ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC 2 PRELIMINARY EXAMINATION

NAME:_____ ( ) **CLASS:** 21 /____

CHEMISTRY **9729/02**

Paper 2 Structured Questions **14 September 2021**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register 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.

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

For Examiner's Use		
Paper 2	1	/21
	2	/10
	3	/13
	4	/10
	5	/11
	6	/10
	Total	/75

This document consists of **23** printed pages and **1** blank page.

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

1 **(a)** Describe and explain the trend in electronegativity of elements across Period 3 from sodium to chlorine.

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……..

……[2]

(b) Some ionic radii are listed in the *Data Booklet*.

(i) Explain the trend in ionic radius down Group 2.

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……

……

……[2]

(ii) Explain the differences between the ionic radii of P^{3-}, Cl^- and Ca^{2+}.

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……

……

……[1]

(iii) Hence, suggest a value for the ionic radius of a potassium ion, K^+.

……[1]

(iv) Explain the difference in size between the radius of the potassium ion and the radius of a potassium atom.

……

……

……[1]

(c) Anodisation of aluminium is a process which coats an oxide layer on aluminium objects.

(i) Draw a labelled diagram of the electrolysis cell used to anodise a small piece of aluminium object. Include details of the cathode, anode and electrolyte.

[1]

(ii) Complete Table 1.1 to show the type of reaction occurring, with the relevant half–equations, during the anodisation of the aluminium object.

Table 1.1

	type of reaction occurring	half–equation(s)
anode		
cathode		

[2]

(d) The molecules of alcohol **P**, $C_7H_{16}O$, are optically active and does not react with hot, acidified $Na_2Cr_2O_7$(aq).

On treatment with Al_2O_3, **P** produces a mixture of four different isomeric alkenes with the formula C_7H_{14}, **only two** of which are cis–trans isomers of each other.

Suggest the structural formula of compound **P** and the four alkenes.

[4]

Question 1 continues on the next page.

(e) The following equilibrium exists in a sample of aluminium chloride vapour.

$$Al_2Cl_6(g) \rightleftharpoons 2AlCl_3(g)$$

(i) Draw a dot–and–cross diagram of the Al_2Cl_6 molecule, including its co–ordinate bonds.

[1]

When 1.50 g of aluminium chloride was introduced into an evacuated flask of 250 cm^3 capacity and heated to 500 K, the pressure inside the flask rose to 1.16 x 10^5 Pa.

(ii) Assuming the gaseous mixture behaves ideally, calculate the average M_r of the mixture. Give your answer to **four** significant figures.

[2]

(iii) Using the following relationships, calculate the mole fraction of Al_2Cl_6, x and the mole fraction of $AlCl_3$, y, in the mixture.

$$x + y = 1$$
$$\text{average } M_r = 267x + 133.5y$$

[1]

(iv) Hence calculate the partial pressures of Al_2Cl_6 and $AlCl_3$ in this mixture.

[1]

(v) Write an expression for K_p for the reaction, and calculate its value. Include units in your answer.

[2]

[Total: 21]

2 **(a)** When Group 2 iodates(V), $M(IO_3)_2$, is heated, it behaves in a similar way to the Group 2 carbonates. Upon heating, it decomposes as shown.

$$2M(IO_3)_2(s) \rightarrow 2MO(s) + 2I_2(g) + 5O_2(g) \qquad \text{(where M is a Group 2 metal)}$$

(i) Using your knowledge of Group 2 carbonates, suggest and explain the trend in thermal stabilities of the Group 2 iodate(V).

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……

……

……[2]

X, **Y** and **Z** are Group 2 metals (Mg to Ba, not necessarily in that order).

$\mathbf{X}(IO_3)_2$, $\mathbf{Y}(IO_3)_2$ and $\mathbf{Z}(IO_3)_2$ are Group 2 iodates(V). The three graphs in Fig. 2.1 show the change in mass when 2.00 g each of $\mathbf{X}(IO_3)_2$, $\mathbf{Y}(IO_3)_2$ and $\mathbf{Z}(IO_3)_2$ were heated separately at a temperature *T* °C.

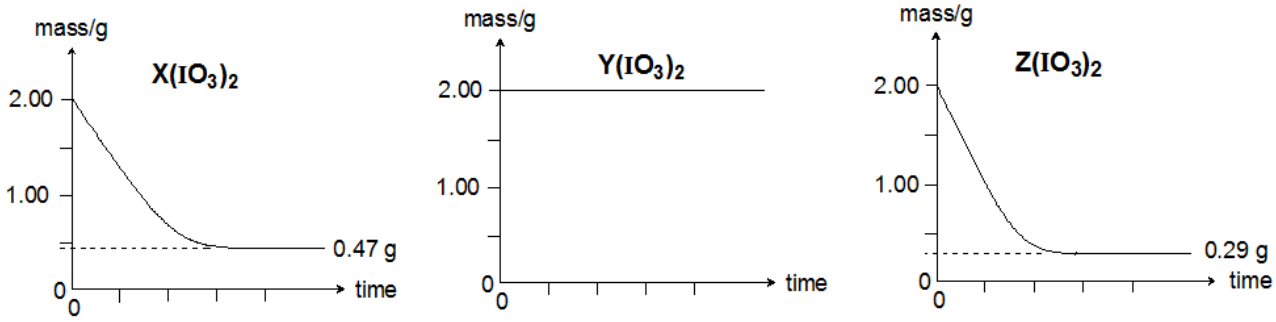

Fig. 2.1

(ii) With reference to the information from Fig. 2.1, show, by calculations, that none of the above iodate(V) samples contains $Mg(IO_3)_2$.

[2]

(iii) Hence, suggest the identities of the three iodates(V).
[No calculation is required.]

iodates(V)	**X**$(IO_3)_2$	**Y**$(IO_3)_2$	**Z**$(IO_3)_2$
identity			

[1]

(b) When a salt such as a Group 2 sulfate dissolves in water, the lattice energy must be overcome.

(i) How will the **magnitude** of the lattice energy of Group 2 sulfates change from $MgSO_4$ to $BaSO_4$?

……...

……....[1]

(ii) Suggest a reason for this trend.

……

……

……

……

……...….[1]

(iii) Draw a simple diagram to show how a water molecule can be attached to a magnesium cation, and to a sulfate anion. Show the displayed structure of the sulfate anion in your answer and label each diagram to show the type of interaction involved.

Mg^{2+} cation	SO_4^{2-} anion

[3]

[Total: 10]

Question 3 starts on the next page.

3 Trisoxazoline are organic molecules that can function as ligands. Despite their huge molecular structure, they are able to form stable complexes with metals. Metal complexes with trisoxazoline, such as copper(II)-trisoxazoline, are commonly used as catalyst in organic synthesis.

(a) With the aid of a Boltzmann distribution, explain how a catalyst increases the rate of reaction.

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……..

…….[3]

(b) Fig. 3.1 illustrates the synthesis of trisoxazoline.

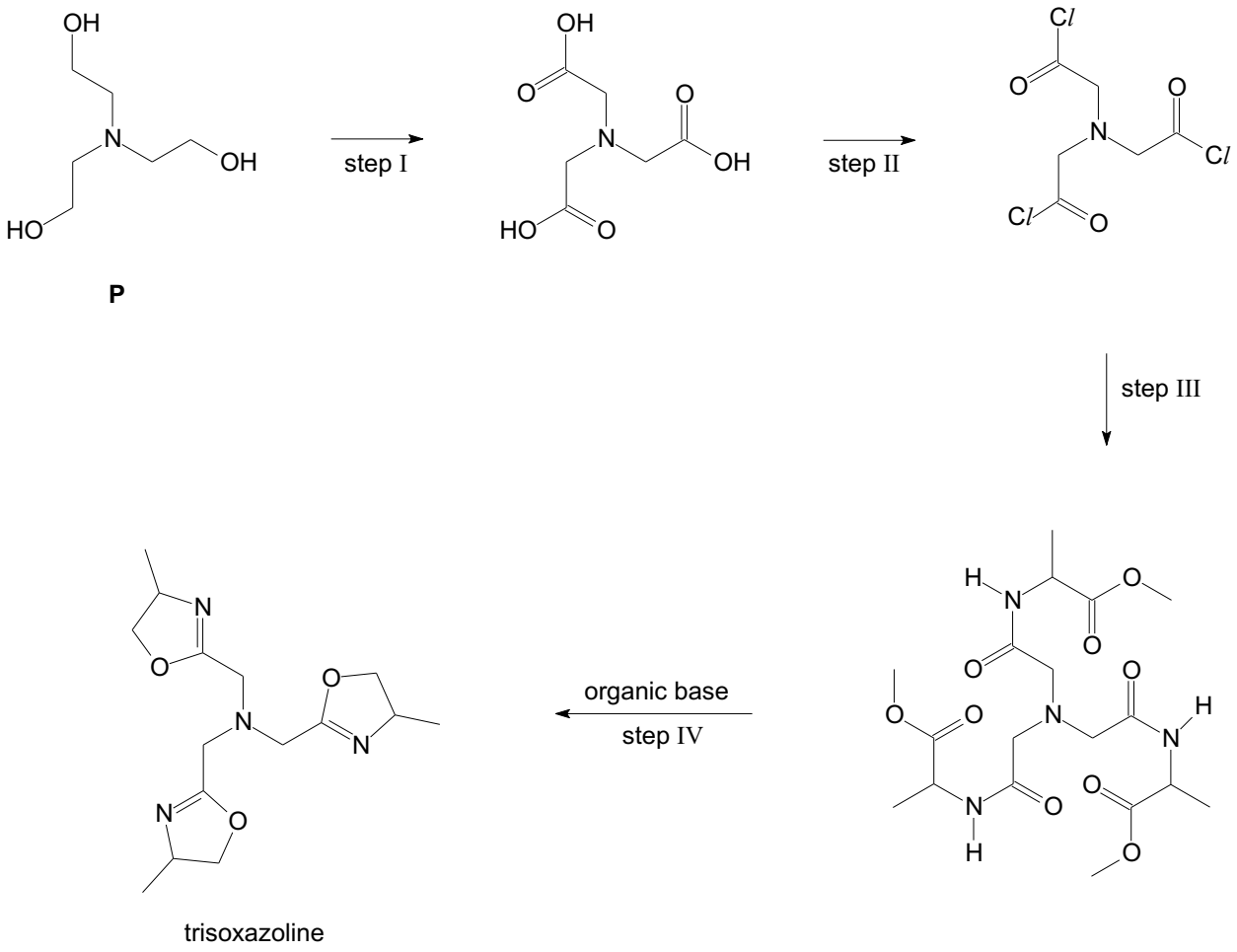

Fig. 3.1

(i) State the *types of reaction* that occur during each of the steps I and II.

step I: ……

step II: ……

[2]

(ii) Suggest, with reason, the pH of the solution when the resultant product from step II is dissolved in water.

……

……[1]

(iii) Suggest the reagents and conditions required for steps II and III.

step II: ……

step III: ……

[2]

(iv) Compound **P** in Fig. 3.1 can be synthesised from ethene via a two–step reaction scheme shown below.

Suggest the reagents required for each step.

step a: …….

step b: …….

[2]

(c) Other than copper(II) ions, it was found that copper(I) ions are also able to form complexes with trisoxazoline.

Complete the full electronic configuration of copper(I) ions.

copper(I) ion: $1s^2$ …… [1]

(d) Copper is in increasing demand for use in electric vehicles, consumer electronics and other energy efficient targets. Most current copper extraction processes burn sulfide minerals in air which produces sulfur dioxide which is harmful to the environment.

Describe and explain with the aid of suitable equations, the role of NO_2 in the oxidation of atmospheric sulfur dioxide.

……..

……..

……..

……..

…….[2]

[Total: 13]

4 **(a)** A 2.00 g sample of an organic substance **Z** containing only C, H and O was burned completely. The only combustion products were 2.90 g of carbon dioxide and 1.20 g of water.

(i) Define the term *relative molecular mass*.

……

……[1]

(ii) Given that the relative molecular mass of the organic substance **Z** is 90.0, show that the molecular formula is $C_3H_6O_3$.

[2]

(iii) Draw two constitutional isomers of **Z** which can react with sodium carbonate.

[2]

(b) Complete the reaction scheme in Fig. 4.1 to show how compound **E** could be synthesised from ethylbenzene in **three** steps using suitable reagents.

Show the structures of the intermediate compounds and state the reagents and conditions for each step.

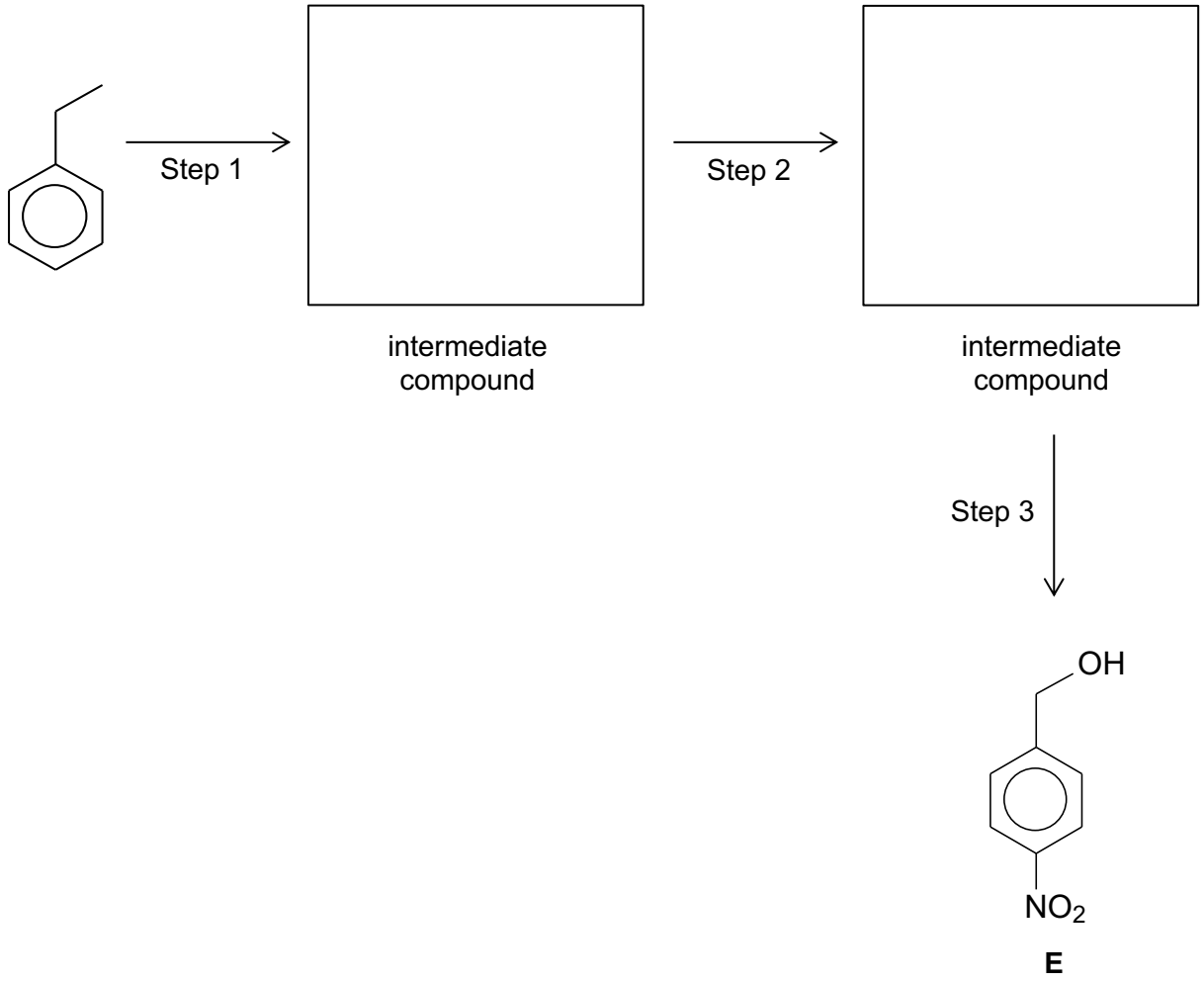

Fig. 4.1

Step 1: ……

Step 2: ……

Step 3: ……

[5]

[Total: 10]

Question 5 starts on the next page.

5 This question is about the chemistry of compounds containing halogen.

(a) Bromoalkane can undergo two different mechanisms for nucleophilic substitution − S_N1 and S_N2.

Experiments were conducted in two different set–ups to measure the relative rates of nucleophilic substitution for three bromoalkanes. Set–up 1 and 2 use different nucleophiles.

Table 5.1 summarises the relative rates of the three bromoalkanes in the experiments.

Table 5.1

bromoalkane	CH_3CH_2Br	$(CH_3)_2CHBr$	$(CH_3)_3CBr$
relative rate in set–up 1	4×10^{-2}	1	4×10^{6}
relative rate in set–up 2	30	1	5×10^{-5}

(i) Predict the predominant mechanism for set–up 2. Explain your answer.

……..

……..

……..

……..

…….[2]

(ii) Explain the relative rate of $(CH_3)_3CBr$ in set–up 1.

……..

……..

……..

……..

…….[1]

(b) 2–iodobutane can be readily converted into 2–aminobutane using ethanolic ammonia.

$$CH_3CHICH_2CH_3 + 2NH_3 \rightarrow CH_3CH(NH_2)CH_2CH_3 + NH_4I$$

In order to determine the rate equation for this reaction, an investigation was carried out at a constant temperature. Equal volume of 0.20 mol dm^{-3} 2–iodobutane and 4.00 mol dm^{-3} ethanolic ammonia were mixed. At suitable time intervals, 10 cm^3 of the reaction mixture was pipetted into a conical flask and quenched.

Chlorine gas was bubbled into the aliquot and excess chlorine gas was subsequently removed. Iodine is liberated by the following reaction.

$$Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$$

The iodine was then titrated with 0.0250 mol dm^{-3} sodium thiosulfate in the presence of an indicator.

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

Fig. 5.1 shows the volume of sodium thiosulfate used against time for this experiment.

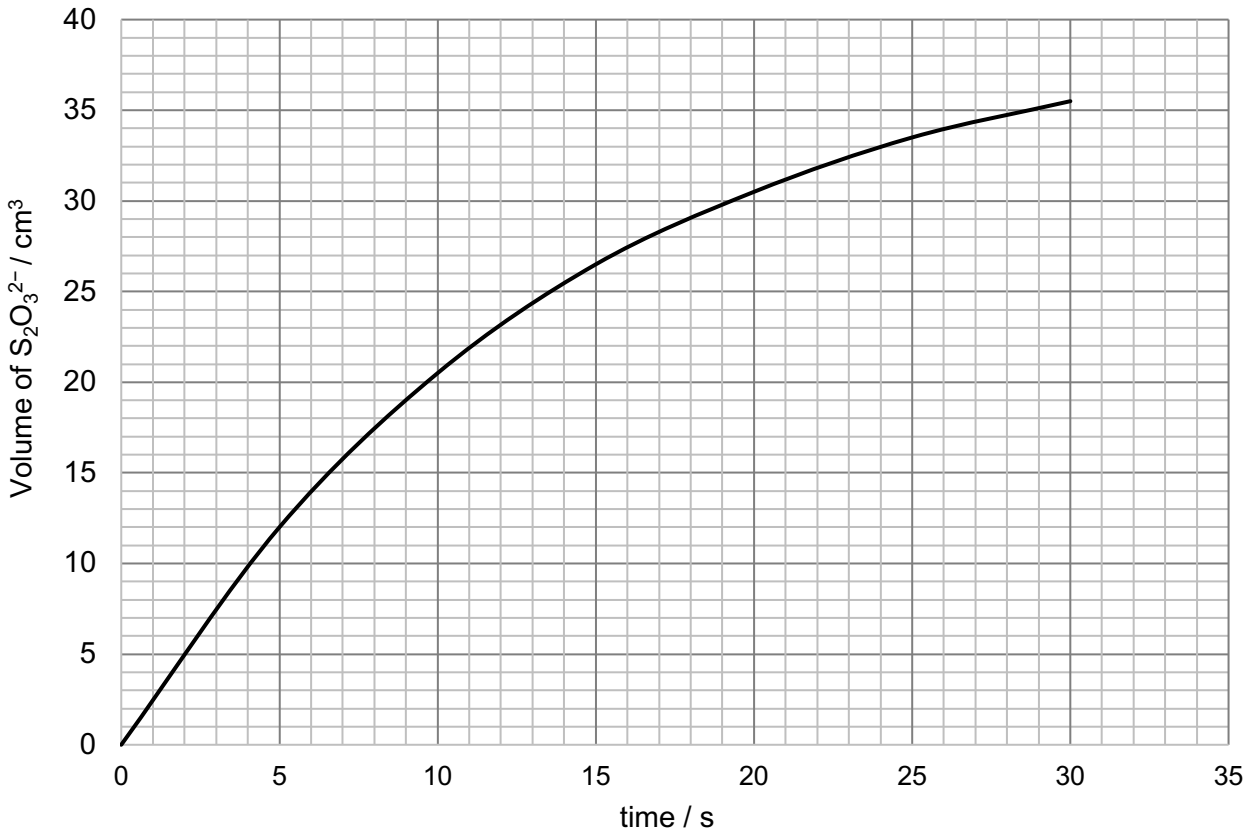

Fig. 5.1

(i) Prove that the volume of $S_2O_3^{2-}$ required when the reaction between 2–iodobutane and ethanolic ammonia goes to completion in this investigation is 40 cm^3.

[1]

(ii) Hence, use Fig. 5.1 to deduce the order of reaction with respect to 2–iodobutane.

order = ……[2]

(iii) The concentration of ethanolic ammonia is halved and a new series of experiments was carried out at the same temperature.

It is known that that the order of reaction with respect to ethanolic ammonia is one.

Suggest how the gradient at each point will change when a similar graph like the one in Fig. 5.1 was plotted.

……

……

……[1]

(iv) Hence, construct the rate equation for the reaction between 2–iodobutane and ethanolic ammonia.

……[1]

(v) Calculate the value of the rate constant for the reaction between equal volumes of 0.20 mol dm^{-3} 2–iodobutane and 4.00 mol dm^{-3} ethanolic ammonia and state its units.

value of rate constant = ……

units = ……
[2]

(c) Iodide ions, I^-, can react with peroxodisulfate, $S_2O_8^{2-}$.

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

A student wanted to investigate the effect of changes in volume used on the rate of this reaction.

Table 5.2 shows the results obtained when a series of experiments was carried out using different volumes of the two reagents, each solution being made up to the same total volume with water, where necessary.

Table 5.2

experiment	volume of KI / cm^3	volume of $Na_2S_2O_8$ / cm^3	volume of water / cm^3	initial rate / mol dm^{-3} s^{-1}
1	10	20	10	0.0200
2	5	20	15	0.0100
3	30	10	0	0.0303

Given that the order of reaction with respect to I^- is 1, determine the order of reaction with respect to $S_2O_8^{2-}$.

order = ……[1]

[Total: 11]

6 **(a)** Ammonia can act as a weak base.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq) \qquad pK_b = 4.75$$

$(NH_4)_2SO_4$ is a weak acid. Calculate the pH of 0.10 mol dm^{-3} $(NH_4)_2SO_4(aq)$.

[2]

(b) A buffer solution with a pH 8.90 is made by adding 150 cm^3 of solution **B** containing ammonium chloride to 100 cm^3 of 0.0200 mol dm^{-3} aqueous NH_3.

Calculate the concentration of ammonium chloride in solution **B**.

[3]

(c) Write equations to explain how the $NH_3(aq)/NH_4^+(aq)$ buffer system helps to maintain the pH.

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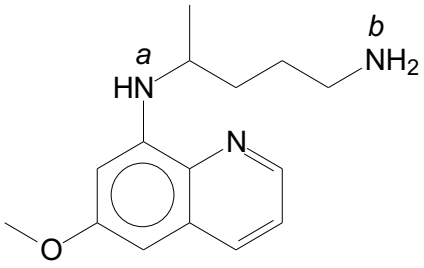
……[2]

(d) Malaria is a serious and sometimes fatal mosquito–borne disease. *Primaquine* is an antimalaria drug used to prevent relapse of malaria infections.



primaquine

Two of the pK_b values associated with *primaquine* are 4.1 and 9.8.

(i) Using this information, write the pK_b values for the nitrogen–containing groups *a* and *b* in *primaquine*.

nitrogen–containing	group *a*	group *b*
pK_b		

[1]

(ii) Suggest an explanation for your assignment of the pK_b values in **(d)(i)**.

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……

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……

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……[2]

[Total: 10]

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