

ST ANDREW'S JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS

HIGHER 2

CANDII	DAT	E
NAME		

CLASS

2 1 S

CHEMISTRY 9729/02

Paper 2 Structured Questions

31 August 2022

Candidates answer on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work that you hand in.

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

A Data Booklet is provided.

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

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

For	Examine Use	r's
Q1		12
Q2		14
Q3		14
Q4		10
Q5		25
Total		75

This document consists of 24 printed pages (including this cover page).

		N ₂ H ₄ , is a colourles maceuticals industr		mmonia-like odou	r. It is an important precu	rsor
(a)	-	azine exists as a liq ure. State two reas			at room temperature and sical state.	[2]
(b)	The I	√ _b values of hydrazi			re shown in Table 1.1 .	
			Tab	le 1.1	٦	
			base	K _b / mol dm ⁻³		
			Hydrazine	1.7 x 10 ⁻⁶		
			Eth. de mine	(for K_{b1}) 4.5×10^{-4}	_	
			Ethylamine Phenylamine	7.4 x 10 ⁻¹⁰		
			Prienylamine	7.4 × 10		
	(i)	Explain what is m	eant by the term <i>l</i>	Bronsted-Lowry ba	ase.	[1]

	(ii)	Explain the relativ	e magnitudes of t	the K₀ values in Ta	able 1.1.	[2]
				•••••		

(iii) The K_b values of diethylamine and triethylamine are shown in **Table 1.2**.

Table 1.2

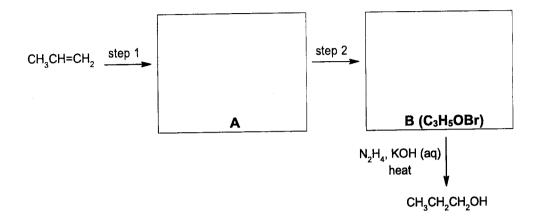
base	K _b / mol dm ^{−3}
Diethylamine	6.9 x 10 ⁻⁴
Triethylamine	6.5 x 10 ⁻⁵

	Suggest why the K_b value of triethylamine is significantly smaller than the K_b values of ethylamine and diethylamine.	[1]
(c)	The Wolff-Kishner reaction is a valuable synthetic method to convert carbonyl compound into alkanes. This is done by reacting a carbonyl compound with excess hydrazine in presence of potassium hydroxide.	

0			KOH (aq), heat					
	+	$N_2^{}H_4^{}$		R	R	+ N ₂	+	H_2O
R R								

(i)	Suggest a simple chemical test to monitor the completion of the Wolff-Kishner reaction.	[2]

(ii) Propan-1-ol can be synthesised from propene by the following 3-step route that incorporates the Wolff-Kishner reaction.



Suggest the structures of intermediate products **A** and **B** and state the reagents and conditions for each step.

Reagents and conditions

Step 1:	
Step 2:	[4]

[Total: 12]

2 Organic matter is known to decay under low oxygen conditions, such as in swamps. The sulfate-reducing bacteria present in the organic matter will reduce the various sulfates into hydrogen sulfide, H₂S. Some of the hydrogen sulfide will react with Fe²⁺ present in swamp to produce insoluble FeS, which is responsible for the brown colour of sludge in the swamp.

reaction 1 $H_2S(g) + aq \rightleftharpoons 2H^+(aq) + S^2-(aq)$

reaction 2 $Fe^{2+}(aq) + S^{2-}(aq) \rightleftharpoons FeS(s)$ ΔH^{e}_{pot}

(a) (i) In a saturated solution of hydrogen sulfide, [H⁺]²[S²⁻] is 1.0 × 10⁻²³ mol³ dm⁻⁹.
 Calculate the maximum concentration of sulfide ions present in the swamp, given that the pH of swamp water is 6.8.

(ii) Hence, calculate the minimum concentration of Fe²⁺ in the swamp required for the precipitation of FeS.

 $(K_{\rm sp} \text{ of FeS} = 4.9 \times 10^{-18} \text{ mol}^2 \text{ dm}^{-6})$ [1]

(iii)	ΔG°_{ppt} , can be determined by using the following expression, where R is the
	molar gas constant and T is the temperature measured in K.

$$\Delta G^{\bullet}_{ppt} = 2.303RT \text{ Ig } K_{sp}$$

Using the K_{sp} in (a)(ii), calculate ΔG^{e}_{ppt} for the precipitation of FeS. Express your	
answer in kJ mol ⁻¹ .	[2]

(iv)	Predict how the brown colour intensity of sludge will change when pH decreases. Explain your answer.	[2]

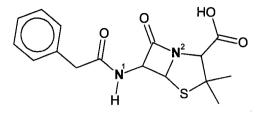
(b) Using data from **Table 2** below, together with relevant data from the *Data Booklet*, draw an energy cycle and calculate ΔH^{e}_{ppt} for **reaction 2**.

Table 2

standard enthalpy change of formation of FeS(s)	−102 kJ mol ^{−1}
standard enthalpy change of atomisation of Fe(s)	+415 kJ mol ⁻¹
standard enthalpy change of atomisation of S(s)	+279 kJ mol ⁻¹
sum of first and second electron affinity of sulfur	+337 kJ mol ⁻¹
standard enthalpy change of hydration of Fe ²⁺ (g)	−1970 kJ mol ^{−1}
standard enthalpy change of hydration of S2-(g)	-1372 kJ mol ⁻¹

c)	(i)	Use your answers in (a)(iii) and (b), calculate the ΔS_{ppt}^{*} for the formation of respectivities.	[1]
	(ii)	Hence, explain the significance of the sign of ΔS_{ppt}^{e} in (c)(i).	[1]
(d)		ough hydrogen sulfide and water molecules have the same shape, they have thy different bond angles. State and explain which species has a larger bond	[2]
			l: 14]

3 Ionisable drugs have acidic, basic or amphoteric properties. An example of an acidic drug is benzylpenicillin G, which is an antibiotic used to treat certain bacterial infection.



benzylpenicillin G

(a)	DOUI	nitrogen atoms in benzylpenicillin G are sp² hybridised.	
	(i)	Draw the shape of the hybrid orbitals around N ¹ .	[1]

(ii)	Suggest why sp ² hybridisation at N ¹ and N ² will make benzylpenicillin G more stable.	[1]
(iii)	Suggest a reason why C-N ² bond is weaker than C-N ¹ bond.	[1]

(b) The solubility of three different ionisable drugs is shown in Fig. 3.1.

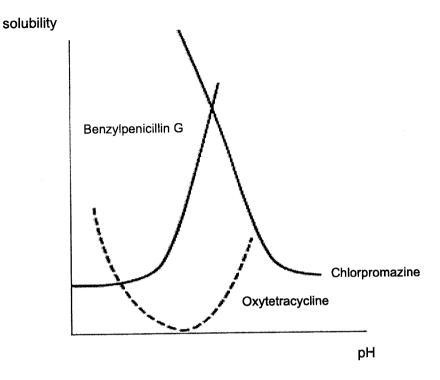


Fig. 3.1

(i)	Explain why the solubility of benzylpenicillin G in aqueous increases from low to high pH.	[2]
(ii)	Classify the following compounds according to the type of ionisable drug (acidic, basic and amphoteric).	[1]
	A) Chlorpromazine:	
	B) Oxytetracycline:	

(iii) The pH of blood containing benzylpenicillin G is 7.4.
 Given that the pK_a of benzylpenicillin G is 2.76, calculate the concentration of the undissociated benzylpenicillin G.

(iv) The Henderson-Hasselbalch equation can be re-expressed to relate the solubility of a drug to the pH of the solution and its pK_a .

$$pH = pK_a + \log_{10} \left(\frac{S - S_0}{S_0} \right)$$

where S is the concentration of the dissolved drug and S_0 is the concentration of the undissociated drug.

The solubility of the undissociated benzylpenicillin G in blood with pH 7.4 is 9×10^{-13} mol dm⁻³. Using the information above and in **(b)(iii)**, calculate the solubility of benzylpenicillin G in blood with pH 7.4. Express your answer in mol dm⁻³.

[2]

(c) Benzylpenicillin G is administered intravenously as potassium benzylpenicillin G,

which is an ionic compound.

	drug is prepared in a buffer solution made of citric acid, $C_5H_7O_5COOH$ and sium citrate, $C_5H_7O_5COOK$ to maintain its solubility and stability.	
(i)	Define the term buffer.	[1]
(ii)	Write an equation to show how the citric acid/citrate buffer maintains the pH of the solution when small amounts of alkali are added.	[1]
(iii)	Explain the difference between the ionic radius and atomic radius of potassium.	[2]
	[Total	: 14]

4 Compound **X** has the molecular formula C₈H₈O₂. It contains 2 different functional groups. Data about the reactions of **X** are given in the table below.

reaction	reagent	observations
1	alkaline aqueous iodine	yellow ppt
2	Cr ₂ O ₇ ²⁻ /H ⁺ , heat	orange solution
3	Br ₂ (aq)	white solid Y with $M_r = 293.8$

(a)	(i)	Based on reaction 1 only, state all the deductions about X .	[1]
	(ii)	Which deduction in (a)(i) is confirmed by reaction 2? Explain your answer.	[2]
		· · · · · · · · · · · · · · · · · · ·	
	(iii)	Based on your answer in (a)(ii), construct an equation to represent reaction 1.	
		You may use R to represent part of compound X which does not react with alkaline aqueous iodine.	[1]
	(iv)	State the type of reaction taking place in reaction 3.	[1]

	(v)	group found in X based on reaction 3.	[3]
(b)	Base of X.	ed on your answers in (a), draw the structural formulae of the 2 possible isomers	[2]

[Total: 10]

5 Wearables, such as smartwatches and fitness trackers, are gaining popularity with new detecting abilities constantly being developed.

In recent years, research has been done to integrate chemical sensors into wearables to detect metabolites in sweat. One such metabolite is lactate, which can be used to determine the fatigue level of muscles in our body. Under conditions of high energy demand, glucose breaks down rapidly into lactate, which accumulates in the muscles. **Fig. 5.1** shows the breakdown of glucose to pyruvate, and eventually to lactate ($M_r = 89.0$).

Fig. 5.1

Table 5.1 shows the lactate concentration in sweat before and after intense exercise.

Table 5.1

	Lactate concentration (mol dm ⁻³)	
	before exercise	after exercise
sweat	2.0 x 10 ⁻⁴	6.2 x 10 ⁻⁴

Table 5.2 shows the possible lactate concentration ranges that can exist in blood.

Table 5.2

Lactate concentration (mmol dm ⁻³)	Medical condition
0.5 - 1	Normal
2 - 4	Hyperlactatemia
> 4	Acidosis

(a)	(i)	State the number of chiral centres present in glucose molecule.	[1]

[2]

[1]

(ii) A normal person loses an average of 3.5 dm³ of sweat for every hour of exercise. Using the data in **Table 5.1**, calculate the mass of lactate lost in sweat after two hours of intense exercise.

(iii) 10 cm³ of blood was drawn from an individual and the mass of lactate was found to be 0.0027 g.

Determine the medical condition of this individual.

The reduction of pyruvate to lactate involves a compound known as reduced nicotinamide adenine dinucleotide (NADH). The reduction is an equilibrium where all species are in aqueous state.

 $K_c \, \text{value}$ for this equilibrium at 298 K is 1.46 x $10^{11}.$

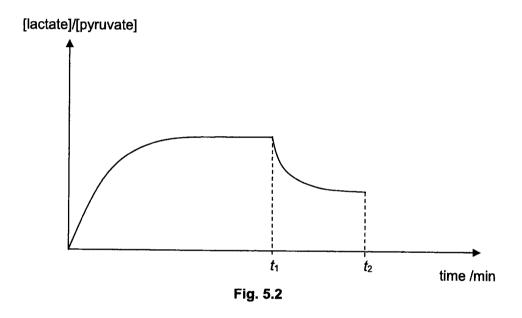
(b)	(i)	State the change in oxidation number for carbon α .	[1]

[2]

(ii) During an intense exercise, the pH of blood decreases from 7.4 to 7.1.

Assuming that [NADH] is equal to [NAD+], calculate the [lactate] / [pyruvate] ratio at pH 7.1.

(iii) Fig. 5.2 shows the graph of [lactate] / [pyruvate] against time. At time t_1 , the temperature of the reaction was increased.



Determine the sign of Δ*H* for this reaction. Explain your answer. [2]

(iv) On Fig. 5.2, complete the diagram to show the effect on [lactate] / [pyruvate] when OH^- was added to the reaction mixture at time t_2 . [1]

Fig. 5.3 shows the reduction of pyruvate. This reaction happens in the following manner.

- The lone pair of electrons on N of NADH delocalises into a nearby alkene. This causes the π bond to be broken but a new one is subsequently formed.
- A C—H bond of NADH breaks and the two electrons form a σ bond with carbonyl carbon of pyruvate.
- The π bond of C=O breaks and a σ bond is formed with H⁺ as shown.

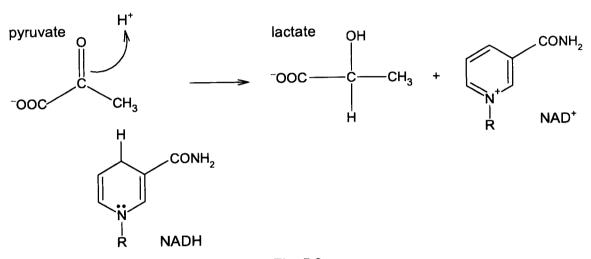


Fig. 5.3

(v) On Fig. 5.3, draw curly arrows to show the movement of electron pairs when NADH reduces pyruvate into lactate. [2]

ITURN OVER

(c) Polyurethane is a polymer used to make the straps of fitness bands and smartwatches as they have good resistance towards salt water and ultra-violet radiation. Hence, unlike cheaper plastic or resin straps, polyurethane straps are more suited for a wide range of sporting activities.

The reaction between diisocyanate and diol to form polyurethane is shown in Equation 1.

Equation 1

n = degree of polymerisation

toluene diisocyanate (Mr. 174)

Suggest the structure of the polyurethane polymer formed when toluene diisocyanate is reacted with ethane-1,2-diol. [1]

(ii) The average molar mass of the polyurethane polymer formed in (c)(i) is $1.3688 \times 10^4 \,\mathrm{g \, mol^{-1}}$. Calculate the degree of polymerisation, n, for this polymer. [1]

(d) Toluene diisocyanate is synthesised from methylbenzene by the following route.

(i)	Complete the reaction scheme to show how toluenediamine could be	
	synthesised from methylbenzene in two steps. Show the structure of the	
	intermediate product and state the reagents and conditions for each step.	[3]

Step 1	••••••	 	 	 	
Step 2		 	 	 	

intermediate compound

(11)	Suggest the type of reaction in step 4 .	[1]
(iii)	The reaction between toluenediamine and phosgene gas, COCl ₂ , in step 3 is carried out at a temperature of 500 °C and 400 kPa. Assuming the process is 100% efficient, calculate the volume of phosgene required to produce 1 kg of toluene diisocyanate.	[2]
(iv)	Phosgene gas is known to exhibit non-ideal gas behaviour. State a reason for this observation.	[1]
(v)	Toluene diisocyanate must be stored in an anhydrous condition. In the presence of water, toluene diisocyanate will react to form toluenediamine and an acidic gas. Suggest the identity of the acidic gas.	[1]

(e) The production of polyurethane occurs in the presence of diethyltin dichloride catalyst. Tin atoms are capable of undergoing ligand exchange with ethane-1,2-diol as shown in **Fig. 5.4**.

$$\begin{array}{c|c} & H \\ & O \\ & Sn \\ & Cl \\ & O \\ & H \\ \end{array} \qquad \begin{array}{c} & H \\ & O \\ & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \qquad \begin{array}{c} & & \\ & & \\ \end{array} \qquad \begin{array}{c} & & \\ & \\ \end{array} \qquad \begin{array}{c} & & \\ & \\ \end{array} \qquad \begin{array}{c}$$

Fig. 5.4

(i)	Suggest how the presence of a catalyst would affect the magnitudes of the rate constant, k , and activation energy, E_a , of the reaction in Fig. 5.4 .	[1]
(ii)	Suggest a chemical test to show that ligand exchange has occurred according to Fig. 5.4 . Include the expected observations in your answers.	[2]
		. 251

END OF PAPER

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Additional Answer Space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.
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ST ANDREW'S JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS

HIGHER 2

CANDIDAT	E
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CHEMISTRY 9729/03

Paper 3 Free Response

14 September 2022

Candidates answer on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work that you hand in.

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.

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.

A Data Booklet is provided.

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

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.

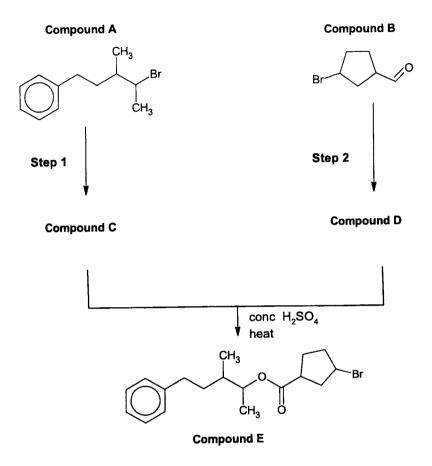
For E	xaminer's	Use
Q1		21
Q2		19
Q3		20
Q4 or Q5		20
Total		80

This document consists of 26 printed pages (including this cover page).

Section A

Answer all the questions in this section.

1 (a) The diagram below shows how compound E may be prepared.



- (i) Draw the structural formulae for C and D. [2]
- (ii) Suggest the reagents and conditions for steps 1 and 2. [2]
- (iii) Draw the structures of the products formed when E is reacted with hot aqueous sodium hydroxide. [2]
- (iv) State the type of reaction when C and D react to form E. [1]
- (v) Equal amounts of A, F and G are added separately to three test-tubes, which each contains equal concentration of ethanolic silver nitrate. The test-tubes are placed in a hot water bath. No precipitate is formed in one of the test-tubes. For the other two test-tubes, precipitates are formed at different rates.

Explain these observations.

$$\begin{array}{c|c} CH_3 & CH_3 \\ \hline \\ CH_3 & CH_3 \\ \hline \\ Compound F & Compound G \\ \end{array}$$

[3]	Compound G	Compound F
	••••••	
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(b) Copper is an important metal which can be used to catalyse many organic reactions. It

exists naturally as an ore containing calcium and silver impurities. To obtain copper me				
the c	the ore is purified using electrolysis.			
(i)	Draw a labelled diagram for the purification set-up. With reference to relevant data from the Data Booklet, explain what happens	[2]		
(ii)	to the calcium and silver impurities during the purification.	[3]		
(iii)	A current was passed through the set up in (b)(i) for 50 minutes and the			
	electrodes were then removed, washed, dried and weighed. It was found that			
	the cathode had gained 0.95 g in mass.	.		
	Calculate the current passing through the cell.	[2]		
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(c)	enou	um phosphate, $Ca_3(PO_4)_2$, is used as a supplement for people who either do not ghouse calcium from their diet or those who suffer from medical conditions approaries.	_
	(i)	With the aid of relevant data from the <i>Data Booklet</i> , deduce whether copper(II) phosphate or calcium phosphate will decompose at a lower temperature.	
			[2]
	(ii)	50 cm ³ of 0.05 mol dm ⁻³ sodium phosphate solution is mixed with 30 cm ³ of	
		0.05 mol dm ⁻³ calcium nitrate solution.	
		Determine whether calcium phosphate precipitate is formed.	
		(K_{sp} of calcium phosphate = 2.07 x 10^{-33} mol ⁵ dm ⁻¹⁵)	[2]
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2	Chloric acid, HCIO is both a strong acid and an oxidising agent. It is corrosive and will accelerate
	the burning of combustible materials.

(a) When reacted with excess aqueous potassium hydroxide, HClO is converted into water and two chloro-containing products, one of which is a chloro-oxo anion.

In an experiment, 0.5 mol of chloro-oxo anion was reacted with excess potassium iodide to form a brown solution and chloride ion. It was discovered that the brown solution required 3 moles of sodium thiosulfate for complete reaction.

(i) (ii)	Calculate the number of moles of electrons gained by 1 mole of chloro-oxo anion in the reaction with potassium iodide. Hence, prove that the chloro-oxo anion is ClO_3^- . The other chloro-containing product formed a white precipitate with silver nitrate solution.	[3]
	Identify this other chloro-containing product. Write an equation for the reaction	
	between chloric acid and excess potassium hydroxide.	[2]
	••••••	
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(b)	Use of Data Booklet is relevant to this question.				
	An e	xperiment was carried out to determine the enthalpy change of neutralisation of chlo	oric		
	acid.	25 cm ³ of 1 mol dm ⁻³ chloric acid was mixed with 25 cm ³ of 1.5 mol dm ⁻³ potassis	um		
	hydro	oxide and there was an increase in temperature by 8 °C.			
	(i)	Explain the term standard enthalpy change of neutralisation.	[1]		
	(ii)	Calculate the enthalpy change of neutralisation. Assume that the specific heat	_		
	(iii)	The enthalpy change of neutralisation between a strong acid and a strong base	[2]		
	(,	is -57.3 kJ mol ⁻¹ . Suggest a reason for the difference between this value and			
		1.400	[1]		
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(c) Glutamic acid is often used as a food additive and a flavour enhancer. The structure of a fully protonated glutamic acid is as shown, with the p K_a values (2.1, 4.1 and 9.5) assigned.

- (i) Explain the assignment of pK_a values to the respective acidic groups. [3]
- (ii) Suggest the structural formulae of the major species present in solutions of glutamic acid with the pH values of 3.0, 6.0, and 10.0. [3]
- (iii) The structure of compound **H** is as shown.

H has 2 pKb values.

- $pK_{b1} = 4.5$
- $pK_{b2} = 11.9$

Calculate the pH of a 0.50 mol dm⁻³ solution of **H**. Ignore the effect of pK_{b2} on pH.

(iv) Sketch the pH-volume curve that you would expect to obtain when 25 cm³ of 0.50 mol dm⁻³ compound **H** is titrated with 60 cm³ of 0.50 mol dm⁻³ chloric acid.

Briefly describe how you have calculated the various key points on the curve.

[3]

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	[Total: 19]

3 (a) LiAlH₄ and H₂ are useful reducing agents in organic chemistry. Esters are reduced by LiAlH₄ and the equation is as shown.

Compound I contains an ester functional group and undergoes the following reactions with LiA/H₄ and H₂.

(i)	Compounds I, J, K and L react with Na, as well as with alkaline aqueous louine.	
	Suggest the structures for I, J and L.	[3]
(ii)	Sodium boron hydride, NaBH ₄ , is used in the reduction of compound M to form compound K . Given that M reacts with 2,4-DNPH but not Fehling's solution, suggest the structure for M .	[1]
		••••
		••••
		••••
		••••

(b)	Both	NaBH4 and LiA/H4 produce the hydride ion, H-, as the reacting species du	ıring
	redu	ction.	
	(i)	Explain why LiA/H₄ is a stronger reducing agent than NaBH₄.	[1]
	(ii)	When NaBH ₄ is added to propanal and propanone separately, it was found that	
		propanal reacts faster than propanone.	
		Suggest two reasons for this observation.	[2]
	/***		

(iii) LiA/ H_4 is used in the following synthesis.

Suggest a 3-stage synthesis for the above conversion. You should state the
reagents and conditions needed for each step and show clearly the structures of
any intermediate compounds. [4]

(c) Sodium hydride is a strong base commonly used in the Williamson Ether Synthesis. An example is the synthesis of isopropyl methyl ether from isopropanol.

The mechanism is as follows:

Step 1: Hydride ion removes a H^+ from isopropanol to form an alkoxide, $CH(CH_3)_2O^-$ and hydrogen gas.

Step 2: The alkoxide acts attacks the electron deficient carbon atom of chloromethane to form the ether and Cl^- .

(i)	Outline the mechanism for step 2 of the Williamson Ether Synthesis of isopropyl	
	methyl ether. Label the partial charges on the reacting species and use curly	
	arrows to show the flow of electrons during the reaction.	[2]
(ii)	CH ₂ ClCH ₂ OH reacts with sodium hydride via the Williamson Ether Synthesis to	
	form an ether with the molecular formula C ₂ H ₄ O. Draw the structure of this ether.	[1]
		• • • •
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(d) Compound Q, C₁₁H₁₄, exists as a mixture of two stereoisomers but it contains no chiral centre. Q decolourises hot acidified potassium manganate(VII) to give R, C₉H₈O₃, as one of the organic products. R reacts with alkaline aqueous iodine to give a yellow precipitate and a soluble salt. Upon acidification, the soluble salt forms aqueous benzene-1,2-dicarboxylic acid as shown.

 ${f Q}$ also reacts with cold concentrated sulfuric acid followed by steam to give ${f S}$, ${f C}_{11}{f H}_{16}{f O}$. ${f S}$ is able to rotate plane-polarised light but does not react with aqueous alkaline iodine.

Deduce the structures of Q , R and S , explaining the reactions described.	[6]
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[Total: 20

Section B

Answer one question from this section.

4 Nitrogen is a critical nutrient for the survival of all living organisms, as it is a necessary component of many biomolecules, such as proteins. Although nitrogen is very abundant in the atmosphere, it needs to be converted into ammonia for it to be available to primary producers, such as plants. This process is called nitrogen fixation. Only a select group of bacteria can carry out this energetically demanding process. The equation for nitrogen fixation is as shown.

$$N_2 + 8H^+ + 8e^- \rightarrow 2NH_3 + H_2$$

(a)	By using appropriate data from the <i>Data Booklet</i> , explain why nitrogen fixation is an				
	energetically demanding process.	[1]			
		· • • • • • • • • • • • • • • • • • • •			

(b) Bacteria that carry out nitrogen fixation have an enzyme called nitrogenase. Nitrogenase contains an iron-sulfur-molybdenium metal cluster, as shown in **Fig. 4.1**. Histidine (His) and cysteine (Cys) are two important amino acids present in the active site of nitrogenase.

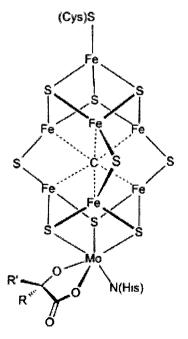


Fig. 4.1

[1]

(i)	Molybdenium, 42Mo, is in the same group as chromium and has a similar
	electronic configuration as chromium.

In the diagram below, show how the electrons are arranged in the 4d and 5s orbitals of Mo atom.

<u></u>	4d	5s	[1]
Draw a fully labelled diagram	of a 4d orbita	al that lies along bo	th the x and y
axis.			[1]

State the shape about Mo in Fig. 4.1. (iii)

(ii)

axis.

The structure of cysteine (Cys) amino acid is given below. (iv)

Draw the stereoisomers of Cys.	[1]
	•••••

(c) Nitrogenase are deactivated in the presence of oxygen, as oxygen and nitrogen can compete for binding to iron in the active site of the enzyme.

Explain how oxygen is able to interact with nitrogenase in a similar manner as nitrogen. [1]

(d) Nitrogenase is stable when the temperature is between 20 °C to 40 °C.
The kinetics of nitrogen fixation by nitrogenase was studied at 20 °C. The final concentration of NH₃ formed was found to be 0.16 mol dm⁻³.

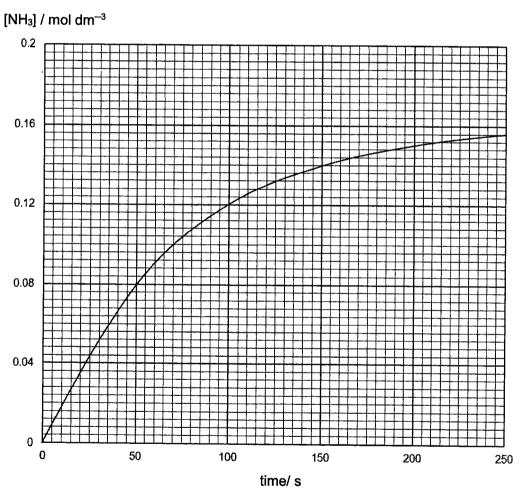


Fig. 4.2

i)	Explain the term rate of reaction.	[1]
ii)	Using Fig. 4.2, calculate the initial rate of reaction.	[1]
iii)	Use Fig. 4.2 to determine the order of reaction with respect to [N2]. Hence,	
-	sketch a graph of rate against initial $[N_2]$.	[3]
iv)	On Fig. 4.2, sketch how the graph would look like when the experiment is	
	carried out at 40 °C. Label this new graph as Y.	
	Explain your answer using the Collision Theory.	[3]
	•••••	
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(e) Denitrification is an important process because it converts nitrate back into nitrogen gas.

A Latimer diagram shows the standard electrode potentials connecting various oxidation states of an element. The sum of the standard electrode potential for each reduction is the same as the standard electrode potential for the overall reduction.

The Latimer diagram for some nitrogen-containing species in acidic medium is as shown below.

$$+0.42V$$
 $+0.34V$ $+1.18V$ $+1.35V$
 $NO_3^ \longrightarrow$ $NO_2^ \longrightarrow$ NO \longrightarrow $1/2N_2O$ \longrightarrow $1/2N_2O$
Step 1 Step 2 Step 3 Step 4

(i) (ii)	Draw a dot-and-cross diagram of NO ₂ ⁻ . State the bond angle of the ion. Explain how the Latimer diagram shows that NO is an intermediate in the	[2]
	denitrification process.	[1]
(iii)	Write a half equation for the reduction of NO_3^- to N_2 in acidic medium.	[1]
(iv)	Use the Latimer diagram to calculate the standard electrode potential for the	
	reduction of NO ₃ ⁻ to N ₂ . Hence, calculate the standard Gibbs free energy	
	change, ΔG^{e} , per mole of N_{2} formed.	[2]
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[Total:	20]

- 5 This question is about the chemistry of titanium and its ions.
 - (a) Titanium (II) oxide, TiO, and titanium (IV) dioxide, TiO₂, are common sources of titanium ions with different oxidation states.

compound	melting point / °C
TiO	1750
TiO₂	1843

- (i) State the electronic configuration of a Ti²⁺ ion.
- (ii) Explain, in terms of structure and bonding, the difference in melting point between TiO and TiO₂.
- (iii) TiO₂ is a catalyst used in the anti-Markvonikov hydrosilyation of gaseous alkenes with gaseous silane, SiH.

$$R$$
 + SiH $\xrightarrow{\text{TiO}_2}$ R Si

Outline the mode of action of TiO₂ catalyst in this reaction.

[2]

[1]

[2]

(iv) Alkynes can react with silane in a similar way as alkenes.
Suggest the alkene formed when the following alkyne undergoes hydrosilyation with TiO₂.

H— 	CH ₃	[1]
	••••••	

(b) The use of renewable energy sources, such as solar energy, has been gaining momentum around the world with the aim of realising a carbon-zero society. However, climate change can affect the power output and therefore, there is a need to use large-scale batteries to store the power harnessed.

One such example is shown in **Fig. 5.1**. The battery uses the redox couple Mn²⁺/Mn³⁺ in one electrolyte tank and Ti³⁺/TiO²⁺ in another. Sulfuric acid is the electrolyte in both tanks.

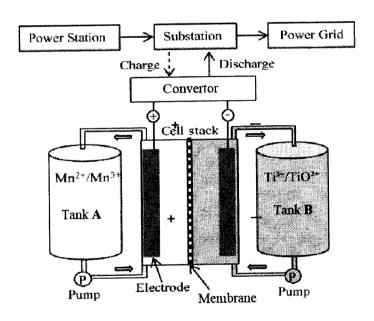


Fig. 5.1

The standard electrode potential for the reduction of TiO²⁺ is as given.

$$TiO^{2+} + 2H^+ + e^- \rightleftharpoons Ti^{3+} + H_2O$$
 $E^0 = +0.10 \text{ V}$

(i)	Write an equation to represent the discharging of this battery.	[1]
(ii)	Use the Data Booklet to calculate the E^{e}_{cell} when the battery is discharged.	
	Hence, calculate the standard Gibbs free energy change, ΔG° , per mole of Mn ³⁺	
	used in the discharging process.	[2]
(iii)	Suggest and explain the effect on E_{cell} if an electrolyte of lower pH was used.	[2]
(iv)	Sulfuric acid, which is a source of H ⁺ , will flow through the exchange membrane	
	as the battery discharges.	
	Suggest the direction of flow of H ⁺ through the membrane. Explain your answer.	[2]
(v)	Suggest an advantage of using porous carbon electrodes.	[1]
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[1]

(c)	(i)	With reference to the table below, suggest the colour change in Tank B wher
		the battery is charging.

Species

Ti³⁺ (aq)

TiO²⁺ (aq)

Colour

violet

colourless

		r41
(ii)	Explain what is meant by the term transition element.	[1]
(iii)	Explain why Ti ³⁺ (aq) ions are coloured, but TiO ²⁺ (aq) ions are not.	[3]
(iv)	Two separate solutions of Ti ³⁺ and Al ³⁺ are acidic.	
	Using relevant data from the Data Booklet, predict which solution of equal	
	concentration, Ti ³⁺ or Al ³⁺ , will give a lower pH.	[1]
	[Total	: 20]

END OF PAPER

Additional Answer Space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

Name:		Shift:
Class:	218	Lab:

ST ANDREW'S JUNIOR COLLEGE



JC2 PRELIMINARY EXAMINATION

CHEMISTRY

Paper 4 Practical

9729/04

18 Aug 2022

2 hours 30 minutes

Additional Materials: Qualitative Analysis Notes

READ THESE INSTRUCTIONS FIRST.

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

Give details of the practical shift and laboratory in the boxes provided above.

Write in dark blue or black pen.

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

Do not use staples, paper clips, highlighters, 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.

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

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

For Examiner's Use	
1	
	19
2	14
3	14
4	8
Total	55

This document consists of 22 printed pages, including 1 blank page.

Turn Over

1 Determination of water of crystallisation in a sample of hydrated copper(II) sulfate

The formula of hydrated copper(II) sulfate is $CuSO_4 \cdot xH_2O$, where x refers to the number of moles of water of crystallisation. In 1(a)(i), you will perform titration to determine the value of x.

Excess aqueous KI is first added to copper(II) sulfate solution. This will produce a white precipitate in a brown solution of I_2 .

equation 1
$$Cu^{2+}(aq) + 2I^{-}(aq) \rightarrow CuI(s) + \frac{1}{2}I_{2}(aq)$$

The liberated iodine is then titrated against sodium thiosulfate.

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

You are provided with:

- solid FA 1, hydrated copper(II) sulfate
- FA 2, 0.100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃
- FA 3, potassium iodide solution, KI
- Solution S, starch solution.

Note: Solution S will also be used in Question 2.

(a) (i) Procedure

- 1. Fill a burette with FA 2.
- Weigh accurately about 5 g of FA 1. Record the mass on page 3. Transfer all the solids into a 100 cm³ beaker. Add about 75 cm³ of deionised water and stir with a glass rod to dissolve them.
- Transfer the solution into a 250 cm³ volumetric flask. Rinse the beaker with deionised water and pour the washings into the volumetric flask.
- Make up to the 250 cm³ mark with deionised water. Stopper the volumetric flask and shake well to mix. Label this solution as FA 4.
- Pipette 25.0 cm³ of FA 4 into a conical flask and use a measuring cylinder to add 15 cm³ of FA 3 into the same conical flask.
- 6. Titrate this solution with **FA 2** until the mixture becomes pale brown. An off-white precipitate is also present in the conical flask.

- 7. Add approximately 1 cm³ of **solution S** to the conical flask and continue titration until the blue-black colour just disappears, with the off-white precipitate remaining in the conical flask.
- 8. Discard the contents and rinse the conical flask with water.
- 9. Repeat the titration to obtain consistent results. Record your titration results in the space below.

Results

4

	(ii)	From your titrations, obtain a suitable volume of FA 2 to be used in your calculations. Show clearly how you obtained this volume.	
(b)	(i)	Volume of FA 2 =	[1]
	(ii)	Amount of $Cu^{2+} = \dots mol$ Calculate the concentration of Cu^{2+} in FA 4 .	[1]
	(iii)	Concentration of $Cu^{2+} = \dots$ mol dm ⁻³ Given that the concentration of $CuSO_4*xH_2O$ in FA 4 is 20.00 g dm ⁻³ , use your answer in (b)(ii) to determine the value of x . [A_r : H, 1.0 Cu, 63.5 S, 32.1 O, 16.0]	[1]
		x =	[4]

(iv) In step 5, FA 3 was added using a 25 cm3 measuring cylinder. Calculate the

		percentage error in the measurement of the specified volume in step 5.	
		Percentage error = %	[1]
(c)	(i)	A student conducted the experiment as mentioned in (a)(i). After carrying out step 5, he left the conical flask containing FA 3 and FA 4 to stand for 30 minutes, before continuing with steps 6 to 8. It was noted that his titre volume was less than expected. Suggest a reason for this observation.	
			[1]
	(ii)	Two other students conducted the same experiment in (a)(i) but with the following modifications to the procedures.	
		Student 2: In Step 5, add 30 cm ³ of FA 3 instead of 15 cm ³ .	
		Student 3: In Step 7, omit the use of solution S.	
		Explain how each of these modifications will affect the accuracy of the results.	
		Student 2	
		Student 3	
			[2]

(iii)	Another student proposed the followin	g modification
-------	---------------------------------------	----------------

• Filtering the contents in the conical flask after step 5, before carrying out the titration in step 6.

State an advantage and a disadvantage of this modification.	
	[2
	L~

(d) Table 1.1 shows some standard electrode potential values.

Table 1.1

electrode reaction	E°/V
Cu ²⁺ + e ⁻ ⇌ Cu ⁺	+0.15
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54

The E^{\bullet}_{cell} for equation 1 is -0.39 V. Explain why the reaction occurred in (a)(i) despite the	t
negative <i>E</i> ° _{œll} value.	
	[2]
Пот	al: 19

2 Determination of the kinetics of the iodide-peroxodisulfate redox reaction

This question seeks to investigate the kinetics of the redox reaction between iodide ions, I^- , and peroxodisulfate ions, $S_2O_8^{2-}$. The redox reaction may be represented by the equation below.

$$2I^{-}(aq) + S_2O_8^{2-}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

In order to measure the rate of this reaction, a fixed volume of aqueous sodium thiosulfate, $Na_2S_2O_3$, is added to the reaction mixture. Starch is also added to the reaction mixture. When the sodium thiosulfate completely reacts with the iodine produced, the remaining iodine reacts with starch to form a dark blue complex.

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

The rate of reaction is studied by measuring the time taken for the solution to turn dark blue, t, in a series of five experiments. You will then graphically analyse your results to determine the order of reaction with respect to $[I^-]$.

FA 5 is 0.100 mol dm⁻³ potassium iodide, KI.

FA 6 is 0.500 mol dm⁻³ sodium peroxodisulfate, Na₂S₂O₈.

FA 7 is 0.00500 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

You will also need Solution S from Question 1.

- (a) Prepare a table in the space provided on page 9 to record, to an appropriate level of precision:
 - volume of FA 5, V_{FA 5}
 - · volume of deionised water,
 - all values of t.
 - all calculated values of 1/t, lg(1/t) and lg(V_{FA 5}).

Experiment 1

- 1. Fill the burette with FA 5.
- 2. Transfer 20.00 cm³ of FA 5 into a 250 cm³ conical flask.
- 3. Using separate 10 cm³ measuring cylinders, add 10.0 cm³ of FA 7 and 1.0 cm³ of Solution S into the same conical flask.
- 4. Using a 25 cm³ measuring cylinder, measure 20.0 cm³ of FA 6.
- 5. Start the stopwatch upon adding **FA 6** into the conical flask. Swirl the reaction mixture and place the conical flask on a white tile.

[Turn Over

- 6. Stop the stopwatch when the solution first turns dark blue.
- 7. Record the time taken, t, to the nearest second in your table.
- 8. Discard the reaction mixture and wash out the conical flask. Stand it upside down on a paper towel to drain.

Experiments 2 to 5

Repeat experiment 1 four times, using 18.00 cm³, 16.00 cm³, 14.00 cm³ and 12.00 cm³ of **FA 5** respectively at step 2.

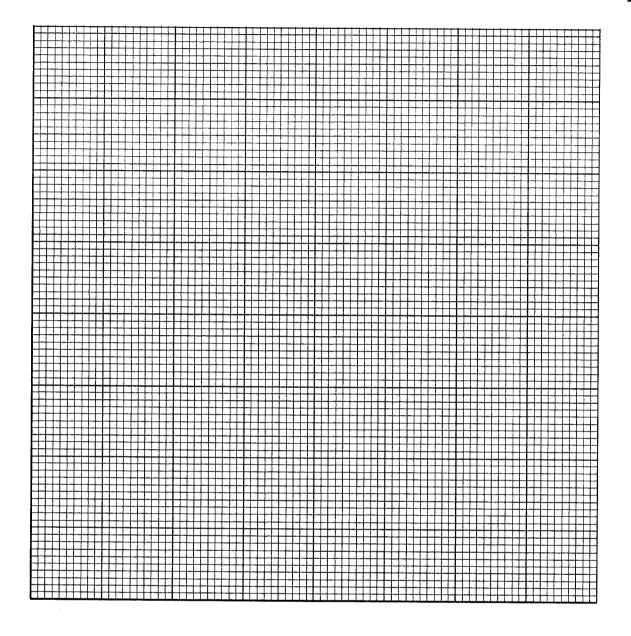
In each experiment, you will need to ensure that the same total volume of reaction mixture is used by adding appropriate volumes of deionised water.

You should alternate the use of the two conical flasks.

Results

(b) (i) Plot a graph of $\lg(1/t)$ on the y-axis against $\lg(V_{FA5})$ on the x-axis. Draw a best-fit straight line through your plotted points.

[3]



(ii)	Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence, deduce the order of reaction with respect to $[I^-]$.	
	Gradient = Order of reaction with respect to [I ⁻] =	[3]
(iii)	Explain why the total volume of the reaction mixture needs to be kept constant in all five experiments in (a).	
(i)	Iron(III) salts are sometimes used as a catalyst for the reaction you performed in (a).	[1]
	Suggest why there is a need for a catalyst.	[1]
	(iii)	Gradient = Order of reaction with respect to [I ⁻]. (iii) Explain why the total volume of the reaction mixture needs to be kept constant in all five experiments in (a). (iv) Iron(III) salts are sometimes used as a catalyst for the reaction you performed in (a). Suggest why there is a need for a catalyst.

(ii) Using data from **Table 2.1** below, show how iron(III) ions can perform this role and write relevant equation(s).

Table 2.1

electrode reaction	E°∕V
Fe ³⁺ + 3e ⁻ === Fe	-0.04
Fe ³⁺ + e ⁻ Fe ²⁺	+0.77
$I_2 + 2e^- \longrightarrow 2I^-$	+0.54
$S_2O_8^{2^-} + 2e^- = 2SO_4^{2^-}$	+2.01

[2]

[Total: 14]

3 Investigation of some inorganic reactions

(a) FA 8 is a solid which contains one cation and one anion from those listed in the Qualitative Analysis Notes.

Perform the tests described in **Table 3.1**. Record your observations in the table. In all the tests, the reagent should be added gradually until no further change is observed, with shaking after each addition. Test and identify any gases evolved. No additional or confirmatory tests for ions present should be attempted.

Table 3.1

	Tests	Observations for FA 8
1.	Place a spatula of FA 8 in a dry boiling tube and heat.	
2.	Add a spatula of FA 8 in a test-tube. Add 1 cm depth of H ₂ O ₂ , followed by 1 cm depth of aqueous sodium hydroxide.	
3.	Add half a spatula of FA 8 into a test-tube. Add aqueous ammonia dropwise until it is in excess.	

	4.	Add half a spatula of FA 8 into a test- tube and dissolve with 1 cm depth deionised water. Use a glass rod to stir if necessary. Add aqueous sodium carbonate		
		dropwise to the resultant solution until it is in excess.		[4]
(b)	Cons	ider your observations in Table 3.1 .		
	(i)	Based on your observations for test 2,	suggest the role of FA 8 .	
				[1]
	(ii)	Table 3.2 shows the K_{sp} values for both	copper(II) carbonate and cop	per(II) hydroxide.
			Table 3.2	
			K _{sp}	
		CuCO₃	1.4 x 10 ⁻¹⁰ mol ² dm ⁻⁶	-
		Cu(OH) ₂	4.8 x 10 ⁻²⁰ mol ³ dm ⁻⁹	-

Calculate the solubility of each salt. Hence, suggest the identity of the species responsible for the observations seen in test 4.

 [3]

[Turn Over

[1]

c)		determine the identity of anion in FA 8 , a tion of FA 8 . A white ppt is formed.	student added barium nitrate solution to a
	(i)	Based on the observations given, state t	he possible identities of the anions.
			······
	(ii)	Suggest a test to confirm the identity of	the anion in FA 8 . DO NOT carry out the test.
		Test:	
d)	Note	e: You are NOT given FA 9.	
	Ana		nd one anion from those listed in the Qualitation is performed on FA 9 and the correspond
		Та	ble 3.3
		Test Test	Observations for FA 9
			Observations for FA 9
	(i)	Test To 1 cm depth of a solution of FA 9, add aqueous ammonia dropwise	Observations for FA 9 A white ppt is formed. It dissolves in excess aqueous ammonia to give a colourless solution.
	(i) (ii)	Test To 1 cm depth of a solution of FA 9, add aqueous ammonia dropwise until it is in excess. Suggest the identity of the cation preserved	Observations for FA 9 A white ppt is formed. It dissolves in excess aqueous ammonia to give a colourless solution.
		Test To 1 cm depth of a solution of FA 9, add aqueous ammonia dropwise until it is in excess. Suggest the identity of the cation preserved	Observations for FA 9 A white ppt is formed. It dissolves in excess aqueous ammonia to give a colourless solution.

(iii) Assuming you have an aqueous solution of FA 9.

There is no observable change when barium nitrate solution is added to FA 9 solution.

Devise a series of simple tests to identify the anion in **FA 9**. Your tests should be based on the Qualitative Analysis Notes and should use only the bench reagents provided. Record your tests in the space below.

[2]

[Total: 14]

4 Planning

The labels for a bottle of carbonic acid and a bottle of citric acid were mixed up. Both acids have the same concentration of 1.00 mol dm⁻³. Carbonic acid is dibasic and citric acid is tribasic. In order to identify the correct acids, a series of six experiments will be performed, where different volumes of the acid from one of the bottles and sodium hydroxide are chosen to ensure there are sufficient points before and after the equivalence point. The total volume for each experiment should be kept constant at 60.0 cm³.

The temperature change, ΔT , for each neutralisation is calculated using the formula below:

$$\Delta T = T_{\text{final}} - T_{\text{average}}$$

where T_{average} is the weighted average of the initial temperatures of the acid and sodium hydroxide:

$$T_{\text{average}} = \frac{(V_{\text{acid}} \times T_{\text{acid}}) + (V_{\text{NaOH}} \times T_{\text{NaOH}})}{V_{\text{acid}} + V_{\text{NaOH}}}$$

A suitable graph can then be plotted to determine the basicity of the acid.

Let the unknown acid be HxA. The neutralisation reaction is shown below.

$$H_xA + xNaOH \rightarrow Na_xA + xH_2O$$
, where x = 2 or 3

You are provided with:

- 1.00 mol dm⁻³ sodium hydroxide, NaOH
- 1.00 mol dm⁻³ acid from one of the bottles, H_xA
- the equipment normally found in a school or college laboratory.
- (a) (i) Calculate the volumes of acid required for complete reaction if the acid is dibasic and tribasic respectively.

(ii) Using your answers in (i), fill in the volumes of acid and NaOH in the table below.

Experiment	Volume of acid / cm ³	Volume of NaOH / cm ³
1		
2		
3		
4		
5		
6		

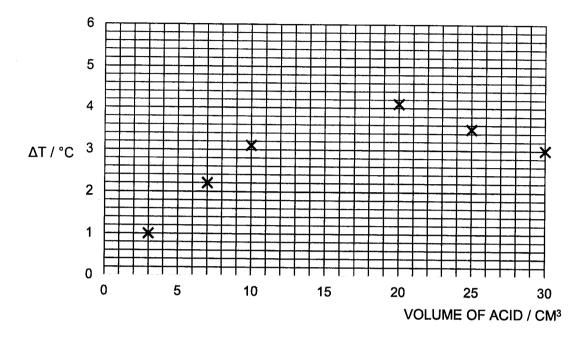
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- (b) In your plan to determine the basicity of H_xA, you should include brief details of:
 - the apparatus you would use;
 - the procedure you would follow;
 - the measurements you would make.

[Turn Over

[4]
 r -,1

(b) A student conducted the experiment and obtained the following graph of ΔT against volume of acid.



Draw 2 best-fit straight lines and extrapolate both lines to find volume of acid required to completely react with NaOH.

Hence, deduce the identity of the acid.

[2]

[Total: 8]

[BLANK]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

Cation	reaction with		
Cation	NaOH(aq)	NH₃(aq)	
aluminium,	white ppt.	white ppt.	
A <i>l</i> ³⁺(aq)	soluble in excess	insoluble in excess	
ammonium, NH₄⁺(aq)	ammonia produced on heating	_	
barium, Ba ²⁺ (aq)	no ppt. (if reagents are pure)	no ppt.	
calcium, Ca²⁺(aq)	white ppt. with high [Ca²+(aq)]	no ppt.	
chromium(III), Cr³⁺(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, Mg²⁺(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess	
manganese(II), Mn²+(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

ion	reaction		
carbonate,	CO ₂ liberated by dilute acids		
chloride, C <i>l</i> ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))		
bromide, Br (aq)	gives pale cream ppt. with Ag⁺(aq) (partially soluble in NH₃(aq))		
iodide, l⁻(aq)	gives yellow ppt. with Ag⁺(aq) (insoluble in NH₃(aq))		
nitrate, NO₃⁻(aq)	NH ₃ liberated on heating with OH ⁻ (aq) and A <i>l</i> foil		
nitrite, NO₂⁻(aq)	NH₃ liberated on heating with OH⁻(aq) and A <i>l</i> foil NO liberated by dilute acids (colourless NO → (pale) brown NO₂ in air)		
sulfate, SO₄²⁻(aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids)		
sulfite, SO₃²⁻(aq)	SO ₂ liberated on warming with dilute acids; gives white ppt. with Ba ²⁺ (aq) (soluble in dilute strong acids)		

(c) Tests for gases

gas	test and test result		
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, H₂	"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

Halogen	colour of element	colour in aqueous solution	colour in hexane
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