Q1.

Endomorphin-2 is a peptide with the amino acid sequence shown.

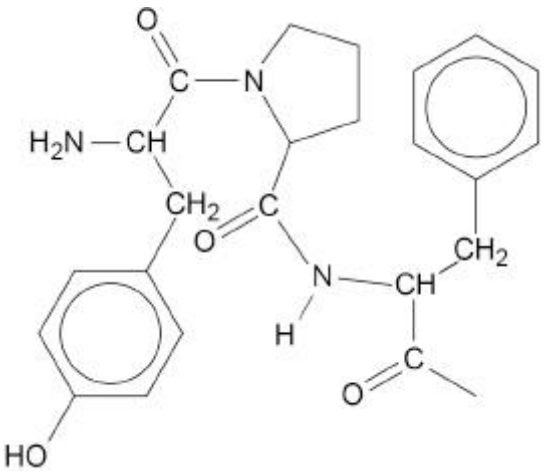
Tyr–Pro–Phe–Phe–NH_2

Each amino acid is represented by a three-letter abbreviation.

Tyr = tyrosine Pro = proline Phe = phenylalanine

Figure 1 shows part of the structure of endomorphin-2, showing the Tyr–Pro–Phe– part of the molecule.

Figure 1



(a) The –NH_2 at the end of the amino acid sequence of endomorphin-2 shows that the terminal functional group is an amide, not an acid.

Complete the structure of endomorphin-2 in **Figure 1**.

(2)

(b) Use the structure in **Figure 1** to draw the skeletal formula of proline, Pro.

(1)

A student hydrolyses a sample of endomorphin-2 to break it down into its constituent amino acids.

The student analyses the resulting mixture by thin-layer chromatography, TLC.

(c) State a reagent and the conditions needed for the hydrolysis.

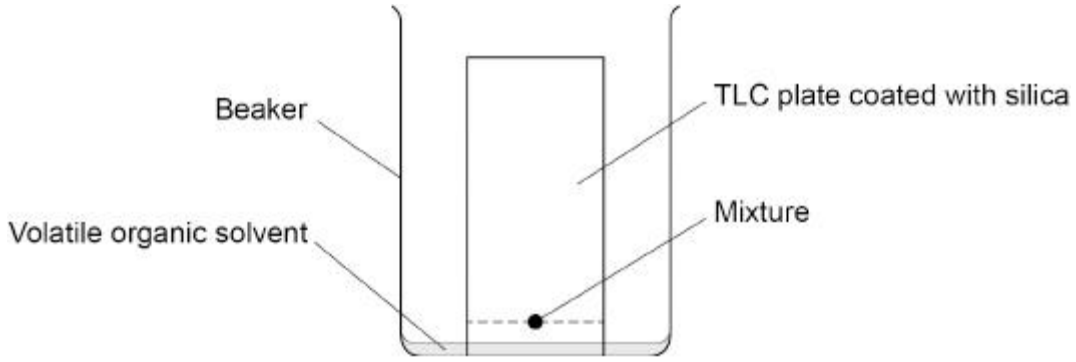
Reagent _____

Conditions _____

(2)

(d) **Figure 2** shows the apparatus used for the TLC.

Figure 2



There is a piece of the apparatus missing from **Figure 2**. This omission will result in an inaccurate chromatogram.

Identify the missing piece of the apparatus.

State and explain why this piece of the apparatus is needed.

Missing piece _____

Explanation _____

_____

_____

_____

(3)

(e) State why the amino acids separate on the TLC plate.

_____

_____

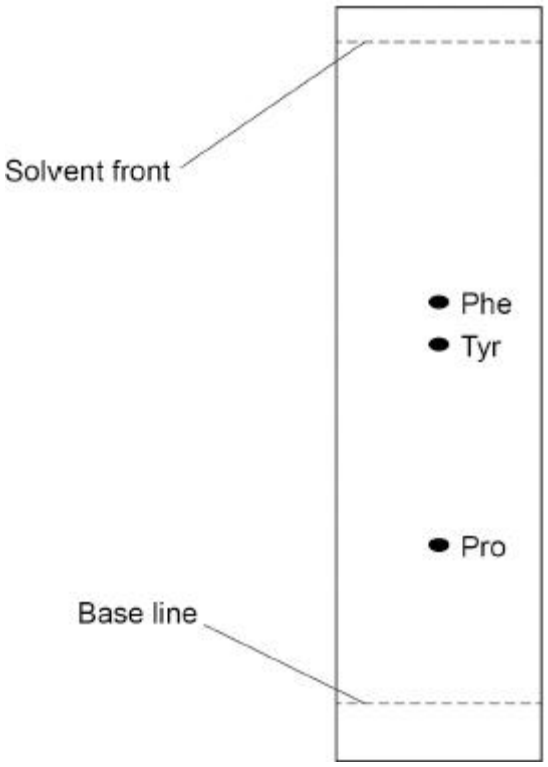
_____

(1)

When the solvent has risen up the TLC plate, the student removes the plate from the beaker and sprays it with a developing agent.

Figure 3 shows the result.

Figure 3



(f) Name a suitable developing agent.

State why the developing agent is needed.

Name _____

Why needed _____

_____

_____

(2)

(g) Determine the R_f value for Tyr.

R_f _____

(1)

(Total 12 marks)

Q2.

Proteins are polymers made from amino acids.
Part of the structure of a protein is shown.

–Cys–Ser–Asp–Phe–

Each amino acid in the protein is shown using the first three letters of its name.

(a) Identify the type of protein structure shown.

Tick (✓) **one** box.

Primary ☐

Secondary ☐

Tertiary ☐

(1)

(b) Draw a structure for the –Cys–Ser– section of the protein.
Use the Data Booklet to help you answer this question.

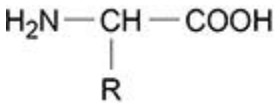
(2)

(c) Name the other substance formed when two amino acids react together to form part of a protein chain.

_____

(1)

The general structure of an amino acid is shown.



R represents a group that varies between different amino acids.
R groups can interact and contribute to protein structure.

(d) Explain why the strength of the interaction between two cysteine R groups differs from the strength of the interaction between a serine R group and an aspartic acid R group.

Use the Data Booklet to help you answer this question.

_____

(4)

(e) Deduce the type of interaction that occurs between a lysine R group and an aspartic acid R group.

(1)

(Total 9 marks)

Q3.

Which type of interaction between polypeptide chains is mainly responsible for maintaining the secondary structure of a protein in the form of an alpha helix?

A covalent bonds ⬭

B hydrogen bonds ⬭

C ionic interactions ⬭

D van der Waals forces ⬭

(Total 1 mark)

Q4.

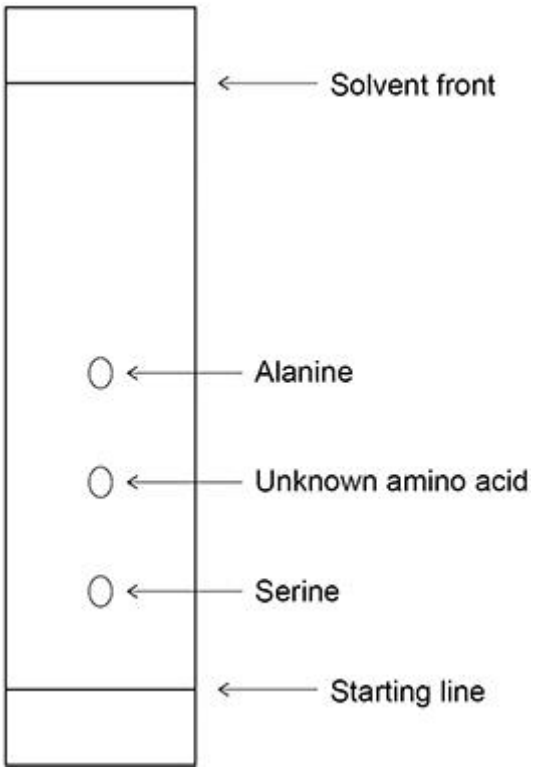
The protein fibroin can be broken down into amino acids using an enzyme.

(a) A student uses thin-layer chromatography (TLC) to identify these amino acids.

The student identifies two of the amino acids as alanine and serine.

Use the figure below to calculate the R_f value of the unknown amino acid. Show your working.

Use your R_f value and the table below to identify the unknown amino acid.



Amino acid	R_f value
tyrosine	0.25
glycine	0.34
valine	0.64
leucine	0.73

Rf value _____

Identity _____

(2)

(b) The amino acids cannot be seen as they move during the experiment.

State how the amino acids can be made visible at the end of the experiment.

_____

_____

(1)

(c) State why each amino acid has a different R_f value.

_____

_____

_____

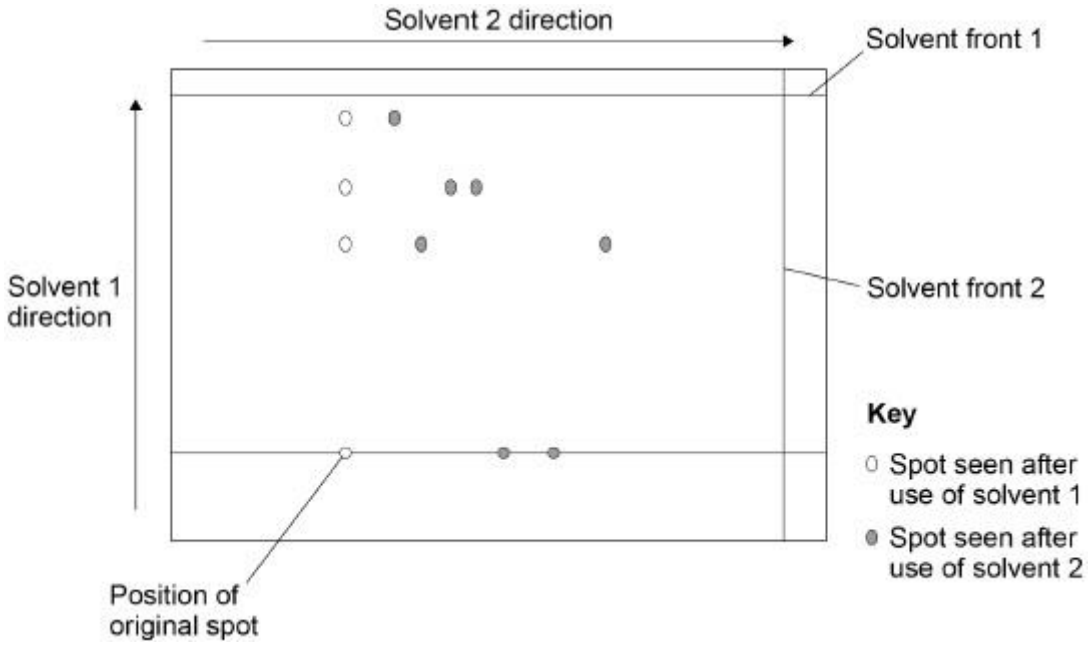
(1)

(Total 4 marks)

Q5.

This question is about thin-layer chromatography (TLC).

- A protein was hydrolysed to form a mixture of amino acids.
- A spot of this mixture was added to a TLC plate and the plate placed vertically in a small volume of solvent 1.
- When the solvent front reached nearly to the top of the plate, the plate was removed and allowed to dry.
- The plate was turned anticlockwise through 90° and placed vertically in a small volume of solvent 2.
- When the solvent front reached nearly to the top of the plate, the plate was again removed and allowed to dry.
- The diagram shows the final TLC plate.



(a) Suggest a suitable reagent for the hydrolysis of a protein.

_____

_____

(1)

(b) Suggest how the positions of the amino acids on the TLC plate were located.

_____

_____

(1)

(c) Deduce the minimum number of amino acids present in the original mixture.

_____

_____

(1)

(d) Suggest why it was necessary to use two different solvents.

_____

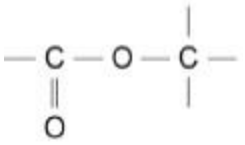
_____

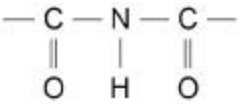
(1)

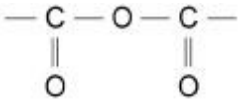
(Total 4 marks)

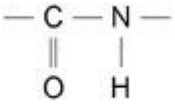
Q6.

Which structure shows part of a peptide link in a protein?

A 

B 

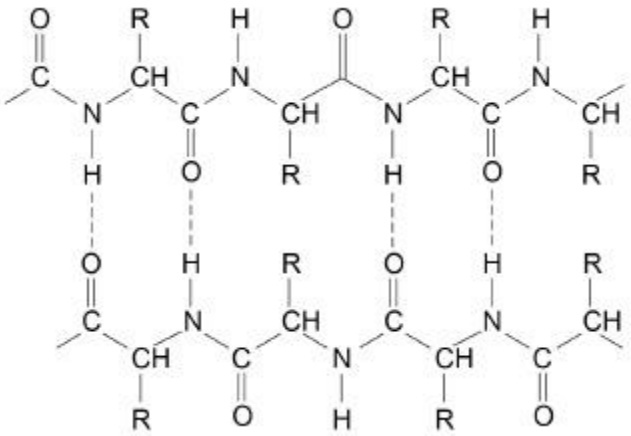
C 

D 

(Total 1 mark)

Q7.

Use the Data Booklet to help you answer this question about amino acids.
The diagram shows parts of two polypeptide chains in a beta-pleated sheet of a protein.



(a) The polypeptide chains are held together by hydrogen bonding as shown in the diagram.

Explain how these hydrogen bonds form.

_____

_____

_____

_____

_____

(2)

(b) A different type of bond can form between two polypeptide chains when the chains each contain the amino acid cysteine.

Complete the structure to show the bond that forms between the side chains of two cysteine molecules.

(1)

(c) The type of bond in **part (b)** between two polypeptide chains influences the three-dimensional structure of the protein.

Name this type of protein structure.

_____

(1)

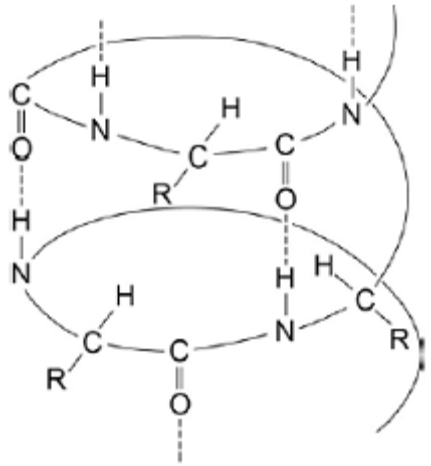
(d) Draw the structure of the zwitterion of a dipeptide formed by alanine and serine.

(2)

(Total 6 marks)

Q8.

The following figure shows a simplified representation of the arrangement of some amino acids in a portion of a protein structure in the form of an α-helix.



(a) Name the type of protein structure in the figure.

_____

(1)

(b) Explain the origin of the interaction represented by the dotted lines in the figure above.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

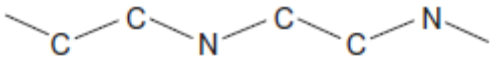
(Total 5 marks)

Q9.

Proteins contain sequences of amino acids joined by peptide links.
Amino acid chains (polypeptides) are attracted to each other by hydrogen bonding.

(a) (i) A section of a protein is formed from one molecule of each of the amino acids glycine (H_2NCH_2COOH) and alanine ($H_2NCH(CH_3)COOH$).

Add bonds and atoms to the diagram to complete a structural formula for this section of the protein.

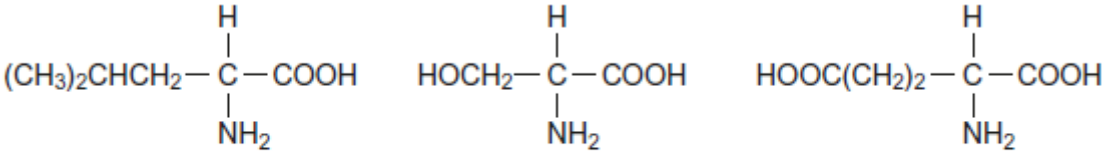


(2)

(ii) Draw a diagram to show how an amino acid chain can form a hydrogen bond with another amino acid chain.
Your diagram need only show the relevant atoms from one amino acid in each chain.

(1)

(b) Leucine, serine and glutamic acid are naturally-occurring amino acids.



leucine serine glutamic acid

(i) Give the IUPAC name of leucine.

_____

(1)

(ii) Draw the structure of the zwitterion of serine.

(1)

(iii) Draw the structure of the ester formed by two molecules of serine.

(1)

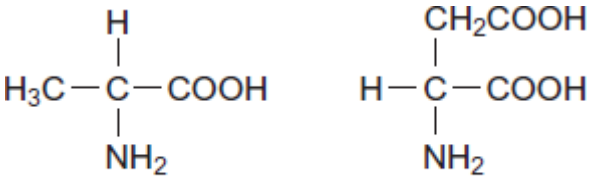
(iv) Draw the structure of the species formed by glutamic acid at low pH.

(1)

(Total 7 marks)

Q10.

Alanine and aspartic acid are naturally occurring amino acids.



alanine aspartic acid

(a) Draw the structure of the zwitterion formed by alanine.

(1)

(b) Draw the structure of the compound formed when alanine reacts with methanol in the presence of a small amount of concentrated sulfuric acid.

(1)

(c) Draw the structure of the species formed by aspartic acid at high pH.

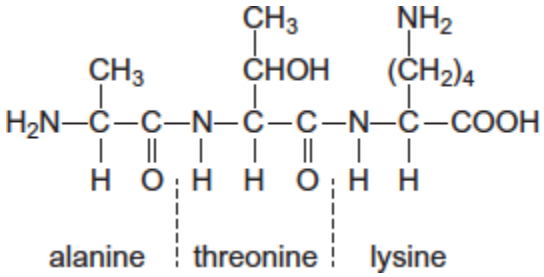
(1)

(d) Draw the structure of a dipeptide formed by two aspartic acid molecules.

(1)
(Total 4 marks)

Q11.

(a) The tripeptide shown is formed from the amino acids alanine, threonine and lysine.



(i) Draw a separate circle around **each** of the asymmetric carbon atoms in the tripeptide.

(1)

(ii) Draw the zwitterion of alanine.

(1)

(iii) Give the IUPAC name of threonine.

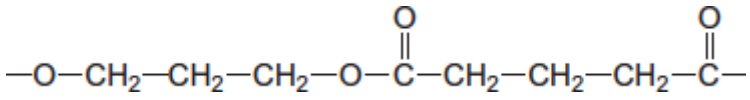
_____

(1)

(iv) Draw the species formed by lysine at low pH.

(1)

(b) The repeating unit shown represents a polyester.



(i) Name this type of polymer.

_____

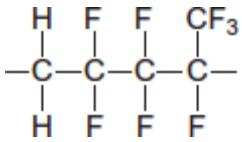
(1)

(ii) Give the IUPAC name for the alcohol used to prepare this polyester.

_____

(1)

(c) The repeating unit shown represents a polyalkene co-polymer. This co-polymer is made from two different alkene monomers.



(i) Name the type of polymerisation occurring in the formation of this co-polymer.

_____

(1)

(ii) Draw the structure of each alkene monomer.

Alkene monomer 1 Alkene monomer 2

(2)

(d) One of the three compounds shown in parts (a), (b) and (c) cannot be broken down by hydrolysis.

Write the letter **(a)**, **(b)** or **(c)** to identify this compound and explain why hydrolysis of this compound does **not** occur.

Compound _____

Explanation _____

_____

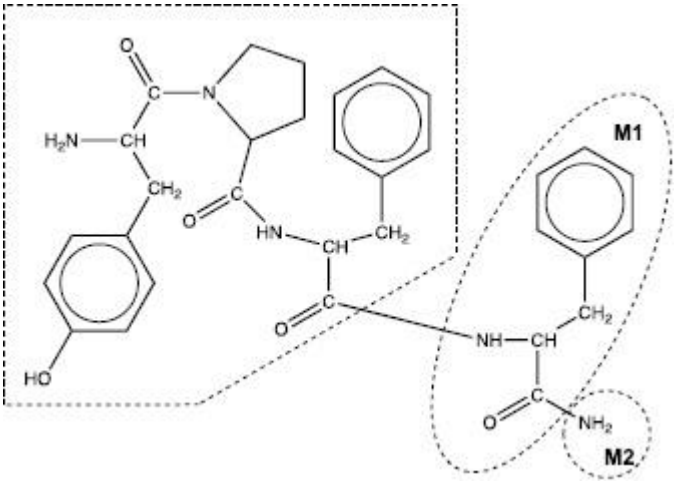
_____

(2)
(Total 11 marks)

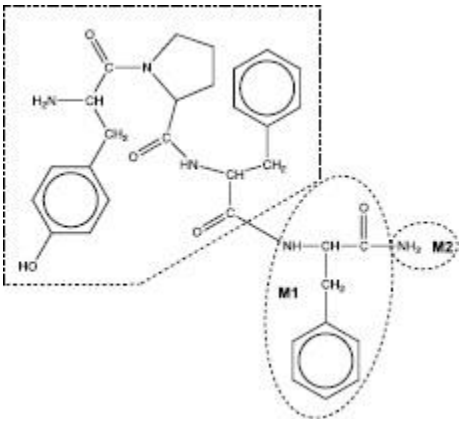
Mark Scheme

Q1.

(a)



Alternative form

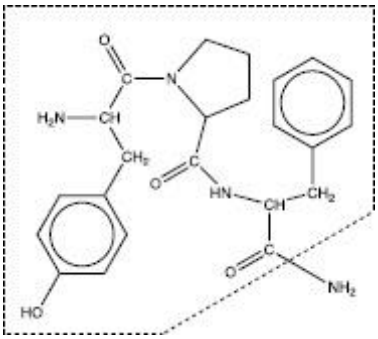


M1 Phe structure drawn with correct peptide link

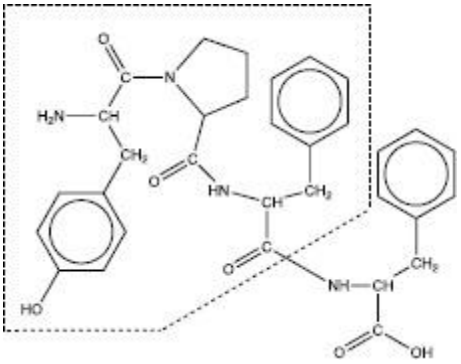
M2 amide group shown on end

M1 *if Phe drawn with COOH or* $CONH_2$

M2 ALLOW *if no Phe drawn i.e. if* NH_2 *only attached directly to C=O on diagram*



*Scores **M2** for ending in amide group*

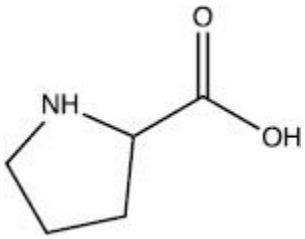


*Scores **M1** for Phe group*

***M1** H needed on N of peptide link drawn unless C-CH-CH_2 drawn skeletal*

2

(b)



***ALLOW** zwitterion*

***ALLOW** -NH_2^+ and/or COO^-*

***ALLOW** with C shown in COOH group*

***ALLOW** without H on N*

***ALLOW** N-H*

***NOT** N-*

1

(c) **M1** (aqueous) HCl/hydrochloric acid

Name or formula of any strong acid or alkali

M2 reflux/heat

***ALLOW** warm / hot / high temperature for heat*

***NOT** T>200°C*

***IGNORE** conc as condition with acid/alkali*

***IGNORE** pressure*

Alternative

***M1** protease/(poly)peptidase/peptase/named protease*

***IGNORE** enzyme*

***M2** warm*

***NOT** hot / high temperature / T>50°C*

2

(d) **M1** lid/cover (on beaker)

Then any 2 from these 3

- prevents escape of vapour (from beaker) / evaporation of solvent (from beaker)

- so atmosphere in beaker is saturated with solvent vapour owtte
- to reduce evaporation from the plate

ALLOW *(for bullet point 3) so solvent can rise up plate*

ALLOW *(for bullet point 3) to avoid plate drying out*

3

(e) Difference in the balance between solubility in solvent/mobile phase and attraction to/retention on stationary phase

ALLOW *difference between (relative) affinity/attraction for solvent and stationary phase*

ALLOW *absorption/adsorption for retention on stationary phase*

1

(f) **M1** ninhydrin

M2 amino acids are colourless / to make the amino acids visible

ALLOW *iodine*

IGNORE *UV*

IGNORE *stated final colour e.g. "turns the amino acids purple" is not enough on its own*

IGNORE *clear*

2

(g) 0.54

ALLOW *0.53 - 0.55 (to min two sig figs)*

1

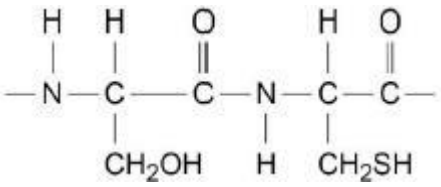
[12]

Q2.

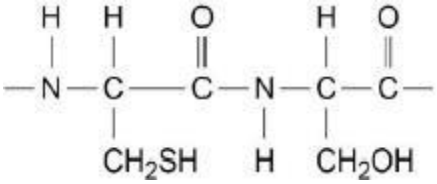
(a) Primary

1

(b)



OR



M1 for correct peptide link (Allow -CONH- as a minimum)

M1

M2 for the correct amino acid R groups

Dipeptide can only score M1

M2

Trailing bonds ***not*** *needed*

(c) Water

Allow H_2O

1

(d) Two Cys R groups form a disulfide bridge/link stated or described

Could score via a correct diagram showing min -SS-

M1

Ser and Asp R groups form Hydrogen bonds

Allow H bonds

M2

Disulfide bridges are stronger than H bonds

Interactions between cys R groups are stronger

M3

Because disulfide bridges are covalent bonds (while H bonds aren't)

Because covalent bonds are stronger (than H bonds)

M4

(e) Ionic bond

1

[9]

Q3.

B

hydrogen bonds

[1]

Q4.

(a) **M1** $\frac{27}{80} = 0.34$

1

M2 glycine

***M1** some relevant working is needed to arrive at 0.325 - 0.35*

*no ECF based on **M1***

1

(b) use uv lamp or ninhydrin

***allow** developing / locating agent / iodine*

1

(c) each amino acid has different (relative) affinity/attraction to/solubility in stationary and mobile phases

***allow** reference to different solubility in solvent OR different affinity for stationary phase*

1

[4]

Q5.

(a) Conc HCl

Allow concentrations of 5M or higher
Allow conc sulfuric or conc strong alkalis

1

(b) Using ninhydrin or ultraviolet light
Allow I_2 (vapour)

1

(c) 7 or seven

1

(d) Some of the amino acids did not separate/dissolve with the first/either solvent

OR

Some amino acids have the same Rf value or have the same affinity with the first/either solvent
Not amino acids have different Rf values in different solvents

1

[4]

Q6.

D

[1]

Q7.

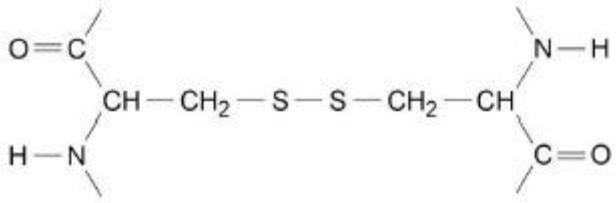
(a) electron deficient H
Allow H delta plus / slightly positive

M1

(Which attracts) lone pair/electron pair on O
Penalise lone pair/electron pair donation

M2

(b)



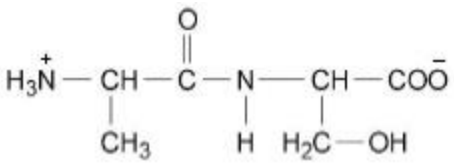
Penalise dashed/dotted S—S
Ignore extra additions to structures

1

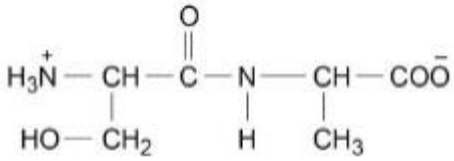
(c) Tertiary or Quaternary
Allow 3° or 4°
do not penalise minor error in spelling e.g. Quarternary

1

(d)



OR



Incorrect peptide bond CE=0
M1 for correct dipeptide
M2 for correct charges
Ignore additional dipeptide in working
Allow –CONH— or –COHN—

1
1

[6]

Q8.

(a) Secondary

1

(b) Nitrogen and oxygen are very electronegative

1

Therefore, C=O and N–H are polar

1

Which results in the formation of a hydrogen bond between O and H

1

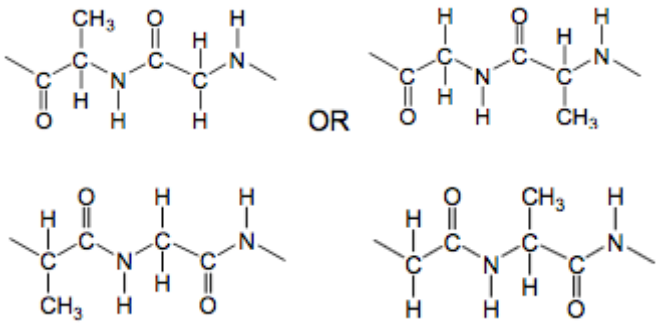
In which a lone pair of electrons on an oxygen atom is strongly attracted to the δ+H

1

[5]

Q9.

(a) (i)



Only one molecule of each used
M1 for 2 amide links

M2 CH_2 and $CH(CH_3)$

Allow 1 mark after one error

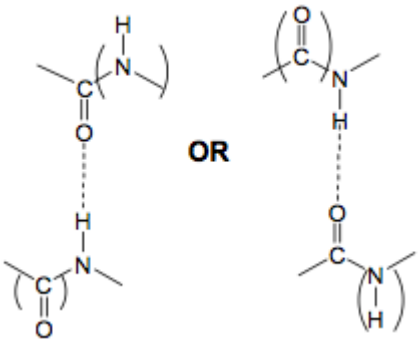
Dipeptide max 1

Treat both trailing bonds missing as one error

Ignore n

2

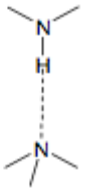
(ii)



No need to show lp

The covalent bond and the hydrogen bond either side of the H must be linear.

Allow



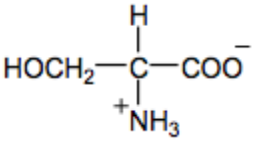
1

(b) (i) 2-amino-4-methylpentan(-1-)oic acid

Ignore hyphens, commas, spaces

1

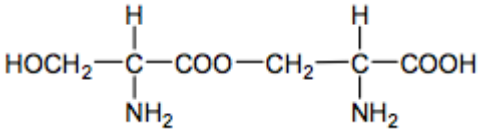
(ii)



Allow $-NH_3^+$

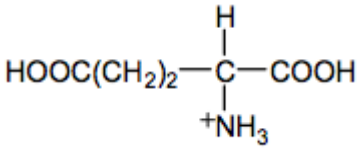
1

(iii)



1

(iv)



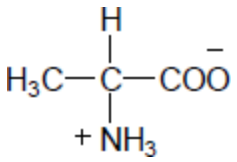
Allow $-NH_3^+$

1

[7]

Q10.

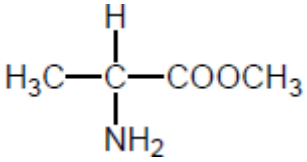
(a)



Allow $-NH_3^+$ and $^+NH_3-$

1

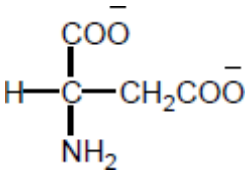
(b)



Allow protonated form, i.e. $-NH_3^+$ or $^+NH_3-$

1

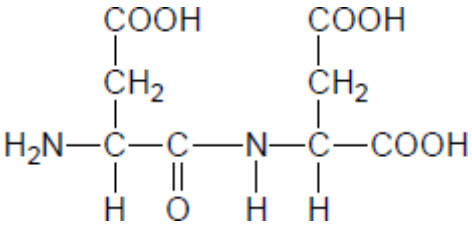
(c)



Allow – CO_2^-

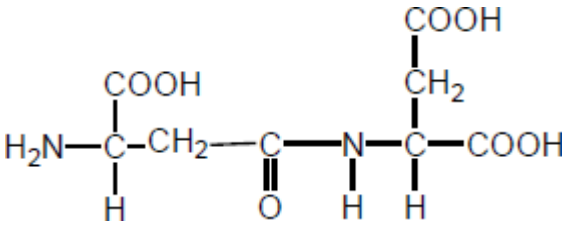
1

(d)



Allow zwitterion with any COO^-

Allow use of "wrong" COOH

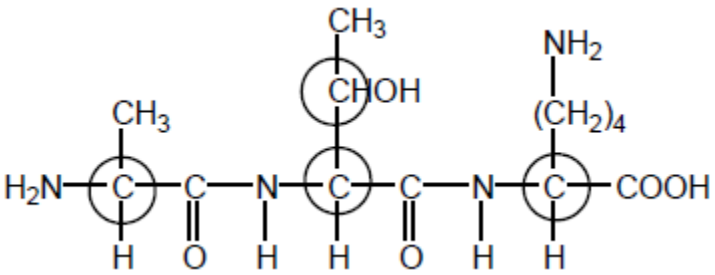


1

[4]

Q11.

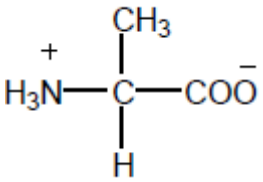
(a) (i)



These four only

1

(ii)



Allow − NH_3^+ and $^+NH_3^-$

1

(iii) <u>2-amino-3-hydroxybutanoic acid</u>

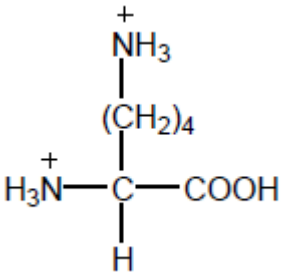
Ignore 1 in butan-1-oic acid

Do not penalise commas or missing hyphens

Penalise other numbers

1

(iv)



Allow –NH_3^+ and $^+NH_3^-$

1

(b) (i) Condensation

Allow polyester

1

(ii) <u>propan**e**-1,3-diol</u>

Must have e

*Allow 1,3-propan**e**diol*

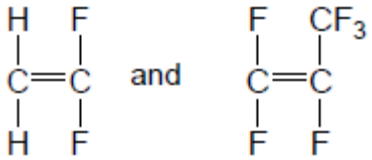
1

(c) (i) Addition

Not additional

1

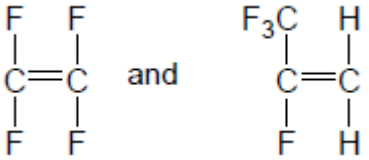
(ii)



Allow monomers drawn either way round
Allow bond to F in CF_3

1

OR



1 for each structure within each pair

1

(d) c

If wrong, CE = 0

1

C-C or C-F bonds too strong

1

[11]