

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.4 ALKENES

SCORE

/243

PERCENTAGE

%

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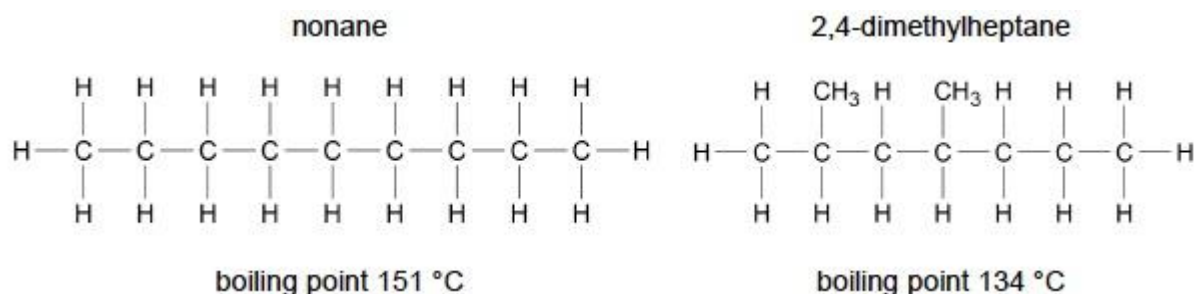
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Q1.

The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}

They are found in crude oil and can be separated by fractional distillation.

Both can be used in fuels or cracked to form other products.



- (a) State the general formula of an alkane containing n carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of n .

General formula _____

Expression _____

(2)

- (b) Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

(2)

- (c) Give an equation for the complete combustion of nonane.

(1)

- (d) Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

(2)

- (e) Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

(1)

- (f) The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

(1)

(Total 9 marks)

Q2.

Which statement is correct about poly(chloroethene)?

- A** It has the empirical formula CHCl
- B** It decolourises bromine water.
- C** Its brittleness is reduced by plasticisers.
- D** Its polymer chain contains alternate single and double bonds.

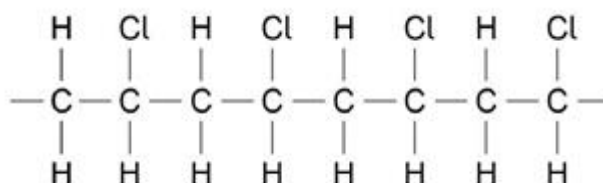
☐☐☐☐

(Total 1 mark)

Q3.

Chloroethene can be polymerised to form poly(chloroethene), commonly known as PVC. This polymer can be used to make pipes, window frames and electrical insulation. Plasticisers can be added to change the properties of PVC

A section of poly(chloroethene) is shown.



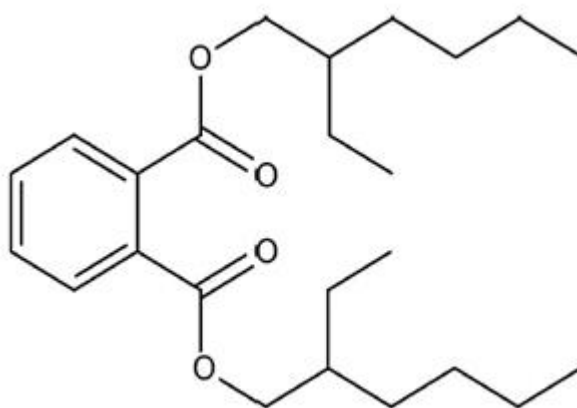
- (a) Chloroethene has a melting point of $-154\text{ }^{\circ}\text{C}$

All types of PVC melt at temperatures over 100 °C

Explain why PVC melts at a higher temperature than chloroethene.

(2)

- (b) This structure shows a molecule that has been used as a plasticiser in PVC.



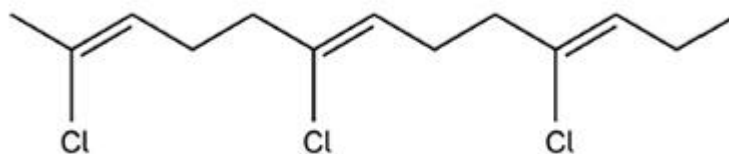
Deduce the number of hydrogen atoms in this molecule.

(1)

- (c) Use your understanding of the properties of PVC to explain whether you would expect to find a plasticiser in the PVC used to insulate electrical cables.

(1)

- (d) A section of the polymer poly(chloroprene), a synthetic rubber, is shown.



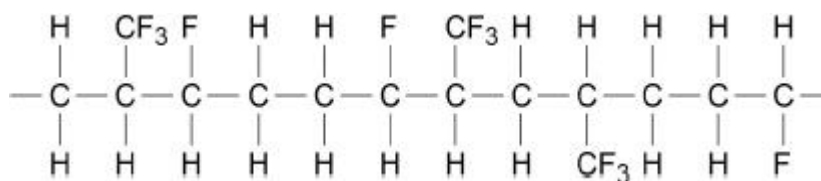
Draw the **displayed** formula for the repeating unit of poly(chloroprene).

(1)

(Total 5 marks)

Q4.

This structure shows a section of a polymer chain formed from the random polymerisation of two different monomers.



Which pair of monomers could produce this polymer?

- | | | |
|----------|---|--------------------------|
| A | $\text{CH}_2=\text{CHF}$ and $\text{CH}_2=\text{CHCF}_3$ | ☐ |
| B | $\text{CH}_2=\text{CH}_2$ and $\text{CHF}=\text{CHCF}_3$ | ☐ |
| C | $\text{CH}_2=\text{CH}_2$ and $\text{CH}_2=\text{CHCF}_3$ | ☐ |
| D | $\text{CH}_2=\text{CHF}$ and $\text{CHCF}_3=\text{CHF}$ | ☐ |

(Total 1 mark)

Q5.

This question is about halogenoalkanes.

- (a) Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

1. _____

2. _____

(2)

- (b) Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

Role of potassium hydroxide _____

Role of propan-1-ol _____

(2)

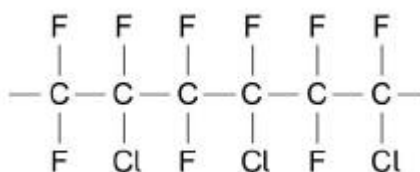
- (c) Name and outline a mechanism for the reaction in part (b) between chloroethane and potassium hydroxide to produce ethene.

Name of mechanism _____

Mechanism

(4)

- (d) The structure of polymer **A** is shown.



Draw the structure of the monomer used to form polymer **A**.

(1)

- (e) Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes, ^{35}Cl and ^{37}Cl , in the ratio 3:1
Fluorine only exists as one isotope, ^{19}F .

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at $m/z = 220$, 222 and 224.

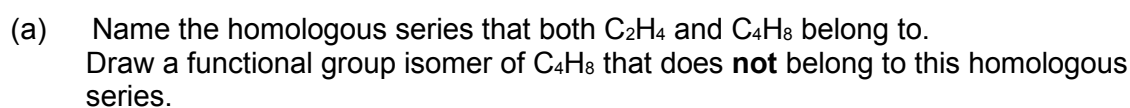
Determine the formula of each of the three molecular ions of **B**.

To gain full marks you must show all your working.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(Total 15 marks)

Dodecane ($\text{C}_{12}\text{H}_{26}$) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.



Functional group isomer

(2)

- (b) Identify compound **X**.

(1)

- (c) Name polymer **Y**.

(1)

- (d) Reaction **1** is an example of thermal cracking and is carried out at a temperature of 750 °C.

State **one other** reaction condition needed.

(1)

- (e) Reaction **2** is exothermic. A typical compromise temperature of 200 °C is used industrially for this reaction.

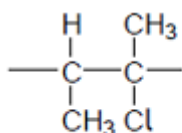
Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

(6)

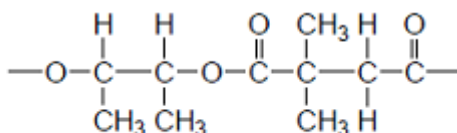
(Total 11 marks)

Q7.

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.

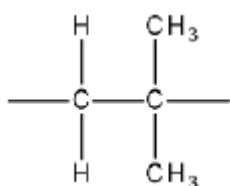
Advantage _____

Justification _____

(3)
(Total 7 marks)

Q8.

The repeating unit of a polymer is



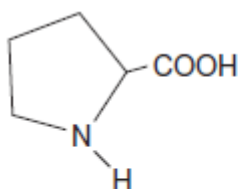
Which of the following molecules would form a polymer containing this repeating unit?

- A** But-1-ene ☐
- B** *E*-but-2-ene ☐
- C** *Z*-but-2-ene ☐
- D** Methylpropene ☐

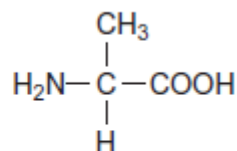
(Total 1 mark)

Q9.

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



proline



alanine

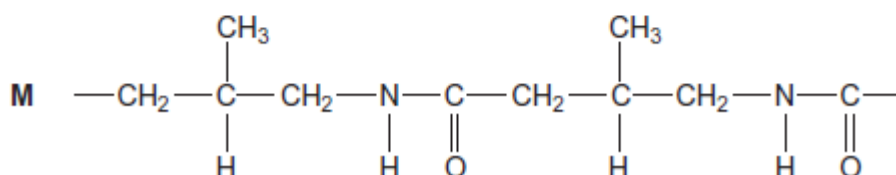
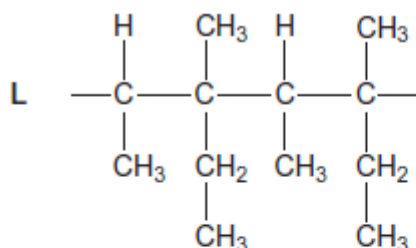
(i) Draw the structure of the zwitterion of proline.

(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.



- (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.

(1)

(Total 7 marks)

Q10.

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.



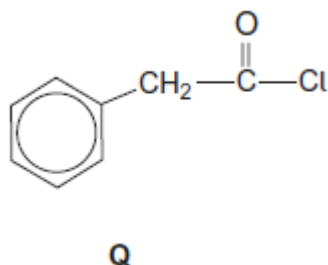
- (i) Draw the structure of the electrophile formed by the reaction of **X** with AlCl_3 .

(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.



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** _____

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.

(2)

(Total 12 marks)

Q11.

The carbonyl compound $\text{CH}_3\text{CH}_2\text{CHO}$ reacts very slowly with HCN

- (a) Name and outline a mechanism for the reaction of $\text{CH}_3\text{CH}_2\text{CHO}$ with HCN

Name of mechanism _____

Mechanism

(5)

(b) The reaction in part (a) produces a pair of enantiomers.

(i) Draw the structure of each enantiomer to show how they are related to each other.

(2)

(ii) State and explain how you could distinguish between the two enantiomers.

(2)

(c) Give the IUPAC name of the product of the reaction in part (a).

(1)

(d) In practice, KCN rather than HCN is added to the carbonyl compound.

Given that K_a for HCN = $4.0 \times 10^{-10} \text{ mol dm}^{-3}$, suggest why the reaction with HCN is very slow.

(2)

(e) Acrylic fibres are used as a substitute for wool. Acrylics are copolymers of

acrylonitrile with other compounds.

Acrylonitrile is the common name for the following compound.



- (i) Acrylonitrile can be formed from propene.

Write an equation for the reaction of propene with ammonia and oxygen to form acrylonitrile and one other product.

(1)

- (ii) The term copolymer is used to describe the product obtained when two or more different monomers form a polymer.

Draw the repeating unit of the acrylic copolymer that contains 75% acrylonitrile monomer and 25% chloroethene monomer.

(1)

- (iii) Name the type of polymerisation involved in part (ii)

(1)

(Total 15 marks)

Q12.

Lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$, is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.

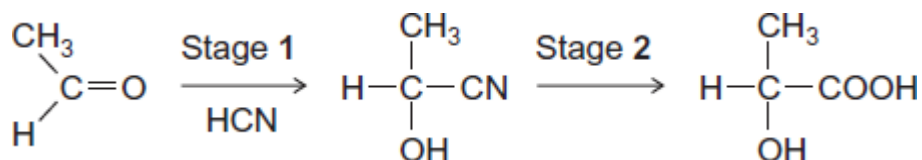
- (a) (i) Give the IUPAC name for lactic acid.

(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.

(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 $1.38 \times 10^{-4} \text{ mol dm}^{-3}$ 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.

(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.

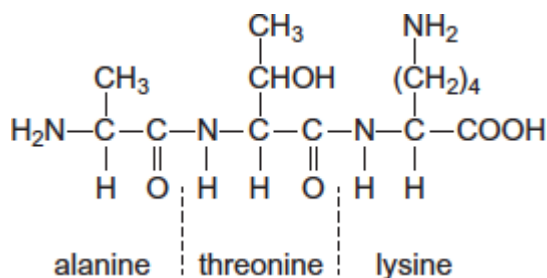
Suggest **one** reason why PLA in landfill may take longer than 12 weeks to break down.

(1)

(Total 22 marks)

Q13.

- (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)

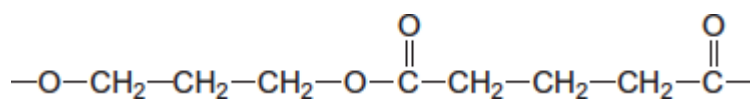
- (iii) Give the IUPAC name of threonine.

(1)

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

(1)

- (b) The repeating unit shown represents a polyester.



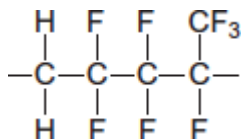
- (i) Name this type of polymer.

(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)

Q14.

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

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

(2)

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

(3)

- (b) (i) Name and outline a mechanism for the reaction of $\text{CH}_3\text{CH}_2\text{COCl}$ with CH_3NH_2

Name of mechanism _____

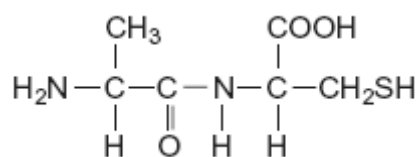
Mechanism

(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.

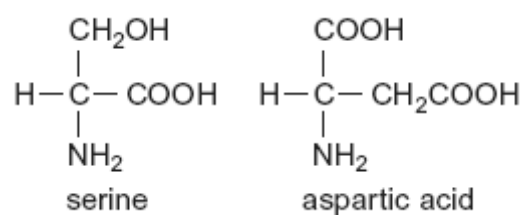


Draw the structure of the alternative dipeptide that could be formed by these two

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)

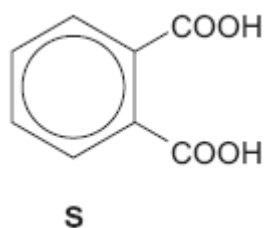
- (iv) Draw the structure of the species formed when serine reacts with an excess of bromomethane.

Q15.

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).



- (a) Give the IUPAC name for phthalic acid.

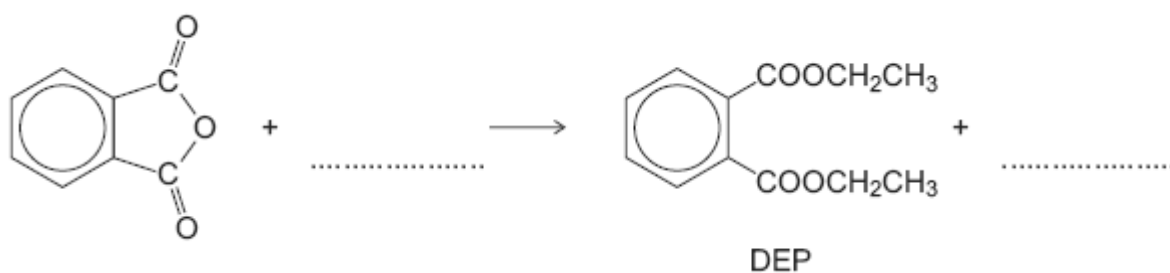
_____ (1)

- (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.



(2)

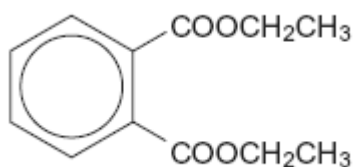
- (ii) Deduce the number of peaks in the ^{13}C n.m.r. spectrum of DEP.

(1)

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

(2)

(Total 11 marks)

Q16.

- (a) Name compound **Y**, $\text{HOCH}_2\text{CH}_2\text{COOH}$

(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)

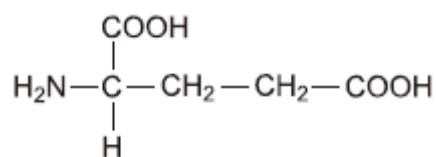
- (iii) The organic product from part (ii) can also be polymerised.
Draw the repeating unit of the polymer formed from this organic product.

(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)

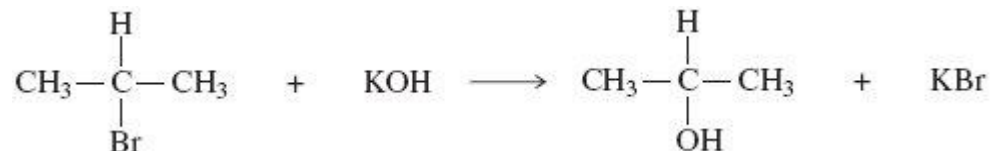
- (f) A tripeptide was heated with hydrochloric acid and a mixture of amino acids was formed. This mixture was separated by column chromatography. Outline briefly why chromatography is able to separate a mixture of compounds. Practical details are **not** required.

(3)

(Total 13 marks)

Q17.

- (a) Consider the following reaction.



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

Name of mechanism _____

Mechanism

(3)

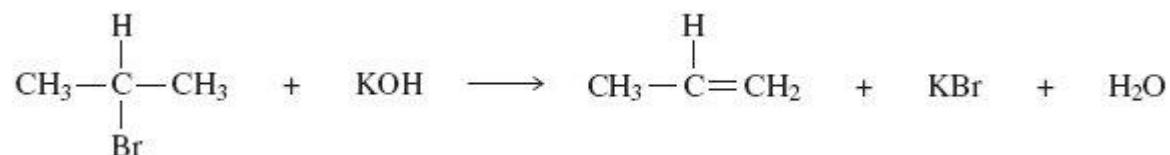
- (ii) Name the haloalkane in this reaction.

(1)

- (iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

(1)

- (b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(4)

- (c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

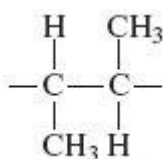
(1)

- (d) Alkenes can be polymerised to produce poly(alkenes).

- (i) State the type of polymerisation that alkenes undergo.

(1)

- (ii) Name the alkene that gives a polymer with the repeating unit shown below.



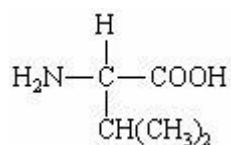
Name of alkene _____

Q18.

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**, $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$, which can be polymerised.

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

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

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

(3)

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

(2)

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

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

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

(3)

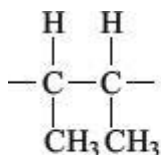
(ii) Describe an advantage or a disadvantage of a different method of disposal of such objects compared with landfill.

(3)

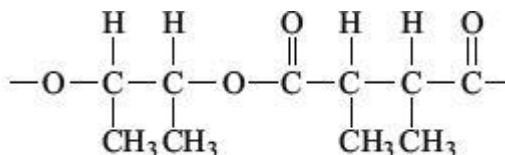
(Total 14 marks)

Q19.

- (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 _____

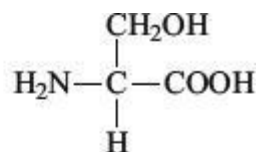
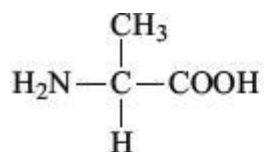
Structure of compound 2

Name of compound 2 _____

Type of polymerisation _____

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

- (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, $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$, 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.

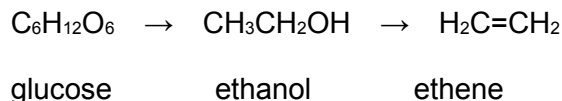
Route giving the less pure product _____

Explanation _____

Structure of an impurity

Q20.

Glucose can be used as a source of ethanol. Ethanol can be burned as a fuel or can be converted into ethene.



- (a) Name the types of reaction illustrated by the two reactions above.

Glucose to ethanol _____

Ethanol to ethene _____

(2)

- (b) (i) State what must be added to an aqueous solution of glucose so that ethanol is formed.

- (ii) Identify a suitable catalyst for the conversion of ethanol into ethene.

(2)

- (c) (i) State the class of alcohols to which ethanol belongs.

- (ii) Give **one** advantage of using ethanol as a fuel compared with using a petroleum fraction.

(2)

- (d) Most of the ethene used by industry is produced when ethane is heated to 900°C in the absence of air. Write an equation for this reaction.

(1)

- (e) Name the type of polymerisation which occurs when ethene is converted into poly(ethene).

(1)

(Total 8 marks)

Q21.

Tetrafluoroethene, C₂F₄, is obtained from chlorodifluoromethane, CHClF₂, according to the equation:



- (a) A 1.0 mol sample of CHClF_2 is placed in a container of volume 18.5 dm^3 and heated.

When equilibrium is reached, the mixture contains 0.20 mol of CHClF_2

- (i) Calculate the number of moles of C_2F_4 and the number of moles of HCl present at equilibrium.

Number of moles of C_2F_4 _____

Number of moles of HCl _____

- (ii) Write an expression for K_c for the equilibrium.

- (iii) Calculate a value for K_c and give its units.

Calculation _____

Units _____

(6)

- (b) (i) State how the temperature should be changed at constant pressure to increase the equilibrium yield of C_2F_4

- (ii) State how the total pressure should be changed at constant temperature to increase the equilibrium yield of C_2F_4

(2)

- (c) C_2F_4 is used to manufacture the polymer polytetrafluoroethene, PTFE. Name the type of polymerisation involved in the formation of PTFE.

(1)

(Total 9 marks)

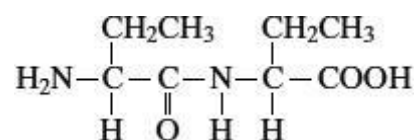
Q22.

- (a) The compound $\text{H}_2\text{C}=\text{CHCN}$ 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.

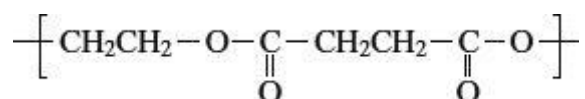


- (i) Name this amino acid.

- (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 _____

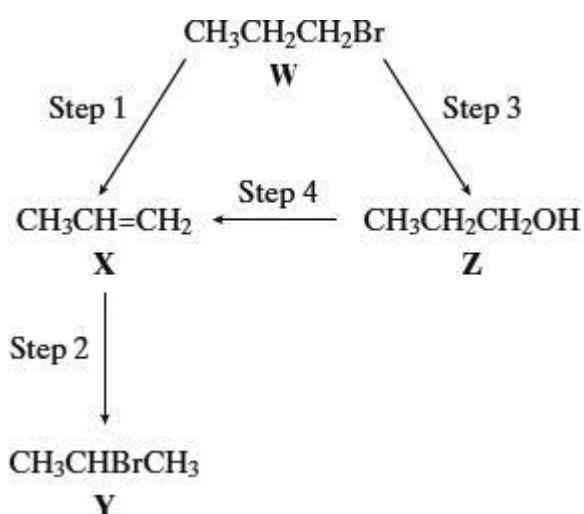
- (iii) Give **one** reason why the polyester is biodegradable.

(4)

(Total 8 marks)

Q23.

For this question refer to the reaction scheme below.



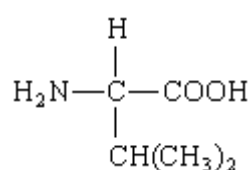
Which one of the following statements is **not** correct?

- A** Reaction of **W** with sodium cyanide followed by hydrolysis of the resulting product gives propanoic acid.
- B** Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.
- C** **Z** reacts with ethanoic acid to produce the ester propyl ethanoate.
- D** **W** undergoes addition polymerisation to form poly(propene).

(Total 1 mark)

Q24.

- (a) Consider the following amino acid.



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

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

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

(3)

(b) Consider the hydrocarbon **G**, $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$, which can be polymerised.

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

Type of polymerisation _____

Repeating unit

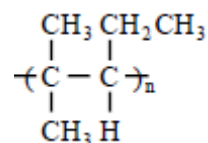
(ii) Draw the structure of an isomer of **G** which shows geometrical isomerism.

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

(4)
(Total 7 marks)

Q25.

The correct name for the alkene monomer which forms the polymer shown below is



- A** 2-methyl-3-ethylpropene
B 2-methylpent-2-ene
C 2-methylpent-3-ene
D 4-methylpent-2-ene

(Total 1 mark)

Q26.

Propene reacts with bromine by a mechanism known as electrophilic addition.

- (a) Explain what is meant by the term *electrophile* and by the term *addition*.

Electrophile _____

Addition _____

(2)

- (b) Explain why bromine, a non-polar molecule, is able to react with propene.

(2)

- (c) Outline the mechanism for the electrophilic addition of bromine to propene. Give the

name of the product formed.

Mechanism

Name of product _____ (5)

- (d) The polymerisation of propene to form poly(propene) is an important industrial process.

Name the type of polymerisation involved.

(1)
(Total 10 marks)

Q27.

Which one of the following does **not** contain any delocalised electrons?

- A** poly(propene)
- B** benzene
- C** graphite
- D** sodium

(Total 1 mark)

Mark schemes

Q1.

(a) **M1** C_nH_{2n+2}

1

M2 $14.0n + 2.0$ or $14n + 2$
or $2(7.0n + 1.0)$ or $2.0(7n + 1)$ or $2(7n + 1)$

1

(b) **M1** nonane has stronger / greater / more van der Waals' forces between molecules

or converse arguments for 2,4-dimethylbutane having lower boiling point

question refers to nonane if not expressly stated by candidate

intermolecular forces = forces between molecules

M1 ignore abbreviations vdW and/or imf

1

M2 nonane molecules pack closer together / more (surface) contact

M2 ignore reference to surface area alone

CE=0 reference to breaking (covalent) bonds / breaking chain

1

(c) $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

allow multiples; ignore any state symbols; correct structures rather than formulae are fine

1

(d) **M1** nitrogen and oxygen from air react

M1 must be at least one reference to air and no reference to nitrogen/oxygen coming from the fuel

1

M2 at high temperature

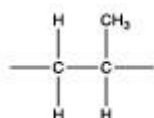
ignore reference to pressure, heat, hot, incomplete combustion

if temperature is stated, must be over 1000°C

1

(e) thermal (cracking)

1



(f)

allow any correct structural representation

ignore any n or brackets

1

[9]

Q2.
c

[1]

Q3.

- (a) **M1** it / PVC is bigger/longer molecule / has more electrons / has bigger surface area / greater M_r 1
- M2** it / PVC has stronger (van der Waals' / dipole-dipole) forces between molecules / intermolecular forces 1

M1 and **M2** independent of each other

CE = 0 if reference to hydrogen bonds or breaking of covalent bonds when substances are melted

Comparison must be implied in **M1** or **M2** to score 2 marks

If there is no comparison at all, then 1 mark could score either for explaining that PVC has strong intermolecular forces due to being a big/long molecule / having many electrons / large surface area / large M_r , or, for explaining that chloroethene has weak intermolecular forces due to being a small/short molecule / having few electrons / low surface area / low M_r ,

- (b) 38

ignore additional words

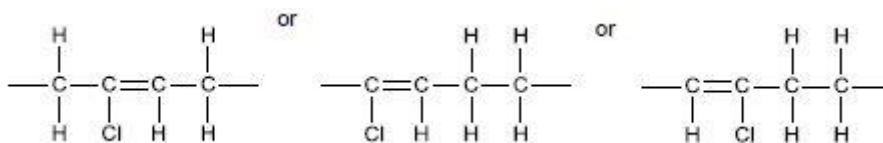
1

- (c) Need both ideas that

- it is present AND
 - because PVC needs to be flexible / bendy
- penalise incorrect properties

1

- (d) Displayed structure required



ignore any bracket or n

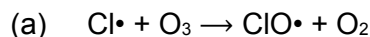
1

[5]

Q4.
A

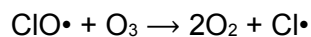
[1]

Q5.



Allow dot in free-radical on either O or Cl.

1



1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

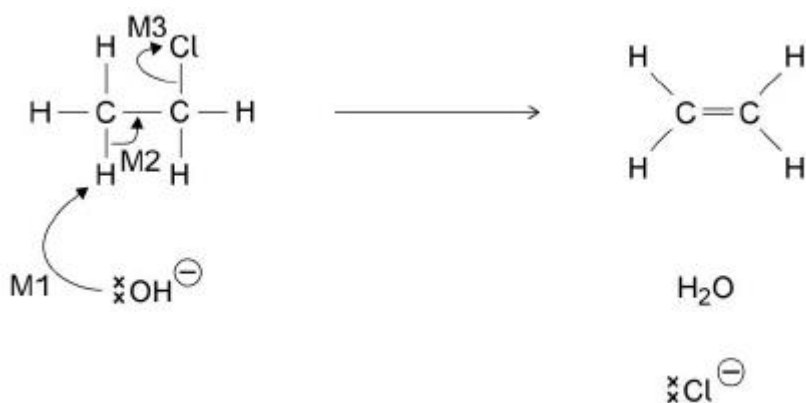
Allow product of reaction between KOH and propan-1-ol / $\text{CH}_3\text{CH}_2\text{CH}_2\text{O}^-$ acts as base.

1

(c) (Name of mechanism) Elimination

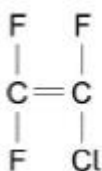
1

mechanism: 3 arrows (1 mark each).



3

(d)



1

(e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

If the formulae of the three molecular ions are not correct (2d) then the

student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).

5-6 marks

Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.

3-4 marks

Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

OR

Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1 (determines empirical formula)

1a 16.3% carbon

1b Divide by A_r

1c Divide by smallest (0.904)

1d Convert ratio in simplest integer ($\times 2$)

C	Cl	F
$\frac{16.3}{12.0} = 1.358$	$\frac{32.1}{35.5} = 0.904$	$\frac{51.6}{19.0} = 2.716$
$\frac{1.358}{0.904}$	$\frac{0.904}{0.904}$	$\frac{2.716}{0.904}$
3	2	6

Stage 2 (determines formulae of three molecular ions)

2a For E.F. M_r (corresponds to the molecule) = 221

2b since $M_r = 221$ lies within molecular ion range 220–224

2c Thus empirical formula = molecular formula

2d Three correct formulae

2e Correct M_r for each of three molecules

$C_3^{35}Cl_2F_8^+$	$C_3^{35}Cl^{37}ClF_8^+$	$C_3^{37}Cl_2F_8^+$
220	222	224

Stage 3 (explains the ratio of 3 molecular ion peaks)

3a Working

2b Correct (simplified) ratio **9:6:1**

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

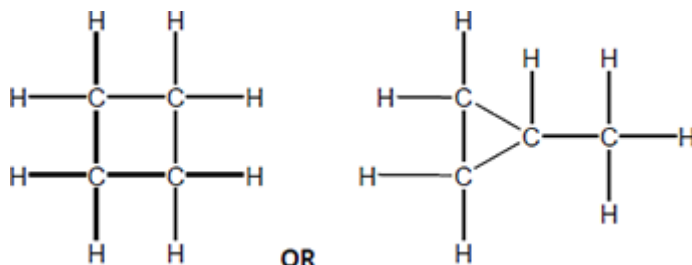
$C_3^{35}Cl_2F_8^+$	$C_3^{35}Cl^{37}ClF_8^+$	$C_3^{37}Cl_2F_8^+$
220	222	224
$^{35}Cl_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$	$^{35}Cl^{37}Cl \text{ and } ^{37}Cl^{35}Cl = 2 \times \frac{1}{4} \times \frac{3}{4} = \frac{6}{16}$	$^{37}Cl_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

[15]

Q6.

(a) Alkenes

1



Correctly drawn molecule of cyclobutane or methylcyclopropane, need not be displayed formula

1

(b) C_6H_{14} (or correct alkane structure with 6 carbons)

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure ☐ MPa

Mention of catalyst loses the mark

1

(e) This question is marked using levels of response. Refer to the Mark Scheme

Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

5–6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

3–4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

1–2 marks

Level 0

Insufficient correct chemistry to gain a mark.

0 marks

Indicative chemistry content

Stage 1: consider effect of higher temperature on yield
(Or vice versa for lower temperature)

- Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature
- Exothermic reaction, so equilibrium shifts in endothermic direction / to the left
- So a Higher T will reduce yield

Stage 2: consider effect of higher temperature on rate
(Or vice versa for lower temperature)

- At higher temperature, more high energy molecules
- more collisions have $E > E_a$
- So rate of reaction increases / time to reach equilibrium decreases

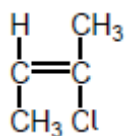
Stage 3: conclusion

Industrial conditions chosen to achieve (cost-effective)
balance of suitable yield at reasonable rate

[11]

Q7.

(a)

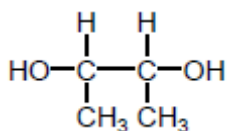


1

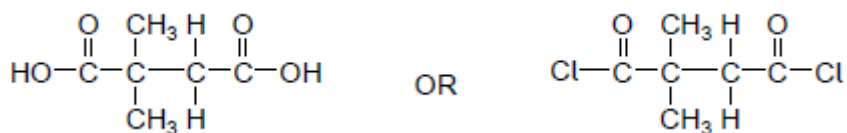
Addition

1

(b)



1



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]

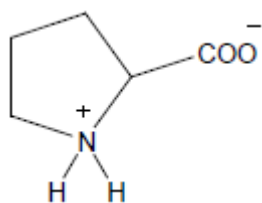
Q8.

D

[1]

Q9.

(a) (i)



Allow CO_2^- and NH_2^+

1

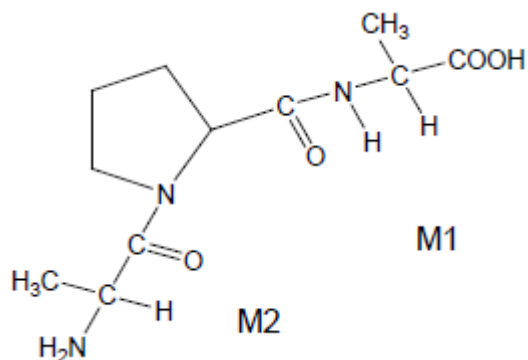
(ii) NOTE – **Two** marks for this clip

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

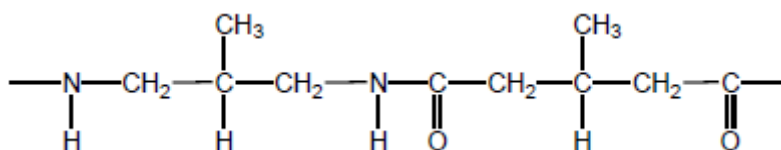
1

- (ii) 4-amino-3-methylbutanoic acid

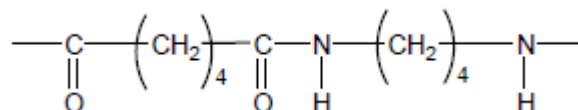
Ignore commas, spaces or missing hyphens

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)

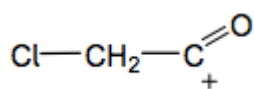
C-C bonds are strong

1

[7]

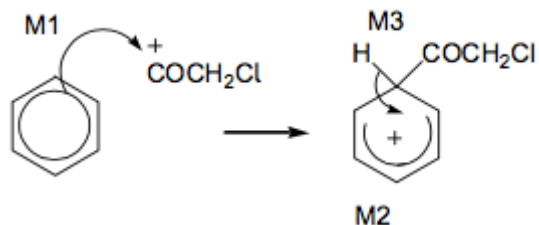
Q10.

- (a) (i)



Allow [ClCH₂CO]⁺

1



(ii)

M1 for arrow from inside hexagon to C or + on C on correct electrophile

M2 for structure of intermediate

- *Horseshoe centred on C1;*
- *+ in intermediate not too close to C1 (allow on or "below" a line from C2 to C6)*

M3 for Arrow from bond to H into ring

- *Allow M3 arrow independent of M2 structure*
- *+ on H in intermediate loses M2 not M3*
- *Ignore Cl- removing H⁺*

1
1
1

(b) Reagent

Water

(Aqueous) silver nitrate

NaOH followed by acidified silver nitrate

(Water +) named indicator

Named alcohol

Na₂CO₃ or NaHCO₃

Ammonia

1

P

No reaction

No reaction (or slow formation of ppt)

No reaction (or slow formation of ppt)

No colour change

NVC

NVC

No reaction

Do NOT award

No observation

1

Q

Steamy /misty/ white fumes

White precipitate (immediately formed)

White precipitate (immediately formed)

Indicator turns to correct acid colour

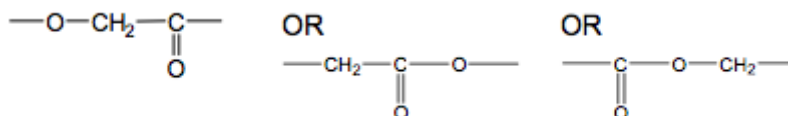
Fruity or sweet smell or misty fumes

Fizzing or effervescence (not just gas produced)

White smoke

1

(c) (i)



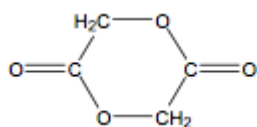
One unit only

Must have trailing bonds

Ignore n and brackets

allow $\text{---O---CH}_2\text{---CO---}$

1

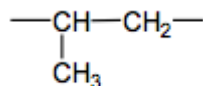


(i)

Allow CO for C=O

1

(d) (i)



One unit only

Must have trailing bonds

Ignore n and brackets

1

(ii) PGA sutures react/dissolve/break down/are biodegradable/ are hydrolysed / attacked by water or nucleophiles /no need to remove

OR Polypropene not biodegradeable/ not hydrolysed / not attacked by water/nucleophiles

1

(Ester links have) polar bonds

polypropene contains non-polar bonds

ignore intermolecular forces

1

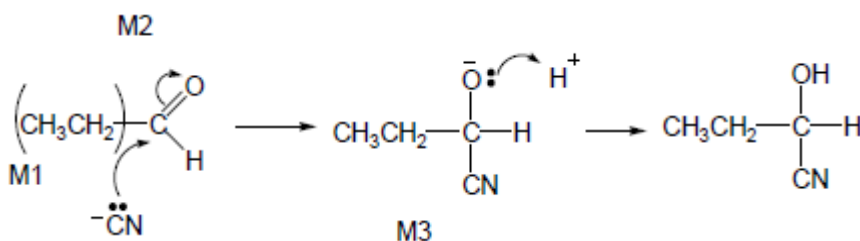
[12]

Q11.

(a) Nucleophilic addition

1

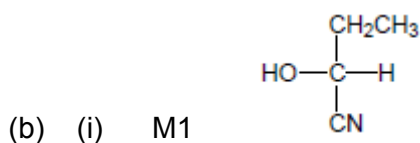
M4 for lp, arrow and H⁺



Allow C₂H₅- for CH₃CH₂-

- M1 and M4 include lone pair and curly arrow.
- Allow: CN⁻ but arrow must start at lone pair on C.
- M2 not allowed independent of M1, but allow M1 for correct attack on C⁺.
- + rather than δ⁺ on C=O loses M2.
- Penalise incorrect partial charges.
- M3 is for correct structure including minus sign but lone pair is part of M4.
- Penalise extra curly arrows in M4.

4



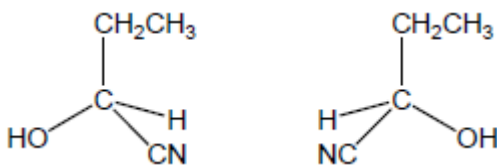
M1 for correct structure of product of part (a).

Allow C₂H₅- for CH₃CH₂-.

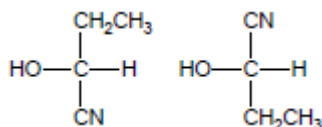
Penalise wrongly bonded, OH or CN or CH₂CH₃ once only in clip.

1

M2

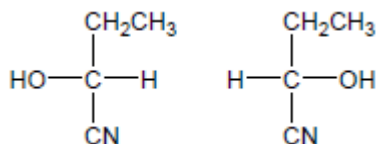


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not show the enantiomers as mirror images.

Students must show an attempt at mirror images, eg allow

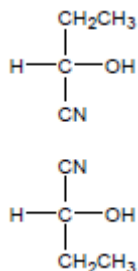


ie vertical groups same and horizontal swapped as if there was a mirror between them

No mirror need be shown

Do not penalize wedge bond when wedge comes into contact with both C & N

However these two could score M2 if placed as below as if with a "mirror" horizontally between them.



1

- (ii) M1 (Plane) polarized light

M2 only scores following correct M1

1

M2 or Rotated in opposite directions (equally) (only allow if M1 correct close)

Not just in different directions but allow one rotates light to the left and one to the right.

Not molecules rotate.

1

- (c) 2-hydroxybutane(-1-)nitrile

1

- (d) Weak acid / (acid) only slightly / partially dissociated / ionised

Ignore rate of dissociation.

1

[CN⁻] very low

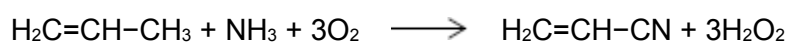
Allow (very) few cyanide ions.

Mark independently.

1

- (e) (i) $\text{H}_2\text{C}=\text{CH}-\text{CH}_3 + \text{NH}_3 + \frac{3}{2}\text{O}_2 \longrightarrow \text{H}_2\text{C}=\text{CH}-\text{CN} + 3\text{H}_2\text{O}$

OR

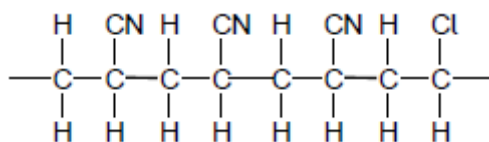


OR doubled.

Allow C₃H₆ and CH₂CHCN or C₃H₃N on this occasion only.

1

(ii)

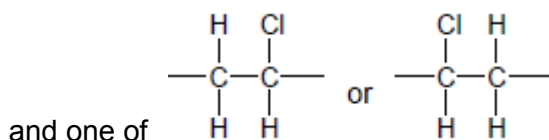
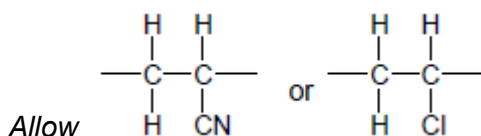
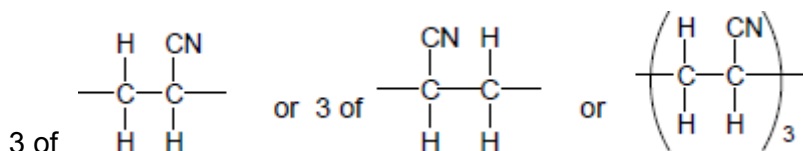


Ignore n.

Must show trailing bonds.

Do not penalise C–NC bond here on this occasion.

Must contain, in any order,



Allow –CH₂CH(CN)CH₂CHCl– etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

1

[15]

Q12.

(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) $\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{O} \longrightarrow 4\text{CH}_3\text{CH}(\text{OH})\text{COOH}$

Allow 4C₃H₆O₃

OR

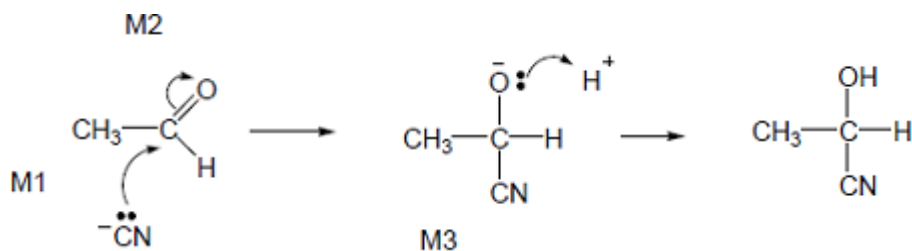
$\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{O} \longrightarrow 2\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{C}_6\text{H}_{12}\text{O}_6$

Allow 2C₃H₆O₃

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) $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COONa} + \text{H}_2\text{O}$
OR $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}$
Not ambiguous mol formulae for product - must show COONa or CO₂Na or COO⁻ or CO₂⁻

1

(ii) $[\text{H}^+] = K_a$ **OR** $\text{pH} = \text{p}K_a$

1

$\text{pH} = 3.86$

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^-

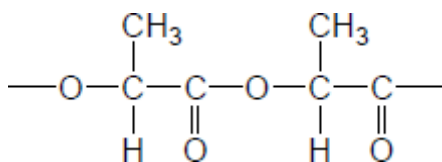
Ignore reference to equilibrium unless it is shown.

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 $-COO-$

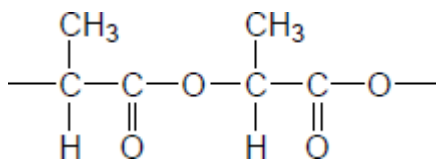
NB Correct answer scores 2

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

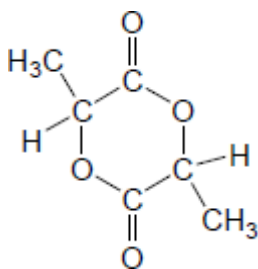
(ii) (Poly)ester ie allow ester

Not terylene.

Ignore spaces and brackets in answer.

1

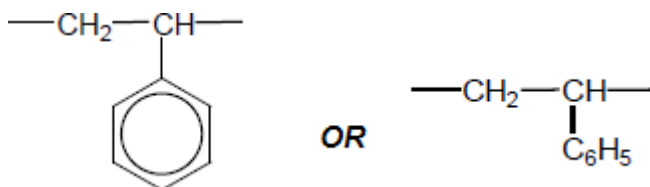
(iii)



Allow any cyclic $C_6H_8O_4$

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

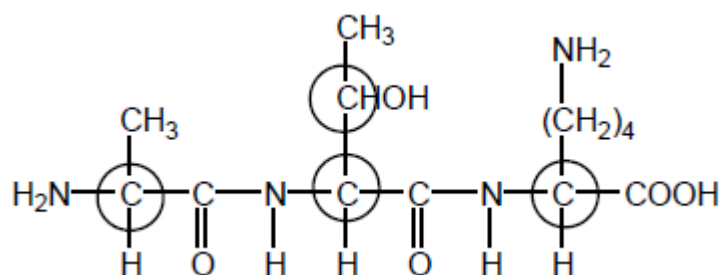
OR lower temperature.

1

[22]

Q13.

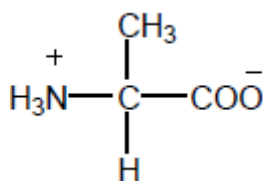
- (a) (i)



These four only

1

- (ii)



Allow $-\text{NH}_3^+$ and $^+\text{NH}_3-$

1

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

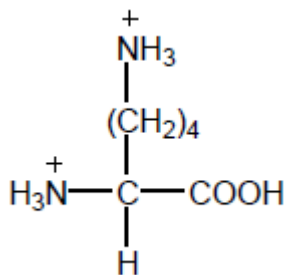
Ignore 1 in butan-1-oic acid

Do not penalise commas or missing hyphens

Penalise other numbers

1

- (iv)



Allow $-\text{NH}_3^+$ and $^+\text{NH}_3$

1

- (b) (i) Condensation

Allow polyester

1

- (ii) propane-1,3-diol

Must have e

Allow 1,3-propanediol

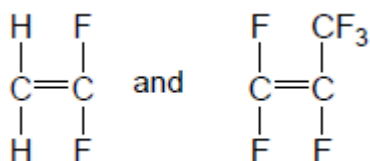
1

- (c) (i) Addition

Not additional

1

- (ii)

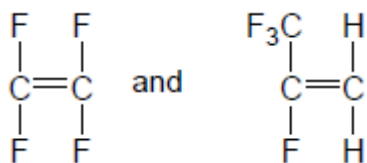


Allow monomers drawn either way round

Allow bond to F in CF_3

1

OR



1 for each structure within each pair

1

- (d) c

If wrong, CE = 0

1

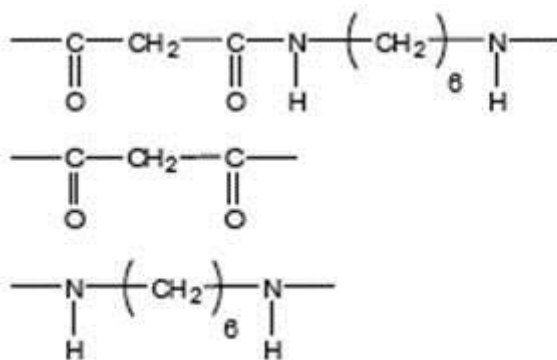
C-C or C-F bonds too strong

1

[11]

Q14.

(a) (i)



Allow -CONH- or -COHN-

Mark two halves separately

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

1

Not allow $\text{-(C}_6\text{H}_{12}\text{)-}$

Ignore n

1

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

1

M2 in polyalkenes - van der Waals forces

Penalise forces between atoms or van der Waals bonds

1

M3 Stronger forces (of attraction) in polyamides

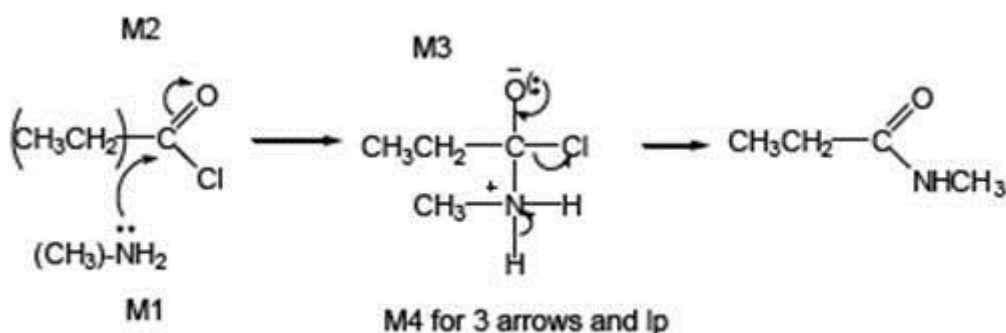
Or H bonding is stronger

(must be a comparison of correct forces to score M3)

Do not award if refer to stronger bonds

1

(b) (i) (nucleophilic) addition elimination



Not allow N-H_2

Minus sign on NH_2 loses **M1**

1

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

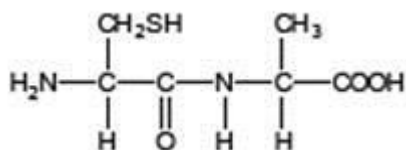
+ rather than δ^+ on C=O loses **M2**
 If Cl lost with C=O breaking, max 1 for **M1**
M3 for correct structure with charges but
 lp on O is part of **M4**
 only allow **M4** after correct/ very close M3
 For M4, ignore NH_3 removing H^+ but lose
M4 for Cl removing H^+ in mechanism,
 but ignore HCl as a product

4

- (ii) N-methylpropanamide
 Not N-methylpropaneamide

1

(c)



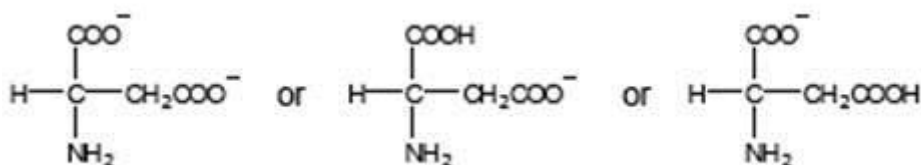
Allow $-\text{CONH}-$ or $-\text{COHN}-$

1

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

1

(ii)



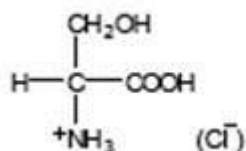
Must be salts of aspartic acid

allow $-\text{CO}_2^-$

allow NH_2-

1

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



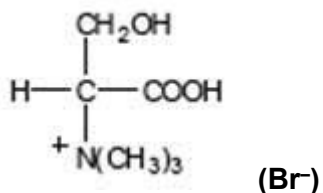
allow $-\text{CO}_2\text{H}$

allow $^+\text{NH}_3-$

don't penalize position of + on NH_3

1

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



allow $-\text{CO}_2^-$

must show C-N bond

don't penalize position of + on $\text{N}(\text{CH}_3)_3$

1

[16]

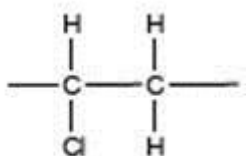
Q15.

- (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 $\text{C}_2\text{H}_5\text{OH}$

NB Two ethanols

1



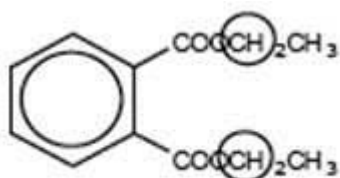
but only one water

1

- (ii) 6 or six

1

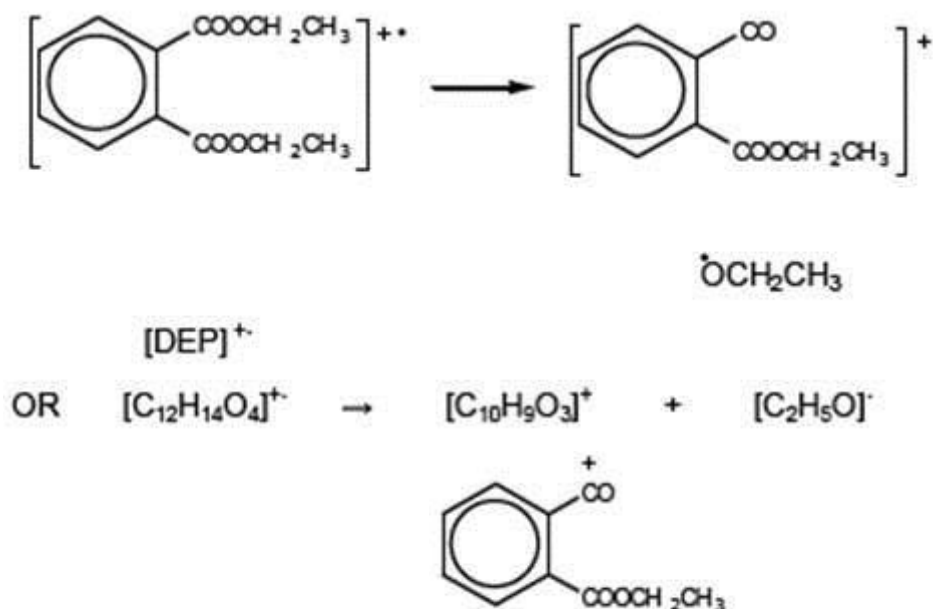
- (iii)



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 = $k[\text{DEP}]$
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

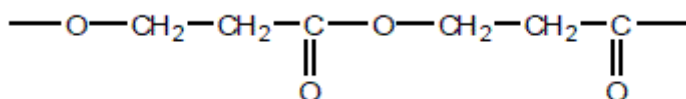
[11]

Q16.

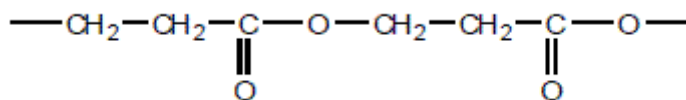
- (a) 3-hydroxypropanoic acid
allow 3-hydroxypropionic acid
must be correct spelling

1

- (b) (i) must show trailing bonds



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



not allow dimer

allow $\text{---O---CH}_2\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CO---}$

or $\text{---CH}_2\text{CH}_2\text{COOCH}_2\text{CH}_2\text{COO---}$

ignore () or n

NB answer has a total of 6 carbons and 4 oxygens

1

(ii) condensation (polymerisation)

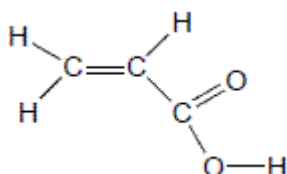
Allow close spelling

1

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

1

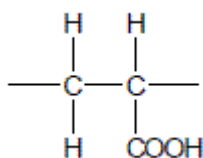
(ii)



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

1

(iii) must show trailing bonds

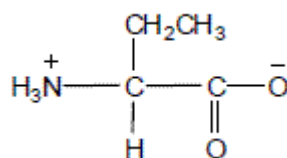


allow polyalkene conseq on their c(ii)

ignore n

1

(d)

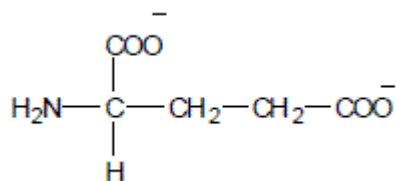


allow $\text{NH}_3^+\text{---}$

allow COO^-

1

(e) (i)



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

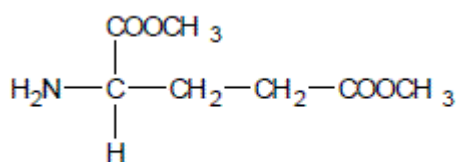
NB two carboxylate groups

Allow COONa or COO⁻ Na⁺ but not covalent bond to Na

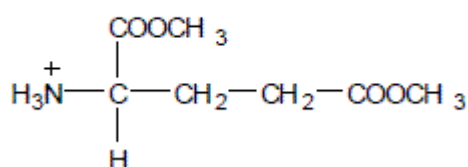
allow NH₂-

1

(ii)



OR



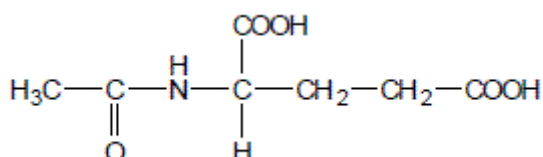
In (e), do not penalise a slip in the number of carbons in the -CH₂CH₂- chain, but all must be bonded correctly

NB two ester groups

allow NH₂- or ⁺NH₃-

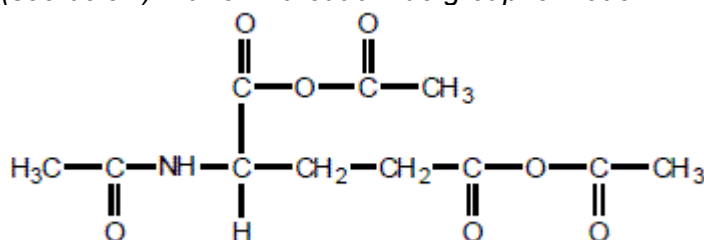
1

(iii)



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

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



1

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

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

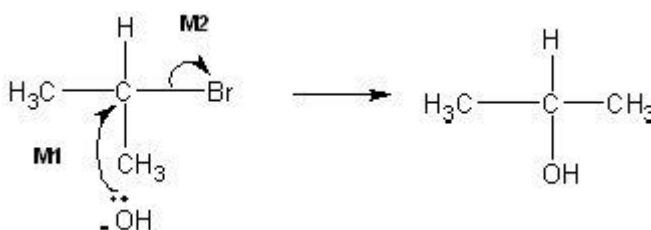
1

[13]

Q17.

(a) (i) Nucleophilic substitution

1



2

M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks"*

Ignore product

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

(iii) Polar C-Br **OR** polar carbon-bromine bond **OR** dipole on C-Br
OR δ^+ (δ^-)
C atom of carbon-bromine bond is δ^+ /electron deficient **OR** C-Br

(Credit carbon-halogen bond as an alternative to carbon-bromine bond)

It must be clear that the discussion is about the carbon atom of the C-Br bond. NOT just reference to a polar molecule.

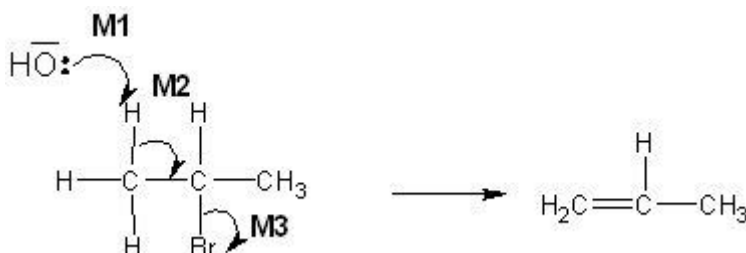
Ignore X for halogen

1

(b) Elimination

Credit "base elimination" but NOT "nucleophilic elimination"
No other prefix.

1



3

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 is independent.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks **for the mechanism** for wrong reactant and/or "sticks"

Ignore product

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

(c) Any one condition from this list to favour elimination;

Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide **OR** concentrated KOH/hydroxide
Ignore "aqueous"
- high temperature or hot or heat under reflux or $T = 78$ to 100°C
Ignore "excess"

1

(d) (i) Addition (polymerisation) ONLY

Penalise "additional"

1

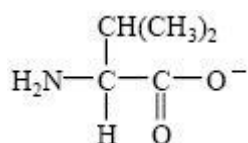
(ii) But-2-ene ONLY (hyphens not essential)

Ignore references to cis and trans or E/Z

Ignore butane

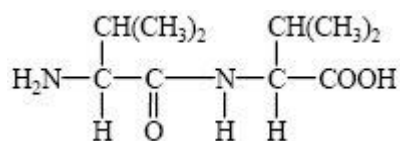
Q18.

(a) (i)



1

(ii)

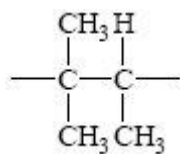


1

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

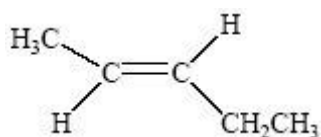
1

(b) (i)



1

(ii)

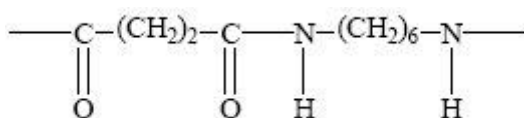


1

(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]

Q19.

(a) (i) $\text{CH}_3\text{CH}=\text{CHCH}_3$

1

Addition or radical (**QoL**)

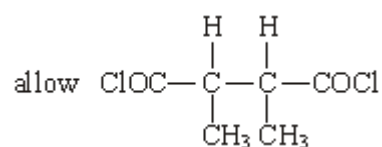
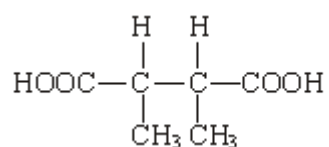
1

(ii) $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{OH})\text{CH}_3$ or with no brackets

1

butan(e)-2,3-diol or 2,3-butan(e)diol

1



1

2,3-dimethylbutan(e)dioic acid

2,3-dimethylbutan(e)dioyl chloride

ignore -1,4-

1

condensation (**QoL**)

1

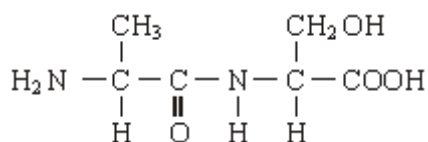
(iii) NaOH or HCl etc or Na_2CO_3

Allow conc sulphuric/nitric

NOT water nor acidified water nor weak acids

1

(b) Structure 1



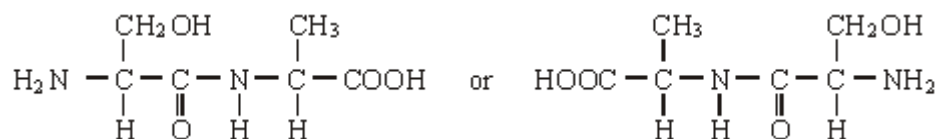
Allow -CONH- and -COHN-

Allow zwitterions

NOT polypeptides/repeating units

1

Structure 2 either of



1

- (c) (i) $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$
allow -Cl, -I

1

- (ii) $\text{CH}_3\text{CH}_2\text{CN}$

1

- (iii) (nucleophilic) substitution or from $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$
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
 $(\text{CH}_3\text{CH}_2\text{CH}_2)_2\text{NH}$
 $(\text{CH}_3\text{CH}_2\text{CH}_2)_3\text{N}$
 $(\text{CH}_3\text{CH}_2\text{CH}_2)_4\text{N}^+ \text{Br}^-$
Allow salts including NH_4Br
Allow HBr

1

[15]

Q20.

- (a) M1 fermentation

1

M2 dehydration or elimination

1

- (b) (i) yeast OR zymase OR an enzyme

1

- (ii) concentrated sulphuric or phosphoric acid
(penalise aqueous or dilute as a contradiction)

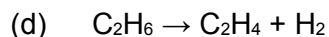
1

- (c) (i) primary or 1°

1

- (ii) sugar or glucose or ethanol is renewable
OR ethanol does not contain sulphur-containing impurities
OR ethanol produces less pollution or is less smoky or less CO/C
(the objective is a positive statement about ethanol)
(penalise the idea that ethanol is an infinite source or vague statements that ethanol has less impurities) (penalise the idea that ethanol produces no pollution)

1



1

(e) Addition

(ignore self or chain as a preface to "addition")
(penalise additional)

1

[8]

Q21.

(a) (i) moles of $\text{C}_2\text{F}_2 = 0.40$ mark independently from HCl

1

moles of HCl = 0.80 **not** consequential

1

(ii)
$$K_c = \frac{[\text{C}_2\text{F}_4][\text{HCl}]^2}{[\text{CHClF}_2]^2}$$

wrong K_c means they can only

score for units in (iii) consequ

on their K_c

1

(iii)
$$K_c = \frac{(0.40/18.5)(0.8/18.5)^2}{(0.20/18.5)^2}$$

1

$$= 0.35$$

1

mol dm^{-3}

1

(b) (i) increase

1

(ii) decrease

1

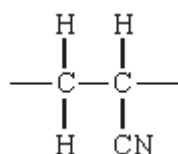
(c) addition or radical

1

[9]

Q22.

(a) (i)



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

- (ii) Addition or radical 1
- (b) (i) 2-aminobutanoic (acid) 1
- (ii)
- $$\begin{array}{c} \text{CH}_2\text{CH}_3 \\ | \\ \text{H}_3\text{N}^+ - \text{C} - \text{COOH} \\ | \\ \text{H} \end{array}$$
- 1
- (c) (i) $\text{C}_3\text{H}_4\text{O}_2$ 1
- (ii)
- $$\begin{array}{c} \text{HO} - \text{C} - \text{CH}_2\text{CH}_2 - \text{C} - \text{OH} \\ || \qquad \qquad \qquad || \\ \text{O} \qquad \qquad \qquad \text{O} \end{array}$$
- 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

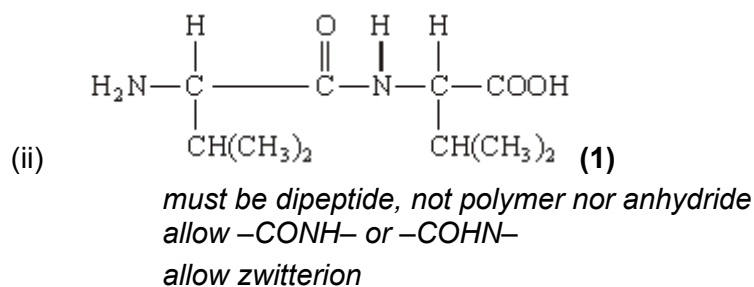
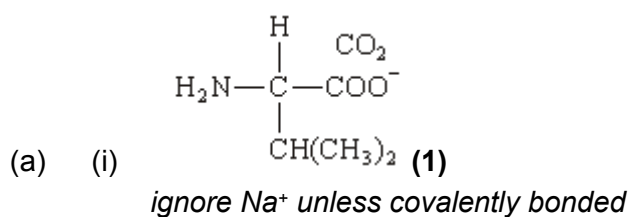
[8]

Q23.

A

[1]

Q24.



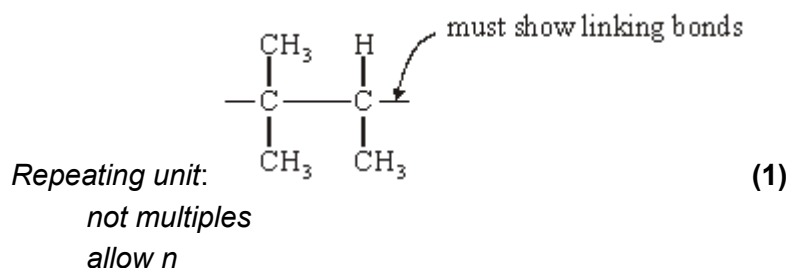
(iii) hydrogen bonding (1)

QL

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

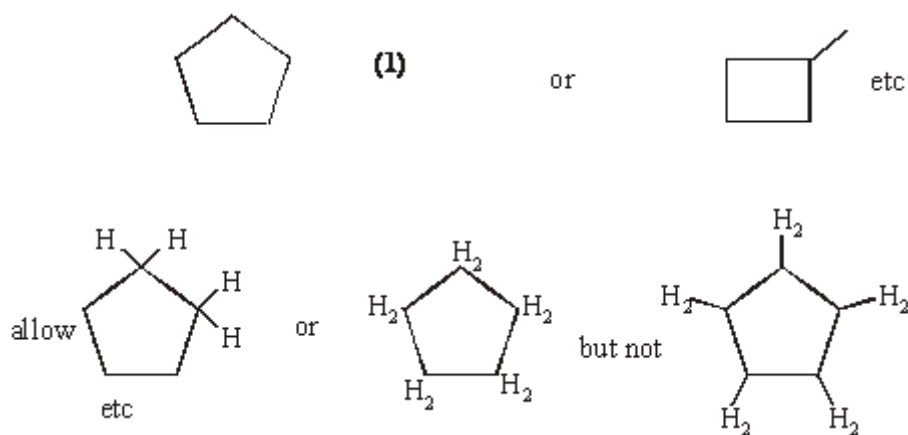
3

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



(ii) $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_3$ (1) C_2H_5

(iii)



4

[7]

Q25.

B

[1]

Q26.

(a) *Electrophile:* e^- pair / lone pair acceptor or e^- deficient species or e^- seeking species (1)

For 'species' accept atom, molecule, ion

NOT '+' ion

NOT 'attracted to '-' charge'

Addition: reaction which increases number of substituents or convert double bond to single bond or where two molecules form one molecule (1)

2

(b) (High) e^- dense or e^- rich $\text{C}=\text{C}$ or e^- rich π bond or 4 e^- between the C's (1)

NOT just 'C=C'

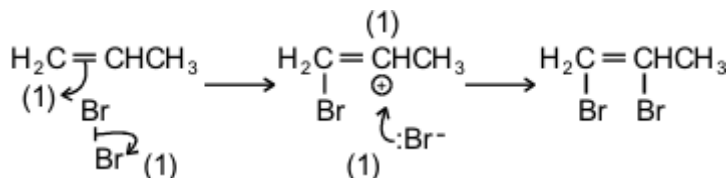
causes induced dipole in Br₂ (1)

Ignore refs to 'temporary'

can score M2 from δ^+ / δ^- on Br₂ in (c) unless a contradicting error in (b)

2

(c) Mechanism:



If incorrect alkene, lose M3 (wrong cation)

Mark M4 conseq on M3

If M1 curly
arrow $C \equiv C$
allow

Name of product: 1,2-dibromopropane (1)

5

(d) addition (1)

Not additional

1

[10]

Q27.

A

[1]

Examiner reports

Q1.

- (a) Most students knew the general formula of alkanes and many could also deduce the M_r in terms of n , where n is the number of C atoms.
- (b) A lot of students believed that covalent bonds break when alkanes are boiled. Other students lost a mark for poor use of terminology by not referring to forces between molecules. 62.2% of students failed to score on this question.
- (c) Nearly all students (82.8%) could write the balanced equation for the complete combustion of nonane.
- (d) A good number of students knew how NO is formed in an engine, but many did not appreciate that the nitrogen comes from the air and that high temperatures are required for the formation of NO.
- (e) Most students (75.7%) knew that thermal cracking is used to form alkenes.
- (f) Few students (30.9%) could draw the repeating unit of poly(propene) correctly.

Q2.

Many students (52.2%) got this question correct but many others incorrectly thought that the polymer contained a C=C bond and would decolourise bromine water.

Q3.

- (a) Many students believed incorrectly that covalent bonds break when PVC melts and failed to score on this question.
- (b) This question required students to know how many hydrogen atoms were on each carbon atom in a skeletal structure, but many struggled to count them correctly.
- (c) Very few students appeared to know why plasticisers are added to some polymers. This is new content for this specification.
- (d) This question required students to draw the displayed structure of a repeating unit and proved to be challenging.

Q9.

Part (a)(i) was very well done, although some answers included too many hydrogens on the nitrogen of proline. Part (a)(ii) was less well answered; some students drew the nitrogen atom either not in the ring or with a hydrogen atom attached. A few misread the question and used two proline molecules.

The name in part (b)(i) was well answered but that in (b)(ii) was found more difficult. Part (b)(iii) was answered correctly by about a third of the students. The most common error was not forming the polymer from a dicarboxylic acid and a diamine, but instead using amino carboxylic acids. A small number of students did not give the correct number of C atoms in the polymer section. Part (b)(iv) was well understood with strong C-C bonds being the most common correct answer.

Q10.

Apart from the occasional suggestion of AlCl_4^- as the electrophile, part (a)(i) was answered well as was the mechanism in (a)(ii). Marks are still lost by some students who draw curly arrows that lack the precise start and end positions required to gain the mark. About a third of students scored full marks in part (b). The vast majority of incorrect answers involved oxidation: using Tollens or Fehling's or acidified potassium dichromate solution. Students should be reminded that when asked to give an observation, those who write the word "nothing" or "no observation" will not gain a mark.

Part (c)(i) was answered well although a few students drew more than one repeating unit. Part (c)(ii) was also answered well. About a third of students did not answer part (d)(i) correctly. Part (d)(ii) proved a good differentiator with many gaining a mark for noting that PGA is biodegradable, but only the best students were able to link this to the presence of polar bonds in PGA. Some students included the term polar but applied it to the whole molecule and not a specific bond.

Q11.

In part (a), the nucleophilic addition mechanism was very well done; common errors included missing the charge on the nucleophile or on the intermediate structure and showing a bond between the carbonyl carbon and the N of CN in the intermediate. In part (b)(i), students were not used to drawing 3D structures, and credit was given where attempts showed a pair of mirror images. Again there were some problems with wrongly bonded OH, CN and CH_2CH_3 groups in these structures. The method needed to distinguish between two enantiomers was well known, although to gain M2 polarised light had to be 'rotated' not turned or reflected, and rotated in 'opposite' directions not just different directions. A few students suggested wrongly that the molecules polarised the light or that the molecules themselves were rotated. The name in part (c) was well answered but part (d) was answered poorly. There was confusion of K_a , the acid dissociation constant, with a rate constant, and many students missed the link to low concentrations of cyanide ions from the weak acid HCN and focused mainly on the rate of the dissociation of the acid. Parts (e)(i) and (e)(iii) were answered well but responses to part (e)(ii) sometimes included the C=C bond or the CN group as part of the polymer chain.

Q12.

Parts (a), (b)(i) and (b)(ii) were answered well. In part (b)(iii), students often correctly identified that polarised light could be used but then failed to gain the marks because they did not mention the effect of a racemic mixture on the light. Another concern was that answers appeared to suggest that the light caused the molecules themselves to rotate.

Parts (c)(i) and (c)(ii) were answered well but very few students scored full marks for part (c)(iii) where explanations were often muddled or referred to unspecified equilibria.

Part (d) was generally well attempted, with the main errors being in part (d)(i), where many gave three or more repeating units or failed to show an ester linkage, in part (d)(iv), where many gave the formula of the polymer or missed this part out completely, and in part (d)(v), where hydrogen bonding was often offered as an explanation.

Part (d)(iii) contained an unfortunate typographical error, which was identified after the examination had taken place. The end of the first sentence should have read "...from two lactic acid molecules" rather than ".....from two PLA molecules". AQA apologises for this error. The expected answer was given by about a quarter of the students. To ensure that students were not disadvantaged, a mark was also awarded to those students who drew any correct cyclic compound with molecular formula $\text{C}_6\text{H}_8\text{O}_4$. The number of students

who did not attempt this question was low and in line with other question parts on this paper. The most common errors involved attempts to draw a cyclic compound but with one or more carbons having fewer than four bonds or oxygens with fewer than two bonds.

Q13.

Part (a)(i) was only answered correctly by 28% of students but the rest of part (a) was well done including the name in part (a)(iii) although some had the prefixes in the wrong order or had the numbers reversed.

Part (b)(ii) was not well done. The 'e' is required in the names of diols, triols etc as in the example here, propane-1,3-triol.

There were very few wrong answers in part (c).

Many students scored 1 mark in part (d) for identifying the correct compound as 'c', but the explanations were almost always incorrect. The C-F bond in the copolymer is polar but is not hydrolysed because it and all other bonds in the compound are strong.

Q14.

The repeating unit in part (a)(i) was generally well attempted, although a number of benzene rings appeared in place of (CH₂)₆ in the diamine section. Part (a)(ii) was less well done; many candidates omitted the name of the relevant intermolecular force in both types of polymers or gave dipole-dipole attractions as the strongest type in polyamides. Some sadly described breaking bonds in the carbon chains.

Part (b)(i) was well answered although some common errors continue to appear. These include writing a minus charge on methylamine, omitting the + on the N in the intermediate and drawing the curly arrow which shows breaking of the N-H bond going to the H rather than to the N. Many gave the correct name in (b)(ii), but an appreciable number of candidates were unfamiliar with naming of N-substituted amides or did not recognise the product as one of these.

Part (c) was well answered but by contrast part (d)(i) was not. Even candidates who identified the correct substituents failed to write them in alphabetical order or gave the wrong position numbers. Parts (d)(ii) and (d)(iii) were generally well attempted, although a number used aspartic acid in (d)(iii). Part (d)(iv), however, was less well done. Many candidates did not realise that a quaternary ammonium salt was required and even those who did often gave answers containing ethyl groups rather than methyl groups on N.

Q15.

There were very few correct answers to part (a), but part (b) was well answered, although some misread the question here and tried to use benzene-1,2-dicarboxylic acid or tetrachloroethene.

Part (c)(i) was quite well done although many wrong answers included CH₂CH₃OH for ethanol or two moles of water.

In part (d), many candidates missed the +. from the molecular ion or put the . on the radical in the wrong place. Several of those who chose to write a formula for the benzene ring in DEP, rather than use the structure given, lost the mark if they gave C₆H₆ rather than C₆H₄ in the formula for the molecular ion and fragment ion.

A surprising number of candidates wrote a chemical equation or included [H₂O] in the rate equation in part (e)(i). Not many candidates scored both marks in part (e)(ii), with many

simply referring to more repeats.

Q16.

Part (a) was answered well by two thirds of the candidates. In part (b)(i), half gave a correct structure; many wrong answers showed too many repeating units or included an extra oxygen atom. The type of polymerisation in part (b)(ii) and the required bond in part (c)(i) were both very well known. In part (c)(ii) the answer was required as a displayed formula, ie it must show **all** the bonds. Many candidates have still not realised that all includes the O–H bond. Part (d) was correctly answered by fewer than a fifth of the candidates. Many simply drew 2-aminobutanoic acid rather than its zwitterion. In parts (e)(i) and (e)(ii), many candidates did not recognise that both acid groups in glutamic acid would react. Two thirds of candidates answered part (e)(i) correctly, but parts (e)(ii) and (e)(iii) were found more difficult. In part (f), some candidates explained clearly how column chromatography worked and just under a third gained full marks in this section. Others described paper chromatography or were obviously unfamiliar with the topic.

Q17.

Candidates are able to tackle organic reaction mechanisms with confidence and this question was well answered. The most demanding part was part (a)(iii) in which they had to indicate that the carbon-bromine bond was polar.

Q19.

Part (a)(i) was answered well by almost all candidates. In part (a)(ii) most were able to draw correct structures of the diol and the diacid but only the better candidates were able to name these molecules correctly. Even naming the relatively straightforward butan-2,3-diol caused problems. The dipeptides in part (b) were usually well drawn. In part (c) most candidates were able to draw the structure of a suitable halopropane in part (i), but many found the structure of the nitrile much harder. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$ and $\text{CH}_3\text{CH}_2\text{CH}_2\text{NO}_2$ were common wrong answers. In part (iii), the first two parts were well answered, but relatively few candidates were able to draw the structure of a correct secondary or tertiary amine or a quaternary ammonium salt formed when propylamine reacts with an excess of halopropane.

Q20.

All parts of this question proved to be very accessible to all but the lowest achieving candidates. The most common errors arose from failing to use *concentrated* sulphuric (or phosphoric) acid in part (b)(ii) and from failing to give a clear statement of the advantage which ethanol offers as a fuel.

Q21.

Only the better candidates were able to calculate the number of moles of C_2F_2 and of HC_1 correctly. However, if the rest of the answer used correct chemistry, no further marks were lost. The expression for K_c was well known, but there was uncertainty over the use of the volume of the container in the calculation. Many forgot to include it at all and so used a number of moles instead of the concentration in mol dm^{-3} . Some tried to include the number 18.5 dm^3 in the expression for K_c and others tried to convert the volume into m^3 . Parts (b) and (c) were well answered even by those who lost marks in the calculation in part (a).

Q22.

Weaker candidates gained the marks in part (a) but scored few others in this question. In part (b) many attempted to name the dipeptide rather than the amino acid as asked. Similarly the correct structure of the protonated amino acid was given only by the more able candidates; many others attempted to draw the protonated dipeptide. In part (c), the empirical formula was reasonably well answered, but few candidates seemed to understand that the polyester must have been formed from a diacid, so that common answers such as propanoic or butanoic acids could not be correct. The statement that “polyesters and polyamides can be broken down by hydrolysis and are, therefore, biodegradable” appears in the specification. Unfortunately few candidates were able to recall or understand this point.

Q24.

Most candidates were able to draw the structure of the anion required in part (a)(i) and the dipeptide in part (a)(ii), although a common wrong answer in part (ii) was the repeating unit of the polymer. “Hydrogen bonding” was correctly given by most candidates in part (iii) and “addition” polymerisation was well known in part (b)(i). Weaker candidates simply drew hydrocarbon **G** again in part (b)(ii) rather than pent-2-ene and better candidates were able to deduce that a saturated cycloalkane, such as cyclopentane was required in part (iii).

Q26.

While some good answers to part (a) were seen, in general the definitions were poor. Electrophiles were often described as being positive ions or as having a surplus of electrons. Many candidates tried to describe addition simply as ‘one molecule/atom adding on to another’. Correct simple definitions based on two molecules joining to form a single molecule were not common and were usually offered by the better candidates. The responses offered for part(b) were quite varied. Many candidates described the induced polarisation of the bromine molecule but fewer identified the high electron density present around the double bond in propene as its cause. Some candidates incorrectly described a process in which a lone pair from bromine was donated to the double bond, or suggested heterolytic fission of the Br-Br bond followed by an electrophilic attack by Br⁺ on the double bond. Many clear and accurately drawn mechanisms were seen; however, it was not uncommon to see a primary carbocation as the intermediate. Poorly drawn curly arrows, which did not start at a bond/lone pair, or which did not end at a bond/atom, were also quite common. In some cases, candidates showed the bromine molecule with full charges or the intermediate/bromide ion with a partial charge. Curly arrows moving in the wrong direction, e.g. from a bromine atom towards the double bond, were not uncommon. The product was usually correctly named, with the most common errors being the use of ‘bromopropane’, rather than ‘dibromopropane’, or quoting the carbon skeleton as ‘ethane’, ‘butane’ or ‘pentane’. Part (d) was generally well done although a number of candidates described the process as ‘additional polymerisation’ or as ‘condensation’.