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Centre Number					Candidate Number				
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**Pearson Edexcel International Advanced Level**

**Time** 1 hour 45 minutes

**Paper reference** **WCH15/01**

**Chemistry**

**International Advanced Level**

**UNIT 5: Transition Metals and Organic Nitrogen Chemistry**

**You must have:**  
Scientific calculator, Data Booklet, ruler

Total Marks

## Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided  
– *there may be more space than you need.*

## Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets  
– *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (\*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

## Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ►

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## SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☐. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☐.

1 This question is about transition metal complexes.

(a) The bonding **within** the complex  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  is

(1)

- ☐ A covalent, dative covalent and ionic
- ☐ B covalent and dative covalent only
- ☐ C covalent only
- ☐ D dative covalent only

(b) Which complex is tetrahedral?

(1)

- ☐ A  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
- ☐ B  $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2]$
- ☐ C  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$
- ☐ D  $[\text{CoCl}_4]^{2-}$

(c) Which complex contains a bidentate ligand?

(1)

- ☐ A  $[\text{Co}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2\text{NH}_2)_2]^{3+}$
- ☐ B  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$
- ☐ C  $[\text{Ni}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$
- ☐ D  $[\text{Mn}(\text{EDTA})]^{2-}$

(Total for Question 1 = 3 marks)

Use this space for rough working. Anything you write in this space will gain no credit.



2 A hydrogen-oxygen fuel cell is used to provide electrical energy for an electric motor in a car.

(a) The electrolyte in the fuel cell is acidic. What is the half-equation at the anode?

(1)

- ☐ **A**  $\frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2\text{O}(\text{l})$
- ☐ **B**  $\text{H}_2\text{O}(\text{l}) \rightarrow \frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$
- ☐ **C**  $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2\text{e}^-$
- ☐ **D**  $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$

(b) Hydrogen-oxygen fuel cells have advantages over methanol-oxygen fuel cells in vehicles.

Which of these is an advantage of the hydrogen-oxygen fuel cell?

(1)

- ☐ **A** more energy is released per mole of fuel used
- ☐ **B** emissions do not contribute to climate change
- ☐ **C** hydrogen is easier to store than methanol
- ☐ **D** only hydrogen can be obtained from renewable resources

(Total for Question 2 = 2 marks)

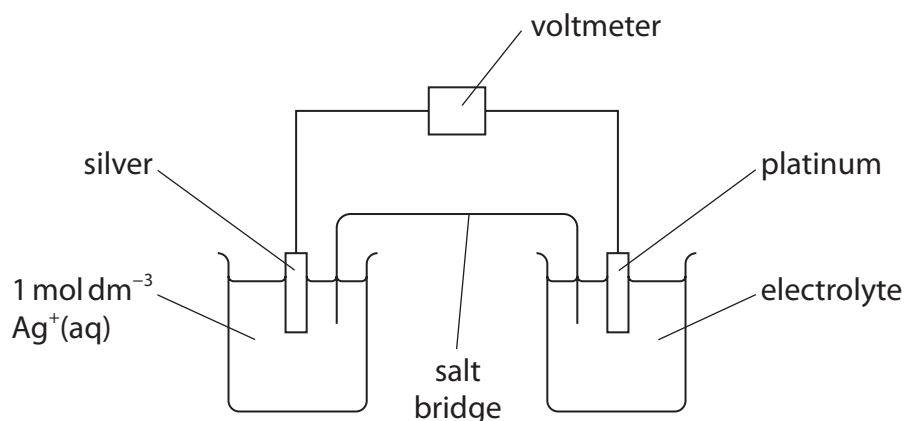
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- 3 An electrochemical cell is made from the electrode systems shown by these half-equations.



The apparatus used to measure the value for  $E^\ominus_{\text{cell}}$  under standard conditions is shown.



- (a) Which silver compound could be used as the electrolyte in the left-hand half-cell?

(1)

- ☐ A silver nitrate
- ☐ B silver hydroxide
- ☐ C silver chloride
- ☐ D silver carbonate

- (b) The electrolyte in the right-hand half-cell is prepared using equal volumes of

(1)

- ☐ A 1 mol dm<sup>-3</sup> acidified VO<sub>2</sub><sup>+</sup>(aq) and 1 mol dm<sup>-3</sup> acidified VO<sup>2+</sup>(aq)
- ☐ B 2 mol dm<sup>-3</sup> acidified VO<sub>2</sub><sup>+</sup>(aq) and 2 mol dm<sup>-3</sup> acidified VO<sup>2+</sup>(aq)
- ☐ C 1 mol dm<sup>-3</sup> VO<sub>2</sub><sup>+</sup>(aq) and 1 mol dm<sup>-3</sup> HCl(aq)
- ☐ D 1 mol dm<sup>-3</sup> VO<sup>2+</sup>(aq) and 1 mol dm<sup>-3</sup> HCl(aq)

(c) Which is the equation for the overall cell reaction under standard conditions?

(1)

- ☐ **A**  $\text{VO}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{VO}_2^+(\text{aq}) + \text{Ag}(\text{s}) + 2\text{H}^+(\text{aq})$
- ☐ **B**  $\text{VO}_2^+(\text{aq}) + \text{Ag}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{VO}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- ☐ **C**  $\text{VO}^{2+}(\text{aq}) + 3\text{Ag}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{VO}_2^+(\text{aq}) + 3\text{Ag}^+(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- ☐ **D**  $\text{VO}_2^+(\text{aq}) + 3\text{Ag}^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{VO}^{2+}(\text{aq}) + 3\text{Ag}(\text{s}) + 2\text{H}^+(\text{aq})$

(d) Which is the value of  $E_{\text{cell}}^\ominus$  in volts?

(1)

- ☐ **A**  $-1.80$
- ☐ **B**  $-0.20$
- ☐ **C**  $+0.20$
- ☐ **D**  $+1.80$

(e) Which is the cell diagram for this cell, using the conventional representation of half-cells?

(1)

- ☐ **A**  $\text{Ag}(\text{s}) \mid \text{Ag}^+(\text{aq}) \parallel [\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq})] \mid [\text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})] \mid \text{Pt}(\text{s})$
- ☐ **B**  $\text{Ag}(\text{s}) \mid \text{Ag}^+(\text{aq}) \parallel [\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq})], [\text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})] \mid \text{Pt}(\text{s})$
- ☐ **C**  $\text{Ag}(\text{s}) \mid \text{Ag}^+(\text{aq}) \parallel [\text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})] \mid [\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq})] \mid \text{Pt}(\text{s})$
- ☐ **D**  $\text{Ag}(\text{s}) \mid \text{Ag}^+(\text{aq}) \parallel [\text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})], [\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq})] \mid \text{Pt}(\text{s})$

(Total for Question 3 = 5 marks)

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- 4 A mass of 4.179 g of hydrated iron(III) sulfate,  $\text{Fe}_2(\text{SO}_4)_3 \cdot \text{H}_2\text{O}$ , was dissolved in deionised water and the solution made up to  $200 \text{ cm}^3$ .

What is the concentration of sulfate ions,  $\text{SO}_4^{2-}$ , in the solution, in  $\text{mol dm}^{-3}$ ?

[Molar mass of  $\text{Fe}_2(\text{SO}_4)_3 \cdot \text{H}_2\text{O} = 417.9 \text{ g mol}^{-1}$ ]

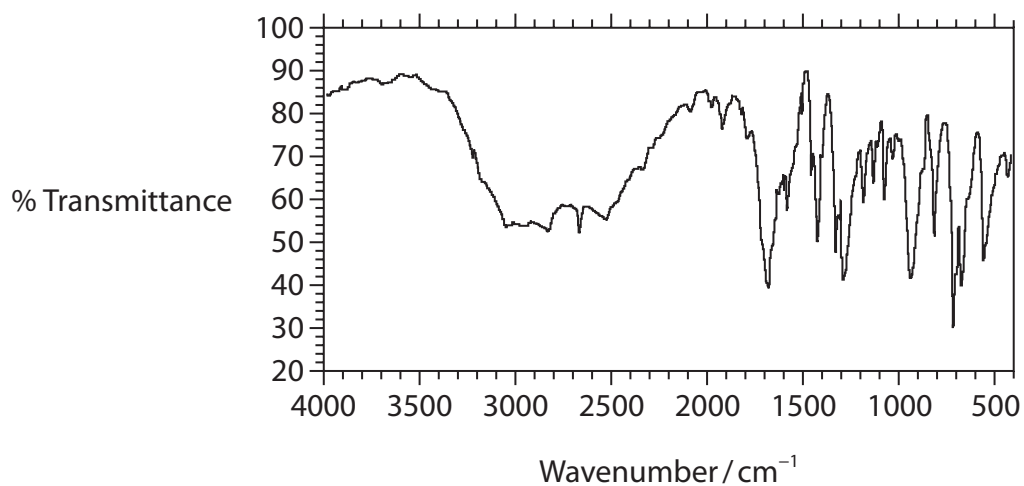
- ☐ A 0.01  
☐ B 0.05  
☐ C 0.10  
☐ D 0.15

(Total for Question 4 = 1 mark)

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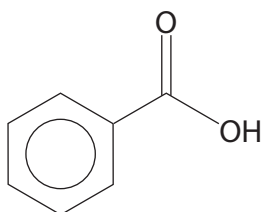
5 The infrared spectrum of a compound **X** is shown.



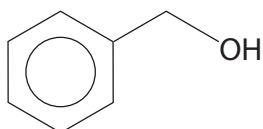
Which could be compound **X**?



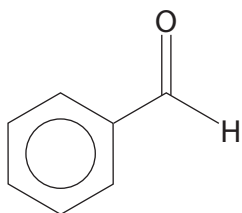
**A**



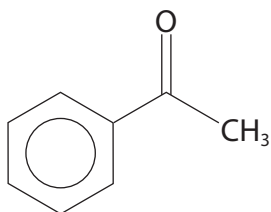
**B**



**C**

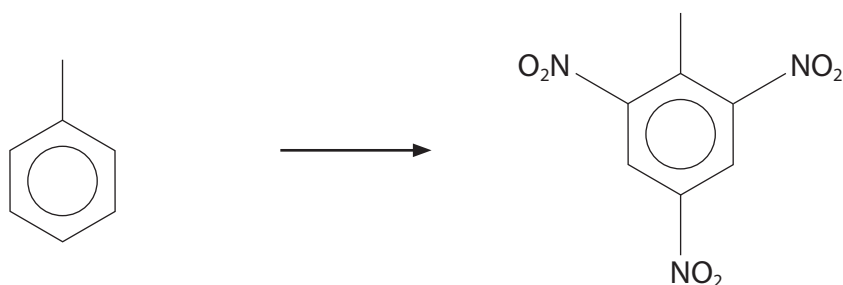


**D**



(Total for Question 5 = 1 mark)

- 6 Methylbenzene reacts with a mixture of concentrated nitric acid and concentrated sulfuric acid to form 2,4,6-trinitromethylbenzene.



- (a) What is the number of peaks in the  $^{13}\text{C}$  NMR spectrum of methylbenzene?

(1)

- ☐ **A** seven
- ☐ **B** six
- ☐ **C** five
- ☐ **D** four

- (b) What type of reaction takes place?

(1)

- ☐ **A** nucleophilic addition
- ☐ **B** nucleophilic substitution
- ☐ **C** electrophilic addition
- ☐ **D** electrophilic substitution

- (c) Which expression shows the mass in grams of 2,4,6-trinitromethylbenzene formed from 10 g of methylbenzene if the yield of the reaction is 85 %?

[ $M_r$  values: methylbenzene = 92      2,4,6-trinitromethylbenzene = 227]

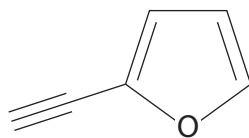
(1)

- ☐ **A**  $(10 \times 85 \times 227) \div (92 \times 100)$
- ☐ **B**  $(10 \times 100 \times 227) \div (92 \times 85)$
- ☐ **C**  $(10 \times 100 \times 227) \div (92 \times 115)$
- ☐ **D**  $(10 \times 115 \times 227) \div (92 \times 100)$

(Total for Question 6 = 3 marks)



- 7 The mass spectrum of the compound shown is obtained using a high resolution mass spectrometer.



What is the mass to charge ratio,  $m/z$ , of the molecular ion of this compound?

[ $A_r$  values: H = 1.0078      C = 12.0000      O = 15.9949]

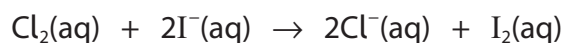
- ☐ A 92.0261
- ☐ B 92.0312
- ☐ C 93.0339
- ☐ D 93.0390

(Total for Question 7 = 1 mark)

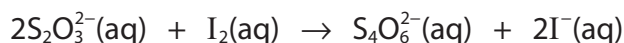
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- 8 A group of students carry out an experiment to find the concentration of chlorine,  $\text{Cl}_2(\text{aq})$ , in a solution.

Excess potassium iodide solution is added to a  $10.0\text{ cm}^3$  sample of the chlorine solution.



The iodine produced is titrated with a solution of thiosulfate ions of known concentration, using starch indicator.



The concentration of the  $\text{Cl}_2(\text{aq})$  is between  $0.038$  and  $0.042\text{ mol dm}^{-3}$ .

- (a) What concentration of thiosulfate ions, in  $\text{mol dm}^{-3}$ , is required to give a titre of approximately  $20\text{ cm}^3$ ?

(1)

- ☐ A 0.010
- ☐ B 0.020
- ☐ C 0.040
- ☐ D 0.080

- (b) What is the most suitable volume of  $0.1\text{ mol dm}^{-3}$  potassium iodide solution, in  $\text{cm}^3$ , to add to the  $10.0\text{ cm}^3$  of chlorine solution?

(1)

- ☐ A 7.6
- ☐ B 8.0
- ☐ C 8.4
- ☐ D 10.0

- (c) What is the colour change at the end-point of the titration?

(1)

- ☐ A colourless to pale yellow
- ☐ B pale yellow to colourless
- ☐ C colourless to blue-black
- ☐ D blue-black to colourless

(Total for Question 8 = 3 marks)



9 The formulae of four ions are shown.

Formula of ion
$\text{CrO}_4^{2-}$
$\text{AlO}_2^-$
$[\text{Fe}(\text{CN})_6]^{4-}$
$[\text{CrCl}_2(\text{H}_2\text{O})_4]^+$

How many of these ions contain a metal with an oxidation number of +3?

- ☐ **A** one
- ☐ **B** two
- ☐ **C** three
- ☐ **D** four

(Total for Question 9 = 1 mark)

**TOTAL FOR SECTION A = 20 MARKS**

## SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

10 This question is about silver and silver compounds.

Glass decorations are made reflective by coating their inner surface with silver. This is achieved by using the reaction between silver nitrate solution, ammonia and glucose, under alkaline conditions.

Initially the colourless complex ion diamminesilver(I),  $[\text{Ag}(\text{NH}_3)_2]^+$ , forms.

(a) (i) Explain the shape of  $[\text{Ag}(\text{NH}_3)_2]^+$ .

(3)

(ii) Explain why  $[\text{Ag}(\text{NH}_3)_2]^+$  is colourless.

(2)

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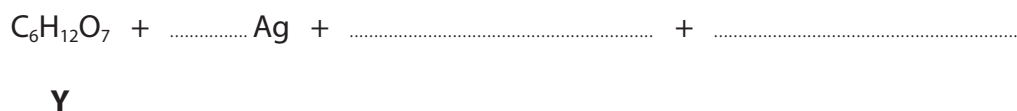
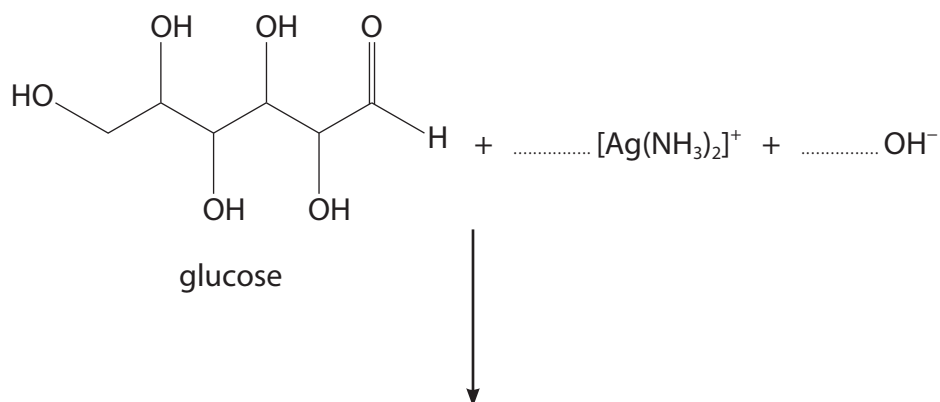
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(b) The diamminesilver(I) complex then reacts with glucose forming silver and an organic compound, **Y**. Two other products also form.

(i) Complete the equation for the reaction.

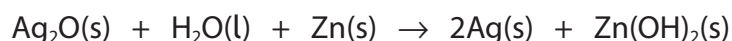
(2)



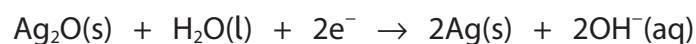
(ii) Draw the structure of **Y**.

(1)

(c) The overall reaction in a silver cell used in watch batteries is



The half-equation for the reaction at the positive electrode is



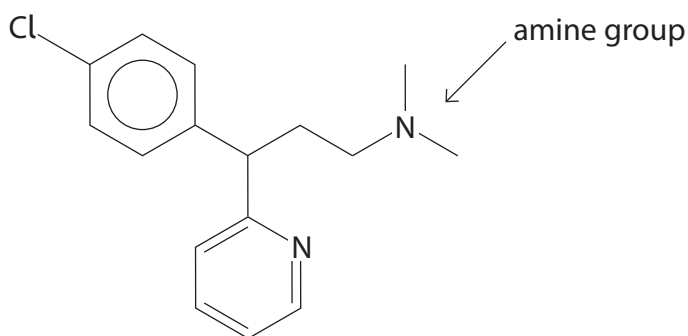
Deduce the half-equation for the reaction at the negative electrode.  
State symbols are **not** required.

(1)

(Total for Question 10 = 9 marks)



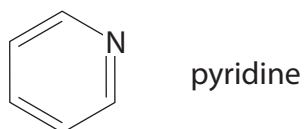
11 Chlorpheniramine is an amine used in the treatment of hayfever.



(a) Deduce the classification of the labelled amine group.

(1)

(b) The compound pyridine is used in the synthesis of chlorpheniramine.



Like many amines, pyridine is miscible with water and the solution formed is alkaline.

Explain **each** of these properties of pyridine.

(4)

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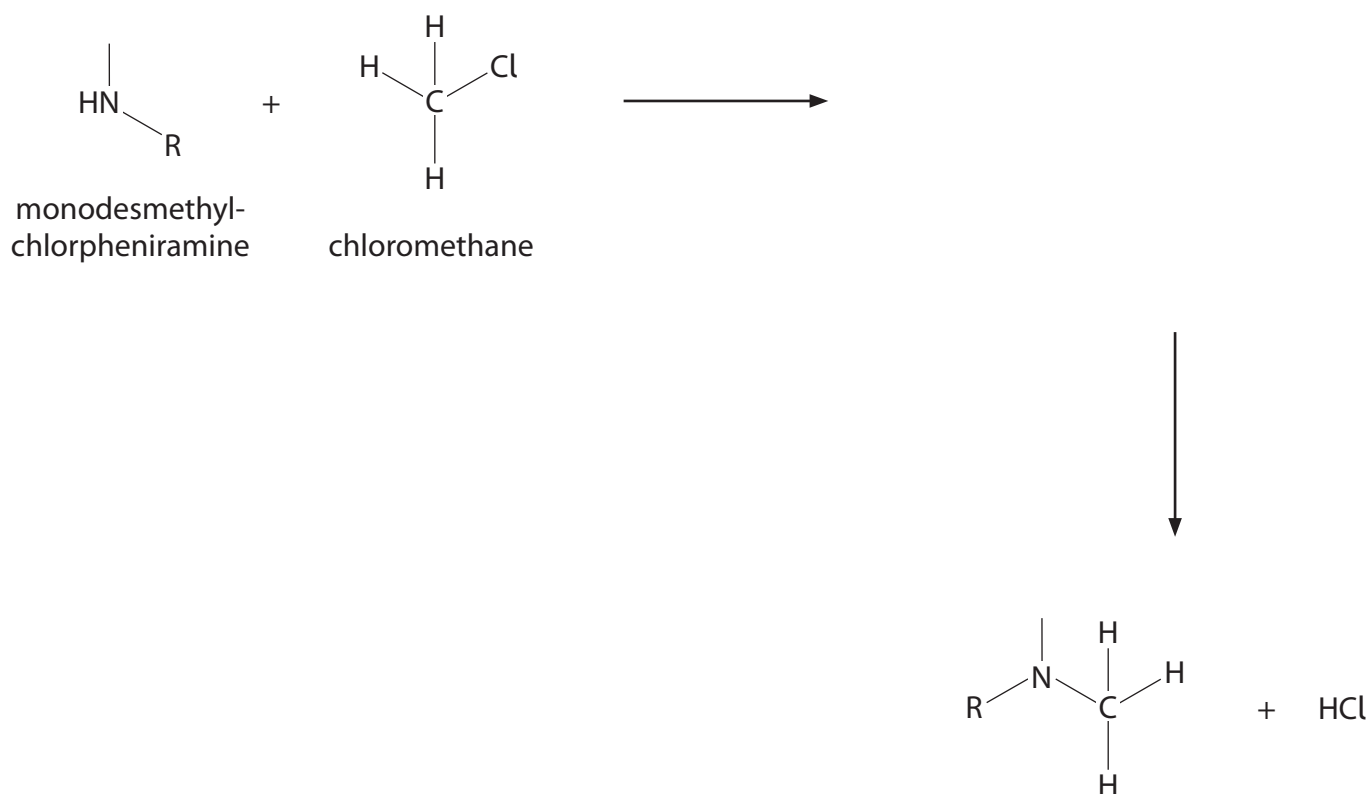


- (c) A student suggested that the final step in the synthesis of chlorpheniramine starts with the reaction between monodesmethylchlorpheniramine and chloromethane.

Assuming the reaction is similar to that between ammonia and chloromethane, complete the mechanism for this proposed reaction. Some of the organic structures shown have been simplified.

Include curly arrows, and any relevant dipoles and lone pairs of electrons.

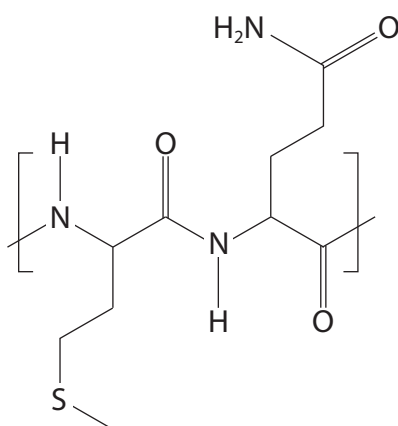
(4)



(Total for Question 11 = 9 marks)

12 This question is about polymers.

- (a) The diagram shows part of the structure of a polymer formed by a **condensation** reaction between two amino acids.

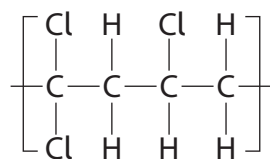


Predict the structures of the two monomers that produce this polymer.

(2)



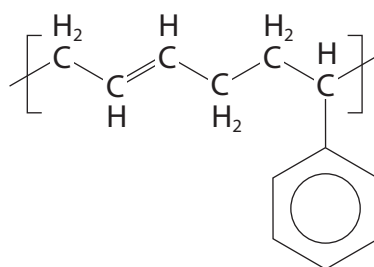
- (b) The diagram shows a repeat unit of an addition polymer used in some food wraps. It is formed from two different monomers.



Deduce the structures of the two monomers that produce this polymer.

(2)

- (c) A synthetic rubber polymer has the structure shown.



The molar mass of the synthetic rubber is approximately  $300\,000\text{ g mol}^{-1}$ .

Calculate the approximate number of repeat units in the polymer.

(2)

(Total for Question 12 = 6 marks)

**13** The hydride of arsenic, arsine, is a toxic gas used in the production of semiconductors.

(a) Draw a dot-and-cross diagram for arsine,  $\text{AsH}_3$ .

(1)

(b) Arsine is a reducing agent and reacts with cerium(IV) sulfate solution, forming arsenic.

The data from an experiment are shown.

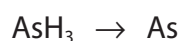
Volume of arsine gas =  $350 \text{ cm}^3$  at  $115\,000 \text{ Pa}$  and  $20^\circ\text{C}$

Volume of cerium(IV) sulfate solution =  $488 \text{ cm}^3$

Concentration of cerium(IV) sulfate solution =  $0.102 \text{ mol dm}^{-3}$

(i) Complete the half-equation.

(1)



(ii) Calculate the final oxidation state of the cerium ion formed in the reaction.

(6)

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(Total for Question 13 = 8 marks)



**\*14** Describe the reactions of separate samples of aqueous cobalt(II) sulfate with aqueous sodium hydroxide, excess aqueous ammonia and concentrated hydrochloric acid.

For each reaction, link your description to an appropriate equation.  
State symbols are not required.

(6)

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(Total for Question 14 = 6 marks)



P 6 9 5 0 8 A 0 2 1 3 2

**15** A compound **Q** contains the elements carbon, hydrogen and oxygen only.

- (a) Combustion analysis of 4.91 g of **Q** produces 14.6 g of carbon dioxide and 3.58 g of water.

Show that the molecular formula of **Q** is  $\text{C}_{10}\text{H}_{12}\text{O}$ .

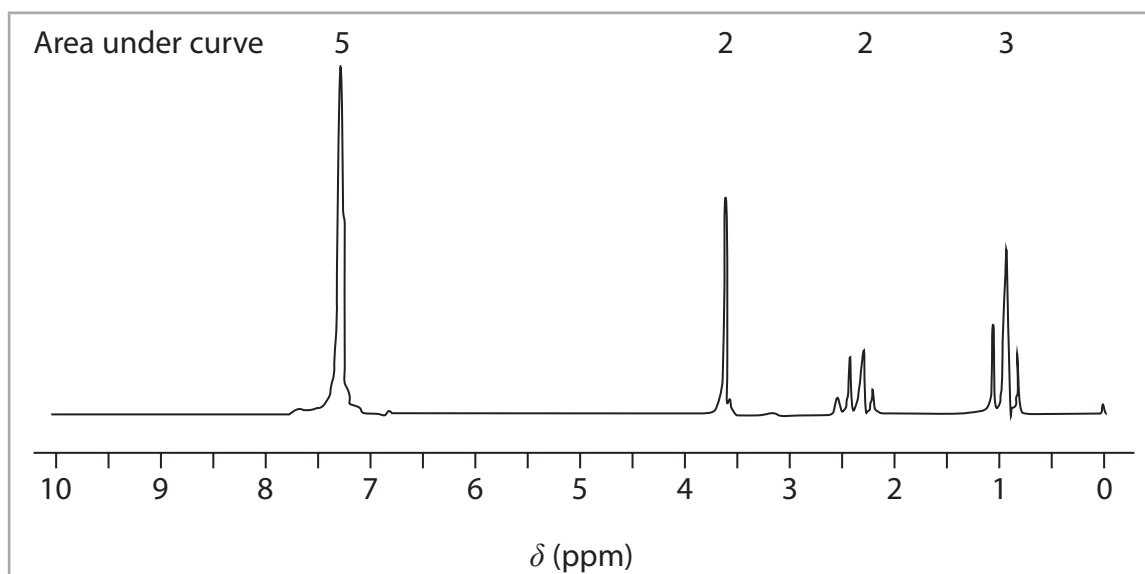
You **must** show all your working.

[ $M_r$  of **Q** = 148]

(4)



(b) The high resolution proton NMR spectrum of **Q** is shown.



Deduce the structure of **Q**. Justify your answer by considering the relative peak areas, the chemical shifts and the splitting patterns.

You will find it helpful to refer to page 8 of the Data Booklet.

The peak at 3.6 ppm is due to a proton environment on a carbon bonded to the benzene ring. The peak is not where it might be expected from the general values in the Data Booklet.

(7)

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(Total for Question 15 = 11 marks)

**TOTAL FOR SECTION B = 49 MARKS**



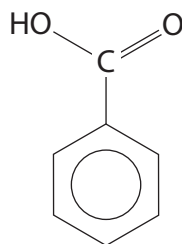
P 6 9 5 0 8 A 0 2 5 3 2



## SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

- 16 Benzoic acid is a white crystalline solid with the structure shown.



It is found in many plants as it is an important building block for the biosynthesis of a variety of compounds, such as plant hormones and attractants for pollinators.

The role of benzoic acid in the chemical industry is also widespread and approximately 500 000 tonnes are produced annually. It is used in the synthesis of many compounds, including medicines, dyes and insect repellents.

Such synthetic dyes are often classified as aryl azo dyes. These dyes have a range of vivid colours and a wide range of uses in many industries, including food and textiles. Their synthesis involves the formation of a diazonium ion. This ion then reacts with a phenol in a coupling reaction, to form the dye. The relative simplicity of the reactions involved and ready availability of starting materials make azo dyes cheap to produce.

Salts of benzoic acid, such as calcium benzoate and sodium benzoate, are used in the food industry as preservatives.

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- (a) Devise a reaction scheme to produce benzoic acid from benzene, via bromobenzene and then a Grignard reagent.

Include the reagents and essential conditions for each step and give the name or structure of each of the intermediate compounds.

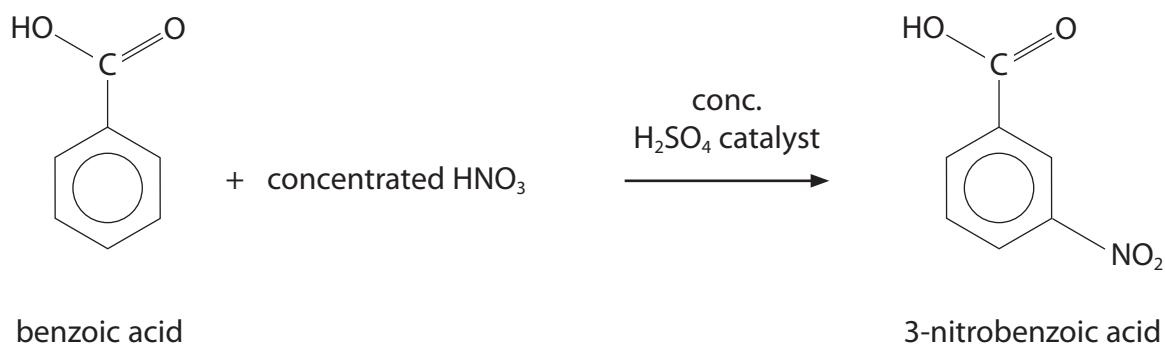
Details of practical procedures and reaction mechanisms are **not** required.

(6)



(b) Benzoic acid can be used in the synthesis of azo dyes.

- (i) In Step 1, benzoic acid reacts with concentrated nitric acid to form 3-nitrobenzoic acid.

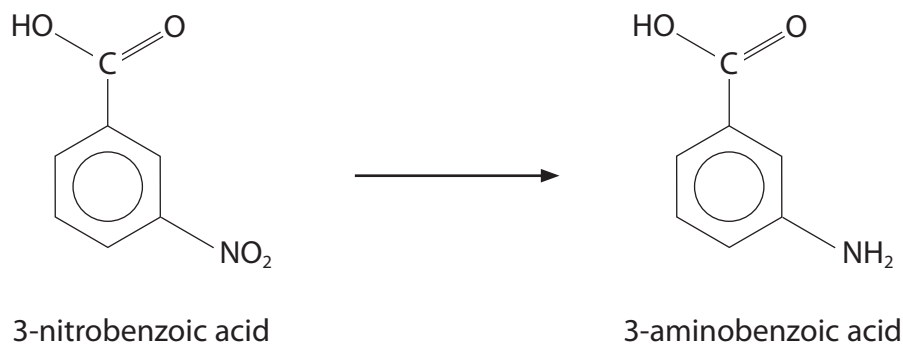


Draw the mechanism for the reaction, using appropriate curly arrows.

Include equations showing the role of the catalyst and how it is regenerated.

(5)

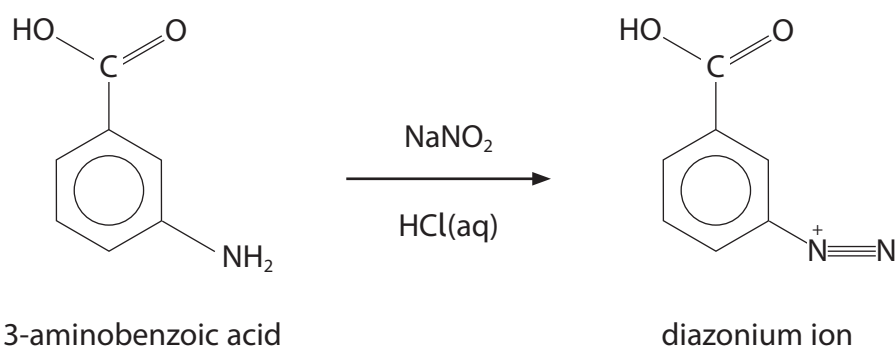
(ii) In Step 2, the 3-nitrobenzoic acid reacts to form 3-aminobenzoic acid.



State the reagents required for this reaction.

(1)

(iii) In Step 3, the 3-aminobenzoic acid reacts with sodium nitrite and dilute hydrochloric acid, forming a diazonium ion.



State a temperature at which this reaction should take place, giving **one** reason for your answer.

(2)

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(iv) Draw the structure of the azo dye formed when the diazonium ion reacts with phenol.

(1)

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- (c) Hydrated calcium benzoate is used as a preservative in soft drinks.  
It has the formula  $\text{Ca}(\text{C}_6\text{H}_5\text{COO})_2 \cdot x\text{H}_2\text{O}$ .

2.60 g of hydrated calcium benzoate was dissolved in deionised water.  
Excess lead(II) nitrate solution was added, forming a precipitate of  
lead(II) benzoate,  $\text{Pb}(\text{C}_6\text{H}_5\text{COO})_2(\text{s})$ . This precipitate was removed and dried.  
The mass of the dry solid was 3.89 g.

Calculate the molar mass of hydrated calcium benzoate and hence deduce the  
value of  $x$ .

(6)

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(Total for Question 16 = 21 marks)

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**TOTAL FOR SECTION C = 21 MARKS**  
**TOTAL FOR PAPER = 90 MARKS**

