



Mock Exam 1

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701

Paper 4 A Level Structured Questions

2 hours 10 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

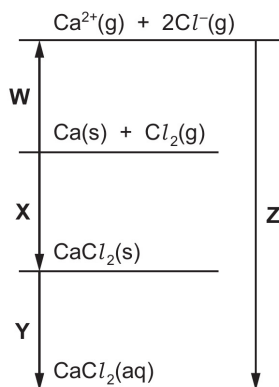
INFORMATION

- The total mark for this paper is 110.
- The number of marks for each question or part question is shown in brackets **110**
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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

1

- (a) The energy cycle shown can be used, along with suitable data, to calculate the enthalpy change of hydration of $\text{Ca}^{2+}(\text{g})$. Each arrow indicates a transformation, **W**, **X**, **Y** and **Z**. Each transformation consists of one or more steps.



The following data and data from the *Data Booklet* should be used.

electron affinity of $\text{Cl}(\text{g})$	$= -349 \text{ kJ mol}^{-1}$
enthalpy change of atomisation of $\text{Ca}(\text{s})$	$= +193 \text{ kJ mol}^{-1}$
enthalpy change of formation of $\text{CaCl}_2(\text{s})$	$= -795 \text{ kJ mol}^{-1}$
enthalpy change of solution of $\text{CaCl}_2(\text{s})$	$= -83 \text{ kJ mol}^{-1}$
enthalpy change of hydration of $\text{Cl}^{-}(\text{g})$	$= -364 \text{ kJ mol}^{-1}$

- (i) Calculate the value of the enthalpy change corresponding to transformation **W**. Show your working.

enthalpy change **W** = kJ mol^{-1} [2]

- (ii) Use your answer to (a)(i) and other data to calculate the value of the enthalpy change corresponding to transformation **Z**.

enthalpy change **Z** = kJ mol^{-1} [2]

- (iii) Use your answer to (a)(ii) to calculate the enthalpy change of hydration of $\text{Ca}^{2+}(\text{g})$.

enthalpy change of hydration of $\text{Ca}^{2+}(\text{g}) = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

- (iv) Write an expression, in terms of **W**, **X**, **Y** and/or **Z**, to show how the enthalpy changes of **two** of the transformations can be used to calculate the lattice energy of $\text{CaCl}_2(\text{s})$.

lattice energy of $\text{CaCl}_2(\text{s}) = \dots\dots\dots$ [1]

- (v) State whether the lattice energy of $\text{CaCl}_2(\text{s})$ is more or less exothermic than the lattice energy of $\text{MgF}_2(\text{s})$.

Explain your answer.

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

- (b) The sulfates of the Group 2 elements vary in solubility down Group 2.

- (i) Give the names of **two** solutions that could be mixed to form barium sulfate.

..... [1]

- (ii) State and explain how the solubilities of the sulfates of the Group 2 elements vary down Group 2.

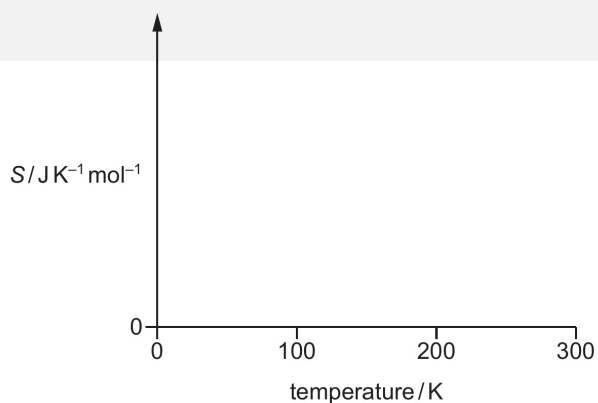
.....
.....
.....
.....
.....
.....
..... [4]

Entropy is a measure of the disorder of a system.

(c)

Assume the entropy, S , for H_2O is zero at 0 K.

Sketch a graph on the axes to show how the entropy changes for H_2O between 0 K and 300 K.



[2]

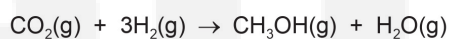
Place **one tick (✓)** in **each row** of the table to show the sign of the entropy changes, ΔS .

(d)

	ΔS is negative	ΔS is positive
solid dissolving in water		
water boiling to steam		

[1]

The equation for a reaction that produces methanol is shown.



(e)

Use relevant bond energies from the *Data Booklet* to calculate the enthalpy change, ΔH , for this gas phase reaction.

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

[Total: 18]

Two elements, **V** and **W**, are in adjacent groups in the Periodic Table.

V reacts with oxygen to form an acidic gas, **X**. **V** forms an anion with formula VO_m^- .

W reacts with oxygen to form an acidic gas, **Y**. **W** forms an anion with formula WO_n^{2-} .

A solution of WO_n^{2-} forms a white precipitate with $\text{Ba}^{2+}(\text{aq})$ but shows no visible reaction with $\text{Mg}^{2+}(\text{aq})$.

(a) Complete the table below.

	identity or value
V	
X	
m	
W	
Y	
n	

[3]

(b) By referring to enthalpy changes, explain why WO_n^{2-} forms a white precipitate with $\text{Ba}^{2+}(\text{aq})$ but shows no visible reaction with Mg^{2+} .

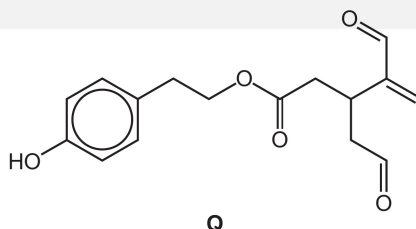
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.....

..... [3]

[Total: 6]

Oleocanthal, **Q**, is a natural compound found in olive oil. It has antioxidant and anti-inflammatory properties and is thought to have a protective effect against Alzheimer's disease.



- (a) **Q** shows optical and cis-trans isomerism.

On the structure of **Q** above, **circle** the functional group that shows cis-trans isomerism and indicate with an **asterisk (*)** the chiral carbon atom. [1]

- (b) **Q** can be isolated from olive oil by partitioning between two solvents.

- (i) Explain what is meant by the term *partition coefficient*.

.....

 [2]

- (ii) When 40.0 cm³ of hexane was shaken with 10.0 cm³ of a solution containing 0.25 g of **Q** in 10.0 cm³ of methanol, it was found that 0.060 g of **Q** was extracted into the hexane.

Calculate the partition coefficient, $K_{\text{partition}}$, of **Q** between hexane and methanol.

$K_{\text{partition}} = \dots\dots\dots$ [2]

(c) Complete the following table to show the structures of the products formed when **Q** reacts with the three reagents.

reagent	structure of product(s)		type of reaction
excess $\text{Br}_2(\text{aq})$			
NaBH_4			
excess hot $\text{NaOH}(\text{aq})$			

[6]

(d) When a sample of **Q** synthesised in a laboratory was compared to a natural sample from olive oil, it was found that the therapeutic activity of the synthetic sample was lower.

Suggest a reason for this.

.....
 [1]

[Total: 12]

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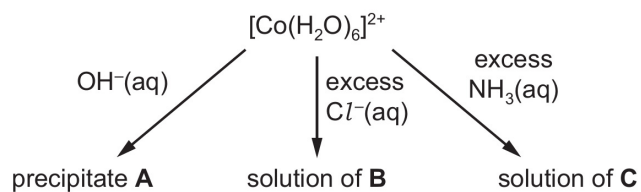
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(a) Cobalt is a transition element that forms complex ions with oxidation states +2 and +3.

Explain what is meant by the term *transition element*.

[1]

(b) The following scheme shows some reactions of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.



(i) State the formula of each of the following.

A

B

C

[2]

(ii) State the colour of the following solutions.

$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$

solution of **B**

solution of **C**

[2]

A solution is made by dissolving $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in an excess of aqueous ammonia. This solution contains the copper complex $[\text{Cu}(\text{NH}_3)_4]^{2+}$.

(c)

(i) Write an expression for the K_{stab} of $[\text{Cu}(\text{NH}_3)_4]^{2+}$.

$K_{\text{stab}} =$

[1]

(ii) State the colour of the solution of $[\text{Cu}(\text{NH}_3)_4]^{2+}$.

..... [1]

The solution of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ is heated gently in a fume cupboard so that NH_3 is released. Some NH_3 remains in solution and some forms NH_3 gas. The colour of the solution changes; a precipitate of $\text{Cu}(\text{OH})_2$ forms and is collected.

A sample of $\text{Cu}(\text{OH})_2$ is added to concentrated hydrochloric acid. A reaction takes place forming a coloured copper complex, **Y**.

A sample of $\text{Cu}(\text{OH})_2$ is added to dilute sulfuric acid. A reaction takes place forming a coloured copper complex, **Z**.

$[\text{Cu}(\text{NH}_3)_4]^{2+}$, **Y** and **Z** are different colours.

(d)

Suggest an equation for the reaction of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ to form $\text{Cu}(\text{OH})_2$ as the aqueous solution of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ is heated.

..... [1]

(e)

Suggest an equation for the reaction of $\text{Cu}(\text{OH})_2$ with concentrated hydrochloric acid, forming **Y**.

..... [2]

(f)

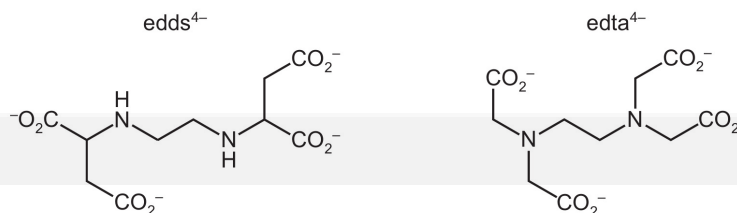
Complete the table with the colour and geometry of complex **Y** and the colour, geometry and formula of complex **Z**.

	Y	Z
colour of complex		
geometry of complex		
formula of complex		

[2]

(g)

Edds⁴⁻ and edta⁴⁻ are polydentate ligands that form octahedral complexes with Fe³⁺(aq).



The formulae of the complexes are [Fe(edds)]⁻ and [Fe(edta)]⁻ respectively.

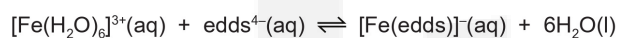
(i) On the diagram of edds⁴⁻, circle each atom that forms a bond to the Fe³⁺ ion in [Fe(edds)]⁻. [1]

(ii) [Fe(edds)]⁻ is red and [Fe(edta)]⁻ is yellow.

Explain why the two complexes have different colours.

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

(iii) When edds⁴⁻(aq) is added to Fe³⁺(aq), the following reaction occurs.

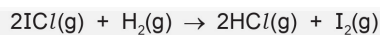


State the type of reaction that occurs.

..... [1]

[Total: 16]

Iodine monochloride, ICl , is a yellow-brown gas. It reacts with hydrogen gas under certain conditions as shown.



Experiments are performed using different starting concentrations of ICl and H_2 . The initial rate of each reaction is measured. The following results are obtained.

experiment	$[\text{ICl}]/\text{mol dm}^{-3}$	$[\text{H}_2]/\text{mol dm}^{-3}$	relative rate of reaction
1	4.00×10^{-3}	4.00×10^{-3}	1.00
2	4.00×10^{-3}	7.00×10^{-3}	1.75
3	4.00×10^{-3}	1.00×10^{-2}	2.50
4	5.00×10^{-3}	8.00×10^{-3}	2.50
5	7.00×10^{-3}	8.00×10^{-3}	3.50

- (a) Identify a change, taking place in the reaction mixture, that would enable measurements of the rate of this reaction to be made.

..... [1]

- (b) Use the data in the table to show that the reaction is first order with respect to $\text{H}_2(\text{g})$.

.....

 [1]

- (c) Use the data in the table to show that the reaction is first order with respect to $\text{ICl}(\text{g})$.

.....

 [1]

- (d) Complete the rate equation for the reaction between $\text{ICl}(\text{g})$ and $\text{H}_2(\text{g})$.

rate = [1]

(e) Use experiment 3 to calculate a numerical value for the rate constant, k .

$k =$ [1]

(f) The reaction $2\text{ICl(g)} + \text{H}_2\text{(g)} \rightarrow 2\text{HCl(g)} + \text{I}_2\text{(g)}$ is first order with respect to ICl(g) and first order with respect to $\text{H}_2\text{(g)}$.

Suggest a mechanism for this reaction. You should assume

- the mechanism has two steps,
- the first step is much slower than the second step.

first step \rightarrow

second step \rightarrow [2]

(g) An alternative method is used to show that the reaction is first order with respect to $\text{H}_2\text{(g)}$. This method uses a large excess of ICl(g) and measures how the concentration of $\text{H}_2\text{(g)}$ varies with time.

(i) Describe two ways of using these results to show the reaction is first order with respect to $\text{H}_2\text{(g)}$ concentration.

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

(ii) Explain the reason for using a large excess of ICl(g) .

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

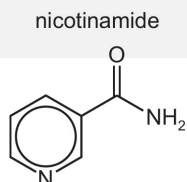
(h) A chemical reaction may be speeded up by the presence of a catalyst.

Explain why a catalyst increases the rate of a chemical reaction.

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

[Total: 12]

The structure of nicotinamide is shown.



(a) The nitrogen atom in the six-membered ring has one electron in an unhybridised p-orbital. This electron becomes delocalised, becoming part of a single delocalised system of electrons. This delocalised system also includes:

- electrons from the carbon atoms in the six-membered ring
- the two electrons in the π bond of the C=O group
- the two electrons in the lone pair on the nitrogen atom of the amide group.

(i) State the number of delocalised electrons in one nicotinamide molecule.

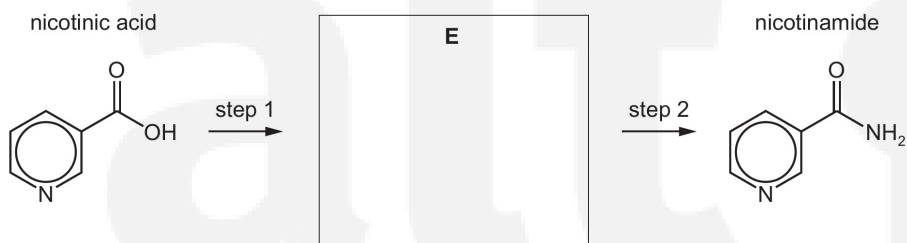
..... [1]

(ii) Predict the H–N–H bond angle in the NH_2 group in nicotinamide.

..... [1]

(b) Nicotinamide can be synthesised from nicotinic acid.

The synthesis involves two steps.



(i) Draw the structural formula of E in the box.

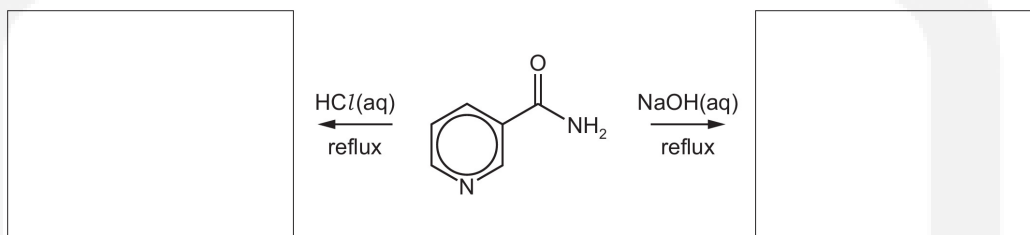
[1]

(ii) Give the name or formula of a suitable reagent for step 2.

..... [1]

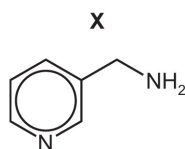
- (c) Nicotinamide reacts separately with aqueous acid and aqueous alkali. The six-membered ring remains unchanged in these reactions.

Complete the reaction scheme below to give the structural formula of the organic product of each reaction.



[2]

- (d) Nicotinamide can be reduced to compound **X**.



- (i) Identify a suitable reducing agent for this reaction.

..... [1]

- (ii) Predict and explain the relative basicities of the NH_2 groups in phenylamine, $\text{C}_6\text{H}_5\text{NH}_2$, nicotinamide and compound **X**.

.....

 [3]

- (e) The height of the M peak in a mass spectrum of nicotinamide is 80.

Calculate the expected height of the M+1 peak.

[2]

[Total: 12]

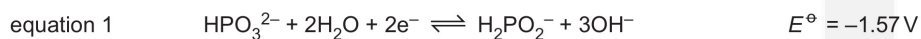
Hypophosphorous acid is an inorganic acid.

The conjugate base of hypophosphorous acid is H_2PO_2^- .

(a) Give the formula of hypophosphorous acid.

..... [1]

(b) H_2PO_2^- is a strong reducing agent. It can be used to reduce metal cations without the need for electrolysis.



(i) In an experiment, an alkaline $\text{HPO}_3^{2-}/\text{H}_2\text{PO}_2^-$ half-cell is constructed with $[\text{H}_2\text{PO}_2^-] = 0.050 \text{ mol dm}^{-3}$.

All other ions are at their standard concentration.

Predict how the value of E of this half-cell differs from its E^\ominus value.

Explain your answer.

.....

 [2]

(ii) The Cr^{3+}/Cr half-cell has a standard electrode potential of -0.74 V .

An electrochemical cell consists of an alkaline $\text{HPO}_3^{2-}/\text{H}_2\text{PO}_2^-$ half-cell and a Cr^{3+}/Cr half-cell.

Calculate the standard cell potential, E_{cell}^\ominus .

$E_{\text{cell}}^\ominus = \dots\dots\dots \text{ V}$ [1]

- (iii) Complete the diagram in Fig. 2.1 to show how the standard electrode potential of the Cr^{3+}/Cr half-cell can be measured relative to that of the standard hydrogen electrode.

Identify the chemicals, conditions and relevant pieces of apparatus.

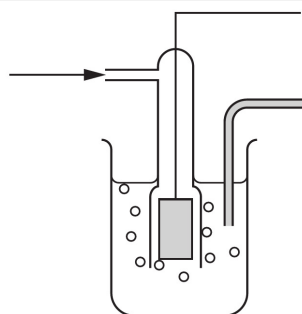


Fig. 2.1

[3]

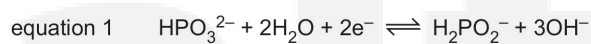
- (iv) Label Fig. 2.1 to show:

- which is the positive electrode
- the direction of electron flow in the external circuit.

[1]

- (v) H_2PO_2^- reduces Ni^{2+} to Ni in alkaline conditions.

Use equation 1 to construct the ionic equation for this reaction.

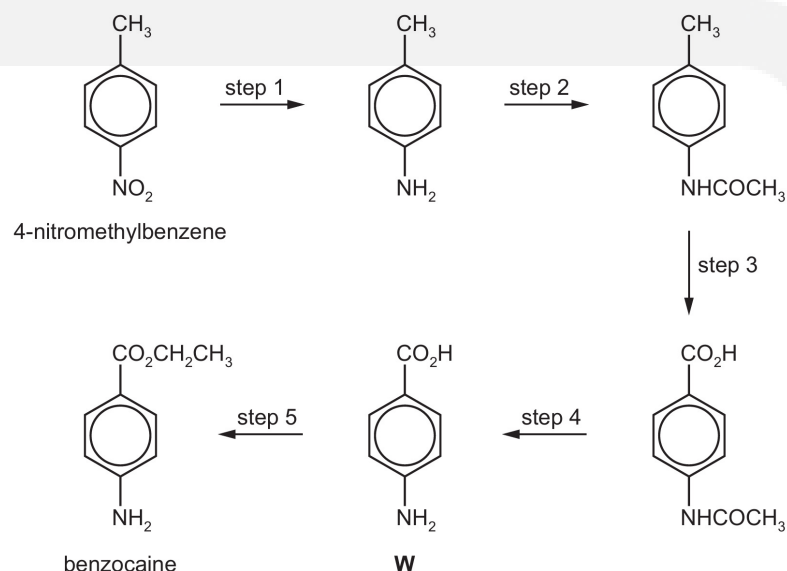


[1]

[Total: 9]

8 (a)

Benzocaine is used as a local anaesthetic. It can be synthesised from 4-nitromethylbenzene by the route shown.



(i) Give the systematic name of compound **W**.

..... [1]

(ii) Suggest the reagents and conditions for steps 1–5.

step 1
step 2
step 3
step 4
step 5 [6]

(b)

Suggest how the basicity of benzocaine would compare to that of ethylamine.
Explain your answer.

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

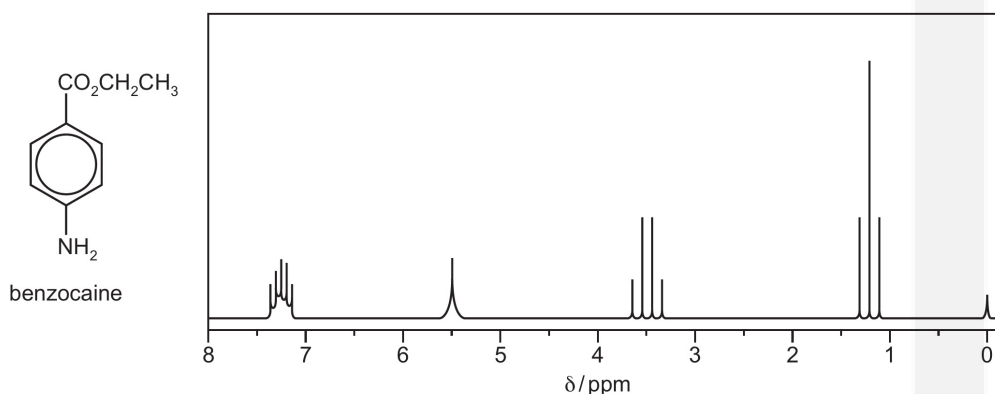
(c)

A sample of benzocaine, shown below, was analysed by proton NMR and carbon-13 NMR spectroscopy.

(i) Predict the number of peaks that would be seen in the carbon-13 NMR spectrum.

..... [1]

(ii) Benzocaine was dissolved in CDCl_3 and the proton NMR spectrum of this solution was recorded.



Suggest why CDCl_3 and not CHCl_3 is used as the solvent when obtaining a proton NMR spectrum.

..... [1]

(iii) Use the *Data Booklet* and the spectrum in (d)(ii) to complete the table for the proton NMR spectrum of benzocaine. The actual chemical shifts, δ , for the four absorptions have been added.

δ/ppm	group responsible for the peak	number of ^1H atoms responsible for the peak	splitting pattern
1.2			
3.5			
5.5			
7.1–7.4			multiplet

[4]

(iv) Explain the splitting pattern for the absorption at $\delta 1.2\text{ ppm}$.

..... [1]

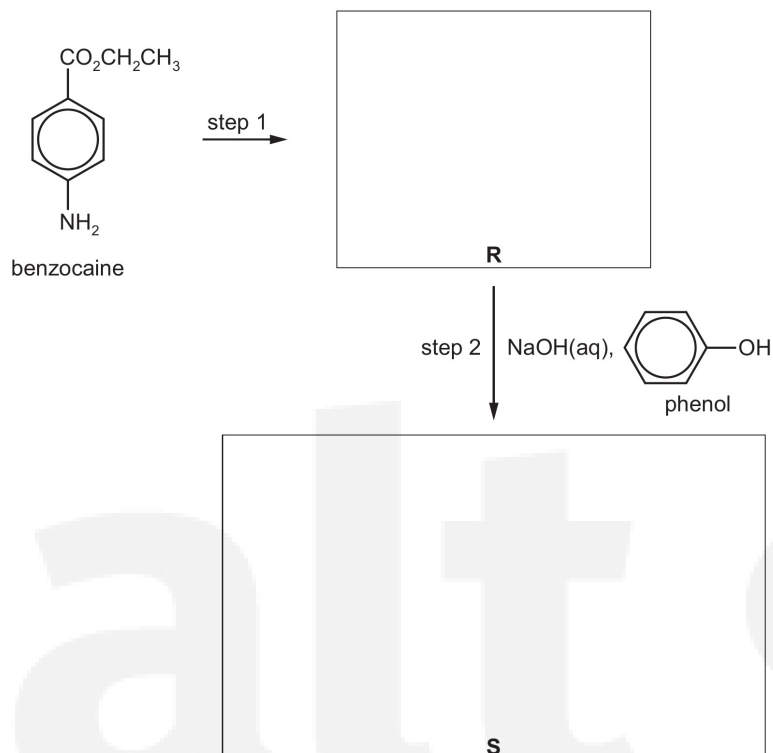
(v) The proton NMR spectrum of benzocaine dissolved in D₂O was recorded.

Suggest how this spectrum would differ from the spectrum in (d)(ii).
Explain your answer.

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

(d)

Benzocaine can also be used to synthesise the dyestuff **S** by the following route.



(i) Suggest the reagents used for step 1.

..... [1]

(ii) Suggest structures for compounds **R** and **S** and draw them in the boxes. [2]

[Total: 25]



Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

alt

The Periodic Table of Elements

Group																							
1	2													13	14	15	16	17	18				
		<div>1 H hydrogen 1.0</div>																					
		<div>Key</div>																					
		<div>atomic number atomic symbol name relative atomic mass</div>																					
3 Li lithium 6.9	4 Be beryllium 9.0																	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3																	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8						
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3						
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —					
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —					

lanthanoids		57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids		89 Ac actinium —	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —