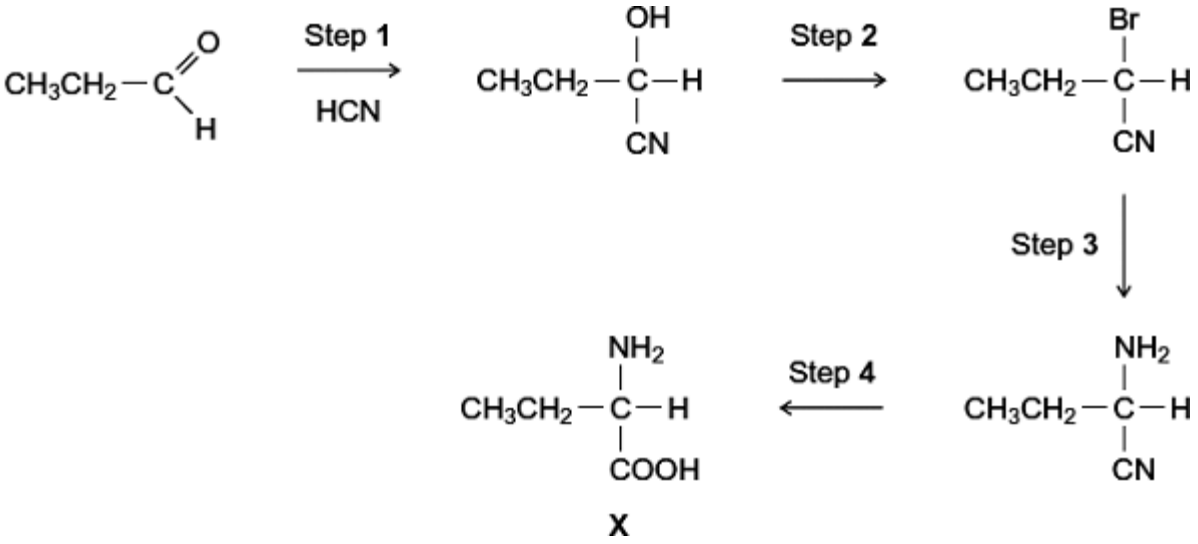
Q12.

A possible synthesis of the amino acid **X** is shown below.



(a) Name and outline a mechanism for Step **1**.

Name of mechanism _____

Mechanism

(5)

(b) Give the IUPAC name of the product of Step **2**.

_____

(1)

(c) For Step **3**, give the reagent, give a necessary condition and name the mechanism.

Reagent _____

Condition _____

Name of mechanism _____

(3)

(d) At room temperature, the amino acid **X** exists as a solid.

(i) Draw the structure of the species present in the solid amino acid.

(1)

(ii) With reference to your answer to part (d)(i), explain why the melting point of the amino acid **X** is higher than the melting point of $CH_3CH_2CH(OH)COOH$.

_____

_____

_____

_____

_____

(2)

(e) There are many structural isomers of **X**, $CH_3CH_2CH(NH_2)COOH$.

(i) Draw a structural isomer of **X** that is an ethyl ester.

(1)

(ii) Draw a structural isomer of **X** that is an amide and also a tertiary alcohol.

(1)

(iii) Draw a structural isomer of **X** that has an unbranched carbon chain and can be polymerised to form a polyamide.

(1)

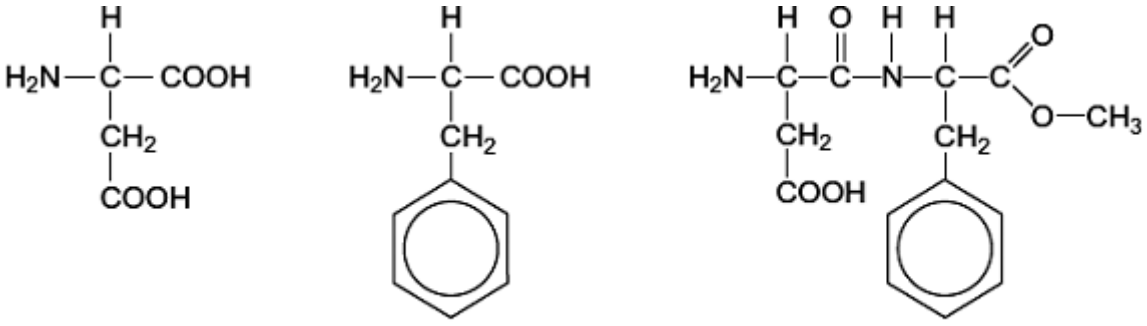
(f) Draw the structure of the tertiary amine formed when **X** reacts with bromomethane.

(1)

(Total 16 marks)

Q13.

The amino acids aspartic acid and phenylalanine react together to form a dipeptide.
This dipeptide can be converted into a methyl ester called aspartame.



aspartic acid

phenylalanine

aspartame

Aspartame has a sweet taste and is used in soft drinks and in sugar-free foods for people with diabetes.

Hydrolysis of aspartame forms methanol initially. After a longer time the peptide link breaks to form the free amino acids. Neither of these amino acids tastes sweet.

(a) Apart from the release of methanol, suggest why aspartame is **not** used to sweeten foods that are to be cooked.

_____

_____

(1)

(b) Give the IUPAC name of aspartic acid.

_____

(1)

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

(1)

(d) Draw the zwitterion of phenylalanine.

(1)

(e) Phenylalanine exists as a pair of stereoisomers.

(i) State the meaning of the term *stereoisomers*.

_____

_____

_____

_____

(2)

(ii) Explain how a pair of stereoisomers can be distinguished.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q14.

The amide or peptide link is found in synthetic polyamides and also in naturally occurring proteins.

(a) (i) Draw the repeating unit of the polyamide formed by the reaction of propanedioic acid with hexane-1,6-diamine.

(2)

(ii) In terms of the intermolecular forces between the polymer chains, explain why polyamides can be made into fibres suitable for use in sewing and weaving, whereas polyalkenes usually produce fibres that are too weak for this purpose.

_____

_____

_____

_____

_____

_____

(3)

(b) (i) Name and outline a mechanism for the reaction of CH_3CH_2COCl with CH_3NH_2

Name of mechanism _____

Mechanism

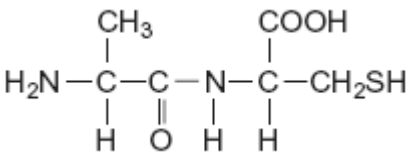
(5)

(ii) Give the name of the product containing an amide linkage that is formed in the reaction in part (b) (i).

_____

(1)

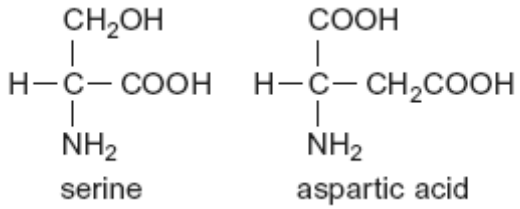
(c) The dipeptide shown below is formed from two different amino acids.



Draw the structure of the alternative dipeptide that could be formed by these two amino acids.

(1)

(d) The amino acids serine and aspartic acid are shown below.



(i) Give the IUPAC name of serine.

_____

(1)

(ii) Draw the structure of the species formed when aspartic acid reacts with aqueous sodium hydroxide.

(1)

(iii) Draw the structure of the species formed when serine reacts with dilute hydrochloric acid.

(1)

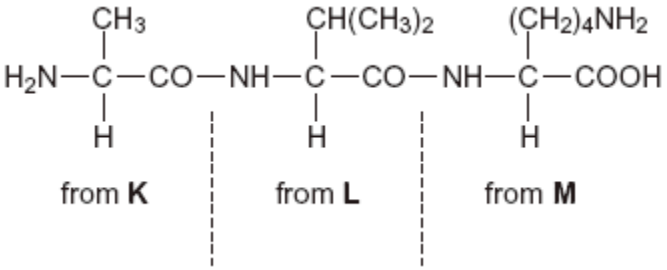
(iv) Draw the structure of the species formed when serine reacts with an excess of bromomethane.

(1)

(Total 16 marks)

Q15.

(a) Consider the tripeptide shown below that is formed from three amino acids, **K**, **L** and **M**.



(i) Name the process by which the tripeptide is split into three amino acids.

_____

(1)

(ii) Give the IUPAC name for the amino acid **K**.

_____

(1)

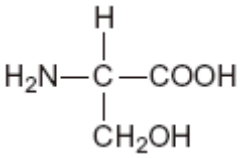
(iii) Draw the structure of the zwitterion of amino acid **L**.

(1)

(iv) Draw the structure of the species formed by amino acid **M** at low pH.

(1)

(b) Consider the amino acid serine.



(i) Draw the structure of the product formed when serine reacts with an excess of CH_3Br

(1)

(ii) Draw the structure of the dipeptide formed by two molecules of serine.

(1)

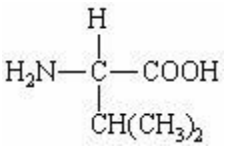
(Total 6 marks)

Q16.

Fibres are made from natural and from synthetic polymers. Both types of polymer have advantages and disadvantages.

(a) Amino acids are the building blocks of naturally-occurring polymers called proteins.

Consider the following amino acid.



(i) Draw the structure of the amino acid species present in a solution at pH 12.

(ii) Use your understanding of amino acid chemistry to deduce the structure of the dipeptide formed from two molecules of this amino acid and illustrate your answer with a sketch showing the structure of the dipeptide.

(iii) Protein chains are often arranged in the shape of a helix. Name the type of interaction that is responsible for holding the protein chain in this shape.

_____

(3)

(b) Alkenes are the building blocks of synthetic addition polymers.

Consider the hydrocarbon **G**, $(CH_3)_2C=CHCH_3$, which can be polymerised.

(i) Draw the repeating unit of the polymer.

(ii) Draw the structure of an isomer of **G** which shows *E-Z* isomerism.

(iii) Draw the structure of an isomer of **G** which does not react with bromine water.

(3)

(c) Draw the repeating unit of the polymer formed by the reaction between butanedioic acid and hexane-1,6-diamine.

(2)

(d) Two plastic objects were manufactured, one from the polyalkene represented by the repeating unit in part (b)(i) and the other from the polyamide represented by the repeating unit in part (c).

After use it was suggested that both objects be disposed of as landfill.

(i) Describe an experiment in which you could compare the biodegradability of these two objects.

(3)

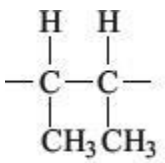
(ii) Describe an advantage or a disadvantage of a different method of disposal of such objects compared with landfill.

(3)

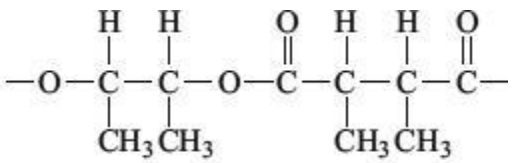
(Total 14 marks)

Q17.

(a) The repeating units of two polymers, **P** and **Q**, are shown below.



P



Q

(i) Draw the structure of the monomer used to form polymer **P**. Name the type of polymerisation involved.

Structure of monomer

Type of polymerisation _____

(ii) Draw the structures of **two** compounds which react together to form polymer **Q**. Name these **two** compounds and name the type of polymerisation involved.

Structure of compound 1

Name of compound 1 _____

Structure of compound 2

Name of compound 2 _____

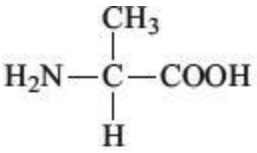
Type of polymerisation _____

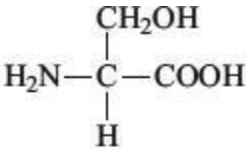
(iii) Identify a compound which, in aqueous solution, will break down polymer **Q** but not polymer **P**.

_____

(8)

(b) Draw the structures of the **two** dipeptides which can form when one of the amino acids shown below reacts with the other.





Structure 1 *Structure 2*

(2)

(c) Propylamine, $CH_3CH_2CH_2NH_2$, can be formed either by nucleophilic substitution or by reduction.

(i) Draw the structure of a compound which can undergo nucleophilic substitution to form propylamine.

(ii) Draw the structure of the nitrile which can be reduced to form propylamine.

(iii) State and explain which of the two routes to propylamine, by nucleophilic substitution or by reduction, gives the less pure product. Draw the structure of a compound formed as an impurity.

Route giving the less pure product _____

Explanation _____

_____

Structure of an impurity

(5)

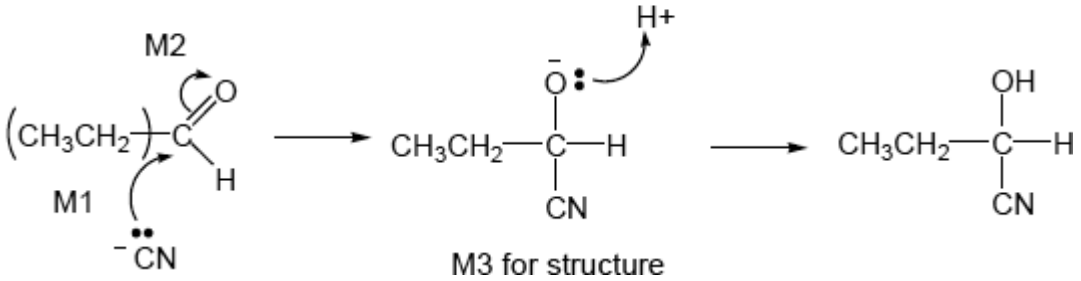
(Total 15 marks)

Mark Scheme

Q12.

(a) nucleophilic addition

M4 for lp and arrow to H^+



M3 for structure

- *allow :CN–*
- *M2 not allowed independent of M1, but*
- *allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2*
- *M3 is for correct structure including minus sign but lone pair is part of M4*
- *Allow C_{2H5}*
- *M1 and M4 for lp and curly arrow*

1

(b) *2-bromobutanenitrile*

Allow 2-bromobutane-1-nitrile

1

(c) ***M1*** *ammonia or NH_3*

Ignore temp or pressure

1

M2 *excess (ammonia)* *excess tied to NH_3 and may score in M1 unless contradicted*

Ignore concentrated or sealed container, Acid loses conditions mark

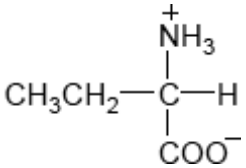
1

M3 *nucleophilic substitution*

Allow close spelling

1

(d) *(i)*



Allow C_2H_5

Allow $–CO_2^-$

Allow $^+NH_3–$

Don't penalize position of + on NH_3

1

(ii) ***M1*** *electrostatic forces between ions in **X*** ***QOL***

Allow ionic bonding.

1

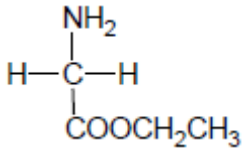
Marks independent

M2 *(stronger than) hydrogen bonding between $CH_3CH_2CH(OH)COOH$*

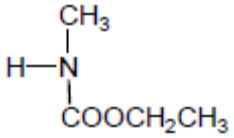
CE *mention of molecules of **X** or inter molecular forces between **X** loses both marks*

1

(e) (i)



OR

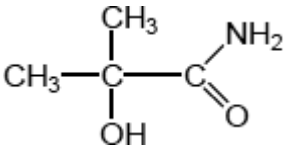


Isomer of $C_4H_9NO_2$

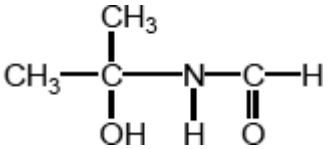
Allow NH_2–

1

(ii)



Isomer of $C4H_9NO_2$ allow NH_2–



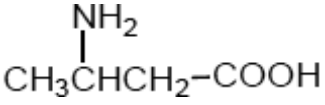
Allow

1

(iii) *$H_2N–CH_2CH_2CH_2–COOH$ or $H_2N–(CH_2)_3–COOH$*

Isomer of $C_4H_9NO_2$ allow NH_2–

OR

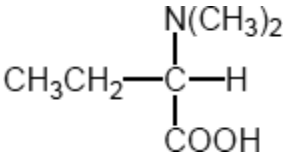


*Do **not** allow $–C_3H_6-$*

*Beware – do not credit **X** itself*

1

(f)



*Answer has 6 carbons so **NOT** isomer of **X***

Allow C_2H_5

Must have bond from C to N not to methyl group

1

[16]

Q13.

(a) *Heating <u>speeds up</u> (hydrolysis / breaking of peptide bonds)*

***OR** forms non-sweet (amino acids)*

1

(b) *(2-)aminobutan**<u>e</u>**dioic acid OR*

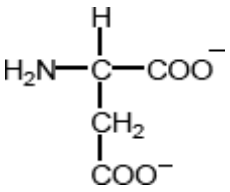
2 not necessary but penalise other numbers at start

*(2-)aminobutan**<u>e</u>**(-1,4-)dioic acid*

1,4 not necessary but penalise other numbers and 1,4 must be in correct place (QoL)

1

(c)

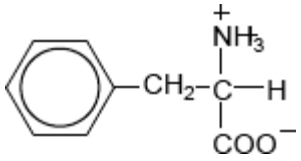


allow $–CO_2^-$

allow $NH_2–$

1

(d)



allow $–CO_2^-$

allow $+NH_3–$

don't penalize position of + on NH_3

1

(e) *(i)* ***M1*** *Compounds/molecules with same <u>structural formula</u>*

Not just structure

1

M2 *But with <u>bonds/atoms/groups</u> arranged differently <u>in space</u> or <u>in 3D</u>*

Allow –with different <u>spatial</u> arrangement of <u>atom/bond/group</u>

1

Independent marks

(ii) *(Plane) polarised light*

1

Rotated in opposite directions

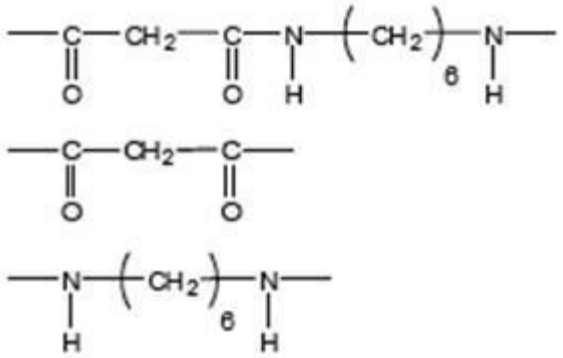
Not bent or turned or twisted; not different directions (QoL)

1

[8]

Q14.

(a) *(i)*



Allow –CONH- or - COHN -

Mark two halves separately

lose 1 each for missing trailing bonds at one or both ends or error in peptide link or either or both of H or OH on ends

1

Not allow –(C_6H_{12})–

Ignore n

1

(ii) ***M1*** *in polyamides - H bonding*

1

M2 *in polyalkenes - van der Waals forces*

Penalise forces between atoms or van der Waals bonds

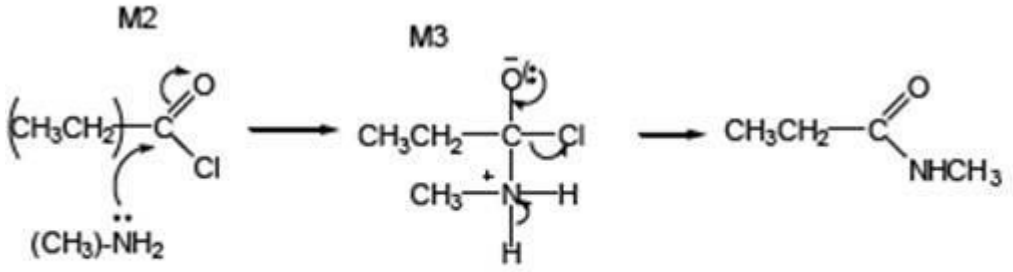
1

M3 *Stronger forces (of attraction) in polyamides*
Or H bonding is stronger
(must be a comparison of correct forces to score M3)

Do not award if refer to stronger bonds

1

(b) *(i)* *(nucleophilic) addition elimination*



Not allow N–H_2

*Minus sign on NH_2 loses **M1***

1

*M2 not allowed independent of **M1**, but allow **M1** for correct attack on C+*

*+ rather than δ+ on C=O loses **M2***

*If Cl lost with C=O breaking, max 1 for **M1***

***M3** for correct structure <u>with charges</u> but*

*lp on O is part of **M4***

*only allow **M4** after correct/ very close M3*

For M4, ignore NH_3 removing H^+ but lose

***M4** for Cl removing H^+ in mechanism,*

but ignore HCl as a product

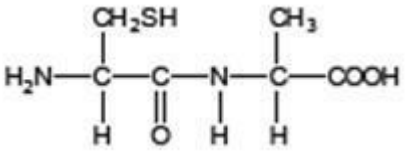
4

(ii) <u>*N-methylpropanamide*</u>

Not N-methylpropaneamide

1

(c)



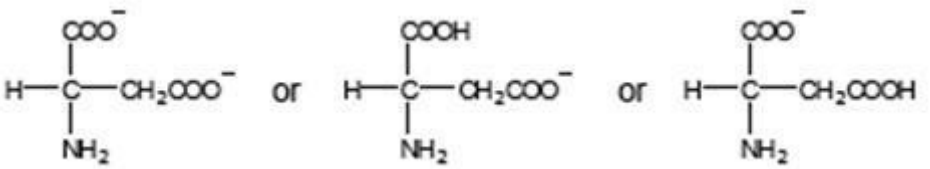
Allow –CONH– or –COHN–

1

(d) (i) <u>*2-amino-3-hydroxypropanoic acid*</u>

1

(ii)

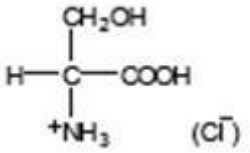


Must be salts of aspartic acid

allow $-CO_2^-$
allow NH_2-

1

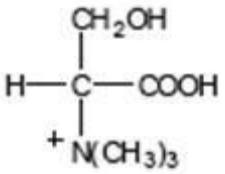
(iii) Penalise use of aspartic acid once in d(iii) and d(iv)



allow $-CO_2H$
allow $^+NH_3-$
don't penalize position of + on NH_3

1

(iv) Penalise use of aspartic acid once in d(iii) and d(iv)



(Br^-)

allow $-CO_2^-$
must show C-N bond
don't penalize position of + on $N(CH_3)_3$

1

[16]

Q15.

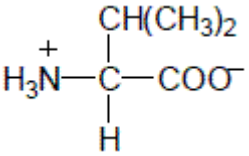
(a) (i) hydrolysis
not hydration

1

(ii) 2-aminopropanoic acid
ignore alanine
QoL

1

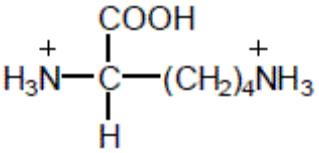
(iii)



allow $-CO_2^-$
allow $^+NH_3-$
don't penalize position of + on NH_3

1

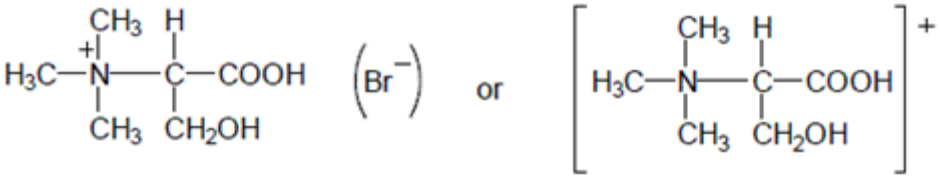
(iv)



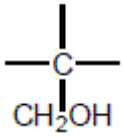
allow $-CO_2^-$
allow $^+NH_3-$
don't penalize position of + on NH_3

1

(b) (i)



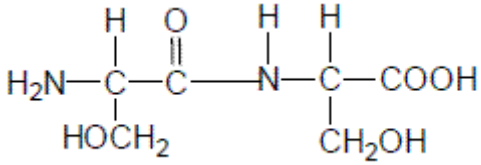
allow $-CO_2H$



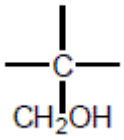
allow limit as
+ on N or outside [ ]

1

(ii)



allow $-CO_2H$ allow $-CONH-$ or $-COHN-$
allow NH_2-



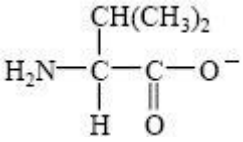
allow limit as

1

[6]

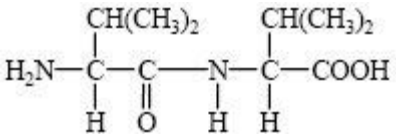
Q16.

(a) (i)



1

(ii)

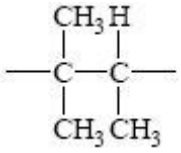


1

(iii) *hydrogen bonding (do not allow H-bonding) QWC*
do not penalise any error twice.

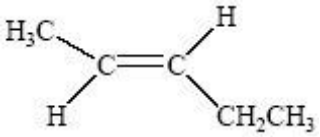
1

(b) *(i)*



1

(ii)

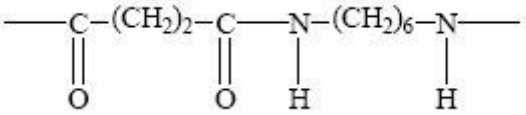


1

(iii) *Isomer must be saturated or must not contain a double bond*

1

(c)



2

(d) *(i)* *heat/reflux with aqu NaOH*

1

poly(alkene) is inert/ no reaction

1

polyamide is hydrolysed (or undergoes hydrolysis) to form acid salt and alcohol QWC

1

(ii) *e.g combustion*

1

heat energy produced

1

toxic gases produced

1

[14]

Q17.

(a) (i) $CH_3CH=CHCH_3$

1

*Addition or radical (**QoL**)*

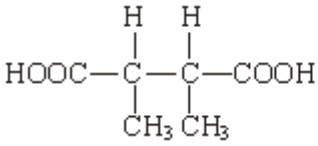
1

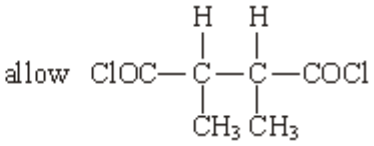
(ii) $CH_3CH(OH)CH(OH)CH_3$ *or with no brackets*

1

butan(e)–2,3–diol or 2,3–butan(e)diol

1





1

2,3–dimethylbutan(e)dioic acid *2,3–dimethylbutan(e)dioyl chloride*

ignore –1,4–

1

*condensation (**QoL**)*

1

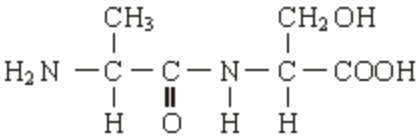
(iii) *NaOH or HCl etc or* Na_2CO_3

Allow conc sulphuric/nitric

***NOT** water nor acidified water nor weak acids*

1

(b) *Structure 1*



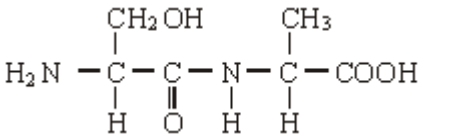
Allow –CONH– and –COHN–

Allow zwitterions

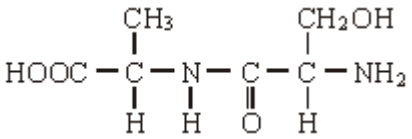
NOT polypeptides/repeating units

1

Structure 2 either of



or



1

(c) (i) $CH_3CH_2CH_2Br$

allow –Cl, –I

1

(ii) CH_3CH_2CN

1

(iii) *(nucleophilic) substitution or from* $CH_3CH_2CH_2Br$

if reduction written here, no further marks

1

further substitution/reaction occurs or other products are formed

Allow reduction forms only one product

1

one of

$(CH_3CH_2CH_2)_2NH$

$(CH_3CH_2CH_2)_3N$

$(CH_3CH_2CH_2)_4N^+ Br^-$

Allow salts including NH_4Br

Allow HBr

1

[15]