

**RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION**

Higher 2



CHEMISTRY

Paper 1 Multiple Choice

9729/01

22 September 2022

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write in soft pencil.

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

Write your name, class and index number in the spaces provided on the Answer Sheet.

There are **thirty** questions in this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in the question booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of 14 printed pages.

- 1 *Use of the Data Booklet is relevant to this question.*

Which statement is correct?

- A 2 mol of $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2$ has the same number of ions as 4 mol of $\text{K}_2\text{Cr}_2\text{O}_7$.
- B 46 g of nitrogen dioxide gas contains the same number of molecules as 14 g of nitrogen gas.
- C The number of electrons in 1 mol of nitrogen gas is the same as that in 1 mol of carbon monoxide gas.
- D The number of atoms in a 5 dm^3 sample of oxygen gas is half that of a 10 dm^3 sample of argon gas at the same temperature and pressure.

- 2 *Use of the Data Booklet is relevant to this question.*

Bronze is an alloy of copper and tin. The following information is obtained for a sample of bronze.

mass number	63	65	118
% composition	d	$88 - d$	12

Naturally occurring copper contains only two isotopes, ^{63}Cu and ^{65}Cu .

Given the ratio of ^{63}Cu and ^{65}Cu in naturally occurring copper is the same as that in bronze, what is the value of d?

- A 22 B 25 C 66 D 75

- 3 *Use of the Data Booklet is relevant to this question.*

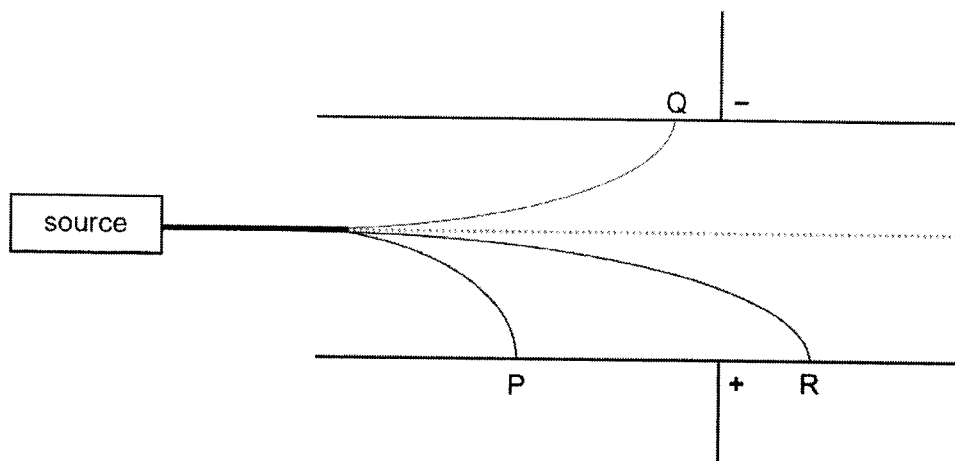
Which statements regarding the ions $^{30}\text{Si}^{4+}$, $^{31}\text{P}^{3-}$ and $^{32}\text{S}^{2-}$ are correct?

- They contain the same number of neutrons.
- They have the same electronic configuration.
- Their ionic radii increase in the order $^{30}\text{Si}^{4+} < ^{31}\text{P}^{3-} < ^{32}\text{S}^{2-}$.

- A 1 only
- B 1 and 2
- C 1 and 3
- D 2 and 3

- 4 A beam containing a mixture of three ions, P, Q and R, approaches an electric field with oppositely charged plates at the same velocity.

The identities of the three ions could be $^{11}\text{C}^{3+}$, $^{15}\text{O}^{2+}$, $^7\text{Li}^{2-}$ and $^{15}\text{N}^{4-}$.



Which ion is Q?

- A $^{11}\text{C}^{3+}$ B $^{15}\text{O}^{2+}$ C $^7\text{Li}^{2-}$ D $^{15}\text{N}^{4-}$
- 5 Use of the Data Booklet is relevant to this question.

The first four ionisation energies, IE, of four Period 5 elements, indium, tin, antimony and tellurium are shown in the table below.

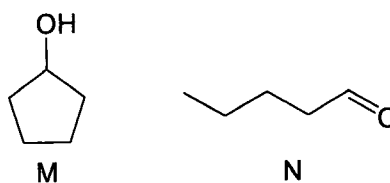
Which element is indium?

	first IE / kJ mol^{-1}	second IE / kJ mol^{-1}	third IE / kJ mol^{-1}	fourth IE / kJ mol^{-1}
A	558	1830	2704	5210
B	709	1411	2943	3930
C	834	1594	2440	4260
D	869	1790	2698	3610

- 6 In which row does G have a smaller overall dipole moment than H?

	G	H
A	COS	CS ₂
B	PCl ₃	PF ₃
C	IF	BrCl
D	XeF ₄	PCl ₅

- 7 The structures of M and N are as shown.



Which statements are correct?

- 1 M has a lower volatility than N.
- 2 M and N are constitutional isomers.
- 3 M and N have the same number of σ bonds.

A 2 only

B 1 and 2

C 1 and 3

D 2 and 3

- 8 Which compound has the greatest covalent character?

- A** MgO
- B** MgS
- C** CaO
- D** CaS

- 9 A 1 m^3 vessel containing 20 kPa of helium was connected to a 2 m^3 vessel containing 10 kPa of neon and the gases were allowed to mix at a constant temperature.

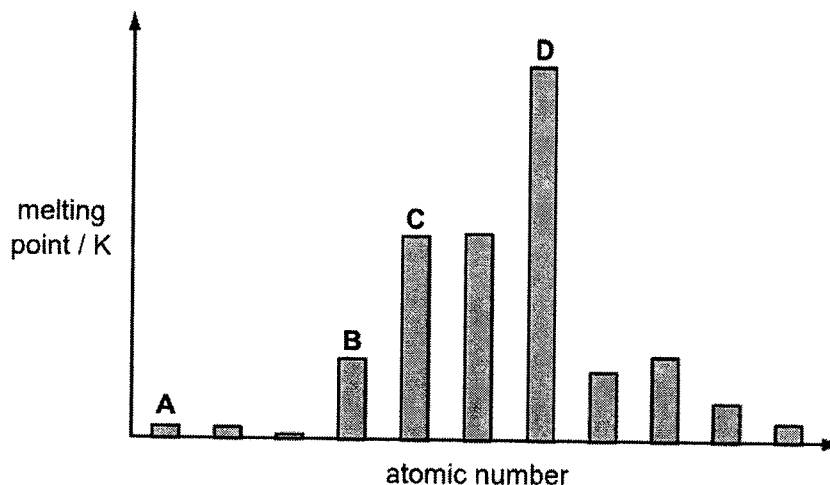
The two vessels were then cooled, and the temperature of the system decreased. The partial pressures of helium and neon were measured to be U kPa and V kPa respectively.

What could be the values of U and V ?

	U	V
A	10	5
B	7.5	7.5
C	8	4
D	6	6

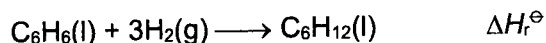
- 10 The bar chart shows the melting points of a series of consecutive elements arranged in order of increasing atomic number. The elements sodium to chlorine form part of this series.

Which bar represents sodium?



- 11 Which statement about the element astatine is correct?
- A** Silver astatide is insoluble in aqueous ammonia.
 - B** Astatine is a liquid at room temperature and pressure.
 - C** The bond energy of hydrogen astatide is larger than that of hydrogen iodide.
 - D** Astatine is not a product of the reaction between sodium astatide and bromine.

- 12 Cyclohexane, C_6H_{12} , is prepared industrially by the hydrogenation of benzene as shown in the equation below.



Using the data in the table, what is the standard enthalpy change, ΔH_r^\ominus , of this reaction?

compound	standard enthalpy change of combustion / kJ mol^{-1}
$C_6H_6(l)$	-3268
$H_2(g)$	-286
$C_6H_{12}(l)$	-3754

- A -372 kJ mol^{-1} B -200 kJ mol^{-1} C $+200 \text{ kJ mol}^{-1}$ D $+372 \text{ kJ mol}^{-1}$
- 13 Which equation represents the standard enthalpy change stated?

	standard enthalpy change of	equation
A	atomisation of $Cl_2(g)$	$Cl_2(g) \longrightarrow 2Cl(g)$
B	combustion of $H_2S(g)$	$H_2S(g) + O_2(g) \longrightarrow H_2(g) + SO_2(g)$
C	formation of $H_2SO_4(l)$	$2H(g) + 4O(g) + S(s) \longrightarrow H_2SO_4(l)$
D	solution of $K_2SO_4(s)$	$K_2SO_4(s) \longrightarrow 2K^+(aq) + SO_4^{2-}(aq)$

- 14 The kinetics of the following reaction is investigated, and the experimental data is given in the table below.

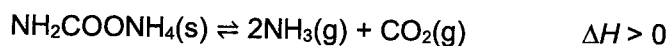


$[R] / \text{mol dm}^{-3}$	$[S] / \text{mol dm}^{-3}$	initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
0.015	0.010	5.10×10^{-4}
0.030	0.020	4.08×10^{-3}
0.045	0.010	1.53×10^{-3}

What is the numerical value of the rate constant for this reaction?

- A 0.00294 B 3.40 C 227 D 340

- 15 Ammonium carbamate, $\text{NH}_2\text{COONH}_4$, undergoes thermal decomposition.



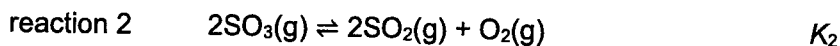
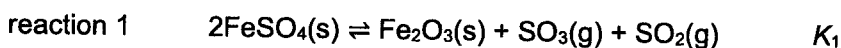
A vessel containing only $\text{NH}_2\text{COONH}_4$ is heated to 250°C . The reaction reached equilibrium at time t_1 . Subsequently both the temperature and volume of the vessel are decreased, and the reaction established a new equilibrium at time t_2 .

Which statements are correct?

- 1 At t_2 , $P_{\text{NH}_3} : P_{\text{CO}_2}$ is 2 : 1.
- 2 The rate of the forward reaction at t_1 is the same as that at t_2 .
- 3 The degree of decomposition of $\text{NH}_2\text{COONH}_4$ at t_1 is smaller than that at t_2 .
- 4 Decreasing the volume of the vessel at constant temperature has no effect on the equilibrium partial pressures of NH_3 and CO_2 .

- A 2 only B 1 and 3 C 1 and 4 D 2 and 3

- 16 When a sample of iron(II) sulfate, FeSO_4 , is heated to 920 K, reactions 1 and 2 occurred.



At equilibrium, the total pressure is 0.836 atm and the partial pressure of oxygen is 0.0275 atm.

What is the value of K_2 at 920 K?

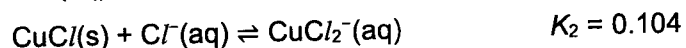
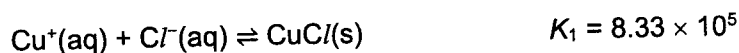
- A 0.000147 B 0.0362 C 0.0476 D 0.160
- 17 The K_a of lactic acid is $1.4 \times 10^{-4} \text{ mol dm}^{-3}$ at 298 K.

A buffer solution contains 1.5 mol dm^{-3} lactic acid and 0.5 mol dm^{-3} sodium lactate.

Which statement correctly describes the buffer solution?

- A The pH of the buffer solution is 4.33.
- B The pH of the buffer solution decreases upon dilution with water.
- C The buffering capacity of the buffer solution increases upon dilution with water.
- D The buffer solution has a greater buffering capacity against a base compared to an acid.

- 18 Some equilibria, and the value of their equilibrium constants at 298 K, are given below.

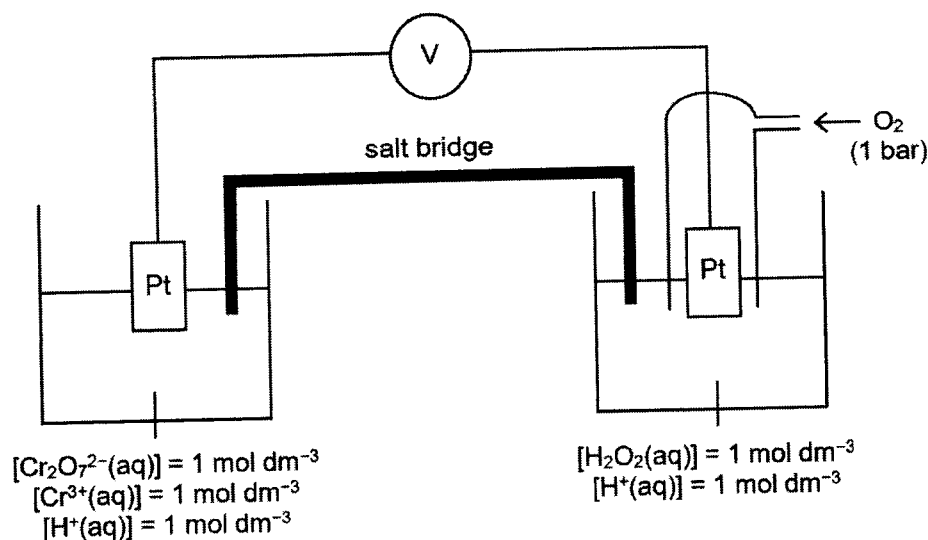


Which row is correct?

	z	value of solubility product of CuCl(s) at 298 K
A	8.66×10^4	1.10×10^{-3}
B	8.66×10^4	1.20×10^{-6}
C	8.01×10^6	1.10×10^{-3}
D	8.01×10^6	1.20×10^{-6}

- 19 Use of the Data Booklet is relevant to this question.

An electrochemical cell is set up under standard conditions as shown below.

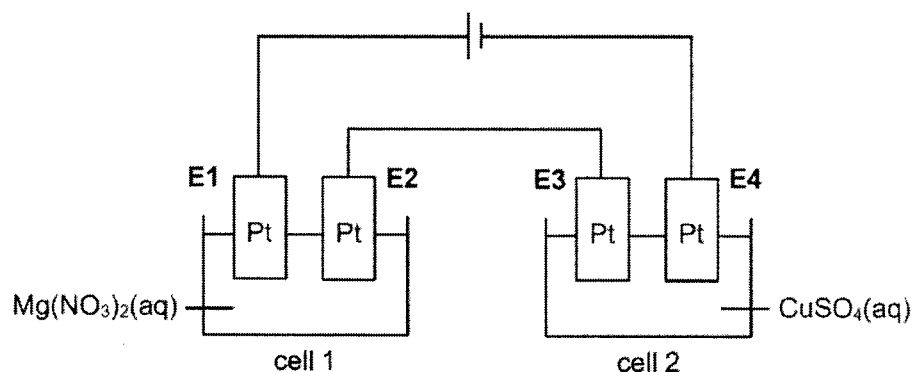


Which change would result in an increase in cell potential?

- A Addition of water to the $\text{O}_2/\text{H}_2\text{O}_2$ half-cell.
- B Addition of $\text{KI}(\text{s})$ to the $\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}$ half-cell.
- C Using $\text{O}_2(\text{g})$ of 1 atm pressure in the $\text{O}_2/\text{H}_2\text{O}_2$ half-cell.
- D Using $2 \text{ mol dm}^{-3} \text{ Cr}^{3+}(\text{aq})$ in the $\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}$ half-cell.

20 Use of the Data Booklet is relevant to this question.

Cell 1 and cell 2 are connected in series as shown in the diagram below.



E1, E2, E3 and E4 are platinum electrodes.

After a current of 5 A is passed through the two cells for time t , the increase in mass of electrode E4 is found to be 0.635 g.

Which statement is correct?

- A t is 3.22 min.
- B A white precipitate is formed around E2.
- C Effervescence is observed only at E1 and E3.
- D The colour intensity of the solution in cell 2 remains unchanged.

21 Use of the Data Booklet is relevant to this question.

The table below shows some vanadium-containing ions and their colours.

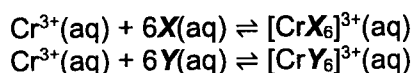
species	VO_2^+	VO^{2+}	V^{3+}	V^{2+}
colour in aqueous solution	yellow	blue	green	violet

A metal is added in excess to an aqueous solution containing VO_2^+ . The resultant solution is violet in colour.

What is the identity of this metal?

- A magnesium
- B silver
- C tin
- D zinc

22 When mixed with $\text{Cr}^{3+}(\text{aq})$, ligands **X** and **Y** form complexes with Cr^{3+} as shown below.

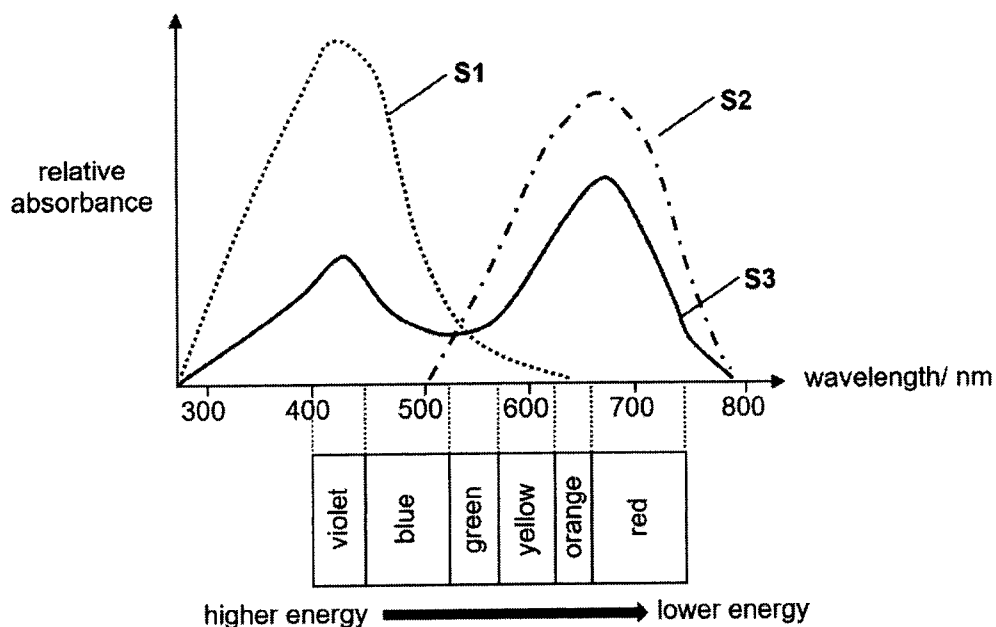


As the equilibrium constants for the above two reactions are large, $[\text{Cr}^{3+}(\text{aq})]$ is very low in the presence of these ligands.

Solutions **S1**, **S2** and **S3** are prepared by mixing aqueous solutions of Cr^{3+} , **X** and **Y** of equal concentrations. The table below shows the volumes of each solution used.

solution	volume of solution / cm^3		
	$\text{Cr}^{3+}(\text{aq})$	X (aq)	Y (aq)
S1	4	96	0
S2	4	0	96
S3	4	48	48

The absorption spectra of **S1**, **S2** and **S3** and the colours corresponding to the wavelengths of visible light are shown below.



The absorbance of a solution at a particular wavelength is proportional to the concentration of the species responsible for the absorbance.

Which of the following can be deduced from the information given above?

- $[\text{CrY}_6]^{3+}(\text{aq})$ is orange in colour.
- Cr^{3+} forms stronger bonds with **Y** than with **X**.
- The size of d-orbital splitting is larger in $[\text{CrX}_6]^{3+}$.

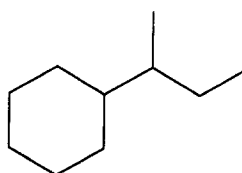
A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

- 23 The molecular formula for compound A is $C_{11}H_{14}O$. The structure of A includes an aldehyde group, a cyclohexene ring and a straight chain.

How many π bonds does A have?

- A 2 B 3 C 4 D 5

- 24 Compound B ($C_{10}H_{20}$) is reacted with limited chlorine gas in the presence of ultra-violet light.



B

Assuming that only mono-chlorination takes place, which statements are correct?

- 1 Homolytic fission occurs in both initiation and propagation steps.
- 2 A total of eight possible mono-chlorinated products, ignoring stereoisomers, can be formed.
- 3 A compound with the formula $C_{20}H_{38}$ is found in small quantities in the mixture of products.

- A 2 only B 3 only C 1 and 3 only D 1, 2 and 3

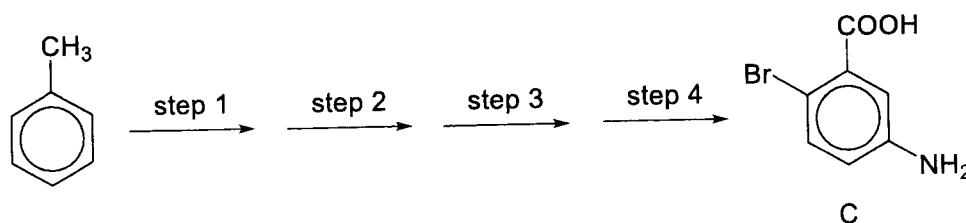
- 25 A catalytic converter is part of the exhaust system in modern cars.

Which reactions occur in the catalytic converter?

- 1 carbon monoxide + oxygen \longrightarrow carbon dioxide
- 2 nitrogen dioxide + carbon monoxide \longrightarrow carbon dioxide + nitrogen
- 3 hydrocarbons + oxygen \longrightarrow carbon dioxide + water
- 4 hydrocarbons + carbon monoxide \longrightarrow carbon dioxide + water

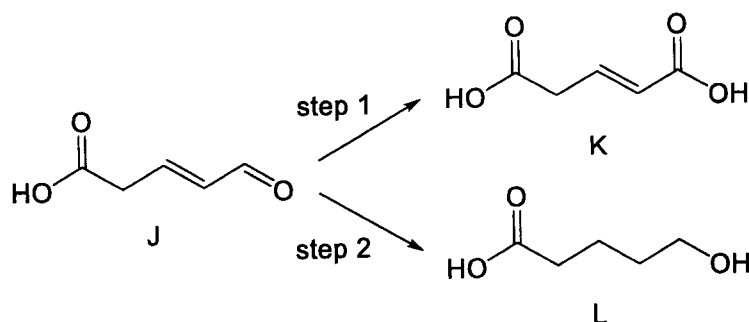
- A 1 and 3 B 2 and 4 C 1, 2 and 3 D 1, 3 and 4

- 26 Which sequence of reactions would give the highest yield of compound C from methylbenzene?



	step 1	step 2	step 3	step 4
A	KMnO ₄ , H ₂ SO ₄ , heat	conc. HNO ₃ , conc. H ₂ SO ₄ , heat	Br ₂ , Fe	Sn, conc. HCl, heat, followed by NaOH
B	KMnO ₄ , H ₂ SO ₄ , heat	conc. HNO ₃ , conc. H ₂ SO ₄ , heat	Sn, conc. HCl, heat, followed by NaOH	Br ₂ , Fe
C	Br ₂ , Fe	conc. HNO ₃ , conc. H ₂ SO ₄ , heat	Sn, conc. HCl, heat, followed by NaOH	KMnO ₄ , H ₂ SO ₄ , heat
D	Br ₂ , Fe	KMnO ₄ , H ₂ SO ₄ , heat	conc. HNO ₃ , conc. H ₂ SO ₄ , heat	Sn, conc. HCl, heat, followed by NaOH

- 27 Compound J can be converted to compounds K and L as shown.



What could be the reagents and conditions for steps 1 and 2?

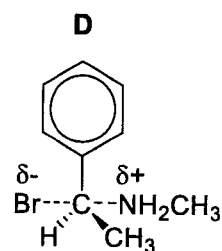
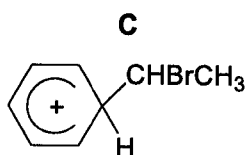
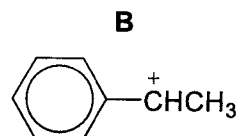
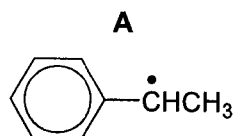
	step 1	step 2
A	K ₂ Cr ₂ O ₇ , H ₂ SO ₄ , heat	NaBH ₄
B	K ₂ Cr ₂ O ₇ , H ₂ SO ₄ , heat	H ₂ , Ni, heat
C	KMnO ₄ , H ₂ SO ₄ , heat	NaBH ₄
D	KMnO ₄ , H ₂ SO ₄ , heat	H ₂ , Ni, heat

- 28 (1-Bromoethyl)benzene reacts with excess concentrated methylamine as shown below.



The rate of reaction is independent of the concentration of CH_3NH_2 .

Which species could be formed during this reaction?



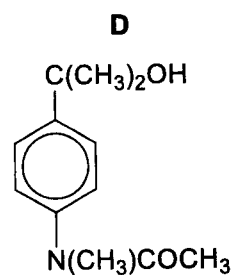
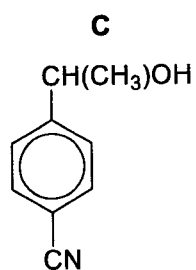
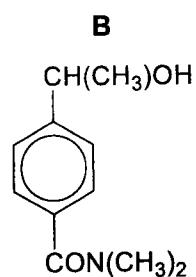
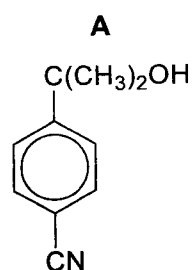
- 29 Which row correctly shows the reagent that can be used to distinguish between compounds 1 and 2?

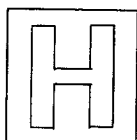
	compound 1	compound 2	reagent added
A	$\text{CH}_3\text{CH}_2\text{NH}_3^+\text{Cl}^-$	$(\text{CH}_3\text{CH}_2)_4\text{N}^+\text{Cl}^-$	hot aqueous NaOH
B			Fehling's solution
C		$\text{CH}_3\text{CH}_2\text{OH}$	aqueous Na_2CO_3
D			hot ethanolic AgNO_3

30 Compound W is tested with various reagents and gives the following results.

- W does not form a yellow precipitate with hot alkaline aqueous I_2 .
- When W is treated with $LiAlH_4$ in dry ether, it forms a product that reacts with ethanoyl chloride in a 1:1 molar ratio.

What could W be?





**RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION**

Higher 2



CANDIDATE
NAME

CLASS

INDEX NUMBER

CHEMISTRY

9729/02

Paper 2 Structured Questions

14 September 2022

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided. Do not write anything in it.

You are reminded of the need for good English and clear presentation in your answers.

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	/ 19
2	/ 20
3	/ 19
4	/ 17
Total	/ 75

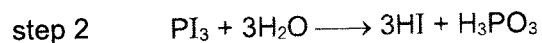
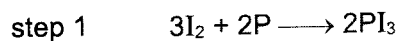
This document consists of **24** printed pages and **4** blank pages.

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

For
examiner's
use

1 This question is about the compounds of iodine and their reactions.

(a) Hydrogen iodide is a primary source of iodine in chemical reactions. It can be synthesised from iodine via the following two steps.



Given that 65 cm³ of HI gas is collected at standard temperature and pressure, calculate the mass of iodine reacted.

[2]

(b) (i) Explain the trend and variation in the boiling points of the hydrogen halides shown in the table below.

hydrogen halide	HF	HCl	HBr	HI
boiling point / °C	+20	-85	-67	-35

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..... [2]

- (ii) Describe and explain the trend in the thermal stability of HCl, HBr and HI.

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

*For
examiner's
use*

- (c) Iodate(V) ion, IO_3^- , is commonly used as an oxidising agent in chemical reactions.

- (i) Draw a 'dot-and-cross' diagram of IO_3^- .

[1]

- (ii) With reference to the Valence Shell Electron Pair Repulsion theory, state and explain the shape and bond angle about the iodine atom in IO_3^- .

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

Both iodate(V) and iodide ions can be obtained via the disproportionation of iodine under alkaline conditions.

- (iii) Using oxidation numbers, or otherwise, construct a balanced chemical equation for the disproportionation of iodine under alkaline conditions.

..... [1]

(d) IO_3^- can be converted to periodic acid, HIO_4 .

HIO_4 can be used to split alcohols with two adjacent hydroxy groups, such as glycol **A**.

Fig. 1.1 shows the splitting of glycol **A** by HIO_4 to form ethanal and butanone, via an intermediate **B**.

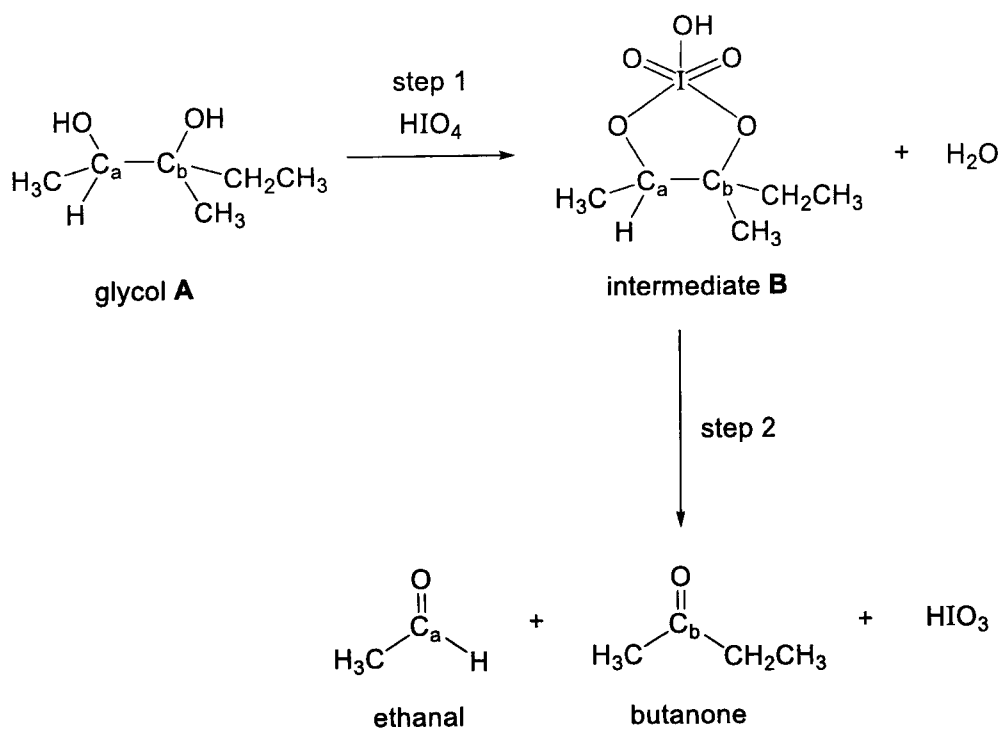


Fig. 1.1

- (i) On intermediate **B** in Fig. 1.1, draw three curly arrows to indicate the movement of electron pairs for step 2. [1]
- (ii) By considering the hybridisation of the atoms, compare the $\text{C}_a\text{-H}$ bond strength in glycol **A** and in ethanal. Explain your answer.

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..... [2]

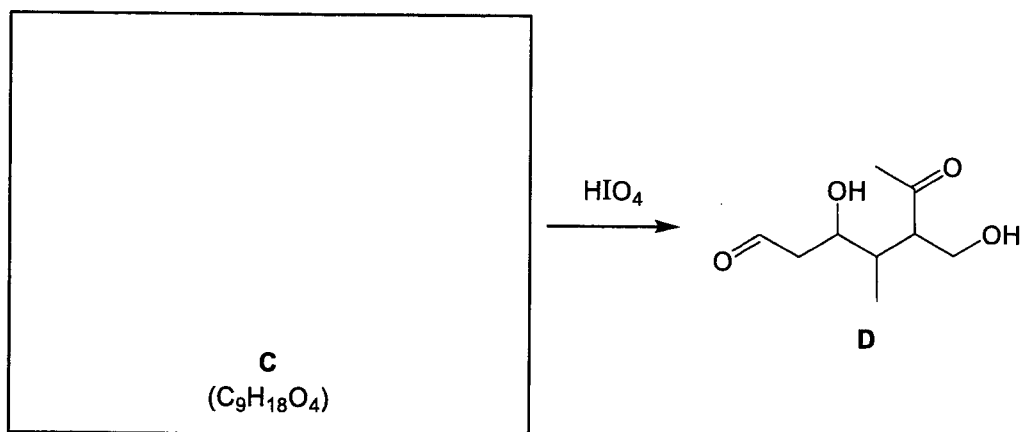
- (iii) Draw a labelled diagram to show all the valence orbitals of C_a and O in ethanal and how they overlap to form the $C_a=O$ bond.

For
examiner's
use

Assume that the O atom in ethanal is sp^2 hybridised.

[2]

- (iv) Compound **C** reacts with HIO_4 to form compound **D** as shown below.



Draw the skeletal formula of compound **C** in the box provided.

[1]

- (v) Butanone reacts with HCN in the presence of trace amount of KOH.

Describe the mechanism for this reaction, showing all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows.

*For
examiner's
use*

[3]

[Total: 19]

2 Nitrogen dioxide, NO_2 , is a highly reactive gas due to the presence of an unpaired electron on the nitrogen atom.

*For
examiner's
use*

(a) (i) State three basic assumptions of the kinetic theory as applied to an ideal gas.

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..... [2]

(ii) Fig. 2.1 shows how $\frac{pV}{T}$ varies with pressure for 1 mol of ideal gas and 1 mol of NO_2 at T_1 K.

On Fig. 2.1, sketch a graph to show how $\frac{pV}{T}$ varies with pressure for 1 mol of NO_2 at a higher temperature of T_2 K. Label your graph as (a)(ii) and explain your answer.

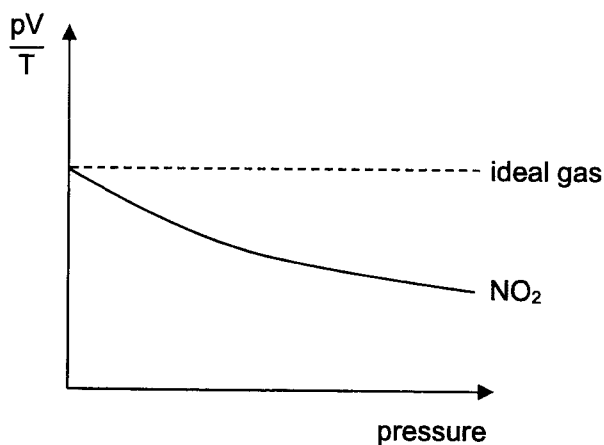


Fig. 2.1

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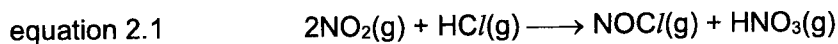
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..... [2]

- (b) Nitrogen dioxide undergoes the following gas phase reaction with hydrogen chloride, as shown in equation 2.1.

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examiner's
use



To study the kinetics for this reaction, three separate experiments were carried out in a vessel of fixed volume at a constant temperature of 500 K. The initial concentrations of NO_2 and HCl are shown in Table 2.1.

Table 2.1

experiment	initial $[\text{NO}_2]$ / mol dm^{-3}	initial $[\text{HCl}]$ / mol dm^{-3}
1	1.00	0.05
2	0.50	0.05
3	0.50	0.01

To monitor the progress of the reaction for each experiment, the total pressure in the vessel was measured at regular time intervals and the corresponding concentrations of NOCl were calculated.

Fig. 2.2 shows how the concentration of NOCl varies with time for experiments 1 and 2.

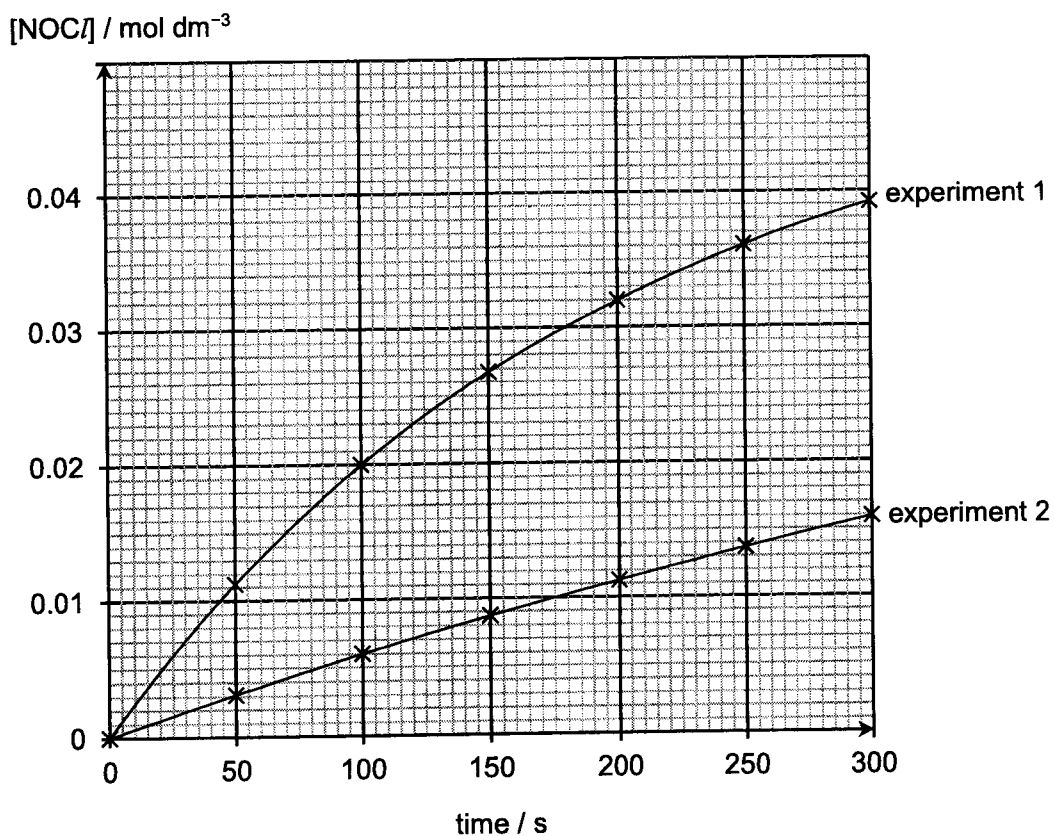


Fig. 2.2

- (i) With reference to Fig. 2.2, calculate the mole fraction of NOCl present in the vessel for experiment 1 at $t = 200$ s.

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use*

[2]

- (ii) Calculate the total pressure, in Pa, in the vessel for experiment 1 at $t = 200$ s.
You may assume that all the gases behave ideally.

[2]

- (iii) Using Fig. 2.2, determine the initial rate of reaction for experiments 1 and 2.
Hence, deduce the order of reaction with respect to NO_2 .

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use

[2]

- (iv) State the final concentration of NOCl in the vessel for experiment 1 if the reaction were to proceed to completion.

..... [1]

- (v) Hence, determine the order of reaction with respect to HCl .
Show your working, including construction lines on Fig. 2.2.

[1]

(vi) The half-life of the reaction in experiment 2 was found to be 540 s.

With reference to Table 2.1, suggest how the half-life of the reaction in experiment 3 will compare to that of experiment 2. Explain your answer.

For
examiner's
use

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..... [2]

(c) N_2O_4 can undergo dissociation to form NO_2 , which then reacts with ethene to form 1,2-dinitroethane. The reaction mechanism consists of three steps as shown in Fig. 2.3.

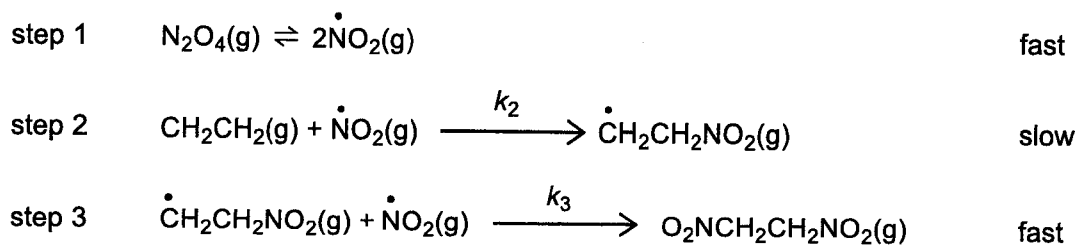


Fig. 2.3

(i) Write an overall equation for the reaction.

..... [1]

(ii) Name the type of reaction occurring in (c)(i).

..... [1]

- (iii) The dissociation of N_2O_4 in step 1 of the mechanism rapidly reaches equilibrium due to the use of solid platinum which acts as a heterogeneous catalyst.

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examiner's
use

Outline the mode of action of the platinum catalyst in the dissociation of N_2O_4 .

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

- (iv) The equilibrium constant for step 1 of the mechanism is K_c .

Write an expression for $[NO_2]$ in terms of K_c .

[1]

- (v) Using your answer in (c)(iv) and the mechanism in Fig. 2.3, write the overall rate equation for the reaction.

[1]

[Total: 20]

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- 3 COVID-19 is an illness caused by the virus SARS-CoV-2, which was first identified amid an outbreak of respiratory illness cases in 2019.

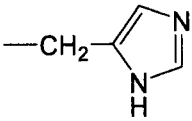
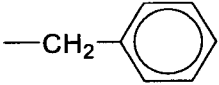
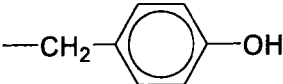
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In November 2021, a new Omicron variant was found to be the most transmissible variant compared to the previous variants, such as the Delta variant.

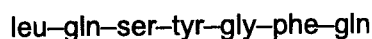
- (a) The differences in the transmissibility of the variants are due to their varying amino acid sequences in a specific region X of their peptide chains.

Some of the amino acids present in the variants are listed in Table 3.1.

Table 3.1

name	abbreviation	formula of side chain (R in R-CH(NH ₂)CO ₂ H)
arginine	arg	
glutamine	gln	-CH ₂ CH ₂ CONH ₂
glutamic acid	glu	-CH ₂ CH ₂ COOH
glycine	gly	-H
leucine	leu	-CH ₂ CH(CH ₃) ₂
phenylalanine	phe	
serine	ser	-CH ₂ OH
tyrosine	tyr	

A heptapeptide found in region X of the Delta variant has the sequence shown below.



The heptapeptide was partially hydrolysed by heating with a concentrated solution of sodium hydroxide. The partial hydrolysis produced a mixture of dipeptides.

- (i) Upon acidification of the dipeptides, leu-glu and phe-glu were obtained instead of leu-gln and phe-gln.

By referring to Table 3.1, suggest why this is so.

.....
 [1]

- (ii) Ser-tyr was also one of the dipeptides formed.
Draw the structure of this dipeptide at pH 13.

*For
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use*

[1]

Another heptapeptide found in region X of the Omicron variant was also subjected to hydrolysis under the same conditions.

The initial partial hydrolysis of this heptapeptide produced the tetrapeptides shown below.

tyr-ser-phe-arg, arg-ser-tyr-ser, leu-arg-ser-tyr

- (iii) Deduce the sequence of amino acids in this heptapeptide.

..... [1]

Increasing evidence suggests that gut health may be compromised in COVID-19 patients. One indicator of bad gut health is high levels of trimethylamine.

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examiner's
use

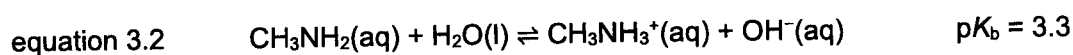
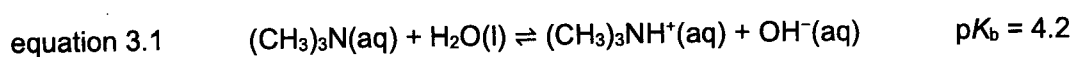
Both trimethylamine, $(\text{CH}_3)_3\text{N}$, and methylamine, CH_3NH_2 , behave as bases in the gaseous and aqueous phases.

(b) (i) Explain why, in the gaseous phase, $(\text{CH}_3)_3\text{N}$ is a stronger base than CH_3NH_2 .

.....

 [1]

In aqueous solution, the following equilibria are established.



(ii) State the predominant interaction, other than hydrogen bonding, between $(\text{CH}_3)_3\text{NH}^+$ and water.

..... [1]

(iii) Compared to $(\text{CH}_3)_3\text{NH}^+$, CH_3NH_3^+ has a stronger interaction with water.

With reference to your answer in (b)(ii), explain why this is so.

.....

 [1]

(iv) Hence, suggest why the pK_b of CH_3NH_2 is lower than that of $(\text{CH}_3)_3\text{N}$ in an aqueous solution.

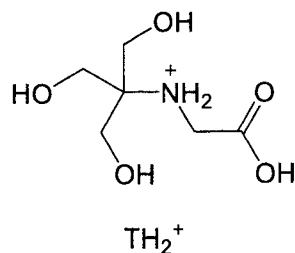
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 [1]

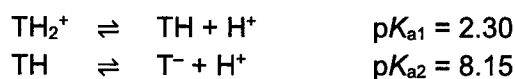
Antigen-based rapid diagnostic test kits have been used to detect the SARS-CoV-2 virus.

(c) The test kit includes a vial containing a buffer solution prepared from tricine, TH.

The structure of protonated tricine, TH_2^+ , is shown below.



The acid dissociation involving TH_2^+ and TH and their corresponding pK_a values at 25 °C are shown below.



(i) TH exists as a solid at room temperature.

Draw the structure of TH and explain why it has a high melting point.

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..... [2]

For
examiner's
use

The buffer solution is prepared by dissolving 0.1 mol of solid tricine, TH, in 1.0 dm³ of aqueous sodium hydroxide. The pH of this buffer is 8.78.

For
examiner's
use

- (ii) Calculate the concentration of aqueous sodium hydroxide used in the preparation of this buffer solution.

[2]

- (iii) Explain how a more dilute buffer solution of the same volume will compare in terms of buffering capacity.

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..... [1]

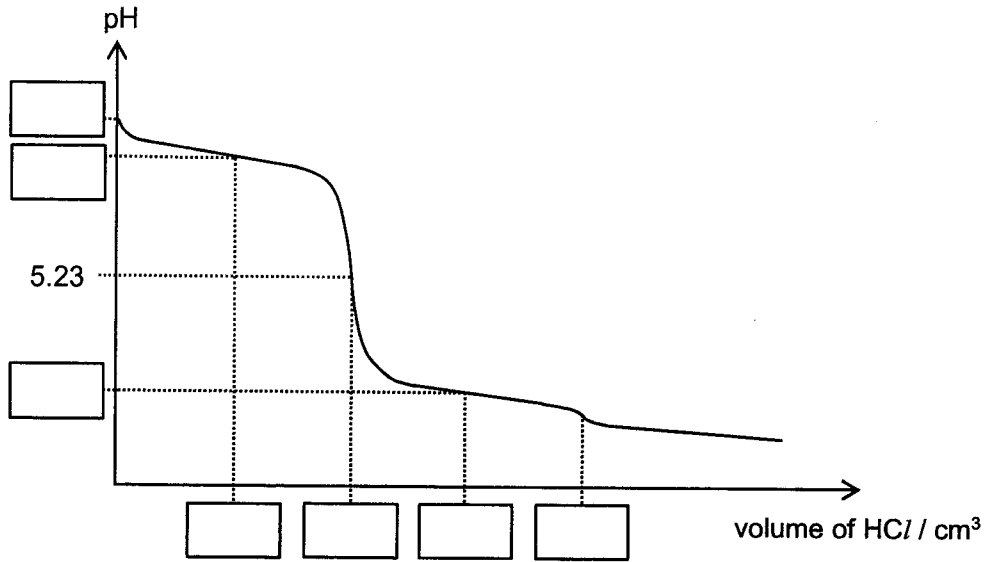
- (d) 10 cm³ of 0.1 mol dm⁻³ of the deprotonated tricine, T⁻, was titrated against 0.1 mol dm⁻³ of HCl from a burette.

- (i) Calculate the pH of 0.1 mol dm⁻³ of T⁻ solution at 25 °C.

[2]

- (ii) Using your answer in (d)(i) and information in (c), fill in the boxes below with the correct pH values and HCl volumes.

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examiner's
use



[2]

- (iii) Methyl red is used as the indicator for determining the first end-point for this titration. It changes colour from red at pH 4.4 to yellow at pH 6.2.

Explain why methyl red is suitable for determining the first end-point.

Hence, state the colour change at the first end-point of the titration.

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..... [2]

- (iv) Suggest why the second end-point cannot be determined by titration.

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

[Total: 19]

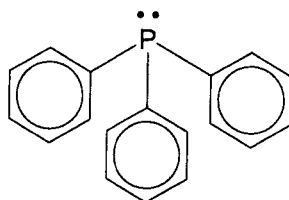
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- 4 Nickel, copper and their compounds have many uses such as coinage metals, electrical components and catalysts.

For
examiner's
use

- (a) Nickel forms complexes readily, one of which has the formula $\text{NiCl}_2(\text{PPh}_3)_2$.

The structure of triphenylphosphine, PPh_3 , is shown below.



PPh_3

There are two main isomers of $\text{NiCl}_2(\text{PPh}_3)_2$ which co-exist in equilibrium as shown in equation 4.1.

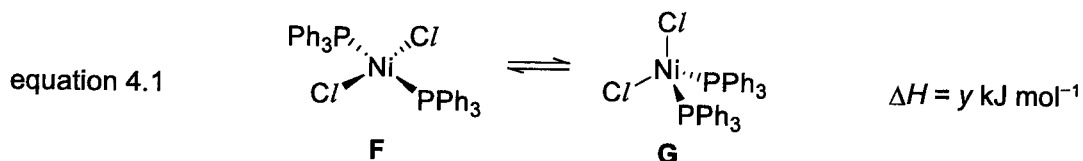


Table 4.1 gives some information about isomers **F** and **G**.

Table 4.1

isomer	F	G
geometry	square planar	tetrahedral
colour	red	blue

- (i) The proportion of **G** to **F** increases with temperature.

Deduce whether y in equation 4.1 has a positive or negative value.

.....

.....

.....

..... [1]

Nickel has an oxidation state of +2 in $\text{NiCl}_2(\text{PPh}_3)_2$.

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examiner's
use

(ii) State the electronic configuration of a Ni^{2+} ion.

..... [1]

The five 3d orbitals in Ni^{2+} are split differently in complexes with square planar and tetrahedral geometries as shown in Fig. 4.1.

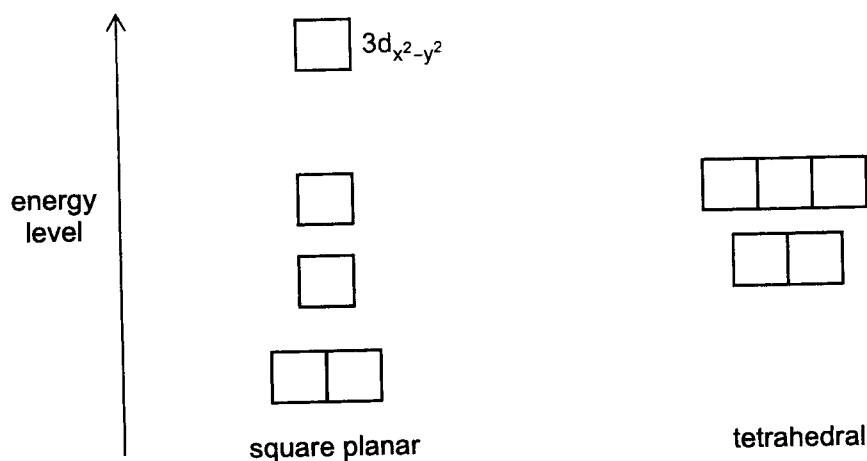
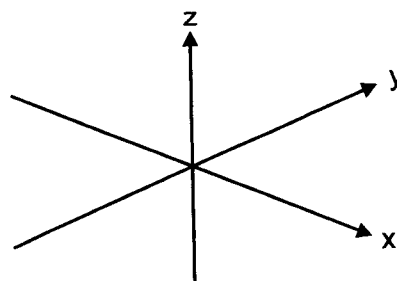


Fig. 4.1

(iii) The $3d_{x^2-y^2}$ orbital in a complex with square planar geometry has the highest energy level among the five 3d orbitals, as shown in Fig. 4.1.

Draw the $3d_{x^2-y^2}$ orbital in the axes provided.

Explain why the $3d_{x^2-y^2}$ orbital in F has the highest energy level.



.....

 [2]

- (iv) A paramagnetic substance contains one or more unpaired electrons and is attracted to an external magnetic field.

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use

G is paramagnetic but **F** is not.

On Fig. 4.1, draw the distribution of the 3d electrons of Ni^{2+} ion in both the square planar and tetrahedral geometries. [2]

- (v) Explain why **F** and **G** have different colours.

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..... [2]

- (vi) Compound **H** is the *cis*-isomer of **F**.

Draw the structure of **H**.

Hence, suggest why **G** converts to **F** rather than to **H** in the backward reaction of equation 4.1.

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..... [2]

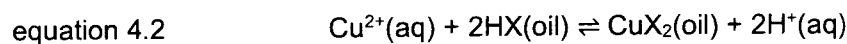
- (b) Mine water from copper mines contains appreciable quantities of Cu^{2+} ions from which valuable copper can be recovered.

For
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use

To separate Cu^{2+} ions from other impurities in a sample of mine water, an organic acid dissolved in oil, $\text{HX}(\text{oil})$, is mixed with the mine water.

HX reacts with Cu^{2+} to form a complex, CuX_2 , which is soluble in oil but not in water.

An equilibrium is established as shown in equation 4.2.



- (i) State a feature of ligand X^- which enables CuX_2 to be soluble in oil but not in water.

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

To determine the concentration of CuX_2 in oil, a calibration curve is first obtained by finding the absorbance of known concentrations of CuX_2 in oil, as shown in Fig. 4.2.

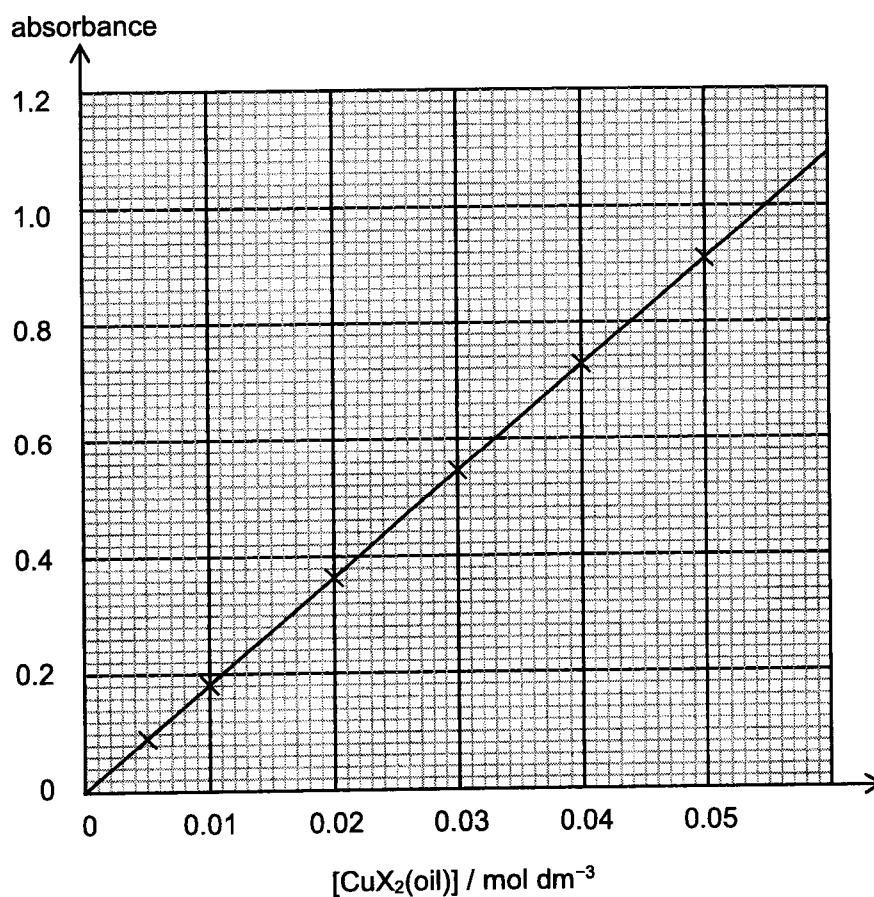


Fig. 4.2

A 1 dm³ solution of HX in oil is mixed with 2 dm³ mine water containing Cu²⁺ ions and allowed to reach equilibrium at pH 3 at 25 °C.

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use

- (ii) CuX₂(oil) formed at equilibrium is found to have an absorbance of 0.82.

Using Fig. 4.2, find the concentration of CuX₂(oil) at equilibrium.

[1]

The K_c expression for the reaction in equation 4.2 is shown below.

$$K_c = \frac{[\text{CuX}_2(\text{oil})] [\text{H}^+(\text{aq})]^2}{[\text{Cu}^{2+}(\text{aq})] [\text{HX}(\text{oil})]^2}$$

- (iii) At 25 °C, the value of K_c is 2.1×10^{-2} .

Given that [HX(oil)] in the equilibrium mixture is 0.20 mol dm⁻³ and using your answer in (b)(ii), calculate the concentration of copper(II) ions remaining in the mine water.

Hence, calculate the percentage of copper extracted from the mine water.

[2]

(iv) With reference to equation 4.2, suggest how Cu^{2+} can be released from the CuX_2 molecules in the oil solution back into aqueous solution.

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..... [1]

(c) Some copper ornaments are tarnished due to the formation of solid copper(II) sulfide, CuS .

The CuS tarnish can be removed by using metal polishes containing aqueous ammonia.

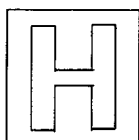
With the aid of equations, explain how the aqueous ammonia in the metal polish can remove the CuS tarnish.

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..... [2]

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**RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION**

Higher 2



CANDIDATE
NAME

CLASS

INDEX NUMBER

CHEMISTRY

9729/03

Paper 3 Free Response

16 September 2022

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A

Answer **all** questions.

Section B

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided. Do not write anything in it.

You are reminded of the need for good English and clear presentation in your answers.

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				
Section A		Section B		Total
1	/ 17	(Circle the question you have answered)		/ 80
2	/ 23	4	/ 20	
3	/ 20	5	/ 20	

This document consists of **40** printed pages.

2 (a) A compound is aromatic if it satisfies the following two criteria.

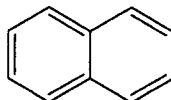
1. The compound must contain a ring comprised of continuously overlapping p orbitals.
2. The compound has $(4n + 2)$ delocalised π electrons, where n is 0 or a positive integer (1, 2, 3 etc.)

(i) Based on the criteria above, cyclopentadienyl anion is aromatic. By considering the hybridisation of the carbon atoms, explain how cyclopentadienyl anion satisfies both criteria. [2]



cyclopentadienyl anion

(ii) Given that naphthalene is aromatic, explain why it undergoes substitution instead of addition reaction. [1]



naphthalene

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(b) Fig. 2.1 shows some electrophilic substitution reactions.

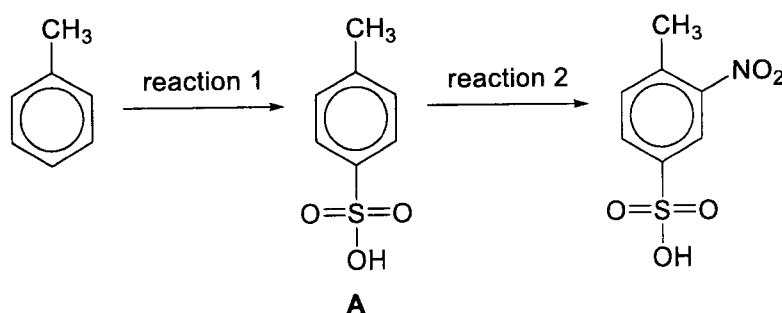
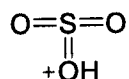


Fig. 2.1

In reaction 1, oleum is used as the reagent to convert methylbenzene to compound A. Oleum is a concentrated solution of sulfur trioxide, SO_3 , in sulfuric acid, H_2SO_4 .

Reaction 1 involves the following steps.

- Protonation of SO_3 by H_2SO_4 to form the HSO_3^+ electrophile. The structure of the HSO_3^+ electrophile is shown below.



- Two-step electrophilic substitution mechanism involving the reaction of methylbenzene and the HSO_3^+ electrophile, resulting in the formation of A and the regeneration of H_2SO_4 .

(i) Write a balanced equation for the formation of the HSO_3^+ electrophile. [1]

(ii) Describe the two-step electrophilic substitution mechanism in reaction 1. Show the structure of the intermediate and all relevant charges and show the movement of electron pairs using curly arrows. [2]

(iii) State the reagents and conditions for reaction 2. [1]

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For
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- (c) When 4-aminophenol is reacted with Br_2 dissolved in an organic solvent, compounds **B** and **C** are two of the products formed, as shown in Fig. 2.2.

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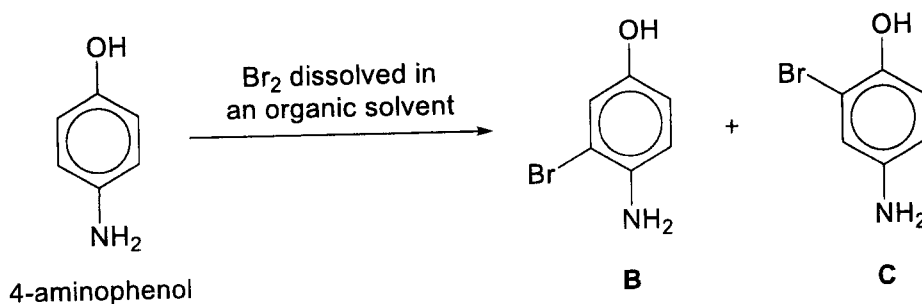


Fig. 2.2

Suggest why **B** is formed in a greater proportion compared to **C**. [2]

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- (d) Fig. 2.3 shows the synthesis of compound **W**.

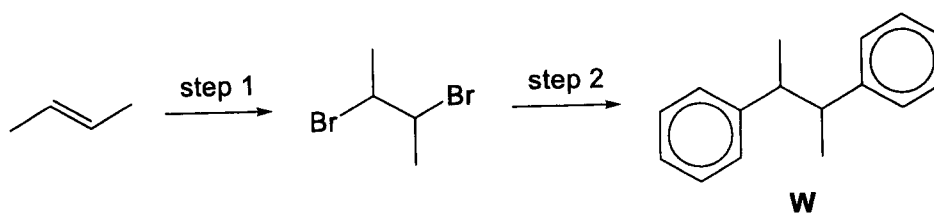


Fig. 2.3

- (i) Suggest the reagents and conditions for step 2. [1]

There are three different types of compound **W** molecules.

- molecule **X** has no effect on plane-polarised light
- molecule **Y** rotates plane-polarised light by 15° clockwise
- molecule **Z** rotates plane-polarised light by 15° anti-clockwise

- (ii) Draw the structures of molecules **X**, **Y** and **Z**. Suggest an explanation for the above observations. [3]

- (e) (i) Propane-2,2-diol undergoes dehydration to form propanone.

Draw the displayed formula of propane-2,2-diol.

[1]

For
examiner's
use

- (ii) Under acidic conditions, propanone reacts to form **K**, which exists as a liquid at room temperature.

0.001 mol of **K** underwent complete combustion with 250 cm³ of oxygen gas. The resulting gaseous mixture was passed through a tube containing anhydrous calcium chloride. The mass of the tube increased by 0.090 g. The gaseous mixture was then cooled to room temperature and the volume of the gaseous mixture was 202 cm³. When the gaseous mixture was passed into aqueous NaOH, the volume decreased by 144 cm³. All volumes of gases are measured at room temperature and pressure.

Use the information to show that the molecular formula for **K** is C₆H₁₀O.

[3]

- (iii) **K** (C₆H₁₀O) gives an orange precipitate with 2,4-dinitrophenylhydrazine but does not form a silver mirror with Tollens' reagent. When **K** is heated with acidified KMnO₄, **L** and propanone are formed. When **L** is heated with aqueous I₂ in dilute NaOH followed by acidification, **M** and a yellow precipitate are formed. When **M** is heated with acidified KMnO₄, the only product formed is a gas that gives a white precipitate with limewater.

Deduce the structures of **K**, **L** and **M**. Explain your reasoning.

[6]

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3 Use of the Data Booklet is relevant to this question.

The Electrochemically Driven CO₂ Separator (EDCS) is a modified hydrogen-oxygen fuel cell used to remove CO₂ from air, as shown in Fig. 3.1.

For
examiner's
use

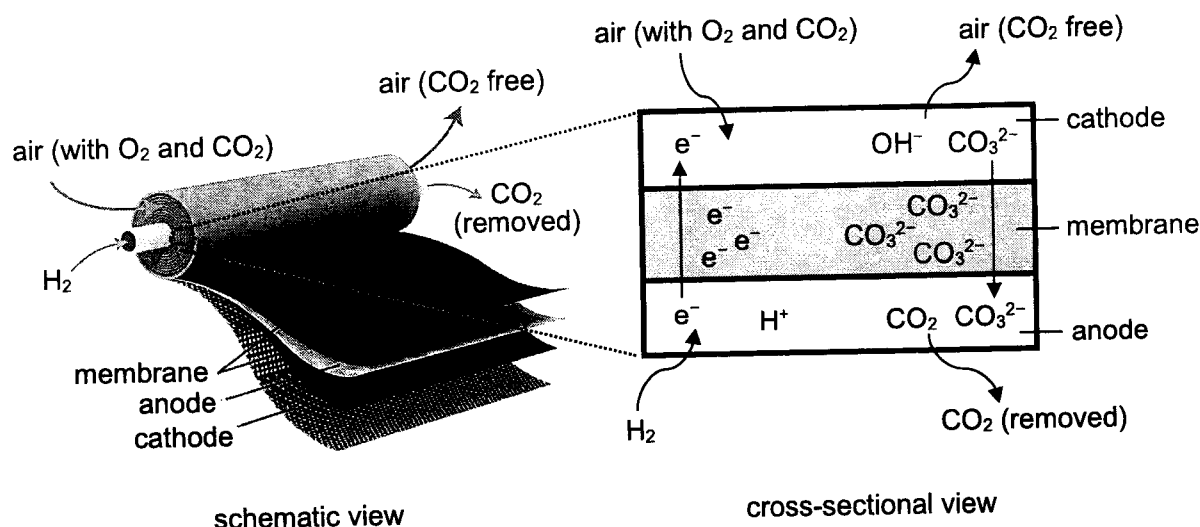


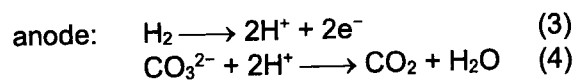
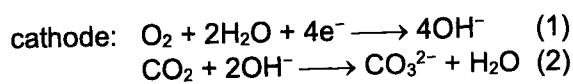
Fig. 3.1

The cross-sectional view of EDCS shows the transport of anions and electrons across the membrane, and the transport of gases at the cathode and anode.

The EDCS uses a membrane which acts as a salt bridge. The membrane also prevents diffusion of CO₂, OH⁻ and H⁺ ions, but allows movement of CO₃²⁻ ions and electrons between the cathode and the anode.

Air, which contains O₂ and CO₂, enters the cathode where CO₂ is converted to CO₃²⁻ ions, which then diffuse to the anode through the membrane. H₂ is pumped into the anode and the CO₃²⁻ ions are converted to CO₂ which is removed from the anode into a separate storage.

In the EDCS, the following reactions take place at the cathode and anode.



- (a) (i) In the absence of atmospheric CO₂, only reactions (1) and (3) occur at the cathode and anode of EDCS respectively.

Calculate the E^\ominus_{cell} of the EDCS in the absence of atmospheric CO₂. [1]

- (ii) By considering reactions (1) to (4), state and explain how the E_{cell} of the EDCS in the presence of atmospheric CO₂ would compare with your answer in (a)(i). [3]

- (c) When heated under acidic conditions, compound **D** undergoes decarboxylation to form a ketone and carbon dioxide, as shown in Fig. 4.1.

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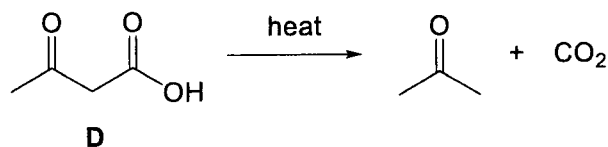


Fig. 4.1

- (i) When heated under acidic conditions, compound **G** undergoes decarboxylation, similar to that of compound **D** shown in Fig. 4.1.

Suggest the organic product formed from the decarboxylation of **G**.

[1]

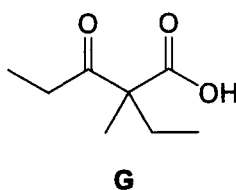


Fig. 4.2 shows the synthesis of propanone from compound **H**.

Compound **D** was formed as an intermediate and undergoes decarboxylation to form propanone and carbon dioxide.

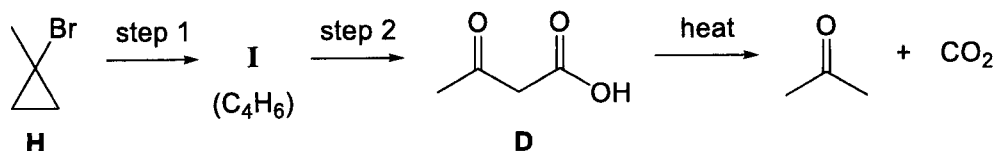


Fig. 4.2

- (ii) State the reagents and conditions for steps 1 and 2, and suggest the structure of compound **I**, C₄H₆.

[3]

(f) Ethanamide reacts under acidic conditions as shown in Fig. 4.7.

For
examiner's
use

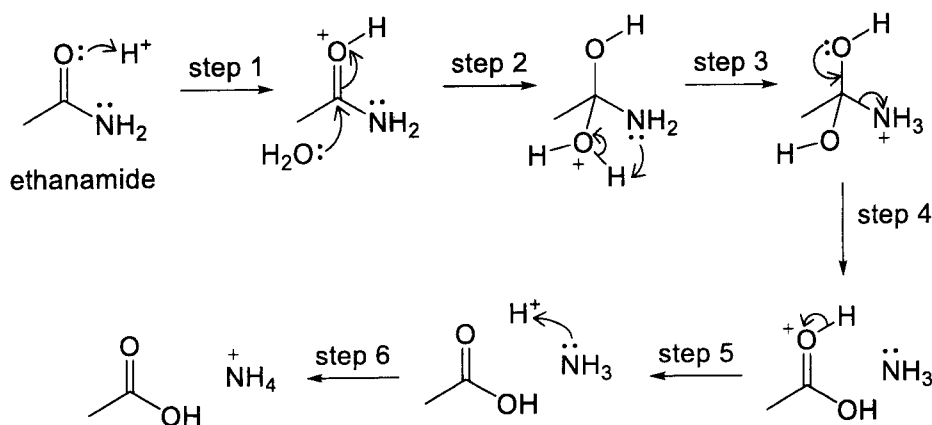
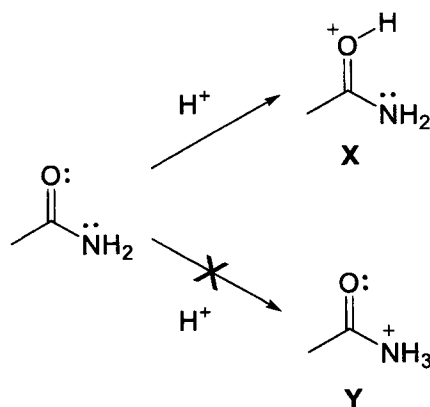


Fig. 4.7

- (i) Although H^+ acts as the catalyst for the hydrolysis of amides, a catalytic amount of H^+ is **not** sufficient for the reaction in Fig. 4.7. Explain why this is so. [1]
- (ii) Step 1 involves the protonation of ethanamide at the oxygen atom instead of the nitrogen atom.



By considering the structures of the conjugate acids **X** and **Y**, suggest why **X** is formed instead of **Y**. [2]

- (iii) Using Fig. 4.7, suggest the structures of two organic products formed when ethanamide is hydrolysed with H_2^{18}O , which is water containing ^{18}O isotope. [2]

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.....

.....

.....

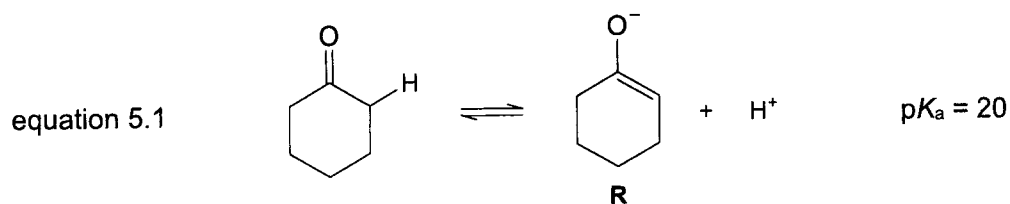
.....

.....

- (b) The hydrogen bonded to the carbon that is adjacent to the carbonyl group is acidic because the resultant anion formed is resonance stabilised.

For
examiner's
use

The acid dissociation of cyclohexanone is shown in equation 5.1.



The strength of an acid is measured by its K_a value. Table 5.1 shows the pK_a values and conjugate bases of some acids. All pK_a values are measured under the same conditions.

Table 5.1

acid	pK_a	conjugate base
	16	
	18	
	36	
NH_3	38	NH_2^- IV

- (i) Describe and explain, in terms of hybridisation and orbital overlap, why the conjugate base of cyclohexanone, **R**, is resonance stabilised.

Draw a labelled diagram, showing orbital overlap, to illustrate your answer. [2]

- (ii) Conjugate base **III** is the most suitable base to deprotonate cyclohexanone to form **R**.

By considering the pK_a values and structures of the conjugate bases in Table 5.1, suggest **two** reasons why this is so. [2]

(c) Fig. 5.3 shows the conversion of cyclohexanone to 2-propylcyclohexanone.

For
examiner's
use

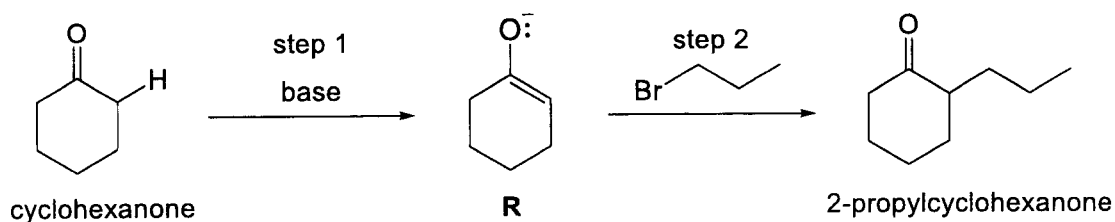


Fig. 5.3

In step 1, the base removes a hydrogen bonded to the carbon that is adjacent to the carbonyl group to form **R**.

In step 2, an S_N2 reaction occurs between **R** and 1-bromopropane to form 2-propylcyclohexanone.

- (i) Suggest the mechanism for steps 1 and 2 for the conversion of cyclohexanone to 2-propylcyclohexanone. Show all relevant charges, dipoles, lone pairs and curly arrows.

You may use **B**: to represent the base used in the reaction. [3]

- (ii) The solution containing 2-propylcyclohexanone synthesised from step 2 does not exhibit optical activity. Explain why. [2]

Fig. 5.4 shows the synthesis of cyclohexanone from compound **S**.

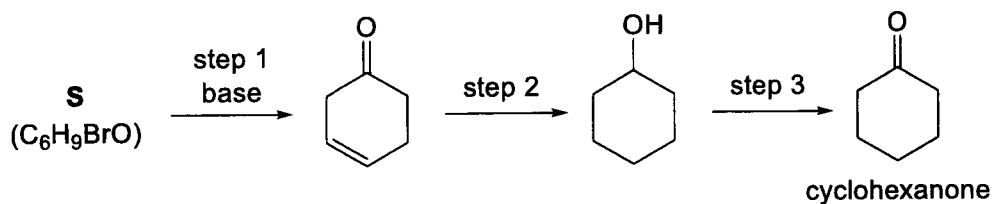


Fig. 5.4

S is a non-cyclic compound which decolourises bromine at room temperature in the dark and forms an orange precipitate with 2,4-dinitrophenylhydrazine. When heated with alkaline aqueous iodine, **S** gives yellow crystals.

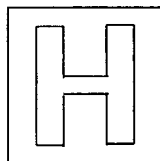
- (iii) Suggest the structure of compound **S**. [1]
- (iv) State the reagents and conditions for steps 2 and 3. [2]

CANDIDATE
NAME

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CLASS

22S0		
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RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION

Higher 2

**CHEMISTRY****9729/04**

Paper 4 Practical

24 August 2022

2 hours 30 minutes

Do NOT turn over the Question Booklet until you are told to do so.

READ THESE INSTRUCTIONS FIRST.

Write your name and class on the space provided when instructed to do so.
Give details of the practical shift and laboratory where appropriate, in the space provided.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The number of marks is given in brackets [] at the end of each question or part question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 22 and 23.

Shift	
Laboratory	
Bench Number	

For Examiner's Use	
Question	Marks
1	/ 14
2	/ 14
3	/ 16
4	/ 11
Total	/ 55

This document consists of **22** printed pages and **2** blank pages.

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

1 Investigation of the effect of temperature on the rate of a reaction

D-glucose, $C_6H_{12}O_6$, is a sugar that can act as a reducing agent.

In this question, you will investigate the effect of temperature on the rate of the redox reaction between acidified potassium manganate(VII) and D-glucose.

FA 1 is $0.010 \text{ mol dm}^{-3}$ potassium manganate(VII), $KMnO_4$.

FA 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

FA 3 is 0.20 mol dm^{-3} D-glucose, $C_6H_{12}O_6$.

Initially, the reaction mixture is intensely purple. As the reaction proceeds, the intensity of the purple colour will decrease until the reaction mixture becomes colourless when the reaction is completed. The rate of the reaction is studied by measuring the time taken for the purple colour to disappear.

You will perform a series of four experiments. Graphical analysis of your results will enable you to determine how temperature affects the rate of the reaction.

For each experiment, you will measure and record the

- time taken, t , in seconds for the reaction mixture to turn colourless,
- initial temperature, T_{initial} , and final temperature, T_{final} , in degree Celsius of the reaction mixture.

You will then calculate values for

- $1/t$,
- $\lg(1/t)$,
- T_{ave} , which is the average temperature of T_{initial} and T_{final} in degree Celsius,
- T_K , which is the average temperature in kelvin ($0^\circ\text{C} = 273 \text{ K}$),
- $1/T_K$.

(a) In Table 1.1 on page 4, record:

- all values of t to the nearest second,
- all values of T_{initial} and T_{final} to an appropriate level of precision,
- all calculated values of $1/t$, $\lg(1/t)$, T_{ave} , T_K and $1/T_K$ to three significant figures.

Experiment 1

1. Fill the burette labelled **FA 1**, with **FA 1**.
2. Transfer 10.00 cm³ of **FA 1** into a 100 cm³ conical flask.
3. Use a 50 cm³ measuring cylinder to transfer 25.0 cm³ of **FA 2** into the conical flask containing **FA 1**.
4. Using a 25 cm³ measuring cylinder, measure 25.0 cm³ of **FA 3**.
5. Record the initial temperature, T_{initial} , of the solution in the conical flask.
6. Add the **FA 3** from the measuring cylinder into the conical flask. Start the stopwatch during this addition.
7. Mix the contents thoroughly by swirling the flask. Then place the flask on a white tile.
8. Stop the stopwatch as soon as the solution turns colourless. Record the final temperature, T_{final} , of the solution.
9. Record the time taken, t , to the nearest second.
10. Discard the reaction mixture. Wash out the conical flask and stand it upside down on a paper towel to drain.

Experiment 2

11. Use the burette to transfer 10.00 cm³ of **FA 1** into a 100 cm³ conical flask.
12. Use a 50 cm³ measuring cylinder to transfer 25.0 cm³ of **FA 2** into the conical flask containing **FA 1**.
13. Place the conical flask on the tripod and heat its contents to between 55 °C and 65 °C.
14. When the temperature of the solution in the conical flask has reached between 55 °C and 65 °C, use a paper towel and **carefully** remove the conical flask from the Bunsen burner.
15. Repeat points 4 to 10 of **Experiment 1**.

Experiments 3 and 4

Repeat points 11 to 15 of **Experiment 2** two times, keeping the temperature of the contents of the conical flask between that of **Experiment 1** and **Experiment 2**. You should ensure that there is a difference of at least 5 °C between each of the initial temperatures in all your experiments.

You should alternate the use of the two 100 cm³ conical flasks.

Record all temperatures, time taken and calculated values in Table 1.1.

4

Table 1.1

expt	T_{initial} / °C	T_{final} / °C	t / s	$1/t$ / s ⁻¹	lg (1/t)	T_{ave} / °C	T_{K} / K	$1/T_{\text{K}}$ / K ⁻¹
1								
2								
3								
4								

[3]

(b) (i) Plot a graph of $\lg (1/t)$, on the y -axis, against $1/T_K$, on the x -axis, on the grid in Fig. 1.1.

Draw the best-fit straight line taking into account all of your plotted points.

Extrapolate (extend) your line to $1/T_K = 0.00340 \text{ K}^{-1}$.

[3]

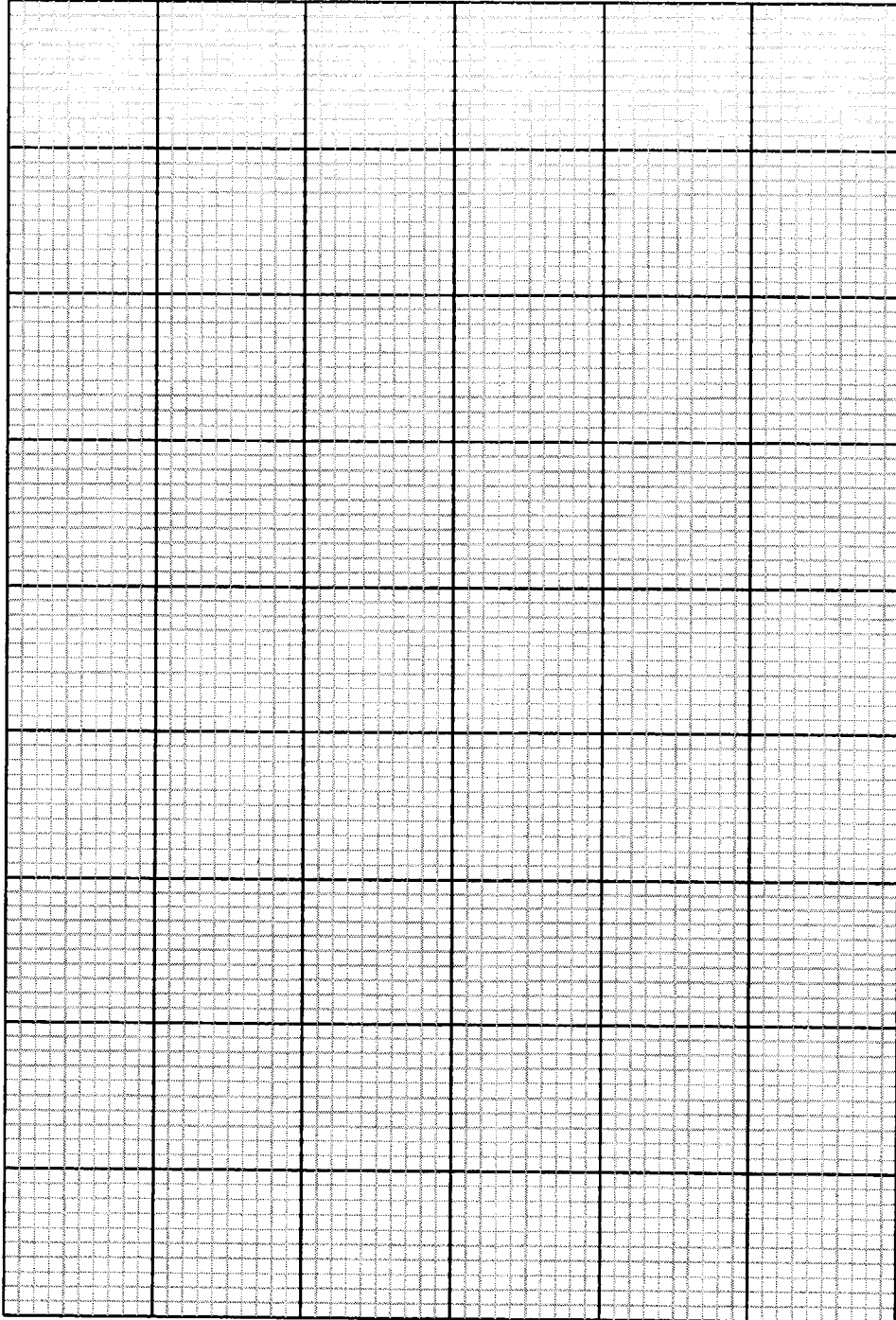


Fig. 1.1

6

- (ii) The clock reaction can be used as a timer, such that the time taken for the reaction mixture to turn colourless is 3 minutes.

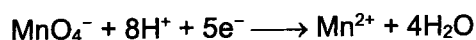
Use your graph to calculate the average temperature, T_{ave} , at which this reaction should be carried out. Give your answer to one decimal place.

Show on Fig. 1.1 how you obtained your answer.

average temperature, $T_{ave} = \dots\dots\dots$ °C [2]

- (c) In an experiment, it was found that 1 mol of acidified potassium manganate(VII), KMnO_4 , oxidised 2.5 mol of D-glucose.

The half-equation for the reduction of MnO_4^- under acidic conditions is given below.



- (i) Calculate the amount of electrons lost per mole of D-glucose.

amount of electrons lost per mole of D-glucose = $\dots\dots\dots$ mol [1]

- (ii) The structure of D-glucose is shown in Fig. 1.2.

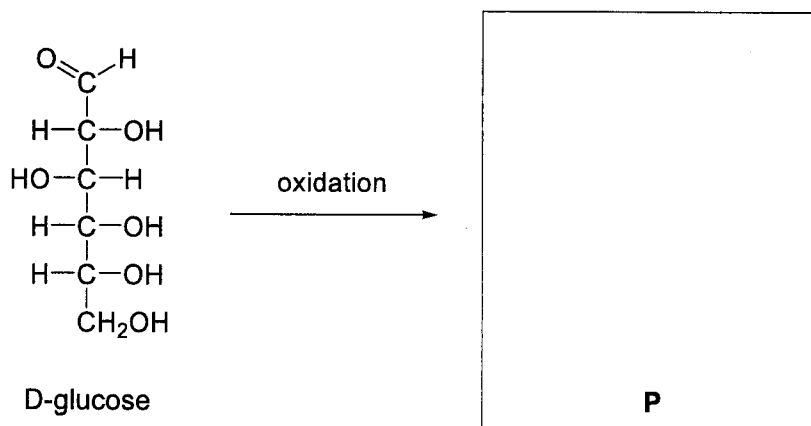


Fig. 1.2

Given that only one carbon atom in D-glucose is oxidised, suggest a structure of the organic product **P** formed from the oxidation of D-glucose. Draw your structure of **P** on Fig. 1.2.

Explain your answer by describing the change in oxidation state of the carbon atom which has undergone oxidation.

.....

.....

.....

.....

.....

.....

..... [2]

- (d) (i) The uncertainty (error) associated with each reading using either a 25 cm³ or 50 cm³ measuring cylinder is ± 0.5 cm³.

Calculate the maximum total percentage uncertainty (error) in the total volume of the reaction mixture for **Experiment 1**.

maximum total percentage uncertainty = [1]

(ii) Identify a source of error in the experimental procedure. Do not include any errors involving the precision of apparatus.

Hence, suggest a modification that could be used to reduce this error.

source of error:
.....
.....
.....
.....

modification:
.....
.....
.....
..... [2]

[Total: 14]

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2 Determination of the formula of a hydrated salt

FA 4 is a hydrated salt of ammonium iron(II) sulfate and has the formula $(\text{NH}_4)_a\text{Fe}(\text{SO}_4)_b \cdot 6\text{H}_2\text{O}$.

In this question, you will prepare **FA 5**, a solution containing **FA 4**, and perform a titration. The data from the titration will be used to calculate:

- the concentration of Fe^{2+} in **FA 5**
- the M_r of **FA 4** and hence the values of a and b .

FA 1 is $0.010 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

In the space provided on page 11, prepare tables in which to record for your experiment:

- all weighings to an appropriate level of precision
- titration results to an appropriate level of precision.

(a) (i) Preparation of **FA 5** and titration of **FA 5** against **FA 1**

1. Weigh the capped container containing solid **FA 4**. Record the mass in your table.
2. Empty the solid **FA 4** into a 100 cm^3 glass beaker. Reweigh the capped container after emptying the solid. Record this mass in your table.
3. Use a 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 2** into the beaker. Stir to dissolve the solid.
4. Transfer the solution from the beaker quantitatively to a 250 cm^3 graduated flask. Rinse the beaker with deionised water a few times, adding all the washings to the graduated flask.
5. Make up to the mark with deionised water. Stopper and shake well to obtain a homogeneous solution, **FA 5**.
6. Fill the burette labelled **FA 1**, with **FA 1**.
7. Use the pipette to transfer 25.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
8. Titrate the solution in the conical flask until the end-point is reached.
9. Record your titration results in your table.
10. Repeat points 7 to 9 until consistent results are obtained.

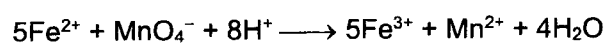
Results

[5]

- (ii) From your titrations, obtain a suitable volume of **FA 1** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 1** = cm³ [1]

- (b) (i) The equation for the reaction in the titration is as shown.



Calculate the concentration of Fe^{2+} in **FA 5**.

concentration of Fe^{2+} = mol dm⁻³ [2]

- (ii) Determine the M_r of **FA 4**.

M_r of **FA 4** = [1]

- (iii) The formula of the hydrated salt in **FA 4** is $(\text{NH}_4)_a\text{Fe}(\text{SO}_4)_b \cdot 6\text{H}_2\text{O}$.

By considering that the salt is electrically neutral, express a in terms of b .

[1]

- (iv) Using your answers from **2(b)(ii)** and **2(b)(iii)**, determine the values of a and b .
[A: H, 1.0 N, 14.0 O, 16.0 S, 32.1 Fe, 55.8]

$a =$

$b =$ [2]

- (c) A student performs the same experiment but mistakenly uses 5.0 cm^3 instead of 50.0 cm^3 of **FA 2** in the preparation of **FA 5**.

The student observes that a brown-black precipitate is formed during the titration.

Besides making the end-point more difficult to be determined, state the effect this mistake has on the student's titration results. Explain your answer.

effect on titration results

.....

explanation

.....

.....

.....

..... [2]

[Total: 14]

3 Investigation of some organic and inorganic reactions

Safety Precautions

Wear safety goggles and gloves to avoid any direct contact with these chemicals. Wash with plenty of water immediately if there is any accidental skin contact with these chemicals.



FA 3 is 0.20 mol dm^{-3} D-glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.

FA 6 and **FA 7** each contains an organic compound comprising C, H and O atoms only. Both do not decolourise $\text{Br}_2(\text{aq})$.

FA 8 is a solution containing one cation and one anion listed in the Qualitative Analysis Notes on pages 22 and 23.

Carry out the following tests. Carefully record your observations in Tables 3.1, 3.2 and 3.4. Unless otherwise stated, the volumes given are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Preparation of hot water bath

Fill a 250 cm^3 glass beaker with about 150 cm^3 of water. Using a Bunsen burner, heat this beaker of water until the water starts to boil.

While you are waiting for the water to boil, continue with Question 4.

Table 3.1

	test	observations
(a)	<p>Once the water in the beaker starts to boil, turn off the Bunsen burner.</p> <p>Using a 10 cm^3 measuring cylinder, add 5.0 cm^3 of FA 3 to a boiling tube.</p> <p>To this boiling tube, add 5.0 cm^3 of FA 8 using the same 10 cm^3 measuring cylinder.</p> <p>Leave this boiling tube in the hot water bath for about 3 minutes.</p> <p>Filter the reaction mixture into another boiling tube.</p> <p>Wash the residue with some deionised water.</p> <p>The residue is FA 9.</p> <p>Retain the filter funnel containing FA 9 for 3(c)(iii).</p>	
<p>While you are waiting for the mixture to filter, continue with 3(b).</p>		

[1]

Table 3.2

		test	observations with FA 6	observations with FA 7
(b)	(i)	<p>Add about 2 cm depth of FA 6 to a test-tube. To this test-tube, add 2 cm depth of dilute sulfuric acid, followed by 1 drop of potassium manganate(VII) solution and shake well.</p> <p>Leave the test-tube to stand in a beaker of hot water for about 5 minutes.</p>		no observable change
	(ii)	<p>Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide.</p> <p>Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to stir the mixture and help dissolve the precipitate.</p> <p>Add 1 cm depth of FA 6 to this mixture, shake the tube and place it in the test-tube rack to stand.</p>		no observable change
	(iii)	<p>Add about 1 cm depth of FA 7 to a test-tube. To this test-tube, add 4 drops of sodium hydroxide solution followed by iodine solution, dropwise, until a permanent orange/red colour is present.</p> <p>Warm the mixture in a beaker of hot water for about 2 minutes.</p>	solution FA 6 turns orange	
		<p>Add sodium hydroxide solution using a teat pipette until no further change is seen.</p> <p>Dispose the contents into the beaker labelled "waste".</p>	solution FA 6 turns colourless	

[4]

- (iv) Complete Table 3.3 with the functional groups present in **FA 6** and **FA 7**. Give evidence from the observations in Table 3.2 to support your conclusions.

Table 3.3

	functional group	evidence
FA 6		
FA 7		

[2]

Table 3.4

		test	observations
(c)	(i)	Test solution FA 8 with Universal Indicator paper.	
	(ii)	Add about 1 cm depth of FA 8 to a test-tube. Then add 1 cm depth of dilute nitric acid. To this test-tube, add about 1 cm depth of aqueous barium nitrate slowly, with shaking, until no further change is seen.	
	(iii)	Place the filter funnel containing FA 9 into a clean test-tube. Using a 10 cm ³ measuring cylinder, carefully add 2.0 cm ³ of dilute sulfuric acid to the filter funnel. The filtrate will collect in the test-tube. The residue is FA 10 . The filtrate is FA 11 .	
	(iv)	Add 1 cm depth of FA 11 to a test-tube. Add aqueous ammonia slowly, with shaking, until no further change is seen.	

[4]

FA 9, FA 10 and FA 11 contain the same element **X** but in three different oxidation states.

FA 10 is the solid metal of the cation present in **FA 11**.

(v) State the identity of the cation present in **FA 11**.

..... [1]

(vi) In **3(c)(iii)**, **FA 10** and **FA 11** are formed in equal amounts.

Identify the oxidation state of element **X** in **FA 9** and state the type of reaction in **3(c)(iii)**.

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

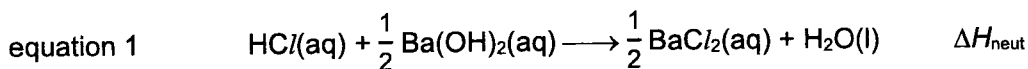
(vii) Use your observations in Table 3.4 to deduce the identity of the anion in **FA 8**.

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

[Total: 16]

4 Planning

Hydrochloric acid, HCl , reacts with barium hydroxide, $\text{Ba}(\text{OH})_2$, according to equation 1.



When HCl is mixed with $\text{Ba}(\text{OH})_2$, the neutralisation reaction releases heat causing a rise in the temperature of the solution.

A series of experiments can be carried out using different volumes of the two solutions, HCl and $\text{Ba}(\text{OH})_2$. In each experiment, the total volume of the two solutions is to be kept constant at 100 cm^3 and the change in temperature, ΔT , is to be determined.

A suitable graph can then be plotted and used to determine the concentration of the $\text{Ba}(\text{OH})_2$ solution and ΔH_{neut} .

- (a) (i) In an experiment, $0.200 \text{ mol dm}^{-3}$ of HCl was reacted with $\text{Ba}(\text{OH})_2$ and the total volume of the two solutions used was 100 cm^3 .

Assuming that the concentration of $\text{Ba}(\text{OH})_2$ is $0.080 \text{ mol dm}^{-3}$, determine the volume of $\text{Ba}(\text{OH})_2$ to be used so that stoichiometric amounts of $\text{Ba}(\text{OH})_2$ and HCl react.

volume of $\text{Ba}(\text{OH})_2 = \dots\dots\dots \text{ cm}^3$ [1]

- (ii) Describe how you would use your answer in 4(b)(i) to determine
- the concentration of the Ba(OH)₂ solution, in mol dm⁻³,
 - ΔH_{neut} , in kJ mol⁻¹.

You may assume the following:

- specific heat capacity of all solutions is 4.18 J g⁻¹ °C⁻¹,
- density of all solutions is 1.00 g cm⁻³.

[2]

- (c) Suggest why using a bottle of barium hydroxide solution which has been left standing in the air for some time will result in an inaccurate determination of ΔH_{neut} .

.....

.....

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.....

.....

.....[2]

[Total: 11]

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Qualitative Analysis notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH₃(aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	ammonia produced on heating	–
barium, Ba ²⁺ (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. with high [Ca ²⁺ (aq)]	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	blue-ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

<i>anion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Tests for gases

<i>gas</i>	<i>test and test result</i>
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple