Q1.

4 (a) (i) $HCONHC_3H_7$ *or* $CH_3CONHC_2H_5$ *or* $C_2H_5CONHCH_3$ *or* $C_3H_7CONH_2$

[1]

[for propyl groups allow C_3H_7 or $CH_3CH_2CH_2$ or $(CH_3)_2CH$]

(ii) boil/heat/reflux with dil/aq. $H_2SO_4/H^+/OH^-$ *or* with H_3O^+ [1]

(iii) $RCONHR' + H_2O \longrightarrow RCO_2H + R'NH_2$
(R and R' = H or alkyl)

or $RCONHR' + OH^- \longrightarrow RCO_2^- + R'NH_2$

or $RCONHR' + H_3O^+ \longrightarrow RCO_2H + R'NH_3^+$

[2]

[award [2] for a balanced equation with the same R groups as in (i). If [2] cannot be awarded, apply the following part-marks: [1] *for –CONH- → $-CO_2H$ + NH_2.*
[1] *for all four R groups consistent with (i)]*

(b) (i) C_2H_5COCl

[1]

(ii) $C_2H_5CO_2H + SOCl_2$ *or* PCl_5 *or* PCl_3 (or names) [1]

(iii) $C_2H_5COCl + C_2H_5OH \longrightarrow C_2H_5CO_2C_2H_5 + HCl$ [1]

Total = [7]

Q2.

4 **(a)** HC*l* *or* H_2SO_4 *or* H^+ *or* acid [1]

conc(if HC*l* only)/dilute/aqueous + heat [1]

[2]

(b) **two** rings only (1 ring around the α-C of tyrosine & 1 around the α-C of lysine) [1]

[1]

(c) $^+NH_3CH_2CO_2^-$ (*or* displayed formula) [1]

[1]

(d) **(i)** $NH_2CH_2CO_2^-$ (Na^+) (*either* $-CO_2^-Na^+$ *or* $-CO_2Na$ but NOT –CO-O-Na) [1]

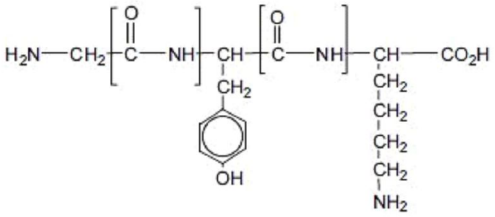
(ii) $(Na^+)\ ^-O\text{-}C_6H_4\text{-}CH_2CH(NH_2)CO_2^-$ (Na^+) [1] + [1]

(iii) $(Cl^-)^+NH_3(CH_2)_4CH(NH_3^+)CO_2H$ (Cl^-) [1] + [1]

(iv) $HO\text{-}C_6H_2Br_2\text{-}CH_2CH(NH_2)CO_2H$ (if shown, Br at 2,6 to OH group) [1]

[6]

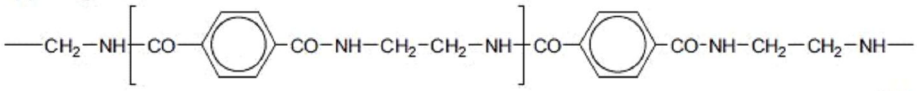
(e)



structure [1]
at least one peptide group identified [1]

[2]

(f) **(i)** e.g.



[1]

(ii)

or C*l*CO----------COC*l*

[1]
[1]

[3]

[Total: 15 max 14]

Q3.

8 **(a)** $-NH_2$ (*or* $-CO_2^-$) group can be protonated and the molecule moves towards the cathode/negative [1]

$-CO_2H$ (*or* $-NH_3^+$) group can lose a proton and the molecule moves towards the anode/positive [1]

salvage: ***either:*** *if H^+ gain/loss is described but no direction of movement is given, award [1] mark.*

or: *if H^+ gain/loss is not described but correct movement of ions with stated charge (+/–) is given, award [1] mark.*

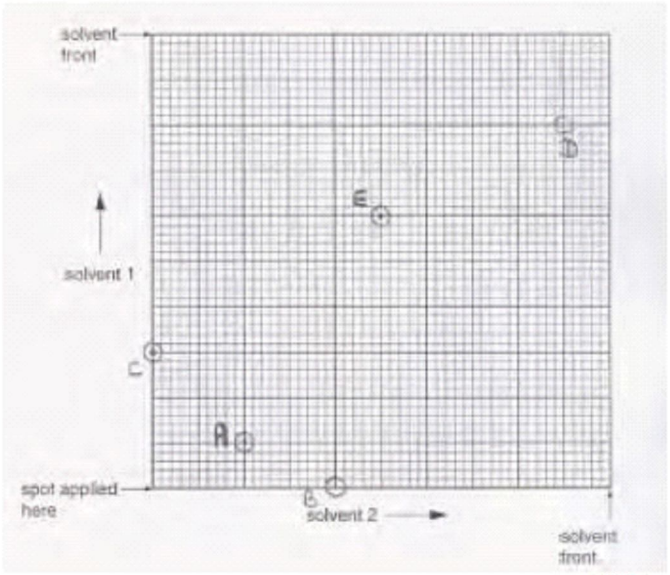
acidic/low pH will protonate the amino acid *or* basic/high pH will deprotonate [1] **[3]**

(b) (i) **Q** forms mainly zwitterions, because it does not move *or* ends up midway between (+) and (–) [1]

(ii) **R** is larger, since it travels more slowly/does not move as far as **S** [1] **[2]**

(c) (i) Second phase is water/moisture (NOT aqueous, NOT stationary) [1]

(ii)



all 5 positions correct [2]

4 correct *[1]*

(iii) **D** [1]

(iv) **C** [1] **[5]**

[Total: 10]

Q4.

4 **(a)** hydrogen bonding (1)

diag: $NH_2CH_2CH_2OH$---$OHCH_2CH_2NH_2$ *or* $NH_2CH_2CH_2OH$---$NH_2CH_2CH_2OH$
(i.e. H-bond from OH group to either OH or NH_2) (1) [2]

(b) propylamine is more basic than phenylamine (1)
because lone pair on N is delocalised over ring in phenylamine (so less available for protonation)
or the propyl group is electron-donating, so the lone pair is more available (1) [2]

(c) $HOCH_2CH_2NH_2 + H^+ \longrightarrow HOCH_2CH_2NH_3^+$
or $HOCH_2CH_2NH_2 + HCl \longrightarrow HOCH_2CH_2NH_3^+Cl^-$
or $HOCH_2CH_2NH_2 + H_2O \longrightarrow HOCH_2CH_2NH_3^+OH^-$
(reaction with any acceptable Bronsted acid accepted) [1]

(d) **(i)** **X** is CH_3CH_2CN (1)

(ii) step 1 is KCN in ethanol, heat [HCN negates] (1)
step 2 is H_2+Ni / Pt or $LiAlH_4$ or Na in ethanol [NOT $NaBH_4$ or Sn/HCl] (1) [3]

(e) ethanolamine:

	Na		effervescence / bubbles produced
or	$Cr_2O_7^{2-}$ / H^+		colour turns from orange to green
or	MnO_4^- / H^+		purple colour disappears
or	PCl_3/ PCl_5 / $SOCl_2$	(1)	steamy fumes (1)

phenylamine:

	Br_2(aq)		decolourises / white ppt formed
or	HNO_2/ H^+ at T<10°C, then phenol in NaOH	(1)	coloured dye formed (1) [4]

[Total: 12]

Q5.

4 **(a)** (due to the) strong N≡N bond [1]
[1]

(b) **(i)** Any balanced equation forming a stable nitrogen oxide
e.g. $N_2 + O_2 \longrightarrow 2NO$
or
$N_2 + 2O_2 \longrightarrow 2NO_2$ [1]

(ii) in lightning [1]

in an engine/combustion of fuels (or a specific example) [1]

(iii) (NO_x produces) acid rain *or* forms (photochemical) smog [1]
[4]

(c) (base is a) proton acceptor [1]

basicities: ethylamine > NH_3 > phenylamine [1]

ethylamine (more basic) due to electron donating ethyl group [1]

phenylamine (less basic) due to lone pair being delocalised into the ring [1]
[4]

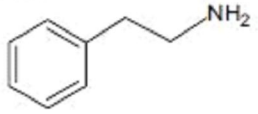
(d) **(i)** step 1: nucleophilic substitution [1]

step 2: hydrolysis [1]

(ii) step 1: KCN (in ethanol) **and** reflux [1]

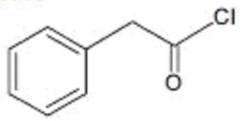
step 2: H_3O^+ / aqueous acid **and** reflux [1]

(iii) **T** is



[1]

W is



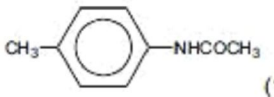
[1]
[6]

[Total: 15]

Q6.

5 (a) (i) Br_2(aq) (*or* solution *or* in an inert solvent) [light or $AlCl_3$ etc negates] (1)

(ii) **G** is



(1)

H is

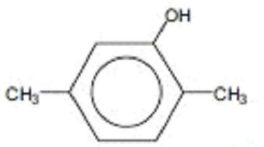
[charges needed] (1)

(iii) amide [NOT peptide] (1) **[4]**

(b) IV: $H^+/HCl + NaNO_2$ *or* HNO_2/nitrous acid (1)

$0°C \leq T \leq 10°C$ ["REFLUX" negates] (1)

V:



(1)

in NaOH(aq) (1) **[4]**

(c) To increase its solubility in water *or* to increase binding to food components (1)

due to ionic solvation *or* more oxygen atoms to H-bond to H_2O/glucose etc (1) **[2]**

[Total: 10]

Q7.

(c) **(i)** catalyst [1]

(ii) $CH_3CH_2CO_2H + Cl_2 \longrightarrow CH_2CHClCO_2H + HCl$ [1]

(iii) nucleophilic substitution NOT addition/elimination [1]

(iv) $M_r(CH_3CH_2CO_2H) = 74$ $M_r(CH_2CH(NH_2)CO_2H) = 89$ [1]
$\therefore$ 10.0 g should give 10 x 89/74 = 12.03 g
$\therefore$ percentage yield = 100 x 9.5/12.03 = **79%** ecf [1]
([2] for correct answer)
[5]

(d) $^+NH_3\text{-}CH(CH_3)\text{-}CO_2^-$ correct atoms [1]
Allow charges on H of H_3N, and –COO but not –C-O-O correct charges [1]
[2]

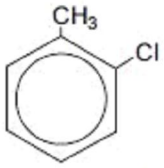
[Total: 15]

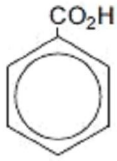
Q8.

7 **(a)** $HNO_3 + H_2SO_4$ [1]
at 50 – 60°C (*or* ≤ 60°C) not dilute or (aq) [1]
[2]

(b) $2H_2SO_4 + HNO_3 \longrightarrow 2HSO_4^- + H_3O^+ + NO_2^+$
(allow equ. with only one H_2SO_4, giving H_2O) [1]
[1]

(c)

G is 

H is 

[1] + [1]

reaction I: Cl_2 + $AlCl_3$/accept other halogen carriers *NOT* aq, *nor* u.v.
reaction II: $KMnO_4 + H^+$ *NOT* HCl *nor* HNO_3
reaction III: $KMnO_4 + H^+$ *NOT* HCl *nor* HNO_3
reaction IV: Cl_2 + $AlCl_3$/accept other halogen carriers *NOT* aq, *nor* u.v.

both I + IV [1]
both II + III [1]
[4]

[Total: 7]

Q9.

7 **(a)** *protein*: polymer of amino acids / amino acids are monomers. [1]

(b) diagram of at least two amino acids joining by the loss of water [1]
at least one peptide bond drawn out in full [1]
correct formula of the tripeptide [1]

(c) acid/H^+/HC*l* etc. *or* alkali/OH^-/NaOH NOT conc H_2SO_4 or any HNO_3 [1]
heat/boil/reflux if temp given >90 °C [1]

(d) **(i)** six [1]

(ii) M_r = 3 × 75 + 2 × 89 + 2 × 165 – 6 × 18 [1]
= **625** [1]
(allow [1] for M_r = 733)
*(also ecf from **(i)**)*

[Total: 9]

Q10.

5 **(a)** **(i)** I: $KMnO_4$ [1]
heat with H^+ *or* OH^- [1]
II: $SOCl_2$ *or* PCl_5 *or* PCl_3 (NOT aq) [1]

(ii) -[-CO-C_6H_4-CO-NH-C_6H_4-NH-]- (Peptide bond must be displayed for minm) [1]
[4]

(b) **(i)** CH_3NHCO-C_6H_4-$CONHCH_3$ (1 mark for each end) [1] + [1]

(ii) $HOCH_2CH_2O$-CO-C_6H_4-CO-OCH_2CH_2OH for [1]
or the polymer -[- OCH_2CH_2O-CO-C_6H_4-CO-]- for [2]
[4 max 3]

(c) **(i)** Cl^- $^+NH_3$-C_6H_4-NH_3^+ Cl^- (1 mark for each end) [1] + [1]

(ii) H_2N-$C_6H_2Br_2$-NH_2 *or* H_2N-$C_6H_2Br_3$-NH_2 *or* H_2N-C_6Br_4-NH_2 [1]
[3]

(d) I: HNO_2 (*or* $NaNO_2$ + HCl/H_2SO_4) [1]
at T < 10°C [1]

II: *m*-prop-2-yl phenol, $(CH_3)_2CH$-C_6H_4OH [1]
+ NaOH(aq) [1]
[4]

(e) **(i)** A species having positive and negative ionic centres / charges, with no overall charge [1]

(ii) -O_2C-C_6H_4-NH_3^+ [1]
[2]

[Total: 16]

Q11.

6 (a) **L** is CH_3CH_2Br
M is CH_3CO_2H
N is $CH_3CH_2NH_2$
Q is $CH_3CH_2CO_2H$
P is $CH_3CH_2CH_2NH_2$
J is $CH_3CH_2CONHCH_2CH_3$
K is $CH_3CONHCH_2CH_2CH_3$ [7]
[7]

(b) reaction **I**: KCN, heat NOT H^+ OR HCN aq negates [1]
reaction **II**: $SOCl_2$ *or* PCl_5 *or* PCl_3 BUT aq negates [1]
reaction **IV**: H_2 + Ni *or* $LiAlH_4$ *or* $NaBH_4$ NOT Sn + HCl [1]
[3]

(c) reaction **IV**: reduction [1]
reaction **VI**: nucleophilic substitution *or* condensation reaction [1]
[2]

(d) **(i)** amide [1]

(ii) amine [1]
[2]

[Total: 14]

Q12.

6 (a) (i) Br_2 (ignore solvent, but do not credit $AlCl_3$ or HCl or light) (1)

(ii) curly arrow from C=C to Br (1)
another one breaking Br-Br bond. (1)
correct intermediate cation and Br^- produced (not $Br^{\delta-}$) (1) **[max 3]**

(b) **B** is $NH_2CH_2CH_2NH_2$ (1)
C is $NCCH_2CH_2CN$ (1)
E is $ClCOCH_2CH_2COCl$ (1) **[3]**
(Allow $(CH_2)_2$ or C_2H_4. Allow correct atoms in any order on LHS but order must be correct on RHS)

(c) reaction II: heat, dilute $H^+(aq)$ or HCl(aq) or HCl(conc) or $H_2SO_4(aq)$ (1)
reaction III: H_2 + Ni (or other named catalyst) or $LiAlH_4$ or Na in ethanol (1) **[2]**

(d) NH_4^+ (1) **[1]**

(e) (i) [-NHCH$_2$CH$_2$CH$_2$CH$_2$NH-COCH$_2$CH$_2$CO-] (1)
(allow $(CH_2)_4$ and $(CH_2)_2$)
(**not** dimer, needs bonds both ends)

(ii) HCl (1) **[2]**

(f) (i) $[H^+] = 10^{-pH} = 10^{-2.6} = 2.51 \times 10^{-3}$ (mol dm^{-3}) (1)

(ii) $Ka = [H^+]^2/c = 6.31 \times 10^{-5}$ (mol dm^{-3}) (allow ecf from **(i)**) (1) **[2]**

[Total: 13]

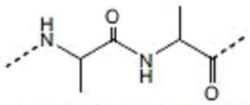
Q13.

3 (a) (i) **E** is $CH_3CH(NH_2)CN$ [1]

(ii) $C_6H_5CH_2CHO$ [1]
[2]

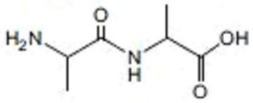
(b) (i) a polymer/polypeptide of amino acids, (joined by peptide bonds)
(allow '**chain** of amino acids' but not 'sequence': the idea of 'many' has to be conveyed)
[1]

(ii)



peptide bond shown in full (C=O) in an ala-ala fragment in a chain [1]
two repeat units [1]

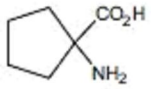
Allow peptide bond shown in full (C=O) in a dipeptide ala-ala for 1 mark



[3]

(c) (i) HC*l* *or* H_2SO_4 *or* NaOH *or* H^+ *or* OH^- reagents [1]
+ heat and H_2O/aq (allow H_3O^+).
If T is quoted, 80 °C < T < 120 °C. NOT warm. conditions [1]

(ii)



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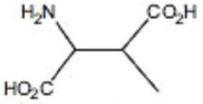
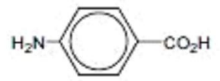
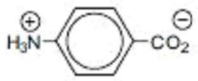
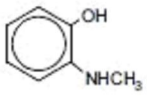
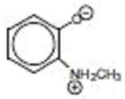
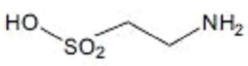
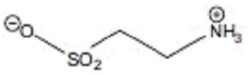


(if a structural formula, it must have all H atoms) allow protonated or deprotonated versions [1] + [1]
[max 3]

(d) (i) $NH_3^+–CH(CH_3)–CO_2^-$ [1]

(ii)

compound	zwitterion
	
	
	

[3]
[4]

(e) (i) A buffer is a solution whose pH stays **fairly** constant *or* which maintains **roughly** the same pH *or* which resists/minimises changes in pH [1]
when **small/moderate** amounts of acid/H^+ or alkali/OH^- are added [1]

(ii) $NH_2CH(CH_3)CO_2H + H(Cl) \longrightarrow {}^+NH_3CH(CH_3)CO_2H\ (+ Cl^-)$ [1]

(iii) blood contain $\mathbf{HCO_3^-}$ (*or* in an equation) [1]
which absorbs H^+ *or* equn $H^+ + HCO_3^- \longrightarrow H_2CO_3\ (H_2O + CO_2)$
or absorbs OH^- *or* equn $OH^- + HCO_3^- \longrightarrow CO_3^{2-} + H_2O$ [1]

(iv) $[CH_3CO_2Na] = 0.05\ [CH_3CO_2H] = 0.075$ [1]
pH = 4.76 + log (0.05/0.075) = **4.58** *or* **4.6** [1]
[7]

[Total: 19]

Q14.

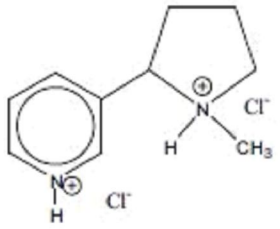
5 (a) (i) contains a lone pair on N (that can react with H^+) [1]

(ii) e.g. $C_2H_5NH_2 + H(Cl) \longrightarrow C_2H_5NH_3^+\ (Cl^-)$ [1]
or $C_2H_5NH_2 + H_3O^+ \longrightarrow C_2H_5NH_3^+ + H_2O$
or $C_2H_5NH_2 + H_2O \longrightarrow C_2H_5NH_3^+ + OH^-$ etc

e.g. $C_2H_5NH_2 + CH_3Br \longrightarrow C_2H_5NHCH_3 + HBr$
or $C_2H_5NH_2 + CH_3COCl \longrightarrow CH_3CONHC_2H_5 + HCl$ [1]

(iii) the lone pair (on N) in phenylamine overlaps with ring **or** is delocalised [1]
electron density of N is reduced **or** N becomes more positive **or** lone pair is less available [1]

(iv)

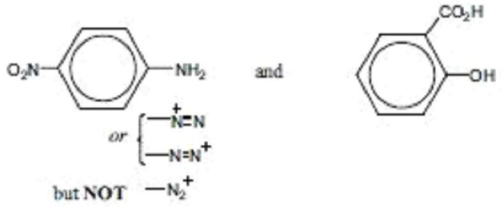


[1] + [1]

[7 max 6]

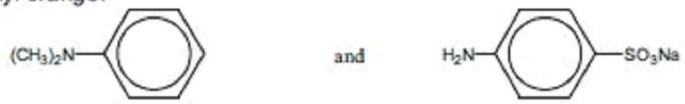
(b) (i) $NaNO_2$ + HCl/H^+ **or** HNO_2 (HNO_3 or NO_3^- negates this mark) [1]
$-10\,°C < T \leq 10\,°C$ *or* 'less than 10 °C' [1]

(ii) alizarin yellow R:



[1] + [1]

methyl orange:



(NH_2 alternatives as above)

[1] + [1]

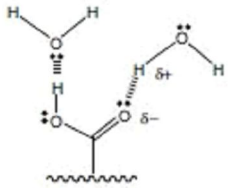
(iii) makes the molecule (more) hydrophilic/soluble in water (due to H-bonding or ionic solvation)
or increases its melting point [1]

[Total: 7]

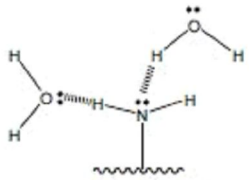
Q15.

6 **(a)** A (Bronsted-Lowry) acid is a proton donor. [1]
[1]

(b) **(i)**

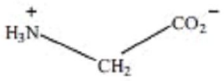


carboxylic acid


amino group

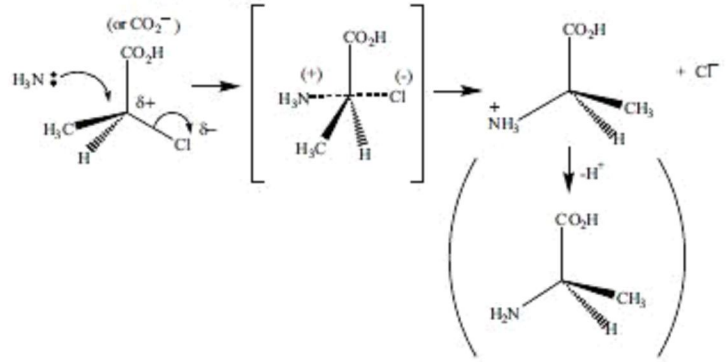
at least one H_2O molecule in the right orientation: attached to $–CO_2H$ [1]
attached to $–NH_2$ [1]
lone pair (on oxygen in H_2O *or* $–CO_2H$ *or* on nitrogen) shown at least once on a H-bond [1]
δ+ and δ– shown at least once (at each end of the same H-bond) [1]

(ii)



[1]
[5]

(c) allow either S_N1 or S_N2



any three of δ+ and δ– shown in C–C*l*
curly arrow from **lone pair on NH_3** to (δ+) carbon
curly arrow from C–C*l* bond to C*l*
5-coordinate transition state *or* carbocation intermediate if S_N1, with correct charge

[3]
[3]

(d) lysine @ pH 1: $^{+}NH_3(CH_2)_4CH(NH_3^{+})CO_2H$ [1]
aspartic acid @ pH 12: $^{-}O_2CCH_2CH(NH_2)CO_2^{-}$ [1]
[2]

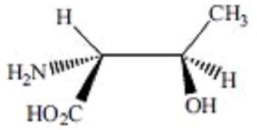
(e) **(i)** 6 (six) [1]

(ii) *either* $H_2NCH(CH_3)CO–NHCH(CH_2OH)CO_2H$
or $H_2NCH(CH_2OH)CO–NHCH(CH_3)CO_2H$ [2]
[3]

(f) **(i)** Compounds have the same **structural** formula but ....
different (spatial) arrangement / position *or* orientation of atoms in space [1]

(ii) **J** [1]

(iii)



[1]
[3]

[Total: 17]