1] [1] [1] [1] [1]
	(c)	step 1: electrophilic substitution OR nucleophilic substitution step 5: hydrolysis OR nucleophilic substitution	[1] [1]

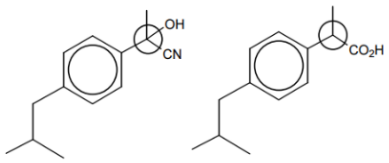
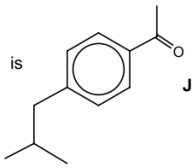
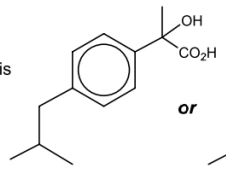
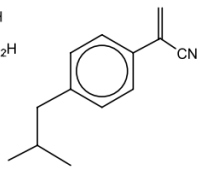
9. 9701/42/M/J/16 Q3

3	(a) (i)	$(CH_3)_2CHCN$	1
	(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN **and** heat / reflux (in ethanol) reaction 3: H_2 + Ni *or* $LiAlH_4$	3
	(b) (i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$	1
	(ii)	ethylamine is **more basic** than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the lone pair (on N) more available for donation **or** the lone pair (on N) more available for a proton / H^+	2

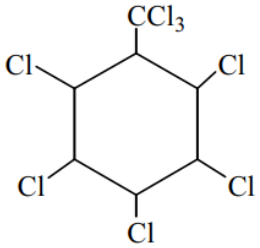
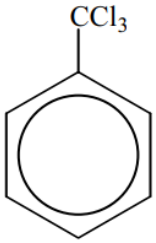
10. 9701/42/M/J/16 Q6a

6	(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **active site** – can be awarded from a labelled diagram as below **or** diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the active site of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  	3

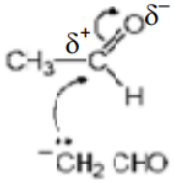
11. 9701/42/M/J/16 Q9

9 (a)		1
(b)	H is  J is  *or*  **J1** **J2**	2
(c)	step 1: $(CH_3)_2CHCH_2Cl$ + $AlCl_3$ (+ heat) step 2: CH_3COCl + $AlCl_3$ (+ heat) step 3: HCN + NaCN ***or*** HCN + base ***or*** HCN + CN^- *(steps 4 and 5 could be reversed on J)* ***If J1*** *step 4 then step 5* ***J2*** *step 5 then step 4* step 4: H_3O^+ + heat / aqueous HCl + heat step 5: conc H_2SO_4 + heat / conc H_3PO_4 + heat **or** Al_2O_3 + heat step 6: H_2 + Ni (+ heat)	6
(d)	step 1: electrophilic substitution ***or*** alkylation step 6: reduction / hydrogenation / addition	2

12. 9701/42/F/M/16 Q1c

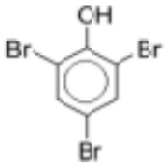
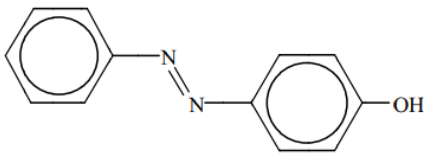
(c) (i)	reaction 1: Cl_2 and UV light; reaction 2: $AlCl_3$, Cl_2 (NOT aqueous);	**1** **1**
(ii)	(free) radical substitution	**1**
(iii)	 *or* 	**1**

13. 9701/42/F/M/16 Q4d

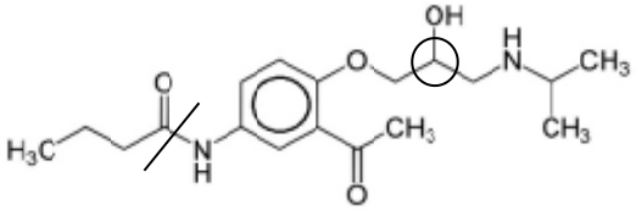
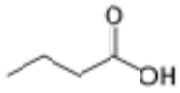
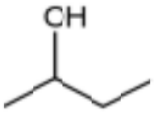
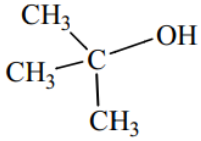
(d)	**M1**: both curly arrows **M2**: dipole correctly shown 	**1** **1**

14. 9701/42/F/M/16 Q7

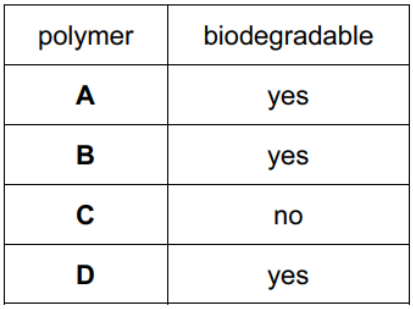
<table>
<tr><td>7 (a) (i)</td><td>M1: phenol is more acidic than ethanol because the O–H bond in phenol is weakened / the phenoxide anion is stabilised / ethanol has an electron donating group
M2: p orbital / lone pair of electrons on O can be delocalised over / overlaps with ring</td><td>1

1</td></tr>
<tr><td>(ii)</td><td><table>
<tr><th>reagent</th><th>conditions</th><th>Structure</th></tr>
<tr><td>HNO_3</td><td>dilute, 5 °C</td><td>  </td></tr>
<tr><td>Br_2</td><td>aqueous
(I: temperature)</td><td>  </td></tr>
</table></td><td>3</td></tr>
<tr><td>(iii)</td><td>electrophilic substitution</td><td>1</td></tr>
<tr><td>(b) (i)</td><td>white precipitate / solid</td><td>1</td></tr>
<tr><td>(ii)</td><td>between 0° C and 10 °C</td><td>1</td></tr>
<tr><td>(iii)</td><td>M1: double bond between nitrogen atoms
M2: rest of molecule
  </td><td>1
1</td></tr>
</table>

15. 9701/42/F/M/16 Q8

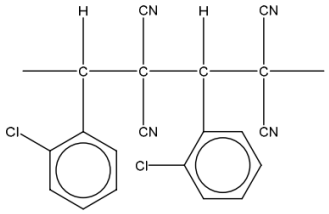
8 (a)	**P** amide **Q** ketone **R** **secondary** alcohol **Q** = carbonyl and **R** = alcohol scores [1]	**1** **1** **1**
(b)		**1**
(c) (i)	see line on diagram in **(b)**	**1**
(ii)		**1**
(d)	reagent / observation alkaline iodine solution / yellow ppt. formed universal indicator / blue / purple colour formed 2,4-dinitrophenylhydrazine / yellow / orange ppt formed Tollens' reagent / no reaction	**3**
(e) (i)	$LiAlH_4$	**1**
(ii)	 (must be skeletal)	**1**
(iii)		**1**

16. 9701/42/F/M/16 Q9

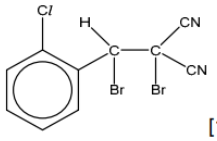
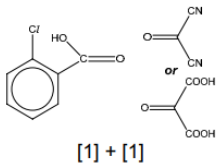
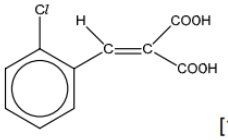
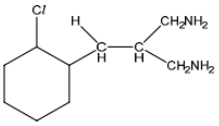
9 (a) (i)	polyester : *Terylene* / polylactic acid (PLA) / polyamide : nylon / *Kevlar* / Nomex	**1**
(ii)	water *or* hydrochloric acid / hydrogen chloride	**1**
(b) (i)		**2**
(ii)	$HOCH_2CH_2OH$ and  or equivalent 1,4-diacyl chloride or equivalent 1,4-diester	**2**

polymer	biodegradable
A	yes
B	yes
C	no
D	yes

17. 9701/41/O/N/17 Q5

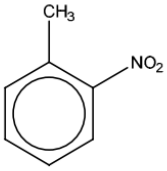
5(a)	nitrile; alkene; chloro; benzene / arene	**2**
5(b)		**1**
	addition (polymerisation)	**1**

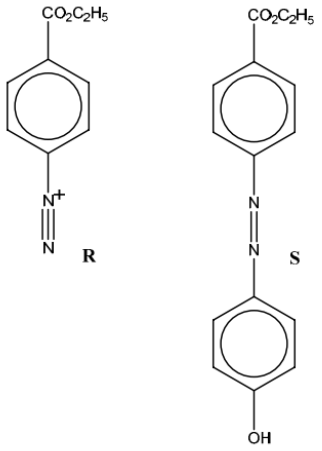
5(c)

reagent	structure of product	type of organic reaction
excess $Br_2(aq)$	 [1]	(electrophilic) addition
excess hot, conc. $MnO_4^-(aq)$	 [1] + [1]	oxidation
excess hot, aqueous HCl	 [1]	hydrolysis
excess H_2 / Pt catalyst	 both CH_2NH_2 formed [1] both arene and alkene reduced [1]	reduction / hydrogenation
	structures [6]	2 correct for 1 mark total [2]

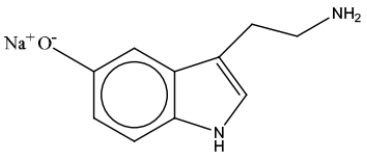
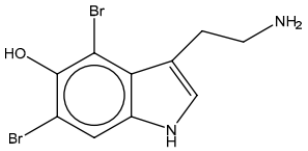
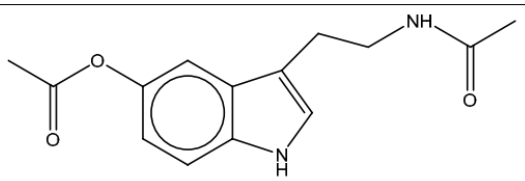
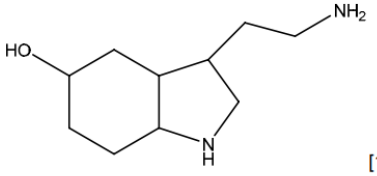
8

18. 9701/41/O/N/17 Q6

6(a)(i)		**1**
6(a)(ii)	$HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + NO_2^+ + 2HSO_4^-$	**1**
6(a)(iii)	**any three** from: Point 1: bonds / electrons are **partially** delocalised in **T** **or** delocalised / π system / π bonding extends over only five carbons Point 2: four π-electrons in the (delocalised system of **T**) **or** methylbenzene has (two) more π-electrons / (two) more delocalised electrons Point 3: contains a carbon that is sp^3 hybridised in **T** ***or*** (all the) carbons are sp^2 hybridised in methylbenzene Point 4: one carbon has a bond angle of 109.5° / tetrahedral (in **T**) ***or*** (C-C) bond strengths / lengths are not all the same **or** not all the bond angles are 120° (in **T**)	**3**
6(b)(i)	4-aminobenzoic acid	**1**
6(b)(ii)	step 1 Sn + HCl [1] concentrated / reflux / heat [1] step 2 CH_3COCl [1] step 3 $KMnO_4$ / manganate(VII) / MnO_4^- (acidified / alkaline) **and** heat [1] step 4 aqueous HCl **and** heat [1] step 5 ethanol, H_2SO_4, concentrated / reflux / heat [1]	**6**

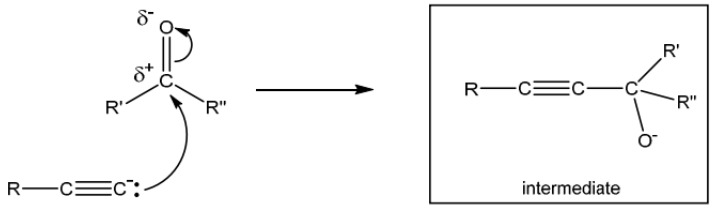
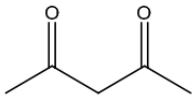
6(c)	(benzocaine) is less (basic than ethylamine) **AND** **lone pair** (on N) is less available to **accept** a proton / H^+ since (lone pair on N) is delocalised over the ring ***or*** phenyl ring is electron withdrawing group **OR** ethylamine is more basic (than benzocaine) **AND** **lone pair** (on N) is more available to **accept** a proton / H^+ since ethyl / alkyl group is electron-donating group	**2**
6(e)(i)	$NaNO_2 + HCl$ ***or*** HNO_2	**1**
6(e)(ii)		
	structure of diazonium salt **R**	**1**
	structure of azo dye **S**	**1**

19. 9701/42/O/N/17 Q3

3(b)	reagent	structure of product	type of organic reaction
	Na	 [1]	redox or reduction
	excess $Br_2(aq)$	 [1]	(electrophilic) substitution
	excess CH_3COCl	 acylated OH [1] acylated $NH_{(2)}$ [1]	condensation (or addition + elimination)
	excess H_2 / Pt catalyst	 [1]	reduction or hydrogenation or addition
			8

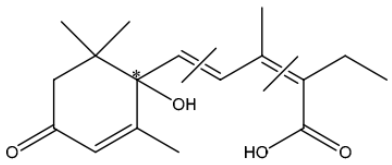
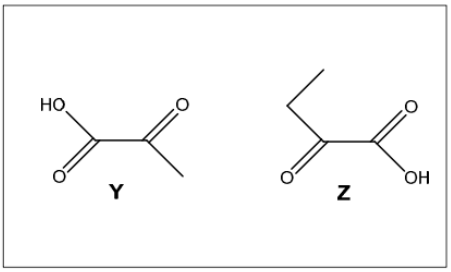
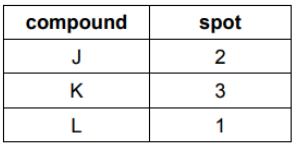
20. 9701/42/O/N/17 Q7b

7(b)	C_nH_{2n-2}	**1**
7(c)(i)	delocalised electrons	**1**
7(c)(ii)	CH	**1**
7(c)(iii)	less dense	**1**

7(d)(i)	 2 curly arrows [1] dipole [1] intermediate [1]	**3**
7(d)(ii)	nucleophilic addition	**1**
7(d)(iii)	$C_2H_5—C\equiv C—H$ [1] **Q**  [1] **R**	**2**
7(e)		**4**

	CH_3CHO	HCO_2H	CH_3COCH_3	HO_2CCO_2H
hot acidified MnO_4^-(aq)	✓	✓	×	✓
alkaline I_2(aq)	✓	×	✓	×
Tollens' reagent	✓	✓	×	×

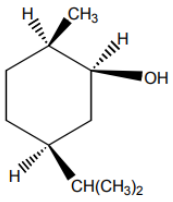
21. 9701/42/O/N/17 Q8

8(a)(i)	 circle or asterisk on correct C atom only [1] lines through the two correct bonds only [1]	**2**
8(a)(ii)	ketone, (tertiary) alcohol, alkene, carboxylic acid two for each mark	**2**
8(a)(iii)	sp carbons = 0 sp^2 carbons = 8 sp^3 carbons = 9	**1**
8(a)(iv)		**2**
8(b)(i)		**1**

compound	spot
J	2
K	3
L	1

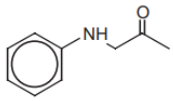
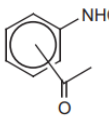
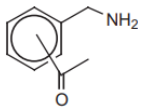
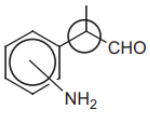
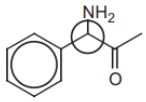
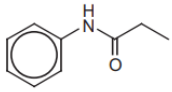
22. 9701/41/M/J/17 Q4

4(a)(i)	optical, because it contains a / one chiral C-atom or chiral C-atoms or chiral atom / centre or C* indicated or C with 4 **different** groups	**1**
4(a)(ii)	$C_{10}H_{14}O + 3H_2 \longrightarrow C_{10}H_{20}O$ correct formulae	**1**
	balancing	**1**
4(b)(i)	electrophilic substitution	**1**
4(b)(ii)	step 3 reduction	**1**
	step 5 substitution / hydrolysis	**1**
4(b)(iii)	step 1 $(CH_3)_2CHCl$ + $AlCl_3$ / $AlBr_3$ / $FeCl_3$ / $FeBr_3$	**1 + 1**
	step 2 HNO_3 + H_2SO_4 conc (T < 55 °C)	**1**
	step 3 Sn + HCl	**1**
	step 4 HNO_2 (*or* $NaNO_2$ + HCl) (at T < 10 °C)	**1**
	the two temperatures for steps 2 and 4	**1**
4(c)(i)	**H_2** + Pt or **H_2** + Ni + heat or pressure	**1**

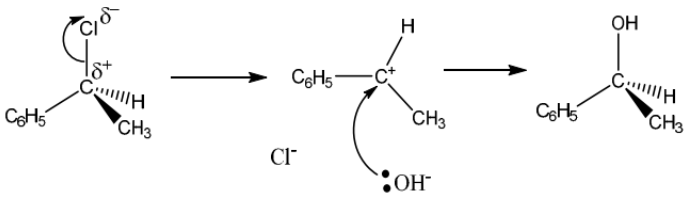
4(c)(ii)	 $(CH_3)_2CH$, CH_3 and OH on the correct ring atoms i.e. structure is correct	**1**
	all Hs on the same side of the ring	**1**

23. 9701/41/M/J/17 Q5

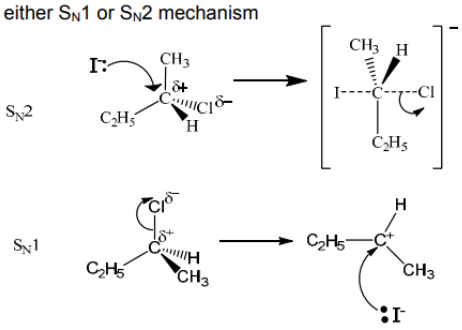
5(a)	<table><tr><th>J</th><th>K</th><th>L</th><th>M</th></tr><tr><td>amine methyl ketone</td><td>aromatic amine aldehyde</td><td>amine methyl ketone</td><td>amide</td></tr></table>	
	J and L correct	**1 + 1**
	K correct	**1 + 1**
	M correct	**1**
5(b)(i)	hydrolysis	**1**
5(b)(ii)	**P** is $C_6H_5NH_2$	**1**
	Q is $CH_3CH_2CO_2Na$	**1**

5(c)	**J** is  *or*  *or* 	**1**
	K is 	**1**
	L is 	**1**
	M is 	**1**
	K&L only: two chiral atoms shown	**1**
5(d)	**W** is $C_6H_5CO_2Na$	**1**

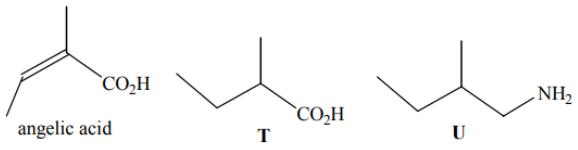
24. 9701/41/M/J/17 Q6c

6(c)(i)	 C-C*l* dipole and first curly arrow	**1**
	intermediate cation	**1**
	OH^- with lone pair and curly arrow	**1**
6(c)(ii)	Beginning with candidate's mechanism in (c)(i): **If S_N1:** racemate / mixture of / two optical isomers will be formed, because: the intermediate is planar / has a plane of symmetry / OH^- can approach from top or bottom or from any direction **If S_N2:** one optical isomer because attack always from fixed direction / from same side / the "configuration" always inverts / there is an asymmetric transition state	**1**

25. 9701/42/M/J/17 Q2d

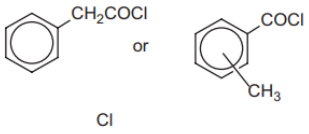
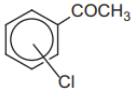
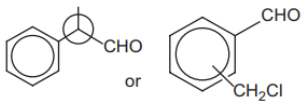
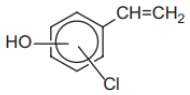
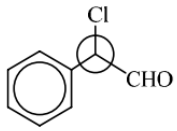
2(d)(i)	either S_N1 or S_N2 mechanism  C-C*l* dipole AND C-C*l* curly arrow	**1**
	intermediate cation OR 5-valent transition state (charge essential)	**1**
	I^- with lone pair AND other curly arrow	**1**
2(d)(ii)	If S_N1 in 2(d)(i) **mixture of / two** optical isomers will be formed, AND the intermediate can be formed by the I^- approaching from top or bottom plane If S_N2 in 2(d)(i) **one optical isomer** AND attack always from fixed direction / opposite side	**1**

26. 9701/42/M/J/17 Q3c

3(c)(i)	$LiAlH_4$	**1**
3(c)(ii)		**3**
3(c)(iii)	angelic acid: geometrical OR cis-trans compound **T**: optical	**1**

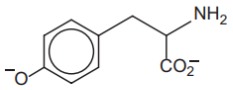
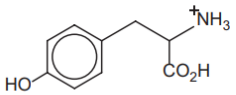
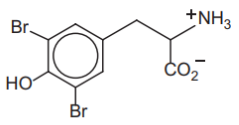
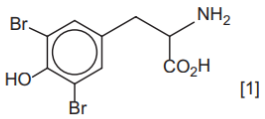
27. 9701/42/M/J/17 Q7

7(a)	<table><tr><th>W</th><th>X</th><th>Y</th><th>Z</th></tr><tr><td>acyl chloride / COC*l*</td><td>methyl ketone / CH3CO group aryl chloride</td><td>aldehyde / CHO chloro(alkane) / RC*l*</td><td>Alkene / C=C phenol / C_6H_5OH aryl chloride</td></tr></table> 0–1 [0]; 2 [1]; 3 [2]; 4 [3]; 5 [4]; 6–8 [5]	**5**

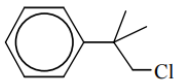
7(b)(i)	**W**  **X** 	**1 + 1**
	Y  **Z** 	**1 + 1**
7(b)(ii)	**Y**  OR any chiral atom correctly labelled	**1**

28. 9701/42/M/J/17 Q8

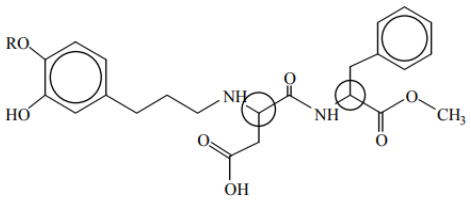
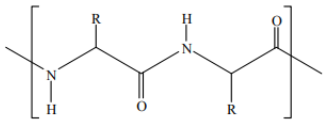
8(a)(i)	step 1 electrophilic substitution **ignore** acylation	**1**
	step 2 nucleophilic addition	**1**
8(a)(ii)	hydrolysis	**1**

8(a)(iii)	step 1 $ClCH_2CHO$ (**allow** Br, I for Cl)	**1**
	$AlCl_3$	**1**
	step 2 HCN + NaCN	**1**
	step 3 heat in H_3O^+ / heat $H^+(aq)$	**1**
	step 5 NH_3 under pressure (+ heat) **or** heat NH_3 in a sealed tube	**1**
8(a)(iv)	with NaOH(aq)  [2]	**1 + 1**
	with HCl(aq)  [1]	**1**
	with $Br_2(aq)$  or  [1]	**1**

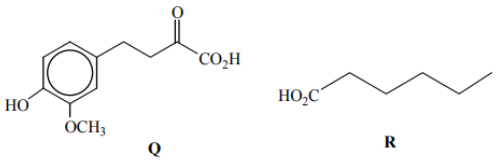
29. 9701/42/F/M/17 Q5

5(a)(i)	$(CH_3)_3C\text{-}Cl$ / $(CH_3)_2C = CH_2$	**1**
	$AlCl_3$ + heat	**1**
5(a)(ii)	(UV) light	**1**
5(a)(iii)		**1**
5(a)(iv)	ammonia / NH_3	**1**
	heat in sealed tube / heat under pressure	**1**
5(b)	$C_{10}H_{13}NH_2 + H_3O^+ \rightleftharpoons C_{10}H_{13}NH_3^+ + H_2O$	**1**
5(c)	in compound **H**, the alkyl groups are electron donating / have a positive inductive effect, so it is more basic than NH_3	**1**
	in phenylamine, the lone pair (of N) is delocalised over the aryl group / benzene ring, so phenylamine is less basic than NH_3	**1**

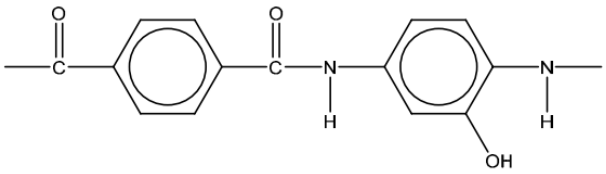
30. 9701/42/F/M/17 Q7

7(a)		**1**
7(b)(i)	$H^+(aq)$ + heat	**1**
7(b)(ii)	hydrolysis	**1**
7(b)(iii)	CH_3OH	**1**
7(c)(i)	white precipitate	**1**
7(c)(ii)	$C_{14}H_{19}O_6N + 3NaOH \rightarrow C_{14}H_{16}O_6NNa_3 + 3H_2O$	**2**
7(d)(i)	no change / colour remains orange	**1**
7(d)(ii)	 amide bond displayed **two** repeat units	**2** 1 1
7(e)(i)	seven	**1**

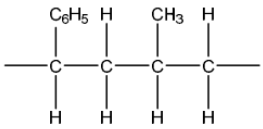
31. 9701/42/F/M/17 Q8

8(a)	oxidation of –OH / alcohol to C=O / ketone / carbonyl	**1**
8(b)(i)	dehydration / elimination	**1**
8(b)(ii)	heat with Al_2O_3 **OR** heat with H_3PO_4 / H_2SO_4	**1**
8(b)(iii)	 **Q** **R**	**2**
8(c)	phenol	**1**
	ketone	**1**

32. 9701/41/O/N/18 Q5

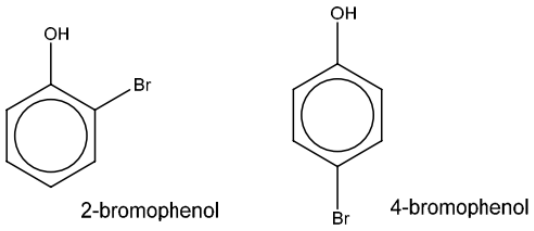
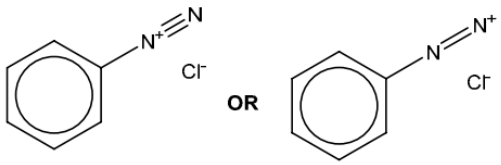
5(a)(ii)	 one amide bond displayed in full [1] rest of the structure – one repeat unit only [1]	**2**
5(b)	[1] for each correct tick	**2**

	σ-bonds only	π-bonds only	both σ- and π-bonds
bonds broken		✓	
bonds formed	✓		

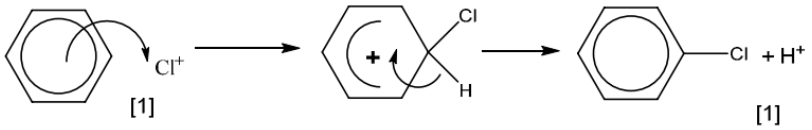
5(c)	 **M1** length of chain with both monomers [1] **M2** continuation bonds [1]	**2**
5(d)(i)	C-C bonds are non-polar / have no dipole so cannot be hydrolysed [1]	**1**
5(d)(ii)	**M1** Hydrolysis using acid / base / alkali / enzymes [1] **M2** action of UV light [1]	**2**

33. 9701/41/O/N/18 Q7

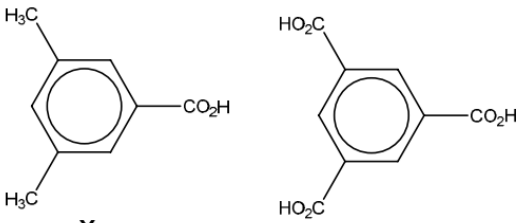
7(a)	**M1** C-X / C-Cl / C-O bond is strong**er** (in chlorobenzene / phenol) [1] **M2** p-orbital / lone pair on Cl / O(H) / X (in chlorobenzene / phenol) [1] **M3** electrons of the (Cl / O / electronegative atom) **AND** overlap / delocalise with π-electron cloud / delocalise into ring [1]	**3**

7(b)	 2-bromophenol 4-bromophenol structure and name correct [1]	**2**
7(c)(i)	step 1 **conc.** HNO_3 + H_2SO_4 (and temperare 50–55 °C) [1] step 2 Sn + HCl **AND one** of conc.HCl + heat [1] step 4 H_2O warm / heat [1]	**3**
7(c)(ii)	 **OR**	**1**
7(c)(iii)	step 1 electrophilic substitution	**1**
7(c)(iv)	$C_6H_5NO_2$ + 6[H] → $C_6H_5NH_2$ + $2H_2O$	**1**

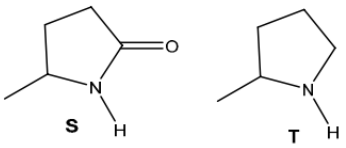
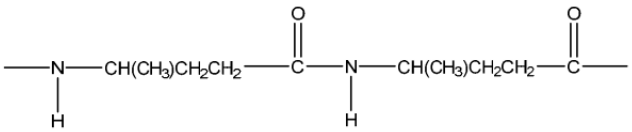
34. 9701/42/O/N/18 Q1b

1(b)(i)	Cl_2 + $AlCl_3$ → Cl^+ + $AlCl_4^-$	**1**
1(b)(ii)	 [1] intermediate [1] curly arrow [1] [1]	**4**
1(b)(iii)	H^+ + $AlCl_4^-$ → $AlCl_3$ + HCl	**1**

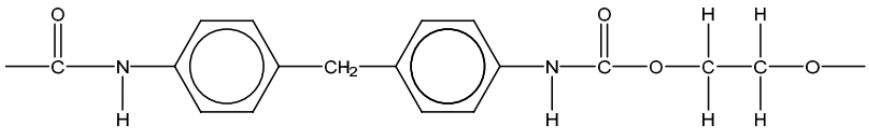
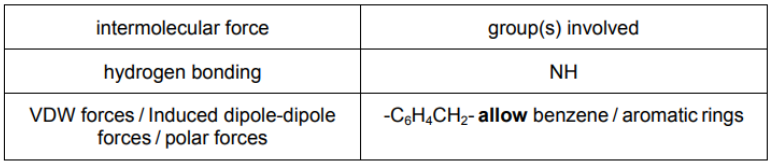
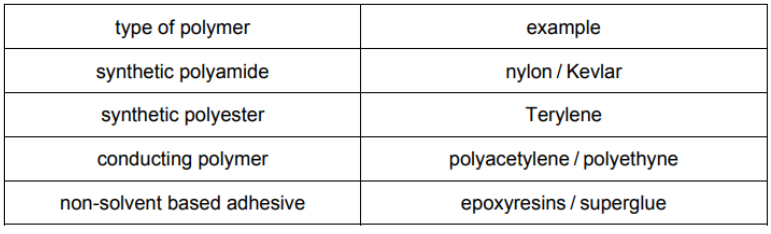
35. 9701/42/O/N/18 Q5f

5(f)(i)	CuCN / copper(I) cyanide	**1**
5(f)(ii)	 **Y** **Z** [1] × 2	**2**

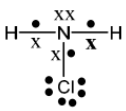
36. 9701/42/O/N/18 Q6

6(a)(i)	KCN / NaCN / CN^-	1
6(a)(ii)	step 1 PCl_3 + heat / PCl_5 / $SOCl_2$ [1] step 4 $NaBH_4$ [1]	2
6(b)(i)	 **S** **T**	2
6(b)(ii)	step I condensation [1] step II reduction [1]	2
6(c)	 • amide bond (CO-NH) • structure of polymer with exactly two repeat units • continuation bonds • hydrocarbon portions correct two points = [1] four points = [1]	2

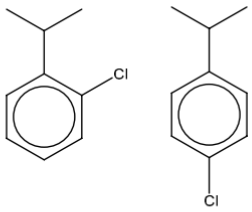
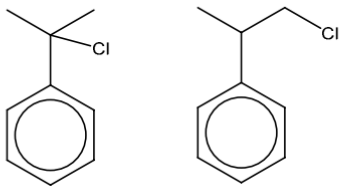
37. 9701/42/O/N/18 Q7

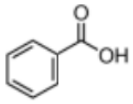
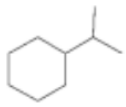
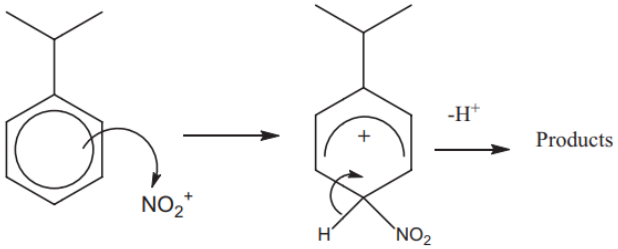
7(a)(i)	$C_{15}H_{10}N_2O_2$	1
7(a)(ii)	 -NH-CO-O- linkage [1] whole molecule correct [1]	2
7(a)(iii)	 **M1** hydrogen bonding [1] **M2** NH group for hydrogen **AND** second correct IMF [1]	2
7(b)	 one mark [1] for each correct answer up to a maximum of [3]	3

38. 9701/42/O/N/18 Q8

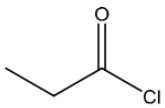
8(a)(i)	species with an unpaired electron	**1**
8(a)(ii)	$NH_2 + Cl \rightarrow NH_2Cl$	**1**
8(b)(i)		**1**
8(b)(ii)	sp^3 **AND** 100–107°	**1**
8(d)	ethylamine > ammonia > phenylamine [1] ethyl group is electron donating group [1] p-orbital from N in phenylamine overlaps with π-ring system **OR** lone pair on N is delocalised into benzene ring [1] basicity linked to ability of N to accept a proton [1]	**4**

39. 9701/41/M/J/18 Q6

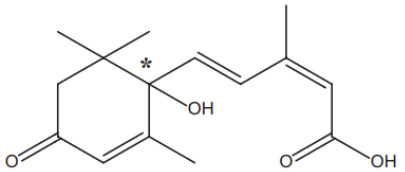
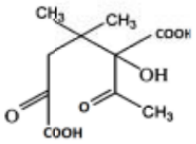
6(a)(i)	**D** 2-chloropropane	**1**
	E hydrogen chloride	**1**
6(a)(ii)	(Friedel-Crafts) alkylation	**1**
6(b)(i)	$AlCl_3$ or $FeCl_3$	**1**
6(b)(ii)		**1**
6(b)(iii)	sunlight or UV **OR** T>100 °C	**1**
6(b)(iv)		**1**

6(c)	reaction with hot $KMnO_4$(aq) 	**1**
	reaction with H_2 + Ni, high pressure 	**1**
6(d)	 	
	attacking species is NO_2^+	**1**
	curly arrow starting within hexagon and going to NO_2^+	**1**
	correct intermediate	**1**
	2nd curly arrow from C-H bond into ring	**1**

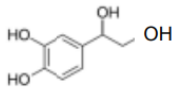
40. 9701/41/M/J/18 Q7

7(a)	$2C_3H_7OH + 2Na \rightarrow 2C_3H_7ONa + H_2$	**1**
7(b)(i)	propanoic acid, phenol, propan-1-ol	**1**
7(b)(ii)	• propan-1-ol: O-H bond strengthened by positive inductive effect of alkyl group **OR** propoxide ion is destabilised by positive inductive effect of alkyl group • phenol: O-H bond weakened by negative inductive effect of ring **OR** phenoxide ion is stabilised by delocalisation of oxygen lone pair into ring • propanoic acid: O-H bond weakened by negative inductive effect of C=O **OR** propanoate ion is stabilised by delocalisation of minus charge by C=O 1 mark for a correct explanation, max 2 marks	**2**
7(c)	Tollens' reagent **or** Fehling's reagent	**1**
	methanoic acid gives a silver mirror/solid with Tollen's reagent **OR** red / orange ppt / solid with Fehlings' reagent	**1**
7(d)	PCl_5 or PCl_3 (+heat) or $SOCl_2$ (added to propanoic acid)	**1**
	product of first step: 	**1**
	add product of first step to phenol in NaOH	**1**

41. 9701/41/M/J/18 Q8

8(a)	correct chiral centre labelled **only**  $C_{15}H_{22}O_4$	**1**
8(b)	$C_{15}H_{22}O_4$	**1**
8(c)(i)		**1**
8(c)(ii)	CO_2	**1**
	oxidation / oxidative cleavage	**1**
8(c)(iii)	CH_3COCO_2H	**1**

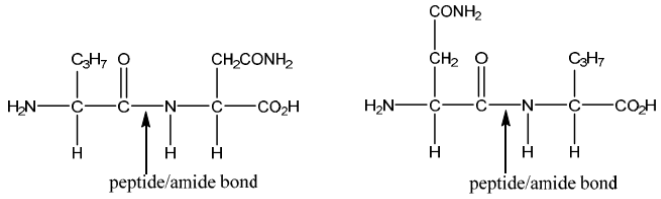
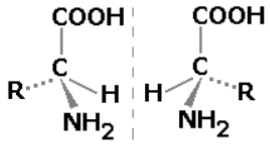
42. 9701/41/M/J/18 Q9

9(a)	$C_8H_{11}O_3N$	**1**
9(b)	yes, as it has a chiral C atom	**1**
9(c)(i)	(phenyldiazonium ion is stabilised because) positive charge is delocalised by ring / positive charge is spread over ring	**1**
9(c)(ii)		**1**
	N_2	**1**

43. 9701/42/M/J/18 Q6

6(a)	<u>any two from</u> K / potassium or KOH / potassium hydroxide or K_2O / potassium oxide	**2**
	correct products: (K) hydrogen, (KOH) water, (K_2O) water	**1**
6(b)(i)	bond circled between N = N	**1**
6(b)(ii)	phenylamine **and** HNO_2	**1**
	T=10 °C or below **and** diazonium ion / salt formed or structure of diazonium ion as $[C_6H_5N_2^+]$	**1**
	add 2-naphthol in aqueous NaOH / alkali	**1**
6(c)(i)	dilute / aqueous nitric acid / HNO_3(aq) (at room temp.)	**1**
	<u>any two from</u> concentrated (acid) needed sulfuric acid / H_2SO_4 needed higher T needed **ora**	**1**
6(c)(ii)	p-orbital(s) / lone pair on oxygen / OH group delocalises into / over ring	**1**

44. 9701/42/M/J/18 Q7

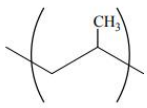
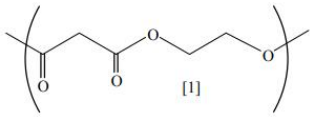
7(a)	$C_4H_8N_2O_3$	1
7(b)	amide, amine, carboxylic acid 2 correct = 1 mark 3 correct = 2 marks	2
7(c)		
	peptide / amide bond / unit labelled or circled	1
	(val-asp or asp-val) rest of the dipeptide structure is correct	1
7(e)	 each structure [1]	2

7(f)	$H_2NCH(CH_2CONH_2)CO_2H + H_2O \rightarrow H_2NCH(CH_2CO_2H)CO_2H + NH_3$ scores **or** $H_2NCH(CH_2CONH_2)CO_2H + H_2O + 2H^+ \rightarrow H_3N^+CH(CH_2CO_2H)CO_2H + NH_4^+$	2

45. 9701/42/M/J/18 Q8

8(a)	0, 2, 1	1
8(b)	6	1
8(c)	4	1

46. 9701/42/F/M/18 Q7

7(a)(i)	 [1]  [1] + H_2O [1]	3
7(a)(ii)	• *for addition polymerisation*: ΔS will be negative, as many gas molecules are combining to form one (large) molecule • *for condensation polymerisation:* ΔS likely to be positive, (as each pair of monomer molecules join to chain, two molecules of) <u>water</u> forms	2
7(b)(i)	($RCO_2H + H_2NR' \longrightarrow$) $RCONHR' + H_2O$	1
7(b)(ii)	*broken:* C-O, N-H *formed:* C-N, O-H	2

7(d)(i)	heat with (conc.) $KMnO_4$	1
7(d)(ii)	Sn and HC*l* heat + conc. (then add NaOH)	2

7(e)	<table><tr><td>*intermolecular force*</td><td>*group(s) involved*</td><td></td></tr><tr><td>hydrogen bonding</td><td>N-H and C=O (of amide)</td><td></td></tr><tr><td>induced dipole / van der Waals</td><td>benzene rings</td><td></td></tr></table>	**2**

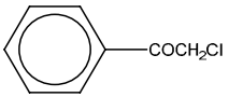
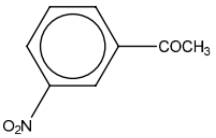
47. 9701/42/F/M/18 Q8b

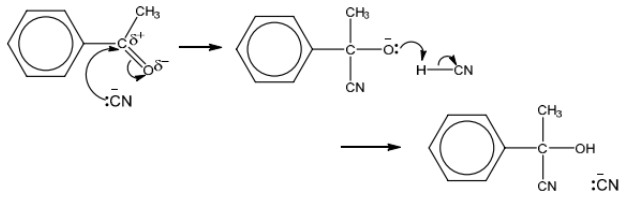
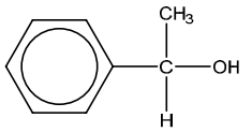
8(b)(i)	step 1 heat with $AlCl_3$ + $(CH_3)_2CHCl$ *or* $CH_3CH{=}CH_2$ step 2 heat with $AlCl_3$ + CH_3COCl step 3 NaOH + I_2 (*or* ClI_2) (then H^+) step 4 $LiAlH_4$ (in dry ether)	**4**
8(b)(ii)	step 2 electrophilic (aromatic) substitution step 4 reduction	**2**

48. 9701/42/F/M/18 Q9b

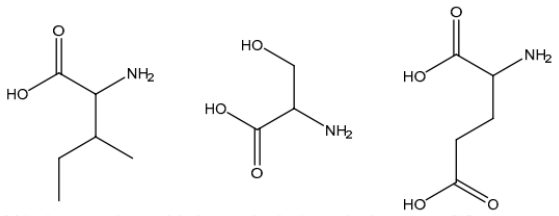
9(b)	benzoic acid > methylphenol > phenylmethanol methylphenoxide anion has delocalisation of the lone pair on oxygen over the ring benzoic acid has an (extra) electronegative oxygen or electron withdrawing C=O	**3**
9(c)	step 1 treat benzoic acid with $SOCl_2$ *or* PCl_5 to make the acyl chloride formula is **C_6H_5COCl** step 2 dissolve the methylphenol in NaOH(aq) (and shake with the benzoyl chloride)	**3**

49. 9701/41/O/N/19 Q4

4(a)	**M1:** CH_3COCl or ethanoyl chloride **M2:** $AlCl_3$ catalyst	**2**
4(b)	<table><tr><td>reagent</td><td>organic product</td><td>name of mechanism</td></tr><tr><td>Cl</td><td>  chlorine atom(s) in side chain only</td><td>free radical substitution</td></tr><tr><td>nitric / sulfuric</td><td>  one only $-NO_2$ group added at 3 position</td><td>electrophilic substitution</td></tr><tr><td>Br</td><td>no reaction with Br_2</td><td></td></tr></table> Award 1 mark for each correct entry to the table [5]	**5**
4(c)(i)	nucleophilic addition	**1**

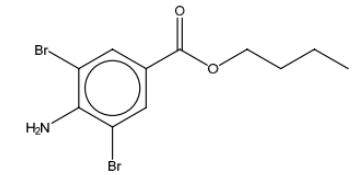
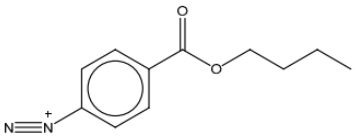
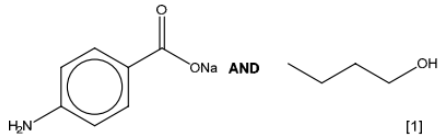
4(c)(ii)	 **M1 and M2:** first structure – award one mark for two points correct, award two marks for four points correct. • correct polarity shown on C=O bond • curly arrow from double bond to O of the C=O • lone pair shown on C of CN^- ion • curly arrow from C (on CN^- ion) to C of C=O **M3:** middle structure • correct intermediate **AND** curly arrow from lone pair on O^- to H^+ **or** H of H_2O or HCN **M4**: third structure • correct product **AND** either CN^- reformed (if HCN seen in step 2) **OR** curly arrow on H-CN bond towards CN in step 2	**4**
4(d)(i)		**1**
4(d)(ii)	$LiAlH_4$ or $NaBH_4$	**1**
4(d)(iii)	**conc** H_2SO_4 / **conc** H_3PO_4 / Al_2O_3	**1**

50. 9701/41/O/N/19 Q8

8(a)(i)	any one from: • OH^- / NaOH; aqueous / dilute; heat under reflux • H^+ / HCl / H_2SO_4, aqueous / dilute; heat under reflux • protease or named protease; water; T = 30° – 40°C all three points in each bullet [1]	**1**
8(a)(ii)	 M1: three amino acids in any ionic / non-ionic states [1] M2: three amino acids in the correct ionic state for their conditions [1]	**2**

8(b)	• permanent dipole-dipole • one group that will have a δ^+ and another with δ^- e.g. CO, NH, COOH, OH **BOTH** [1] • hydrogen bonds • one group that will have a $H^{\delta+}$, e.g. NH, OH and another with lone pair, e.g. NH, COOH, OH, $CONH_2$ **BOTH** [1] • ionic bonding • NH_3^+ **and** COO^- **BOTH** [1] **ALLOW** • London forces • C_4H_9 groups or parts of these alkyl groups	**3**
8(c)(i)	any structure containing one COOH / COCl **and** NH_2 groups in the same molecule [1]	**1**
8(c)(ii)	$HOCH_2CH_2OH$ [1] ethan(e)-1,2-diol [1] **ecf** for diols HO_2CCO_2H or ClOCCOCl [1] ethan(e)dioic acid or ethan(e)dioyl chloride [1] **ecf** for diacids / diacyl chlorides	**4**

51. 9701/41/O/N/19 Q9

9(a)(i)	$RNH_2 + H^+ \rightarrow RNH_3^+$ **OR** $RNH_2 + HCl \rightarrow RNH_3Cl$ [1]	**1**
9(a)(ii)	weaker **AND** lone pair of N delocalised into benzene ring [1]	**1**
9(b)	 [1]  [1]  **AND** [1]	**3**
9(c)(i)	2 [1]	**1**
9(c)(ii)	CH_2 next to ester **and** terminal CH_3 are circled [1]	**1**
9(c)(iii)	• one less peak • the lost peak is NH_2 / aryl amine • protons exchange with D **OR** protons are labile **OR** valid equation •✓✓ for two marks [2]	**2**
9(d)	$C_6H_4NH_2^+$ **and** $CH_3CH_2CH_2CH_2^+$ [1]	**1**

52.

7(a)(i)	• two or more repeat units • correct orientation of groups on all four rings and rings correct • trailing bonds shown • amide links all correct Award 1 mark for two points, award 2 marks for all four points	**2**
7(a)(ii)	polyamide and condensation	**1**
7(a)(iii)	yes **and** can be hydrolysed	**1**
7(a)(iv)	PCl_3 or PCl_5 or $SOCl_2$	**1**
7(a)(v)	**M1:** conc nitric acid + conc sulfuric acid **M2:** Sn + HCl	**2**
7(b)(i)	**M1:** sequence / order of amino acids **M2:** α-helix **or** β-sheet **M3:** folding of chain **or** 3-D shape	**3**
7(b)(ii)	covalent bonds / peptide bonds / amide bonds	**1**
7(b)(iii)	**M1:** hydrogen bonds **M2:** between C=O and N–H	**2**

53. 9701/42/O/N/19 Q8

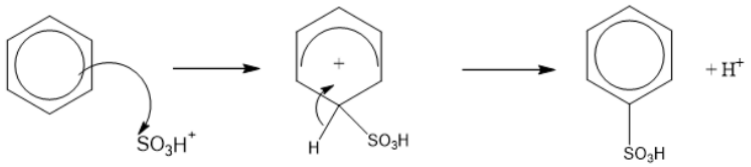
8(a)	bromine / Br_2 **and** uv / light / heat	**1**
8(b)	1,1-dibromoethane	**1**
8(c)	$NCCH_2CH_2CN$ / CH_2CNCH_2CN	**1**
8(d)	**M1:** KCN / NaCN / CN^- **M2:** boil/heat/reflux **and** ethanol as solvent	**2**
8(e)(i)	acidified manganate(VII) or dichromate(VI)	**1**
8(e)(ii)	carbon dioxide and water	**1**

8(f)	**M1:** most acidic: hexanoic acid > phenol > hexan-1-ol :least acidic • the other O atom in CO_2H group of hexanoic acid **either** – withdraws charge from OH group **or** is electronegative **and** weakens O–H bond **or** – stabilises resultant anion/negative ion / $–CO_2^-$ group/carboxylate ion • benzene / aromatic / C_6H_5 ring in phenol <u>delocalises</u> **either** – lone pair on O atom **and** weakens O–H bond **or** – lone pair on resultant anion/negative ion / phenoxide ion this stabilises resultant anion negative ion / $–CO_2^-$ group/carboxylate ion • the alkyl group in hexan-1-ol donates electrons this strengthens O–H bond Award 1 mark for each bullet point identified.	**3**

54. 9701/42/O/N/19 Q9

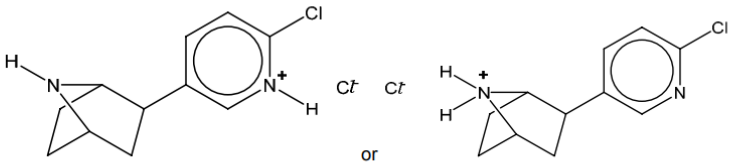
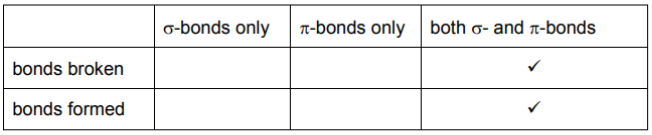
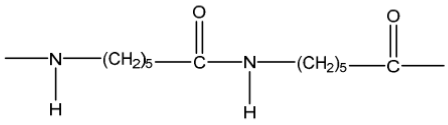
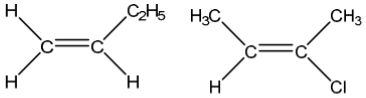
9(a)(i)	10	**1**
9(a)(ii)	120	**1**
9(b)(i)	correct acid chloride	**1**
9(b)(ii)	NH_3 or ammonia	**1**
9(c)	**M1:** $(C_5NH_4)COOH$ or $(C_5NH_5)^+COOH$ **M2:** $(C_5NH_4)COO^-(Na^+)$ or $(C_5NH_4)COONa$	**2**
9(d)(i)	$LiAlH_4$	**1**
9(d)(ii)	**M1:** most basic: X > phenylamine > nicotinamide :least basic **M2:** LP in X cannot be delocalised **M3:** LP in phenylamine delocalised over the benzene ring **or** LP in amide delocalised (more effectively) by C=O	**3**

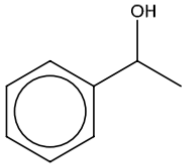
55. 9701/41/M/J/19 Q7

7(a)(i)	**M1**: reduction / hydrogenation **M2**: H_2 + Ni / Pt catalyst	**2**
7(a)(ii)	**M1**: benzene (**120°**) and cyclohexane (**109.5°**) **M2**: as π-bonds are transformed into σ-bonds	**2**
7(b)(i)	 **M1**: first curly arrow to the sulfur atom **M2**: intermediate shown **M3**: 2nd curly arrow and H^+ formed / lost	**3**
7(b)(ii)	$HSO_4^- + H^+ \rightarrow H_2SO_4$	**1**
7(c)	**M1**: $C_{12}H_{25}Br$ **and** halogen carrier e.g. $AlBr_3$ (+ heat) **M2**: electrophilic substitution	**2**

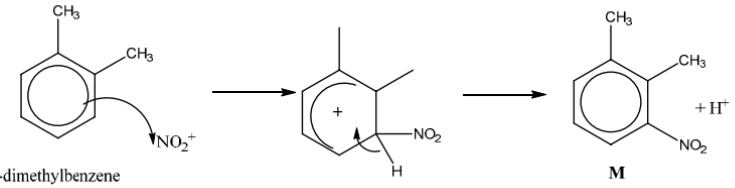
56. 9701/41/M/J/19 Q9

9(a)	**M1**: $CH_3COCl > CH_3CH_2Cl > C_6H_5Cl$ **M2 & M3 any two from:** • in C_6H_5Cl (no hydrolysis) C-C*l* bond is part of delocalised system **OR** p-orbital on C*l* overlaps with π system **OR** electrons from C*l* overlap with π system • CH_3COCl carbon in C-C*l* bond is more electron deficient since it is also attached to an oxygen atom (ora) **or** C-C*l* bond strength is weakest in CH_3COCl (ora) • CH_3CH_2Cl carbon in C-C*l* bond strengthened by positive inductive effect of alkyl group	**3**

9(b)(i)	partially ionised **and** proton acceptor	**1**
9(b)(ii)	 or	**1**
9(c)(i)	 **Both ticks correct**	**1**
9(c)(ii)	 **M1**: amide link **M2**: rest of the structure	**2**
9(d)	 **or** $CH_3CCl{=}CH_2$ and $C_2H_5CH{=}CHCH_3$ each correct structure scores one mark	**2**

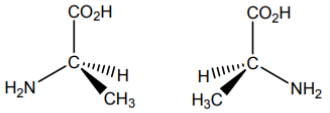
9(e)	C-C bonds are non-polar / polyalkenes cannot be hydrolysed **and** polyamides can be broken down by hydrolysis	**1**
9(f)(i)		**1**
9(f)(ii)	**M1**: step 1: CH_3COCl + $AlCl_3$ [1] **M2**: step 2: $NaBH_4$ / $LiAlH_4$ [1] **M3**: step 3: conc. H_2SO_4, heat [1]	**3**

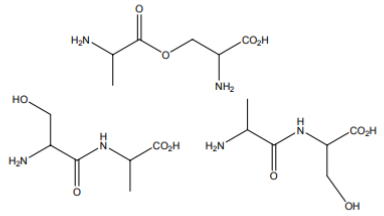
57. 9701/42/M/J/19 Q6

6(a)	any **three** points from: 3 × [1] • bond angle = 120° **and** shape is (hexagonal ring) planar / (trigonal) planar • carbons are sp^2 hybridised • contains <u>delocalised electrons</u> in the **π** bonds / system • sp^2 orbitals between C-H / C-C overlap to form **σ bonds** • a **p orbital** from each carbon atom overlap sideways with each other above and below the ring forming **π bonds** **ALLOW** labelled diagrams for bullets 1–5	**3**
6(b)(i)	$HNO_3 + H_2SO_4 \rightarrow HSO_4^- + H_2O + NO_2^+$ ***or*** $HNO_3 + 2H_2SO_4 \rightarrow 2HSO_4^- + H_3O^+ + NO_2^+$ [1]	**1**
6(b)(ii)	 1,2-dimethylbenzene **M** first curly arrow to N of NO_2^+ [1] correct intermediate [1] 2nd curly arrow **and** H^+ formed / lost [1]	**3**
6(b)(iii)	$HSO_4^- + H^+ \rightarrow H_2SO_4$ [1]	**1**
6(b)(iv)	Sn + conc. HC*l* (+ heat) [1] reduction [1] **IGNORE** redox	**2**
6(c)(i)	$C_{15}H_{15}NO_2$ [1]	**1**
6(c)(ii)	amine **and** carboxylic <u>acid</u> **both** [1]	**1**

6(c)(iii)	amount of 2,3-dimethylphenylamine = 5.00 / 121 = 0.0413 mol [1] amount of mefenamic acid = 0.0413 mol mass of mefenamic acid = 0.0413 × 241 = **9.96 / 9.95** g 3sf required [1] ECF	**2**
6(d)	**3°** carbocations are more stable than **2°** carbocations [1] due to the methyl group acting as an electron donating group (leading to an increase in electron density on the cation stabilising it) [1]	**2**

58. 9701/42/M/J/19 Q7

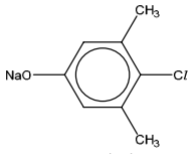
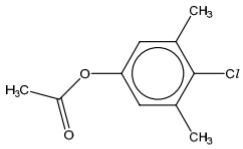
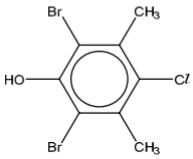
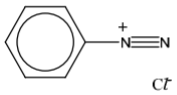
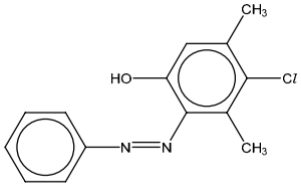
7(a)(i)	A= leucine B= glutamic acid **both** [1]	**1**
7(a)(ii)	greater **and** more soluble in the solvent / mobile phase **OR** greater **and** form more H-bonds with the solvent [1]	**1**
7(b)(i)	$H_2NCH_2CO_2H + HCl \rightarrow ClH_3N^+CH_2CO_2H$ [1] $H_2NCH_2CO_2H + NaOH \rightarrow H_2NCH_2CO_2^-Na^+ + H_2O$ [1]	**2**
7(b)(ii)	$H_3N^+CH_2CO_2^-$ [1] Proton is transferred from the CO_2H group to the NH_2 group [1]	**2**
7(c)	 two non-superimposable mirror images for alanine drawn [1]	**1**

7(d)(i)	NH_3 (in ethanol) heat in a sealed tube [1] nucleophilic substitution [1]	**2**
7(d)(ii)	acidity of $Cl_3CCO_2H > ClCH_2CO_2H > CH_3CO_2H$ [1] **any two of:** Cl is electronegative / electron withdrawing group **AND** Cl_3CCO_2H has more / 3 Cl groups [1] weakens O-H bond **so** more likely to ionise / dissociate **OR negative** charge on anion is more stabilised **OR** charge / electron density on COO^- decreases so anion is (more) stabilised [1] CH_3 is electron donating **so** O-H bond is stronger so less likely to ionise in CH_3CO_2H **OR** CH_3CO_2H has no -I group **so** O-H bond is stronger and less likely to ionise [1]	**3**
7(e)	 One mark for each structure. [1] [1] [1]	**3**

59. 9701/42/M/J/19 Q8

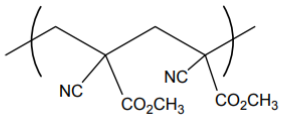
8(a)	4-chloro-3,5-dimethylphenol **OR** 3,5-dimethyl-4-chlorophenol [1] **ALLOW** 2,6-dimethyl-4-hydroxychlorobenzene and 2-chloro-5-hydroxy-1,3-dimethylbenzene	**1**

8(c)

reagent	organic product structure	type of reaction
Na	 or ionic	redox
CH_3COCl		Condensation
$Br_2(aq)$		(electrophilic) substitution
		(electrophilic) substitution

each structure [1] × 4 type of reaction • ✓ • ✓ [2] **6**

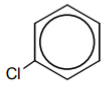
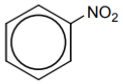
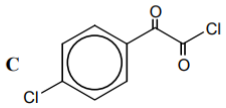
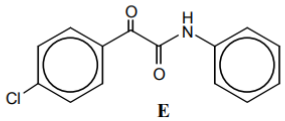
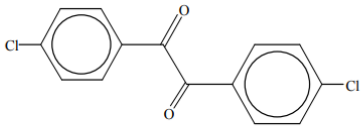
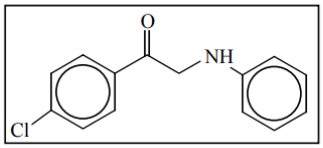
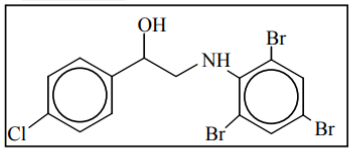
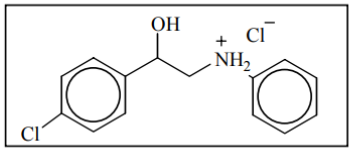
60. 9701/42/F/M/19 Q5

5(a)(i)	 **M1** correct C–C backbone (with correct side groups) **M2** continuation bonds and two repeat units	**2**
5(a)(ii)	addition	**1**
5(a)(iii)	*Any two of:* permanent dipole (attraction): C, N, O, OR CO, CN, CO_2CH_3, OCH_3 H-bonding: N, O OR CO, CN London/van der Waals: N, C, H, O OR CH_3, CN, CO_2CH_3, C–C chains	**2**
5(b)(i)	**Y** $CH_3COCO_2CH_3$ **Z** $CH_3C(OH)(CN)CO_2CH_3$	**2**
5(b)(ii)	**M1/M2** step 1: CH_3OH and (conc) H_2SO_4 + heat **M3** step 2: HCN + NaCN catalyst **M4** step 3: T > 100°C / heat with Al_2O_3 (or heat with c. H_2SO_4)	**4**

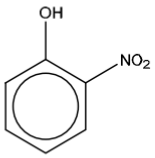
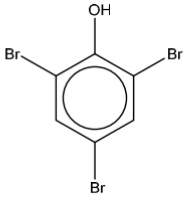
61. 9701/42/F/M/19 Q6

6(a)	*Any two of:* chloro amine / amino alcohol / hydroxyl / phenol benzene / phenyl ring / aryl / arene	1
6(b)(i)	ketamine is acting as a base	1
6(b)(ii)	carbonyl group	1

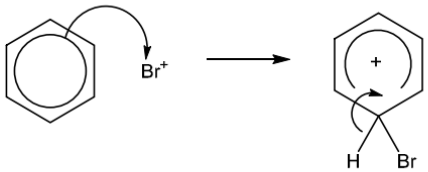
62. 9701/42/F/M/19 Q7

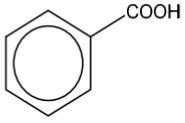
7(a)(i)	$HO_2C–CO_2H$ OR $HO_2C–COCl$	1
7(a)(ii)	$SOCl_2$ OR PCl_5	1
7(b)(i)	**B**  **D**    **C** **E**	4
7(b)(ii)	**M1** step 1: Cl_2 + $AlCl_3$ **M2** step 3: conc. HNO_3 + H_2SO_4 **M3** step 4: Sn + conc. HCl **M4** step 6: $LiAlH_4$ **M5** *any two of:* heat / T ⩾ 60 °C / reflux for step 1 T⩽ 60 °C / warm for step 3 heat / T ⩾ 60 °C / reflux for step 4	5
7(b)(iii)		1
7(b)(iv)	steps 1, 2 and 3	1
7(c)	 no reaction  	4

63. 9701/41/O/N/20 Q7

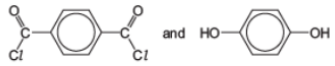
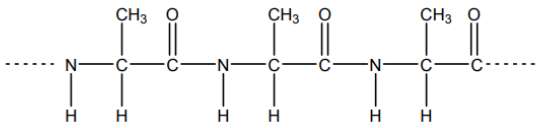
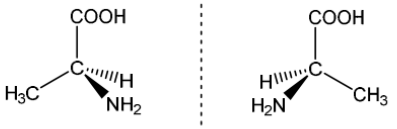
7(a)	**M1:** HNO_2 **OR** $NaNO_2$ + HC*l* [1] **M2:** T ⩾ 10 °C / warm **AND** water [1]	**2**
7(b)	 2-nitrophenol  4-nitrophenol 2 × [1]	**2**
7(c)(i)	 2,4,6-tribromophenol ✓ ✓ [2]	**2**
7(c)(ii)	bromine is decolourised **AND** white precipitate is formed **BOTH** [1]	**1**
7(d)	$C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$ [1] **ALLOW** any equation for phenol acting as an acid	**1**

64. 9701/41/O/N/20 Q8

8(a)(i)	HBr / hydrogen bromide [1]	**1**
8(a)(ii)	 **M1** curly arrow to Br^+ **AND** curly arrow from C–H bond as shown [1] **M2** correct intermediate [1]	**2**
8(a)(iii)	**electrophilic substitution** [1]	**1**
8(b)(i)	reagent: chloroethane / bromoethane / iodoethane **OR** formula [1] catalyst: $FeCl_3$ / $AlCl_3$ etc. [1]	**2**

8(b)(ii)	 [1] **ALLOW** C_6H_5COONa	**1**
8(b)(iii)	step 3 = $LiAlH_4$ [1] step 4 = Pt **AND** H_2 [1]	**2**

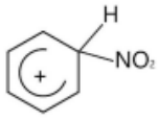
65. 9701/41/O/N/20 Q10

10(a)	<table><tr><th>pair of monomers</th><th>type of polymerisation</th></tr><tr><td>$HOCH_2CH_2OH$ and $HO_2CCH_2CO_2H$</td><td>condensation</td></tr><tr><td>  and </td><td>condensation</td></tr><tr><td>CH_3CHCF_2 and CH_3CHCH_2</td><td>addition</td></tr></table> **ALL** correct [1]	**1**
10(b)(i)	 • amide links displayed correct (NHCO **OR** CONH) • three monomers of Ala only • one repeat unit correctly identified • continuation bonds (with a polypeptide involving Ala only) mark as • ✓ ✓ ✓ [3]	**3**
10(b)(ii)	 3D, tetrahedral, both isomers of 2-aminopropanoic acid [1] optical [1]	**2**
10(c)(i)	**epoxy resin** [1] **ALLOW** Super Glues	**1**
10(c)(ii)	compound with two amine groups per molecule, amine groups must not be on the same carbon atom [1] e.g. $H_2NCH_2CH_2NH_2$	**1**

66. 9701/42/O/N/20 Q6

6(a)	ethanamide – ethanoic acid – trichloroethanoic acid [1] • ethanamide is neutral / not a proton donor • chlorine is electronegative / electron withdrawing [1] • O–H bond weakened / anion stabilised • correct statement linking acid strength to H^+ donation [1]	**3**
6(b)(i)	methanoic acid [1]	**1**
6(b)(ii)	methanoic and ethanedioic acids [1]	**1**
6(c)(i)	CH_3COCl [1] ethanoyl chloride [1]	**2**
6(c)(ii)	Step 1: PCl_5 / PCl_3 / $SOCl_2$ or names [1] Step 2: NH_3 / ammonia [1]	**2**

67. 9701/42/O/N/20 Q7

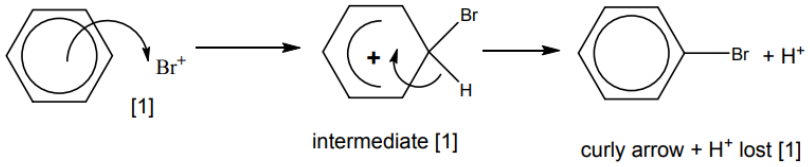
7(a)	Any four from the following points: • (regular) hexagon **OR** planar • all C–C bonds same length [1] • all bond angles 120° • all carbon atoms sp^2 hybridised [1] • C–H bonds are s–sp^2 overlap [1] • C–C bonds have sp^2–sp^2 overlap [1] • C–C bonds have p–p overlap • π used correctly and σ used correctly once each	**4**
7(b)(i)	curly arrow from within hexagon towards NO_2+ **AND** curly arrow from C–H bond to within hexagon [1]  intermediate [1]	**2**
7(b)(ii)	electrophilic substitution [1]	**1**
7(b)(iii)	conc nitric acid and sulfuric acid [1] $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ **OR** [1] $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + SO_4^{2-}$ $2HNO_3 + H_2SO_4 \rightarrow 2NO_2^+ + H_2O + SO_4^{2-}$ $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_2O + HSO_4^-$	**2**
7(b)(iv)	tin and HC*l* [1] conc and heat / boil / reflux [1]	**2**
7(c)(i)	$C_6H_5NH_2 + 3Br_2 \rightarrow C_6H_2Br_3NH_2 + 3HBr$ [1]	**1**
7(c)(ii)	2,4,6-tribromophenylamine [1]	**1**
7(c)(iii)	decolourisation of bromine **AND** white precipitate [1]	**1**

7(d)	phenylamine < ammonia < ethylamine [1] • lp on nitrogen of phenylamine delocalised into ring • alkyl group of ethylamine electron donating / has positive inductive effect [1] • correct statement about availability of lone pair to accept proton once [1]	**3**
7(e)(i)	either a dioic acid or a dioyl chloride [1]	**1**
7(e)(ii)	• trailing bonds • two of each monomer residue, consistent with ei [1] • repeat unit identified • amide link showing C=O [1]	**2**

68. 9701/41/M/J/20 Q4

4(a)	**M1** phenylmethanamine / **U** > phenylamine / **T** > benzamide / **S** [1] any two from: • alkyl group is electron donating so lone pair more able to accept a proton • lone pair on N overlaps with delocalised system so less able to accept a proton • presence of electron-withdrawing oxygen / carbonyl group means lone pair is not available to accept a proton **OR** amides are neutral	**3**
4(b)(i)	reaction 1 $LiAlH_4$ reaction 2 heat NH_3 under pressure/ heat NH_3 in a sealed tube	**2**
4(b)(ii)	reaction 1 reduction reaction 2 nucleophilic substitution	**2**

69. 9701/41/M/J/20 Q5

5(a)(i)	The substitution product is stabilised by delocalisation of (6)π-electrons **OR** The addition product is not stabilised by delocalisation of (6)π-electrons [1]	**1**
5(a)(ii)	 [1] intermediate [1] curly arrow + H^+ lost [1] • first curly arrow • intermediate • 2nd curly arrow, product **and** H^+ formed / lost	**3**
5(a)(iii)	$AlBr_4^- + H^+ \rightarrow AlBr_3 + HBr$	**1**
5(b)	lone pair of oxygen is delocalised into the ring any one from: • phenol has a higher electron density in the ring • phenol can polarise/induce a dipole in Br_2	**2**

70. 9701/41/M/J/20 Q6

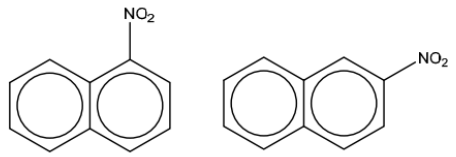
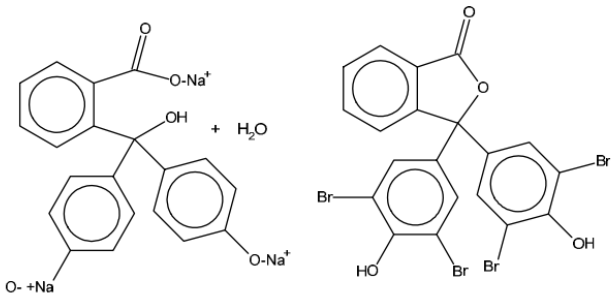
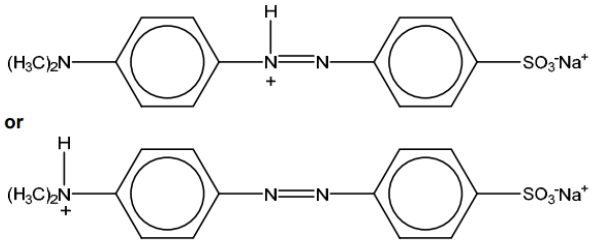
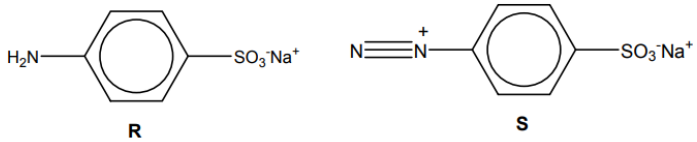
6(a)	**M1** 2-chloropropanoic acid > 3-chloropropanoic acid > propanoic acid [1] **M2** $CH_3CHClCO_2H$ / $ClCH_2CH_2CO_2H$ (are more acidic) as they contain an electronegative Cl atom so weaken O-H bond / stabilise carboxylate anion [1] **M3** $CH_3CHClCO_2H$ (is more acidic than $ClCH_2CH_2CO_2H$) as the Cl atom is closer to CO_2H so weaken O-H bond more / stabilise carboxylate anion more [1]	**3**

6(c)		**5**

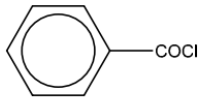
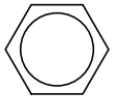
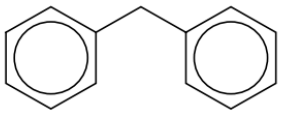
	reagents and conditions	**observed change**
test 1	**M1** Tollen's reagent, warm **OR** Fehling's solution, warm	silver mirror (brick)-red ppt.
test 2	**M2** aqueous alkaline iodine **OR** 2,4-DNPH	yellow ppt. orange ppt.
test 3	**M3** acidified MnO_4^-, warm	decolourises (and bubbles)

Two correct observations = 1 mark
Three correct observations = 2 marks

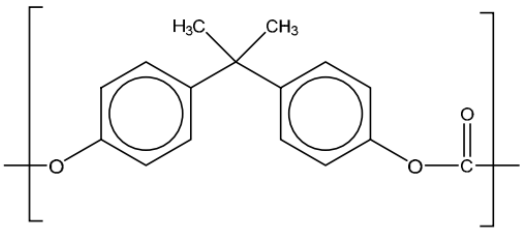
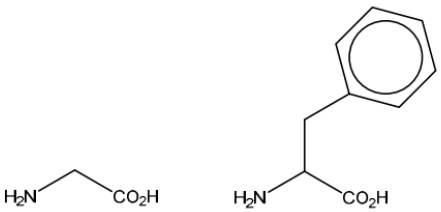
71. 9701/42/M/J/20 Q4

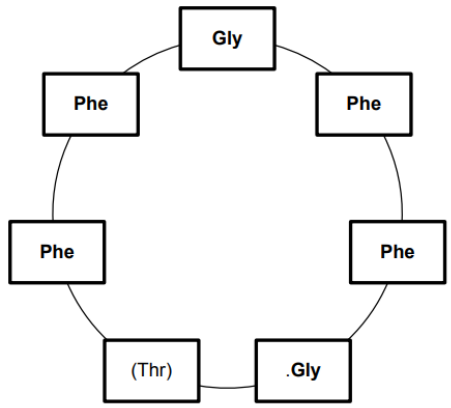
4(a)(i)	• trigonal planar • tetrahedral. • trigonal planar Award one mark for two correct statements, award two marks for three correct statements	**2**
4(a)(ii)	 Both structures required	**1**
4(b)	$C_{10}H_8 + 9[O] \rightarrow C_8H_4O_3 + 2CO_2 + 2H_2O$	**1**
4(c)	condensation/ addition-elimination	**1**
4(d)(i)	phenol **AND** ester	**1**
4(d)(ii)	 **M1** correct hydrolysis product of ester **M2** (di)phenoxide salt **M3** bromination of **both** phenol rings at position 2 or/and 6 **M4** hydrolysis **AND** (electrophilic) substitution	**4**
4(f)(i)	bond circled between the two Ns, or N=N or –N=N–	**1**
4(f)(ii)	 **or** 	**1**
4(g)(i)	 **R** **S** Award one mark for each correct structure	**2**
4(g)(ii)	**M1** step 1 Sn and HC*l* conc. and heat **M2** step 2 $NaNO_2$ and HC*l* and 0-10 °C	**3**

72. 9701/42/M/J/20 Q5c

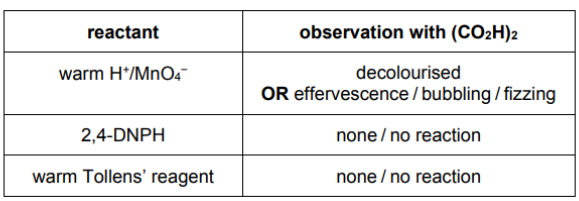
5(b)(ii)	(higher as) benzophenone is more non-polar/more soluble in octan-1-ol **ora**	**1**
5(c)(i)	J =  K =  Award one mark for each correct structure	**2**
5(c)(ii)	step 1 PCl_5 **OR** $SOCl_2$ **OR** PCl_3 + heat	**1**
5(d)(i)		**1**
5(d)(ii)	**M1** step 3 electrophilic substitution **M2** step 3 benzene and $AlCl_3$ (and heat)	**2**
5(d)(iii)	step 4 oxidation	**1**

73. 9701/42/M/J/20 Q6

6(a)(i)	condensation	1
6(a)(ii)		1
6(a)(iii)	id-id forces/London forces **AND** permanent dipole-dipole forces	1
6(b)	**M1** (secondary structure by) hydrogen bonding between CO and NH groups **M2** (tertiary structure by) interactions between R groups **and** one example of a named intermolecular force	2
6(c)	**M1** (hydrogen bonding between) base pairs **M2** A with T **and** C with G	2
6(d)	hydrolysis **and** by action of light/UV	1
6(e)(i)	 Award one mark for each correct structure	2

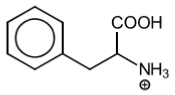
6(e)(ii)	 correct labelling as shown	1
6(e)(iii)	electrophoresis **and** thin-layer / paper chromatography [1]	1

74. 9701/42/F/M/20 Q1c (iii)

1(c)(iii)		2

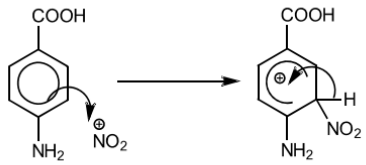
reactant	observation with $(CO_2H)_2$
warm H^+/MnO_4^-	decolourised **OR** effervescence / bubbling / fizzing
2,4-DNPH	none / no reaction
warm Tollens' reagent	none / no reaction

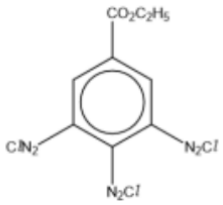
75. 9701/42/F/M/20 Q4

4(a)(i)	A = ester B = (2°) amide	**2**
4(a)(ii)	2	**1**
4(b)	 **M1** phenylalanine **M2** protonated amine **M3** (ethanol) CH_3CH_2OH	**3**
4(c)(i)	catalyst / halogen carrier	**1**
4(c)(ii)	**M1** —OH directs to 2,4 **AND** both 2 positions occupied / only position 4 is available **M2** —COOH directs to 3 position **AND** only position 3 is available / 5 is occupied	**2**

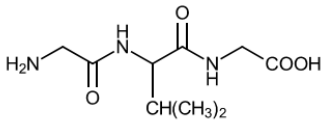
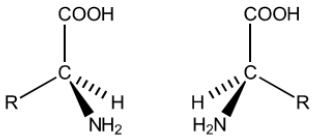
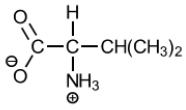
76. 9701/42/F/M/20 Q5

5(a)	**M1** COOH is more acidic than phenol **AND** because the O-H bond in acid is weaker **OR** carboxylate ion is more stable **M2** O-H bond weakened / loses proton more easily **AND** by negative inductive effect of C=O / due to electronegative C=O **OR** carboxylate ion / anion is more stable **AND** due to delocalisation of minus charge by C=O / 2O	**2**

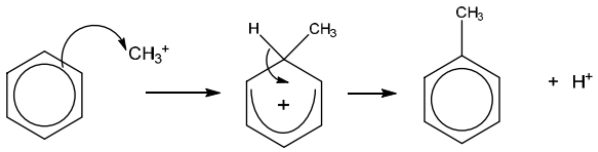
5(c)(i)	$HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + NO_2^+ + 2HSO_4^-$ **OR** $HNO_3 + H_2SO_4 \rightarrow H_2O + NO_2^+ + HSO_4^-$	**1**
5(c)(ii)	 **M1** curly arrow from ring to N of NO_2^+ **M2** correct intermediate **AND** curly arrow from C—H back to ring	**2**

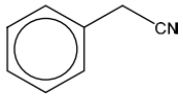
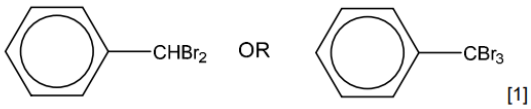
5(c)(iii)	electrophilic substitution	**1**
5(c)(iv)	**M1** Sn and HCl **M2** heat and concentrated (dependent on metal (Fe / Sn) and acid seen for M1)	**2**
5(c)(v)	 **M1** 1 × diazonium salt with ester group unchanged **M2** 3 × diazonium salt (to match formula)	**2**
5(c)(vi)	warm / T ⩾ 30 °C **AND** H_2O / named aqueous acid	**1**

77. 9701/42/F/M/20 Q6

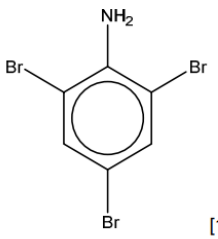
6(a)(i)	$(CH_3)_2CHCHNH_2COOH + 4[H] \rightarrow (CH_3)_2CHCHNH_2CH_2OH + H_2O$ **OR** $C_5H_{11}NO_2 + 4[H] \rightarrow C_5H_{13}NO + H_2O$	**1**
6(a)(ii)	lithium aluminium hydride / $LiAlH_4$ (in dry ether)	**1**
6(a)(iii)	nucleophilic substitution	**1**
6(b)	 **M1** one peptide link fully displayed (but not contradicted by the other peptide link) **M2** rest of structure correct	**2**
6(c)(i)	**M1** optical isomerism **M2** 	**2**
6(c)(ii)		**1**

78. 9701/41/O/N/21 Q7b

7(b)	M1: trend phenylethanoic acid > phenol > ethanol [1] M2: *why phenylethanoic acid is the strongest* • negative inductive electron withdrawing effect of C=O which weakens O-H bond / stabilises anion [1] M3: *why phenol is stronger than ethanol / weaker than phenylethanoic acid* • oxygen lone pair is delocalised into the ring system which weakens O-H bond / stabilises anion [1] M4: *why ethanol is the weakest* • electron donating alkyl / ethyl group which strengthens O-H bond / destabilises anion [1]	**4**
7(c)(i)	$CH_3Cl + AlCl_3 \rightarrow {}^+CH_3 + AlCl_4^-$ [1]	**1**
7(c)(ii)	 M1: arrow to CH_3^+ (arrow must come from inside the hexagon) [1] M2: correct structure of intermediate [1] M3: arrow <u>from</u> C-H bond into the ring **AND** H^+ seen [1]	**3**
7(d)(i)	Br_2 + UV light [1]	**1**

7(d)(ii)	 [1]	**1**
7(d)(iii)	**CHECK Q** is correct step 2 – KCN in ethanol + heat [1] step 3 – HCl(aq) + heat/reflux/boil [1]	**2**
7(d)(iv)	 [1] **ALLOW** any viable organic by-product from this radical substitution reaction, e.g. $C_6H_5CH_2CH_2C_6H_5$	**1**

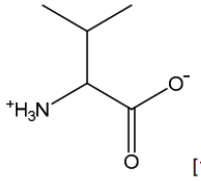
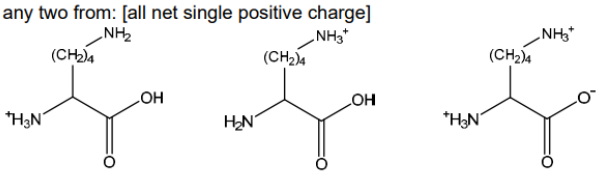
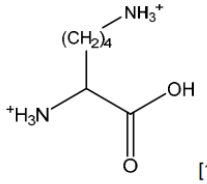
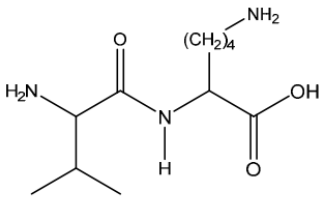
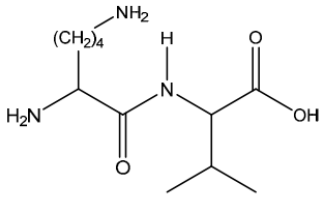
79. 9701/41/O/N/21 Q8

8(a)	bromine decolourised **OR** orange / brown to colourless [1] white precipitate [1]	**2**
8(b)	no change [1]	**1**
8(c)	 [1]	**1**
8(d)	2,4,6-tribromophenylamine [1] **ECF** 8(c) for a bromophenylamine	**1**

80. 9701/41/O/N/21 Q9

9(a)	PCl_5 **OR** PCl_3 **OR** $SOCl_2$ [1]	**1**
9(b)(i)	amide [1]	**1**
9(b)(ii)	HCl / hydrogen chloride **OR** $C_2H_5NH_3Cl$ / ethylammonium chloride [1]	**1**
9(c)(i)	$LiAlH_4$ [1]	**1**
9(c)(ii)	reduction [1]	**1**

81. 9701/41/O/N/21 Q10

10(a)	 [1]	**1**
10(b)	**A** and **B** any two from: [all net single positive charge]  [1] × 2 **C** at pH 1.0 [2+ positive charge]  [1]	**3**
10(c)	M1: peptide link correct and displayed unit including C=O M2: everything else correct  **OR**  [2]	**2**

82. 9701/42/O/N/21 Q7a,c

7(c)(i)	benzoic acid [1]	**1**
7(c)(ii)	COOH directs 3 position [1]	**1**
7(c)(iii)	electrophilic substitution [1]	**1**
7(c)(iv)	M1 curly arrow from within hexagon towards $CH_3C^+=O$ [1] M2 correct intermediate [1] M3 curly arrow from C–H bond into hexagon and correct product Q [1]	**3**
7(c)(v)	MnO_4^- / $KMnO_4$ / manganate VII / permanganate aq / H^+ / acidified / OH^- then acid / alkaline then acid heat / boil / reflux / T>50° **OR** alkaline iodine followed by acidification [1]	**1**

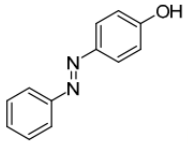
83. 9701/42/O/N/21 Q8a

8(a)	M1 one diagram correct [1] M2 both diagrams correct 3D and different [1]	**2**
8(d)(i)	use of buffer [1]	**1**
8(d)(ii)	• correct circuit including **DC** power supply • paper or gel labelled [1] • sample towards the middle of the paper / gel **OR** on cathode side [1]	**2**
8(d)(iii)	anode / positive / + **AND** anode / positive / + [1]	**1**
8(d)(iv)	M1 ala is –1 and glu is –2 [1] M2 ala is lighter / has lower M_r [1]	**2**

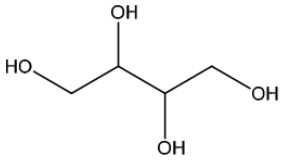
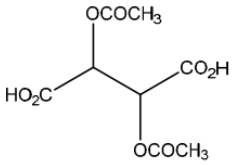
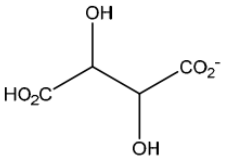
84. 9701/42/O/N/21 Q9

9(a)	organic starting material: 1-butyl halide, e.g. $CH_3CH_2CH_2CH_2Br$ — reagent and conditions: NH_3 under pressure or heated in sealed tube — [1] + [1] organic starting material: butanenitrile $CH_3CH_2CH_2CN$ — reagent and conditions: H_2 and Ni or Pt / $LiAlH_4$ / Na + ethanol — [1] + [1] organic starting material: butanamide $CH_3CH_2CH_2CONH_2$ — reagent and conditions: $LiAlH_4$ / Na + ethanol — [1] + [1]	**6**
9(b)	M1 butylamine > ammonia > phenylamine [1] M2 basicity related to ability of **lp** to accept proton / H^+ [1] M3 butylamine is stronger because of positive inductive effect of **alkyl** group / C_4H_9 [1] M4 phenylamine is weaker because **lp on N** is delocalised into ring [1]	**4**

85. 9701/42/O/N/21 Q10

10(a)	$C_6H_5O^-$ / $C_6H_5O^-Na^+$ / C_6H_5ONa [1] $C_6H_5O^-$ / $C_6H_5O^-Na^+$ / C_6H_5ONa [1] $C_6H_5N_2C_6H_4O^-$ or $C_6H_5N_2C_6H_4OH$ or  [1] $C_6H_5OCOC_6H_4CO_2C_6H_5$ [1]	**4**
10(b)	2 and 4 [1]	**1**

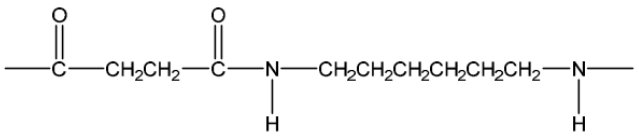
86. 9701/41/M/J/21 Q3e

3(e)(i)	<table><tr><th>reagent</th><th>structure of organic product</th><th>type of reaction</th></tr><tr><td>an excess of LiA/H_4</td><td>  </td><td>reduction</td></tr><tr><td>an excess of CH_3COCl</td><td>  </td><td>condensation</td></tr></table> **M1:** product with LiA/H_4 **M2:** product with CH_3COCl **M3:** both types of reaction	**3**
3(e)(ii)	 $C_6H_5CH(NH_3^+)CH_3$ **OR** dianion of tartrate with two cations present	**1**

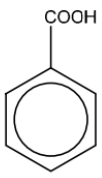
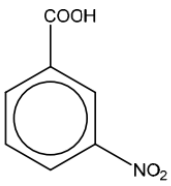
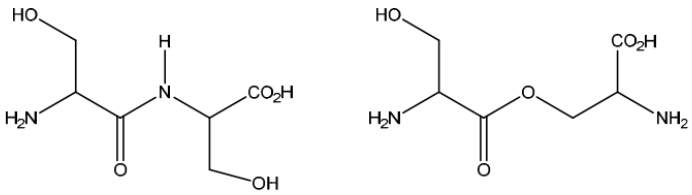
87. 9701/41/M/J/21 Q6

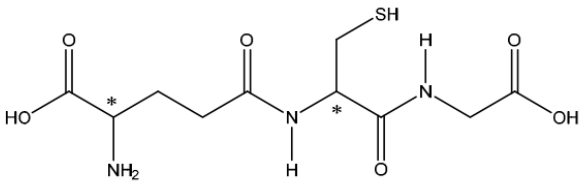
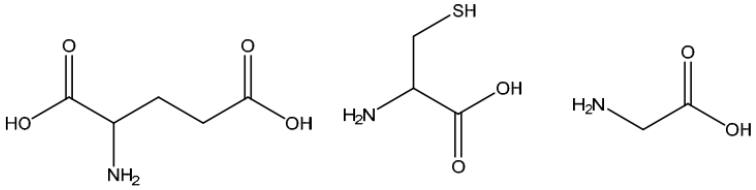
6(a)	**M1:** ethanoic acid > butanoic acid > water > ethanol **M2:** a reason given in terms of an electron donating or an electron withdrawing group for one of: strengthening of O–H bond **OR** weakening of O–H bond **OR** stability of anion *Two out of the three alternatives M3, M4 and M5:* M3: ethanol: positive inductive effect / electron donating effect of ethyl / alkyl / R group M4: butanoic acid: positive inductive effect / electron donating effect of propyl / alkyl / R group M5: (either ethanoic or butanoic) acid: negative inductive effect of either C=O or carbonyl **OR** negative charge delocalised over COO^-	**4**
6(b)(i)	<table><tr><th></th><th>reagents and conditions</th><th>observed change</th></tr><tr><td>test 1</td><td>Tollen's reagent, warm **OR** Fehling's solution, warm</td><td>silver mirror (brick) red ppt / solid</td></tr><tr><td>test 2</td><td>acidified MnO_4^-, warm</td><td>decolourises **OR** bubbles</td></tr></table> **M1 / M2:** reagents and conditions × 2 **M3:** observations both correct	**3**

88. 9701/41/M/J/21 Q6c,d

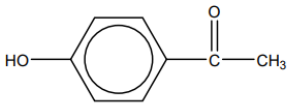
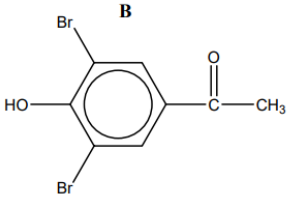
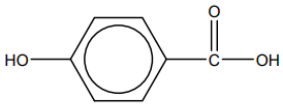
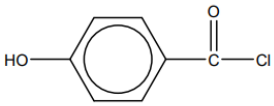
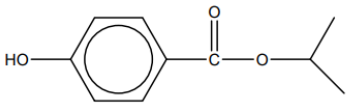
6(c)(i)	**G** = $HOCH_2CH_2CH_2CH_2OH$ **H** = $NCCH_2CH_2CH_2CH_2CN$	**2**
6(c)(ii)	**M1:** step 1 NaOH(aq) + heat **M2:** step 2 acidified $KMnO_4$ + heat / acidified $K_2Cr_2O_7$ + heat **M3:** step 3 CN^- / KCN / NaCN + heat **M4:** step 4 $LiAlH_4$ **ALLOW** Na in ethanol or H_2 + Ni / Pd / Pt	**4**
6(d)	 **M1:** correct displayed amide linkage **M2:** the rest of the repeat unit correct including trailing bonds	**2**

89. 9701/41/M/J/21 Q7

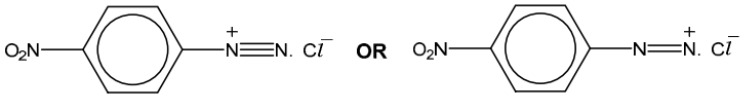
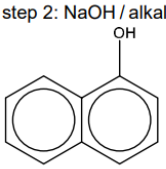
7(a)(i)	**M**  **N** 	**2**
7(a)(ii)	**M1:** step 1 hot $KMnO_4$ / MnO_4^- **M2:** step 2 conc. H_2SO_4 and conc. HNO_3 **M3:** step 3 Sn and conc. HCl (heat)	**3**
7(b)(i)	 **M1 / M2:** each structure **M3:** both displayed linkage	**3**
7(b)(ii)	molecular formula: $C_9H_{19}N_3O_4$ — number of structural isomers formed: 4	**1**

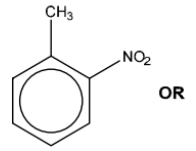
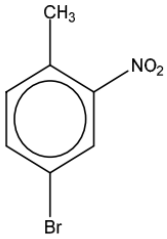
7(c)(i)		**1**
7(c)(ii)	 one mark for two correct two marks for three correct	**2**

90. 9701/41/M/J/21 Q9

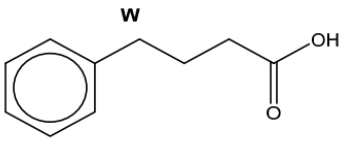
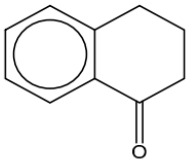
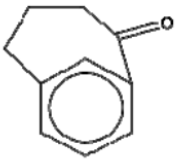
9(a)	**A**  **B**  **C** CHI_3 **D**  **E**  **F**  one mark for each structure	**6**

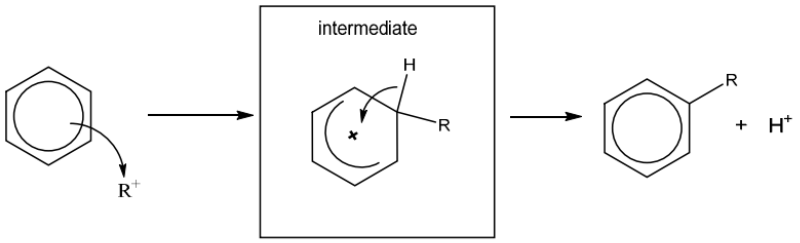
91. 9701/42/M/J/21 Q5

5(a)	**M1:** ethylamine phenylamine 4-nitrophenylamine most basic least basic **M2 / 3 / 4:** *explanation two correct for one mark, three correct for two marks, four correct for three marks* • (basicity linked to) lone pair / p orbital on N **AND** being able accept / donate to / coordinate to a proton / H^+ • ethyl / alkyl group is electron donating / has a positive inductive effect (so lone pair on N is more able to accept a proton) • (phenylamines are less basic than ethylamine as) p orbital / lone pair on N is delocalised (into the ring so less able to accept a proton) • (4-nitrophenylamine is less basic than phenylamine as) nitro / NO_2 group is electron withdrawing (so lone pair on N is less able to accept a proton)	**4**
5(b)(i)	 **OR**	**1**
5(b)(ii)	**M1:** step 1: HNO_2, ⩽ 10°C **OR** $NaNO_2$, HCl(aq), ⩽ 10°C **M2:** step 2: NaOH / alkaline **AND** 1-naphthol / α-naphthol / structure below 	**2**
5(c)(i)	4-bromo-2-nitrobenzoic acid **OR** 4-bromo-2-nitro(-1-)benzenecarboxylic acid	**1**

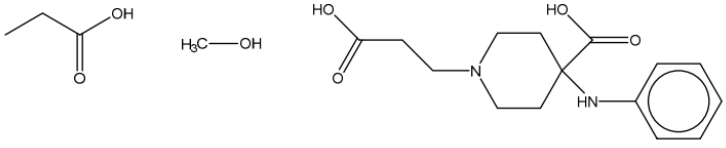
5(c)(ii)	**E =**  **OR**  **F =** 	**2**
5(c)(iii)	**M1:** step 1 conc. H_2SO_4 and conc. HNO_3 **M2:** step 2 Br_2 and $AlBr_3$ **M3:** step 3 hot (alkaline / acidified) MnO_4^- / $KMnO_4$	**3**

92. 9701/42/M/J/21 Q6b

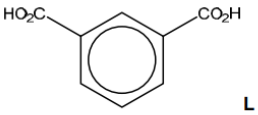
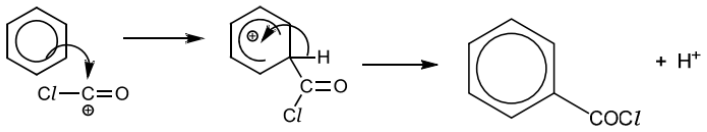
6(b)(i)	$RCl + AlCl_3 \rightarrow R^+ + AlCl_4^-$ **OR** $Cl(CH_2)_3COOH + AlCl_3 \rightarrow {}^+(CH_2)_3COOH + AlCl_4^-$	**1**
6(b)(ii)	**W**  **X** $C_{10}H_{10}O$  **OR** 	**2**

6(b)(iii)	$SOCl_2$ **OR** PCl_5 **ALLOW** PCl_3 **AND** heat	**1**
6(b)(iv)	 **M1:** arrow to R^+ **OR** arrow to positive carbon of ${}^+(CH_2)_3COOH$ **M2:** correct structure of intermediate **M3:** arrow from C-H bond into the ring **AND** H^+	**3**

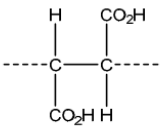
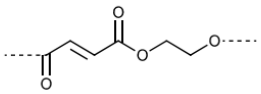
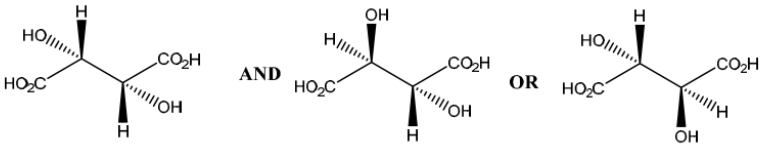
93. 9701/42/M/J/21 Q8

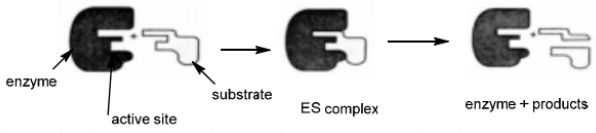
8(a)	**M1:** acyl chlorides > alkyl chlorides > aryl chlorides fastest slowest **M2 / 3:** *Any two from:* • *acyl chlorides* carbon in C-C*l* bond is more electron deficient since it is also attached to an oxygen atom **OR** C-C*l* bond is weakest / weakened in acyl chlorides since it is also attached to an oxygen atom / two electronegative atoms • *aryl chlorides* (no hydrolysis) C-C*l* bond is part of delocalised system / partially double bond character (so C-C*l* bond is stronger) **OR** lone pair / p-orbital on C*l* delocalises with π ring (so C-C*l* bond is stronger) • *alkyl chlorides* C-C*l* bond strengthened by electron donating effect / positive inductive effect of alkyl / R group (as compared to acyl chlorides) **OR** carbon atom has a smaller δ+ and the C-C*l* bond is stronger (than the C-C*l* bond in COC*l*) due to (the carbon) being only attached to one electronegative atom	**3**
8(b)	 **ALLOW** amine salt for the third structure – mono or di ion	**3**

94.

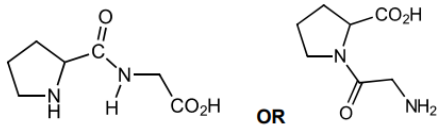
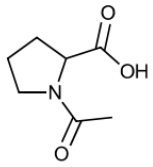
5(b)(i)	 L	1
5(b)(ii)	**M1:** heat / reflux with acidified / alkaline KMnO4 (then acidify) **M2:** PCl_5 **OR** $SOCl_2$ / (heat with) PCl_3	2
5(b)(iii)	$C_8H_6O_4 + 2PCl_5 \rightarrow C_8H_4O_2Cl_2 + 2POCl_3 + 2HCl$ **OR** $C_8H_6O_4 + 2SOCl_2 \rightarrow C_8H_4O_2Cl_2 + 2SO_2 + 2HCl$ **OR** $3C_8H_6O_4 + 2PCl_3 \rightarrow 3\ C_8H_4O_2Cl_2 + 2H_3PO_3$	1
5(b)(iv)	 **M1:** curly arrow from inside hexagon to C of electrophile **M2:** correct intermediate **M3:** curly arrow from C—H bond **AND** formation/loss of H^+	3

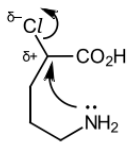
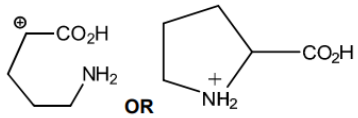
95. 9701/42/F/M/21 Q6

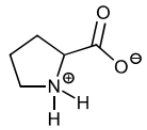
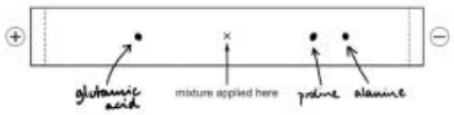
6(a)	CO_2 and H_2O / in words	1
6(b)(i)	 if more than one unit drawn **ALLOW** one repeat unit identified	1
6(b)(ii)	 **M1:** presence of an ester group from the diol and COOH **OR** presence of an ester group from the fumaric acid and OH **M2:** rest of repeat unit including 'dangling' bonds	2
6(b)(iii)	C—C bonds are non-polar / polyalkenes cannot be hydrolysed **OR** polyesters / they can be broken down by hydrolysis	1
6(c)		2

6(d)	 **M1:** (can be in words or diagram) substrate shape is **complementary** to active site **M2:** (can be in words or diagram) the substrate bind / bonds / fits (into the active site) **M3:** (can be in words or diagram) products are released	3

96. 9701/42/F/M/21 Q7

7(a)(i)	 **OR** **M1:** peptide link shown **M2:** rest of Pro–Gly correct	**2**
7(a)(ii)	condensation **ALLOW** substitution / addition–elimination	**1**
7(a)(iii)	there is no H attached to the N	**1**
7(b)(i)	$(C_4H_7NHCO_2H +)\ NaOH \rightarrow C_4H_7NHCO_2Na + H_2O$	**1**
7(b)(ii)	 skeletal only	**1**

7(b)(iii)	$LiAlH_4$	**1**
7(c)(i)	$CH_2(CO_2C_2H_5)_2$: ● (di)ester CH_2=CHCN: ● alkene ● nitrile/cyanide All three correct for two marks	**2**
7(c)(ii)	addition	**1**
7(c)(iii)	H_2 / Ni **OR** H_2 / Pt **OR** H_2 / Pd	**1**
7(c)(iv)	condensation / (nucleophilic) substitution / elimination	**1**
7(c)(v)	ethanol / C_2H_5OH / CH_3CH_2OH	**1**
7(c)(vi)	 **M1/2:** All four correct: • lone pair on NH_2 • curly arrow from N: to C of C—Cl • correct dipole on C—Cl • curly arrow from C—Cl to Cl **M3:** intermediate = 	**3**
7(c)(vii)	Asterisk on *$CHCO_2H$	**1**

7(d)	9	**1**
7(e)(i)	**M1:**  **M2:** proton / H^+ transferred from carboxylic acid to amine	**2**
7(e)(ii)	 **M1:** glutamic acid towards + end (from the diagram) **M2:** proline and alanine towards – end (from the diagram) **M3:** Glu moves towards positive (pole) as negatively charged / contains a COO^- **OR** Pro/Ala move towards negative (pole) as positively charged / contains a NH_2^+ / contains a NH_3^+ **M4:** Ala moves farther than Pro because of lower M_r / size (with positive charge) ORA	**4**

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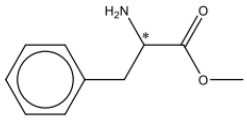
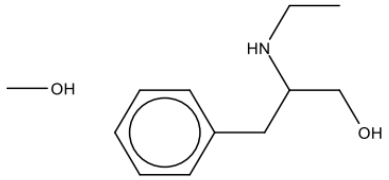
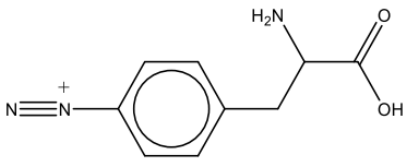
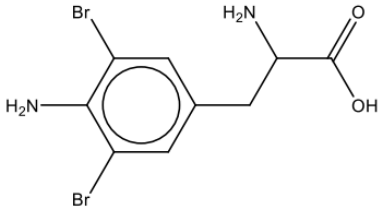
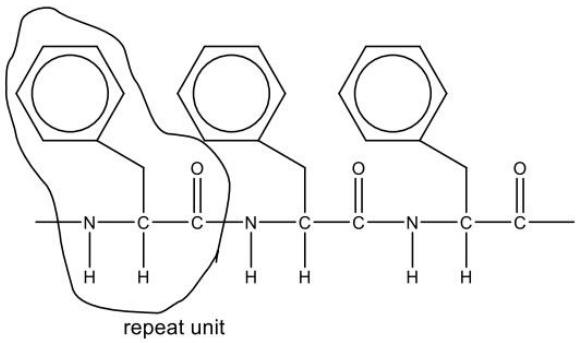
7(a)(i)		**1**
7(a)(ii)	plane of polarised **light** will be **rotated** (in both isomers) [1] by same angle / **equal** amounts in **opposite directions** [1]	**2**
7(b)(i)	CH_3COCl **AND** HCl	**1**

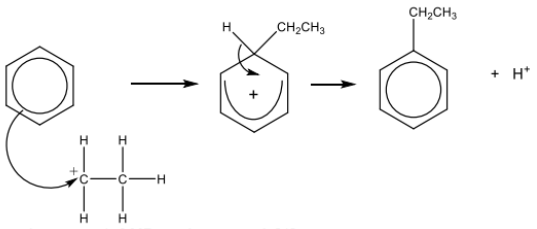
7(b)(ii)	 methanol [1] ester bond → primary alcohol **OR** amide → 2° amine **AND** benzene ring unchanged [1] rest of the structure of second compound is correct [1]	**3**
7(b)(iii)	Q < phenylamine < P [1] <u>any three from:</u> ability of N to **accept** a proton **OR donate** its lone pair to a proton phenylamine **lone pair of N** delocalised into ring **OR p-orbital on N** overlaps with π cloud of ring (and decreases electron density on N) compound P (2° amine) alkyl group has a positive inductive effect (and increases electron density on N) compound Q (amide) **lone pair of N** (in amide) delocalised by C=O **OR** overlap of **lone pair of N** with C=O (and decreases electron density on N)	**3**
7(c)(i)	conc. HNO_3 and H_2SO_4 (25 °C < T ⩽ 60 °C) [1] Sn and conc. HCl and reflux (followed by NaOH(aq)) [1]	**2**

7(c)(ii)	 NH_2 on ring gives diazonium ion [1]  dibromo compound with Br atoms 2,6 to amine group [1]	**2**
7(d)(i)	**pH** where the species is a zwitterion is the dominant form **OR pH** where the species is electrically neutral	**1**

7(d)(ii)	 repeat unit repeat unit identified by label / brackets / circle [1] three monomers complete all amide/peptide bonds correct all $CHCH_2C_6H_5$ / CHR groups correct trailing bonds or other convention(everything else correct) [1]	**2**

98. 9701/41/O/N/22 Q8

8(a)	120° **AND** sp^2	**1**
8(b)(i)	$C_2H_5Cl + AlCl_3 \rightarrow CH_3CH_2^+ + AlCl_4^-$	**1**

8(b)(ii)	 curly arrow 1 **AND** curly arrow 2 [1] correct intermediate structure [1] $C_6H_5C_2H_5$ **AND** H^+ [1]	**3**
8(c)(i)	(aqueous / alkaline) $AgNO_3$ / silver nitrate	**1**
8(c)(ii)	$C_2H_5Cl + H_2O \rightarrow C_2H_5OH + HCl$ / $C_2H_5Cl + NaOH \rightarrow C_2H_5OH + NaCl$ **AND** $Ag^+ + Cl^- \rightarrow AgCl$ **AND NO** equation shown for C_6H_5Cl	**1**
8(c)(iii)	lone pair / p-orbital from **Cl** overlaps with benzene ring **AND** stronger / partial double C-Cl bond **OR** difficult to break C-Cl bond	**1**

99. 9701/42/O/N/22 Q7

7(a)	**C > A > B** [1] chlorine and C=O are electronegative / withdraw charge **and** this causes greatest weakening of O–H bond or greatest stabilisation of the anion [1] 2nd oxygen / C=O is electronegative / withdraws charge **and** this weakens O–H bond or stabilises anion [1]	**3**
7(b)(i)	chloromethane aluminium chloride	**1**
7(b)(ii)	$CH_3Cl + AlCl_3 \rightarrow AlCl_4^- + CH_3^+$	**1**
7(b)(iii)	curly arrow from within benzene to CH_3^+ [1] positively charged intermediate [1] curly arrow from C–H bond into ring, $C_6H_5CH_3$, H^+ [1]	**3**
7(b)(iv)	hot alkaline $KMnO_4$ [1] $C_6H_5CH_3 + 3[O] \rightarrow C_6H_5CO_2H + H_2O$ **OR** $C_6H_5CH_3 + 3[O] + OH^- \rightarrow C_6H_5CO_2^- + 2H_2O$ [1]	**2**
7(b)(v)	2 or 4-nitromethylbenzene and 3-nitrobenzoic acid	**1**
7(c)(i)	HNO_2, T between 0° and 10°C	**1**
7(c)(ii)	warm / T>10°C **and** H_2O	**1**

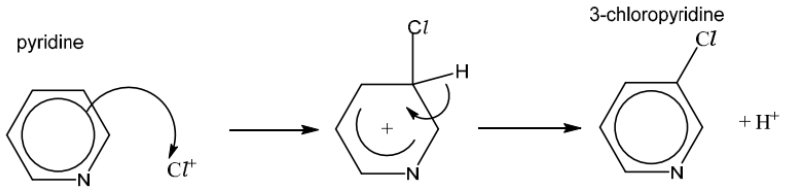
7(c)(iii)	$CH_3C_6H_4–N=N–C_6H_3(CH_3)OH$ [1] T between 0° and 10°C **and** NaOH(aq) [1]	**2**

100. 9701/42/O/N/22 Q9

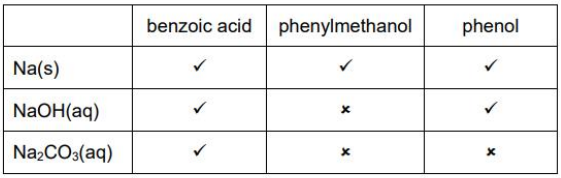
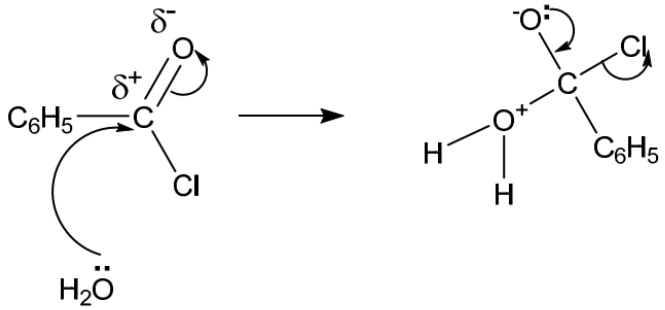
9(a)	pH 7 $^+H_3N(CH_2)_4CHNH_2COOH$ pH 9.47 $^+H_3N(CH_2)_4CHNH_2COO^-$ [1] pH 12 $H_2N(CH_2)_4CHNH_2COO^-$ [1]	**2**
9(b)	D ethanoyl chloride [1] E correct phenyl ester [1] F correct amide [1]	**3**
9(c)	Br substitutes at both 2 and 6 positions [1] both phenol and COOH groups deprotonated [1] NO_2 substitutes at one or both of 2 and 6 positions [1]	**3**

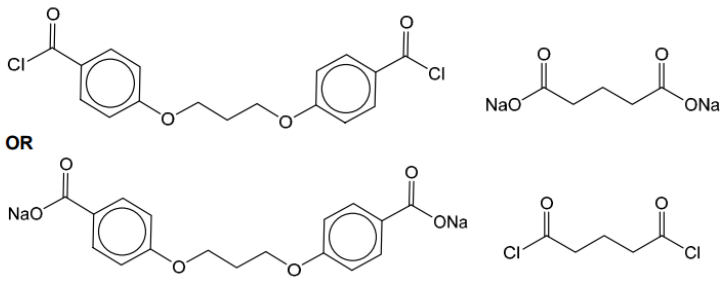
101. 9701/41/M/J/22 Q4d

4(d)	**M1** N sp^2 **AND** C sp^2 **M2** σ bonds are formed by end-on-end overlap orbitals between C-H / C-C / C-N **M3** π bonds are formed by sideways overlap of p orbitals between C-N / C-C	**3**

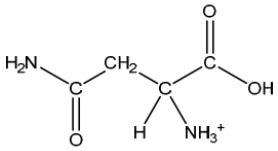
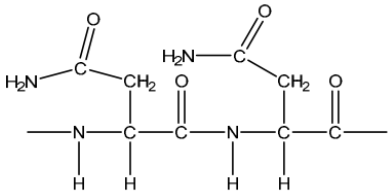
4(e)	 **M1** first curly arrow to Cl^+ **M2** correct intermediate **M3** second curly arrow **AND** H^+ formed / lost	**3**

102. 9701/41/M/J/22 Q5

5(a)	**M1** benzoic acid > phenol > phenylmethanol **M2** / **M3** *Any two of:* • in benzoic acid negative inductive effect of C=O **AND** O-H bond is weakened **OR** due to delocalisation of minus charge by C=O / 2O carboxylate ion is stabilised • in phenol lone pair on oxygen is delocalised into the ring **AND** O-H bond is weakened • in phenyl methanol positive inductive effect of CH_2 group **AND** O-H bond is strengthened	**3**
5(b)	 Three correct for one mark, six correct for two marks, nine correct for three marks	**3**
5(c)(i)	$POCl_3$ and HCl **AND** SO_2 and HCl	**1**
5(c)(ii)	all the by-products / SO_2 and HCl are gaseous **OR** no liquid by-products formed	**1**
5(d)(i)	 On the left-hand side: • lone pair on O • correct arrow from O to C (of C=O) • dipole on C=O • correct arrow on C=O **M1** / **M2** Two correct for one mark, four correct for two marks On the right-hand side: **M3** correct intermediate **M4** arrow from lone pair on O^- to C-O bond **AND** arrow from C-Cl to Cl	**4**
5(d)(ii)	addition-elimination	**1**

5(e)(i)	 **OR** 	**2**
5(e)(ii)	hydrolysis **OR** heating in dilute acid / alkali	**1**

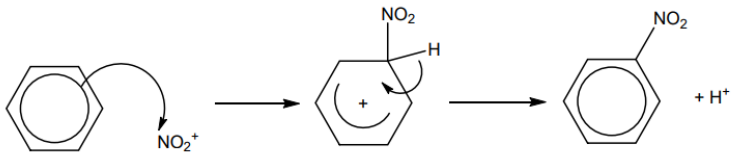
103. 9701/41/M/J/22 Q6

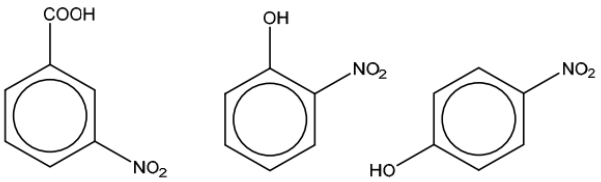
6(a)	a mixture containing equal amounts of each optical isomer	**1**
6(c)(i)	the pH at which an amino acid exists as a zwitterion **OR** the pH at which an amino acid has no overall charge	**1**
6(c)(ii)		**1**
6(d)	 **M1** peptide bond displayed **M2** rest of the structure correct + continuation bonds	**2**

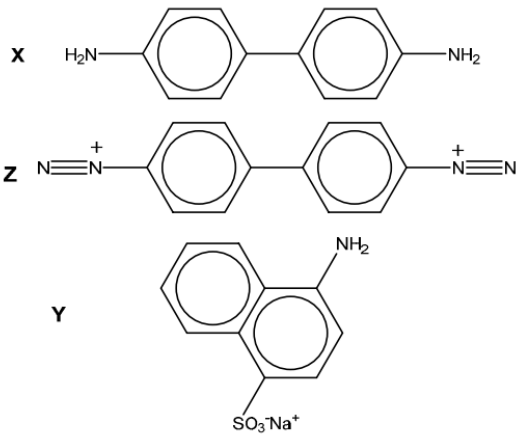
104. 9701/41/M/J/22 Q7

7(a)(i)	phenylamine **AND** amine **AND** ester	**1**
7(a)(ii)	sp carbons = 0, sp^2 carbons = 7, sp^3 carbons = 6	**1**
7(b)	6	**1**
7(c)	lone pair on the N can accept a proton	**1**
7(d)(i)		**1**
7(d)(ii)	step 1 **M1** concentrated HNO_3 and H_2SO_4 step 2 **M2** hot (alkaline) $KMnO_4$ (followed by addition of H^+)	**2**
7(e)	step 4 **M1** $HOCH_2CH_2N(CH_2CH_3)_2$ step 5 **M2** Sn **AND** HC*l* **M3** concentrated (HC*l*) **AND** heat / reflux	**3**

105. 9701/42/M/J/22 Q6

6(a)(i)	 **M1** first curly arrow from within hexagon to N of the NO_2^+ **M2** correct intermediate **M3** second curly arrow from C-H bond into the ring **AND** H^+ formed / lost	**3**
6(a)(ii)	$HSO_4^- + H^+ \rightarrow H_2SO_4$	**1**

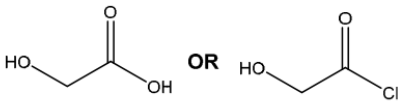
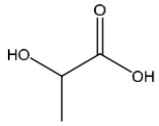
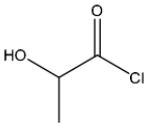
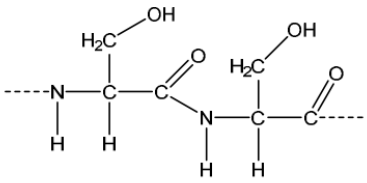
6(b)	**M1** *benzoic acid* **M2** *phenol*  **OR**	**2**
6(c)	**M1** phenol > benzene > benzoic acid **M2 / M3** phenol: • lone pair / p-orbital on oxygen delocalises into the ring / overlaps with π-delocalised ring • accepts / attracts / polarises NO_2^+ / electrophiles better benzoic acid: • COOH / C=O is an electron-withdrawing / positive inductive effect two for one mark, three for two marks **M4** (phenol-oxygen) increases electron density in the ring *(as compared to benzene as a result of the OH group)* **OR** (benzoic acid–COOH) decreases electron density in the ring *(as compared to benzene as a result of the COOH group)*	**4**

6(d)(i)		**3**
6(d)(ii)	step 1 **M1** Sn and hydrochloric acid / HC*l* **M2** concentrated (HC*l*) + heat / reflux (followed by NaOH) step 2 **M3** HNO_2 and (HC*l*) ⩽10°C **OR** $NaNO_2$, HC*l* and ⩽10°C	**3**

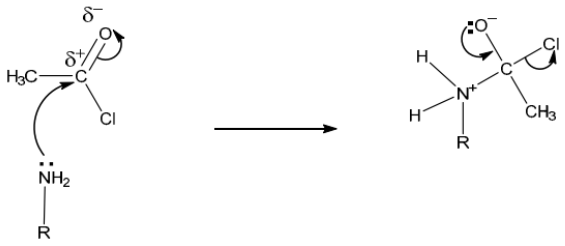
106. 9701/42/M/J/22 Q7c

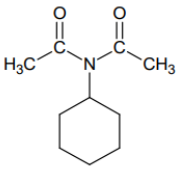
7(c)(i)	six / 6	1
7(c)(ii)	$C_{21}H_{34}O_5$	1
7(c)(iii)	a substance that is able to rotate the plane of polarised light in opposite directions	1

107. 9701/42/M/J/22 Q8

8(a)	**M1** chloroethanoic acid > ethanoic acid > phenol > ethanol **M2** correct link of acidity once can be implied from M1 weakens O—H / carboxylate anion stabilised **M3** / **M4** explanation linked to structure • ($ClCH_2CO_2H$ > ethanoic acid) due to electronegative / electron withdrawing / negative inductive effect of Cl • (ethanoic acid > phenol) due to electronegative / electron withdrawing / negative inductive effect of COOH / C=O • (phenol > ethanol) due to lone pair of oxygen overlapping / delocalised into the ring • (ethanol weakest) alkyl group is electron donating / positive inductive effect two for one mark, four for two marks	4
8(b)	• oxidation • (solution) decolourises **OR** purple → colourless / pale pink **OR** bubbles • $HOOCCOOH + [O] \rightarrow 2CO_2 + H_2O$ **OR** $5HOOCCOOH + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 8H_2O + 2Mn^{2+}$ two for one mark, three for two marks	2
8(c)	**M1**  **OR** **M2**  **OR** 	2
8(d)	 **M1** peptide linkage shown displayed with saturated C each side **M2** rest of structure correct **AND** continuation bonds	2
8(e)	addition polymers do not hydrolyse **OR** condensation polymers can hydrolyse	1

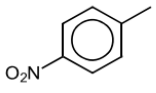
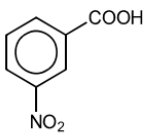
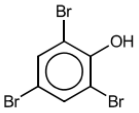
108. 9701/42/M/J/22 Q9

9(a)	cyclohexylamine > ammonia > phenylamine • (order of basicity) linked to ability of N to accept a proton / donate its lone pair (to a proton) • alkyl / cyclo / hexyl group is electron donating group / positive inductive group (and increases electron density on N) • lone pair / p-orbital from N in phenylamine delocalised / overlaps with ring (and decreases electron density on N) two for one mark, three for two marks	**3**
9(b)(i)	(nucleophilic) addition-elimination	**1**
9(b)(ii)	 **M1 / M2** • lone pair on N • correct arrow from (lone pair) N to C (of C=O) • dipole on C=O • correct arrow on C=O two for one mark, four for two marks **M3** correct intermediate **M4** arrow from lone pair on O^- to C-O bond **AND** arrow from C-C*l* to C*l*	**4**

9(b)(iii)		**1**

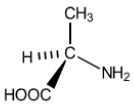
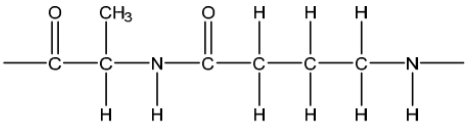
109. 9701/42/F/M/22 Q4

4(a)(i)	In **F**: (phenyl)amine **AND** carboxylic acid In **J**: phenol **AND** ester *Any two for one mark* *All four for two marks*	**2**
4(a)(ii)	0 (zero) in **F AND** 2 (two) in **J**	**1**

4(b)(i)	step 1 CH_3Cl **AND** $AlCl_3$ [1]  step 2 **D** = [1] step 4 (hot) Sn **AND** concentrated **AND** HCl [1]	**3**
4(b)(ii)	 [1] COOH group is electron-withdrawing group and 3,5-/meta- directing [1]	**2**
4(c)(i)	$C_9H_{18}O$	**1**
4(c)(ii)	hydrolysis [1] acid–base / neutralisation [1]	**2**
4(d)(i)	$C_6H_5OH + Na \rightarrow C_6H_5O^{(-)}Na^{(+)} + ½H_2$	**1**
4(d)(ii)		**1**
4(d)(iii)	• (CO)O—H bond **weaker** / more easy to donate H^+ in **K** • owing to negative inductive / electron withdrawing effect of C=O / COOH group • carboxylate anion stabilised / phenoxide anion is less stabilised *All three for two marks*	**2**

4(e)	p-orbital on oxygen overlaps with ring / π system **OR** lone pair of e^- on oxygen is delocalised into the ring [1] electron density in **ring** increases [1] attracts/polarises electrophile better [1]	**3**

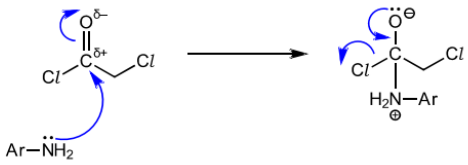
110. 9701/42/F/M/22 Q5b

5(b)(i)	**pH** at which a molecule has no overall charge / is neutral **OR pH** at which it exists as a zwitterion / dipolar ion	**1**
5(b)(ii)	$CH_3CH(N^+H_3)COOH$	**1**
5(b)(iii)		**1**
5(b)(iv)	 middle amide group shown displayed [1] rest of structure correct [1]	**2**

5(b)(v)	condensation	**1**
5(b)(vi)	**C** is biodegradable / easily hydrolysed	**1**

111. 9701/42/F/M/22 Q6

6(a)	$HOCH_2COOH + 2SOCl_2 \rightarrow ClCH_2COCl + 2SO_2 + 2HCl$	**1**
6(b)	to remove / neutralise excess H^+ / acid produced **OR** to react with any acidic by-products / HCl / SO_2 **OR** to react with any unreacted **W**	**1**

6(c)	 M1: curly arrow from **lone pair** on $:NH_2$ to carbonyl $\mathbf{C}^{(\delta+)}=O$ M2: correct dipole on $^{\delta+}C=O^{\delta-}$ **AND** curly arrow from bond C=O to $O^{(\delta-)}$ M3: correct structure of the intermediate (inc. charges) M4: curly arrow from lone pair on $:O^-$ to C=O **AND** curly arrow from C—Cl to Cl	**4**
6(d)	N / nitrogen can donate its lone pair / LP / pair of electrons	**1**