

NAME \_\_\_\_\_

CLASS 21S



**JURONG PIONEER JUNIOR COLLEGE**  
**JC2 PRELIMINARY EXAMINATION 2022**

**CHEMISTRY****9729/02****Higher 2****14 September 2022**

Paper 2 Structured Questions

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

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

Write in dark blue or black pen on both sides of the paper.

You may use a HB pencil for any diagrams, 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 Examiner's Use	
1	10
2	10
3	17
4	10
5	11
6	12
7	5
<b>Penalty</b> (delete accordingly)	
Bond linkages	-1 / NA
Significant figures & units	-1 / NA
<b>Total</b>	<b>75</b>

This document consists of 21 printed pages inclusive of 1 blank page.

Answer **all** the questions in this section.

- 1 (a) Figure 1.1 shows the **third** ionisation energies of eight consecutive elements A to H, in the Periodic Table.  
[Note that letters A to H are not the atomic symbols of the elements concerned.]

For  
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Use

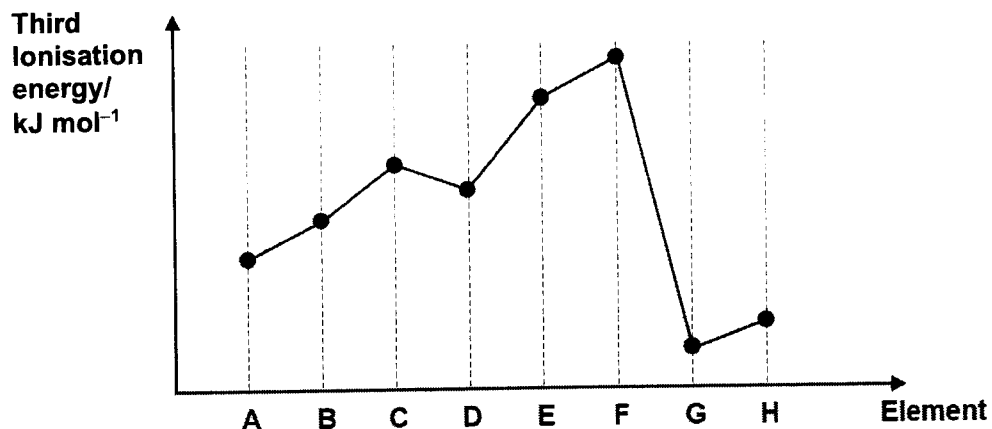


Figure 1.1

- (i) Write an equation, including state symbols, to represent the *third ionisation energy* of element A.

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[1]

- (ii) From Figure 1.1, suggest the identity of B. Explain how you arrived at your answer.

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[2]

- (iii) Explain why the third ionisation energy of element D is slightly lower than that of element C.

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[1]

(b) Nitrogen and phosphorus are elements of Group 15 in the Periodic Table. Nitrogen exists naturally as gaseous diatomic  $\text{N}\equiv\text{N}$  molecules whereas phosphorus is a solid and exists as  $\text{P}_4$  molecules comprising of P-P single bonds.

(i) Account for the difference in their physical states in terms of structure and bonding.

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[2]

(ii) Suggest why phosphorus does **not** occur naturally as  $\text{P}\equiv\text{P}$  molecules.

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[1]

(iii) Nitrate,  $\text{NO}_3^-$ , and phosphate,  $\text{PO}_4^{3-}$ , are oxoanions of nitrogen and phosphorus respectively.

Draw a dot-and-cross diagram to show the bonding  $\text{PO}_4^{3-}$ , deducing the shape and the bond angle around the phosphorous atom.

Hence explain why it is not possible for nitrogen to form an oxoanion with formula of  $\text{NO}_4^{3-}$ .

[3]

[Total: 10]

- 2 Iron oxides are chemical compounds composed of iron and oxygen. Most iron ores are oxides, making them important precursors to iron metal and its many alloys.

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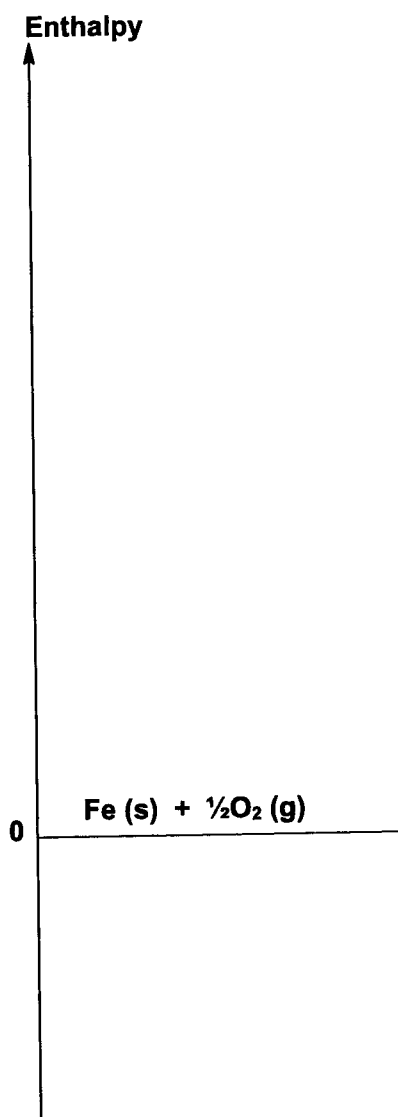
- (a) Iron (II) compounds are only stable in neutral, non-oxidising conditions.

It is difficult to determine the lattice energy of FeO experimentally.

- (i) Given the following data in Table 2.1 and data from the *Data Booklet*, draw and complete the energy diagram below to calculate the lattice energy of FeO(s) in  $\text{kJ mol}^{-1}$ .

standard enthalpy change of atomisation of Fe(s)	+416 $\text{kJ mol}^{-1}$
standard enthalpy change of formation of FeO(s)	-272 $\text{kJ mol}^{-1}$
Sum of 1 <sup>st</sup> and 2 <sup>nd</sup> electron affinity of oxygen	+157 $\text{kJ mol}^{-1}$

Table 2.1



[3]

5

- (ii) Most naturally occurring samples of iron(II) oxides are found as the mineral Wüstite.

Wüstite has the formula  $\text{Fe}_{20}\text{O}_x$ . It contains both  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  ions. 90% of the iron is present as  $\text{Fe}^{2+}$  and the remaining as  $\text{Fe}^{3+}$ .

By means of calculations, deduce the value of x.

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Use

[1]

- (iii) State and explain how the lattice energy of FeO compares with the lattice energy of  $\text{Fe}_2\text{O}_3$ .

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[2]

- (b) Another common iron oxide as hematite,  $\text{Fe}_2\text{O}_3$  is the main source of iron for the steel industry.  $\text{Fe}_2\text{O}_3$  will readily react with acids to form soluble salts such as the following reaction.



- (i) Define standard enthalpy change of solution.

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[1]

- (ii) Use the data in Table 2.2 to calculate the enthalpy change of solution of iron (II) iodide,  $\text{FeI}_2$ .

$\Delta H_{\text{latt}}(\text{FeI}_2(\text{s}))$	$- 2440 \text{ kJ mol}^{-1}$
$\Delta H_{\text{hyd}}(\text{Fe}^{2+}(\text{g}))$	$- 1950 \text{ kJ mol}^{-1}$
$\Delta H_{\text{hyd}}(\text{I}^{-}(\text{g}))$	$- 308 \text{ kJ mol}^{-1}$

**Table 2.2**

For  
Examiner's  
Use

[1]

- (iii) A yellow precipitate of  $\text{PbI}_2$  forms when  $25 \text{ cm}^3$  of  $x \text{ mol dm}^{-3}$   $\text{Pb}^{2+}$  ions are added to  $10 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$   $\text{FeI}_2(\text{aq})$ .

Given that the solubility product,  $K_{\text{sp}}$ , of  $\text{PbI}_2 = 9.8 \times 10^{-9} \text{ mol}^3 \text{ dm}^{-9}$ , find the minimum value for  $x$ , concentration of  $\text{Pb}^{2+}$  for precipitation to occur.

[2]

[Total: 10]

- 3 Carboxylic acids and their derivatives are classes of organic compounds that play important roles in our everyday lives. Some of their uses include the manufacturing of polymers, production of pharmaceutical drugs, as food additives and industrial solvents.

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This question deals with some of the properties of acidic organic compounds, including carboxylic acids and their derivatives.

- (a) Table 3.1 below shows three organic compounds that can be found in nature.

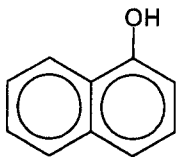
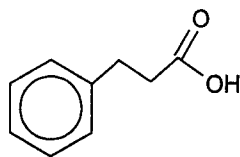
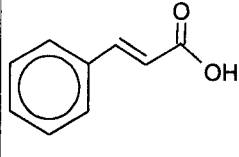
name	1-naphthol	hydrocinnamic acid	cinnamic acid
where it can be found	<i>selaginella sinensis</i> tree	cowberries	cinnamon
structural formula			
$pK_a$	9.51	4.70	4.37

Table 3.1

- (i) By reference to the structures, explain why cinnamic acid will be the first to react when aqueous KOH is added dropwise to a mixture containing both cinnamic acid and hydrocinnamic acid.

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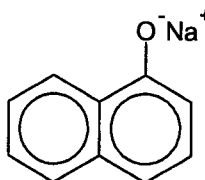
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[2]

- (ii) With the aid of balanced equation(s), explain any reaction(s) that occurs when a solution containing sodium 1-naphtholate is added to a solution containing hydrocinnamic acid.



sodium 1-naphtholate

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[2]

A laboratory technician was tasked to prepare a buffer solution by mixing hydrocinnamic acid and aqueous potassium hydroxide.

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(iii) What is a buffer solution?

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(iv) Write equations to show how a mixture of hydrocinnamic acid and its salt can function as a buffer.

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(v) Using appropriate data from Table 3.1 in (a), determine the volume of  $0.100 \text{ mol dm}^{-3}$  KOH(aq) the student needs to add to  $0.100 \text{ dm}^3$  of  $0.100 \text{ mol dm}^{-3}$  hydrocinnamic acid to form a buffer of pH 5.50.

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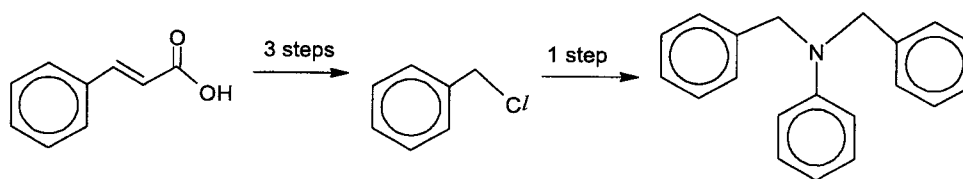
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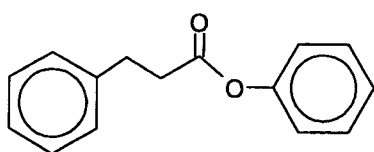
- (b) The diagram below shows a reaction scheme involving cinnamic acid.



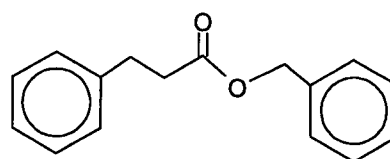
For  
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[3]

- (c) Hydrocinnamic acid form many different types of esters that have great commercial uses. Two such esters are shown below:



ester P



ester Q

- (i) Suggest a simple chemical test that would enable the laboratory technician to distinguish between the two esters.

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- (ii) State the type of reaction that occurred when hydrocinnamic acid forms these esters.

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[1]

- (d) Describe and explain the trend observed in the thermal stability of the carbonates of the Group 2 elements,  $\text{MCO}_3$ .

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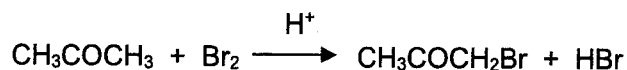
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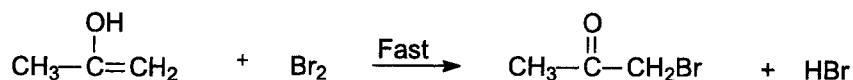
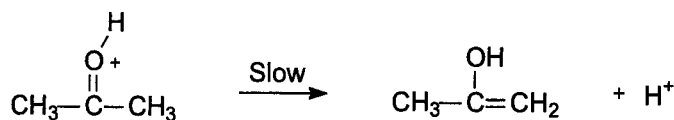
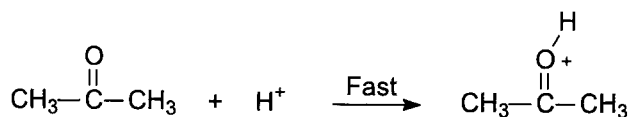
- 4 Carbonyl compounds can react with halogens in acidic or alkaline medium to form different products. Kinetic studies are conducted to investigate the orders of reaction and the mechanisms of these reactions.

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In acidic medium, propanone reacts with bromine to form bromopropanone as shown in the equation below:



The kinetic studies of the above reaction have shown that the reaction is second order overall, and a three-step mechanism is involved in this reaction.



- (a) From the mechanism above, construct the rate equation for the above reaction.

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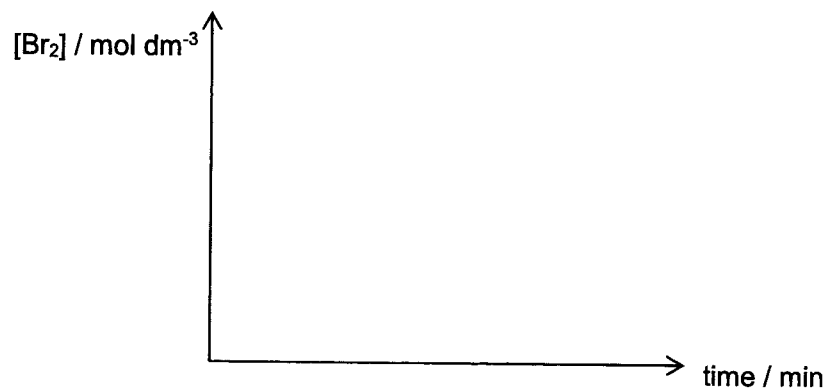
[1]

- (b) From the mechanism above, how can you deduce that  $\text{H}^+$  is acting as a catalyst?

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[1]

- (c) Sketch, in the space below, the graph of  $[\text{Br}_2]$  against time in minutes, given that the initial concentration of  $\text{Br}_2$  is  $0.008 \text{ mol dm}^{-3}$  and initial concentration of propanone,  $\text{CH}_3\text{COCH}_3$ , is  $0.80 \text{ mol dm}^{-3}$ .



[1]

- (d) Explain what will happen to the rate of reaction if chlorine is used in place of bromine, assuming that the mechanism remains unchanged?

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- (e) The kinetics data for the experiment may be collected using a continuous sampling method, which requires a sample of the chemical reaction to be extracted at various time intervals from a reaction mixture followed by titration.

Briefly describe a physical property that allows you to determine the  $[Br_2]$  at various times.

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- (f) The reaction between  $CH_3COCH_3$  and  $Br_2$  was carried out in experiments 1 and 2, and the following results were obtained:

Experiment	Initial $[CH_3COCH_3]/$ $mol\ dm^{-3}$	Initial $[H^+]/$ $mol\ dm^{-3}$	Initial $[Br_2]/$ $mol\ dm^{-3}$	Half-life / min
1	0.40	0.30	0.20	22.5
2	0.60	0.10	0.20	<b>s</b>

The half-life of  $CH_3COCH_3$  in experiment 1 was found to be constant at 22.5 minutes. Predict the value of half-life of  $CH_3COCH_3$  in experiment 2, **s**, giving your reasoning.

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- (g) With the aid of a labelled Boltzmann distribution diagram, explain how the presence of a catalyst affects the rate of a chemical reaction.

[3]  
 [Total:10]

- 5 (a) Compound **P**,  $C_5H_{10}O_2$  is optically active. It reacts with 2,4-dinitrophenylhydrazine to give an orange precipitate. However, **P** does not react with Tollens' reagent.

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Upon reaction with sodium metal, **P** produces effervescence that extinguishes a lighted splint with pop sound. **P** forms a yellow precipitate when treated with alkaline aqueous iodine, and upon acidification, **Q**,  $C_3H_4O_4$  is formed as the resulting compound.

**Q** reacts with  $Na_2CO_3(aq)$  to produce effervescence that forms white precipitate with limewater.

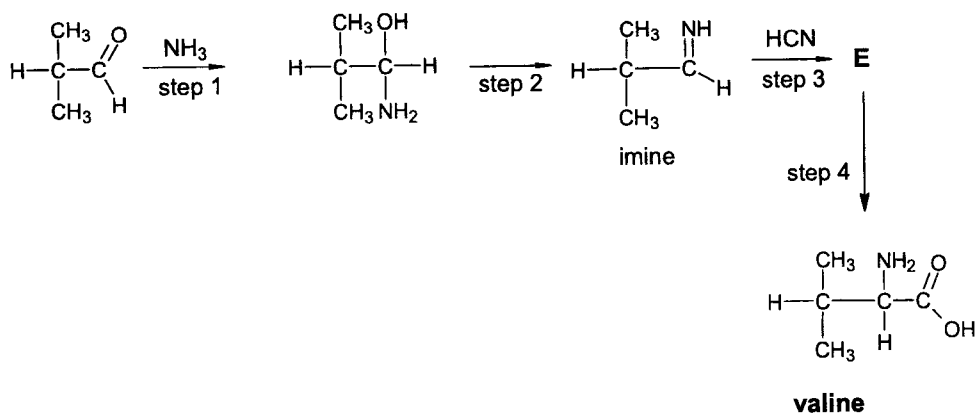
- (i) Suggest the structure of compound **Q**.

[1]

- (ii) Suggest a structure of **P** that is consistent with the information provided, giving your reasoning.

[3]

- (b) The Strecker synthesis is a method to prepare  $\alpha$ -amino acids. The amino acid valine can be prepared from 2-methylpropanal via Strecker synthesis as shown below.



- (i) Suggest the type of reaction occurring in step 2.

[1]

- (ii) Given that the reaction of the imine in step 3 with  $\text{HCN}$  is similar to the reaction of a carbonyl compound with  $\text{HCN}$ , suggest the structure of **E**.

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[1]

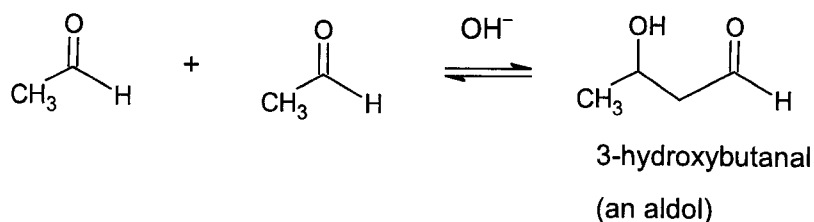
- (iii) Valine can exist as a pair of stereoisomers. Draw the 2 stereoisomers of valine.

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[2]

- (c) The aldol reaction is a useful method of making new carbon-carbon bonds in organic chemistry. It involves combining two molecules of the same aldehyde to form a product which contains both an aldehyde and alcohol functional groups. Thus, it is also known as the **aldol** reaction.

Ethanal undergoes base-catalysed aldol reaction as shown below.

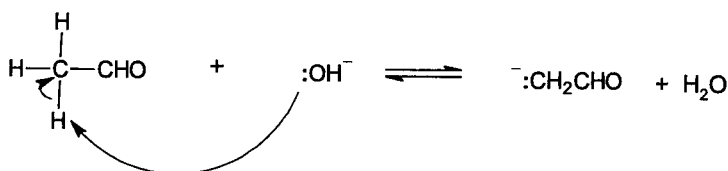


The aldol synthesis involved the following reactions in two stages:

Stage 1:

An acid-base reaction takes place between the  $\text{OH}^-$  base and the acidic H atom bonded to alpha C of an ethanal molecule, forming a carbanion.

The first stage is drawn below.



Stage 2:

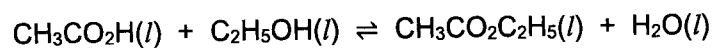
The carbanion formed in stage 1 attacks the delta positive carbon of another ethanal molecule, forming a tetrahedral intermediate which is negatively charged. The tetrahedral intermediate rapidly reacts with  $\text{H}_2\text{O}$  to form the aldol product and regenerates back the  $\text{OH}^-$  catalyst.

Name and outline the mechanism for stage 2.

[3]

[Total:11]

- 6 (a) The value of the equilibrium constant is 4.0 for the reaction below:



- (i) Write an expression for the equilibrium constant,  $K_c$ , of the **reverse** reaction, i.e. the hydrolysis of ethyl ethanoate, stating its numerical value.

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[2]

- (ii) In an experiment, 2 mol of ethyl ethanoate and 2 mol of water are mixed.

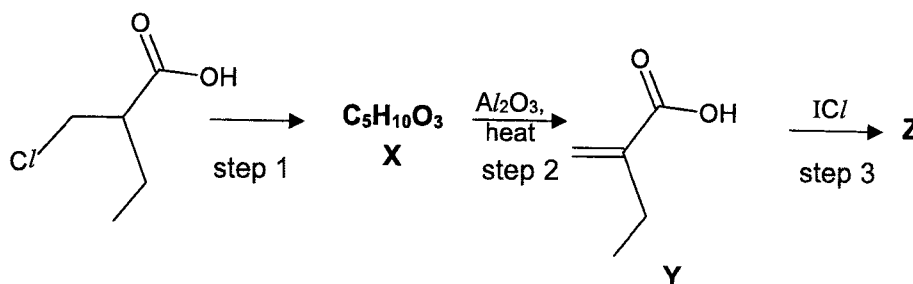
Calculate the number of moles of each substance present when equilibrium is reached.

[2]



- (b) The following shows a flow scheme involving a chlorocarboxylic acid to form compounds X, Y and Z.

For  
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Use



- (i) Suggest the structure of compound X.

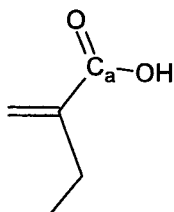
[1]

- (ii) Give the reagents and conditions for step 1.

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[1]

- (iii) State the hybridisation of  $C_a$  labelled in the structure of Y below.



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[1]

- (iv) Give the structure of compound Z.

[1]

- (v) Give the structure of the product formed when compound Y is reacted with hydrogen with nickel, upon heating.

For  
Examiner's  
Use

Aluminium objects that have had the aluminium oxide layer removed may then be oxidised.

[1]

- (c) (i) State why aluminium objects are anodised.

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[1]

- (ii) Complete Table 6.1 below to show the type of reaction occurring, with the relevant half-equations, during the anodising of an aluminium object.

	type of reaction	half-equation(s)
anode		
cathode		

Table 6.1

[2]

[Total:12]

**19**  
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- 7 (a) Baryta water, barium hydroxide,  $\text{Ba}(\text{OH})_2(\text{aq})$  is a Bronsted base.

For  
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Use

Define what is meant by a Bronsted base.

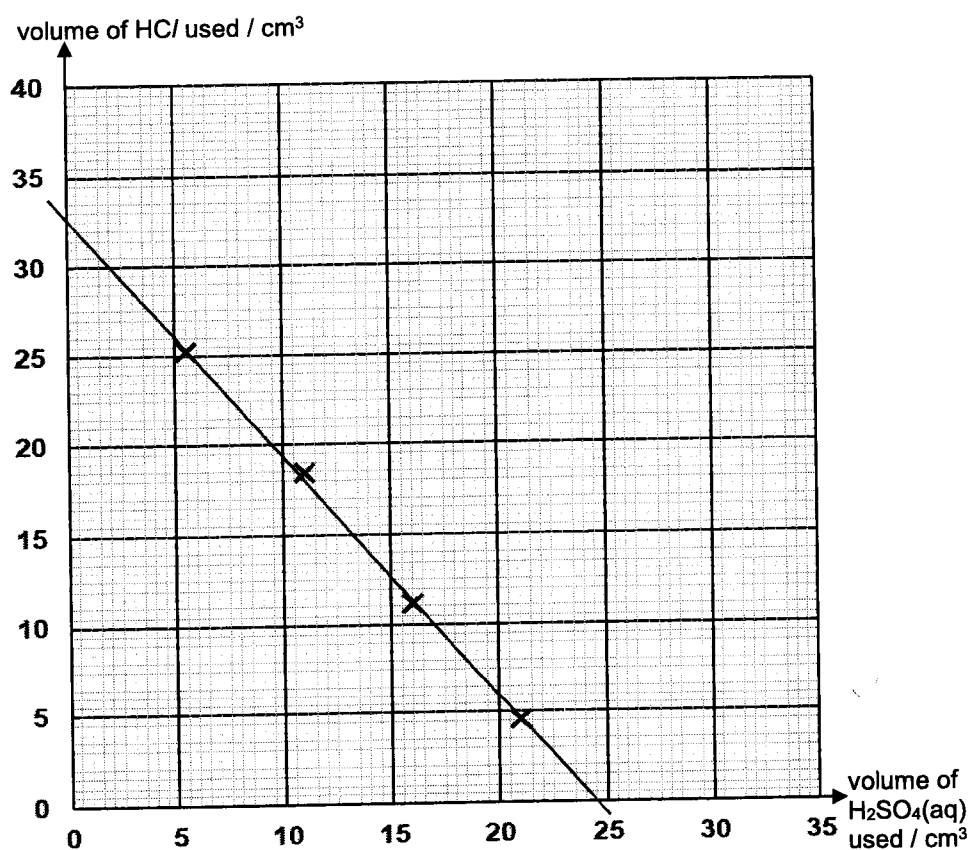
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[1]

- (b)  $\text{Ba}(\text{OH})_2(\text{aq})$  neutralises both  $\text{H}_2\text{SO}_4$  and  $\text{HCl}$  acid. In an experiment, a student prepared 4 mixtures, each containing the same volume of  $25.0 \text{ cm}^3$  of  $\text{Ba}(\text{OH})_2$  solution, but with different volumes of sulfuric acid added.

In each mixture, neutralisation has not been completed, the solution remains alkaline and is neutralised by titration with  $0.150 \text{ mol dm}^{-3}$   $\text{HCl}$  acid. A graph of volume of  $\text{HCl}$  on the y-axis was plotted against volume of  $\text{H}_2\text{SO}_4$  for each of the 4 mixtures. The graph is extrapolated until it touches both axes.



- (i) Read from the graph, and record the volume of  $\text{HCl}$  (Vol. $\text{HCl}$  (max), required to exactly neutralise  $25.0 \text{ cm}^3$  of  $\text{Ba}(\text{OH})_2$ .

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[1]

(ii) Calculate the concentration of  $\text{Ba}(\text{OH})_2$ .

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[2]

(iii) Explain in terms of the chemistry involved, why the direction of the slope of the graph is negative.

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[1]

[Total:5]

End of paper



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CLASS 21S

**JURONG PIONEER JUNIOR COLLEGE**  
**JC2 PRELIMINARY EXAMINATION 2022**

**CHEMISTRY****9729/03****Higher 2****19 September 2022**

Paper 3 Free Response Questions

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.  
 Write in dark blue or black pen on both sides of the paper.  
 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 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 Examiner's Use	
1	21
2	20
3	19
4 or 5	20
<b>Penalty</b> (delete accordingly)	
Lack 3sf in final answer	-1 / NA
Missing/wrong units in final ans	-1 / NA
Bond linkages	-1 / NA
<b>Total</b>	<b>80</b>

This document consists of **29** printed pages.

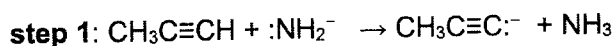
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## Section A

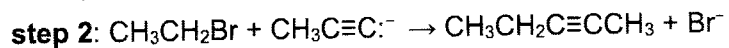
Answer all the questions in this section.

- 1 (a) Bromoethane reacts with "acetylide" anion,  $\text{CH}_3\text{C}\equiv\text{C}^-$  to form new carbon-carbon bonds. This reaction takes place in two steps.

In step 1, an acid-base reaction occurs.  $\text{CH}_3\text{C}\equiv\text{C}^-$  is formed from the reaction of propyne and a strong base, sodium amide,  $\text{NaNH}_2$ .



In step 2, the intermediate anion reacts with bromoethane to form the product.



Name and suggest the mechanism for **step 2**. Show relevant dipoles, using curly arrows to indicate the movement of electron pairs.

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- (b) 4-bromopentanol can be used to synthesise Compound C as shown in Fig. 1.1.

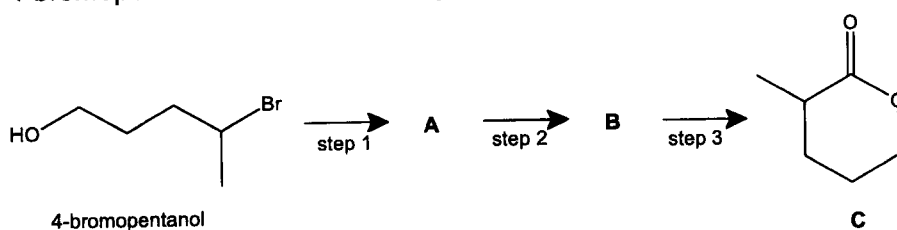


Fig. 1.1

Suggest the structures for compounds A, B, and reagents and conditions for steps 1, 2 and 3 in this route.

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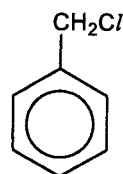
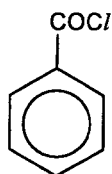
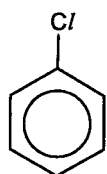
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- (c) Describe and explain the relative ease of hydrolysis of the following three chlorine-containing compounds.



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- (d) Ethanol is formed when bromoethane is heated with NaOH(aq).

The standard enthalpy change of combustion of ethanol is  $-1367 \text{ kJ mol}^{-1}$ . In an experiment, 0.23 g of ethanol was burned under a container, using a spirit lamp.

An unknown mass of water was heated from  $30 \text{ }^\circ\text{C}$  to its boiling point. The process was found to be 70 % efficient. Calculate the mass of water that could be brought to the boiling point by burning this amount of ethanol.

[Given specific heat capacity of water is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ ]

[2]

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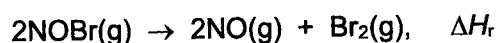
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- (e) (i) Nitrosyl bromide, Br-N=O is an inorganic halogen-containing compound. It decomposes to NO and Br<sub>2</sub> as shown below.



Given that the bond energy of N-Br is  $+120 \text{ kJ mol}^{-1}$ , use appropriate bond energy data from the *Data Booklet* to calculate the enthalpy change of decomposition of nitrosyl bromide.

[2]

- (ii) Enthalpy changes of formation of NOBr(g) and NO(g) and the enthalpy change of vaporisation of Br<sub>2</sub>(l) are given below.

$\Delta H_f(\text{NOBr(g)})$	$y \text{ kJ mol}^{-1}$
$\Delta H_f(\text{NO(g)})$	$+90 \text{ kJ mol}^{-1}$
$\Delta H_{\text{vap}}(\text{Br}_2\text{(l)})$	$+31 \text{ kJ mol}^{-1}$

With the aid of an energy cycle, use your answer in (i) and the given data to calculate the enthalpy change of formation of NOBr(g).

[3]

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- (f) (i) State how the reactivity of the halogens as oxidising agents varies down the group, and relate this variation to relevant  $E^\ominus$  values. [2]
- (ii) Describe a reaction that illustrates the relative oxidising abilities of two halogens of your choice. [1]
- (iii) The halogens iodine and chlorine react together to form solid iodine trichloride,  $ICl_3$ . Given the following enthalpy changes, calculate the standard enthalpy change of formation of  $ICl_3(s)$ .

$I_2(g) + 3Cl_2(g) \rightarrow 2ICl_3(s)$	$\Delta H^\ominus = -214 \text{ kJ mol}^{-1}$
$I_2(s) \rightarrow I_2(g)$	$\Delta H^\ominus = +38 \text{ kJ mol}^{-1}$

[1]

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2 (a) Explain why transition element complexes are usually coloured.

[3]

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(b) In a given electroplating experiment, a solution of  $\text{CrCl}_3(\text{aq})$  is electrolysed using a current of 3.50 A. Calculate the time, in min, required to produce 4.60 g of chromium by this electrolysis.

[2]

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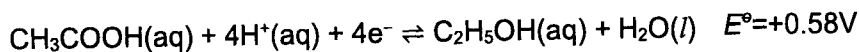
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(c) The half reaction involving conversion of ethanol to ethanoic acid is given below:



(i) Using *Data Booklet* and the above information, draw a fully labelled diagram of the experimental set-up used to measure the standard electrode potential of the  $\text{CH}_3\text{COOH}/ \text{C}_2\text{H}_5\text{OH}$  half-cell. Indicate the direction of movement of electrons in the external circuit when the cell is operating. [3]

(ii) The amount of ethanol in a person's breath can be measured using a breathalyzer, which uses a galvanic process.  $\text{C}_2\text{H}_5\text{OH}$  is oxidised to  $\text{CH}_3\text{COOH}$  and potassium dichromate,  $\text{K}_2\text{Cr}_2\text{O}_7$  is reduced to  $\text{Cr}^{3+}$  in acidic medium. The colour change observed is orange to green. [1]

Calculate  $E^\ominus_{\text{cell}}$  for the above reaction. [1]

(iii) Using the  $E^\ominus_{\text{cell}}$  calculated in (c)(ii), calculate  $\Delta G^\ominus$ , with units, for the cell reaction. [1]

(iv) State and explain how the e.m.f. of the cell would change if  $\text{HCl}(\text{aq})$  is added to the cathode half-cell in (c)(ii). [2]

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- (d) A solution of  $\text{XeF}_2$  is a strong oxidising agent. A solution containing  $25.0 \text{ g dm}^{-3}$  of  $\text{XeF}_2$  is reacted with another solution containing  $0.150 \text{ mol dm}^{-3}$  of a  $\text{Cr(III)}$  salt.

In an experiment,  $15.20 \text{ cm}^3$  of the  $\text{XeF}_2$  solution is required to completely react with  $10.0 \text{ cm}^3$  of the  $\text{Cr(III)}$  solution.  $\text{XeF}_2$  is reduced to  $\text{Xe}$  in the reaction.

Determine the final oxidation state of  $\text{Cr}$  after the reaction.

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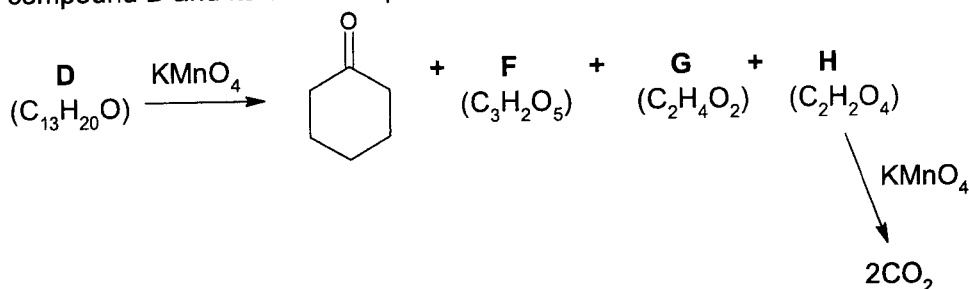
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- (e) Hot acidified  $\text{KMnO}_4$  oxidises several classes of organic compounds to ketones, carboxylic acids or carbon dioxide. By this means, the structures of compounds can be determined. Some compounds are easily oxidised while others require longer heating.

The following scheme shows the reaction with hot acidified  $\text{KMnO}_4$ , of compound **D** and its oxidation products.



- Compound **D** effervesces with sodium metal. **D** also reacts with hot acidified potassium dichromate(VI) to give a product with the formula  $\text{C}_{13}\text{H}_{18}\text{O}$ .
- Compound **F** gives an orange precipitate with 2,4-dinitrophenylhydrazine.
- Compounds **F**, **G** and **H** all dissolve in  $\text{NaOH}(\text{aq})$ .

(i) Explain these observations.

[2]

(ii) Suggest the structures of compounds **D**, **F** and **G**.

[3]

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[Total: 20]

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3 Nitrogen is the most abundant element in our planet's atmosphere. The various nitrogen-containing organic compounds play an important role in our lives, as they serve as the building materials for amino acids, proteins and even in our DNA.

(a) Table 3.1 below shows some **aromatic** organic nitrogen compounds that have important uses in both chemical and pharmaceutical industries.

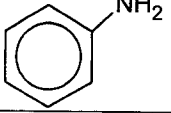
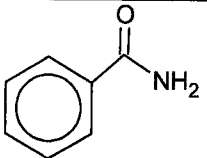
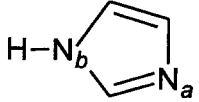
name of compound	structure	$K_b$
phenylamine		$3.98 \times 10^{-10}$
benzamide		$1.00 \times 10^{-14}$
imidazole		-

Table 3.1

- (i) Using the data provided in Table 3.1, suggest an explanation for the difference in the relative basicities of phenylamine and benzamide. [2]
- (ii) Based on the structure of a molecule of imidazole, suggest an explanation why nitrogen  $N_a$  would have a higher  $K_b$  value than  $N_b$ . [1]

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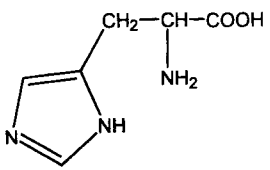
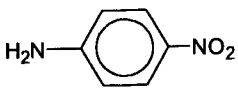
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- (b) Amino acids are sometimes referred to as the “building blocks of life”. In human beings, there are 20 amino acids that are used to manufacture the proteins required by the body.

One such essential  $\alpha$ -amino acid is histidine, that is required to maintain good mental and physical states of the human body.

Food sources such as fish, poultry and nuts are good sources of histidine.

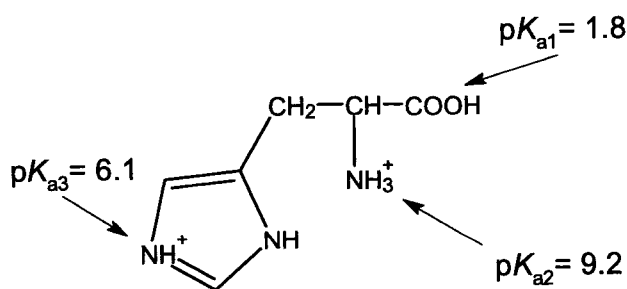
- (i) In terms of structure and bonding, explain why histidine has a much higher melting point than 4-nitrophenylamine, despite having similar *Mr* as shown in Table 3.2.

compound	structure	melting point/ °C
histidine		285
4-nitrophenylamine		146

[2]

Table 3.2

- (ii) The diagram below shows the protonated form of histidine, which can be represented by  $H_3A$ , and the respective acid dissociation constants for its three acidic groups.



Predict the structure of the major species that would be present when histidine is placed into buffer solutions with the following pH values:

- pH = 7
- pH = 12

[2]

(iii) A chemist invented two new enzymes:

- "histidinase-C" that can hydrolyse at the C-terminal of the histidine (His) amino acid residue;
- "lysinase-N" that can hydrolyse at the N-terminal of the lysine (Lys) amino acid residue;

A polypeptide chain from a liver protein consists of a total of 11 amino acids. This polypeptide was subjected to partial hydrolysis by these two enzymes separately, and the following fragments were obtained in Table 3.3.

Amino acid fragments obtained with histidinase-C:	Amino acid fragments obtained with lysinase-N:
Ala-Lys-Ser-His	Lys-Cys-His
Ser-Lys-His	Lys-Ser-His-Ser
Ser-Lys-Cys-His	Ser
	Lys-His-Ala

Table 3.3

Using the above information, deduce the correct sequence of the 11 amino acid residues in the polypeptide chain.

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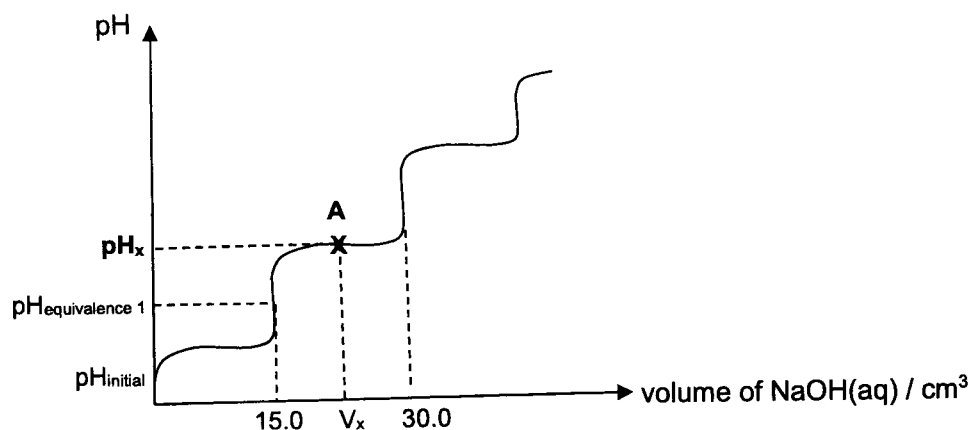
- (c) Information from 3(b)(ii) would be useful for this part of the question.

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Intrigued by his newly found knowledge on amino acids after completing his SLS lesson on Organic Nitrogen Compounds, a H2 Chemistry student from Jurong Pioneer JC decided to seek help from his chemistry tutor to conduct a more in-depth analysis.

He prepared a fresh sample containing 15.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> fully protonated histidine and titrated it against 0.100 mol dm<sup>-3</sup> NaOH(aq).

The following graph was obtained:



- (i) Calculate the initial pH of the 0.100 mol dm<sup>-3</sup> fully protonated histidine, H<sub>3</sub>A, pH<sub>initial</sub>. (Ignore the effect of pK<sub>a2</sub> and pK<sub>a3</sub> on the pH). [1]
- (ii) An amphiprotic species is one that is able to donate and accept a proton. The pH of a solution containing an amphiprotic species is given by the following expression.

$$\text{pH} = \frac{1}{2}(\text{p}K_1 + \text{p}K_2)$$

In the titration above, an amphiprotic species is formed at the first equivalence point, when 15.0 cm<sup>3</sup> of NaOH(aq) was added to the sample of protonated histidine.

Calculate the pH of the amphiprotic species formed at the first equivalence point and draw its structure. [2]

- (iii) Using your answer to 3(c)(ii) and Table 3.4 given below, choose the best indicator to detect the 1<sup>st</sup> end-point of the titration when 15.0 cm<sup>3</sup> of NaOH is added. Briefly explain your answer.

indicator	thymol blue	methyl yellow	methyl red
pK <sub>a</sub>	1.7	3.1	5.2

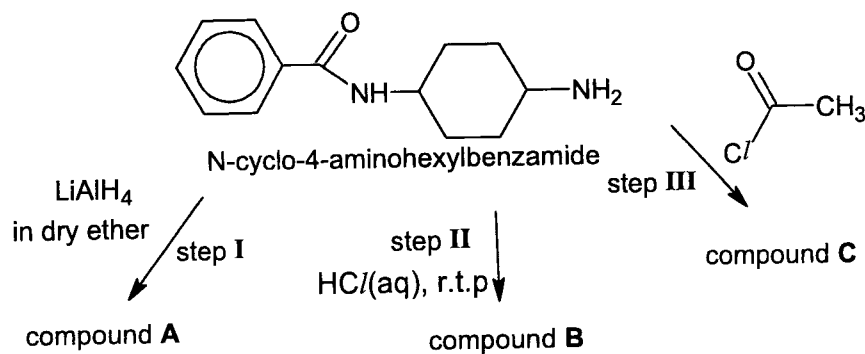
Table 3.4

- (iv) Point A on the titration graph represents a solution of maximum buffering capacity that is equally effective in removing small amounts of H<sup>+</sup> and OH<sup>-</sup> ions added. [1]
- State the value of V<sub>x</sub>, the volume of NaOH(aq) added and the value of pH<sub>x</sub>, at point A.

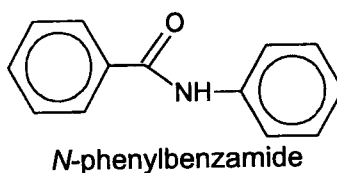
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- (d) The diagram below shows some reactions involving N-cyclo-4-aminoethylbenzamide.



- (i) Give the structures of compounds A, B and C. [3]
- (ii) Suggest a simple chemical test that could be used to distinguish between N-cyclo-4-aminoethylbenzamide and N-phenylbenzamide.



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## Section B

Answer **one** question from this section.

- 4 (a) Phosphoryl chloride is a colourless liquid with the formula  $\text{POCl}_3$ . Table 4.1 below shows the electronegativity values of the atoms in  $\text{POCl}_3$ .

atom	electronegativity / pauling units
phosphorus	2.2
chlorine	3.0
oxygen	3.5

Table 4.1

- (i)  $\text{POCl}_3$  hydrolyses in moist air releasing phosphoric acid  $\text{H}_3\text{PO}_4$  and fumes of hydrogen chloride.

Write an equation to show the reaction of  $\text{POCl}_3$  with water.

[1]

- (ii) Draw the shape of  $\text{POCl}_3$ .

Indicate clearly the polarity of each bond it contains, and its overall net polarity.

[2]

- (iii) Predict all possible intermolecular forces which could exist between  $\text{POCl}_3$  molecules.

[2]

Explain how these forces arise.

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(b) The boiling points of phosphorus trichloride,  $\text{PCl}_3$  and nitrogen trichloride,  $\text{NCl}_3$  are given below in Table 4.2.

At 373 K, both  $\text{PCl}_3$  and  $\text{NCl}_3$  exist as gases. Predict with reasons, which of the two gases will deviate more from ideal gas behavior.

compound	formula	$M_r$	boiling point/ K
phosphorus trichloride	$\text{PCl}_3$	137.5	350
nitrogen trichloride	$\text{NCl}_3$	120.5	344

Table 4.2

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(c) X, Y and Z are Period 3 elements.

Element X forms a white oxide that is insoluble in water.

Element Y forms an oxide which forms a white precipitate when shaken with excess aqueous  $Ba(NO_3)_2$  solution. The oxide of element X dissolves when a solution of oxide of element Y is added to it.

Element Z forms an oxide that dissolves readily in water and the resulting solution turns moist red litmus blue. The oxide of element X dissolves when a solution of oxide of element Z is added to it.

Deduce the identity of the elements Y, Z and the oxide of X.

Write equations to account for the dissolution of the oxide of X in the two reactions above.

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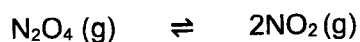
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- (d) Dinitrogen tetroxide,  $N_2O_4$ , is a useful reagent in chemical synthesis. It forms an equilibrium mixture with nitrogen dioxide according to the equation below.



- (i) At 318 K and 1 atm, the degree of dissociation of  $N_2O_4$  is 37.8%.  
Calculate the equilibrium constant,  $K_p$ . [2]
- (ii) The degree of dissociation is found to be 28% when total pressure is increased.  
Comment on why is there a difference in the degree of dissociation compared to (d)(i). [1]

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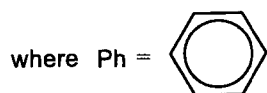
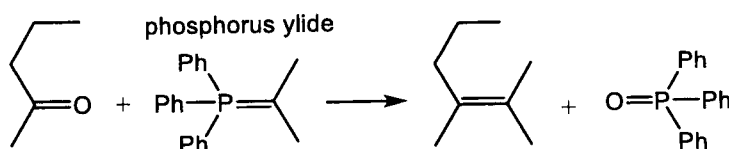
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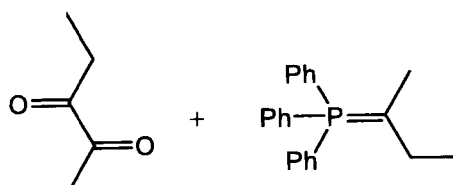
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- (e) A phosphorous ylide is used in the Wittig reaction which converts a carbonyl compound to an alkene. An example of a Wittig reaction is shown below.



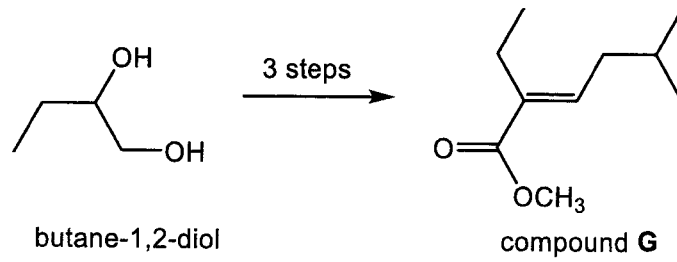
- (i) Suggest the structure formed when 1 mole of the following carbonyl compound reacts with 2 moles of the phosphorous ylide via the Wittig reaction.



Hence, suggest the total number of stereoisomers that can be formed. [2]

- (ii) Using the Wittig reaction as one of the steps in a three-step synthesis route, suggest suitable reagents and conditions to synthesise compound **G** from butane-1,2-diol.

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In your answer, include the structure of the intermediates formed.

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- (b) Brass is used to make window frames and other architectural models. Brass is a mixture of copper and zinc.

The process of etching brass involves dissolving the unprotected brass in aqueous iron (III) chloride,  $\text{FeCl}_3$ , until all the unwanted brass has been removed.

By using the relevant  $E^\ominus$  values, explain if one or both components of the brass are soluble in aqueous  $\text{FeCl}_3$ .

[2]

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- (c) (i) Solid aluminium chloride,  $\text{AlCl}_3$ , may be produced by passing a stream of  $\text{Cl}_2$  gas over heated  $\text{Al}$  metal in a long hard-glass tube.

The pH of a  $1.0 \text{ mol dm}^{-3}$  solution of  $\text{AlCl}_3$  in water is 3. Write equations where appropriate to account for the reactions of  $\text{AlCl}_3$  in water.

[1]

- (ii) The pH of a  $1.0 \text{ mol dm}^{-3}$  solution of  $\text{FeCl}_3$  in water has the value of  $y$ .

compound	pH of $1.0 \text{ mol dm}^{-3}$ solution
$\text{FeCl}_3$	$y$

Table 5.1

With reference to the *Data Booklet*, quote relevant values and suggest whether the value of  $y$  is larger or smaller than 3. Explain your answer.

[2]

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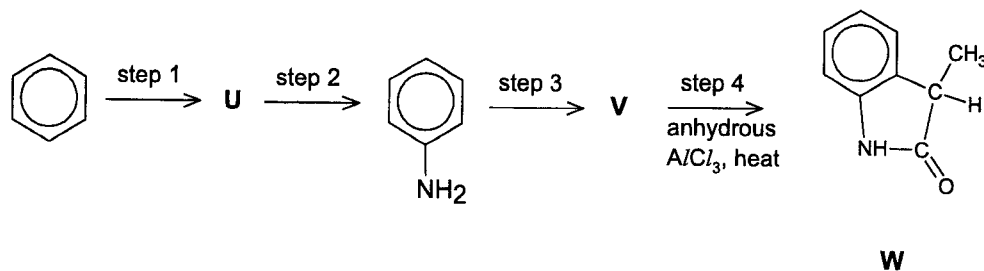
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(d) Compound **W** can be formed from benzene in the following reaction scheme.



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- (i) Suggest the reagents and conditions for steps 1, 2 and 3. [3]
- (ii) Draw the structure of compound **V** in the space provided below. [1]
- (iii) Draw the organic product obtained when compound **W** is treated with hot, acidified potassium manganate(VII). [1]

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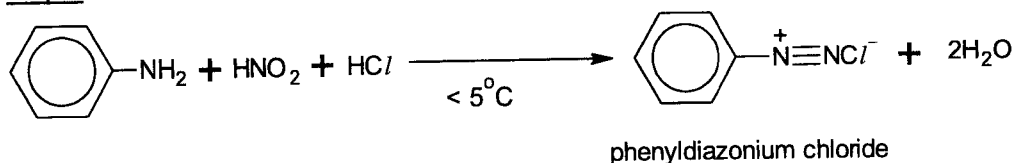
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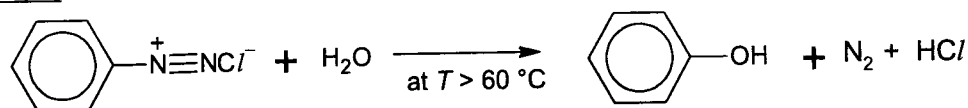
- (e) The equations below show the formation of phenol from phenylamine in 2 steps:  
In step 1, phenylamine reacts with cold nitrous acid,  $\text{HNO}_2$ , and hydrochloric acid,  $\text{HCl}$ , to form phenyldiazonium chloride.

step 1



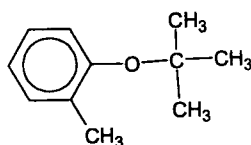
In step 2, phenyldiazonium chloride can react with water upon heating to give phenol.

step 2



phenyldiazonium chloride

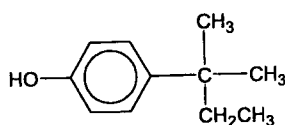
- (i) Propose a two-step synthetic pathway for the conversion of 2-methylphenylamine to compound **S** below.



Compound **S**

[2]

- (ii) Compound **T**, an isomer of Compound **S**, reacted with  $\text{Br}_2$  in the presence of uv light to produce 3 different mono-brominated products, **X**, **Y** and **Z**.



Compound **T**

During free-radical substitution of alkanes, different types of hydrogen atoms are replaced by bromine atoms at different rates as shown in Table 5.2

Type of hydrogen atom	Reaction	Relative rate
primary	$\text{RCH}_3 \rightarrow \text{RCH}_2\text{Br}$	1
secondary	$\text{R}_2\text{CH}_2 \rightarrow \text{R}_2\text{CHBr}$	7
tertiary	$\text{R}_3\text{CH} \rightarrow \text{R}_3\text{CBr}$	21

Table 5.2

Using the information in Table 5.2 and considering the number and type of hydrogen atoms within the molecule **T**, draw the structures of the three monobrominated structural isomers formed and predict their relative ratio.

[3]



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CLASS 21S

**JURONG PIONEER JUNIOR COLLEGE**  
**JC2 PRELIMINARY EXAMINATION 2022**

**CHEMISTRY**

**9729/04**

**Higher 2**

**16 August 2022**

Paper 4 Practical

**2 hours 30 minutes**

**Candidates answer on the Question paper.**

**Additional Materials:** As listed in the Confidential Instructions

**READ THESE INSTRUCTIONS FIRST**

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

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams, 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.

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 18 and 19.

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.

<b>Shift</b>	
<b>Laboratory</b>	
<b>For Examiner's Use</b>	
1	
2	
3	
4	
<b>Total</b>	

This document consists of **19** printed pages.

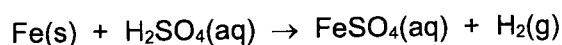
Answer all the questions in the spaces provided.

**1 Determination of the percentage by mass of iron in a sample of iron wire**

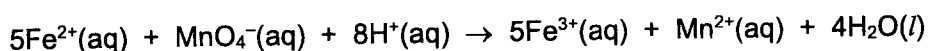
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Iron wire contains impurities. You will investigate the percentage by mass of iron in a sample of iron wire.

A sample of iron wire is reacted with an excess of sulfuric acid to produce a solution of iron(II) sulfate.



You will titrate the solution of iron(II) sulfate with potassium manganate(VII) of known concentration to determine the amount of iron(II) ions present and hence the percentage by mass of iron in the wire. You may assume the impurities do not form any products that react with potassium manganate(VII).



**FA 1** is a solution of  $\text{FeSO}_4$  prepared by reacting 3.03 g of iron wire with sulfuric acid to make  $500 \text{ cm}^3$  of solution.

**FA 2** is  $3.16 \text{ g dm}^{-3}$  potassium manganate(VII),  $\text{KMnO}_4$ .

**FA 3** is  $1.00 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .

**(a) Method**

1. Fill the burette labelled "FA 2" with FA 2.
2. Pipette  $25.0 \text{ cm}^3$  of FA 1 into a conical flask.
3. Use the  $50 \text{ cm}^3$  measuring cylinder to transfer  $25 \text{ cm}^3$  of FA 3 to the same conical flask.
4. Titrate this mixture with FA 2 until a permanent pale pink colour is obtained.
5. Record your titration results, to an appropriate level of precision, in the space provided below.
6. Repeat points 2 to 5 until consistent results are obtained.

**Results**

[3]

- (b)** From your titrations, obtain a suitable volume of FA 2,  $V_{\text{FA 2}}$ , to be used in your calculations. Show clearly how you obtained this volume.

$V_{\text{FA 2}} = \dots\dots\dots$  [3]

For  
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- (c) (i) Calculate the amount of  $\text{KMnO}_4$  present in the volume of **FA 2**,  $V_{\text{FA 2}}$ , calculated in (b).  
[A: O, 16.0; K, 39.1; Mn, 54.9]

amount of  $\text{MnO}_4^-$  present = ..... [1]

- (ii) Calculate the amount of  $\text{Fe}^{2+}$  ions in  $25.0 \text{ cm}^3$  of **FA 1**.

amount of  $\text{Fe}^{2+}$  ions = ..... [1]

- (iii) Calculate the percentage by mass of iron in the sample of iron wire.  
[A: Fe, 55.8]

percentage by mass of iron in the wire = ..... [3]

(d) The maximum error in any single burette reading is  $\pm 0.05 \text{ cm}^3$ .

(i) State the maximum possible error in the volume run from the burette recorded in any titration.

..... [1]

(ii) Explain how an error of  $(-0.10) \text{ cm}^3$  may arise when using a burette to obtain an individual titre value.

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

(e) A student suggested that when a piece of iron wire was dissolved in a known volume and concentration of sulfuric acid, the number of moles of iron that reacted with the acid could be determined by working out how much acid was left after the reaction. The amount of excess acid could be determined by titrating the mixture with a known concentration of sodium hydroxide.

Explain whether the student was correct.

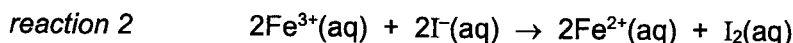
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..... [1]

[Total: 14]

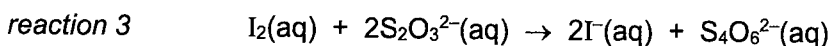


## 2 Investigation of the kinetics of the reaction between $\text{I}^{-}(\text{aq})$ and $\text{Fe}^{3+}(\text{aq})$

Iron(III) ions,  $\text{Fe}^{3+}(\text{aq})$ , and iodide ions,  $\text{I}^{-}(\text{aq})$ , react to give iodine,  $\text{I}_2(\text{aq})$ , in the presence of acid.



If acidified iron(III) chloride and potassium iodide are mixed in the presence of starch indicator and sodium thiosulfate, the iodine liberated reacts immediately with the thiosulfate ions and is reduced back to iodide ions.



When all the thiosulfate ions have reacted, the iodine which continues to be produced then turns the starch indicator blue-black. The rate of *reaction 2* may be determined by timing how long it takes for the reaction to turn blue-black.

You are to investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

**FA 4** is  $0.0500 \text{ mol dm}^{-3}$  potassium iodide,  $\text{KI}(\text{aq})$

**FA 5** is  $0.0500 \text{ mol dm}^{-3}$  acidified iron(III) chloride,  $\text{FeCl}_3(\text{aq})$ ,

**FA 6** is  $0.00500 \text{ mol dm}^{-3}$  sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$

**FA 7** is starch indicator.

**Read through the whole method carefully and prepare a table for your results on page 6 before starting any practical work.**

### (a) Method

#### Experiment 1

- Fill the burette labelled "FA 4" with FA 4.
- Run  $20.00 \text{ cm}^3$  of FA 4 into the  $100 \text{ cm}^3$  beaker.
- Use the  $50 \text{ cm}^3$  measuring cylinder to add the following to the same  $100 \text{ cm}^3$  beaker:
  - o  $20.0 \text{ cm}^3$  of FA 6
  - o  $10.0 \text{ cm}^3$  of FA 7
- Place the beaker on the white tile and stir the contents of the beaker using a glass rod.
- Use the  $25 \text{ cm}^3$  measuring cylinder to measure  $10.0 \text{ cm}^3$  of FA 5.
- Add this FA 5 into the same  $100 \text{ cm}^3$  beaker and start timing immediately at the instant of mixing.
- Stir once. The reaction mixture will turn *light brown* and then *pale yellow* before a sudden intense blue-black colouration is observed. Stop timing as soon as the solution turns blue-black.
- Record this reaction time,  $t$ , to the nearest 0.1 s.
- Wash out the beaker and dry it with a paper towel.

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**Experiment 2**

1. Fill another burette with deionised water.
2. Run 7.00 cm<sup>3</sup> of **FA 4** into the 100 cm<sup>3</sup> beaker.
3. Run 13.00 cm<sup>3</sup> of deionised water into the beaker containing **FA 4**.
4. Use the 50 cm<sup>3</sup> measuring cylinder to add the following to the same 100 cm<sup>3</sup> beaker:
  - o 20.0 cm<sup>3</sup> of **FA 6**
  - o 10.0 cm<sup>3</sup> of **FA 7**
5. Place the beaker on the white tile and stir the contents of the beaker using a glass rod.
6. Use the 25 cm<sup>3</sup> measuring cylinder to measure 10.0 cm<sup>3</sup> of **FA 5**.
7. Add the **FA 5** to the same 100 cm<sup>3</sup> beaker and start timing immediately at the instant of mixing.
8. Stir once and stop timing as soon as the solution turns blue-black.  
Note: This may take **more than 2 minutes**.
9. Record this reaction time, **t**, to the nearest 0.1 s.
10. Wash out the beaker and dry it with a paper towel.

**Experiments 3 – 5**

Carry out three further experiments to investigate how the reaction time, **t**, changes with different volumes of potassium iodide, **FA 4**.  
The combined volume of **FA 4** and deionised water must always be 20.00 cm<sup>3</sup>.  
Do not use a volume of **FA 4** that is less than 6.00 cm<sup>3</sup>.

Record all your results in a single table in the space provided below. You should include the experiment number, volume of **FA 4**,  $V_{\text{FA 4}}$ , volume of water,  $V_{\text{water}}$ , and the reaction time, **t**.

You should also include the 'rate of reaction' which is to be calculated as shown:

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

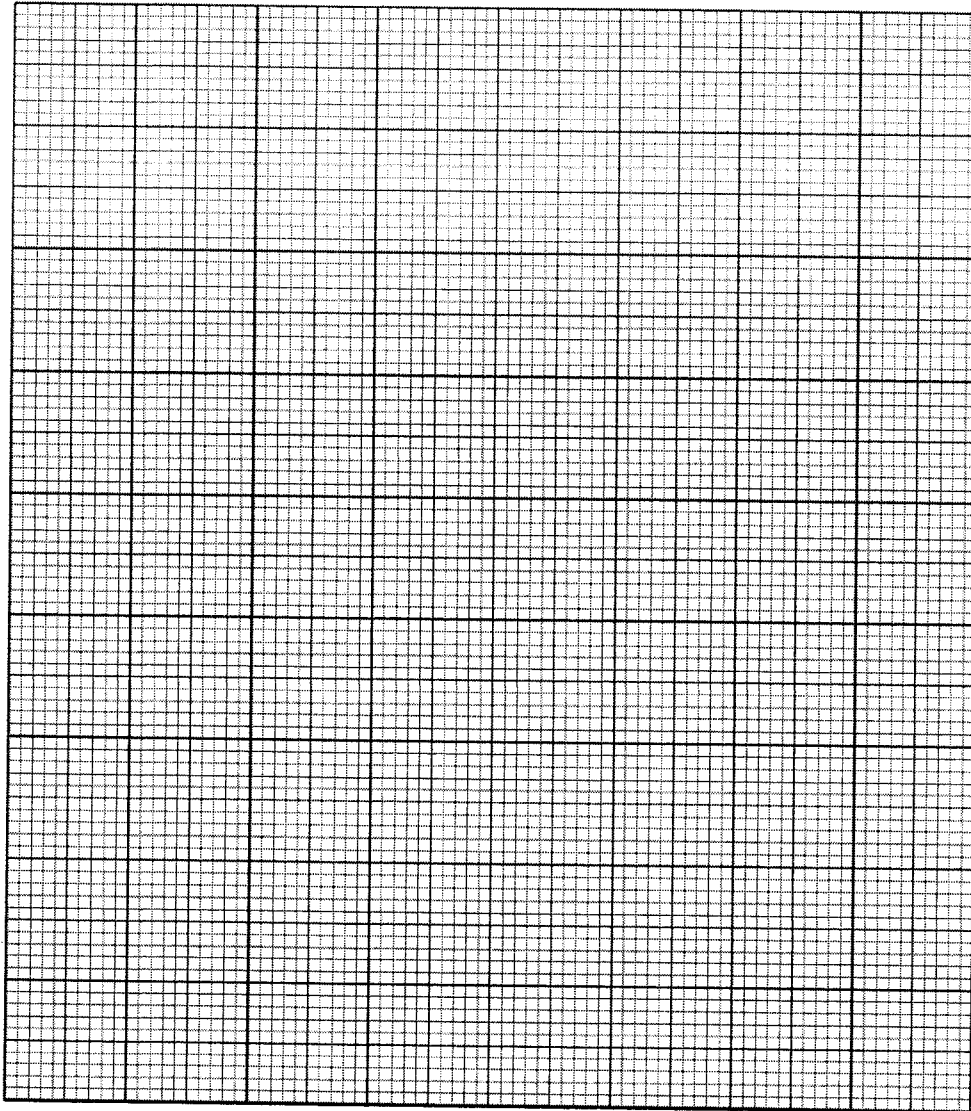
For each experiment, the value of the 'rate of reaction' is to be recorded to 3 significant figures.

**Results**

[5]

- (b) (i) On the grid below, plot a graph of rate of reaction (y-axis) against volume of FA 4 (x-axis). Include the origin, (0,0), in your scale. Circle any points you consider anomalous and draw a line of best fit.

For  
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Use



[3]

- (b) (ii) Explain, by referring to your graph, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, FA 4.

.....  
.....  
.....  
.....  
.....

[2]

(c) Thiosulfate ions can also react with acid to form sulfur, sulfur dioxide and water.

(i) Write an ionic equation for the reaction between thiosulfate ions and hydrogen ions in aqueous solution. Include state symbols.

..... [1]

(ii) A student carries out the same investigation as in (a) but the solutions are mixed in different order. The student places **FA 4** and appropriate volume of deionised water in one beaker and all other reactants in a second beaker. The student then transfers the mixture from the second beaker to the first and starts timing.

Tick the box for the statement you consider correct. Explain your answer.

The student's method is better than in (a).

The two methods are equally good.

The student's method is not as good as that in (a).

Reason: .....

.....

.....

.....

..... [1]

- (d) Another student investigates the effect of iron(III) concentration on the rate of this reaction.

The student carries out another experiment, **Experiment 6**, and the rate is compared to that of **Experiment 2**.

In **Experiment 2**, the volumes used were:

reagent	Volume / cm <sup>3</sup>
<b>FA 4</b>	7.00
<b>FA 5</b>	10.0
<b>FA 6</b>	20.0
<b>FA 7</b>	10.0
deionised water	13.00

- (i) Suggest the volumes the student could use for **Experiment 6**.

reagent	Volume / cm <sup>3</sup>
<b>FA 4</b>	
<b>FA 5</b>	
<b>FA 6</b>	
<b>FA 7</b>	
deionised water	

[1]

- (ii) This student records a time of 140 s for **Experiment 2**.

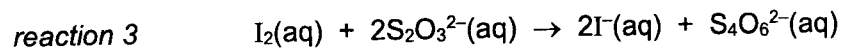
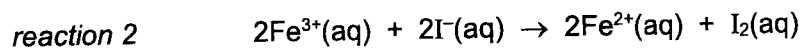
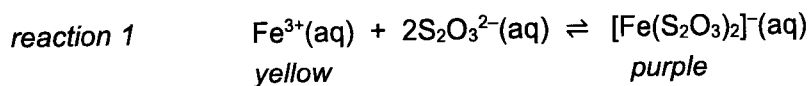
The rate of reaction is directly proportional to the concentration of iron(III) ions.

Suggest how long it would take the reaction mixture proposed for **Experiment 6** in (d)(i) to turn blue-black. Assume that **Experiment 6** is carried out at the same temperature as **Experiment 2**.

Do not carry out **Experiment 6**.

reaction time = ..... s [1]

(e) When **FA 4**, **FA 5** and **FA 6** are mixed, the following three reactions occur.



When **FA 5** was added to the solution prepared in step 6 of **Experiment 1**, the reaction mixture turned *light brown* and then *pale yellow* before the blue-black colour appeared.

The *light brown* colour is due to a mixture of purple  $[\text{Fe}(\text{S}_2\text{O}_3)_2]^{-}(\text{aq})$  and yellow  $\text{Fe}^{3+}(\text{aq})$  in the reaction mixture. Explain why the *light brown* solution turns *pale yellow* before the appearance of blue-black colour.

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.....

.....

[1]

[Total: 15]

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### 3 Qualitative Analysis

Solid **FA 8** contains the polyatomic anion,  $X^{2-}$ , and one cation from the ions listed in the *Qualitative Analysis Notes*.

**FA 9** is an aqueous solution containing a sodium salt of the polyatomic anion,  $X^{2-}$ .

**FA 10** is organic solution containing one functional group.

You will perform tests to

- identify the cation present in **FA 8**
- deduce the nature of **FA 8**
- deduce the identity of  $X^{2-}$
- identify the functional group present in **FA 10**

- (a) (i) Perform the tests described in Table 3.1, and record your observations in the table. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

**Table 3.1**

tests		observations
1	Place a spatula measure of <b>FA 8</b> in a test-tube and add 1-2 cm depth of aqueous iron(II) sulfate.  Shake the tube well until all <b>FA 8</b> dissolves.	
2	Place a spatula measure of <b>FA 8</b> in a boiling tube and add 1 cm depth of dilute nitric acid to dissolve the solid.  Then add 1 cm depth of aqueous manganese(II) sulfate and 4 drops of aqueous silver nitrate to act as a catalyst.  Heat cautiously to bring the mixture to boiling.	
3	To a spatula measure of <b>FA 8</b> in a boiling tube, add 1-2 cm depth of aqueous sodium hydroxide.  Heat cautiously.	

[3]

For  
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Use

- (ii) Identify the cation in
- FA 8**
- .

cation: .....

[1]

- (iii) State, with supporting evidences, the nature (
- acidic, basic, amphoteric, oxidising or reducing*
- ) of
- FA 8**
- .

nature of **FA 8**: .....

evidence: .....

.....

.....

.....

[2]

- (b) (i)
- FA 9**
- is an aqueous solution containing a sodium salt of the polyatomic anion,
- $X^{2-}$
- .

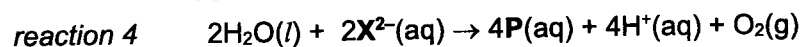
In aqueous solution,  $X^{2-}$  reacts very slowly with water to produce anion **P**,  $H^+$  ions and oxygen gas.Perform the tests described in Table 3.2, and record your observations in the table. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Table 3.2

tests		observations
1	Test solution <b>FA 9</b> with Universal Indicator paper.	
2	To 1 cm depth of <b>FA 9</b> in a boiling tube, add 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Warm the mixture cautiously.	
3	To 1 cm depth of <b>FA 9</b> in a test-tube, add 1 cm depth of aqueous barium nitrate. Then add dilute nitric acid until no further change occurs.	

[3]

- (ii) Identify the anion
- P**
- . Hence, use
- reaction 4*
- equation to deduce the identity of
- $X^{2-}$
- .

Anion **P**: .....  $X^{2-}$  is .....

[2]



- (c) You are provided with an organic solution **FA 10** which contains one functional group.

**Care: FA 10 is flammable. Do not use Bunsen burner for heating. Use the hot water provided if heating is required.**

**FA 10** gives a positive test with 2,4-dinitrophenylhydrazine.

Devise one other confirmatory test using the bench reagents provided to identify the functional group present in **FA 10**.

Carry out the test. Record details of the test performed and observations made in Table 3.3.

**Table 3.3**

<i>Confirmatory Test</i>	<i>Observations</i>

Functional group present in **FA 10**: .....

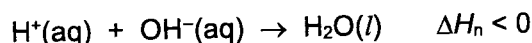
[3]

[Total: 14]

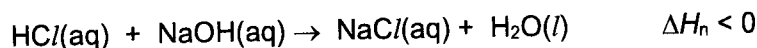
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#### 4 Planning

Enthalpy change of neutralisation,  $\Delta H_n$ , is the heat evolved when one mole of water is formed from the reaction of an acid and an alkali.



When aqueous hydrochloric acid,  $\text{HCl}(\text{aq})$  is mixed with aqueous sodium hydroxide,  $\text{NaOH}(\text{aq})$ , the neutralisation reaction releases heat causing a rise in the temperature of the solution.



A series of experiments can be performed where increasing volumes of  $\text{HCl}(\text{aq})$  and decreasing volumes of  $\text{NaOH}(\text{aq})$  are mixed and the temperature rise,  $\Delta T$ , for each experiment is determined.

In each of the experiments using different volumes of  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$ , the total volume has to be kept constant. Since the total volume of mixture remains the same, the temperature rise,  $\Delta T$ , is a direct measure of the heat liberated by the reaction. The maximum amount of heat is evolved when all the acid present is exactly neutralised by all the alkali present.

Plotting a graph of  $\Delta T$  against the volume of  $\text{HCl}(\text{aq})$  used will give 2 straight lines of best-fit.

Extrapolation of the two straight lines will produce a point of intersection from which the concentration of  $\text{HCl}(\text{aq})$  and the enthalpy change of neutralisation,  $\Delta H_n$ , between  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$  can be determined.

The volume of  $\text{HCl}(\text{aq})$  used should be at least  $10.00 \text{ cm}^3$  and the total volume of the reaction mixture should be kept constant at  $50.00 \text{ cm}^3$  for all experiments.

- (a) Using the information given, you are required to write a plan to determine the concentration of  $\text{HCl}(\text{aq})$  and the enthalpy change of neutralisation,  $\Delta H_n$ , between  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$ .

You may assume that you are provided with:

- $250 \text{ cm}^3$  of  $\text{HCl}(\text{aq})$  of unknown concentration,
- $250 \text{ cm}^3$  of  $1.50 \text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$ ,
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- the apparatus you would use,
- the quantities you would use, including suggested volumes of  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$ ,
- the procedure you would follow,
- the measurements you would make to allow a suitable  $\Delta T$  against the volume of  $\text{HCl}(\text{aq})$  graph to be drawn.

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[6]

(b) Sketch on Fig 4.1 the graph you would expect to obtain from your results.

Indicate clearly on your sketch how you would determine:

- $V_{\text{neut}}$ , the volume of  $\text{HCl}(\text{aq})$  needed to just completely neutralise  $(50 - V_{\text{neut}}) \text{ cm}^3$  of  $\text{NaOH}(\text{aq})$ .
- $\Delta T_{\text{max}}$ , the maximum temperature rise when stoichiometric amount of  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$  reacted.

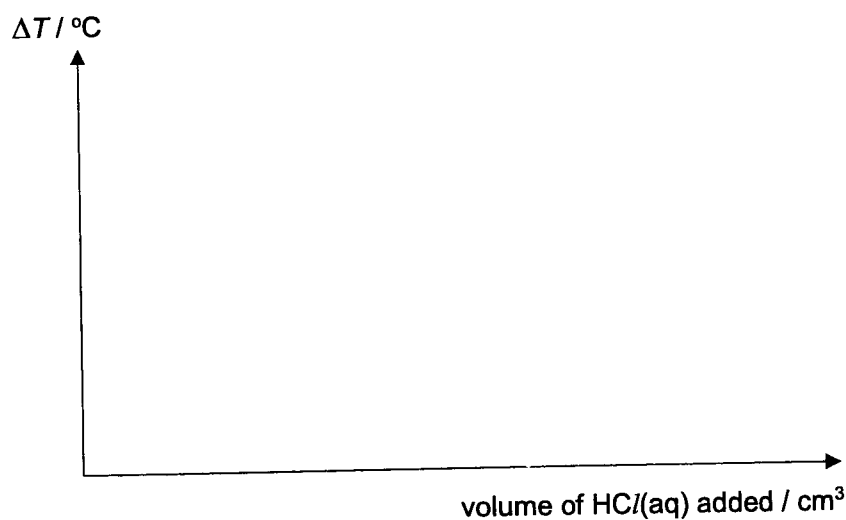


Fig 4.1

[2]

(c) Outline how you would use your answers from (b) to determine

(i) the concentration, in  $\text{mol dm}^{-3}$ , of  $\text{HCl}(\text{aq})$ .

Express your results in terms of  $V_{\text{neut}}$ . It is not necessary to simplify the expression in your final answer.

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[2]

(ii) the enthalpy change of neutralisation,  $\Delta H_n$ , for this reaction.



Express your answers in terms of  $\Delta T_{\text{max}}$  and  $V_{\text{neut}}$ . It is not necessary to simplify the expression in your final answer.

You should assume that the specific heat capacity of the final solution is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$  and its density is  $1.00 \text{ g cm}^{-3}$ .

[2]

[Total: 12]

**Qualitative Analysis Notes**

[ppt. = precipitate]

**(a) Reactions of Aqueous Cations**

<b>cation</b>	<b>Reaction with</b>	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	ammonia produced on heating	–
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey–green ppt. soluble in excess giving dark green solution	grey–green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe <sup>2+</sup> (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 <sup>3+</sup> (aq)	red–brown ppt. insoluble in excess	red–brown ppt. insoluble in excess
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn <sup>2+</sup> (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 <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of Anions**

<b>Anion</b>	<b>Reaction</b>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ 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, $\text{NO}_3^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ 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, $\text{SO}_3^{2-}(\text{aq})$	$\text{SO}_2$ liberated on warming with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

**(c) Tests for Gases**

<b>gas</b>	<b>Test and test results</b>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	turns acidified aqueous potassium manganate(VII) from purple to colourless

**(d) Colour of halogens**

<b>halogen</b>	<b>colour of element</b>	<b>colour in aqueous solution</b>	<b>colour in hexane</b>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas/liquid	orange	orange-red
iodine, $\text{I}_2$	black solid/purple gas	brown	purple

