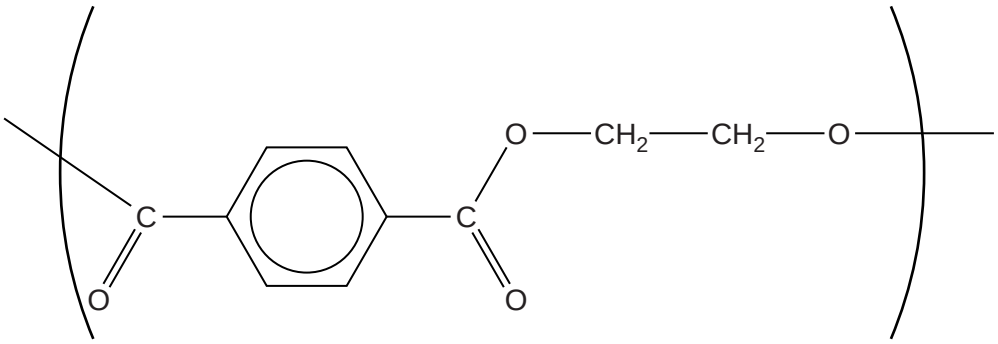
Answer **all** the questions.

1 PET is a polyester which has the repeating unit shown below.



PET

(a) (i) **Draw a ring** around an ester group on the structure above. **[1]**

(ii) State the **types** of intermolecular bonds which hold polyester chains together.

.....

.....

..... **[2]**

(iii) Use the formula above to draw the structural formulae of the monomers which are used to make PET.

[2]

(iv) State the **type** of polymerisation involved in forming PET and identify the other product when PET is formed from the monomers.

.....

..... **[1]**

(b) A student heats PET under reflux with an excess of NaOH(aq). From the mixture the student isolates a solid salt and an organic liquid.

(i) Describe what happens to the vapour when a mixture is heated under reflux and give **one** reason why reflux was used in this reaction.

.....

.....

.....

..... **[2]**

(ii) The student purifies the salt by recrystallisation using a suitable solvent.

Describe and explain the process of recrystallisation, including an explanation for the choice of solvent used and how impurities are removed.

In your answer you should link the removal of impurities to the relevant step of the recrystallisation process.

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..... **[6]**

(c) The student uses infrared spectroscopy to identify the **two** organic products, **A** and **B**, formed by the reaction of PET with an excess of NaOH(aq) in part **(b)**.

(i) Explain why a substance produces a spectrum showing absorption peaks when irradiated with infrared frequencies.

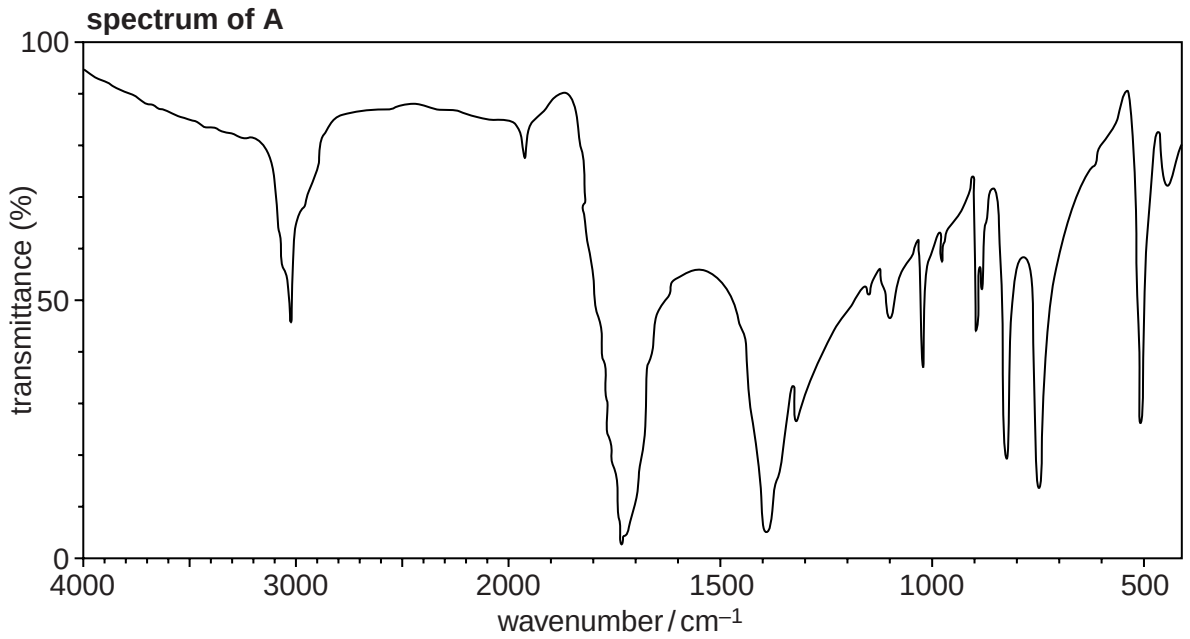
.....

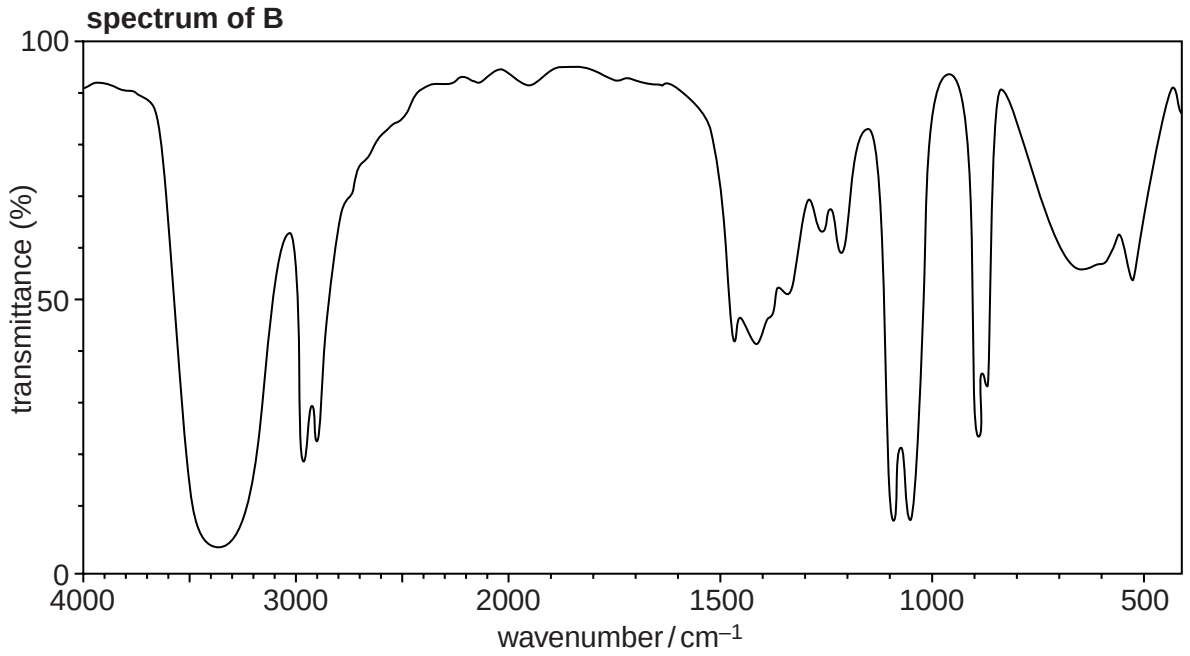
.....

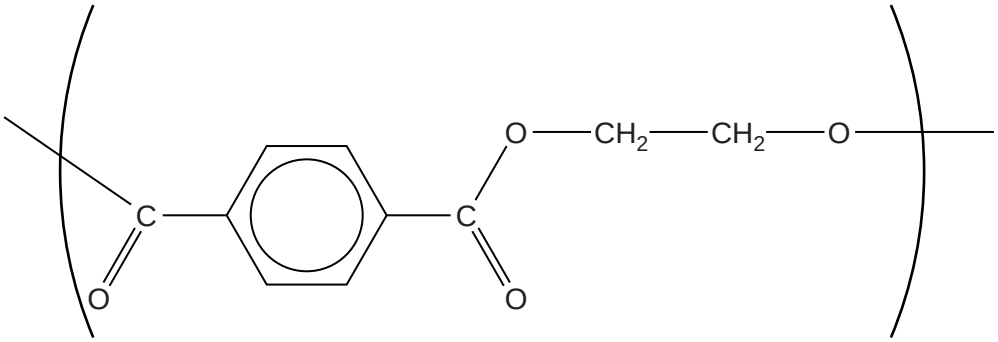
.....

..... **[2]**

The infrared spectra of **A** and **B** are shown below.







PET

(ii) Use your knowledge of the reaction, together with the *Data Sheet* and the spectra to identify products **A** and **B**.

Give the structures of **A** and **B**.

Give your reasoning, stating any relevant absorption peaks and bonds involved.

structure of **A**

reasoning .....

.....

.....

.....

structure of **B**

reasoning .....

.....

.....

.....

[5]

Turn over

(d) PET has a T_g of 75 °C and a T_m of 260 °C.

(i) Give the meaning of the term T_g.

.....

.....

..... **[1]**

(ii) Describe what would happen to a bottle made from PET if it was heated to 300 °C in the absence of air.

.....

.....

..... **[1]**

(e) PBT is a similar polymer to PET. PBT is less crystalline than PET.

(i) Explain why PBT would be more flexible than PET.

.....

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.....

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..... **[3]**

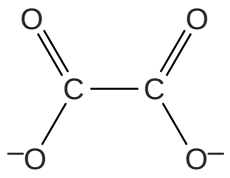
(ii) One of the monomers used to make PBT has a straight chain of carbon atoms and has the molecular formula $C_4H_{10}O_2$.

Give the systematic name of this monomer.

..... **[2]**

[Total: 28]

2 *Bar Keeper's Friend* is a powdered cleaning agent invented over 100 years ago and still in use today. It is particularly effective at removing rust stains. The active ingredients are the ethanedioate ion, shown below, and ethanedioic acid, $(COOH)_2$.



A student decides to investigate how *Bar Keeper's Friend* removes rust stains. The student finds that the ethanedioate ions act as bidentate ligands which form complexes with Fe^{3+} ions.

(a) (i) On the diagram **above** show how this bidentate ligand bonds to a Fe^{3+} ion.

On the diagram name the type of bond formed. **[3]**

(ii) The complex ion formed between the ethanedioate ligands, $C_2O_4^{2-}$, and Fe^{3+} has a charge of 3–.

Give the formula and name the shape of the complex ion.

formula:

name of shape .....

[2]

Turn over

(b) The student also investigates whether ethanedioic acid, $(COOH)_2$, undergoes a redox reaction with Fe^{3+} ions.

Half-reaction	$E^{\ominus}$/V
$2CO_2 + 2H^+ + 2e^- \rightarrow (COOH)_2$	–0.49
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77

(i) Use data from the table above to explain why the student expects $(COOH)_2$ and Fe^{3+} ions to react.

.....

.....

.....

..... **[2]**

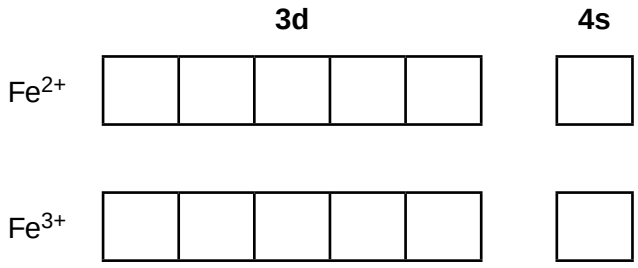
(ii) Write an ionic equation for the reaction that the student expects will occur in solution between $(COOH)_2$ and Fe^{3+} ions.

Include state symbols.

$\rightarrow$

[2]

(iii) Draw arrows in appropriate boxes to show the outer electron structures for Fe^{2+} and Fe^{3+}.



[2]

(iv) Use your answers to **(iii)** to explain why Fe^{3+} ions are more stable than Fe^{2+} ions.

.....

.....

..... **[1]**

(c) The concentration of an ethanedioate solution can be found by titration with a standard potassium manganate(VII) solution in acid conditions. However, the reaction is slow at room temperature and needs to be heated to about 60 °C.

The equation for the reaction is given below.

$$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O \qquad \textbf{equation 2.1}$$

(i) Describe how the titration would be carried out and explain why an indicator does **not** need to be added. In your answer describe how the end point can be recognised.

In your answer you should use technical terms spelled correctly.

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..... **[6]**

$$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$ **equation 2.1**

(ii) A student made up a solution containing ethanedioate ions by dissolving potassium ethanedioate-1-water crystals, $K_2C_2O_4 \cdot H_2O$, in 100 cm^3 of solution.

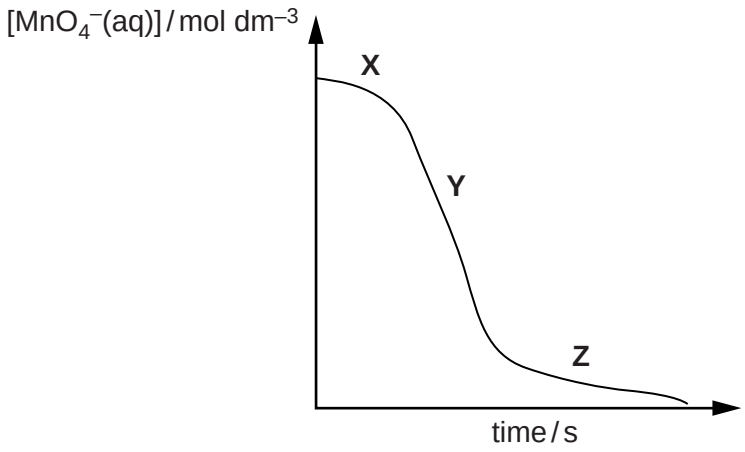
The student found that 25.0 cm^3 of this solution reacted with 18.40 cm^3 of 0.0500 mol dm^{-3} $KMnO_4$ solution.

Calculate the mass of $K_2C_2O_4 \cdot H_2O$ which was used to make up the solution.

Give your answer to an **appropriate** number of significant figures.

mass of $K_2C_2O_4 \cdot H_2O$ = ... g **[6]**

(d) The rate of reaction of ethanedioate ions with acidified manganate(VII) ions is fairly slow at 25 °C. As the reaction progresses, Mn^{2+} ions are formed which act as a catalyst.
The student decides to measure the progress of the reaction at 25 °C and obtains the graph shown below.



(i) Describe and explain the changes in the reaction rate between:

X and Y .....

.....

.....

.....

Y and Z .....

.....

.....

.....

[4]

(ii) Suggest **one** method that the student could use to measure the concentration of the manganate(VII) ions, other than by a **titration**.

..... **[1]**

(iii) During the progress of the reaction, give **one** observation that might be made.

.....

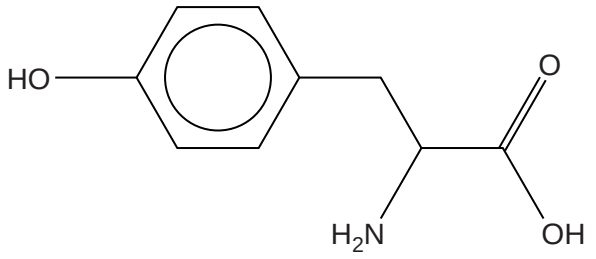
.....

..... **[1]**

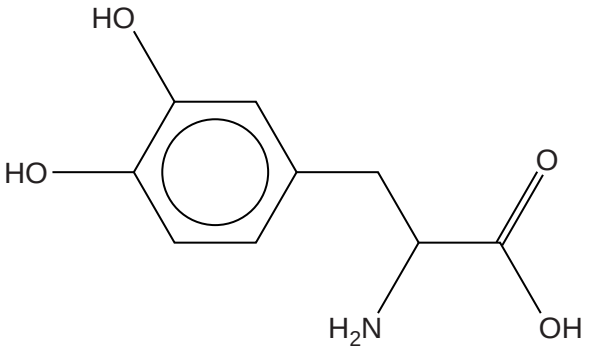
[Total: 30]

Turn over

3 One form of the compound DOPA is used as a drug to treat Parkinson's disease. Although found naturally, DOPA is usually synthesised from tyrosine.



tyrosine



DOPA

(a) (i) **Name** three different functional groups found in **both** tyrosine and DOPA, other than a benzene ring.

1 .....

2 .....

3 .....

[3]

(ii) What reagent can be used to test for the OH group on a benzene ring?

reagent .....

observation .....

.....

[2]

(b) (i) Tyrosine forms a zwitterion.

Explain the term *zwitterion* and draw the structure of the zwitterion formed by tyrosine.

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.....

.....

[2]

(ii) Is an aqueous solution of tyrosine acidic, alkaline or neutral?

Give a reason for your answer.

.....

.....

..... **[2]**

(iii) Draw the structure of the organic ion formed if excess NaOH is added to a solution of tyrosine in water.

[2]

(c) There are two stereoisomers of DOPA only one of which is effective in treating Parkinson's disease.

(i) Suggest why only one of the stereoisomers is effective in treating the disease.

.....

.....

..... **[2]**

(ii) DOPA has many adverse effects.

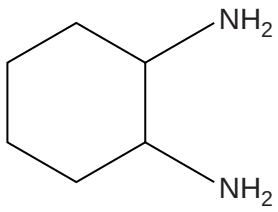
Suggest why it is still used to treat Parkinson's disease.

.....

..... **[1]**

(d) The substance 1,2-diaminocyclohexane has stereochemical properties which are important in the synthesis of DOPA.

The diamino compound shows both optical and *cis-trans* isomerism.



1,2-diaminocyclohexane

For optical isomerism:

- circle the chiral carbons on the structure **above**,
- explain why they are chiral.

.....

.....

.....

For *cis-trans* isomerism:

- suggest the structures of the isomers,
- suggest why two different isomers exist.

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[4]

[Total: 18]

4 Chloroalkanes are considered to be hazardous materials. The most abundant chloroalkane is chloromethane.

(a) Chloromethane is hydrolysed in the atmosphere. The rate of this hydrolysis in the gas phase has been investigated in the laboratory.

The equation for the hydrolysis reaction is given below.

$$CH_3Cl + H_2O \rightarrow CH_3OH + HCl \qquad \textbf{equation 4.1}$$

The rate was found by measuring the rate of formation of HC*l*. The results are given in the table below.

Expt.	$[CH_3Cl]$ /mol dm^{-3}	$[H_2O]$ /mol dm^{-3}	Initial rate of formation of HC*l* /mol dm^{-3} s^{-1}
1	0.250	0.250	2.838
2	0.375	0.250	4.256
3	0.250	0.125	0.709

(i) Use the data from the table to determine the orders of reaction with respect to CH_3Cl and H_2O.

order with respect to CH_3Cl: .....

order with respect to H_2O: ..... **[2]**

(ii) Give the rate equation and overall order for the reaction.

rate =

overall order = ... **[2]**

(iii) A research worker suggested that the mechanism for the reaction might be:

step 1 $2H_2O \rightleftharpoons H_3O^+ + OH^-$ fast

step 2 $CH_3Cl + OH^- \rightarrow CH_3OH + Cl^-$ slow

Explain why this mechanism is consistent with the orders of the reaction in **(i)**.

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.....

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.....

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.....

..... **[2]**

Turn over

$$CH_3Cl + H_2O \rightarrow CH_3OH + HCl$$ **equation 4.1**

(b) After the CH_3Cl has been hydrolysed in the atmosphere to CH_3OH, the CH_3OH formed can be oxidised.

The hydrolysis and oxidation result in two acids being present in the atmosphere.

Name the two acids.

.....

..... **[2]**

(c) In the laboratory, alcohols can be oxidised to form aldehydes.

Give the reagents used and describe how the reaction is carried out to prevent further oxidation of the aldehyde.

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.....

..... **[3]**

(d) A student found that another chloroalkane, $(CH_3)_3CCl$, was readily hydrolysed by water at 12 °C. He determined that the reaction was first-order with respect to $(CH_3)_3CCl$ and zero-order with respect to water.

At a $(CH_3)_3CCl$ concentration of 1.82×10^{-3} mol dm^{-3}, the rate of reaction was 1.56×10^{-4} mol dm^{-3} s^{-1}.

Calculate the rate constant for the reaction and give its units.

rate constant = ... units ..... **[3]**

[Total: 14]

END OF QUESTION PAPER