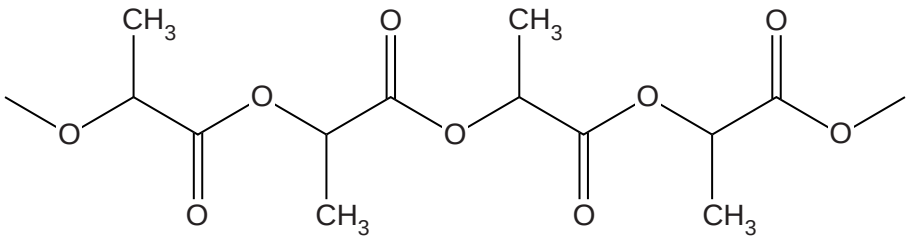
Answer **all** the questions.

1 PLA is a biodegradable polymer made from corn starch. The structure of part of a PLA chain is shown below.



PLA

(a) (i) On the structure of PLA above, circle the repeating unit. **[1]**

(ii) Give the name of the functional group joining the repeating units.

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

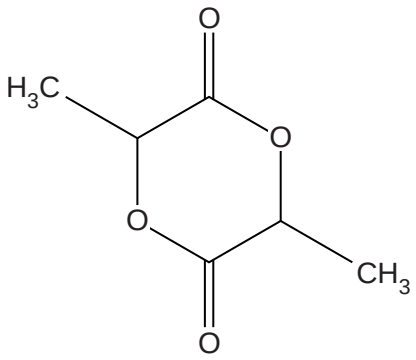
(b) In the box below, draw the structural formula of the monomer, **A**, that could be used to form PLA. Water would also be produced in this reaction.

monomer A

[1]

(c) In practice, monomer **A** cannot be used directly to form PLA because the water produced in the process reacts with the polymer.

Instead, corn starch is processed to form compound **B**. A bond in **B** is then broken and the molecules join together to form PLA.



compound B

(i) On the structure of **B** above, indicate with an arrow a bond that would be broken in this process. **[1]**

(ii) Explain why the process for producing PLA from **B** is more successful than the one starting with **A**.

.....

.....

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

(iii) The polymerisation of **B** to form PLA is more environmentally friendly than the reaction using **A**.

Explain why, in terms of atom economy.

.....

.....

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

Turn over

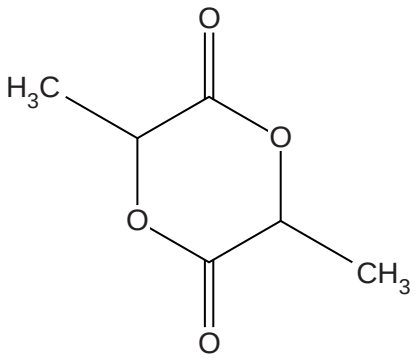
(d) Molecules of compound **B** are chiral. This means that PLA can exist in several different forms.

(i) Explain what is meant if a molecule is referred to as being *chiral*.

.....

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

(ii) Circle **two** carbon atoms on the structure below that are responsible for **B** being chiral.



compound B

[1]

(e) Two particular chiral forms of PLA can be blended together to produce a more crystalline material than normal PLA.

(i) Give the meaning of the term *crystallinity* when it is used to discuss the properties of polymers.

.....

.....

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

(ii) The physical properties of a polymer depend on temperature.

- **Describe** the properties of a polymer at temperatures above its T_m.
- **Describe and explain** the properties of a polymer at temperatures below its T_g.
- Suggest a reason why the blended polymer has a higher T_m than normal PLA.

In your answer, you should clearly relate the difference in T_m of the polymers to the intermolecular bonds between the polymer chains.

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..... **[5]**

(f) PLA has some similar uses to poly(ethene). In addition to its biodegradability, suggest one reason why PLA is considered to be a 'greener' product than poly(ethene).

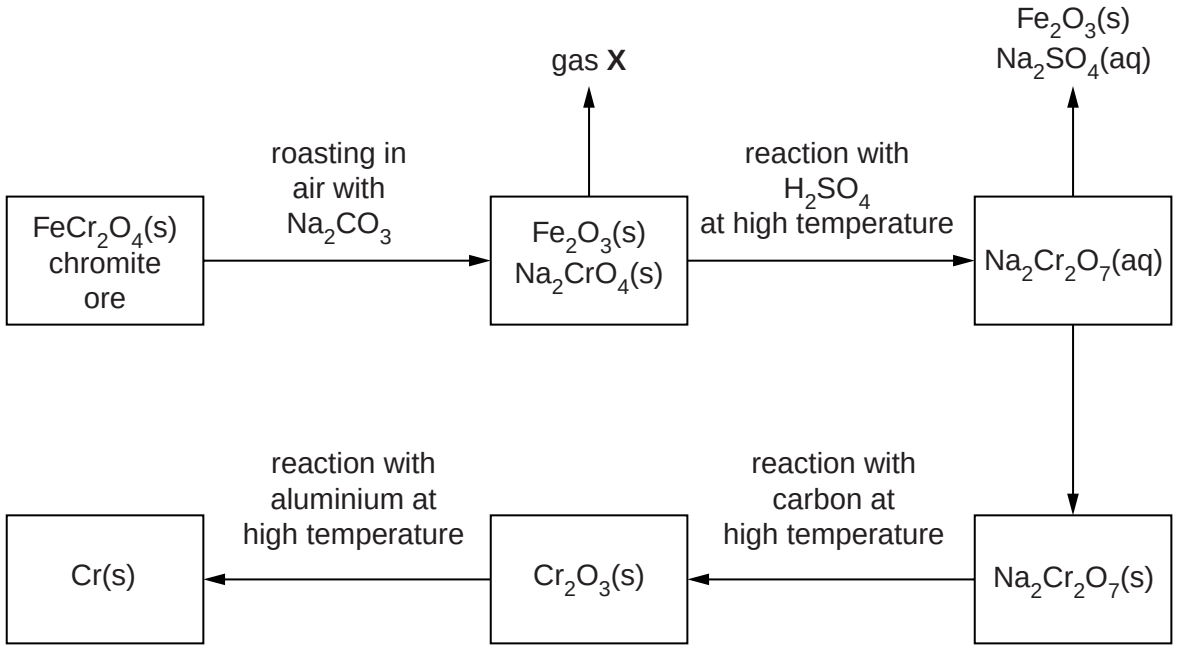
.....

.....

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

[Total: 17]

2 The main ore of chromium contains iron(II) chromite, $FeCr_2O_4$, from which pure chromium is extracted by the process outlined in the flowchart below.



(a) Roasting the chromite ore with sodium carbonate in air produces the gas **X**.

(i) Identify gas **X**.

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

(ii) Use oxidation states to determine the elements oxidised in the **roasting** process. Give reasons for your answer.

.....

.....

.....

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

(iii) Give the systematic name of Na_2CrO_4.

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

(b) Write a balanced equation for the reaction of Na_2CrO_4 with H_2SO_4.

State symbols are not required.

→

[2]

(c) Suggest a method for removing Fe_2O_3 from the mixture formed after the reaction with sulfuric acid.

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

(d) Iron is made from its ores by carbon reduction.

Using this information and evidence from the flowchart, compare the relative oxidising strengths of Fe_2O_3 and Cr_2O_3.

.....

.....

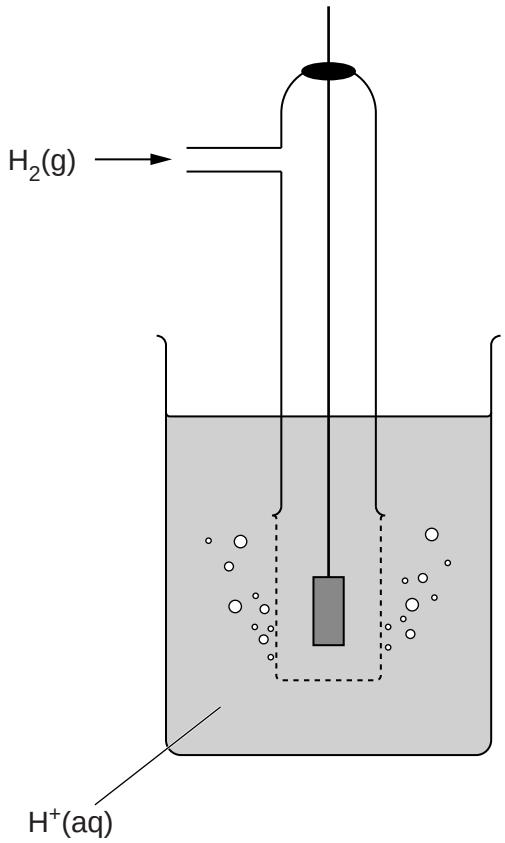
..... **[1]**

QUESTION 2 CONTINUES ON THE NEXT PAGE

(e) A student further investigated the redox chemistry of chromium by measuring $E^{\ominus}$ values.

(i) Complete the diagram below to show a cell that could be used to measure the standard electrode potential, $E^{\ominus}$, of the $Cr^{3+}(aq)/Cr(s)$ half-cell.

Label the diagram and state the standard conditions.



[3]

(ii) A student recorded a value of –0.74V for the standard electrode potential, $E^{\ominus}$, of the $Cr^{3+}(aq)/Cr(s)$ half-cell.

Write an ionic equation, with state symbols, for the overall reaction taking place in the student's cell in **(i)** when the cell is operating.

→

[2]

(iii) The student also measured a value of –0.44 V for the standard electrode potential, $E^{\ominus}$, of the $Fe^{2+}(aq)/Fe(s)$ half-cell.

The student then used the two $E^{\ominus}$ measurements to conclude **incorrectly**:

'$Cr^{3+}(aq)$ is a stronger oxidising agent than $Fe^{2+}(aq)$ because the *electronegativity* of Cr is larger than that of Fe.'

- Explain the meaning of the term *electronegativity*.
- Give the correct conclusion with reasoning.

electronegativity .....

.....

.....

conclusion and reasoning .....

.....

.....

.....

.....

..... **[4]**

(f) Hydrated chromium(III) salts react with water to set up the equilibrium below.

$$[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5OH]^{2+} + H_3O^+$$

Explain why this is an example of an acid–base equilibrium.

Give the **two** chemical species that are acting as acids.

.....

.....

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

(g) Chromium(III) forms a complex ion with the bidentate ligand $H_2NCH_2CH_2NH_2$.

(i) Name the ligand $H_2NCH_2CH_2NH_2$.

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

(ii) Draw a '*dot-and-cross*' diagram for $H_2NCH_2CH_2NH_2$.

[2]

(iii) Use your answer to **(ii)** to explain why $H_2NCH_2CH_2NH_2$ is a *bidentate ligand*.

.....

.....

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

(h) The formula of the complex ion formed between chromium(III) and the ligand $H_2NCH_2CH_2NH_2$ is $[Cr(H_2NCH_2CH_2NH_2)_3]^{3+}$.

(i) State the coordination number of Cr^{3+} in the complex.

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

(ii) Draw a diagram to show the three-dimensional shape of this complex ion.

[2]

(iii) State the bond angle formed by a ligand–Cr–ligand bond.

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

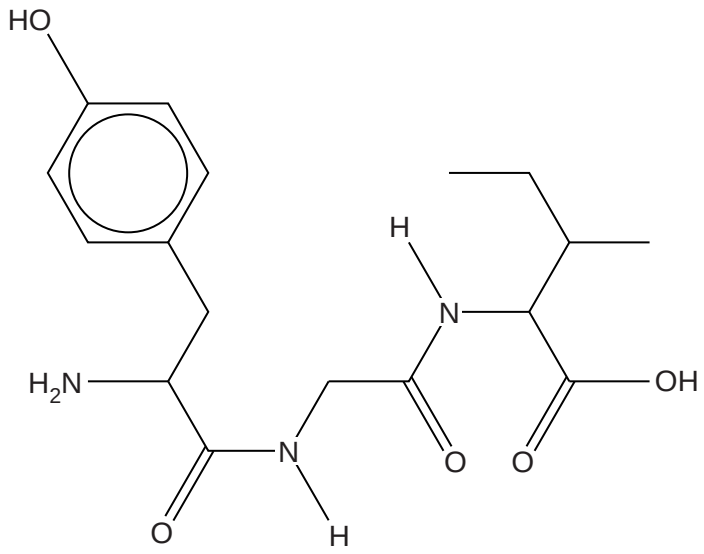
(iv) Use your diagram from **(ii)** to suggest a reason why this complex ion can exist as optical stereoisomers.

.....

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

[Total: 30]

3 Casein is a protein found in cows' milk. The tripeptide shown below illustrates a common amino acid sequence in the peptide chains found in casein.



(a) Underline **one** of the following terms which best describes the reaction in which proteins are formed from amino acids.

acid-base **addition** **condensation** **dehydration** **redox**

[1]

(b) The sequence of amino acids in the tripeptide shown above can be represented as Tyr–Gly–Ile.

(i) Give the chemical reagent and conditions used in the laboratory to break down casein into its constituent amino acids.

reagent .....

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

(ii) In the space below, draw the structural formula of the amino acid represented by Tyr.

[2]

Turn over

(c) A student set out to follow the rate of enzyme-catalysed breakdown of casein by attempting to use a colour-change reaction to measure the rate of production of Tyr.

The student added iron(III) chloride to the reaction mixture at pH 7.

(i) Give the name of the technique the student would use to measure the change in concentration of Tyr.

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

(ii) Describe and explain what happens when iron(III) chloride is added to Tyr.

.....

.....

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

(d) Casein, unlike enzymes, does not have a protein tertiary structure and so is relatively unaffected by small changes in pH.

(i) Explain the term *tertiary structure*.

.....

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

(ii) Explain why a protein with a tertiary structure is affected by pH change.

In your answer give a group that would be affected by lowering the pH, stating what is formed.

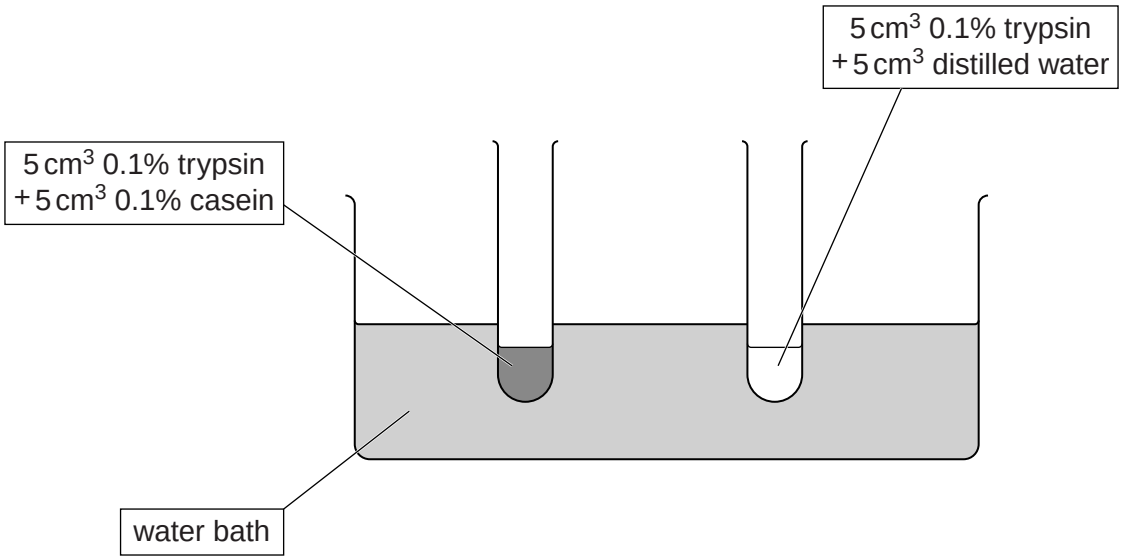
.....

.....

.....

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

(e) Casein is insoluble in water forming a milky suspension. The enzyme trypsin will hydrolyse casein forming a clear solution. A student investigated the effect of temperature on the rate of this reaction by measuring the time for the mixture to clear. The student used two test-tubes for each temperature studied, as shown below. Black card was placed behind the test-tubes.



(i) Why was black card placed behind the test-tubes?

.....

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

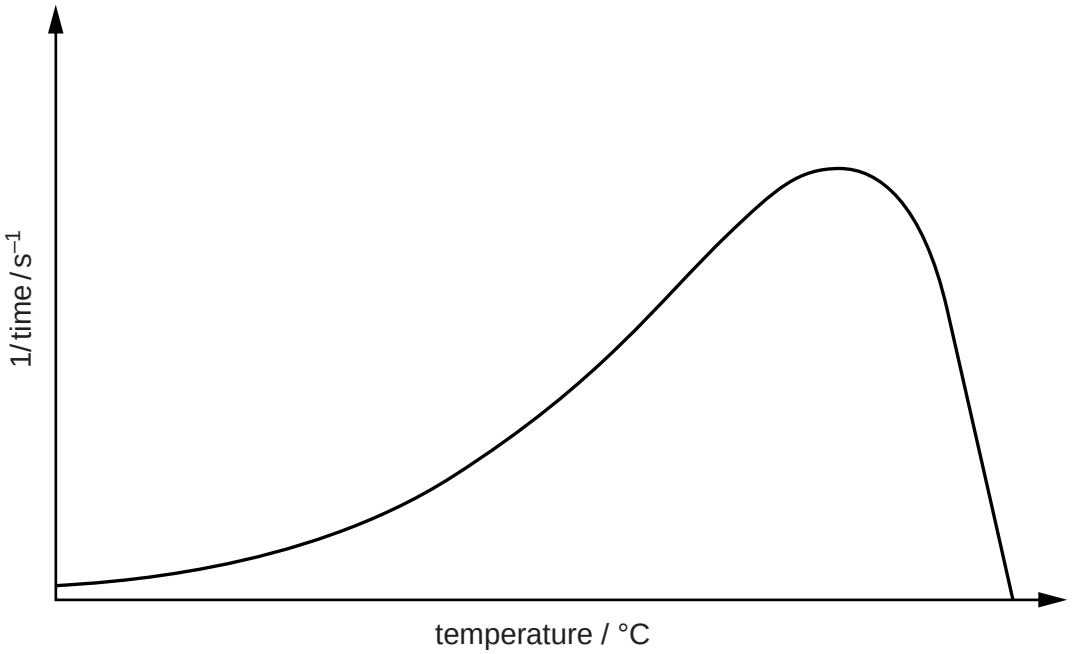
(ii) What is the purpose of the right-hand test-tube?

.....

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

QUESTION 3 CONTINUES ON THE NEXT PAGE

(iii) The student's results were processed and plotted on a graph, as shown below.



Describe how you would use the graph to find the relative rates of reaction at two different temperatures.

.....

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

(iv) Explain why the curve on the graph shown in **(iii)** rises and then falls sharply.

In your answer you should use appropriate technical terms spelled correctly.

.....

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..... **[4]**

(f) An enzyme-catalysed reaction at 40 °C is first order with respect to the enzyme and zero order with respect to the substrate. When the concentration of the enzyme is 0.010 mol dm^{-3} the rate of reaction is 3.08 × 10^{-3} mol dm^{-3} s^{-1}.

Calculate the value of the rate constant at 40 °C and state the units of the rate constant.

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

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

(g) The reaction sequence of an enzyme, **E**, with a substrate, **S**, to form the product, **P**, can be represented as shown below.

$$\mathbf{E} + \mathbf{S} \xrightarrow{\text{step 1}} \mathbf{ES} \text{ complex} \xrightarrow{\text{step 2}} \mathbf{EP} \text{ complex} \xrightarrow{\text{step 3}} \mathbf{E} + \mathbf{P}$$

When the substrate concentration is high, state the order of reaction with respect to the substrate.

Explain your answer.

.....

.....

.....

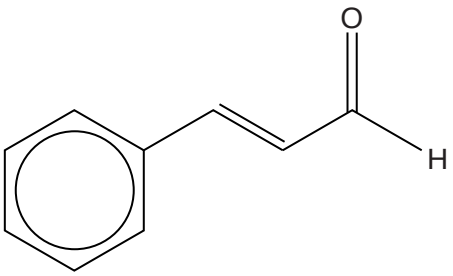
..... **[2]**

[Total: 23]

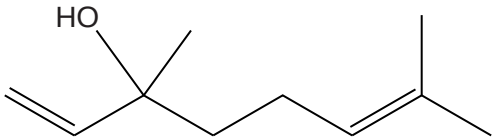
Turn over

4 Cinnamon oil is thought to have health benefits for people suffering from diabetes as it lowers blood-sugar levels. The oil does not mix with water and is a skin irritant.

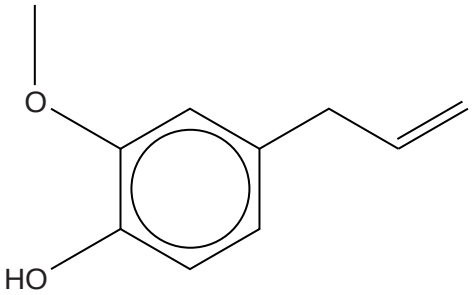
Three of the main constituents of the oil are cinnamaldehyde, linalool and eugenol. The structures of these compounds are shown below.



cinnamaldehyde



linalool



eugenol

(a) Suggest **one** problem chemists must solve in deciding on a suitable dose of the oil for a diabetic patient.

.....

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

(b) Describe how thin-layer chromatography can be used to show that cinnamaldehyde, linalool and eugenol are present in cinnamon oil.

.....

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..... **[5]**

(c) **Name** three functional groups present in **eugenol** other than a benzene ring.

1 .....

2 .....

3 ..... **[2]**

(d) A student devised a test to distinguish between eugenol and linalool. The student made an aqueous suspension of each compound in a separate test-tube. Sodium hydroxide solution was added to each test-tube and the test-tubes were shaken. The suspension of eugenol and water formed a solution; the linalool in water remained cloudy.

Explain the difference in behaviour when shaking the two suspensions with aqueous sodium hydroxide.

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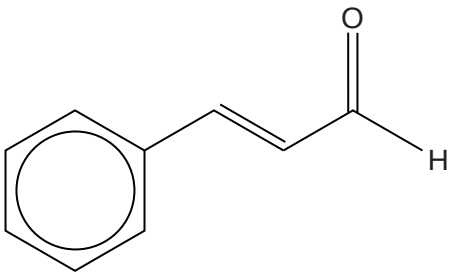
..... **[2]**



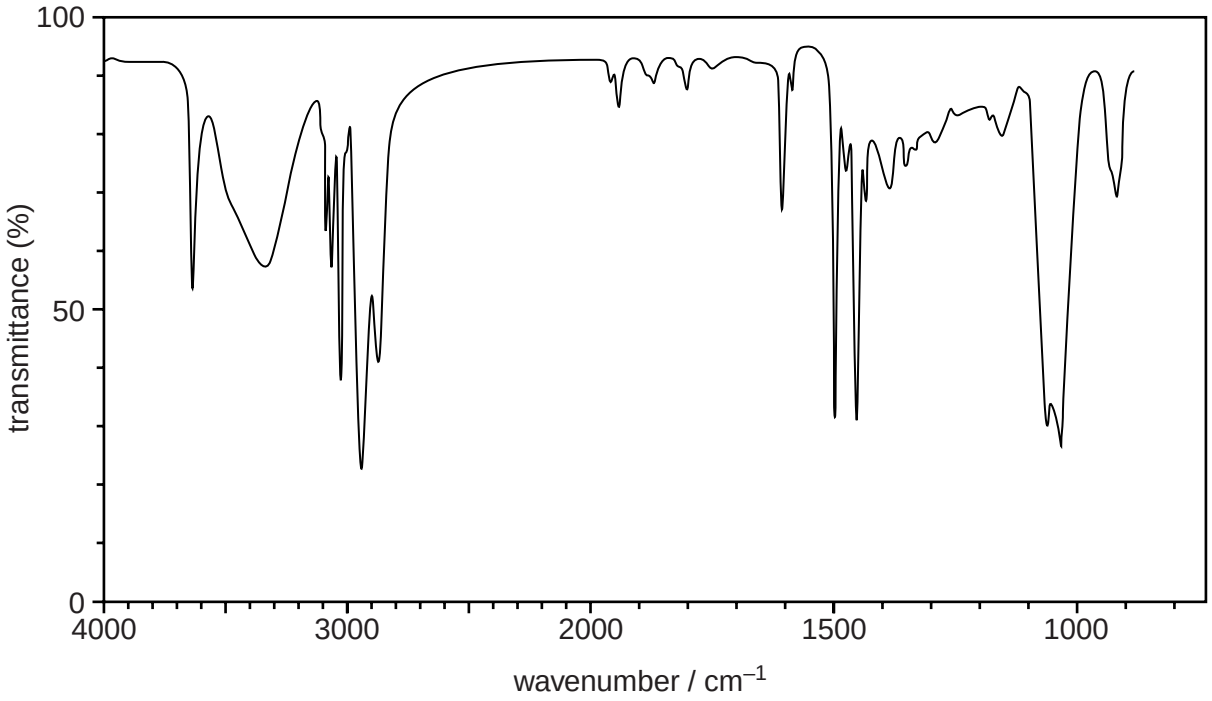
cinnamaldehyde

(e) A student attempts to react cinnamaldehyde with hydrogen. If a reaction takes place, two products, **X** and **Y**, are possible:

- **X** is formed if just the C=C bond reacts
- **Y** is formed if the C=C reacts **and** the C=O is reduced to an alcohol.

The student's infrared spectrum of the product of the reaction is shown below.

Use the *Data Sheet* and the spectrum to work out what is produced in the reaction. On the next page, give your reasoning and draw the structure of the compound responsible for the spectrum.



reasoning .....

.....

.....

.....

structure of compound responsible for the spectrum

[3]

(f) Cinnamaldehyde can be converted to cinnamic acid.

Give the reagents and conditions that are used in the laboratory to convert an aldehyde into a carboxylic acid.

reagents .....

.....

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

QUESTION 4 CONTINUES ON THE NEXT PAGE

(g) A student found the solubility in water of cinnamic acid, C_8H_7COOH, by titrating a saturated solution of cinnamic acid with a standard solution of sodium carbonate, Na_2CO_3, at 25 °C.

$$Na_2CO_3 + 2C_8H_7COOH \rightarrow 2C_8H_7COONa + CO_2 + H_2O$$

The student made a standard Na_2CO_3 solution by dissolving 0.6625 g of anhydrous Na_2CO_3 in water and making it up to 1000 cm^3 of solution. 50.0 cm^3 of the cinnamic acid solution reacted with exactly 10.80 cm^3 of the standard Na_2CO_3 solution.

M_r (cinnamic acid) = 148.2 and M_r (Na_2CO_3) = 106.0

Calculate the mass in grams of cinnamic acid that will dissolve in 1.00 dm^3 of water at 25 °C.

mass of cinnamic acid = ... g **[5]**

[Total: 20]

END OF QUESTION PAPER