



UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/41

Paper 4 Structured Questions

October/November 2012

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Section A

Answer **all** questions.

Section B

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use

1	
2	
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7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.



Section A

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 1 (a) Write down what you would see, and write equations for the reactions that occur, when silicon(IV) chloride and phosphorus(V) chloride are separately mixed with water.

silicon(IV) chloride

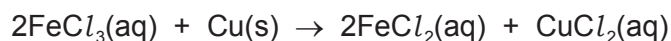
.....

phosphorus(V) chloride

.....

[4]

- (b) Iron(III) chloride, FeCl_3 , is used to dissolve unwanted copper from printed circuit boards (PCBs) by the following reaction.



A solution in which $[\text{Fe}^{3+}(\text{aq})]$ was originally equal to 1.50 mol dm^{-3} was re-used several times to dissolve copper from the PCBs, and was then titrated as follows.

A 2.50 cm^3 sample of the partially-used-up solution was acidified and titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4$.

This oxidised any FeCl_2 in the solution back to FeCl_3 .

It was found that 15.0 cm^3 of $\text{KMnO}_4(\text{aq})$ was required to reach the end point.

- (i) Construct an ionic equation for the reaction between Fe^{2+} and MnO_4^- in acid solution.

.....

- (ii) State here the $\text{Fe}^{2+} : \text{MnO}_4^-$ ratio from your equation in (i).

- (iii) Calculate the number of moles of MnO_4^- used in the titration.

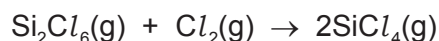
- (iv) Calculate the number of moles of Fe^{2+} in 2.50 cm^3 of the partially-used-up solution.

(v) Calculate the $[\text{Fe}^{2+}]$ in the partially-used-up solution.

(vi) Calculate the mass of copper that could still be dissolved by 100 cm^3 of the partially-used-up solution.

mass of copper = ... g
[6]

(c) When SiCl_4 vapour is passed over Si at red heat, Si_2Cl_6 is formed. Si_2Cl_6 contains a Si-Si bond.
The reaction of Si_2Cl_6 and Cl_2 re-forms SiCl_4 .



Use bond energy data from the *Data Booklet* to calculate ΔH° for this reaction.

$\Delta H^\circ = \dots\dots\dots \text{kJ mol}^{-1}$
[2]

(d) Calcium forms three calcium silicides, Ca_2Si , CaSi and CaSi_2 . The first of these reacts with water as follows.



(i) Balance this equation. You may find the use of oxidation numbers helpful.

(ii) During this reaction, state

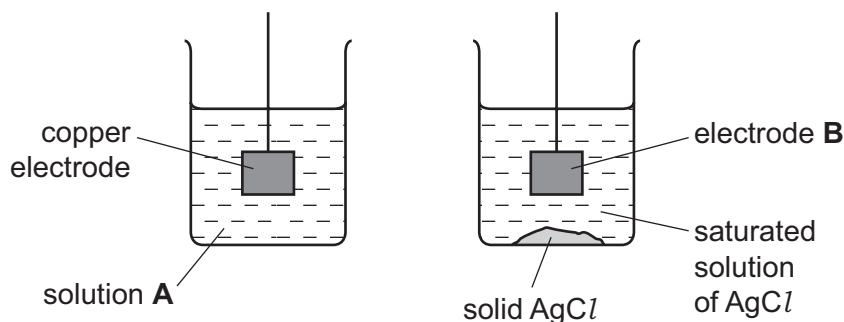
which element(s) have been oxidised, ...

which element(s) have been reduced.

[2]

[Total: 14]

- 2 (a) The diagram below shows an incomplete experimental set-up needed to measure the E_{cell} of a cell composed of the standard Cu^{2+}/Cu electrode and an Ag^+/Ag electrode.



- (i) State the chemical composition of

solution **A**, ...

electrode **B**.

- (ii) Complete the diagram to show the whole experimental set-up.

[4]

- (b) The above cell is not under standard conditions, because the $[\text{Ag}^+]$ in a saturated solution of AgCl is much less than 1.0 mol dm^{-3} . The $E_{\text{electrode}}$ is related to $[\text{Ag}^+]$ by the following equation.

equation 1
$$E_{\text{electrode}} = E_{\text{electrode}}^{\circ} + 0.06 \log[\text{Ag}^+]$$

- (i) Use the *Data Booklet* to calculate the E_{cell}° if the cell was operating under standard conditions.

$$E_{\text{cell}}^{\circ} = \dots\dots\dots \text{ V}$$

In the above experiment, the E_{cell} was measured at +0.17V.

- (ii) Calculate the value of $E_{\text{electrode}}$ for the Ag^+/Ag electrode in this experiment.

.....

- (iii) Use equation 1 to calculate $[\text{Ag}^+]$ in the saturated solution.

$$[\text{Ag}^+] = \dots\dots\dots \text{ mol dm}^{-3}$$

[3]

- (c) (i) Write an expression for K_{sp} of silver sulfate, Ag_2SO_4 , including units.

$K_{sp} = \dots\dots\dots$ units $\dots\dots\dots$

Using a similar experimental set-up to that illustrated opposite, it is found that $[\text{Ag}^+]$ in a saturated solution of Ag_2SO_4 is $1.6 \times 10^{-2} \text{ mol dm}^{-3}$.

- (ii) Calculate the value of K_{sp} of silver sulfate.

$K_{sp} = \dots\dots\dots$ [3]

- (d) Describe how the colours of the silver halides, and their relative solubilities in $\text{NH}_3(\text{aq})$, can be used to distinguish between solutions of the halide ions Cl^- , Br^- and I^- .

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [4]

- (e) Describe and explain the trend in the solubilities of the sulfates of the elements in Group II.

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [4]

[Total: 18]

(i) What is meant by the terms *homogeneous* and *heterogeneous*?

Choose **one** example of each type, and for **each** example you should

- state what the catalyst is, and whether it is acting as a homogeneous or a heterogeneous catalyst,
- write a balanced equation for the reaction,
- outline how the catalyst you have chosen works to decrease the activation energy.

[illegible]

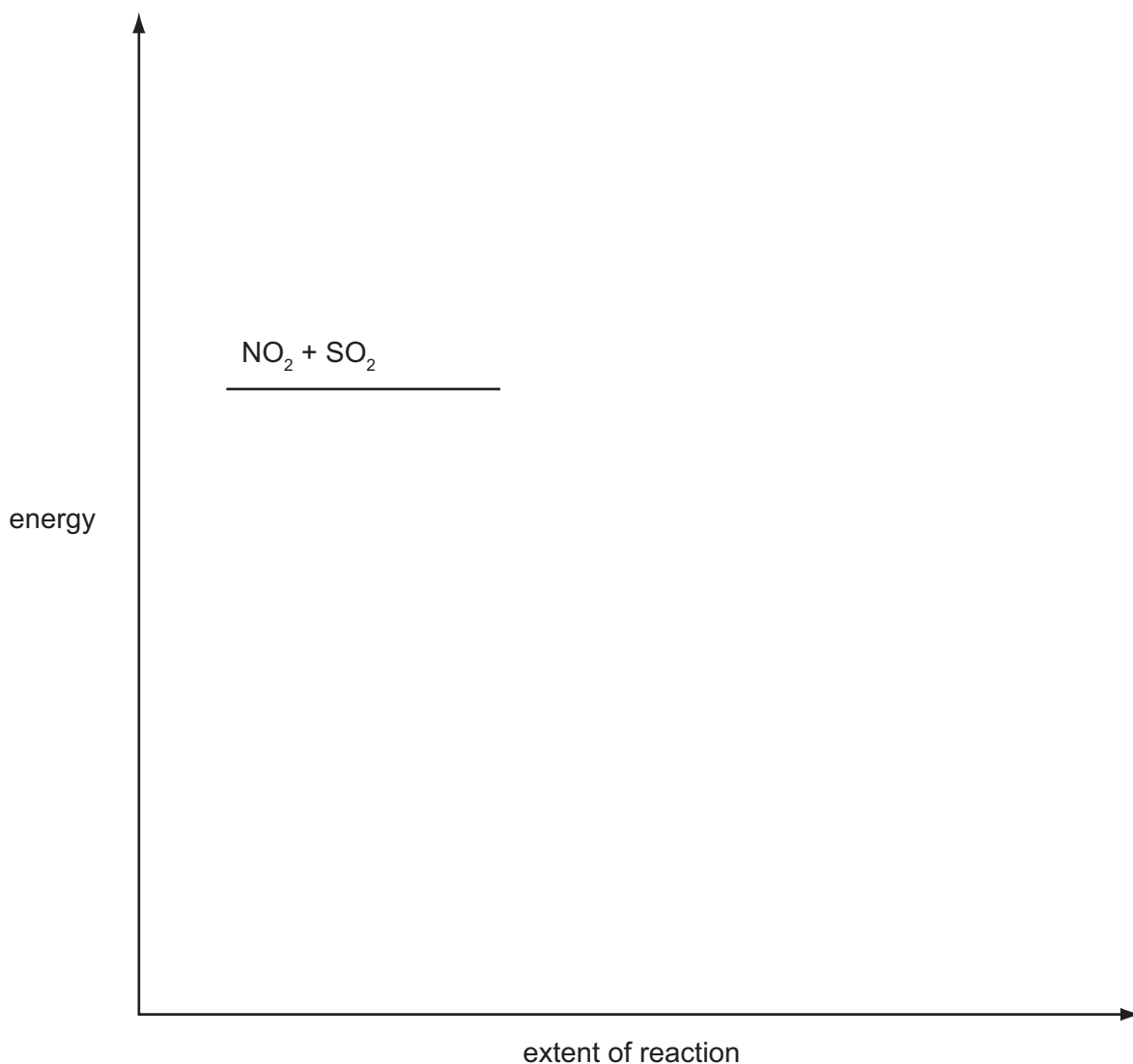
9701/41/O/N/12

(b) The reaction between SO_2 , NO_2 and O_2 occurs in two steps.



The activation energy of the first reaction, E_{a1} , is higher than that of the second reaction, E_{a2} .

Use the axes below to construct a fully-labelled reaction pathway diagram for this reaction, labelling E_{a1} , E_{a2} , $\Delta H_1^\ominus$ and $\Delta H_2^\ominus$.



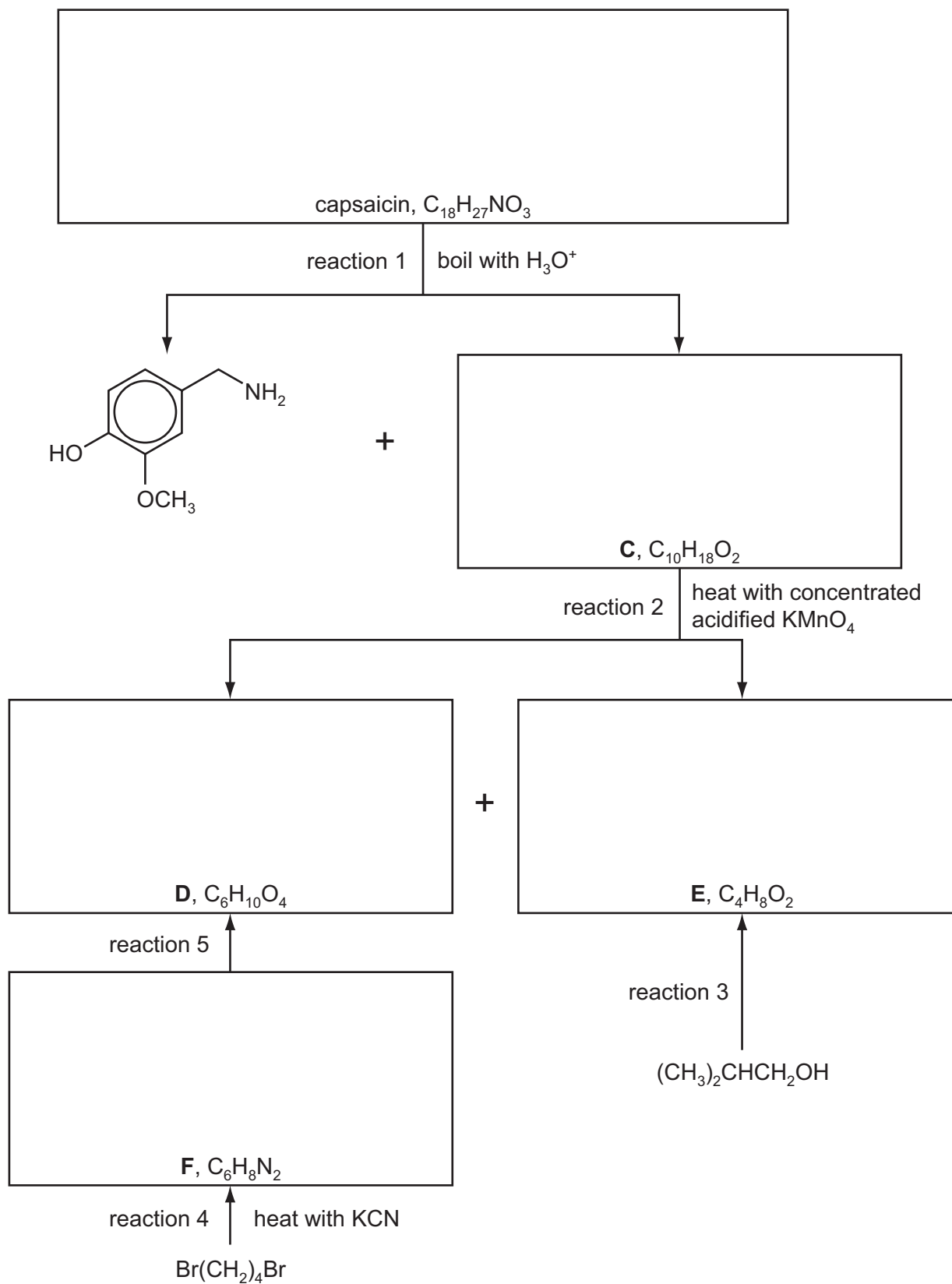
[2]

[Total: 10]

For
Examiner's
Use

- 4 The compound responsible for the hot taste of chilli peppers is capsaicin. Its molecular structure can be deduced by the following reaction scheme.

For
Examiner's
Use



Compounds **C**, **D** and **E** all react with $Na_2CO_3(aq)$.

Answer the following questions.

- (a) Suggest reagents and conditions for reaction 3.

..... [1]

- (b) What *type of reaction* is reaction 4?

..... [1]

- (c) Suggest reagents and conditions for reaction 5.

..... [1]

- (d) Name the functional group in **C** that has reacted with hot concentrated acidified KMnO_4 .

..... [1]

- (e) Suggest the name of the functional group in capsaicin that has reacted in reaction 1.

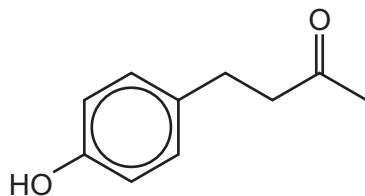
..... [1]

- (f) Work out structures for compounds **C–F** and capsaicin, and draw their structural formulae in the boxes opposite. [5]

[Total: 10]

- 5 Compound **G** is a naturally occurring aromatic compound that is present in raspberries.

For
Examiner's
Use



compound **G**

- (a) Identify the functional groups present in compound **G**.

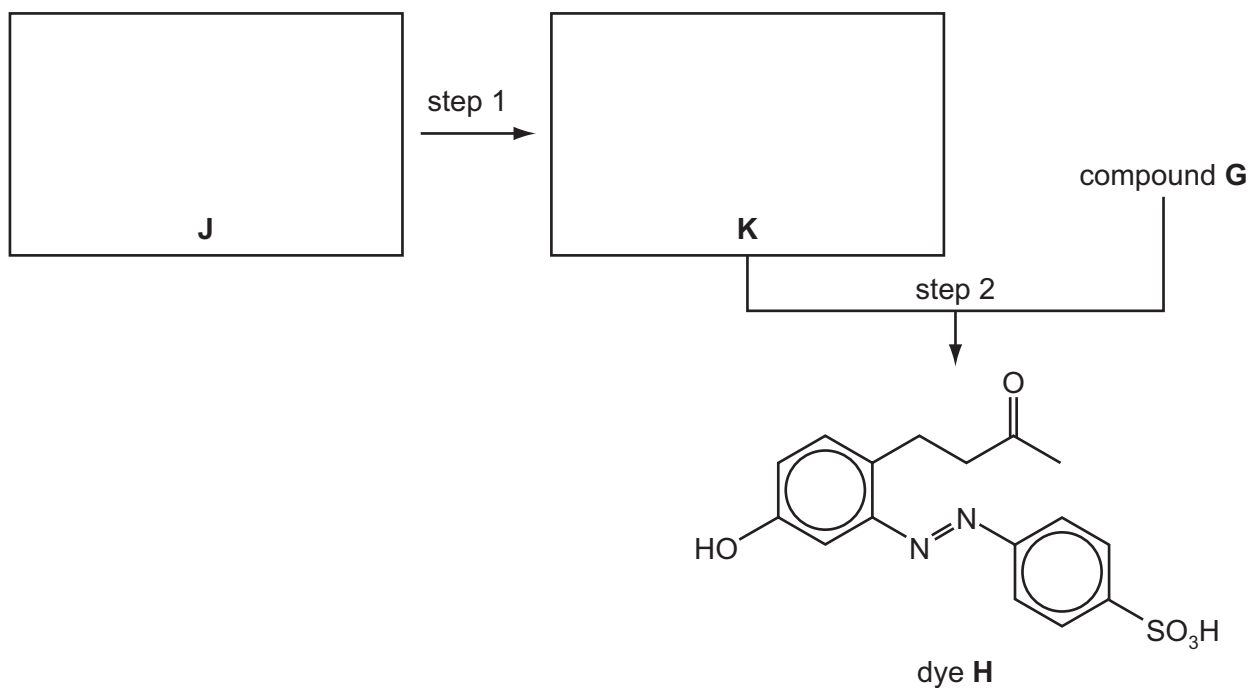
.....
 [2]

- (b) Complete the following table with information about the reactions of the three stated reagents with compound **G**.

reagent	observation	structure of organic product	type of reaction
sodium metal			
aqueous bromine			
aqueous alkaline iodine			

[8]

(c) The dye **H** can be made from compound **G** by the route shown below.



(i) Draw the structures of the amine **J** and the intermediate **K** in the boxes above.

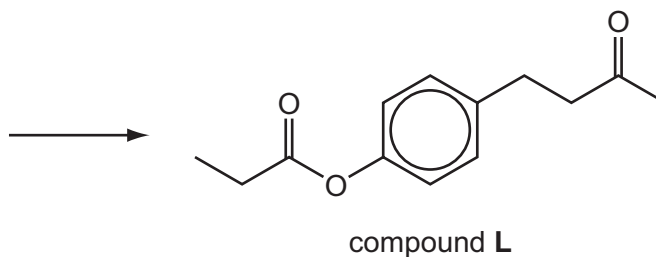
(ii) Suggest reagents and conditions for

step 1, ...

step 2.

[5]

(d) Suggest a reaction scheme by which compound **G** and propanoic acid could be converted into compound **L**.



[3]

[Total: 18]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 6** Proteins are complex molecules made up from long chains that are folded to give a three-dimensional structure.

- (a)** Study the table which describes aspects of bonding in proteins. For each description of a bonding type, indicate whether it contributes to the primary, secondary or tertiary structure of a protein.

bonding type	structure involved
disulfide bonds between parts of the chain	
hydrogen bonds in a β -pleated sheet	
ionic bonds between parts of the chain	
peptide links between amino acids	

[3]

- (b)** Explain, with the use of diagrams as appropriate, the difference between competitive and non-competitive inhibition of enzymes.

.....

.....

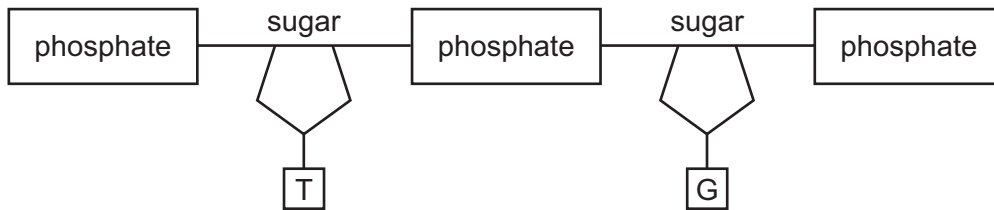
.....

.....

.....

..... [4]

- (c) The diagram shows one strand of DNA. Draw a matching strand showing clearly, with labels, the bonds holding the two strands together. Name the bases in **your** strand, indicating clearly which base bonds to each base in the strand shown.



names of bases [3]

[Total: 10]

- 7 DNA fingerprinting has become an important analytical technique, largely due to its use in 'screening' crime suspects. It also has a range of applications in modern analysis including determining family links, medicine and archaeology.

(a) (i) DNA fingerprinting uses an analytical technique you have studied. What is the name of that technique?

.....

(ii) In order to carry out DNA fingerprinting, the DNA must first be broken down into shorter lengths of polynucleotides. How is this accomplished?

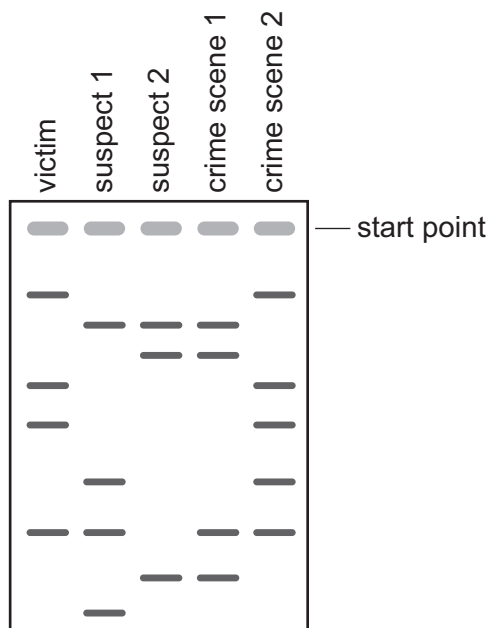
.....

(iii) What part of the DNA fragments enables them to move in an electric field?

.....

[3]

- (b) The DNA fingerprints shown were obtained from a crime scene. DNA samples were recovered from two rooms in the house where the crime took place. The victim's DNA and that of two possible suspects were included in the analysis.



- (i) Indicate with an **X** on the diagram, which lines from suspect 1 and from suspect 2 **cannot** distinguish which of them was present in the house.
- (ii) Based on this evidence one suspect was arrested. Which suspect would you expect this to be? Explain your reasoning.

.....

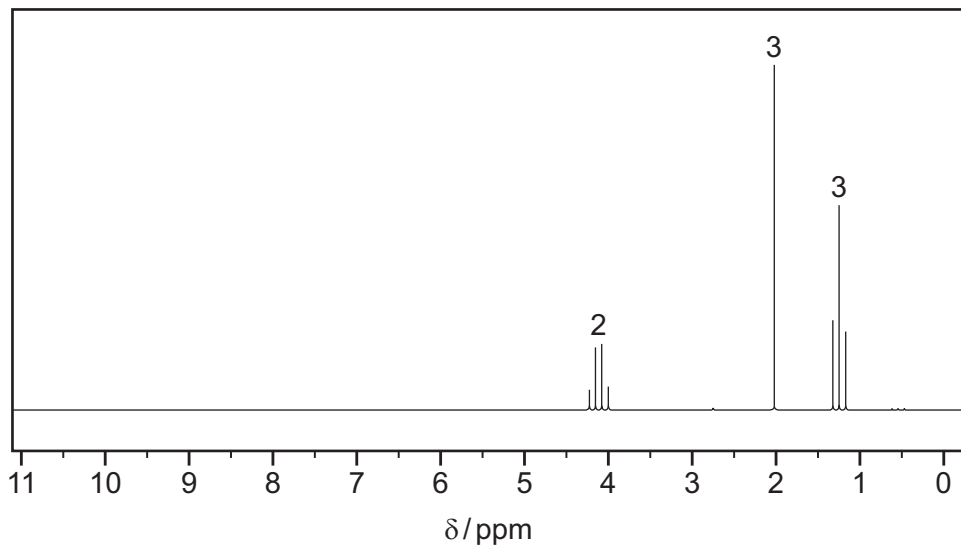
.....

[2]

- (c) A sample of a liquid, **P**, was found at the scene of the crime and was analysed using mass spectrometry and NMR spectroscopy.

The mass spectrum has M and M+1 peaks in the ratio of 5.1:0.22 with the M peak at $m/e = 88$.

The NMR spectrum is shown



Use the data to suggest a structure for **P**, explaining your answer.

.....

.....

.....

.....

.....

.....

.....

structure of **P**

[5]

[Total: 10]

- 8 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polylactide' or PLA, is produced from corn starch and has a range of applications.

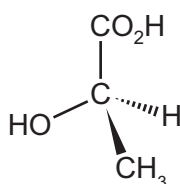
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

- (i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.

Why might high acidity reduce the effectiveness of the enzymes?

.....
.....

- (ii) The structure of lactic acid is shown.



What type of reaction takes place in this polymerisation?

.....

[2]

- (b) Lactic acid exists in two stereoisomeric forms. Draw the other form in the box.



[1]

(c) One of the reasons PLA has attracted so much attention is that it is biodegradable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175 °C, but softens between 60-80 °C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(i) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

.....

.....

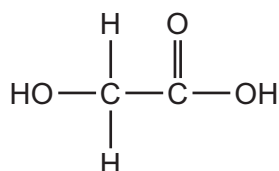
(ii) PLA containers are not used for hot drinks. Suggest why.

.....

.....

[2]

(d) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

.....

.....

.....

(iii) Suggest one property in which the co-polymer differs from PLA.

.....

.....

[5]

[Total: 10]

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CHEMISTRY

9701/42

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Section A

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silicon(IV) chloride

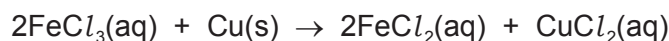
.....

phosphorus(V) chloride

.....

[4]

- (b) Iron(III) chloride, FeCl_3 , is used to dissolve unwanted copper from printed circuit boards (PCBs) by the following reaction.



A solution in which $[\text{Fe}^{3+}(\text{aq})]$ was originally equal to 1.50 mol dm^{-3} was re-used several times to dissolve copper from the PCBs, and was then titrated as follows.

A 2.50 cm^3 sample of the partially-used-up solution was acidified and titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4$.

This oxidised any FeCl_2 in the solution back to FeCl_3 .

It was found that 15.0 cm^3 of $\text{KMnO}_4(\text{aq})$ was required to reach the end point.

- (i) Construct an ionic equation for the reaction between Fe^{2+} and MnO_4^- in acid solution.

.....

- (ii) State here the $\text{Fe}^{2+} : \text{MnO}_4^-$ ratio from your equation in (i).

- (iii) Calculate the number of moles of MnO_4^- used in the titration.

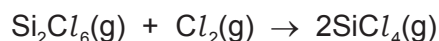
- (iv) Calculate the number of moles of Fe^{2+} in 2.50 cm^3 of the partially-used-up solution.

(v) Calculate the $[\text{Fe}^{2+}]$ in the partially-used-up solution.

(vi) Calculate the mass of copper that could still be dissolved by 100 cm^3 of the partially-used-up solution.

mass of copper = ... g
[6]

(c) When SiCl_4 vapour is passed over Si at red heat, Si_2Cl_6 is formed. Si_2Cl_6 contains a Si-Si bond.
The reaction of Si_2Cl_6 and Cl_2 re-forms SiCl_4 .



Use bond energy data from the *Data Booklet* to calculate ΔH° for this reaction.

$\Delta H^\circ = \dots\dots\dots \text{kJ mol}^{-1}$
[2]

(d) Calcium forms three calcium silicides, Ca_2Si , CaSi and CaSi_2 . The first of these reacts with water as follows.



(i) Balance this equation. You may find the use of oxidation numbers helpful.

(ii) During this reaction, state

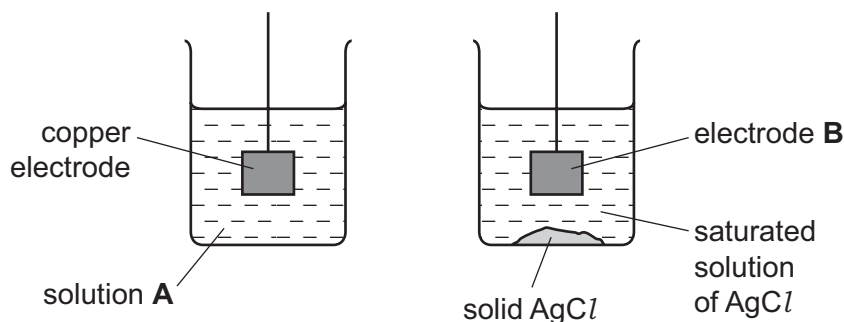
which element(s) have been oxidised, ...

which element(s) have been reduced.

[2]

[Total: 14]

- 2 (a) The diagram below shows an incomplete experimental set-up needed to measure the E_{cell} of a cell composed of the standard Cu^{2+}/Cu electrode and an Ag^+/Ag electrode.



- (i) State the chemical composition of

solution **A**, ...

electrode **B**.

- (ii) Complete the diagram to show the whole experimental set-up.

[4]

- (b) The above cell is not under standard conditions, because the $[\text{Ag}^+]$ in a saturated solution of AgCl is much less than 1.0 mol dm^{-3} . The $E_{\text{electrode}}$ is related to $[\text{Ag}^+]$ by the following equation.

equation 1
$$E_{\text{electrode}} = E_{\text{electrode}}^{\circ} + 0.06 \log[\text{Ag}^+]$$

- (i) Use the *Data Booklet* to calculate the E_{cell}° if the cell was operating under standard conditions.

$$E_{\text{cell}}^{\circ} = \dots\dots\dots \text{ V}$$

In the above experiment, the E_{cell} was measured at +0.17V.

- (ii) Calculate the value of $E_{\text{electrode}}$ for the Ag^+/Ag electrode in this experiment.

.....

- (iii) Use equation 1 to calculate $[\text{Ag}^+]$ in the saturated solution.

$$[\text{Ag}^+] = \dots\dots\dots \text{ mol dm}^{-3}$$

[3]

- (c) (i) Write an expression for K_{sp} of silver sulfate, Ag_2SO_4 , including units.

$K_{sp} = \dots\dots\dots$ units $\dots\dots\dots$

Using a similar experimental set-up to that illustrated opposite, it is found that $[\text{Ag}^+]$ in a saturated solution of Ag_2SO_4 is $1.6 \times 10^{-2} \text{ mol dm}^{-3}$.

- (ii) Calculate the value of K_{sp} of silver sulfate.

$K_{sp} = \dots\dots\dots$ [3]

- (d) Describe how the colours of the silver halides, and their relative solubilities in $\text{NH}_3(\text{aq})$, can be used to distinguish between solutions of the halide ions Cl^- , Br^- and I^- .

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [4]

- (e) Describe and explain the trend in the solubilities of the sulfates of the elements in Group II.

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [4]

[Total: 18]

(i) What is meant by the terms *homogeneous* and *heterogeneous*?

.....

Choose **one** example of each type, and for **each** example you should

- state what the catalyst is, and whether it is acting as a homogeneous or a heterogeneous catalyst,
- write a balanced equation for the reaction,
- outline how the catalyst you have chosen works to decrease the activation energy.

[illegible]

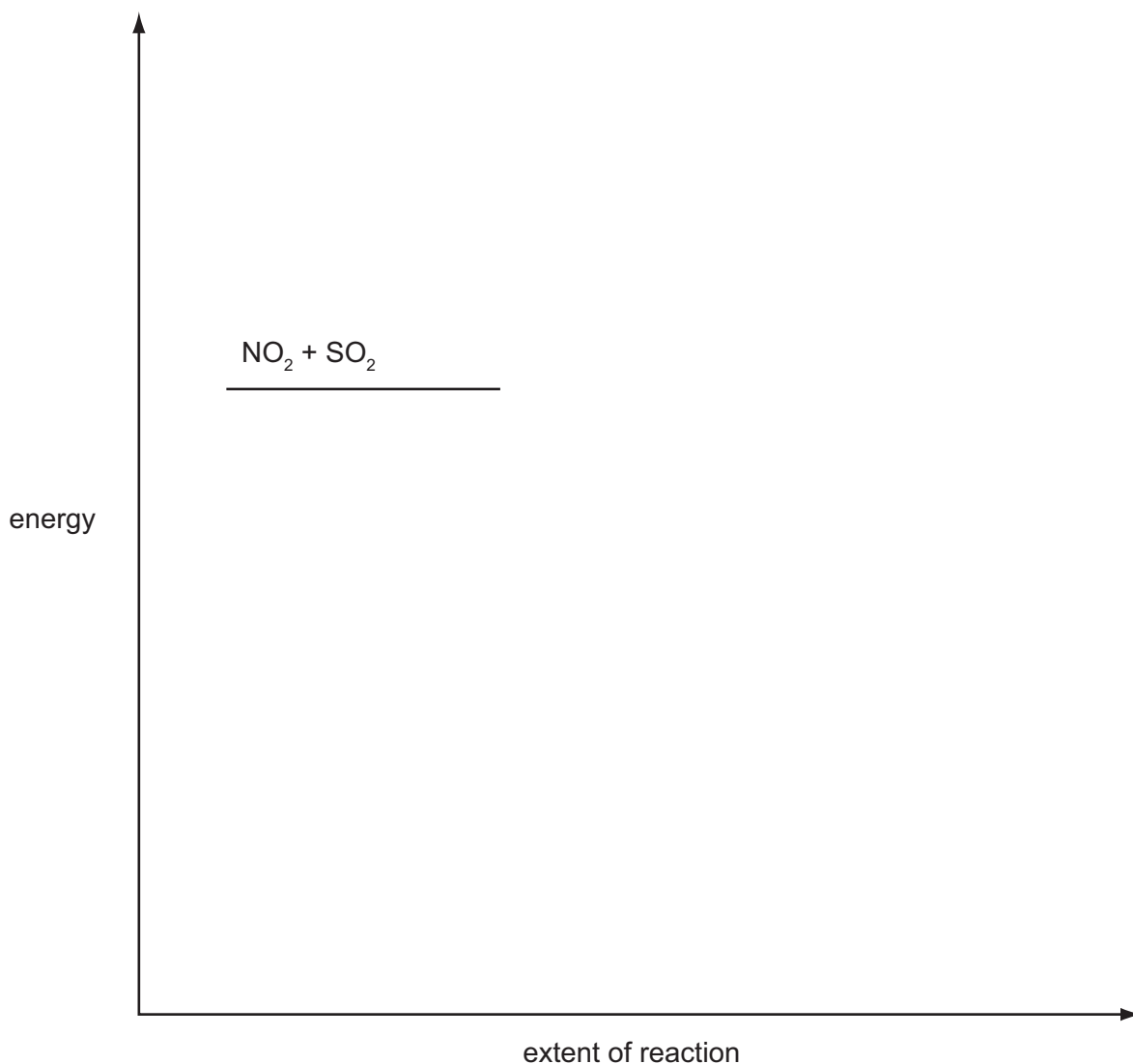
9701/42/O/N/12

(b) The reaction between SO_2 , NO_2 and O_2 occurs in two steps.



The activation energy of the first reaction, E_{a1} , is higher than that of the second reaction, E_{a2} .

Use the axes below to construct a fully-labelled reaction pathway diagram for this reaction, labelling E_{a1} , E_{a2} , $\Delta H_1^\ominus$ and $\Delta H_2^\ominus$.



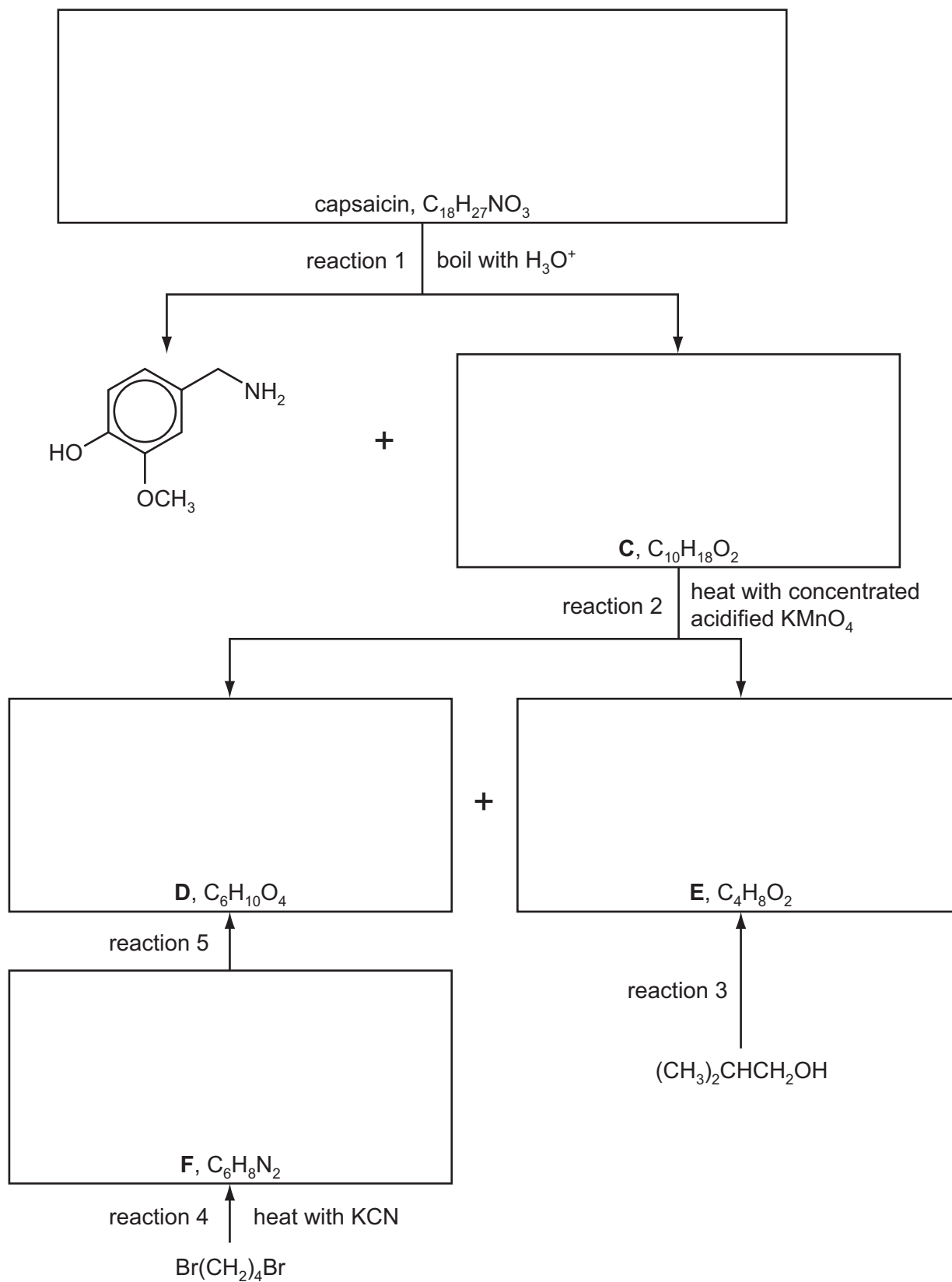
[2]

[Total: 10]

For
Examiner's
Use

- 4 The compound responsible for the hot taste of chilli peppers is capsaicin. Its molecular structure can be deduced by the following reaction scheme.

For
Examiner's
Use



Compounds **C**, **D** and **E** all react with $Na_2CO_3(aq)$.

Answer the following questions.

- (a) Suggest reagents and conditions for reaction 3.

..... [1]

- (b) What *type of reaction* is reaction 4?

..... [1]

- (c) Suggest reagents and conditions for reaction 5.

..... [1]

- (d) Name the functional group in **C** that has reacted with hot concentrated acidified KMnO_4 .

..... [1]

- (e) Suggest the name of the functional group in capsaicin that has reacted in reaction 1.

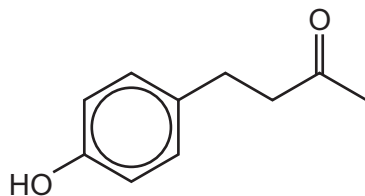
..... [1]

- (f) Work out structures for compounds **C–F** and capsaicin, and draw their structural formulae in the boxes opposite. [5]

[Total: 10]

- 5 Compound **G** is a naturally occurring aromatic compound that is present in raspberries.

For
Examiner's
Use



compound **G**

- (a) Identify the functional groups present in compound **G**.

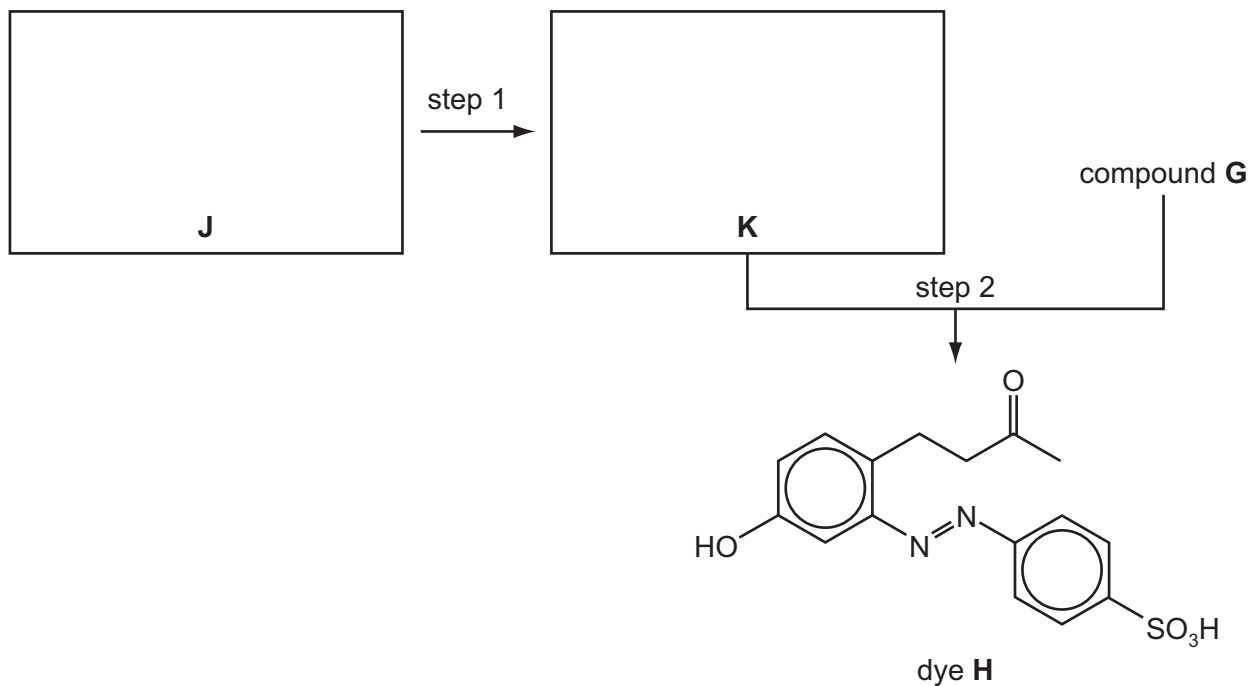
.....
 [2]

- (b) Complete the following table with information about the reactions of the three stated reagents with compound **G**.

reagent	observation	structure of organic product	type of reaction
sodium metal			
aqueous bromine			
aqueous alkaline iodine			

[8]

(c) The dye **H** can be made from compound **G** by the route shown below.



(i) Draw the structures of the amine **J** and the intermediate **K** in the boxes above.

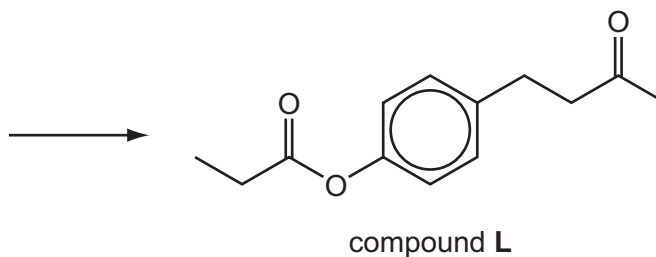
(ii) Suggest reagents and conditions for

step 1, ...

step 2.

[5]

(d) Suggest a reaction scheme by which compound **G** and propanoic acid could be converted into compound **L**.



[3]

[Total: 18]

Section B

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 6** Proteins are complex molecules made up from long chains that are folded to give a three-dimensional structure.

- (a)** Study the table which describes aspects of bonding in proteins. For each description of a bonding type, indicate whether it contributes to the primary, secondary or tertiary structure of a protein.

bonding type	structure involved
disulfide bonds between parts of the chain	
hydrogen bonds in a β -pleated sheet	
ionic bonds between parts of the chain	
peptide links between amino acids	

[3]

- (b)** Explain, with the use of diagrams as appropriate, the difference between competitive and non-competitive inhibition of enzymes.

.....

.....

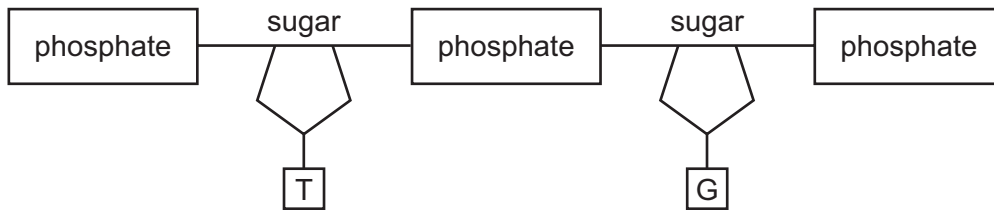
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.....

.....

..... [4]

- (c) The diagram shows one strand of DNA. Draw a matching strand showing clearly, with labels, the bonds holding the two strands together. Name the bases in **your** strand, indicating clearly which base bonds to each base in the strand shown.



names of bases [3]

[Total: 10]

- 7 DNA fingerprinting has become an important analytical technique, largely due to its use in 'screening' crime suspects. It also has a range of applications in modern analysis including determining family links, medicine and archaeology.

(a) (i) DNA fingerprinting uses an analytical technique you have studied. What is the name of that technique?

.....

(ii) In order to carry out DNA fingerprinting, the DNA must first be broken down into shorter lengths of polynucleotides. How is this accomplished?

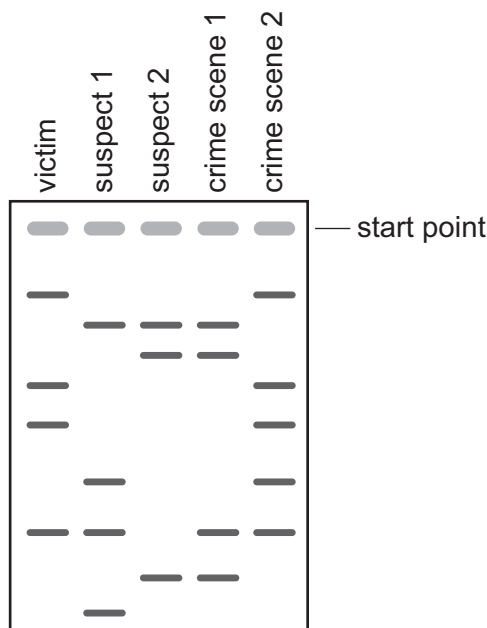
.....

(iii) What part of the DNA fragments enables them to move in an electric field?

.....

[3]

- (b) The DNA fingerprints shown were obtained from a crime scene. DNA samples were recovered from two rooms in the house where the crime took place. The victim's DNA and that of two possible suspects were included in the analysis.



(i) Indicate with an **X** on the diagram, which lines from suspect 1 and from suspect 2 **cannot** distinguish which of them was present in the house.

(ii) Based on this evidence one suspect was arrested. Which suspect would you expect this to be? Explain your reasoning.

.....

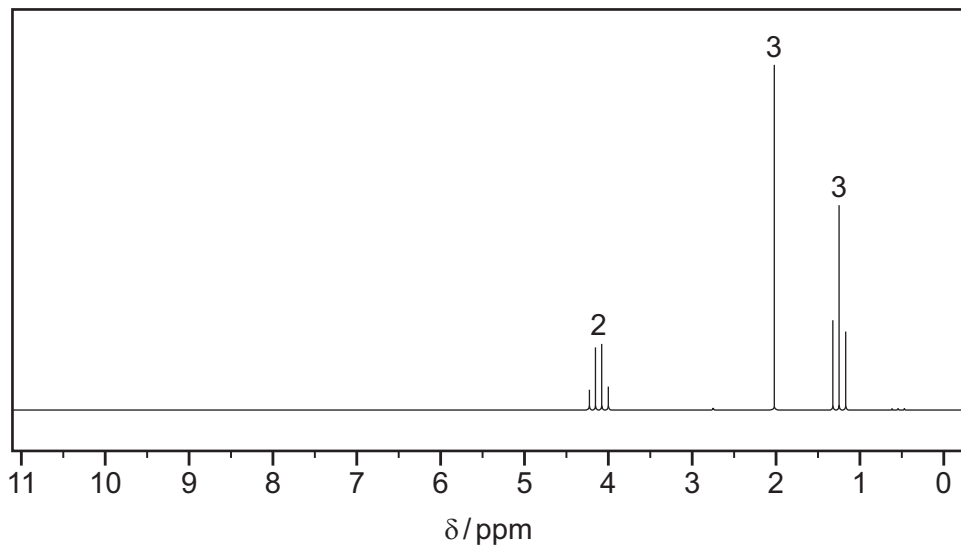
.....

[2]

- (c) A sample of a liquid, **P**, was found at the scene of the crime and was analysed using mass spectrometry and NMR spectroscopy.

The mass spectrum has M and M+1 peaks in the ratio of 5.1:0.22 with the M peak at $m/e = 88$.

The NMR spectrum is shown



Use the data to suggest a structure for **P**, explaining your answer.

.....

.....

.....

.....

.....

.....

.....

structure of **P**

[5]

[Total: 10]

- 8 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polylactide' or PLA, is produced from corn starch and has a range of applications.

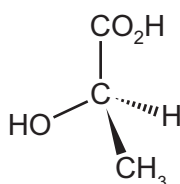
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

- (i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.

Why might high acidity reduce the effectiveness of the enzymes?

.....
.....

- (ii) The structure of lactic acid is shown.



What type of reaction takes place in this polymerisation?

.....

[2]

- (b) Lactic acid exists in two stereoisomeric forms. Draw the other form in the box.



[1]

(c) One of the reasons PLA has attracted so much attention is that it is biodegradeable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175 °C, but softens between 60-80 °C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(i) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

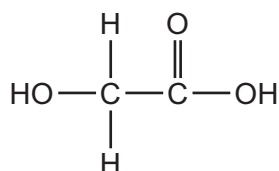
.....

(ii) PLA containers are not used for hot drinks. Suggest why.

.....

[2]

(d) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

.....

(iii) Suggest one property in which the co-polymer differs from PLA.

.....

[5]

[Total: 10]

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CHEMISTRY

9701/43

Paper 4 Structured Questions

October/November 2012

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Section A

Answer **all** questions.

Section B

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use

1	
2	
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7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.



Section A

For
Examiner's
UseAnswer **all** the questions in the spaces provided.

- 1 (a) Write down what you would see, and write equations for the reactions that occur, when magnesium chloride, aluminium chloride and silicon tetrachloride are separately mixed with water.

magnesium chloride

.....

.....

aluminium chloride

.....

.....

silicon tetrachloride

.....

.....

[5]

- (b) Sodium chloride is traditionally added to a particular meat product. In response to the evidence that sodium chloride can lead to high blood pressure, the manufacturers have replaced the sodium chloride with a mixture of sodium and potassium chlorides. 100 g of the meat product usually contains about 2 g of the chloride mixture.

A particular meat product contains 1.10 g of sodium chloride and 0.90 g potassium chloride in 100 g.

- (i) Calculate the number of moles of chloride ions in 100 g of this meat product.

The amount of chloride in the meat product can be found by titration with silver nitrate solution.

- (ii) Write the ionic equation, including state symbols, for the reaction between aqueous sodium chloride and aqueous silver nitrate.

.....

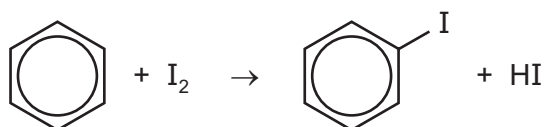
The chlorides from 100 g meat product are extracted into water and the solution made up to 1000 cm³ in a volumetric flask. A 10.0 cm³ portion of this solution is then titrated with 0.0200 mol dm⁻³ silver nitrate solution to precipitate the chloride.

- (iii) Calculate the volume of 0.0200 mol dm⁻³ silver nitrate solution that would be required if this titration were carried out on 100 g of the particular meat product described above.

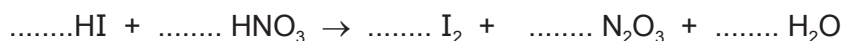
[5]

- (c) The iodination of benzene requires the presence of nitric acid.

- (i) Using bond enthalpies from the *Data Booklet*, calculate the enthalpy change for the following reaction.



- (ii) Nitric acid reacts with hydrogen iodide according to the following unbalanced equation.



Balance this equation, and describe how the oxidation numbers of nitrogen and iodine have changed during the reaction.

nitrogen

iodine

[4]

[Total: 14]

2 Nitrogen oxides in the atmosphere are homogeneous catalysts in the formation of acid rain.

(a) What is meant by the following terms?

catalyst

.....

.....

homogeneous

.....

.....

[2]

(b) (i) State a major source of nitrogen oxides in the atmosphere, explaining how they are formed.

.....

.....

.....

(ii) Use equations to describe the chemical role played by nitrogen oxides in the formation of acid rain.

.....

.....

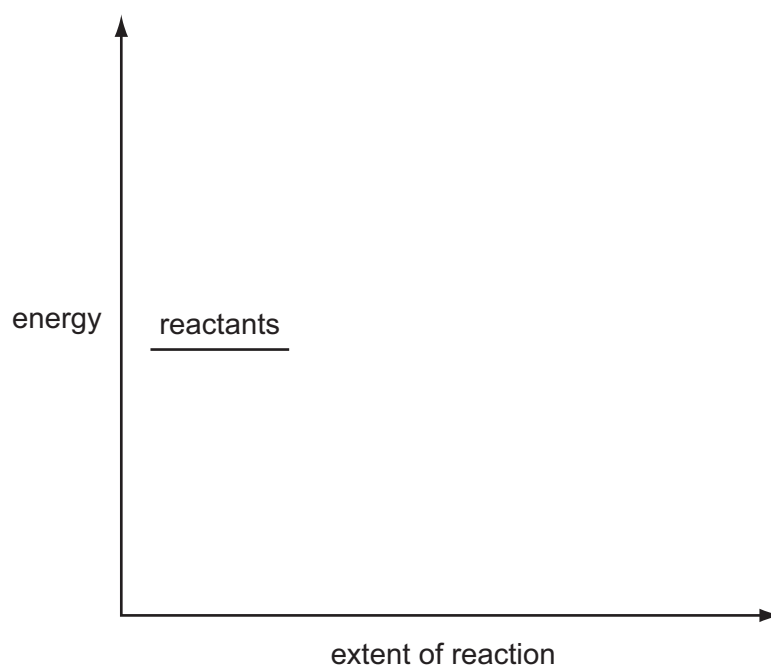
.....

.....

[5]

- (c) Use the following axes to draw a fully labelled reaction pathway diagram showing the effect of a catalyst on an exothermic reaction. Label the ΔH and E_a values.

For
Examiner's
Use



[3]

[Total: 10]

- 3 (a) Complete the following electronic configuration of the Cu^{2+} ion.

$1s^2 2s^2 2p^6$ [1]

- (b) In a free, gas-phase transition metal ion, the d-orbitals all have the same energy, but when the ion is in a complex the orbitals are split into two energy levels.

- (i) Explain why this happens.

.....
.....

- (ii) How does this splitting help to explain why transition metal complexes are often coloured?

.....
.....
.....
.....

- (iii) Why does the colour of a transition metal complex depend on the nature of the ligands surrounding the transition metal ion?

.....
.....

[5]

- (c) Draw a fully-labelled diagram of the apparatus you could use to measure the E° of a cell composed of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ electrode and the Cu^{2+}/Cu electrode.

[5]

- (d) The E° for Cu^{2+}/Cu is +0.34 V. When $\text{NH}_3(\text{aq})$ is added to the electrode solution, the $E_{\text{electrode}}$ changes.

(i) Describe the type of reaction taking place between $\text{Cu}^{2+}(\text{aq})$ and $\text{NH}_3(\text{aq})$.

.....

(ii) Write an equation for the reaction.

.....

(iii) Describe the change in the colour of the solution.

.....

(iv) Predict and explain how the $E_{\text{electrode}}$ might change on the addition of $\text{NH}_3(\text{aq})$.

.....

.....

[4]

- (e) Fehling's reagent is an alkaline solution of Cu^{2+} ions complexed with tartrate ions. It is used in organic chemistry to test for a particular functional group.

(i) **Name** the functional group involved.

.....

(ii) Describe the appearance of a positive result in this test.

.....

(iii) Write an equation for the reaction between Cu^{2+} and OH^- ions and a two-carbon compound containing the functional group you named in (i).

.....

[3]

- (f) A solution containing a mixture of tartaric acid and its sodium salt is used as a buffer in some pre-prepared food dishes.

Calculate the pH of a solution containing 0.50 mol dm^{-3} of tartaric acid and 0.80 mol dm^{-3} sodium tartrate.

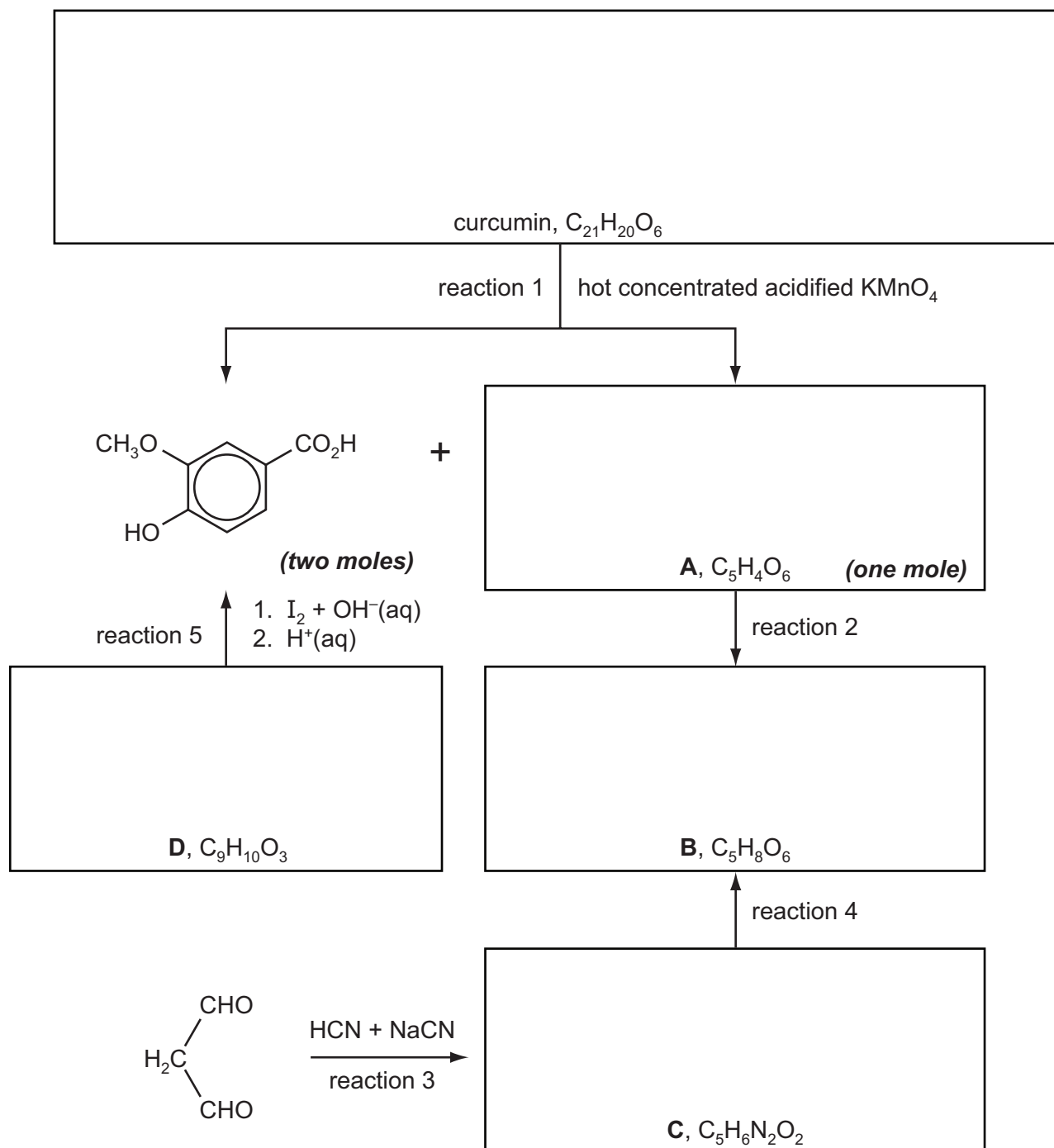
$[K_a(\text{tartaric acid}) = 9.3 \times 10^{-4} \text{ mol dm}^{-3}]$

pH = ...

[2]

[Total: 20]

- 4 The compound responsible for the yellow colour of the spice turmeric is curcumin. Its molecular structure can be deduced from the following series of reactions. The $\text{CH}_3\text{O}-$ group that is present in curcumin may be regarded as unreactive.



Curcumin and compounds **A** and **D** all react with 2,4-dinitrophenylhydrazine reagent.

Compounds **A** and **B** effervesce with $\text{Na}_2\text{CO}_3(\text{aq})$, but curcumin, and compounds **C** and **D**, do not.

Curcumin reacts with $\text{Br}_2(\text{aq})$ and with cold dilute acidified KMnO_4

- (a) (i) Name the functional group common to curcumin and compounds **A** and **D**.

.....

- (ii) Name the functional group common to compounds **A** and **B**.

.....

[2]

- (b) (i) Suggest the structures of compounds **B**, **C** and **D**, and draw their structural formulae in the relevant boxes opposite.

- (ii) Suggest suitable reagents and conditions for reaction 4.

.....

[4]

- (c) (i) Name the *type of reaction* for reaction 2.

.....

- (ii) Suggest a reagent for reaction 2.

.....

- (iii) Suggest the structure of compound **A**, and draw its structural formula in the relevant box opposite.

[3]

- (d) (i) **Name** the functional group in curcumin that reacts with cold dilute acidified KMnO_4 .

.....

- (ii) **Name two** functional groups in curcumin that react with $\text{Br}_2(\text{aq})$.

.....

[2]

- (e) Suggest a structure for curcumin and draw its structural formula in the relevant box opposite.

[2]

[Total: 13]

- 5 (a) (i) Explain why ethylamine is basic.

.....

- (ii) Write an equation showing ethylamine acting as

a base, ...

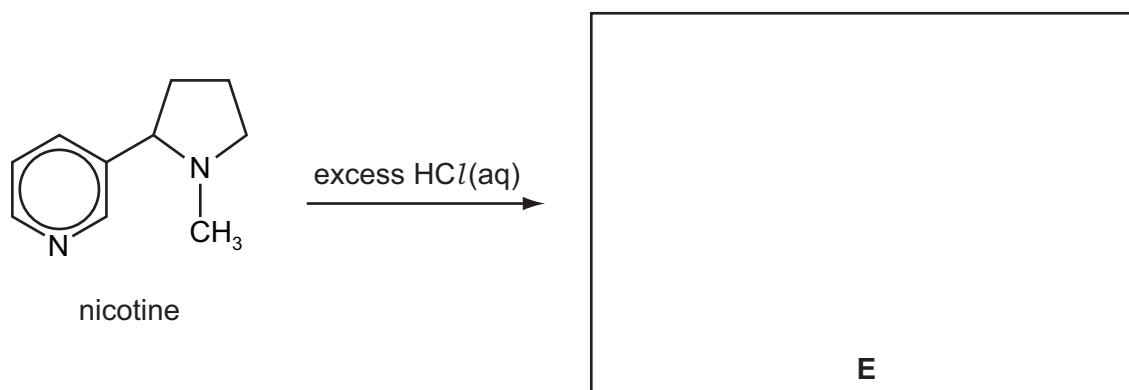
a nucleophile.

- (iii) Why is phenylamine less basic than ethylamine?

.....

Alkaloids are naturally-occurring compounds that act as bases.

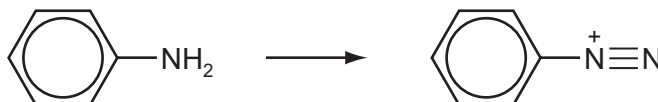
- (iv) Suggest the structure of the product, **E**, of the reaction between the alkaloid nicotine and an excess of HCl(aq) .



[6]

- (b) Phenylamine, and substituted phenylamines, are used to make cloth dyes and food colourants.

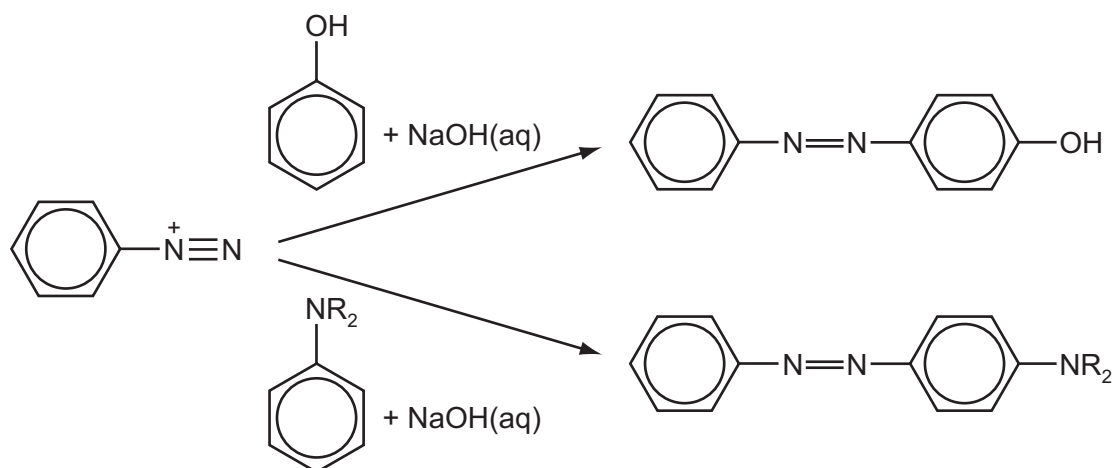
The first step in this process is the production of a diazonium salt.



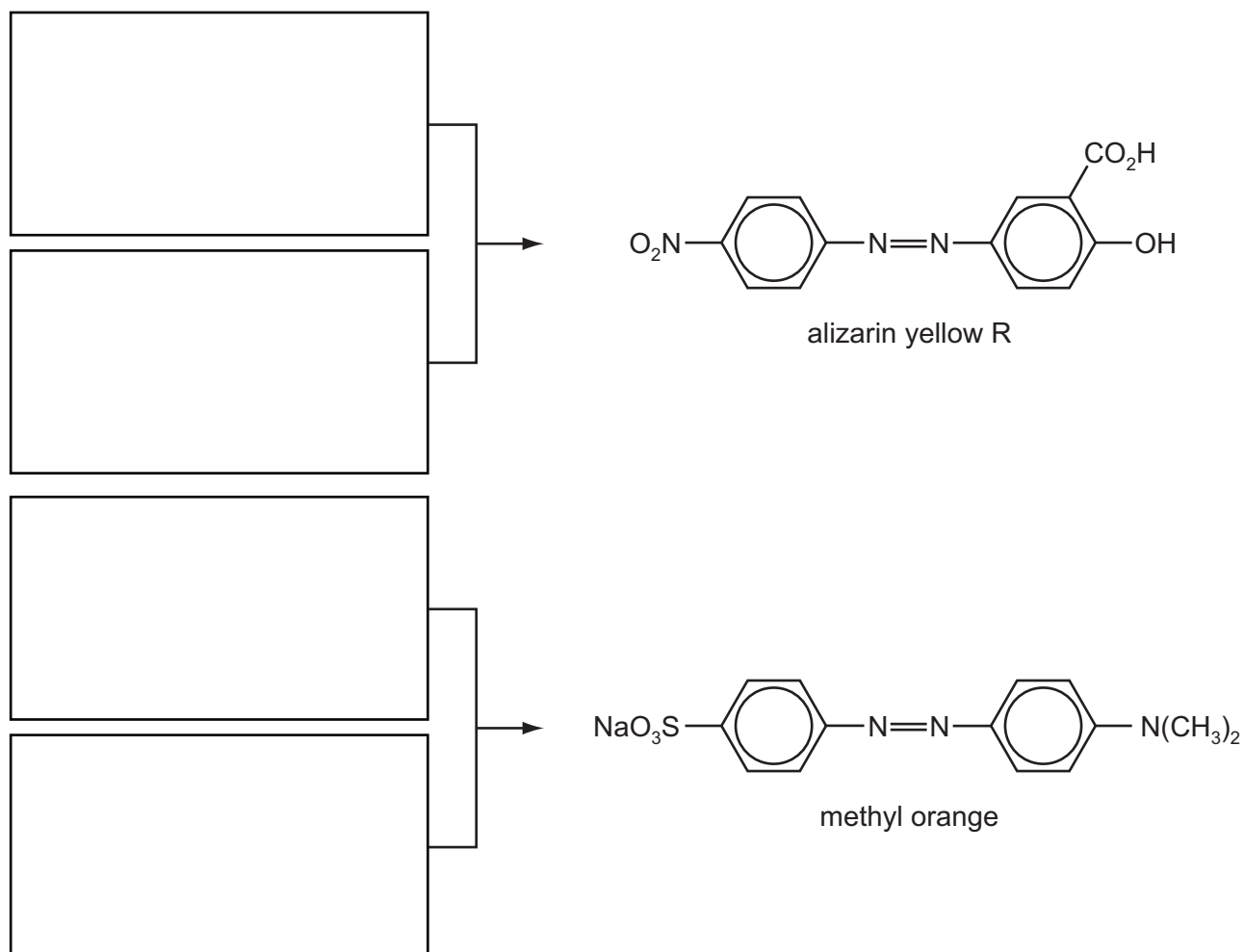
- (i) State the reagents and conditions necessary for this reaction.

.....

The diazonium salt is then reacted with a phenol or an aryl amine in alkaline solution.



- (ii) Suggest the starting materials needed to synthesise the following dyes. Draw their structures in the boxes provided.



- (iii) Suggest what effect the NaO_3S – group in methyl orange has on its properties. This group has no effect on the colour of the compound.

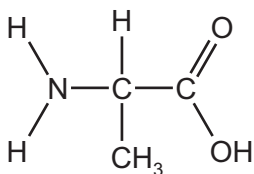
[7]

[Total: 13]

Section B

Answer **all** the questions in the spaces provided.

- 6 The proteins in the human body are complex polymers made up of around 20 different amino acids. Alanine is a typical amino acid.



alanine

- (a) Glycine, $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$, is the simplest amino acid and differs from each of the other 2-amino acids in a significant way. What is this difference?

..... [1]

- (b) Protein molecules coil and fold, producing molecules with complex three-dimensional shapes. This is referred to as the secondary and tertiary structures of a protein.

- (i) State **one** form of **secondary** structure and give the type of bonding responsible.

structure

bonding

- (ii) Give **two** examples of bonding causing the **tertiary** structure, and give the amino acid responsible in each case.

bonding amino acid

bonding amino acid

[6]

- (c) Suggest why globular proteins, such as enzymes, contain relatively small amounts of glycine and alanine when compared to the amounts of some other amino acids. You may wish to refer to their structures given above.

.....

..... [1]

(d) DNA consists of a double helix with each strand having a sugar-phosphate 'backbone' with one of four bases – adenine (A), cytosine (C), guanine (G) and thymine (T) – attached to the sugar.

(i) The two strands of the double helix are held together by hydrogen bonds between pairs of bases. What are the pairs of bases?

.....

In protein synthesis, sections of the DNA are copied by mRNA and this, in turn, is read by the ribosome in order to assemble the amino acids for the new protein chain. Each group of three bases codes for one amino acid, with some amino acids having several codes. The codes are summarised below.

UUU	phe	UCU	ser	UAU	tyr	UGU	cys
UUC	phe	UCC	ser	UAC	tyr	UGC	cys
UUA	leu	UCA	ser	UAA	stop	UGA	stop
UUG	leu	UCG	ser	UAG	stop	UGG	trp
CUU	leu	CCU	pro	CAU	his	CGU	arg
CUC	leu	CCC	pro	CAC	his	CGC	arg
CUA	leu	CCA	pro	CAA	gln	CGA	arg
CUG	leu	CCG	pro	CAG	gln	CGG	arg
AUU	ile	ACU	thr	AAU	asn	AGU	ser
AUC	ile	ACC	thr	AAC	asn	AGC	ser
AUA	ile	ACA	thr	AAA	lys	AGA	arg
AUG	met/ start	ACG	thr	AAG	lys	AGG	arg
GUU	val	GCU	ala	GAU	asp	GGU	gly
GUC	val	GCC	ala	GAC	asp	GGC	gly
GUA	val	GCA	ala	GAA	glu	GGA	gly
GUG	val	GCG	ala	GAG	glu	GGG	gly

(ii) The coding for all protein chains starts with the AUG, and ends with one of three 'stop' codes shown in the table. What amino acid sequence would the following series of bases produce?

-AUGGGUAGCCUCGCAUCGUAA-

.....

(iii) What would be the effect on the amino acid sequence, of a mutation that changed the base at position 10 in the series of bases above from C to G?

.....

[5]

[Total: 13]

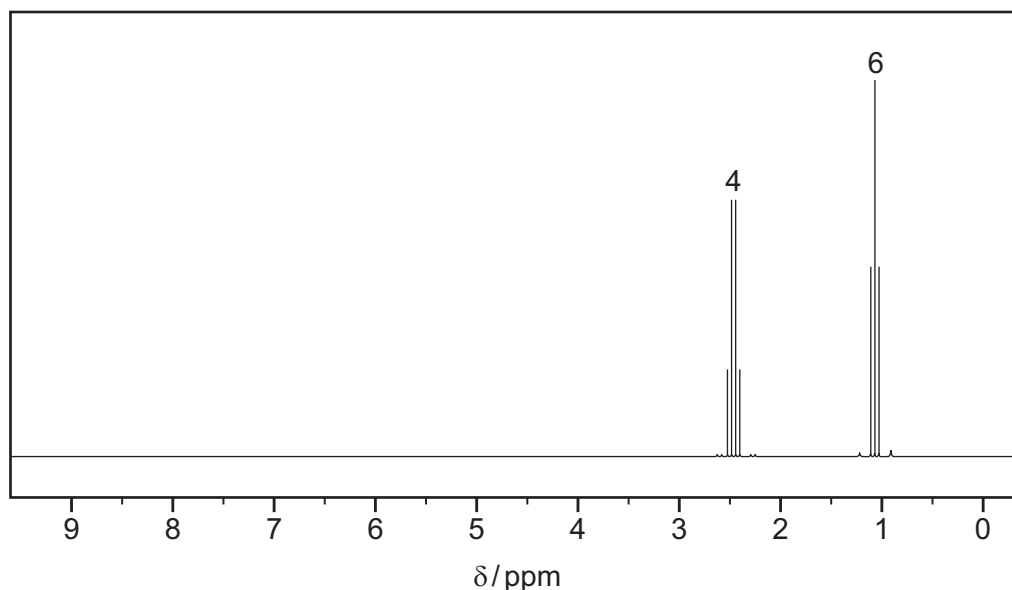
- 7 Although the chemical reactions of compounds remain important pointers to their functional groups, instrumental techniques such as mass spectrometry and NMR spectroscopy are increasingly used to determine molecular structures.

(a) Compound **J** was analysed using these two techniques with the following results.

The mass spectrum showed that

- the M peak was at m/e 86,
- the ratio of heights of the M and M+1 peaks was 23.5 : 1.3.

The NMR spectrum is shown below.



- (i) Use the data to determine the number of carbon and hydrogen atoms present in **J**, showing your working.
- (ii) Use the information given above and your answer to (i) to identify the other element present in **J**.
-
- (iii) Determine the structure of **J**, explaining how you reach your conclusion.

structure of **J**

explanation

.....

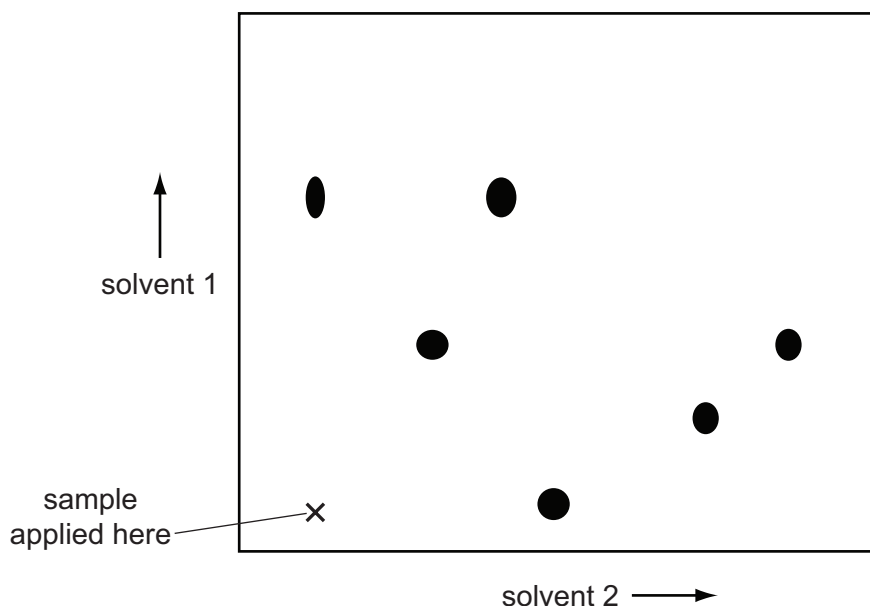
[5]

(b) Chromatography is another important analytical technique used in chemistry.

- (i) Paper, thin-layer and gas-liquid chromatography rely on different physical methods to separate the components in a mixture. Complete the table indicating the appropriate method on which the technique is based.

technique	physical method
paper chromatography	
thin-layer chromatography	
gas-liquid chromatography	

In paper chromatography, better separation may be achieved by running the chromatogram in one solvent, then turning the paper at right angles and running it in a second solvent. The chromatogram below was produced in this way.



- (ii) How many spots were visible **before** solvent 2 was used?

.....

- (iii) Ring the spot that did **not** move in solvent 2.

- (iv) How many spots travelled further in solvent 2 than they did in solvent 1?

.....

[5]

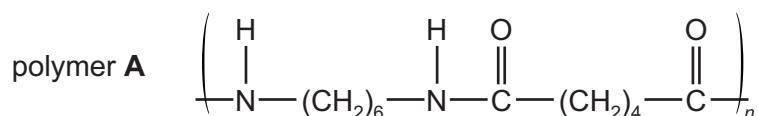
[Total: 10]

- 8 The physical properties of polymers depend on the average relative molecular mass of the polymer chains and on the functional groups present in the monomers.

The presence of side-chains in addition polymers can increase the spacing between polymer chains in the bulk substance and hence reduce the overall density.

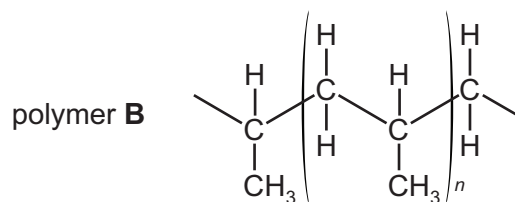
In condensation polymers it is the *nature* of the side-chain that is often more important since this can lead to cross-linking of the polymer chains forming a three-dimensional structure.

- (a) For each of the following polymers, give the structure of the monomer(s) and state the *type of reaction* used to produce the polymer.



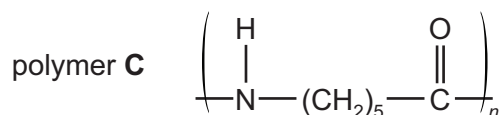
monomer(s)

type of reaction



monomer(s)

type of reaction



monomer(s)

type of reaction

[5]

(b) Look at the structures of the three polymers and answer the following questions.

(i) Suggest why the density of **B** is lower than that of **A**.

.....

.....

(ii) Which polymer will have the weakest forces between chains, and what is the nature of these forces?

.....

.....

[2]

[Total: 7]

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