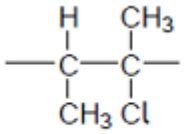
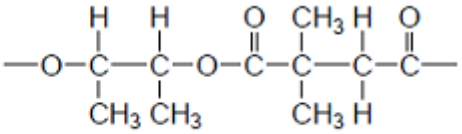
**1** Repeating units of two polymers, **P** and **Q**, are shown in the figure below.



**P**



**Q**

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

Monomer

Type of polymerisation .....

**(2)**

(b) Draw the structures of **two** compounds that react together to form polymer **Q**.

Structure of compound 1

Structure of compound 2

**(2)**

(c) Suggest an environmental advantage of polymer **Q** over polymer **P**.
Justify your answer.

Advantage .....

Justification .....

.....

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**(3)**
**(Total 7 marks)**

**2** Which compound can polymerise by reaction with itself?

**A** $NH_2CH_2CH_2NH_2$ ⬭

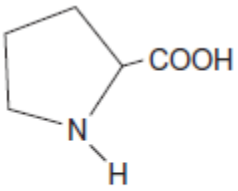
**B** $CH_3CH_2CONH_2$ ⬭

**C** $HOOCCH_2COOH$ ⬭

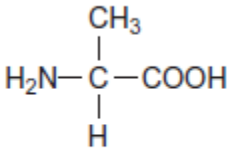
**D** $NH_2CH_2COCl$ ⬭

**(Total 1 mark)**

**3** (a) The structures and common names of two amino acids are shown.




proline




alanine

(i) Draw the structure of the zwitterion of proline.

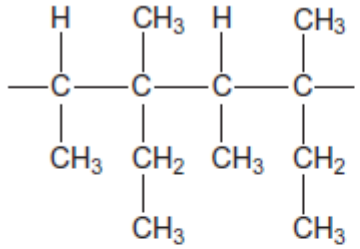
**(1)**

(ii) Draw the structure of the tripeptide formed when a proline molecule bonds to two alanine molecules, one on each side.

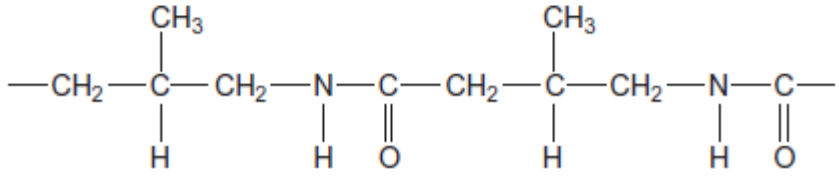
**(2)**

(b) Sections of two polymers, **L** and **M**, are shown.

**L**




**M**




(i) Give the IUPAC name of a monomer that forms polymer **L**.

.....

**(1)**

(ii) Give the IUPAC name of the monomer that forms polymer **M**.

.....

**(1)**

(iii) Draw the section of a polymer made from a dicarboxylic acid and a diamine that is isomeric with the section of polymer **M** shown.

**(1)**

(vi) Explain why polymer **L** is non-biodegradable.

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.....

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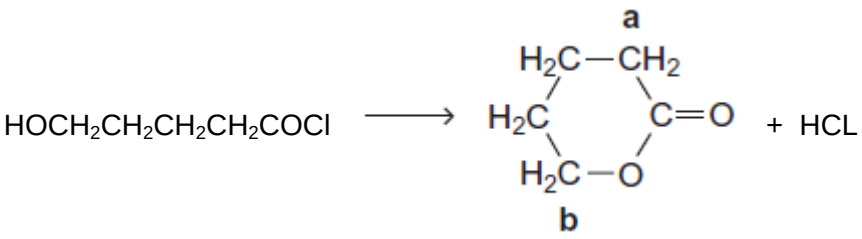
**(1)**
**(Total 7 marks)**

**4** This question is about some isomers of $C_5H_8O_2$

(a) Compound **H** is a cyclic ester that can be prepared as shown.

On the structure of **H**, two of the carbon atoms are labelled.




**H**

(i) Name and outline a mechanism for this reaction.

Use **Table C** on the Data Sheet to give the $^{13}C$ n.m.r. δ value for the carbon atom labelled **a** and the δ value for the carbon atom labelled **b**.

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**(7)**

(ii) $HOCH_2CH_2CH_2CH_2COCl$ can also react to form a polyester in a mechanism similar to that in part (i).

Draw the repeating unit of the polyester and name the type of polymerisation involved.

.....

.....

.....

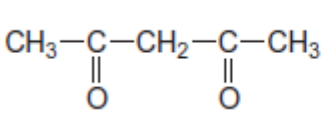
.....

.....

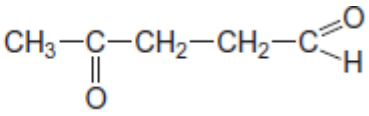
**(2)**

(b) State how you could distinguish between compounds **J** and **K** by a simple test-tube reaction.

State how you could distinguish between **J** and **K** by giving the number of peaks in the $^1H$ n.m.r. spectrum of each compound.



**J**



**K**

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**(5)**

(c) Draw the structure of each of the following isomers of $C_5H_8O_2$
Label each structure you draw with the correct letter **L**, **M**, **N**, **P** or **Q**.

**L** is methyl 2-methylpropenoate.

**M** is an ester that shows E-Z stereoisomerism.

**N** is a carboxylic acid with a branched carbon chain and does **not** show stereoisomerism.

**P** is an optically active carboxylic acid.

**Q** is a cyclic compound that contains a ketone group and has only two peaks in its $^1H$ n.m.r. spectrum.

**(5)**
**(Total 19 marks)**

**5** Lactic acid, $CH_3CH(OH)COOH$, is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose, $C_{12}H_{22}O_{11}$.

(a) (i) Give the IUPAC name for lactic acid.

.....

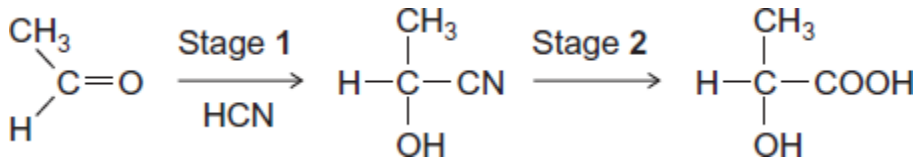
**(1)**

(ii) Write an equation for the formation of lactic acid from sucrose and water.

.....

**(1)**

(b) A molecule of lactic acid contains an asymmetric carbon atom.
The lactic acid in the body occurs as a single enantiomer.
A racemic mixture (racemate) of lactic acid can be formed in the following two-stage synthesis.




(i) Name and outline a mechanism for Stage **1**.

Name of mechanism .....

Mechanism

**(5)**

(ii) Give the meaning of the term *racemic mixture (racemate)*.

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**(1)**

(iii) Explain how you could distinguish between a racemic mixture (racemate) of lactic acid and one of the enantiomers of lactic acid.

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**(2)**

(c) A mixture of lactic acid and its salt sodium lactate is used as an acidity regulator in some foods. An acidity regulator makes sure that there is little variation in the pH of food.

(i) Write an equation for the reaction of lactic acid with sodium hydroxide.

.....

**(1)**

(ii) The acid dissociation constant $K_a$ for lactic acid has the value $1.38 \times 10^{-4}$ mol $dm^{-3}$ at 298 K.

Calculate the pH of an equimolar solution of lactic acid and sodium lactate.

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.....

**(2)**

(iii) Suggest an alternative name for the term *acidity regulator*.
Explain how a mixture of lactic acid and sodium lactate can act as a regulator when natural processes increase the acidity in some foods.

Name .....

Explanation .....

.....

.....

.....

*(Extra space)* .....

.....

**(3)**

(d)


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The cup shown is made from PLA, poly(lactic acid).
PLA is the condensation polymer formed from lactic acid.

The polymer is described as 100% biodegradable and 100% compostable.

Compostable material breaks down slowly in contact with the moist air in a garden bin. This produces compost that can be used to improve soil.

The manufacturers stress that PLA cups differ from traditional plastic cups that are neither biodegradable nor compostable.

(i) Draw a section of PLA that shows **two** repeating units.

**(2)**

(ii) Name the type of condensation polymer in PLA.

.....

**(1)**

(iii) An intermediate in the production of PLA is a cyclic compound ($C_6H_8O_4$) that is formed from two PLA molecules.

Draw the structure of this cyclic compound.

**(1)**

(iv) Traditional non-biodegradable plastic cups can be made from poly(phenylethene), commonly known as *polystyrene*.

Draw the repeating unit of poly(phenylethene).

**(1)**

(v) The manufacturers of PLA claim that the material will break down to compost in just 12 weeks.

Suggest **one** reason why PLA in landfill may take longer than 12 weeks to break down.

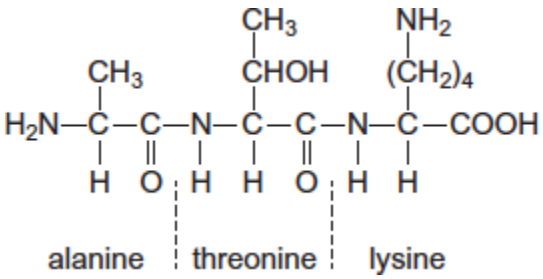
.....

.....

**(1)**

**(Total 22 marks)**

**6** (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.

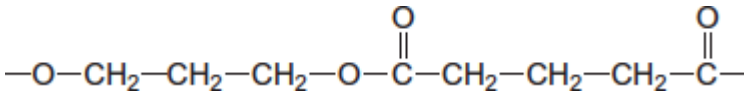
.....

**(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.

.....

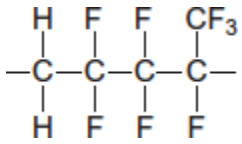
**(1)**

(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)**

**7** Acyl chlorides and acid anhydrides are important compounds in organic synthesis.

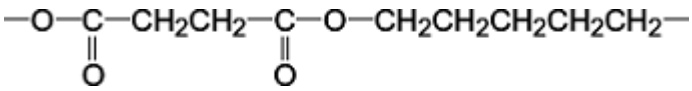
(a) Outline a mechanism for the reaction of $CH_3CH_2COCl$ with $CH_3OH$ and name the organic product formed.

Mechanism

Name of organic product .....

**(5)**

(b) A polyester was produced by reacting a diol with a diacyl chloride. The repeating unit of the polymer is shown below.



(i) Name the diol used.

.....

**(1)**

(ii) Draw the displayed formula of the diacyl chloride used.

**(1)**

(iii) A shirt was made from this polyester. A student wearing the shirt accidentally splashed aqueous sodium hydroxide on a sleeve. Holes later appeared in the sleeve where the sodium hydroxide had been.

Name the type of reaction that occurred between the polyester and the aqueous sodium hydroxide. Explain why the aqueous sodium hydroxide reacted with the polyester.

Type of reaction .....

Explanation .....

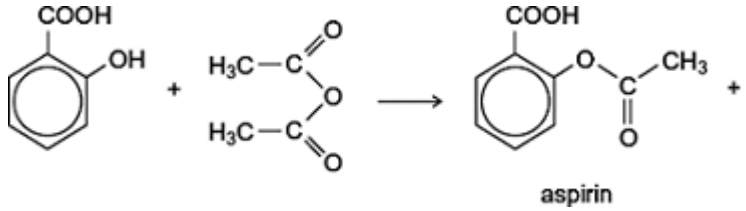
.....

.....

.....

**(3)**

(c) (i) Complete the following equation for the preparation of aspirin using ethanoic anhydride by writing the structural formula of the missing product.




aspirin

.....

**(1)**

(ii) Suggest a name for the mechanism for the reaction in part (c)(i).

.....

**(1)**

(iii) Give **two** industrial advantages, other than cost, of using ethanoic anhydride rather than ethanoyl chloride in the production of aspirin.

Advantage 1 .....

.....

.....

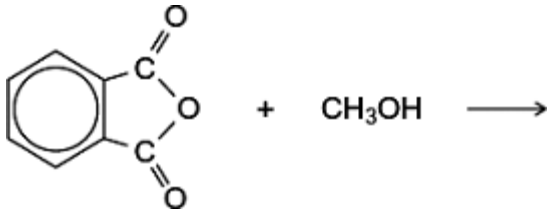
Advantage 2 .....

.....

.....

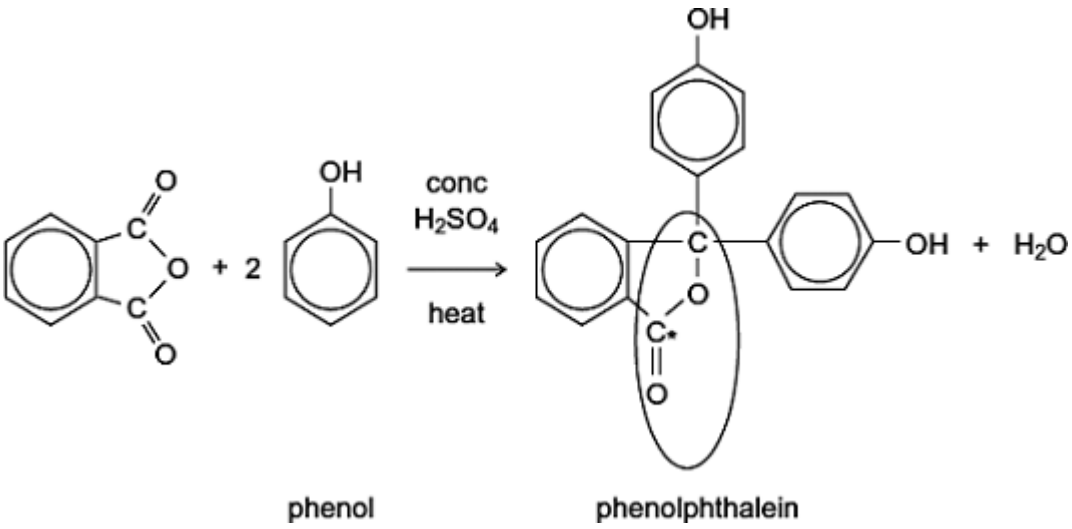
**(2)**

(d) Complete the following equation for the reaction of one molecule of benzene-1,2-dicarboxylic anhydride (phthalic anhydride) with one molecule of methanol by drawing the structural formula of the single product




**(1)**

(e) The indicator phenolphthalein is synthesised by reacting phthalic anhydride with phenol as shown in the following equation.




(i) Name the functional group ringed in the structure of phenolphthalein.

.....

**(1)**

(ii) Deduce the number of peaks in the $^{13}C$ n.m.r. spectrum of phenolphthalein.

.....

**(1)**

(iii) One of the carbon atoms in the structure of phenolphthalein shown above is labelled with an asterisk (*).
Use **Table 3** on the Data Sheet to suggest a range of δ values for the peak due to this carbon atom in the $^{13}C$ n.m.r. spectrum of phenolphthalein.

.....

**(1)**

(f) Phenolphthalein can be used as an indicator in some acid–alkali titrations.
The pH range for phenolphthalein is 8.3 – 10.0

(i) For **each** acid.alkali combination in the table below, put a tick (✓) in the box if phenolphthalein could be used as an indicator.

| **Acid** | **Alkali** | **Tick box (✓)** |
|---|---|---|
| sulfuric acid | sodium hydroxide | |
| hydrochloric acid | ammonia | |
| ethanoic acid | potassium hydroxide | |
| nitric acid | methylamine | |

**(2)**

(ii) In a titration, nitric acid is added from a burette to a solution of sodium hydroxide containing a few drops of phenolphthalein indicator.
Give the colour **change** at the end-point.

.....

**(1)**
**(Total 21 marks)**

**8** Common substances used in everyday life often contain organic compounds.

(a) State an everyday use for each of the following compounds.

(i) $CH_3(CH_2)_{17}COO^-\ Na^+$ .....

**(1)**

(ii) $CH_3(CH_2)_{19}COOCH_3$ .....

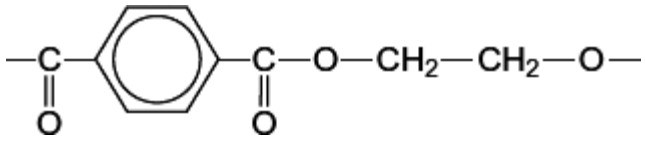
**(1)**

(iii) $[C_{16}H_{33}N(CH_3)_3]^+\ Br^-$ .....

**(1)**

(b) The following structures are the repeating units of two different condensation polymers.

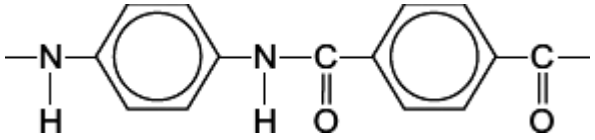
For each example, name the type of condensation polymer. Give a common name for a polymer of this type.

(i) 

Type of condensation polymer .....

Common name .....

**(2)**

(ii) 

Type of condensation polymer .....

Common name .....

**(2)**

(iii) Explain why the polymer in part (b)(ii) has a higher melting point than the polymer in part (b)(i).

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.....

*(Extra space)* .....

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**(2)**

**(Total 9 marks)**

**9** 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 $CH_3CH_2COCl$ with $CH_3NH_2$

Name of mechanism.....

Mechanism

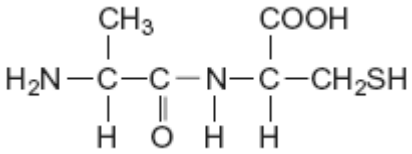
**(5)**

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

.....

**(1)**

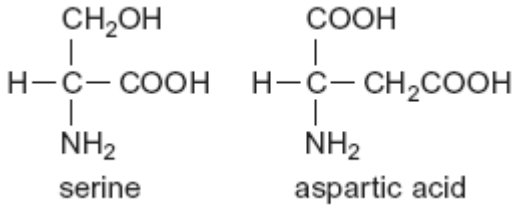
(c) The dipeptide shown below is formed from two different amino acids.



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)**

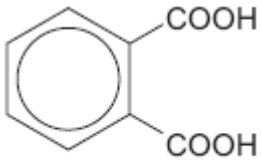
(iv) Draw the structure of the species formed when serine reacts with an excess of bromomethane.

**(1)**
**(Total 16 marks)**

**10** Items softened with plasticisers have become an essential part of our modern society.

Compound **S**, shown below, is commonly known as phthalic acid.

Esters of phthalic acid are called phthalates and are used as plasticisers to soften polymers such as PVC, poly(chloroethene).




**S**

(a) Give the IUPAC name for phthalic acid.

.....

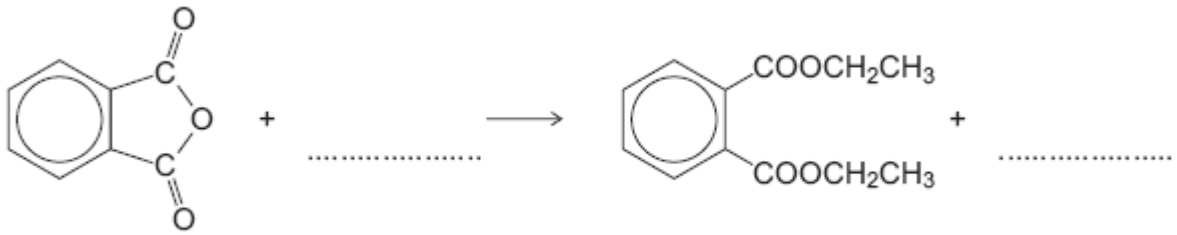
**(1)**

(b) Draw the displayed formula of the repeating unit of poly(chloroethene).

**(1)**

(c) The ester diethyl phthalate (DEP) is used in food packaging and in cosmetics.

(i) Complete the following equation showing the formation of DEP from phthalic anhydride.




DEP

**(2)**

(ii) Deduce the number of peaks in the $^{13}C$ n.m.r. spectrum of DEP.

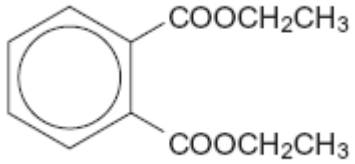
.....

**(1)**

(iii) One of the peaks in the $^{13}C$ n.m.r. spectrum of DEP is at δ = 62 ppm.

**Table 3** on the Data Sheet can be used to identify a type of carbon atom responsible for this peak.

Draw a circle around **one** carbon atom of this type in the structure below.




**(1)**

(d) The mass spectrum of DEP includes major peaks at *m/z* = 222 (the molecular ion) and at *m/z* = 177

Write an equation to show the fragmentation of the molecular ion to form the fragment that causes the peak at *m/z* = 177

.....

**(2)**

(e) Because of their many uses, phthalates have been tested for possible adverse effects to humans and to the environment.

An organisation that represents the manufacturers of plasticisers asserts that experimental evidence and research findings show that phthalates do not pose a risk to human health because they biodegrade in a short time scale.

According to the organization's research, phthalates do not represent a risk for humans or for the environment and they are biodegradable.

(i) Hydrolysis of DEP in an excess of water was found to follow first order kinetics.

Write a rate equation for this hydrolysis reaction using DEP to represent the ester.

.....

**(1)**

(ii) Suggest what needs to be done so that the public could feel confident that the research discussed above is reliable.

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*(Extra space)* .....

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**(2)**
**(Total 11 marks)**

**11** (a) Name compound **Y**, $HOCH_2CH_2COOH$

.....

**(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.

.....

**(1)**

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

**(1)**

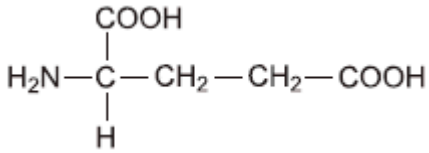
(iii) The organic product from part (ii) can also be polymerised.
Draw the repeating unit of the polymer formed from this organic product.

**(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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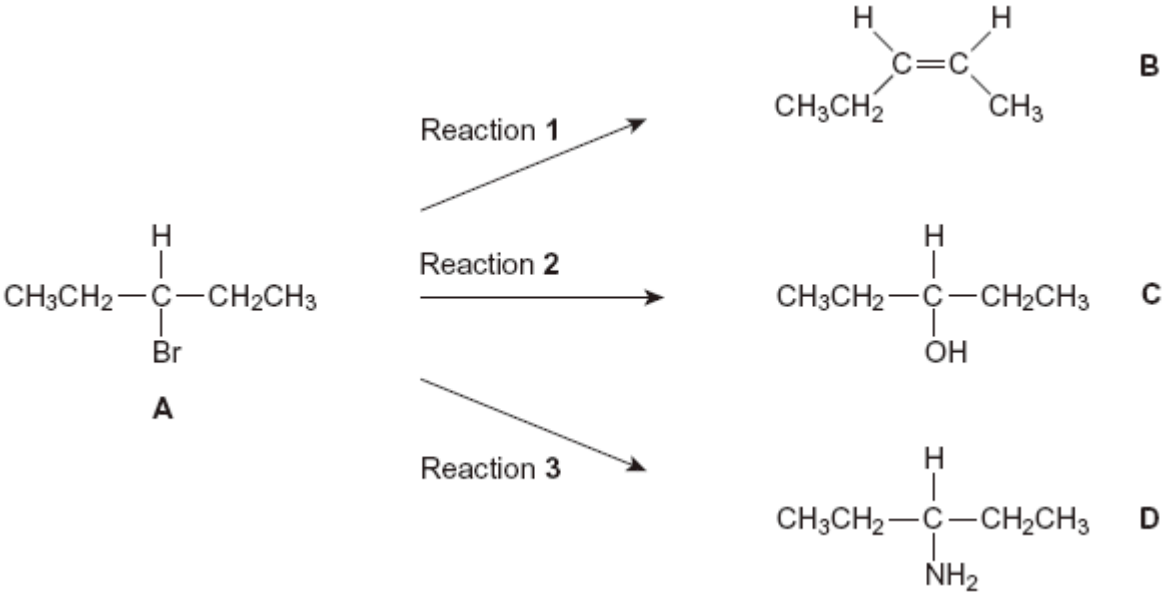
**(3)**
**(Total 13 marks)**

**12** Haloalkanes are useful compounds in synthesis.
Consider the three reactions of the haloalkane **A** shown below.




(a) (i) Draw a **branched-chain** isomer of **A** that exists as optical isomers.

**(1)**

(ii) Name the type of mechanism in Reaction **1**.

.....

**(1)**

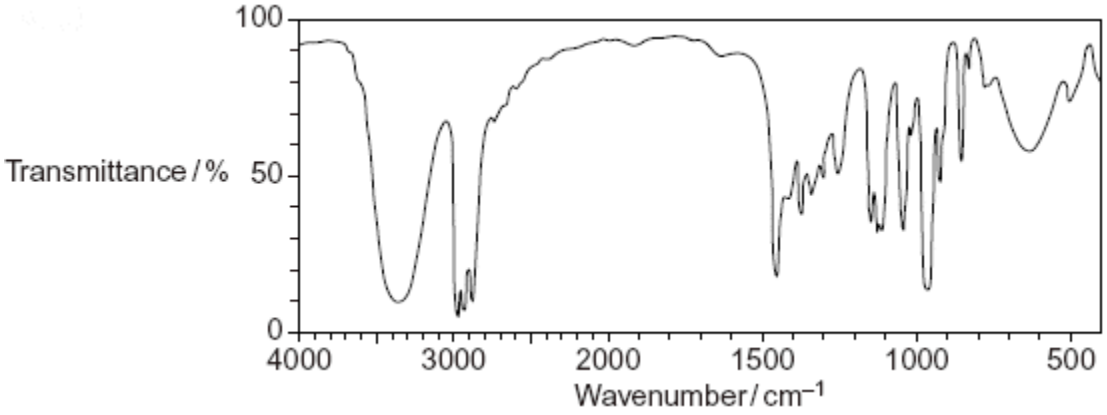
(iii) Give the full IUPAC name of compound **B**.

.....

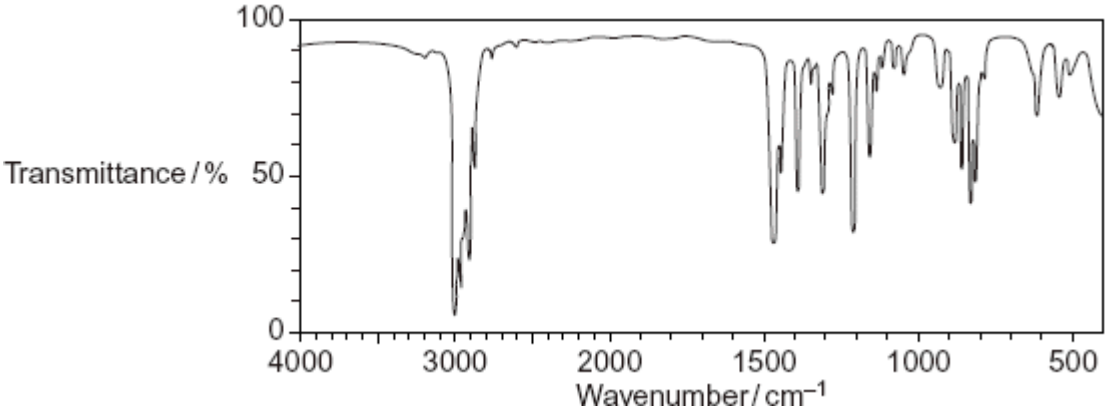
**(1)**

(b) The infrared spectra shown below are those of the four compounds, **A**, **B**, **C** and **D**.
Using **Table 1** on the Data Sheet, write the correct letter in the box next to each spectrum.

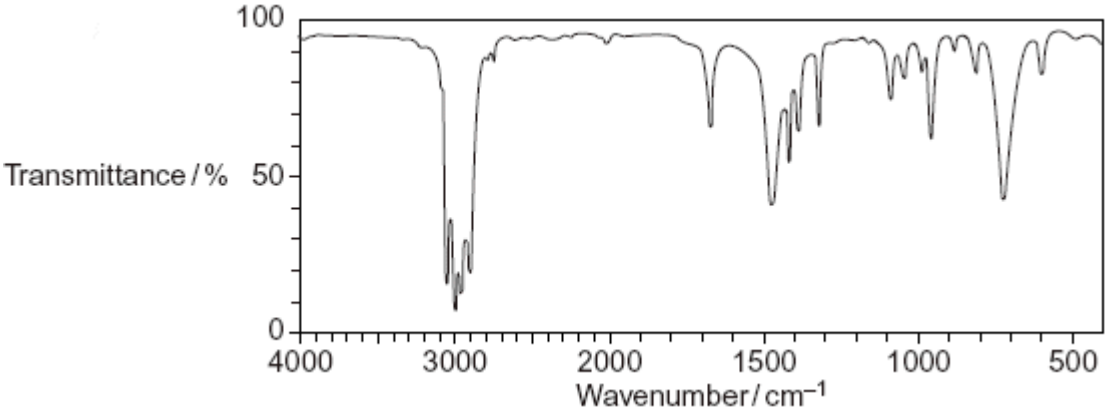
(i)



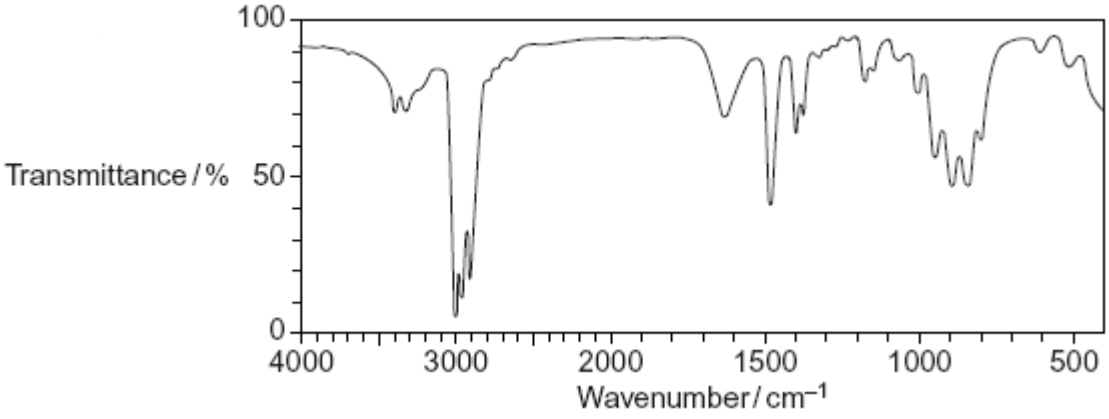

(ii)




(iii)



(iv)




**(4)**

(c) Draw the repeating unit of the polymer formed by **B** and name the type of polymerisation involved.

Repeating unit

Type of polymerisation .....

**(2)**

(d) (i) Outline a mechanism for Reaction **3**.

**(4)**

(ii) State the conditions used in Reaction **3** to form the maximum amount of the primary amine, **D**.

.....

**(1)**

(iii) Draw the structure of the secondary amine formed as a by-product in Reaction **3**.

**(1)**

(e) **D** is a primary amine which has three peaks in its $^{13}C$ n.m.r. spectrum.

(i) An isomer of **D** is also a primary amine and also has three peaks in its $^{13}C$ n.m.r. spectrum. Draw the structure of this isomer of **D**.

**(1)**

(ii) Another isomer of **D** is a tertiary amine. Its $^{1}H$ n.m.r. spectrum has three peaks. One of the peaks is a doublet. Draw the structure of this isomer of **D**.

**(1)**
**(Total 17 marks)**

**13** Esters have many important commercial uses such as solvents and artificial flavourings in foods.

Esters can be prepared in several ways including the reactions of alcohols with carboxylic acids, acid anhydrides, acyl chlorides and other esters.

(a) Ethyl butanoate is used as a pineapple flavouring in sweets and cakes.

Write an equation for the preparation of ethyl butanoate from an acid and an alcohol.

Give a catalyst used for the reaction.

.....

.....

.....

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**(4)**

(b) Butyl ethanoate is used as a solvent in the pharmaceutical industry.

Write an equation for the preparation of butyl ethanoate from an acid anhydride and an alcohol.

.....

.....

.....

.....

**(3)**

(c) Name and outline a mechanism for the reaction of $CH_3COCl$ with $CH_3OH$ to form an ester.

**(5)**

(d) The ester shown below occurs in vegetable oils. Write an equation to show the formation of biodiesel from this ester.

$CH_2OOCC_{17}H_{31}$
|
$CHOOCC_{17}H_{33}$
|
$CH_{23}OOCC_{17}H_{29}$

.....

.....

.....

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**(3)**

(e) Draw the repeating unit of the polyester Terylene that is made from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Although Terylene is biodegradeable, it is preferable to recycle objects made from Terylene.

Give **one** advantage and **one** disadvantage of recycling objects made from Terylene.

.....

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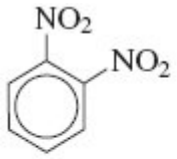
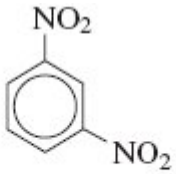
**(4)**
**(Total 19 marks)**

**14** Three isomers of $C_6H_4(NO_2)_2$ are shown below.




W




X


Y

(a) (i) Give the number of peaks in the $^{13}C$ n.m.r. spectrum of each isomer.

.....

.....

.....

**(3)**

(ii) Draw the displayed formula of the compound used as a standard in recording these spectra.

**(1)**

(b) Isomer **X** is prepared from nitrobenzene by reaction with a mixture of concentrated nitric acid and concentrated sulfuric acid.

The two acids react to form an inorganic species that reacts with nitrobenzene to form **X**.

(i) Give the formula of this inorganic species formed from the two acids and write an equation to show its formation.

.....

.....

.....

**(2)**

(ii) Name and outline a mechanism for the reaction of this inorganic species with nitrobenzene to form **X**.

**(4)**

(c) Isomer **Y** is used in the production of the polymer Kevlar.

**Y** is first reduced to the diamine shown below.

(i) Identify a suitable reagent or mixture of reagents for the reduction of **Y** to form this diamine. Write an equation for this reaction using [H] to represent the reducing agent.

.....

.....

.....

.....

**(2)**

(ii) This diamine is then reacted with benzene-1, 4-dicarboxylic acid to form Kevlar. Draw the repeating unit of Kevlar.

**(2)**

(iii) Kevlar can be used as the inner lining of bicycle tyres. The rubber used for the outer part of the tyre is made of polymerised alkenes.

State the difference in the biodegradability of Kevlar compared to that of rubber made of polymerised alkenes.

Use your knowledge of the bonding in these polymer molecules to explain this difference.

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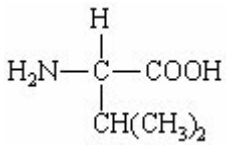
**(4)**
**(Total 18 marks)**

**15** 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.

.....

.....

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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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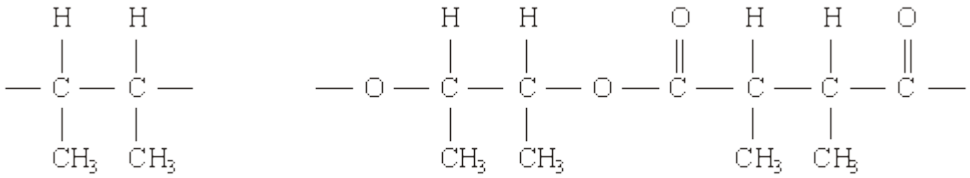
**(3)**
**(Total 14 marks)**

**16** (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* .....

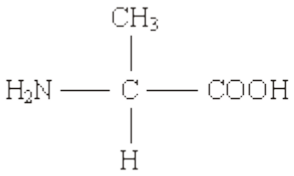
*Type of polymerisation* .....

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

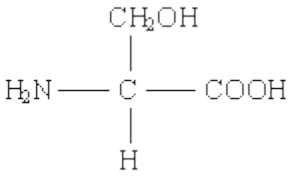
.....

**(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* .....

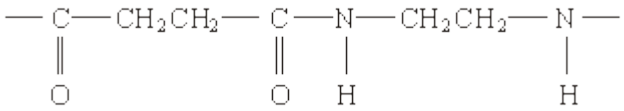
*Explanation* .....

.....

*Structure of an impurity*

**(5)**
**(Total 15 marks)**

**17** (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, $H_2NCH_2COOH$

**(1)**

(c) Explain why the melting point of aminoethanoic acid is much higher than that of hydroxyethanoic acid, $HOCH_2COOH$

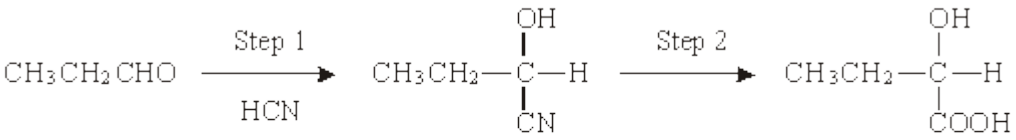
.....

.....

.....

**(2)**
**(Total 5 marks)**

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




propanal

**Q**

(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.

.....

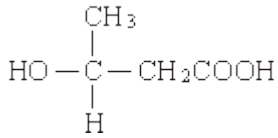
(ii) Two stereoisomers are formed by the dehydration of **Q**. Give the structures of these two isomers and name the type of stereoisomerism shown.

*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.

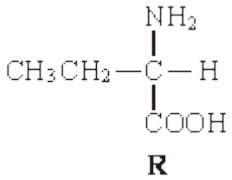
(ii) Suggest a reason why the polymer is biodegradeable.

.....

.....

**(2)**

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



**R**

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

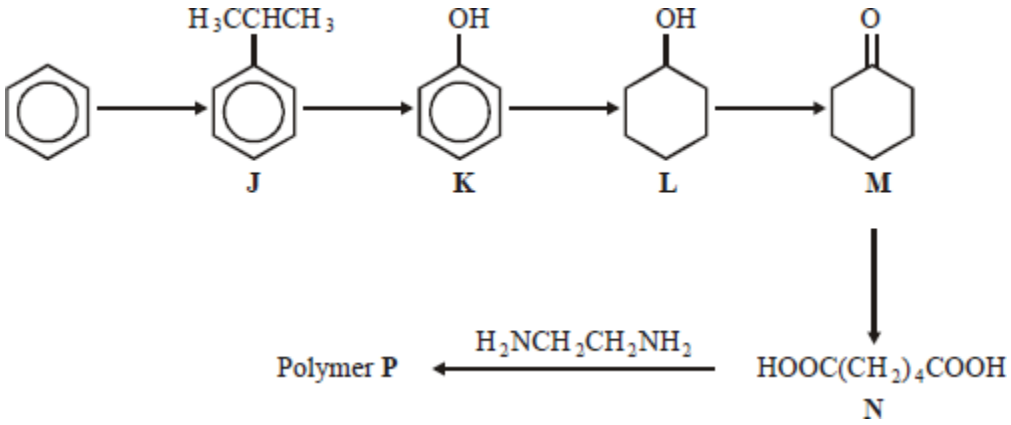
(ii) Draw the structure of the major organic product formed when an excess of **R** is reacted with bromomethane.

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

.....

**(3)**
**(Total 14 marks)**

**19** This question is about the following reaction scheme which shows the preparation of polymer **P**.




Polymer **P** is formed in a two-step reaction from **N**. The first stage is a neutralisation reaction. The volume, in $cm^3$, of a 0.20 mol $dm^{-3}$ solution of $H_2NCH_2CH_2NH_2$ required to neutralise $6.8 \times 10^{-3}$mol of the acid **N** is

**A** 17

**B** 34

**C** 68

**D** 136

**(Total 1 mark)**

**20** (a) The compound $H_2C=CHCN$ is used in the formation of acrylic polymers.

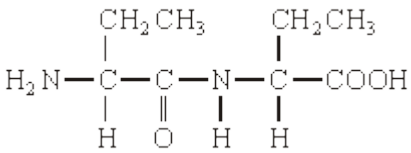
(i) Draw the repeating unit of the polymer formed from this compound.

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

.....

**(2)**

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



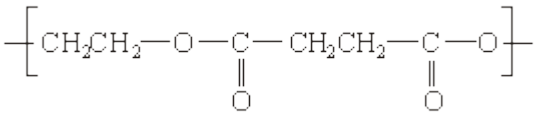
(i) Name this amino acid.

.....

(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.

.....

(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.

.....

.....

**(4)**
**(Total 8 marks)**

**21** Terylene is made by reacting benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Terylene is

**A** an addition polymer.

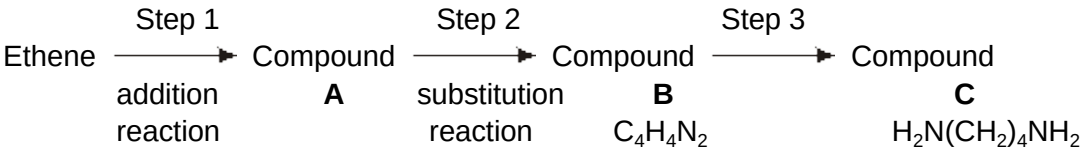
**B** a polyamide.

**C** a polyester.

**D** a nylon.

**(Total 1 mark)**

**22** (a) Compound **C**, $H_2N(CH_2)_4NH_2$, can be synthesised from ethene in three steps as shown below.




Name compound **C** and draw a structure for each of compounds **A** and **B**.
State the reagent(s) required for each step and name the type of reaction involved in the conversion of **B** into **C**.

**(7)**

(b) Draw the repeating unit of the polyamide formed when **C** reacts with hexanedioic acid.
Discuss the interactions between the chains of the polyamide.

**(4)**

(c) Explain why polyamides are degraded by sodium hydroxide whereas polymers such as poly(ethene) are not.

**(3)**
**(Total 14 marks)**

**23** (a) Synthetic polyamides are produced by the reaction of dicarboxylic acids with compounds such as $H_2N(CH_2)_6NH_2$

(i) Name the compound $H_2N(CH_2)_6NH_2$

.....

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

.....

**(2)**

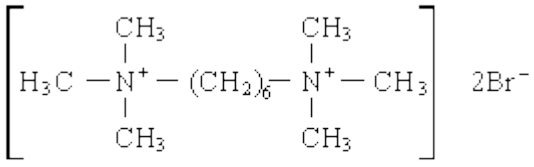
(b) Synthetic polyamides have structures similar to those found in proteins.

(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 $H_2N(CH_2)_6NH_2$ are also used to make ionic compounds such as **X**, shown below.



Compound **X**

(i) **X** belongs to the same type of compound as $(CH_3)_4N^+Br^-$
Name this **type** of compound.

.....

(ii) State a reagent which could produce **X** from $H_2N(CH_2)_6NH_2$ 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**.

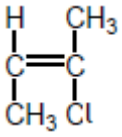
.....

**(4)**
**(Total 8 marks)**

## Mark schemes

**1**

(a)

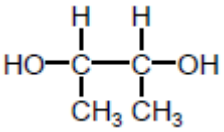


**1**

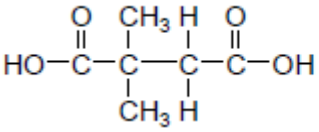
Addition

**1**

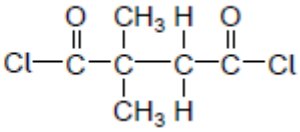
(b)



**1**



OR



**1**

(c) **Q** is biodegradable

**1**

Polar C=O group or δ+ C in **Q** (but not in **P**)

**1**

Therefore, can be attacked by nucleophiles (leading to breakdown)

**1**

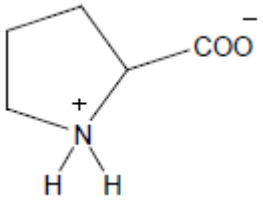
**[7]**

**2**

D

**[1]**

**3** (a) (i)



*Allow $CO_2^-$ and $NH_2^+$*

**1**

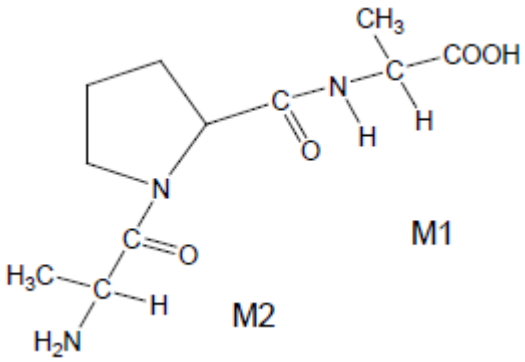
(ii) NOTE − **Two** marks for this clip

*M1 for alanine section bonded through N*

*M2 for alanine section bonded through C*

*But penalise error in proline ring*

**1**




*Allow MAX 1 for correct tripeptide in polymer structure*

**1**

(b) (i) 3-methylpent-2-ene

*Ignore E-Z, commas, spaces or missing hyphens*

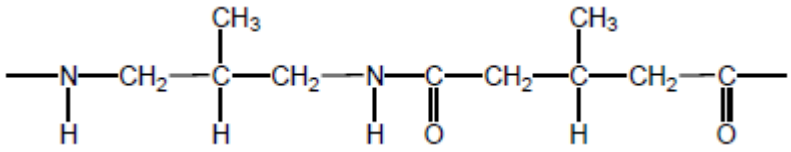
**1**

(ii) 4-amino-3-methylbutanoic acid

*Ignore commas, spaces or missing hyphens*

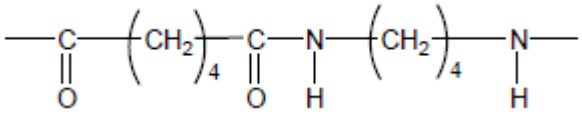
**1**

(iii)



*or any polyamide section containing*

*8 carbons plus two C=O plus two N-H, such as*



*Trailing bonds are required*

**1**

(iv) Non polar OR no polar groups / bonds (for attack by water / acids / alkalis / nucleophiles or for hydrolysis)

C-C bonds are strong

1

**[7]**

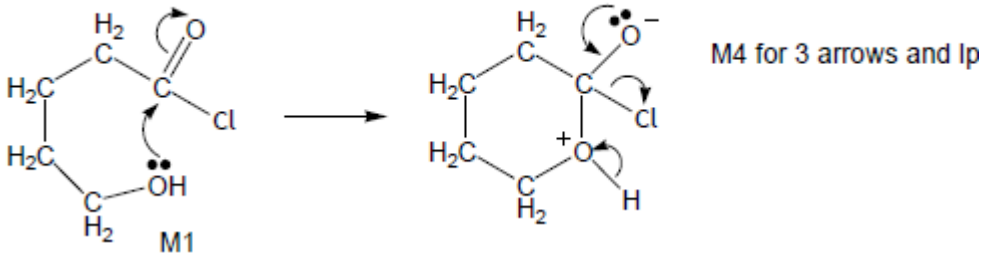
**4** (a) (i) (nucleophilic) addition-elimination

*Not electrophilic addition-elimination*

*Ignore esterification*

1

M2




M4 for 3 arrows and lp

M3 for structure

- *If wrong nucleophile used or O–H broken in first step, can only score M2.*
- *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 lose M2.*
- *M3 for correct structure <u>with charges</u> but lone pair on O is part of M4.*
- *Only allow M4 after correct / very close M3.*
- *Ignore HCl shown as a product.*

4

*a* 20-50 (ppm) or single value or range entirely within this range

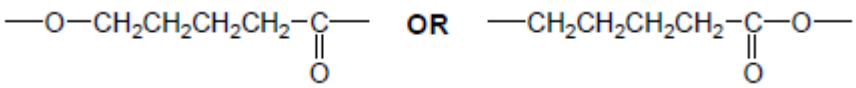
*If values not specified as a or b then assume first is a.*

1

*b* 50-90 (ppm) or single value or range entirely within this range

1

(ii)

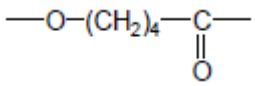



*Must have trailing bonds, but ignore n.*

1

**OR** $-OCH_2CH_2CH_2CH_2CO-$ **OR** $-CH_2CH_2CH_2CH_2COO-$

*Allow*



*but not* - $C_4H_8$-

one unit only

Condensation

**1**

(b)

| | Tollens' | Fehling's / Benedicts | Acidified potassium dichromate |
|---|---|---|---|

*Penalise wrong formula for Tollens or missing acid with potassium dichromate but mark on.*

**1**

| | | | |
|---|---|---|---|
| **J** | No reaction / no (visible) change / no silver mirror | No reaction / no (visible) change / stays blue / no red ppt | No reaction / no (visible) change / stays orange / does not turn green |

*Ignore 'clear', 'nothing'.*

*Penalise wrong starting colour for dichromate.*

**1**

| | | | |
|---|---|---|---|
| **K** | Silver <u>mirror</u> / grey <u>ppt</u> | Red <u>ppt</u><br><br>(allow brick red or red-orange) | (orange) turns green |

**1**

**J** Two (peaks)

*Allow trough, peak, spike.*

**1**

**K** Four (peaks)

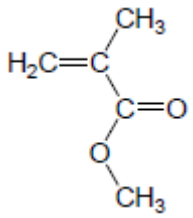
*Ignore details of splitting.*

*If values not specified as J or K then assume first is J.*

**1**

(c) If all the structures are unlabelled, assume that the first drawn ester is L, the second ester is M; the first drawn acid is N, the second P. The cyclic compound should be obvious.

**L**
ester



**OR** $H_2C=C(CH_3)COOCH_3$

***All $C_5H_8O_2$ L to P must have C=C.***

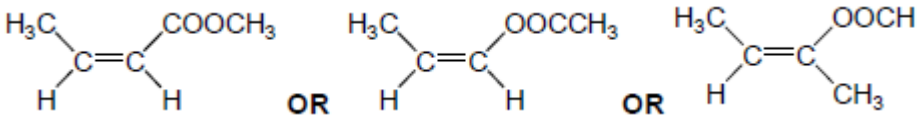
*Allow $CH_3$–.*

*Allow $-CO_2CH_3$ etc.*

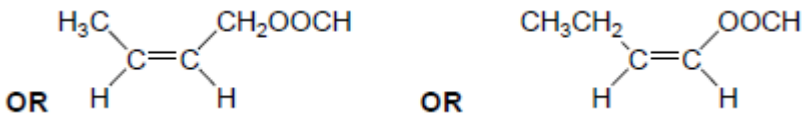
*Allow $CH_2C(CH_3)COOCH_3$.*

**1**

**M**
ester



$CH_3CH=CHCOOCH_3$ $CH_3CH=CHOOCCH_3$ $CH_3CH=C(CH_3)OOCH$



$CH_3CH=CHCH_2OOCH$ $CH_3CH_2CH=CHOOCH$

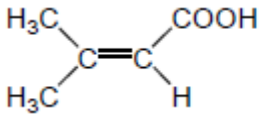
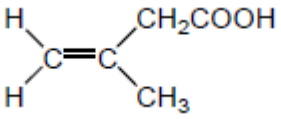
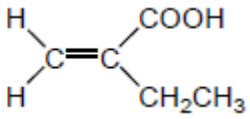
*Allow either E–Z isomer.*

*Allow $CH_3$– or $C_2H_5$– but not $CH_2CH_3$–.*

*Allow $CH_3CHCHCOOCH_3$ etc.*

**1**

**N**

acid  **OR**  **OR** 

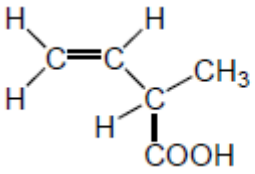
$(CH_3)_2C{=}CHCOOH$ $H_2C{=}C(CH_3)CH_2COOH$ $H_2C{=}C(COOH)CH_2CH_3$

*Allow $CH_3$– or $C_2H_5$– but not $CH_2CH_3$–.*

*Allow $-CO_2H$.*

*Not cyclic isomers.*

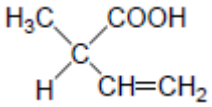
*Not the optically active isomer.*

 which is P anyway

*Allow $(CH_3)_2CCHCOOH$ etc.*

**1**

**P**

acid 

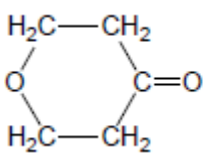
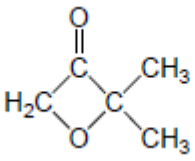
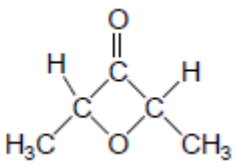
*Allow $-CO_2H$.*

$CH_3CH(COOH)CH{=}CH_2$

*Allow $CH_3CH(CO_2H)CHCH_2$ or $CH_3CH(CO_2H)C_2H_3$.*

**1**

**Q**

 **OR**  **OR** 

*Not cyclic esters.*

**1**

**[19]**

**5** (a) (i) 2-hydroxypropanoic acid

***OR***

2-hydroxypropan(-1-)oic acid

*Do not penalise different or missing punctuation or extra spaces.*

*Spelling must be exact and order of letters and numbers as here.*

*Can ignore −1− before –oic, but penalise any other numbers here.*

**1**

(ii) $C_{12}H_{22}O_{11} + H_2O \longrightarrow 4CH_3CH(OH)COOH$

*Allow $4C_3H_6O_3$*

***OR***

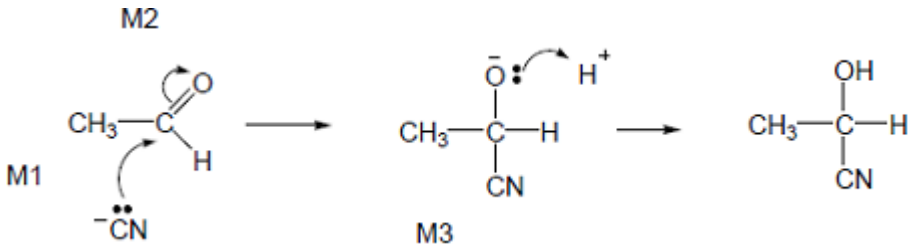
$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2CH_3CH(OH)COOH + C_6H_{12}O_6$

*Allow $2C_3H_6O_3$*

**1**

(b) (i) Nucleophilic addition

M4 for lp, arrow and H+




- *M1 lp and minus must be on C*
- *M1 and M4 include lone pair and curly arrow.*
- *M2 not allowed independent of M1, but allow following some attempt at attack on carbonyl C*
- *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 arrow in M4 to H of H-CN with arrow forming cyanide ion.*

**5**

(ii) Equal mixture of enantiomers / (optical) isomers

**1**

(iii) (Plane) polarized light

*If missing no further mark.*

**1**

(Polarised light) rotated by single enantiomer but unaffected by racemate

*Both needed; not allow bend, twist etc.*

**1**

(c) (i) $CH_3CH(OH)COOH + NaOH \rightarrow CH_3CH(OH)COONa + H_2O$

***OR*** $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$

*Not ambiguous mol formulae for product - must show COONa or $CO_2Na$ or $COO^-$ or $CO_2^-$*

**1**

(ii) $[H^+] = K_a$ ***OR*** $pH = pK_a$

**1**

pH = 3.86

*Allow more than 2 decimal places but not fewer.*

**1**

(iii) M1 buffer

*Ignore acidic but penalise alkaline or basic.*

**1**

**Any two out of the three marks M2 , M3 & M4**

M2 Large lactate concentration in buffer
***OR*** sodium lactate completely ionised

M3 added acid reacts with / is removed by lactate ion or $A^-$ or sodium lactate or salt

***OR*** equation $H^+ + A^- \rightarrow HA$

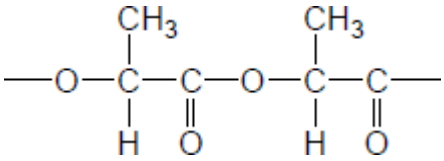
*Ignore reaction of $H^+$ with $OH^-$*
*Ignore reference to equilibrium unless it is shown.*

M4 ratio [HA] / [$A^-$] stays almost constant

*Ignore $H^+$ or pH remains constant.*

**Max 2**

(d) (i)



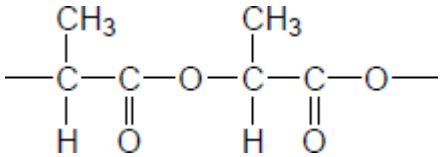
No marks if ester link missing
Correct ester link
allow –COO–

***NB Correct answer scores 2***

*Ignore n here (compare with (d)(iv).*
*Ignore brackets*

**1**

***OR***



All rest correct with trailing bonds

*If OH or COOH on either or both ends, lose one, ie dimer scores 1*

*If more than two repeating units, lose 1*

**1**

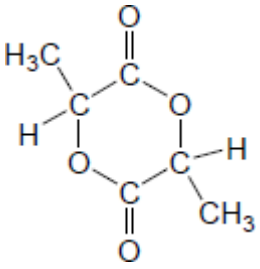
(ii) (Poly)ester ie allow ester

*Not terylene.*

*Ignore spaces and brackets in answer.*

**1**

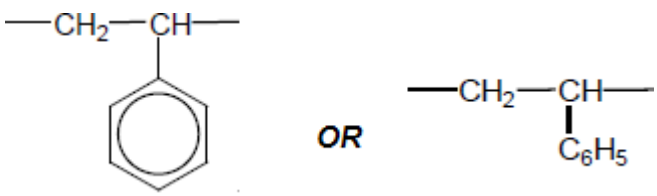
(iii)



*Allow any <u>cyclic $C_6H_8O_4$</u>*

**1**

(iv)



*Penalise n here (compare with (d)(i)*

*Ignore brackets.*

*Not allow Ph for phenyl.*

**1**

(v) In landfill, no air or UV, to assist decay
***OR*** not enough water or moisture (to hydrolyse polyester)

*Allow landfill has / contains:*

*no or few bacteria / micro-organisms / enzymes compared with compost heap*

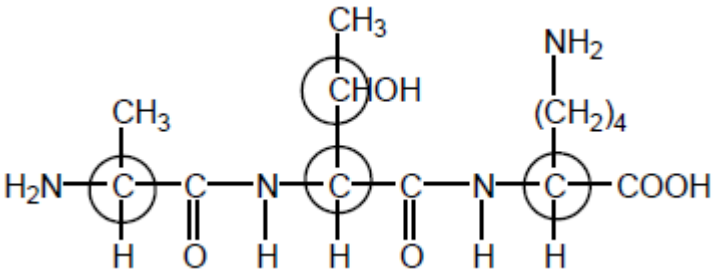
***OR** less oxygen*

***OR** <u>lower</u> temperature.*

**1**

**[22]**

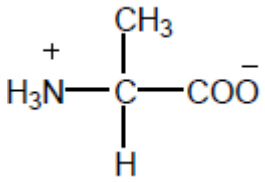
**6** (a) (i)



*These four only*

**1**

(ii)



*Allow − $NH_3^+$ and $^+NH_{3-}$*

**1**

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

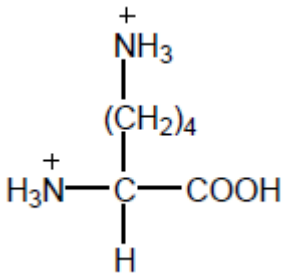
*Ignore 1 in butan-1-oic acid*

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*

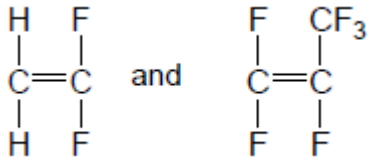
**1**

(c) (i) Addition

*Not additional*

**1**

(ii)

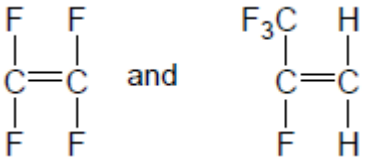


*Allow monomers drawn either way round*

*Allow bond to F in $CF_3$*

**1**

***OR***



*1 for each structure within each pair*

**1**

(d) c

*If wrong, CE = 0*

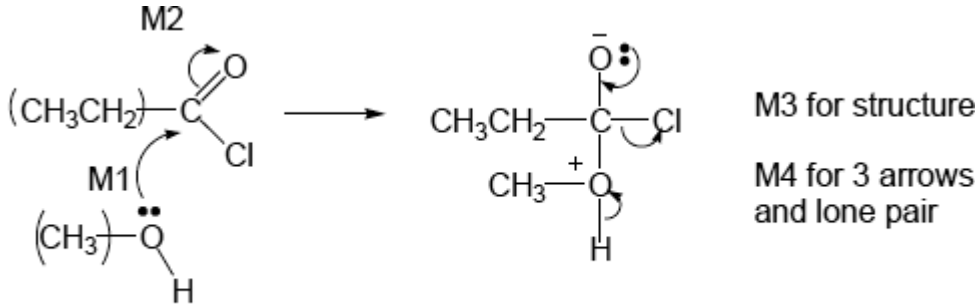
**1**

C-C or C-F bonds too strong

**1**

**[11]**

**7** (a)




methyl propanoate (**NO** mark for name of mechanism)

- *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, max1 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*
- *ignore $Cl^-$ removing $H^+$*

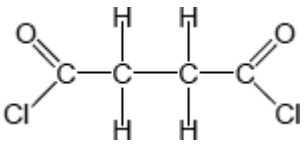
**4**

(b) (i) pentan<u>e</u>-<u>1,5</u>-diol

*Second 'e' and numbers needed*

*Allow <u>1,5</u>-pentan<u>e</u>diol but this is not IUPAC name*

(ii)



*Must show ALL bonds*

**1**

(iii) All three marks are independent

M1 (base or alkaline) Hydrolysis (allow close spelling)

**1**

*Allow (nucleophilic) addition-elimination or saponification*

M2 <u>δ+ C</u> in polyester

**1**

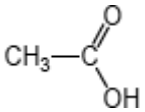
M3 reacts with $OH^-$ or hydroxide ion

**1**

*Not reacts with NaOH*

**1**

(c) (i)



*Allow $CH_3COOH$ or $CH_3CO_2H$*

**1**

(ii) (nucleophilic) <u>addition-elimination</u>

*Both addition and elimination needed and in that order*

OR

(nucleophilic) addition followed by elimination

*Do **not** allow electrophilic addition-elimination / esterification*

*Ignore acylation*

**1**

(iii) any **two** from: ethanoic anhydride is

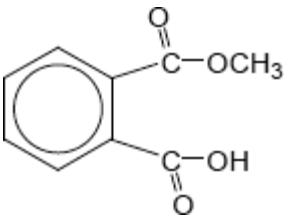
- less corrosive
- less vulnerable to hydrolysis
- less dangerous to use,
- less violent/exothermic/vigorous reaction OR more controllable rxn
- does not produce toxic/corrosive/harmful fumes (of HCl) OR does not produce HCl
- less volatile

***NOT*** *COST*

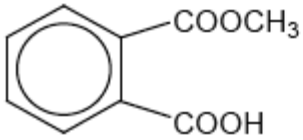
*List principle beyond two answers*

**2**

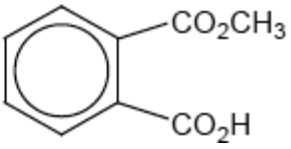
(d)



Allow



or



**1**

(e) (i) ester

*Do **not** allow ether*

*Ignore functional group/linkage/bond*

**1**

(ii) 12 or twelve (peaks)

**1**

(iii) 160 – 185

*Allow a number or range within these limits*

*Penalize extra ranges given*

*Ignore units*

**1**

(f) (i)

| | | |
|---|---|---|
| sulfuric acid | sodium hydroxide | ✓ |
| hydrochloric acid | ammonia | X or blank |
| ethanoic acid | potassium hydroxide | ✓ |
| nitric acid | methylamine | X or blank |

*4 correct scores 2*

*3 correct scores 1*

*2 or 1 correct scores 0*

**2**

(ii) Pink to colourless

*Allow 'red' OR 'purple' OR 'magenta' instead of 'pink'*

*Do **not** allow 'clear' instead of 'colourless'*

**1**

**[21]**

**8**

(a) (i) (As a) soap

*Allow washing, cleaning, degreasing, detergents*

**1**

(ii) (Bio)diesel or biofuel or fuel for cars/lorries

*Allow to make soap*

**1**

(iii) (Cationic) surfactant /detergent /fabric softener /germicide / shampoos / (hair) conditioners /spermicidal jelly

*Allow cleaning*

**1**

(b) (i) (Poly)ester

**1**

Terylene ***OR*** PET

*Allow polyester*

**1**

(ii) (Poly)amide

**1**

Kevlar ***OR*** nylons

*Ignore numbers with nylons Allow polyamide(e)*

**1**

(iii) (Independent marks)

*CE = 0*

Hydrogen bonding in b(ii)

**1**

Imfs in (b)(ii) are stronger

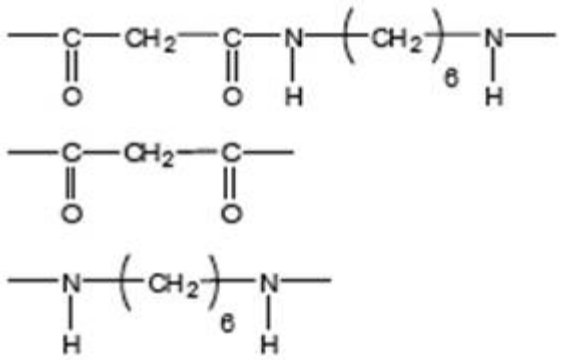
***OR***

H bonding stronger than dipole–dipole/van der Waals/ dispersion/London forces in b(i)

**1**

**[9]**

**9** (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*

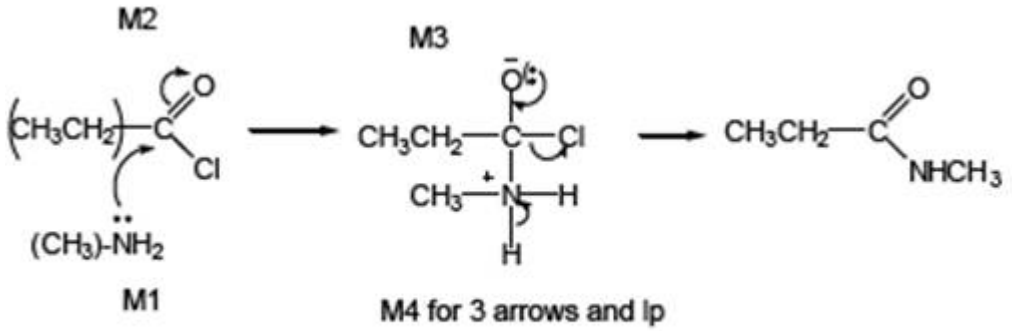
**1**

**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 $\delta$+ 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*

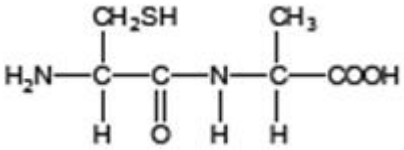
**4**

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

*Not N-methylpropaneamide*

**1**

(c)



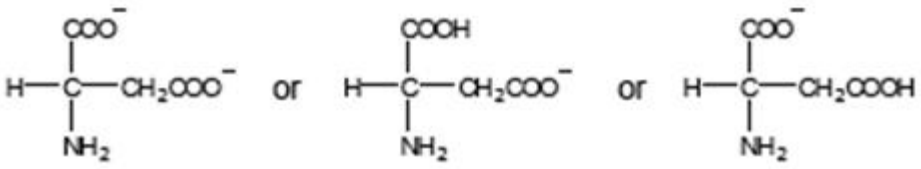

*Allow –CONH– or –COHN–*

**1**

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

**1**

(ii)



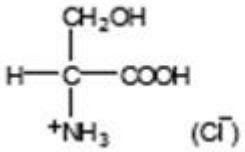
Must be salts of aspartic acid

*allow* $–CO_2^-$

*allow* $NH_2–$

**1**

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



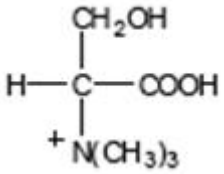
*allow* $–CO_2H$

*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**

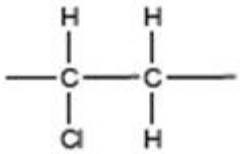
**[16]**

**10** (a) Benzene-1,2-dicarboxylic acid

*Allow 1,2-benzenedicarboxylic acid*

**1**

(b)



*Must show all bonds including trailing bonds*

*Ignore n*

**1**

(c) (i) 2 $C_2H_5OH$

*NB Two ethanols*

**1**

$H_2O$

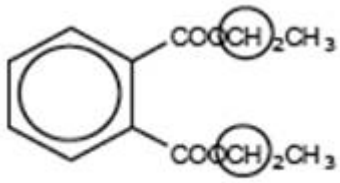
*but only one water*

**1**

(ii) 6 or six

**1**

(iii)

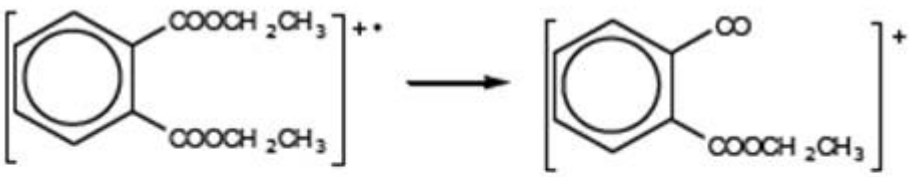


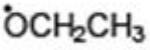
*Ignore overlap with O to the left or H to the right, but must only include this one carbon.*

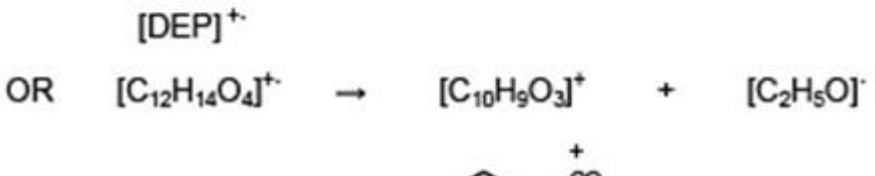
*either or allow both (as they are identical)*

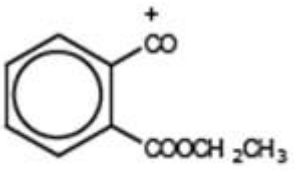
**1**

(d)









*Allow + on C or O in*

**1**

*Dot must be on O in radical*

**1**

(e) (i) Rate = *k*[DEP]

*Must have brackets but can be ( )*

**1**

(ii) Any **two** of

- experiment repeated/continued over a long period
- repeated by independent body/other scientists/avoiding bias
- investigate breakdown products
- results made public

*Not just repetition*

*Ignore animal testing*

**2 max**

**[11]**

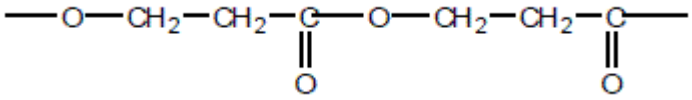
**11** (a) 3-hydroxypropanoic acid

*allow 3-hydroxypropionic acid*

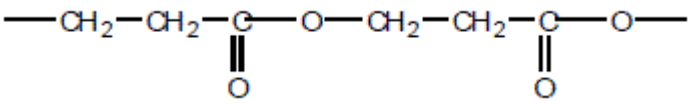
*must be correct spelling*

**1**

(b) (i) must show trailing bonds



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



*not allow dimer*

*allow –O–$CH_2CH_2COOCH_2CH_2CO$–*

*or –$CH_2CH_2COOCH_2CH_2COO$–*

*ignore ( ) or n*

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

**1**

(ii) condensation (polymerisation)

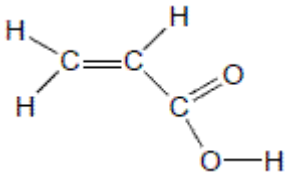
*Allow close spelling*

**1**

(c) (i) C=C or carbon-carbon <u>double</u> bond

**1**

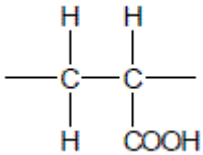
(ii)



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

**1**

(iii) must show trailing bonds

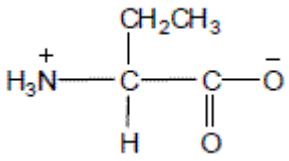


*allow polyalkene conseq on their c(ii)*

*ignore n*

**1**

(d)

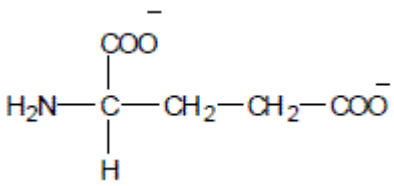


*allow $NH_3^+$ —*

*allow $COO^-$*

**1**

(e) (i)



*In (e), do not penalise a slip in the number of carbons in the $-CH_2CH_2-$ chain, but all must be bonded correctly*

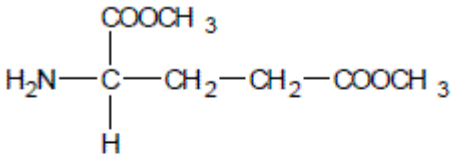
*NB two carboxylate groups*

*Allow COONa or $COO^-$ $Na^+$ but not covalent bond to Na*

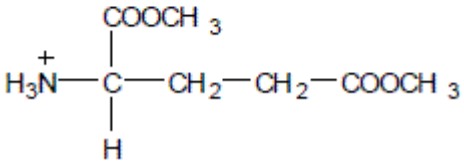
*allow $NH_2$–*

**1**

(ii)



**OR**



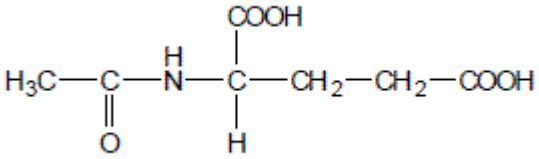
*In (e), do not penalise a slip in the number of carbons in the $-CH_2CH_2-$ chain, but all must be bonded correctly*

*NB two ester groups*

*allow $NH_2$– or $^+NH_3$–*

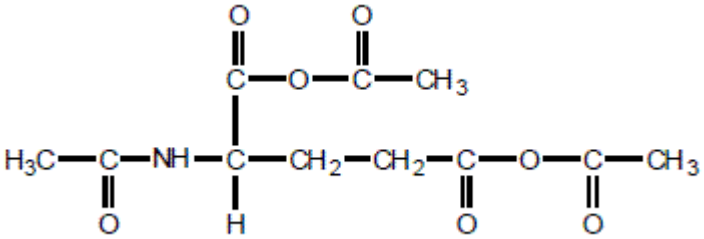
**1**

(iii)



*In 4(e), do not penalise a slip in the number of carbons in the -$CH_2CH_2$- 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 $R_f$ values

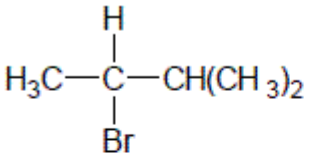
**OR**

(amino acids) travel at different speeds or take different times

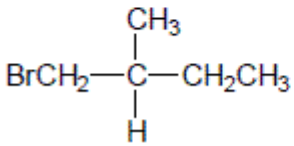
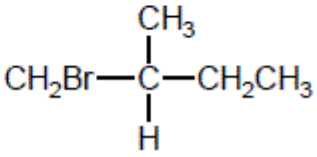
**1**

**[13]**

**12** (a) (i)



must be **branched** and chiral

or  or 

*not allow $C_3H_7$*

*allow $C_2H_5$ bonded to C either way round*

**1**

(ii) elimination

*allow base – elimination*

*but penalise any other qualification*

**1**

(iii) Z-pent-2-ene or cis-pent-2-ene either Z or cis is necessary
(allow Z-2-pentene or cis-2-pentene)

*with or without brackets around Z*
*with or without hyphens*

**1**

(b) (i) C

**1**

(ii) A

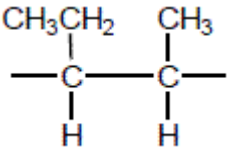
**1**

(iii) B

**1**

(iv) D

**1**

(c) 

*allow $C_2H_5$ bonded via C or H*

*must have both trailing bonds*
*ignore brackets or n*

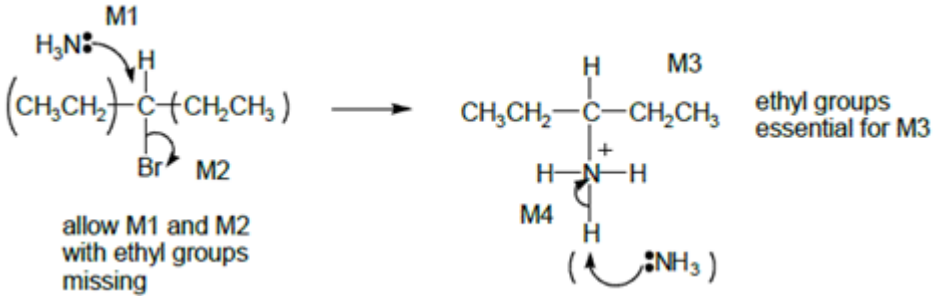
**1**

addition or radical or step or chain growth

*QOL not additional*

**1**

(d) (i)




*Allow SN1, i.e M2 first then attack of $NH_3$ on carbocation.*

*Allow $C_2H_5$ in M3 bonded either way*

*Allow with or without $NH_3$ to remove $H^+$ in M4, but lose mark if $Br^-$ used.*

*ignore δ+ or δ– unless wrong*

*+ on central C instead of δ + loses M2*

**4**

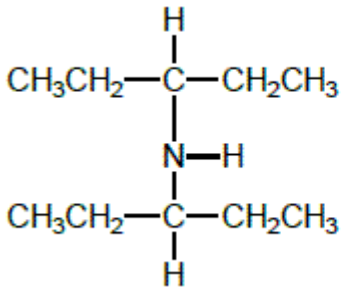
(ii) <u>excess</u> $NH_3$

*ignore reflux*

*allow conc ammonia in sealed tube*

**1**

(iii)

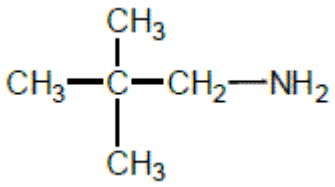


NOT $-C_5H_{11}$

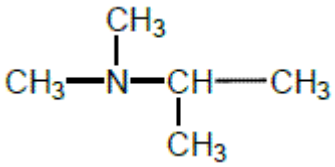
*Allow $C_2H_5$ bonded either way*

**1**

(e) (i)



**1**

(ii) 

*NOT $(C_2H_5)_2NCH_3$ which is tertiary with 3 peaks but its spectrum has no doublet.*

1

**[17]**

**13** (a) **M1** $CH_3CH_2CH_2COOH$

*not $C_3H_7COOH$*

1

**M2** $CH_3CH_2OH$ or $C_2H_5OH$

1

**M3** $CH_3CH_2CH_2COOCH_2CH_3 + H_2O$

*allow $C_3H_7COOC_2H_5$*

*penalise M3 for wrong products and unbalanced equation*

1

**M4** $H_2SO_4$ or HCl or $H_3PO_4$ conc or dil or neither

*not $HNO_3$*

1

(b) **M1** $CH_3CH_2CH_2CH_2OH$

1

*not $C_4H_9OH$*

**M2** $(CH_3CO)_2O$

1

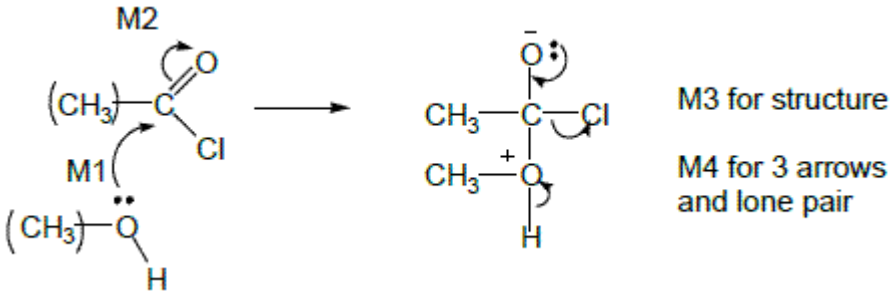
**M3** $\rightarrow CH_3COOCH_2CH_2CH_2CH_3 + CH_3COOH$

*allow $CH_3COOC_4H_9$*

*penalise M3 for wrong products and unbalanced equation*

1

(c) (nucleophilic) addition-elimination




*not acylation alone*

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

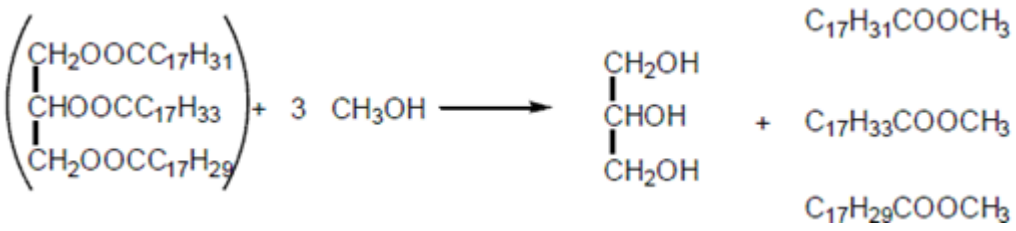
*+C=O loses M2*

*only allow M4 after correct or v close M3*

*ignore $Cl^-$ removing $H^+$*

**5**

(d)




(1) (1) (1)

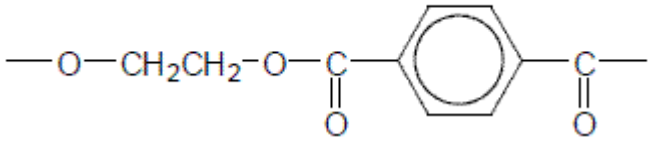
*ignore errors in initial triester*

*First mark for $3CH_3OH$*

*Third mark for all three esters*

**3**

(e) not – $C_2H_4$ –



*First mark for correct ester link second mark for the rest including trailing bonds*

*If ester link wrong, lose second mark also*

**2**

Adv reduces landfill
saves raw materials
lower cost for recycling than making from scratch
reduces $CO_2$ emissions by not being incinerated

*not allow cost without qualification*
*ignore energy uses*

**1**

Disad difficulty/cost of collecting/sorting/processing
product not suitable for original purpose, easily contaminated

*not allow cost without qualification*
*ignore energy uses*

**1**

**[19]**

**14** (a) (i) **W** 3

**1**

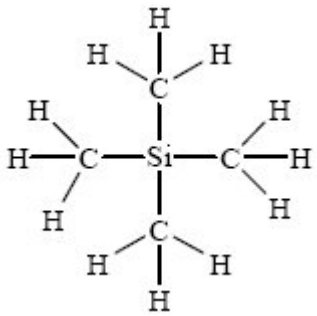
**X** 4

**1**

**Y** 2

**1**

(ii)



*displayed formula shows ALL bonds*

**1**

(b) (i) $NO_2^+$

*allow + anywhere*
*can score in equation*

**1**

$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

**1**

***OR***

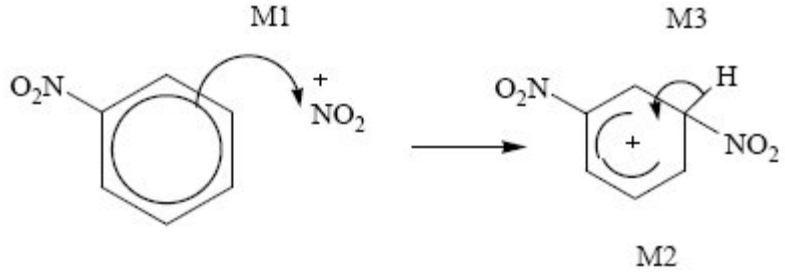
$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$

*or use two equations via $H_2NO_3^+$*

(ii) electrophilic substitution

*Not Friedel Crafts*

**1**




Allow Kekule structures

+ must be on N of $^+NO_2$ (which must be correct)

both $NO_2$ must be correctly positioned and bonded to gain M2

*M1 arrow from circle or within it to N or to + on N*
*horseshoe must not extend beyond C2 to C6 but can be smaller*
*+ not too close to C1*
*M3 arrow into hexagon unless Kekule*
*allow M3 arrow independent of M2 structure*
*ignore base removing H in M3*

**3**

(c) (i) $H_2$/Ni or $H_2$/Pt or Sn/HCl or Fe/HCl (conc or dil or neither)

allow dil $H_2SO_4$

ignore mention of NaOH

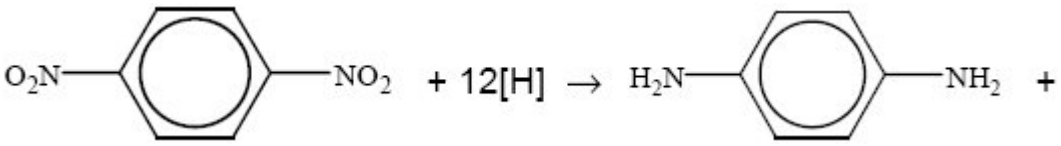
*Not $NaBH_4$*

*Not $LiAlH_4$*

*Not $Na/C_2H_5OH$*

*not conc $H_2SO_4$ or any $HNO_3$*

**1**




$4H_2O$

Or $6H_2$

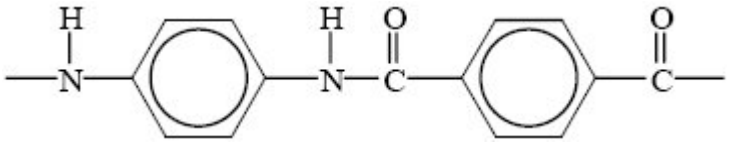
*allow $C_6H_4(NO_2)_2$ etc ,*

*allow $NO_2$– $NH_2$–*

*i.e. be lenient on structures, the mark is for balancing equ*

**1**

(ii)




*allow –CONH*

*ignore $[\ ]_n$ as in polymer*

1st mark for correct peptide link

2nd mark for the rest correct including trailing bonds

**2**

(iii) **M1** Kevlar is <u>biodegradeable</u> but polyalkenes not

*allow Kevlar is <u>more</u> biodegradeable*

**1**

**M2** Kevlar has <u>polar</u> bonds/is a (poly) amide/has peptide link

*comment on structure of Kevlar*

**1**

**M3** can be hydrolysed/attacked by nucleophiles/acids/ bases/enzymes

**1**

**M4** polyalkenes <u>non polar</u>/has <u>non-polar</u> bonds

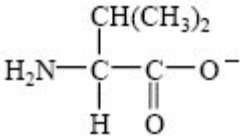
*comment on structure of polyalkenes but not just strong bonds*

**1**

**[18]**

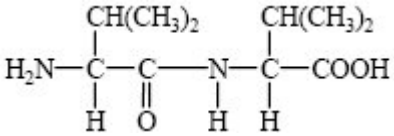
**15**

(a) (i)



1

(ii)



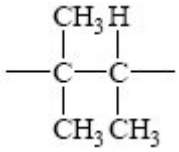
1

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

*do not penalise any error twice.*

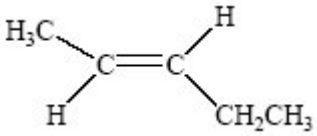
1

(b) (i)



1

(ii)

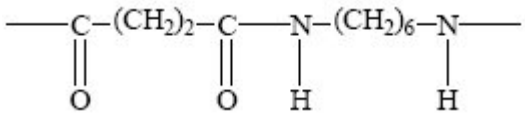


1

(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]**

**16** (a) (i) $CH_3CH=CHCH_3$

1

Addition or radical (**QoL**)

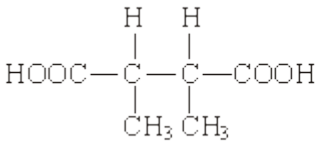
1

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

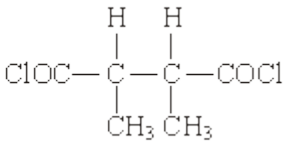
1

butan(e)–2,3–diol or 2,3–butan(e)diol

1



allow



1

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

ignore –1,4–

1

condensation (**QoL**)

1

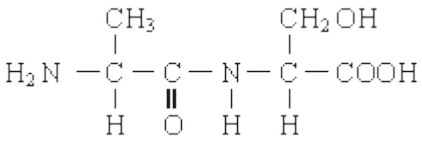
(iii) NaOH or HCl etc or $Na_2CO_3$

*Allow conc sulphuric/nitric*

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

1

(b) Structure 1



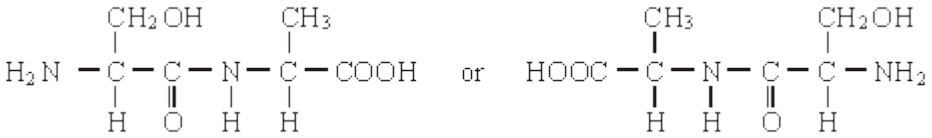
*Allow –CONH– and –COHN–*

*Allow zwitterions*

***NOT polypeptides/repeating units***

**1**

Structure 2 either of



**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]**

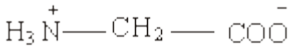
**17** (a) polyamide or nylon (2,4)

*(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

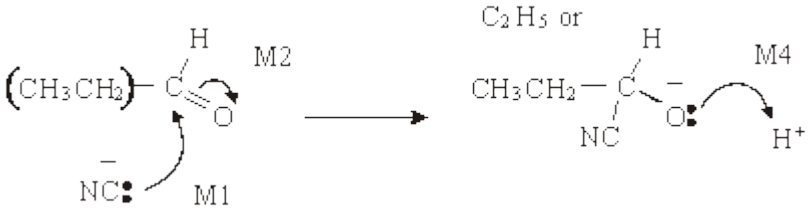
*(e.g. stronger Hydrogen bonding in aminoethanoic acid scores 0)*

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

**1**

**[5]**

**18** (a) necleophilic addition;




**1**

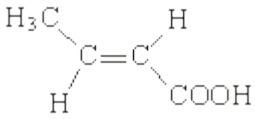
M3 structure;

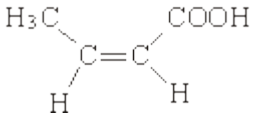
*(be lenient on position of charge on CN– )*
*(M2 not allowed independent of M1,*
*but allow M1 for correct attack on C+*
*if M2 show as independent first.)*
*(+on C of C=O loses M2 but ignore $\delta$+ if correct)*
*(M4 for arrow and lone pair (only allow for correct M3 or close))*

**4**

(b) (i) 2-hydroxybutanoic acid

**1**

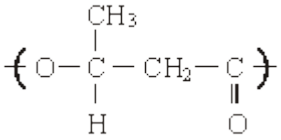
(ii) 



**1**

geometric(al) or cis-trans

**1**

(c) (i) 

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

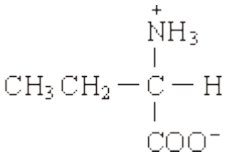
**1**

(ii) can be hydrolysed

OR

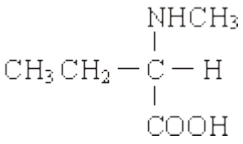
can be reacted with/attacked by acid/base/nucleophiles/$H_2O$/$OH^-$;

**1**

(d) (i) 

*(allow $-NH_3^+$)*

**1**

(ii) 

*(or zwitterions product)*

**1**

(iii) nucleophilic substitution;

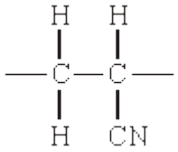
**1**

**[14]**

**19** B

**[1]**

**20** (a) (i)



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

**1**

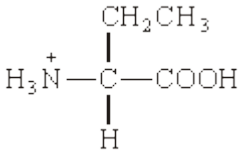
(ii) Addition or radical

**1**

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

**1**

(ii)

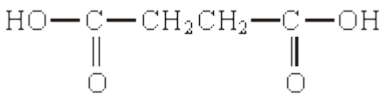


**1**

(c) (i) $C_3H_4O_2$

**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]**

**21** C

**[1]**

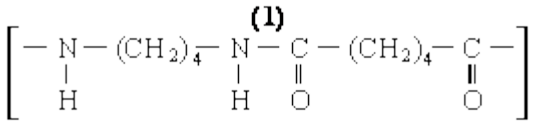
**22**

(a) 1, 4-diaminobutane or butane -1, 4-diamine **(1)**
A: $BrCH_2CH_2Br$ **or** $ClCH_2CH_2Cl$ **(1)**
B: $NC\ CH_2CH_2CN$
Step 1: $Br_2$ or $Cl_2$ **(1) (ignore aq)**
Step 2: KCN **(1) (NOT HCN)**
Step 3: $H_2$ / Ni **or** $LiAlH_4$ **or** Na / $C_2H_5OH$ **(1) (NOT $NaBH_4$)**
Hydrogenation only for $H_2$ / Ni, **or** nucleophilic addition only for $LiAlH_4$**(1)**

*OR reduction or addition*

**7**

(b)



**(1)**

**(1)**

QL hydrogen bonding **(1)**

Polarity of H-bonding shown or discussed **(1)**

**4**

(c) Polyamides / peptide link can be hydrolysed **(1)**

*OR polyalkenes cannot be hydrolysed*

QL $OH^-$ attacks peptide link or $C^{d+}$ **(1)**
poly(ethene) non-polar **(1)**

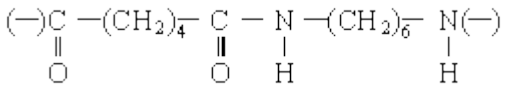
**3**

**[14]**

**23**

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

(ii)

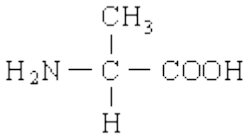


**(1)**

*Allow –CONH–*

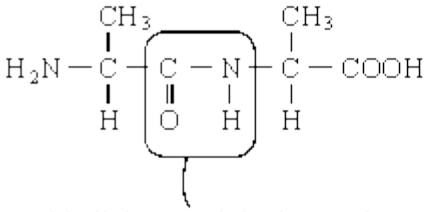
**2**

(b) (i)



**(1)**

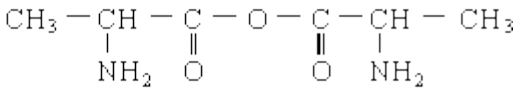
(ii)



**(1)**

peptide link essential : the rest is consequential on b(i)
(allow CONH)

allow anhydride



**2**

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

*(not ion, not compound)*

*Allow quarternery*

(ii) *Reagent*: $CH_3Br$ or bromomethane **(1)**

*penalise $CH_3Cl$ but allow excess for any halomethane*

*Condition*: excess ($CH_3Br$) **(1)**

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

**4**

**[8]**