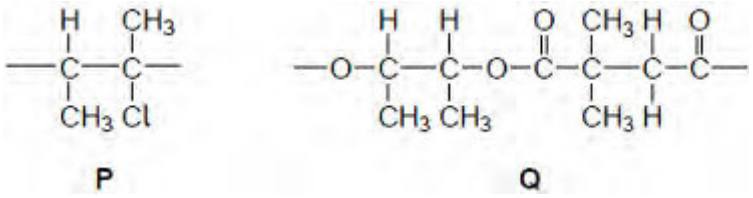
Q1. Repeating units of two polymers, **P** and **Q**, are shown in the figure below.



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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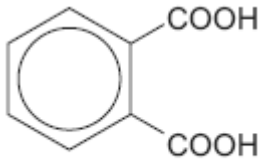
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(3)
(Total 7 marks)

Q2. 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.

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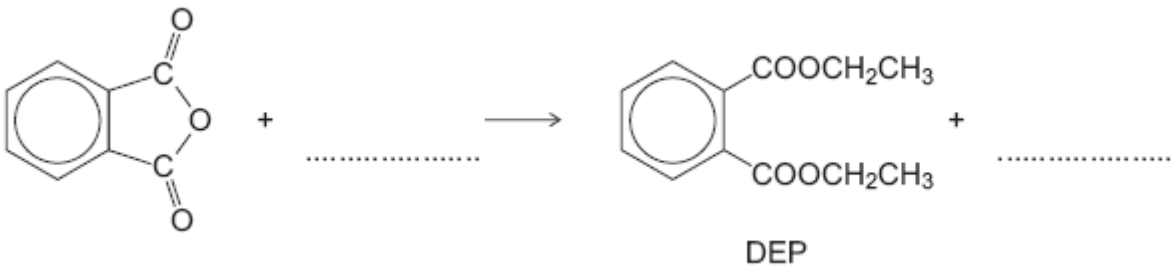
(1)

(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.

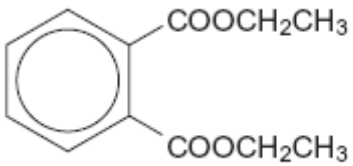
.....

(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.

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(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)

Q3. 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.

.....

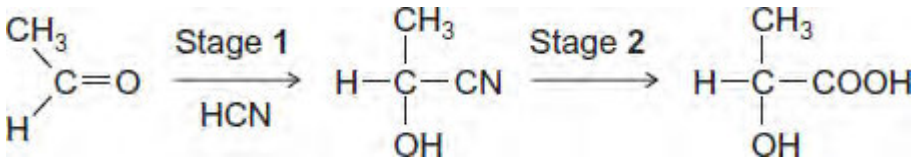
(1)

(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 1.38×10^{-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.

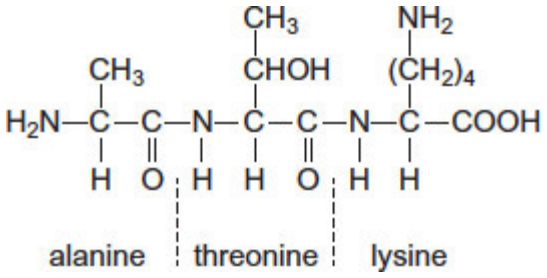
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(1)

(Total 22 marks)

Q4.(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.

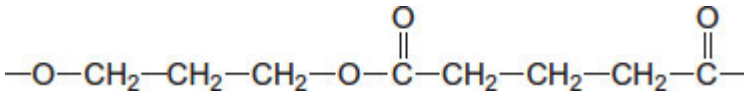
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(1)

(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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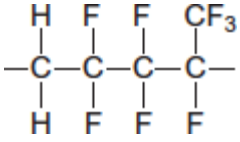
(1)

(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.

.....

(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)

Q1. 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.

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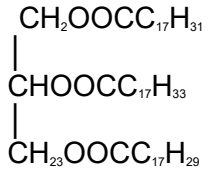
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(3)

(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.



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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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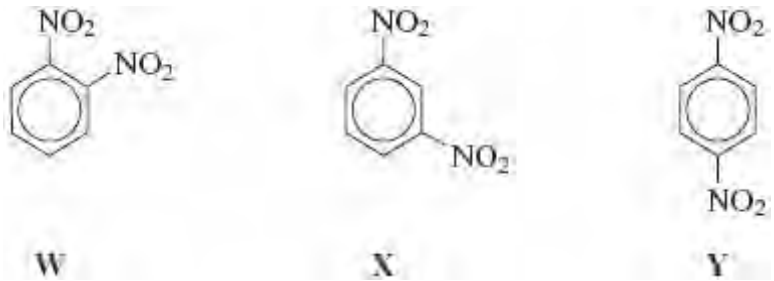
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(4)
(Total 19 marks)

Q2. Three isomers of $C_6H_4(NO_2)_2$ are shown below.



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

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(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.

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(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.

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(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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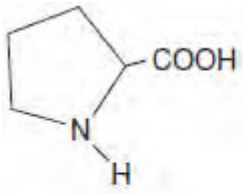
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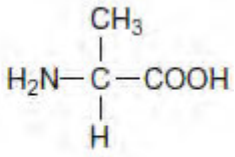
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(4)
(Total 18 marks)

Q1.(a) The structures and common names of two amino acids are shown.



proline



alanine

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

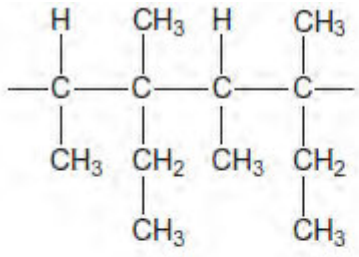
(1)

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

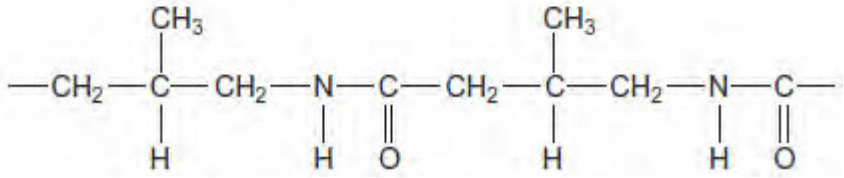
(2)

(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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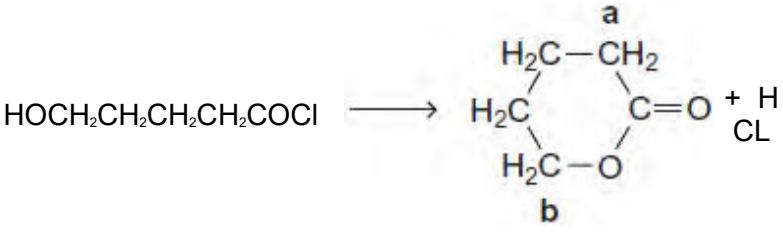
(1)

(Total 7 marks)

Q2. 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.

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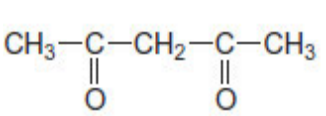
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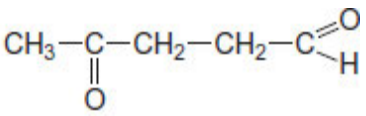
(2)

(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 ^{1}H n.m.r. spectrum.

(5)
(Total 19 marks)

Q3. 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.

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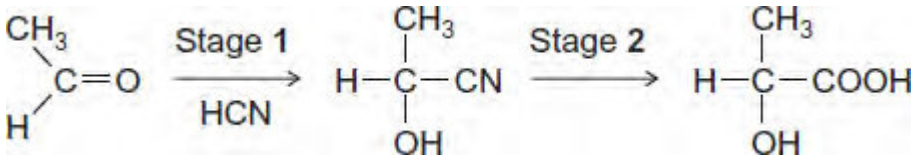
(1)

(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)*.

.....

.....

.....

(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 1.38×10^{-4} mol dm^{-3} at 298 K.

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

.....

.....

.....

.....

(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.

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(1)

(Total 22 marks)

Q4. Which compound can polymerise by reaction with itself?

A $NH_2CH_2CH_2NH_2$ ⬭

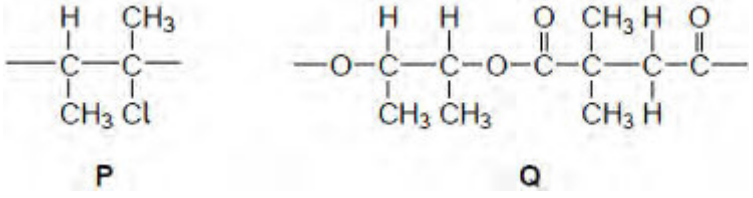
B $CH_3CH_2CONH_2$ ⬭

C $HOOCCH_2COOH$ ⬭

D NH_2CH_2COCl ⬭

(Total 1 mark)

Q5. 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 .....

.....

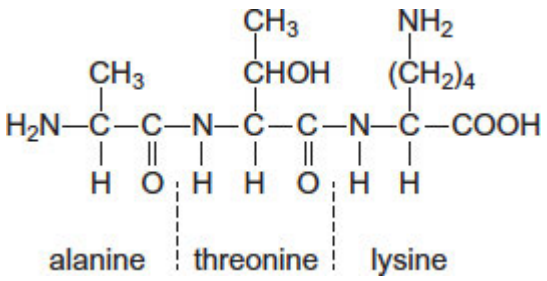
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(3)
(Total 7 marks)

Q1.(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.

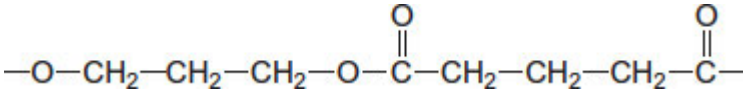
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(1)

(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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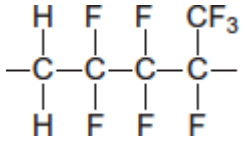
(1)

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

.....

(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 .....

.....

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(2)
(Total 11 marks)

Q2. Acyl chlorides and acid anhydrides are important compounds in organic synthesis.

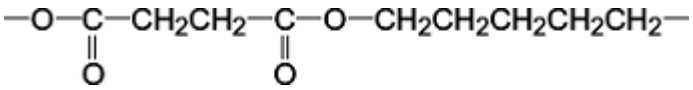
(a) Outline a mechanism for the reaction of CH_3CH_2COCl with CH_3OH and name the organic product formed.

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 .....

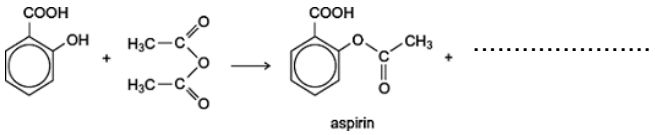
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.....

.....

(3)

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



.....

(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 .....

.....

.....

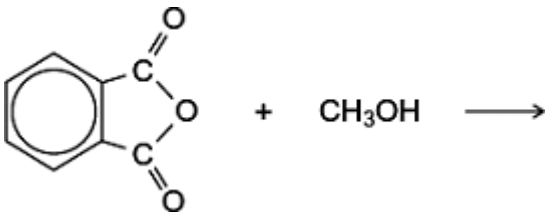
Advantage 2 .....

.....

.....

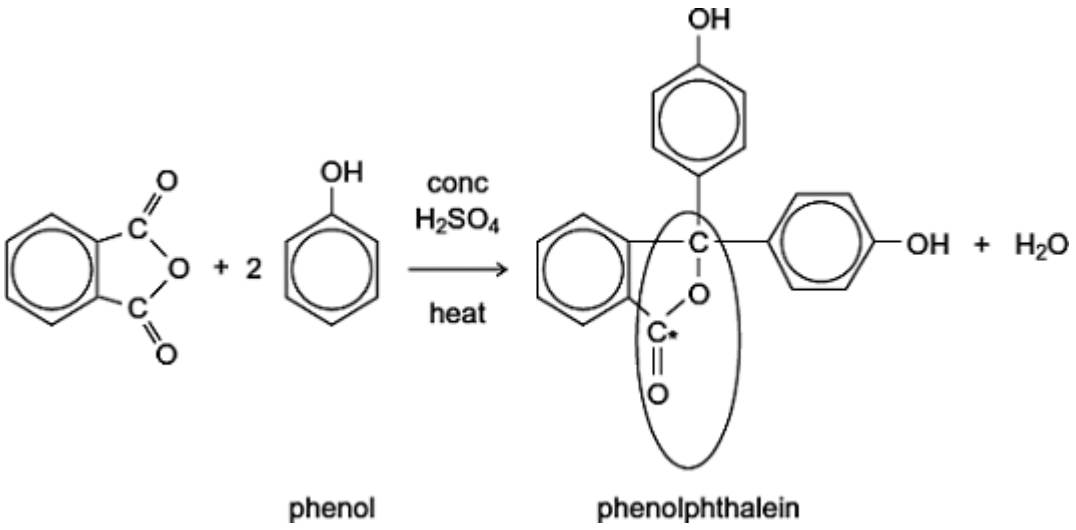
(2)

(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)

Q3. 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.

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

.....

(3)

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

Name of mechanism.....

Mechanism

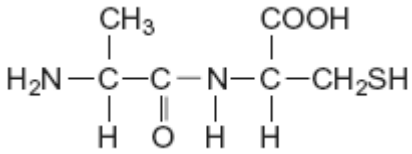
(5)

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

.....

(1)

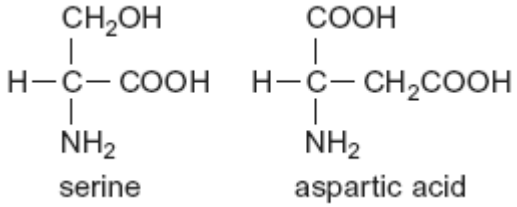
(c) The dipeptide shown below is formed from two different amino acids.



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)

Q4. 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) $CH_3(CH_2)_{19}COOCH_3$ .....

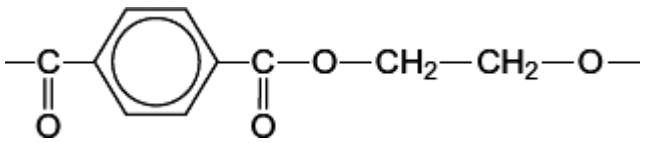
(1)

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

(1)

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

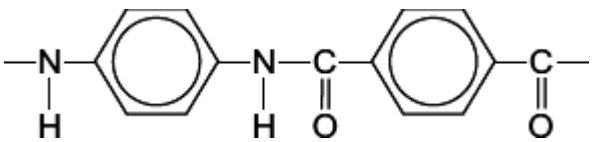
For each example, name the type of condensation polymer. Give a common name for a polymer of this type.

(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).

.....

.....

.....

(Extra space) .....

.....

(2)

(Total 9 marks)