**Q1.**          (a)     Synthetic polyamides are produced by the reaction of dicarboxylic acids with compounds such as H2N(CH2)6NH2

(i)      Name the compound H2N(CH2)6NH2

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(ii)     Give the repeating unit in the polyamide nylon 6,6.

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**(2)**

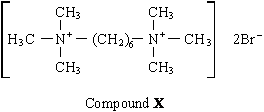
(b)     Synthetic polyamides have structures similar to those found in proteins.

(i)      Draw the structure of 2-aminopropanoic acid.

(ii)     Draw the organic product formed by the condensation of two molecules of 2-aminopropanoic acid.

**(2)**

(c)     Compounds like H2N(CH2)6NH2 are also used to make ionic compounds such as **X**, shown below.



(i)      **X** belongs to the same type of compound as (CH3)4N+Br–Name this **type** of compound.

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(ii)     State a reagent which could produce **X** from H2N(CH2)6NH2 and give a necessary condition to ensure that **X** is the major product.

*Reagent* .............................................................................................

*Condition* ............................................................................................

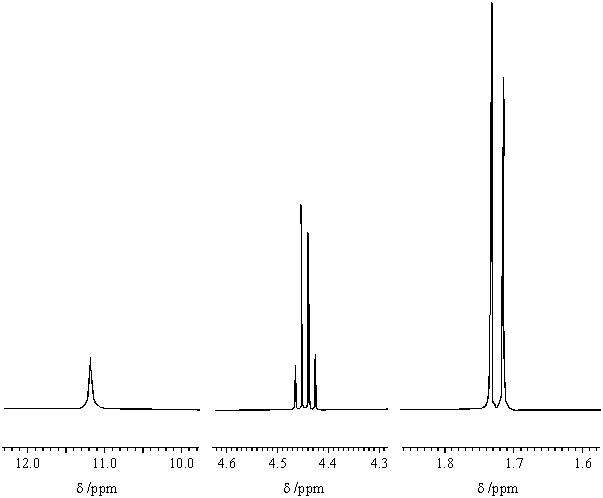
(iii)     Name the mechanism involved in this reaction to form **X**.

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**(4)**

**(Total 8 marks)**

**Q2.**          Three sections of the proton n.m.r. spectrum of CH3CHClCOOH are shown below.



(a)     Name the compound CH3CHClCOOH

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**(1)**

(b)     Explain the splitting patterns in the peaks at δ 1.72 and δ 4.44

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**(2)**

(c)     Predict the splitting pattern that would be seen in the proton n.m.r. spectrum of the isomeric compound ClCH2CH2COOH

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**(1)**

(d)     The amino acid *alanine* is formed by the reaction of CH3CHClCOOH with an excess of ammonia. The mechanism is nucleophilic substitution. Outline this mechanism, showing clearly the structure of *alanine*.

**(5)**

(e)     The amino acid *lysine* has the structure



Draw structures to show the product formed in each case when lysine reacts with

(i)      an excess of aqueous HCl,

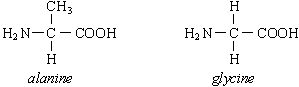
(ii)     an excess of aqueous NaOH,

(iii)     another molecule of lysine.

**(3)**

**(Total 12 marks)**

**Q3.**          The structures of the amino acids *alanine* and *glycine* are shown below.



(a)     Give the systematic name for *alanine.*

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**(1)**

(b)*Alanine* exists as a pair of stereoisomers.

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

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(ii)     State how you could distinguish between the stereoisomers.

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**(4)**

(c)     Give the structural formula of the species formed by *glycine* at pH 14.

**(1)**

(d)     When two amino acids react together, a dipeptide is formed. Give the structural formulae of the **two** dipeptides which are formed when *alanine* and *glycine* react together.

*Dipeptide 1*

*Dipeptide 2*

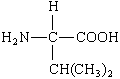
**(2)**

(e)     Give the structural formula of the organic compound formed when *glycine* reacts with methanol in the presence of a small amount of concentrated sulphuric acid.

**(1)**

**(Total 9 marks)**

**Q4.**          (a)     Consider the following amino acid.



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

(ii)     Draw the structure of the dipeptide formed from two molecules of this amino acid.

(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)     Consider the hydrocarbon **G**, (CH3)2C=CHCH3, which can be polymerised.

(i)      Name the type of polymerisation involved and draw the repeating unit of the polymer.

*Type of polymerisation .*.......................................................................

*Repeating unit*

(ii)     Draw the structure of an isomer of **G** which shows geometrical isomerism.

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

**(4)**

**(Total 7 marks)**

**Q5.**          (a)     The compound H2C=CHCN is used in the formation of acrylic polymers.

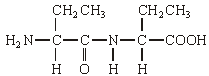
(i)      Draw the repeating unit of the polymer formed from this compound.

(ii)     Name the type of polymerisation involved in the formation of this polymer.

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**(2)**

(b)     When the dipeptide shown below is heated under acidic conditions, a single amino acid is produced.



(i)      Name this amino acid.

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(ii)     Draw the structure of the amino acid species present in the acidic solution.

**(2)**

(c)     The repeating unit of a polyester is shown below.



(i)      Deduce the empirical formula of the repeating unit of this polyester.

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(ii)     Draw the structure of the acid which could be used in the preparation of this polyester and give the name of this acid.

*Structure* ..............................................................................................

*Name* ...................................................................................................

(iii)     Give **one** reason why the polyester is biodegradable.

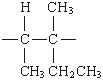
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**(4)**

**(Total 8 marks)**

**Q6.**          The amino acid *alanine* is shown below.



(a)     A sample of alanine is dissolved in water.

(i)      Draw the structure of the main alanine species present in this aqueous solution and give the name of this type of species.

*Structure*

*Type of species* .................................................................................

(ii)     Draw the structure of the alanine species formed when an excess of hydrochloric acid is added to the solution.

**(3)**

(b)     Alanine molecules may be reacted together to form a polypeptide. Give the repeating unit of this polypeptide and name the type of polymerisation involved in its formation.

*Repeating unit*

*Type of polymerisation* .......................................................................

**(2)**

(c)     The repeating unit of a polyalkene is shown below.



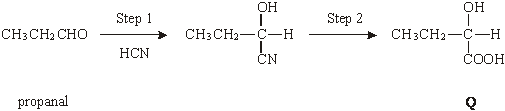
Give the name of the alkene which is used to form this polymer.

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**(1)**

**(Total 6 marks)**

**Q7.**          Consider the reaction sequence shown below.



(a)     Name and outline a mechanism for the reaction in Step 1.

*Name of mechanism ....................................................................................*

Mechanism

**(5)**

(b)     (i)      Name compound **Q** formed in Step 2.

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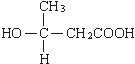
(ii)     Two stereoisomers are formed by the dehydration of **Q**. Give the structures of these two isomers and name the type of stereoisomerism shown.

*Structures of isomers*

*Type of stereoisomerism .*.............................................................................

**(4)**

(c)     An isomer of **Q** which has the structure shown below is polymerised to form the biodegradeable polymer known as PHB.



(i)      Draw the repeating unit of the polymer PHB.

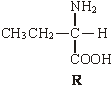
(ii)     Suggest a reason why the polymer is biodegradeable.

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**(2)**

(d)     The amino acid **R** is shown below.



(i)      Draw the structure of the zwitterion formed by **R**.

(ii)     Draw the structure of the major organic product formed when an excess of **R** is reacted with bromomethane.

(iii)     Name the mechanism of the reaction which results in the formation of the product given in part (ii).

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**(3)**

**(Total 14 marks)**

**Q8.**          (a)     The structure below shows the repeating unit of a polymer.



By considering the functional group formed during polymerisation, name this type of polymer and the type of polymerisation involved in its formation.

*Type of polymer* ...........................................................................................

*Type of polymerisation .*................................................................................

**(2)**

(b)     Draw the structure of the species present in solid aminoethanoic acid, H2NCH2COOH

**(1)**

(c)     Explain why the melting point of aminoethanoic acid is much higher than that of hydroxyethanoic acid, HOCH2COOH

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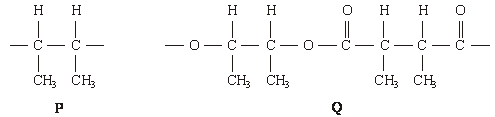
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**(2)**

**(Total 5 marks)**

**Q9.**          (a)     The repeating units of two polymers, **P** and **Q**, are shown below.



(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* ........................................................................

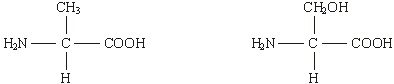
*Type of polymerisation* .......................................................................

(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, CH3CH2CH2NH2, 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* .........................................................................................

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*Structure of an impurity*

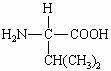
**(5)**

**(Total 15 marks)**

**Q10.**          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**, (CH3)2C=CHCH3, 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.

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**(3)**

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

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**(3)**

**(Total 14 marks)**

**Q11.**          (a)     Name and outline a mechanism for the reaction of CH3CH2NH2 with CH3CH2COCl

Name the amide formed.

**(6)**

(b)     Haloalkanes such as CH3Cl are used in organic synthesis.

Outline a three-step synthesis of CH3CH2NH2 starting from methane. Your first step should involve the formation of CH3Cl

In your answer, identify the product of the second step and give the reagents and conditions for each step.

Equations and mechanisms are **not** required.

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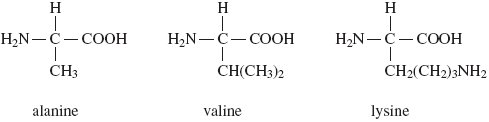
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**(6)**

**(Total 12 marks)**

**Q12.**          The three amino acids shown below were obtained by hydrolysis of a protein.



(a)     (i)      Draw the zwitterion of alanine.

**(1)**

(ii)     Draw the species formed when valine is dissolved in an alkaline solution.

**(1)**

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

**(1)**

(b)     Draw the two dipeptides formed by the reaction of alanine with valine.

**(2)**

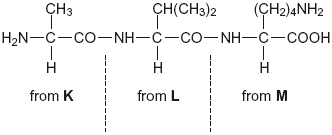
(c)     Name a suitable method by which the mixture of amino acids formed by hydrolysis of the protein can be separated.

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**(1)**

**(Total 6 marks)**

**Q13.**          (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.

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**(1)**

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

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**(1)**

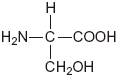
(iii)Draw the structure of the zwitterion of amino acid **L**.

**(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 CH3Br

**(1)**

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

**(1)**

**(Total 6 marks)**

**Q14.**          (a)     Name compound **Y**, HOCH2CH2COOH

......................................................................................................................

**(1)**

(b)     Under suitable conditions, molecules of **Y** can react with each other to form a polymer.

(i)      Draw a section of the polymer showing **two** repeating units.

**(1)**

(ii)     Name the type of polymerisation involved.

.............................................................................................................

**(1)**

(c)     When **Y** is heated, an elimination reaction occurs in which one molecule of **Y** loses one molecule of water. The organic product formed by this reaction has an absorption at 1637 cm–1 in its infrared spectrum.

(i)      Identify the bond that causes the absorption at 1637 cm–1 in its infrared spectrum.

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**(1)**

(ii)     Write the displayed formula for the organic product of this elimination reaction.

**(1)**

(iii)     The organic product from part (ii) can also be polymerised.  
Draw the repeating unit of the polymer formed from this organic product.

**(1)**

(d)     At room temperature, 2-aminobutanoic acid exists as a solid.  
Draw the structure of the species present in the solid form.

**(1)**

(e)     The amino acid, glutamic acid, is shown below.



Draw the structure of the organic species formed when glutamic acid reacts with each of the following.

(i)      an excess of sodium hydroxide

**(1)**

(ii)     an excess of methanol in the presence of concentrated sulfuric acid

**(1)**

(iii)     ethanoyl chloride

**(1)**

(f)      A tripeptide was heated with hydrochloric acid and a mixture of amino acids was formed. This mixture was separated by column chromatography.  
Outline briefly why chromatography is able to separate a mixture of compounds.  
Practical details are **not** required.

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**(3)**

**(Total 13 marks)**

**Q15.**          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.

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*(Extra space)* ......................................................................................

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**(3)**

(b)     (i)      Name and outline a mechanism for the reaction of CH3CH2COCl with CH3NH2

Name of mechanism............................................................................

Mechanism

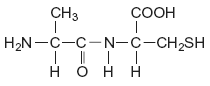
**(5)**

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

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**(1)**

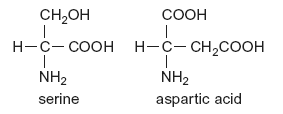
(c)     The dipeptide shown below is formed from two different amino acids.



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.

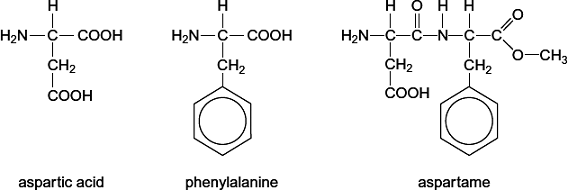
**(1)**

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

**(1)**

**(Total 16 marks)**

**Q16.**The amino acids aspartic acid and phenylalanine react together to form a dipeptide.  
This dipeptide can be converted into a methyl ester called 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.

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*(Extra space)* .................................................................................................

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**(1)**

(b)     Give the IUPAC name of aspartic acid.

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**(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*.

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**(2)**

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

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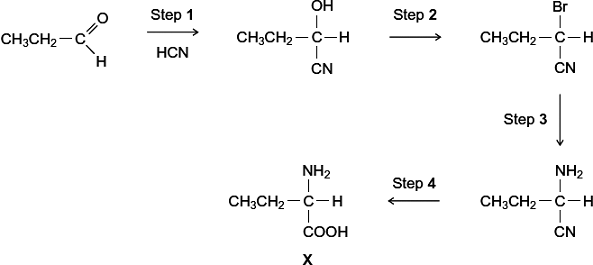
*(Extra space)* ........................................................................................

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**(2)**

**(Total 8 marks)**

**Q17.**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 CH3CH2CH(OH)COOH.

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*(Extra space)* ........................................................................................

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**(2)**

(e)     There are many structural isomers of **X**, CH3CH2CH(NH2)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.

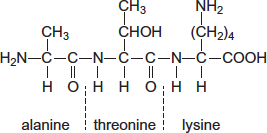
**(1)**

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

**(1)**

**(Total 16 marks)**

**Q18.**(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.

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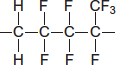
**(1)**

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

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**(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.

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**(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 ....................................................................................................

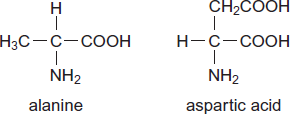
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........................................................................................................................

**(2)**

**(Total 11 marks)**

**Q19.**Alanine and aspartic acid are naturally occurring amino acids.



(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)**

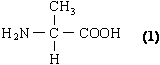
**(Total 4 marks)**

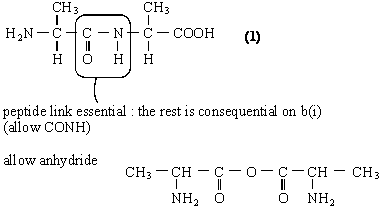
**M1.**         (a)     (i)      hexane-1,6-diamine or 1,6-diaminohexane **(allow ammine)**or 1,6 hexan(e)diamine **(1)**

(ii)     

*Allow –CONH–*

**2**

(b)     (i)      

(ii)     

**2**

(c)     (i)      quaternary ammonium bromide salt **(1)**

*(not ion, not compound)*

*Allow quarternery*

(ii)     *Reagent*: CH3Br or bromomethane **(1)**

*penalise CH3Cl but allow excess for any halomethane*

*Condition*: excess (CH3Br) **(1)**

(iii)     nucleophilic substitution **(1)**

**4**

**[8]**

**M2.**         (a)     2-chloropropanoic acid **(1)**

**1**

(b)     δ 1.72 Doublet  next to CH **(1)**

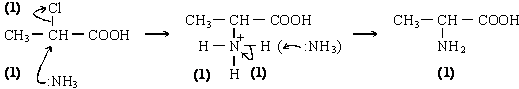
δ 4.44 Quartet  next to CH3 **(1)**

**2**

(c)     Two triplets **(1)**

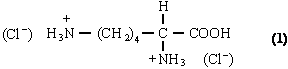
**1**

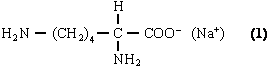
(d)



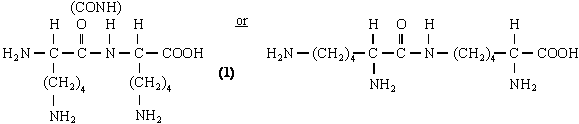
*Allow SN1*

**5**

(e)     (i)      

(ii)     

(iii)



*Or anhydride*

**3**

**[12]**

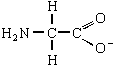
**M3.**          (a)     2-amino(e) propanoic acid **(1)**

**1**

(b)     (i)      molecules with same structure / structural formula **(1)**but with bonds **(atoms or groups)** arranged differently in  
space (3D) **(1)**

(ii)     Plane polarised light **(1)**Rotated (equally) in opposite directions **(1)**

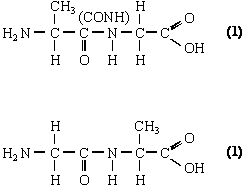
**4**

(c)      **(1)**

*allow H2NCH2COO–*

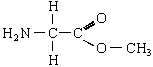
*Penalise NH2‑ and OH‑ once per paper  
but CH3– is allowed*

**1**

(d)     

*Not anhydrides; not repeating units*

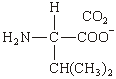
**2**

(e)      **(1)**

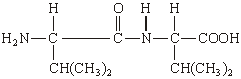
*or H2NCH2COOCH3*

**1**

**[9]**

**M4.**          (a)     (i)       **(1)**

*ignore Na+ unless covalently bonded*

(ii)      **(1)**

*must be dipeptide, not polymer nor anhydride  
allow –CONH– or –COHN–*

*allow zwitterion*

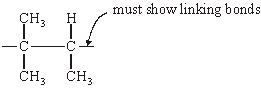
(iii)     hydrogen bonding **(1)**

*QL*

*Allow with dipole-dipole or v derWaals, but not dipole-dipole etc alone*

**3**

(b)     (i)      *Type of polymerisation*: addition(al) **(1)**

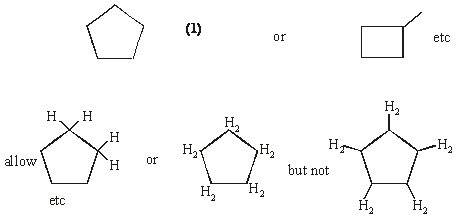
*Repeating unit*:  **(1)**

*not multiples*

*allow n*

(ii)     CH3CH=CHCH2CH3 **(1)** C2H5

(iii)



**4**

**[7]**

**M5.**         (a)     (i)



*(Ignore n or brackets, but trailing bonds are essential)*

**1**

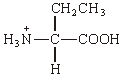
(ii)     Addition or radical

**1**

(b)     (i)      2-aminobutanoic (acid)

**1**

(ii)



**1**

(c)     (i)      C3H4O2

**1**

(ii)



**1**

(1,4-)butan(e)dioic (acid)

*(allow succinic, but not dibutanoic nor butanedicarboxylic acid)*

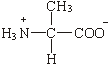
**1**

(iii)     Can be hydrolysed / can react with acid or base or water /  
can react with nucleophiles

**1**

**[8]**

**M6.**         (a)     (i)



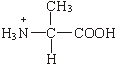
         penalise +NH3— or + on H once per paper

**1**

         zwitterions

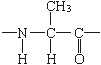
**1**

(ii)



**1**

(b)



*ignore n, but allow* ***one*** *drawn out repeating unit only*

**1**

          condensation or (nucleophilic) addition-elimination

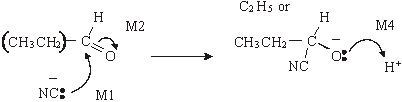
**1**

(c)     3-methylpent-2-ene

**1**

**[6]**

**M7.**          (a)     necleophilic addition;



**1**

M3 structure;

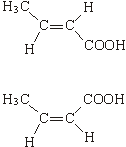
*(be lenient on position of charge on CN– )  
(M2 not allowed independent of M1,   
but allow M1 for correct attack on C+  
if M2 show as independent first.)  
(+on C of C=O loses M2 but ignore δ+ if correct)  
(M4 for arrow and lone pair (only allow for correct M3 or close))*

**4**

(b)     (i)      2-hydroxybutanoic acid

**1**

(ii)

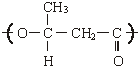


**1**

geometric(al) or cis-trans

**1**

(c)     (i)



*(one unit only) (ignore brackets or n) (trailing bonds are needed)*

**1**

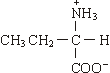
(ii)     can be hydrolysed

         OR

         can be reacted with/attacked by acid/base/nucleophiles/H2O/OH–;

**1**

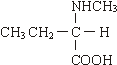
(d)     (i)



*(allow –NH3+)*

**1**

(ii)



*(or zwitterions product)*

**1**

(iii)     nucleophilic substitution;

**1**

**[14]**

**M8.**          (a)     polyamide or nylon (2,4)

*(allow nylon without numbers but if numbers are present they must be correct)*

**1**

condensation

**1**

(b)     

**1**

(c)     ionic bonding in aminoethanoic acid

*(can only score if includes that aminoethanoic is ionic)*

**1**

stronger attractions than Hydrogen bonding in hydroxyethanoic acid

*(e.g. stronger Hydrogen bonding in aminoethanoic acid scores 0)*

*(mention of electrostatic forces between molecules scores 0)*

**1**

**[5]**

**M9.**          (a)     (i)      CH3CH=CHCH3

**1**

Addition or radical (**QoL**)

**1**

(ii)     CH3CH(OH)CH(OH)CH3 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**

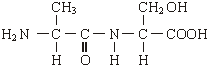
(iii)     NaOH or HCl etc or Na2CO3

*Allow conc sulphuric/nitric*

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

**1**

(b)     Structure 1



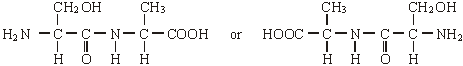
*Allow –CONH– and –COHN–*

*Allow zwitterions*

***NOT polypeptides/repeating units***

**1**

Structure 2 either of



**1**

(c)     (i)      CH3CH2CH2Br

*allow –Cl, –I*

**1**

(ii)     CH3CH2CN

**1**

(iii)     (nucleophilic) substitution or from CH3CH2CH2Br

*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   
(CH3CH2CH2)2NH  
(CH3CH2CH2)3N  
(CH3CH2CH2)4N+ Br–

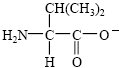
*Allow salts including NH4Br*

*Allow HBr*

**1**

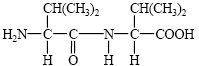
**[15]**

**M10.**          (a)     (i)



**1**

(ii)



**1**

(iii)     hydrogen bonding (do not allow H-bonding) QWC

*do not penalise any error twice.*

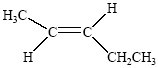
**1**

(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**

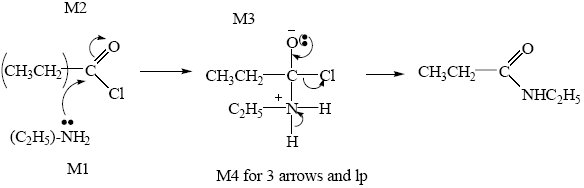
toxic gases produced

**1**

**[14]**

**M11.**          (a)     (nucleophilic) addition-elimination

**1**

****

**4**

N-ethylpropanamide

*minus on NH2 loses M1  
M2 not allowed independent of M1, but allow M1 for correct attack on C+  
+C=O loses M2  
only allow M4 after correct or very close M3  
lose M4 for Cl– removing H+ in mechanism, but ignore HCl as a product  
Not N-ethylpropaneamide*

**1**

(b)     CH3CN or ethan(e)nitrile or ethanonitrile

*not ethanitrile  
but allow correct formula with ethanitrile*

**1**

for each step wrong or no reagent loses condition mark

*contradiction loses mark*

**1**

Step 1    Cl2uv or above 300 °C

*wrong or no reagent loses condition mark*

**1**

Step 2    KCN

**1**

aq and alcoholic (both needed)

*allow uv light/(sun)light/uv radiation*

**1**

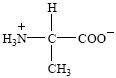
Step 3    H2/Ni or LiAlH4 or Na/C2H5OH

*not CN– but mark on  
NOT HCN or KCN + acid, and this loses condition mark  
NOT NaBH4Sn/HCl (forms aldehyde!)  
ignore conditions*

**1**

**[12]**

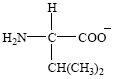
**M12.**          (a)     (i)



*allow –CO2–allow +NH3–  
don’t penalize position of + on NH3*

**1**

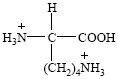
(ii)



*allow –CO2–allow NH2–  
allow C3H7*

**1**

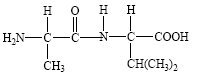
(iii)



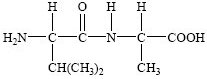
*allow –CO2H  
allow +NH3–  
don’t penalize position of + on NH3*

**1**

(b)



**1**

****

*allow –CO2H  
allow NH2–  
allow C3H7allow as zwitterions  
if error in peptide link e.g.  
  
if twice, penalise both times  
not polymers  
if wrong amino acid in both can score Max 1*

**1**

(c)     chromatography or electrophoresis

*ignore qualification to chromatography*

**1**

**[6]**

**M13.**          (a)     (i)      hydrolysis

*not hydration*

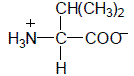
**1**

(ii)     2-aminopropanoic acid

*ignore alanine  
QoL*

**1**

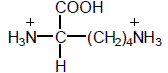
(iii)



*allow –CO2–allow +NH3–  
don’t penalize position of + on NH3*

**1**

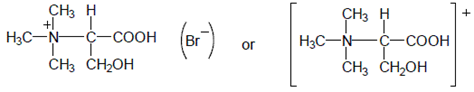
(iv)



*allow –CO2–allow +NH3–  
don’t penalize position of + on NH3*

**1**

(b)     (i)



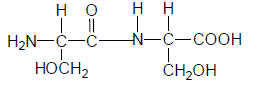
*allow –CO2H*

*allow limit as *

*+ on N or outside [ ]*

**1**

(ii)



*allow –CO2H allow –CONH– or –COHN–*

*allow NH2–*

*allow limit as *

**1**

**[6]**

**M14.**          (a)     3-hydroxypropanoic acid

*allow 3-hydroxypropionic acid  
must be correct spelling*

**1**

(b)     (i)      must show trailing bonds



or can start at any point in the sequence, e.g.



*not allow dimer*

*allow –O–CH2CH2COOCH2CH2CO–*

*or –CH2CH2COOCH2CH2COO–*

*ignore ( ) or n*

*NB answer has a total of 6 carbons and 4 oxygens*

**1**

(ii)     condensation (polymerisation)

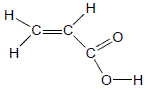
*Allow close spelling*

**1**

(c)     (i)      C=C or carbon-carbon double bond

**1**

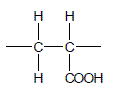
(ii)



*must show* ***ALL*** *bonds including O–H*

**1**

(iii)     must show trailing bonds

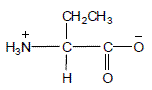


*allow polyalkene conseq on their c(ii)*

*ignore n*

**1**

(d)

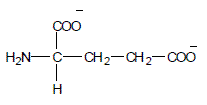


*allow NH3+—*

*allow COO–*

**1**

(e)     (i)



*In (e), do not penalise a slip in the number of carbons in the -CH2CH2- chain, but all must be bonded correctly*

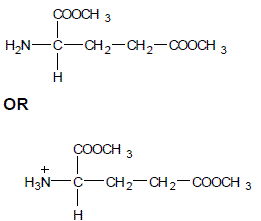
*NB two carboxylate groups*

*Allow COONa or COO– Na+ but not covalent bond to Na*

*allow NH2–*

**1**

(ii)



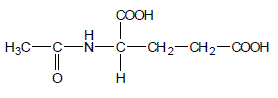
*In (e), do not penalise a slip in the number of carbons in the  
-CH2CH2- chain, but all must be bonded correctly*

*NB two ester groups*

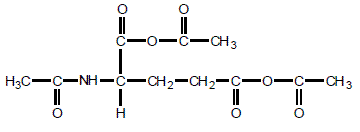
*allow NH2– or +NH3–*

**1**

(iii)



*In 4(e), do not penalise a slip in the number of carbons in the -CH2CH2- chain, but all must be bonded correctly*

*allow anhydride formation on either or both COOH groups (see below) with or without amide group formation  
*

**1**

(f)      **M1** phase or eluent or solvent (or named solvent) is moving or mobile

**1**

**M2** stationary phase or solid or alumina/silica/resin

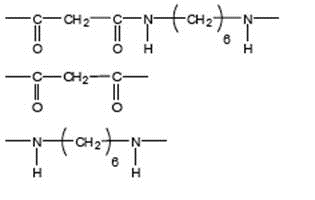
**1**

**M3** separation depends on balance between solubility or affinity  
(of compounds) in each phase  
**OR**different adsorption or retention  
**OR**(amino acids have) different Rf values  
**OR**(amino acids) travel at different speeds or take different times

**1**

**[13]**

**M15.**         (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 –(C6H12)–*

*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*

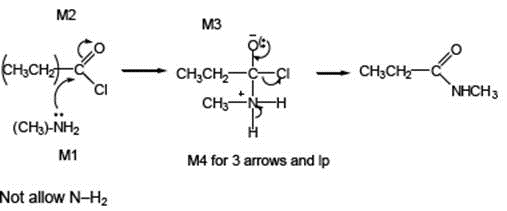
**1**

**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



*Minus sign on NH2 loses* ***M1***

**1**

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

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

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

***M3*** *for correct structure with charges but*

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

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

*For M4, ignore NH3 removing H+ but lose*

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

*but ignore HCl as a product*

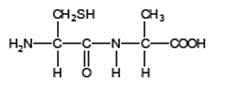
**4**

(ii)     N-methylpropanamide

*Not N-methylpropaneamide*

**1**

(c)



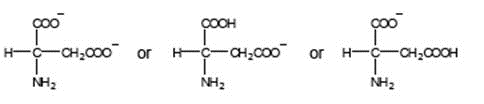
*Allow –CONH– or –COHN–*

**1**

(d)     (i)      2-amino-3-hydroxypropanoic acid

**1**

(ii)



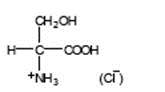
Must be salts of aspartic acid

*allow –CO2–*

*allow NH2–*

**1**

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



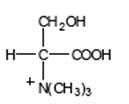
*allow –CO2H*

*allow +NH3–*

*don’t penalize position of + on NH3*

**1**

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

**(Br–)**

*allow –CO2–*

*must show C-N bond*

*don’t penalize position of + on N(CH3)3*

**1**

**[16]**

**M16.**(a)    Heating speeds up (hydrolysis / breaking of peptide bonds)

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

**1**

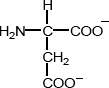
(b)     (2-)aminobutan**e**dioic acid OR

*2 not necessary but penalise other numbers at start*

(2-)aminobutan**e**(-1,4-)dioic acid

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

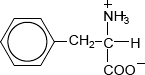
**1**

(c)

*allow –CO2–*

*allow NH2–*

**1**

(d)

*allow –CO2–*

*allow +NH3–*

*don’t penalize position of + on NH3*

**1**

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

*Not just structure*

**1**

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

*Allow –with different spatial arrangement of atom/bond/group*

**1**

*Independent marks*

(ii)     (Plane) polarised light

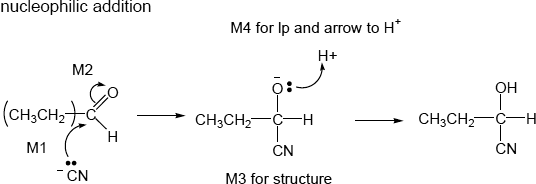
**1**

Rotated in opposite directions

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

**1**

**[8]**

**M17.**(a)

*•   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 C2H5*

*•   M1 and M4 for lp and curly arrow*

***1***

***4***

*(b)     2-bromobutanenitrile*

*Allow 2-bromobutane-1-nitrile*

***1***

*(c)****M1****ammonia or NH3*

*Ignore temp or pressure*

***1***

***M2****excess (ammonia)               excess tied to NH3 and may score in M1 unless   
contradicted*

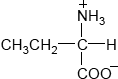
*Ignore concentrated or sealed container, Acid loses conditions mark*

***1***

***M3****nucleophilic substitution*

*Allow close spelling*

***1***

*(d)     (i)*

*Allow C2H5*

*Allow –CO2–*

*Allow +NH3–*

*Don’t penalize position of + on NH3*

***1***

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

*Allow ionic bonding.*

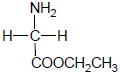
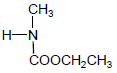
***1***

*Marks independent*

***M2****(stronger than) hydrogen bonding between CH3CH2CH(OH)COOH*

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

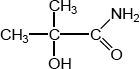
***1***

*(e)     (i)OR*

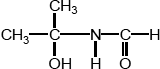
*Isomer of C4H9NO2*

*Allow NH2–*

***1***

*(ii)*

*Isomer of C4H9NO2   allow NH2–*

*Allow *

***1***

*(iii)     H2N–CH2CH2CH2–COOH   or   H2N–(CH2)3–COOH*

*Isomer of C4H9NO2   allow NH2–*

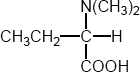
*OR*

**

*Do* ***not*** *allow –C3H6-*

*Beware – do not credit* ***X*** *itself*

***1***

*(f)*

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

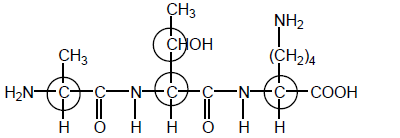
*Allow C2H5*

*Must have bond from C to N not to methyl group*

***1***

***[16]***

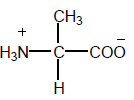
***M18.****(a)     (i)*

**

*These four only*

***1***

*(ii)*

**

*Allow − NH3+ and +NH3−*

***1***

*(iii)    2-amino-3-hydroxybutanoic acid*

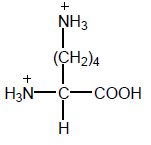
*Ignore 1 in butan-1-oic acid*

*Do not penalise commas or missing hyphens*

*Penalise other numbers*

***1***

*(iv)*

**

*Allow –NH3+ and +NH3−*

***1***

*(b)     (i)      Condensation*

*Allow polyester*

***1***

*(ii)     propan****e****-1,3-diol*

*Must have e*

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

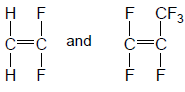
***1***

*(c)     (i)      Addition*

*Not additional*

***1***

*(ii)*

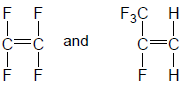
**

*Allow monomers drawn either way round*

*Allow bond to F in CF3*

***1***

***OR***

******

*1 for each structure within each pair*

***1***

*(d)     c*

*If wrong, CE = 0*

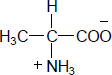
***1***

*C-C or C-F bonds too strong*

***1***

***[11]***

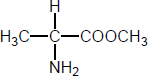
***M19.****(a)*

**

*Allow −NH3+ and +NH3−*

***1***

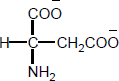
*(b)*

**

*Allow protonated form, i.e. −NH3+ or +NH3−*

***1***

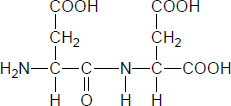
*(c)*

**

*Allow – CO2–*

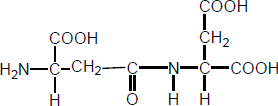
***1***

*(d)*

**

*Allow zwitterion with any COO−*

*Allow use of “wrong” COOH*

**

***1***

***[4]***