AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.12 POLYMERS

SCORE	PERCENTAGE
/130	%

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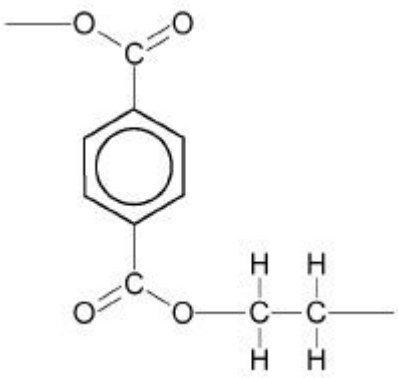
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Q1.

The structure of part of a polyester chain is shown.



Which statement correctly explains why plastics made from this polyester only soften at high temperatures?

A Hydrogen bonds and van der Waals' forces exist between polyester chains. ⬭

B Permanent dipole-dipole forces and van der Waals' forces exist between polyester chains. ⬭

C The carbon-carbon bonds in the chain are strong. ⬭

D The carbon-oxygen bonds in the chain are strong. ⬭

(Total 1 mark)

Q2.

Which polymer is least likely to be biodegraded after several years in a landfill site?

A Kevlar ⬭

B Nylon ⬭

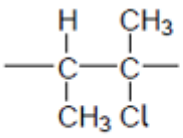
C Polythene ⬭

D Terylene ⬭

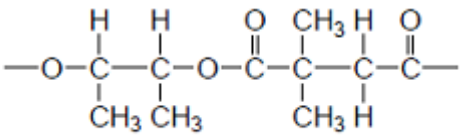
(Total 1 mark)

Q3.

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



P



Q

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(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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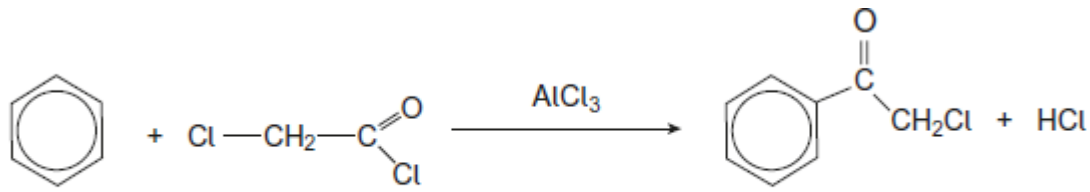
(3)

(Total 7 marks)

Q4.

Compound **X** ($ClCH_2COCl$) is used as a reagent in organic synthesis.

(a) One important reaction of **X** is in the preparation of compound **P** as shown.



X **P**

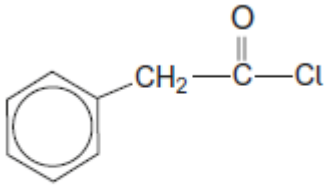
(i) Draw the structure of the electrophile formed by the reaction of **X** with $AlCl_3$.

(1)

(ii) Outline the mechanism for the reaction of the electrophile from part **(a)(i)** with benzene in the preparation of **P**.

(3)

(b) Compound **Q** is an alternative product that could be formed when **X** reacts with benzene.



Q

Describe how you could distinguish between **P** and **Q** by a test-tube reaction. Give the reagent used and the observation with each compound.

Reagent _____

Observation with **P** _____

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Observation with **Q** _____

(3)

(c) **X** is also used to make the compound $HOCH_2COOH$. This compound is polymerised to form the polymer known as PGA. PGA is used in surgical sutures (stitches).

(i) Draw the repeating unit of PGA.

(1)

(ii) Production of PGA occurs via a cyclic compound. Two $HOCH_2COOH$ molecules react together to form the cyclic compound and two molecules of water.

Draw the structure of this cyclic compound.

(1)

(d) Poly(propene) is also used in surgical sutures.

(i) Draw the repeating unit of poly(propene).

(1)

(ii) Suggest an advantage of surgical sutures made from PGA rather than from poly(propene).
Explain your answer.

_____

_____

_____

_____

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(2)

(Total 12 marks)

Q5.

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.

_____

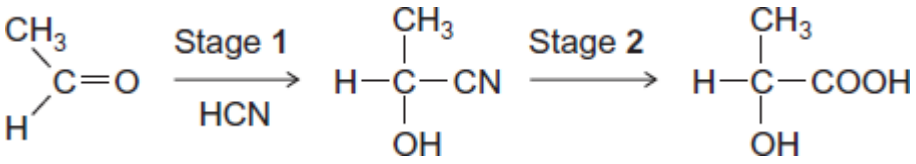
(1)

(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)*.

_____

_____

_____

(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 _____

_____

_____

_____

(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.

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(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.

_____

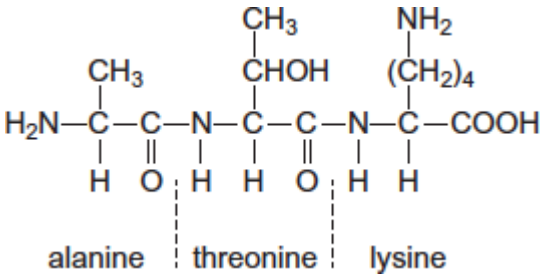
_____

(1)

(Total 22 marks)

Q6.

(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.

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(1)

(iii) Give the IUPAC name of threonine.

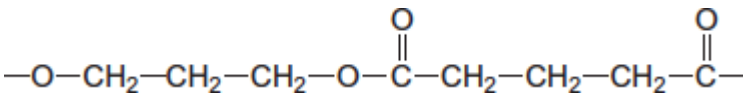
_____

(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.

_____

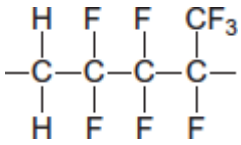
(1)

(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.

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

Compound _____

Explanation _____

_____

_____

(2)

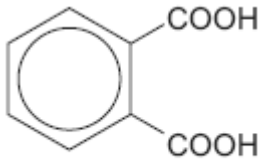
(Total 11 marks)

Q7.

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)

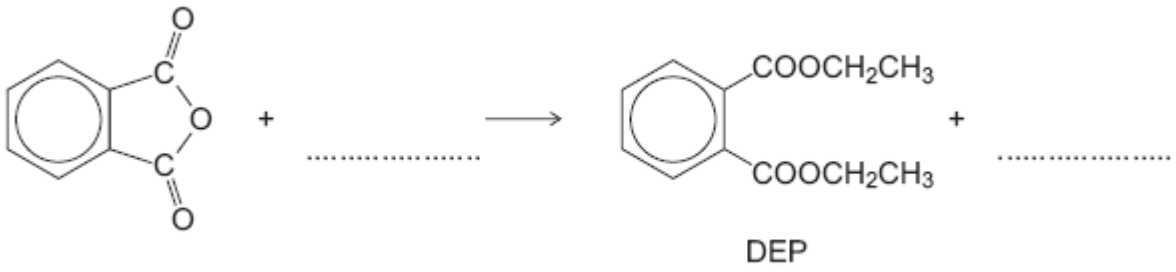
(b) Draw the displayed formula of the repeating unit of poly(chloroethene).

(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.

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DEP

(2)

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

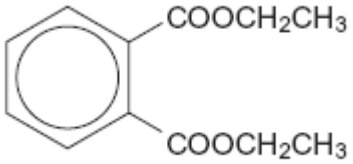
_____

(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.

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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.

_____

_____

_____

_____

_____

(2)

(Total 11 marks)

Q8.

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)

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

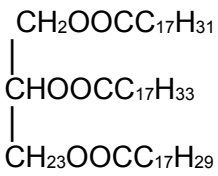
Write an equation for the preparation of butyl ethanoate from an acid anhydride and an alcohol.

(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.



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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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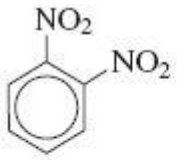
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(4)

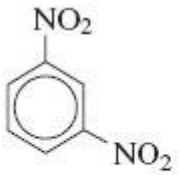
(Total 19 marks)

Q9.

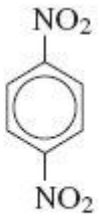
Three isomers of $C_6H_4(NO_2)_2$ are shown below.



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.

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(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.

_____

_____

_____

_____

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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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(4)

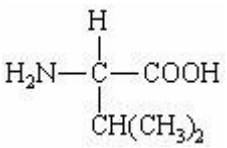
(Total 18 marks)

Q10.

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

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

Consider the following amino acid.



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

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(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.

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(2)

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

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

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

_____

_____

_____

_____

_____

_____

_____

(3)

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

_____

_____

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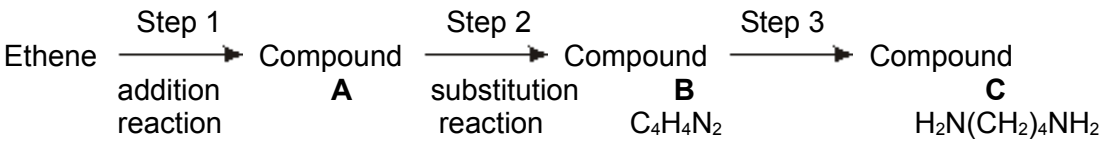
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(3)

(Total 14 marks)

Q11.

(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**.

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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.

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_____

_____

(3)

(Total 14 marks)

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