Q1.

This question is about ethanedioic acid (HOOCCOOH) and the ethanedioate ion ($^{-}$OOCCOO^{-}).

(a) Ethanedioic acid reacts with propane-1,3-diol ($HOCH_2CH_2CH_2OH$) to form a polyester.

Draw the repeating unit of this polyester.

(2)

(b) Explain why polyesters are biodegradable but polyalkenes are not biodegradable.

_____

_____

_____

_____

_____

_____

(2)

(c) Sodium ethanedioate is used to find the concentration of solutions of potassium manganate(VII) by titration. The equation for this reaction is

$$2\ MnO_4^- + 16\ H^+ + 5\ C_2O_4^{2-} \rightarrow 2\ Mn^{2+} + 8\ H_2O + 10\ CO_2$$

A standard solution is made by dissolving 162 mg of $Na_2C_2O_4$ (M_r = 134.0) in water and making up to 250 cm^3 in a volumetric flask.

25.0 cm^3 of this solution and an excess of sulfuric acid are added to a conical flask.
The mixture is warmed and titrated with potassium manganate(VII) solution.
The titration is repeated until concordant results are obtained.
The mean titre is 23.85 cm^3

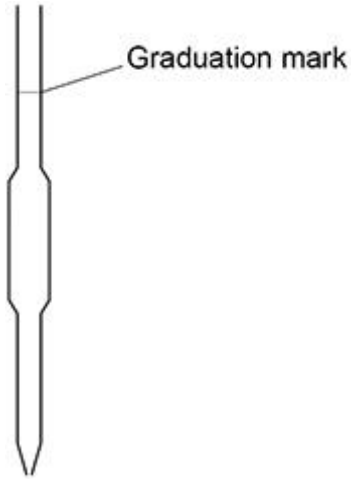
Calculate the concentration, in mol dm^{-3}, of the potassium manganate(VII) solution.

Concentration _____ mol dm^{-3}

(4)

(d) **Figure 1** shows the 25.0 cm^3 pipette used to measure the sodium ethanedioate solution.

Figure 1



On **Figure 1**, draw the meniscus of the solution when the pipette is ready to transfer 25.0 cm^3 of the sodium ethanedioate solution.

(1)

(e) Potassium manganate(VII) is oxidising and harmful.
Sodium ethanedioate is toxic.

Suggest safety precautions, other than eye protection, that should be taken when:

- filling the burette with potassium manganate(VII) solution
- dissolving the solid sodium ethanedioate in water.

Filling the burette _____

_____

Dissolving the solid _____

_____

(2)

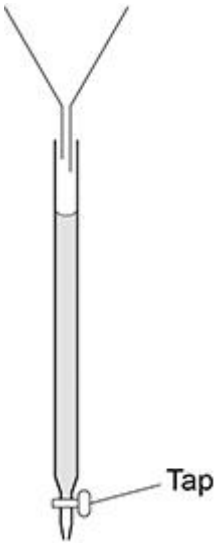
(f) State the colour change seen at the end point of each titration.

_____

(1)

(g) **Figure 2** shows the burette containing potassium manganate(VII) solution.

Figure 2



Give **two** practical steps needed before recording the initial burette reading.

1 _____

2 _____

(2)

(h) When $Na_2C_2O_4(aq)$ is added to a solution containing $[Fe(H_2O)_6]^{3+}$ ions, a reaction occurs in which all six water ligands are replaced by ethanedioate ions.

Explain why the replacement of the water ligands by ethanedioate ions is favourable. In your answer refer to:

- the enthalpy and entropy changes for the reaction
- how the enthalpy and entropy changes influence the free-energy change for the reaction.

_____

_____

_____

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_____

(6)

(Total 20 marks)

Q2.

Which polymer has hydrogen bonding between the polymer chains?

A Kevlar ⬭

B PVC ⬭

C poly(phenylethene) ⬭

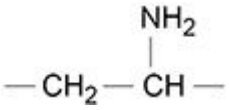
D Terylene ⬭

(Total 1 mark)

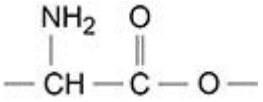
Q3.

Which is the repeating unit of a polyamide?

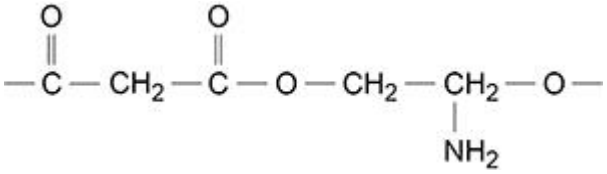
A



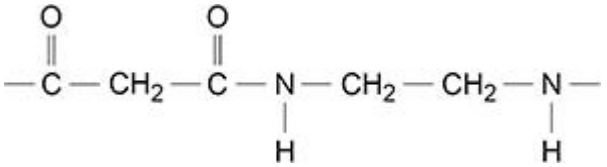
B



C



D



(Total 1 mark)

Q4.

Which type of polymer is **not** hydrolysed by heating with concentrated aqueous sodium hydroxide?

A poly(alkene)

B poly(amide)

C poly(ester)

D protein

(Total 1 mark)

Q5.

Which forms a polymer with $ClOC(CH_2)_8COCl$?

A $NH_2CH_2CH_2NH_2$ ⬭

B $(CH_3CO)_2O$ ⬭

C $CH_3CH_2CONH_2$ ⬭

D NH_2CH_2COOH ⬭

(Total 1 mark)

Q6.

Which polymer has hydrogen bonding between its chains?

A Kevlar ⬭

B Polythene ⬭

C PVC ⬭

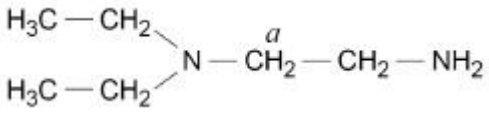
D Terylene ⬭

(Total 1 mark)

Q7.

There are several isomers with the molecular formula $C_6H_{16}N_2$

(a) One isomer is shown.



Give the number of peaks in the ^{13}C NMR spectrum of this isomer.

State and explain the splitting pattern of the peak for the hydrogens labelled *a* in its ^{1}H NMR spectrum.

Number of ^{13}C peaks

_____

Splitting pattern

_____

Explanation

_____

_____

_____

_____

(3)

(b) Draw the structure of the isomer of $C_6H_{16}N_2$ used to make nylon 6,6

(1)

(c) Draw the structure of the isomer of $C_6H_{16}N_2$ that contains two **primary** amine groups and has only two peaks in its ^{13}C NMR spectrum.

(1)

(d) Draw the structure of the isomer of $C_6H_{16}N_2$ that contains two **tertiary** amine groups and has only two peaks in its ^{13}C NMR spectrum.

(1)

(Total 6 marks)

Q8.

The repeating unit of a polymer is shown.

Which monomer or pair of monomers could be used to make this polymer?

A $ClOC(CH_2)_4NH_2$ only ⬭

B $ClOC(CH_2)_4COCl$ only ⬭

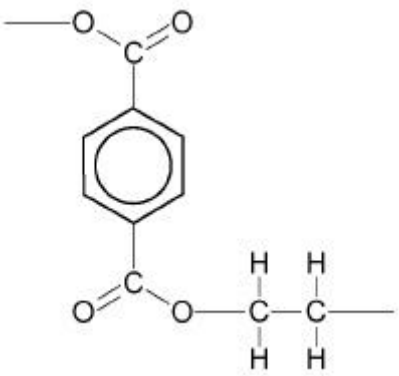
C $ClOC(CH_2)_4COCl$ and $H_2N(CH_2)_6NH_2$ ⬭

D $ClOC(CH_2)_6COCl$ and $H_2N(CH_2)_4NH_2$ ⬭

(Total 1 mark)

Q9.

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. ⬭

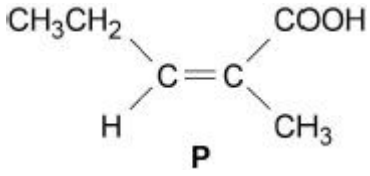
D The carbon-oxygen bonds in the chain are strong. ⬭

(Total 1 mark)

Q10.

This question is about six isomers of $C_6H_{10}O_2$

(a) Give the full IUPAC name of isomer **P**.



P

_____

(1)

(b) A sample of P was mixed with an excess of oxygen and the mixture ignited. After cooling to the original temperature, the total volume of gas remaining was 335 cm^3

When this gas mixture was passed through aqueous sodium hydroxide, the carbon dioxide reacted and the volume of gas decreased to 155 cm^3

Both gas volumes were measured at 25 °C and 105 kPa

Write an equation for the combustion of **P** in an excess of oxygen and calculate the mass, in mg, of **P** used.

The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Mass of **P** used _____ mg

(5)

(c) Isomer Q ($C_6H_{10}O_2$) is a cyclic compound. The infrared spectrum of **Q** is shown in **Figure 1** and the ^{13}C NMR spectrum of **Q** is shown in **Figure 2**.

Figure 1

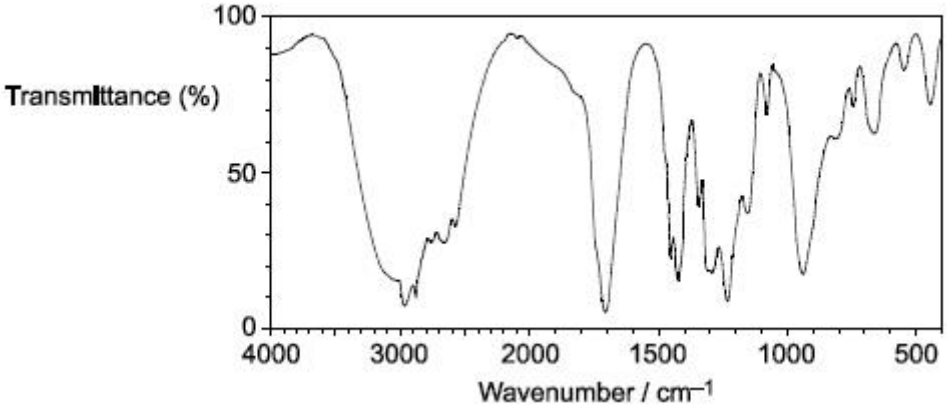
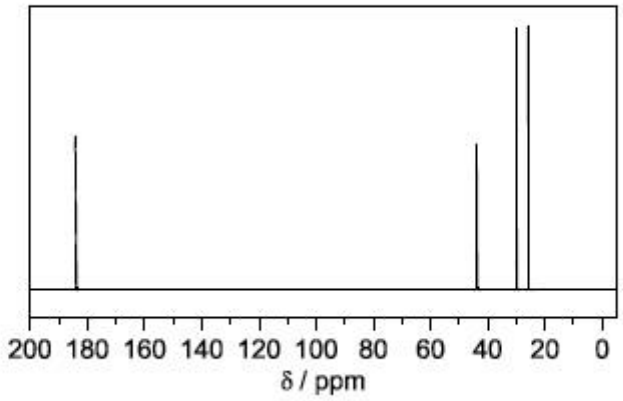


Figure 2



Use these spectra and Tables **A** and **C** in the Data Booklet to deduce the structure of **Q**.

In your answer, state one piece of evidence you have used from each spectrum.

Structure of **Q**.

Evidence from **Figure 1**

_____

_____

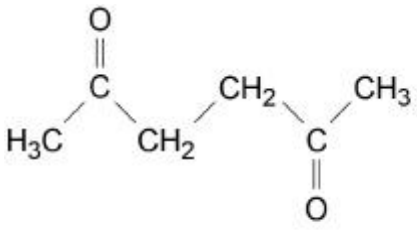
Evidence from **Figure 2**

_____

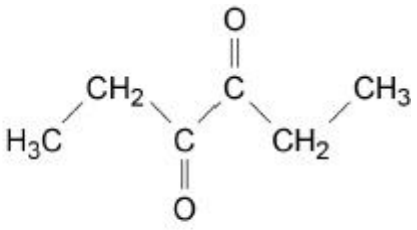
_____

(3)

(d) Isomers **R** and **S** are shown.



R



S

Although the ^{13}C spectra of **R** and **S** both show the same number of peaks, the spectra can be used to distinguish between the isomers.

Justify this statement using Table **C** from the Data Booklet.

Give the number of peaks for each isomer.

Justification

_____

_____

_____

_____

Number of peaks

_____

(3)

(e) Although the ^{1}H spectra of **R** and **S** both show the same number of peaks, the spectra can be used to distinguish between the isomers.

Justify this statement using the splitting patterns of the peaks.

Give the number of peaks for each isomer.

Justification

_____

_____

_____

_____

Number of peaks

_____

(3)

(f) The action of heat on 5-hydroxyhexanoic acid can lead to two different products.

On gentle heating, 5-hydroxyhexanoic acid loses water to form a cyclic compound, **T** ($C_6H_{10}O_2$).

Under different conditions, 5-hydroxyhexanoic acid forms a polyester.

Draw the structure of **T**.

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

Structure of **T**

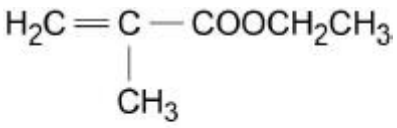
Repeating unit of polyester

Type of polymerisation

_____

(3)

(g) Isomer **U** is shown.



U

The polymer formed by **U** and the polymer formed by 5-hydroxyhexanoic acid in part (f) both contain ester groups that can be hydrolysed.

Draw the repeating unit of the polymer formed by **U**.

Justify the statement that, although both polymer structures contain ester groups, the polymer formed by **U** is not biodegradable.

Repeating unit of polymer formed by **U**.

Justification

_____

_____

_____

_____

(3)

(Total 21 marks)

Q11.

Which compound can form a polymer without needing another reagent?

A $HOCH_2CH_2OH$ ⬭

B $HOOCCH_2CH_2COOH$ ⬭

C $HOCH_2CH_2COCl$ ⬭

D $ClCH_2CH_2COOH$ ⬭

(Total 1 mark)

Q12.

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

A Kevlar ⬭

B Nylon ⬭

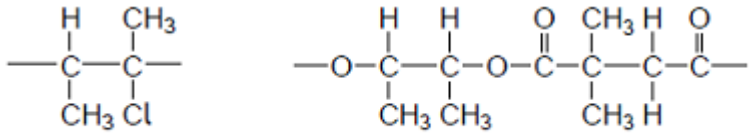
C Polythene ⬭

D Terylene ⬭

(Total 1 mark)

Q13.

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)