Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

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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P 6 9 5 0 8 A 0 1 3 2

Pearson

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 $[Cu(NH_3)_4(H_2O)_2]^{2+}$ 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** $[Pt(NH_3)_2Cl_2]$

☒ **B** $[Cu(H_2O)_4(OH)_2]$

☒ **C** $[Cu(NH_3)_4(H_2O)_2]^{2+}$

☒ **D** $[CoCl_4]^{2-}$

(c) Which complex contains a bidentate ligand?

(1)

☒ **A** $[Co(NH_2CH_2CH_2NHCH_2CH_2NH_2)_2]^{3+}$

☒ **B** $[Cu(NH_3)_4(H_2O)_2]^{2+}$

☒ **C** $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$

☒ **D** $[Mn(EDTA)]^{2-}$

(Total for Question 1 = 3 marks)

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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** $\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$

☒ **B** $H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$

☒ **C** $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

☒ **D** $2H^+(aq) + 2e^- \rightarrow H_2(g)$

(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)

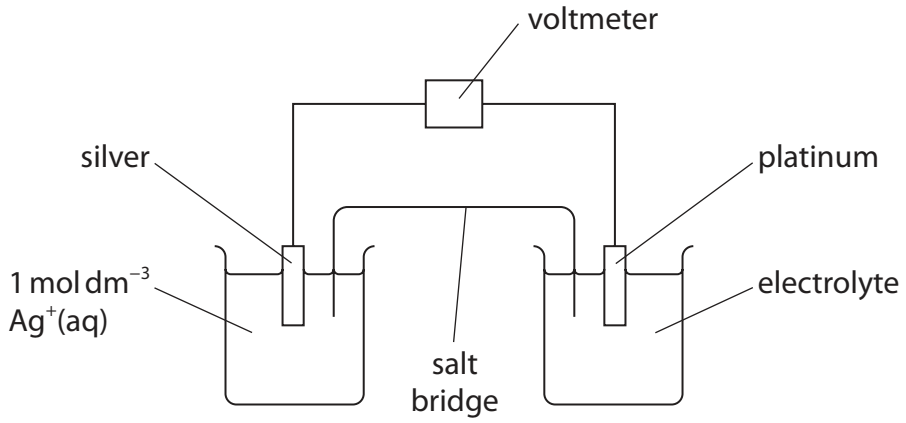
Use this space for rough working. Anything you write in this space will gain no credit.

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

$$Ag^+(aq) + e^- \rightleftharpoons Ag(s) \qquad E^\ominus = +0.80\,V$$

$$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l) \qquad E^\ominus = +1.00\,V$$

The apparatus used to measure the value for $E^\ominus_{cell}$ 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^{-3} acidified $VO_2^+(aq)$ and 1 mol dm^{-3} acidified $VO^{2+}(aq)$
- ☒ **B** 2 mol dm^{-3} acidified $VO_2^+(aq)$ and 2 mol dm^{-3} acidified $VO^{2+}(aq)$
- ☒ **C** 1 mol dm^{-3} $VO_2^+(aq)$ and 1 mol dm^{-3} HCl(aq)
- ☒ **D** 1 mol dm^{-3} $VO^{2+}(aq)$ and 1 mol dm^{-3} HCl(aq)

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

(1)

☒ **A** $VO^{2+}(aq) + Ag^{+}(aq) + H_2O(l) \rightarrow VO_2^{+}(aq) + Ag(s) + 2H^{+}(aq)$

☒ **B** $VO_2^{+}(aq) + Ag(s) + 2H^{+}(aq) \rightarrow VO^{2+}(aq) + Ag^{+}(aq) + H_2O(l)$

☒ **C** $VO^{2+}(aq) + 3Ag(s) + 2H^{+}(aq) \rightarrow VO_2^{+}(aq) + 3Ag^{+}(aq) + H_2O(l)$

☒ **D** $VO_2^{+}(aq) + 3Ag^{+}(aq) + H_2O(l) \rightarrow VO^{2+}(aq) + 3Ag(s) + 2H^{+}(aq)$

(d) Which is the value of $E^{\ominus}_{cell}$ 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** $Ag(s) \mid Ag^{+}(aq) \mid\mid [VO_2^{+}(aq) + 2H^{+}(aq)] \mid [VO^{2+}(aq) + H_2O(l)] \mid Pt(s)$

☒ **B** $Ag(s) \mid Ag^{+}(aq) \mid\mid [VO_2^{+}(aq) + 2H^{+}(aq)], [VO^{2+}(aq) + H_2O(l)] \mid Pt(s)$

☒ **C** $Ag(s) \mid Ag^{+}(aq) \mid\mid [VO^{2+}(aq) + H_2O(l)] \mid [VO_2^{+}(aq) + 2H^{+}(aq)] \mid Pt(s)$

☒ **D** $Ag(s) \mid Ag^{+}(aq) \mid\mid [VO^{2+}(aq) + H_2O(l)], [VO_2^{+}(aq) + 2H^{+}(aq)] \mid Pt(s)$

(Total for Question 3 = 5 marks)

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4 A mass of 4.179 g of hydrated iron(III) sulfate, $Fe_2(SO_4)_3 \cdot H_2O$, was dissolved in deionised water and the solution made up to 200 cm^3.

What is the concentration of sulfate ions, SO_4^{2-}, in the solution, in mol dm^{-3}?

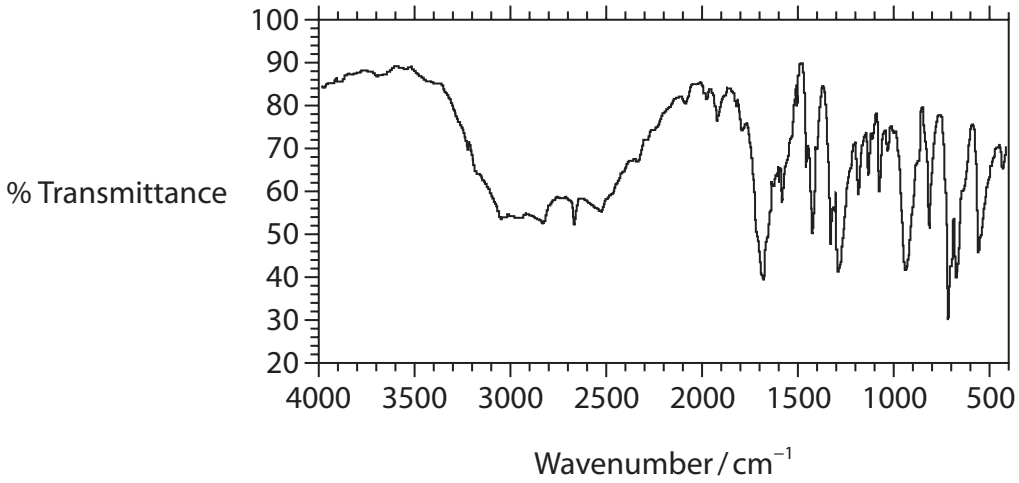
[Molar mass of $Fe_2(SO_4)_3 \cdot H_2O$ = 417.9 g mol^{-1}]

- ☒ **A** 0.01
- ☒ **B** 0.05
- ☒ **C** 0.10
- ☒ **D** 0.15

(Total for Question 4 = 1 mark)

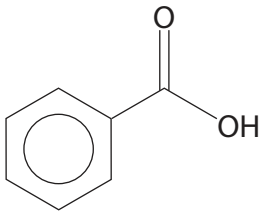
Use this space for rough working. Anything you write in this space will gain no credit.

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

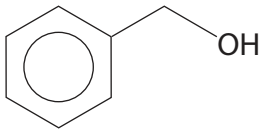


Which could be compound **X**?

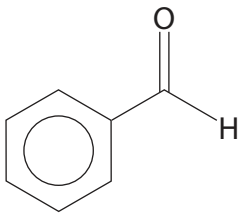
☒ **A**



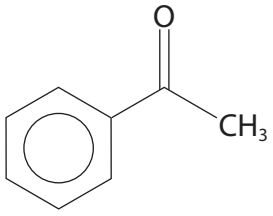
☒ **B**



☒ **C**

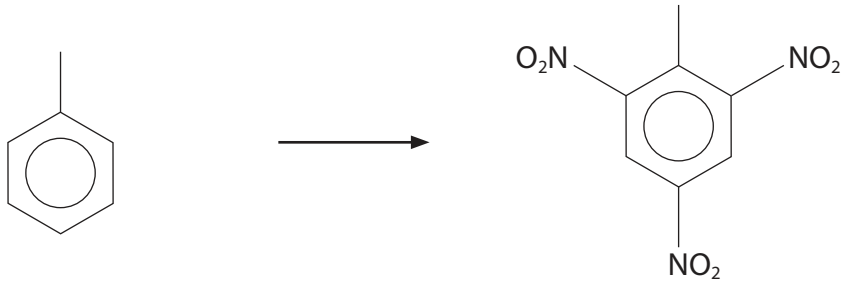


☒ **D**



(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}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)

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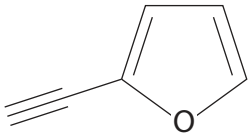
7 The mass spectrum of the compound shown is obtained using a high resolution mass spectrometer.



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)

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

8 A group of students carry out an experiment to find the concentration of chlorine, $Cl_2(aq)$, in a solution.

Excess potassium iodide solution is added to a 10.0 cm^3 sample of the chlorine solution.

$$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$$

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

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

The concentration of the $Cl_2(aq)$ is between 0.038 and 0.042 mol dm^{-3}.

(a) What concentration of thiosulfate ions, in mol dm^{-3}, is required to give a titre of approximately 20 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 mol dm^{-3} potassium iodide solution, in cm^3, to add to the 10.0 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
CrO_4^{2-}
AlO_2^-
$[Fe(CN)_6]^{4-}$
$[CrCl_2(H_2O)_4]^+$

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), $[Ag(NH_3)_2]^+$, forms.

(a) (i) Explain the shape of $[Ag(NH_3)_2]^+$.

(3)

(ii) Explain why $[Ag(NH_3)_2]^+$ is colourless.

(2)

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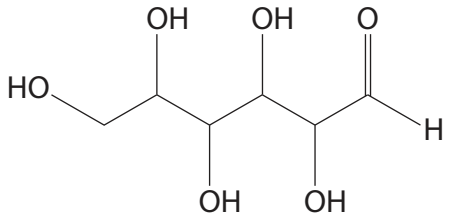
(b) The diamminesilver(I) complex then reacts with glucose forming silver and an organic compound, **Y**. Two other products also form.

(i) Complete the equation for the reaction.

(2)



glucose

$+ \ldots\ldots [Ag(NH_3)_2]^+ + \ldots\ldots OH^-$

$C_6H_{12}O_7 + \ldots\ldots Ag + \ldots\ldots + \ldots\ldots$

Y

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

(1)

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

$$Ag_2O(s) + H_2O(l) + Zn(s) \rightarrow 2Ag(s) + Zn(OH)_2(s)$$

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

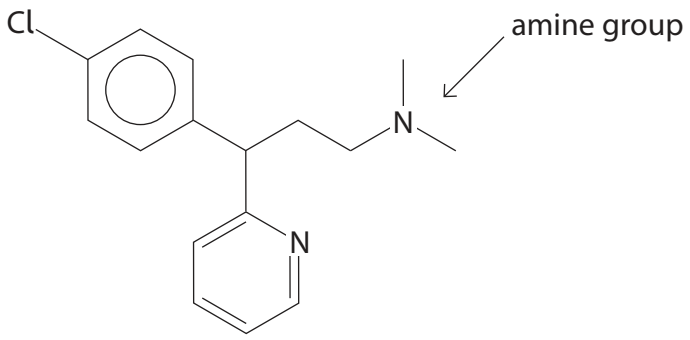
$$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$$

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

(1)

(Total for Question 10 = 9 marks)

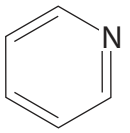
11 Chlorpheniramine is an amine used in the treatment of hayfever.



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

(1)

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



pyridine

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

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

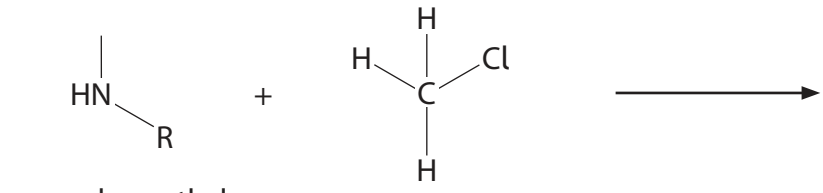
(4)

(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.

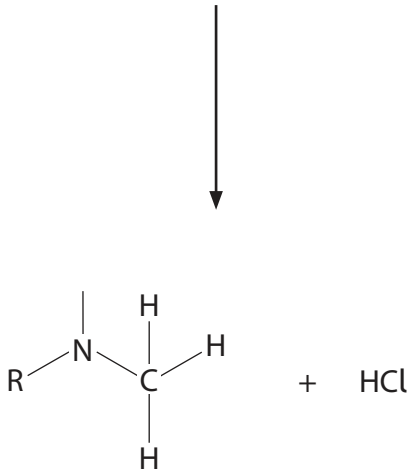
Include curly arrows, and any relevant dipoles and lone pairs of electrons.

(4)



monodesmethyl-chlorpheniramine

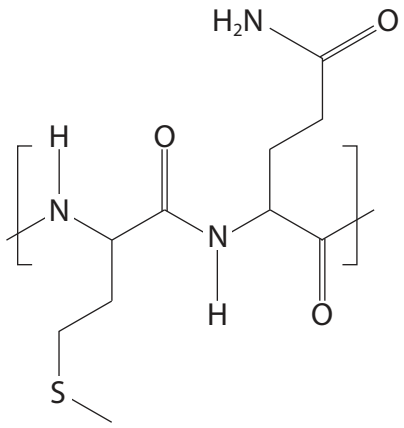
chloromethane



(Total for Question 11 = 9 marks)

12 This question is about polymers.

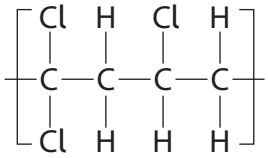
(a) The diagram shows part of the structure of a polymer formed by a **condensation** reaction between two amino acids.



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

(2)

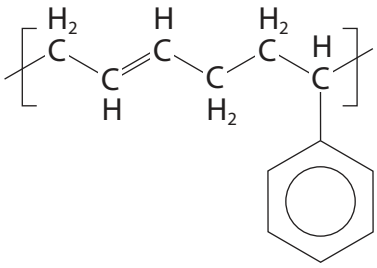
(b) The diagram shows a repeat unit of an addition polymer used in some food wraps. It is formed from two different monomers.



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 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, 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 cm^3 at 115 000 Pa and 20 °C

Volume of cerium(IV) sulfate solution = 488 cm^3

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

(i) Complete the half-equation.

(1)

$$AsH_3 \rightarrow As$$

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

(6)

(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)

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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.

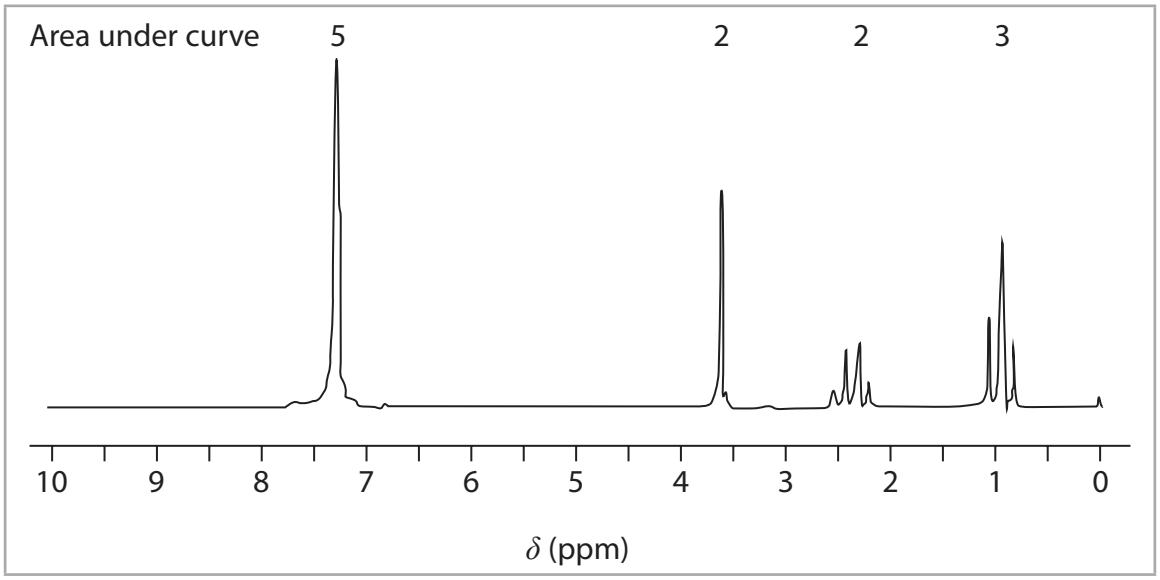
Show that the molecular formula of **Q** is $C_{10}H_{12}O$.

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)

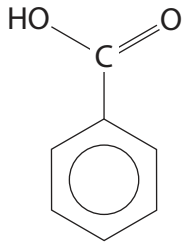
(Total for Question 15 = 11 marks)

TOTAL FOR SECTION B = 49 MARKS

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.

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

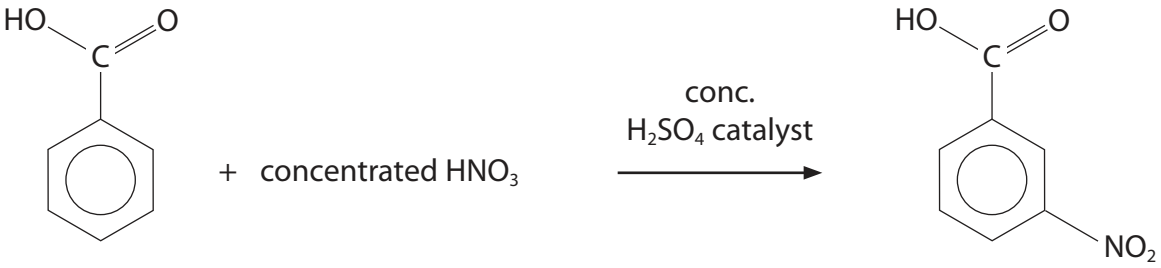
Include the reagents and essential conditions for each step and give the name or structure of each of the intermediate compounds.

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.



benzoic acid

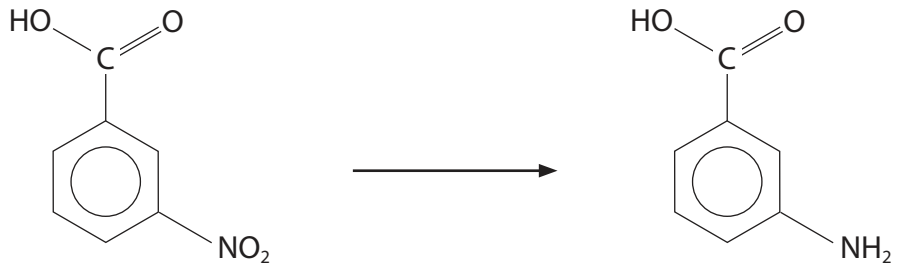
3-nitrobenzoic acid

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.

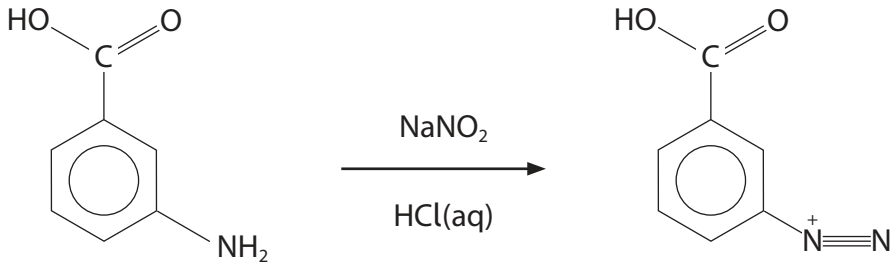


3-nitrobenzoic acid 3-aminobenzoic acid

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.



3-aminobenzoic acid diazonium ion

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

(2)

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

(1)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(c) Hydrated calcium benzoate is used as a preservative in soft drinks.
It has the formula $Ca(C_6H_5COO)_2 \cdot xH_2O$.

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, $Pb(C_6H_5COO)_2(s)$. 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)

(Total for Question 16 = 21 marks)

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

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103