

<b>Name:</b>		<b>Centre/Index Number:</b>		<b>Class:</b>	
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**DUNMAN HIGH SCHOOL**  
**Preliminary Examination**  
**Year 6**

**H2 CHEMISTRY**

Paper 2 Structured Questions

**9729/02**

**13 September 2022**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your centre number, index number, name and class 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.

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

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	
1	12
2	12
3	14
4	16
5	21
<b>Total</b>	<b>75</b>

This document consists of **21** printed pages and **3** blank pages.

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

- 1 (a) Describe the thermal decomposition of the hydrogen halides HCl, HBr and HI and explain any variation in their thermal stabilities.

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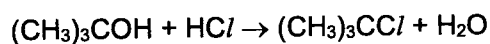
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..... [3]

- (b) Tert-butyl alcohol reacts with hydrogen chloride according to the equation shown.



This reaction occurs in three steps.

- step 1    protonation of –OH group in  $(\text{CH}_3)_3\text{COH}$  to produce  $(\text{CH}_3)_3\text{COH}_2^+$  cation
- step 2    loss of  $\text{H}_2\text{O}$  molecule from  $(\text{CH}_3)_3\text{COH}_2^+$  to produce a carbocation
- step 3    chloride ion reacts with carbocation to produce  $(\text{CH}_3)_3\text{CCl}$

- (i) Describe the mechanisms which occur in **steps 2 and 3**. Use curly arrows to show the movement of electrons and label the slow step.

[3]

- (ii) An enantiomerically pure alcohol, where the carbon atom bonded to the –OH group is chiral, was used for the reaction in (b).

Use your answer in (b)(i) to deduce the stereochemical outcome of this reaction. Explain your reasoning.

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Tert-butyl alcohol also reacts with solid phosphorus pentachloride,  $PCl_5$ , to produce  $(CH_3)_3CCl$ .

- (iii) With the aid of a suitable equation, explain why the reaction is not carried out in aqueous medium.

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- (c)  $(\text{CH}_3)_3\text{CCl}$  is one of the two monochlorinated products of the reaction between an alkane, **X**, and chlorine gas in the presence of UV light.
- (i) Draw the structure of the alkane, **X**, and state the IUPAC name of the other monochlorinated product.

IUPAC name ..... [1]

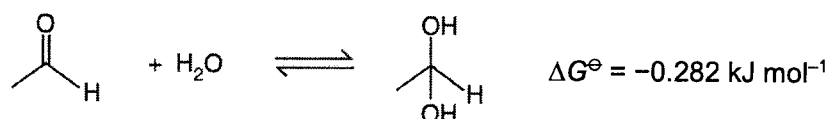
- (ii) The rate of formation of  $(\text{CH}_3)_3\text{CCl}$  is faster than that of the other monochlorinated product.

Suggest an explanation for the different rates of reaction.

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[Total: 12]

- 2 (a) The following equilibrium occurs when ethanal is mixed with water.

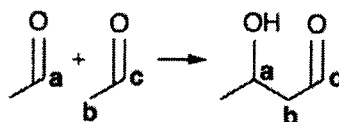


Use relevant data from the *Data Booklet* to calculate the equilibrium constant,  $K$ , for the reaction.

[2]

- (b) The aldol reaction is a useful reaction that forms a carbon–carbon bond between two carbonyl compounds. For example, two ethanal molecules can be combined using the aldol reaction.

The carbonyl carbon, **a**, of one ethanal molecule forms a covalent bond with a carbon atom, **b**, of another ethanal molecule. Carbon atom, **b**, must be adjacent to carbonyl carbon, **c**.



- (i) When different carbonyl compounds are used in an aldol reaction, a mixture of structural isomers is formed.

Suggest two possible structural isomers that can be formed if propanone,  $\text{CH}_3\text{COCH}_3$ , and propanal,  $\text{CH}_3\text{CH}_2\text{CHO}$ , are mixed.

structural isomers	

[2]

- (ii) Both propanal and propanoic acid can be formed from propan-1-ol in the same reaction.

Describe the reagents and conditions needed to ensure that the reaction yields propanal as the major product.

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..... [2]

- (c) Some tin reagents are useful in organic chemistry.

Tin forms two chlorides,  $\text{SnCl}_2$  and  $\text{SnCl}_4$ .

- (i) A mixture of these chlorides was found to contain 50.0% by mass of tin. Calculate the percentage by mass of  $\text{SnCl}_2$  in the mixture.

[3]

- (ii) Tin exists in +2 or +4 oxidation states in many of its compounds. Great care must be taken to ensure the correct oxidation state of tin is formed.

A student proposed the following preparation methods to prepare the two chlorides,  $\text{SnCl}_2$  and  $\text{SnCl}_4$ .

**Preparation method for  $\text{SnCl}_2$**

Heating tin with hydrochloric acid produces hydrogen gas. Careful evaporation of the water and dehydration produces white solid  $\text{SnCl}_2$ .

**Preparation method for  $\text{SnCl}_4$**

Passing chlorine gas over heated tin produces colourless liquid  $\text{SnCl}_4$  as the only product.

Explain if the preparation methods proposed above are feasible without reference to any calculation. Use relevant standard electrode potentials from the *Data Booklet*.

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[Total: 12]

3 (a) Compound **N**,  $C_3H_4O_3$ , liberates a gas when treated with aqueous sodium carbonate.

(i) Identify the gas and state the functional group that is present in compound **N**.

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

When  $0.10 \text{ cm}^3$  of liquid compound **N** was dissolved in an inert solvent and an excess of sodium metal added,  $15 \text{ cm}^3$  of gas was produced at 303 K and 1 atm.  
 [Density of compound **N** =  $1.093 \text{ g cm}^{-3}$ ]

(ii) Calculate the ratio of the amount of compound **N** reacted to the amount of gas that is produced.

[1]

(iii) Use your answers in (a)(i) and (a)(ii) to suggest **two** possible structures of compound **N**. Explain your reasoning.

possible structures of compound <b>N</b>	

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Compound **N**,  $C_3H_4O_3$ , is formed as the only organic product when a neutral organic compound **M**,  $C_4H_8O_3$ , is heated with acidified  $KMnO_4$ . **M** does not decolourise aqueous bromine.

- (iv) Use the information provided and your answer in (a)(iii) to
- identify the structure of **N** and
  - deduce the structure of **M**.

Explain your reasoning and the chemistry of the reactions involved.

<b>N</b>	<b>M</b>
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..... [3]

- (b) Phenylethene,  $C_6H_5CH=CH_2$ , can be used to synthesise three different aromatic compounds **R**, **S** and **T** as shown in Fig. 3.1.

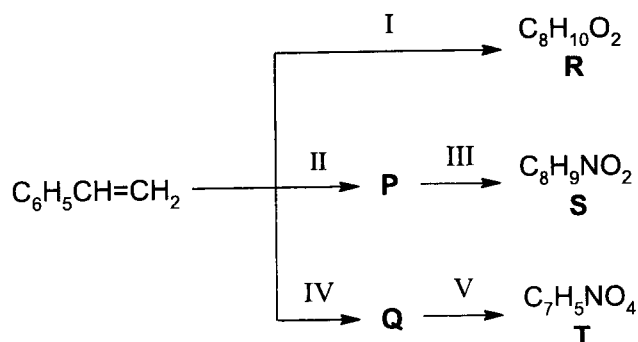


Fig. 3.1

- (i) State the reagents and conditions required for reaction I.

..... [1]

Compounds **S** and **T** have the following features.

- Each compound contains a disubstituted benzene ring.
  - They have an identical substituent on their benzene rings.
  - **S** has its substituents at positions 1 and 2 on the benzene ring.
  - **T** has its substituents at positions 1 and 3 on the benzene ring.
- (ii) Using the information provided and given that the same type of reaction is occurring in III and V, suggest structures for the intermediates **P** and **Q**.

Hence state the reagent and conditions required for reaction II.

<b>P</b>	<b>Q</b>
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reagent and conditions for reaction II .....

..... [3]

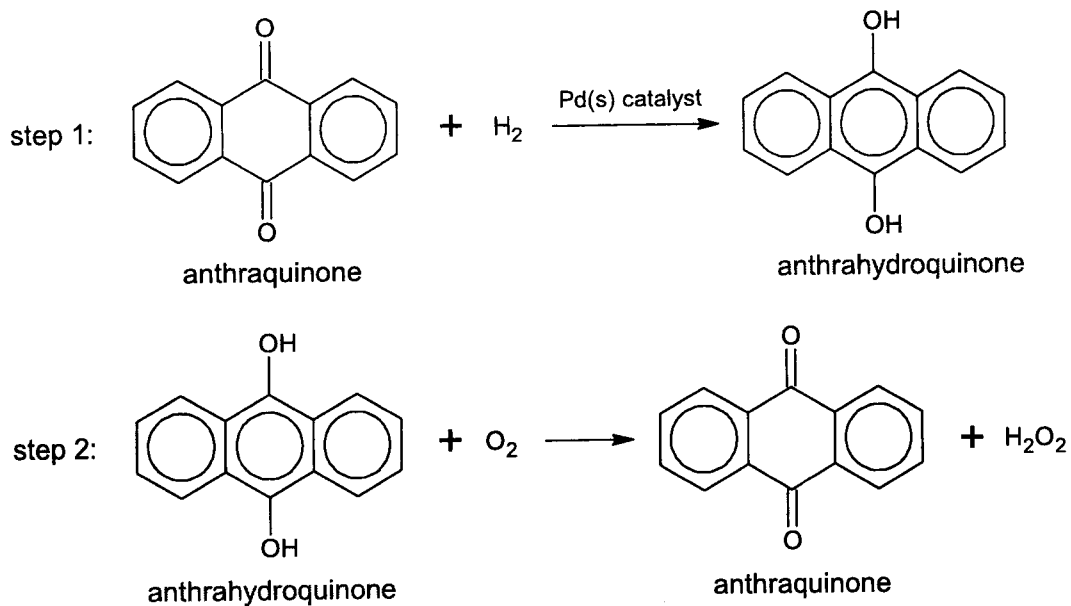
- (iii) Suggest and explain how the conditions for reactions III and V would differ despite the same type of reaction occurring.

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[Total: 14]

- 4 Hydrogen peroxide,  $\text{H}_2\text{O}_2$ , finds its applications in a diversity of fields. Amongst many uses, it is an important precursor for the synthesis of organic peroxides and polymers. As such the manufacture of hydrogen peroxide has been an important industrial process since the 20<sup>th</sup> century.

Today, most of the world's hydrogen peroxide is manufactured by the anthraquinone process. This process involves the two steps shown below.



- (a) Step 1 involves the adsorption of  $\text{H}_2$  gas onto the surface of the palladium metal catalyst.

- (i) State the property that palladium possesses that allows it to act as a catalyst in step 1, and explain how the adsorption of  $\text{H}_2$  gas onto palladium increases the rate of reaction.

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..... [2]

- (ii) A study of the kinetics of step 1 revealed that at low pressures, the rate of reaction increases with increasing pressure of  $H_2$ . However, at high pressures, increasing the pressure of  $H_2$  has no effect on the rate of reaction.

Explain these observations.

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Although palladium and nickel belong to Group 10 of the Periodic Table, both elements have different ways of filling up their d orbitals. For palladium, it has a fully filled 4d subshell.

- (iii) Draw, on the Cartesian axes provided in Fig. 4.1, the orbital from which the first electron of palladium is removed. Label the axes and orbitals clearly.

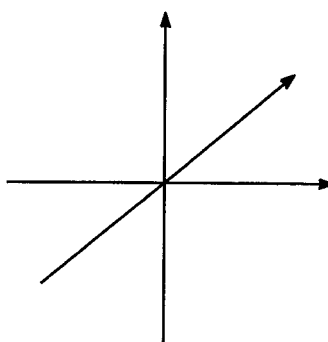


Fig. 4.1

[1]

- (iv) It is observed that the first ionisation energies of the Period 4 transition elements remain relatively invariant. Explain this observation.

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- (b) At the end of step 1, anthrahydroquinone is extracted from the reaction mixture before reacting it with  $O_2$  in step 2.

It is observed that step 2 follows the rate equation below.

$$\text{rate} = k[\text{anthrahydroquinone}][O_2]$$

In this step, a large excess of  $O_2$  is required to ensure that anthrahydroquinone is completely oxidised back to anthraquinone, producing hydrogen peroxide.

- (i) Explain why the rate equation for step 2 can be rewritten as  $\text{rate} = k'[\text{anthrahydroquinone}]$ .

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- (ii) Hence sketch, on Fig 4.2, a labelled graph to show how the concentration of  $H_2O_2$  in step 2 will vary over time.

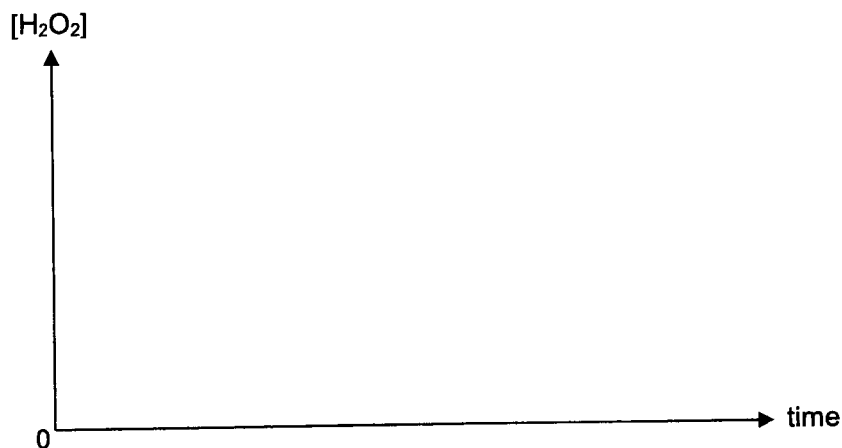


Fig 4.2

[2]

- (iii) Step 2 was repeated with different initial pressures of  $O_2$  and different initial concentrations of anthrahydroquinone.

Table 4.1 shows the initial quantities of reactants used for each experiment and the time required for the initial concentration of anthrahydroquinone to be halved for experiment 1.

**Table 4.1**

experiment	initial pressure of $O_2(g)$ / Pa	initial [anthrahydroquinone] / $mol\ dm^{-3}$	time required for initial [anthrahydroquinone] to be halved / min
1	$4 \times 10^5$	1.00	12.0
2	$4 \times 10^5$	0.50	
3	$8 \times 10^5$	1.00	

Complete Table 4.1 and explain your answer.

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- (c) At the end of step 2, the reaction mixture contains only anthraquinone and  $H_2O_2$ .  $H_2O_2$  can be separated out from the reaction mixture by adding water to the reaction mixture.

With reference to the bonding between relevant molecules, explain how the addition of water allows this to happen.

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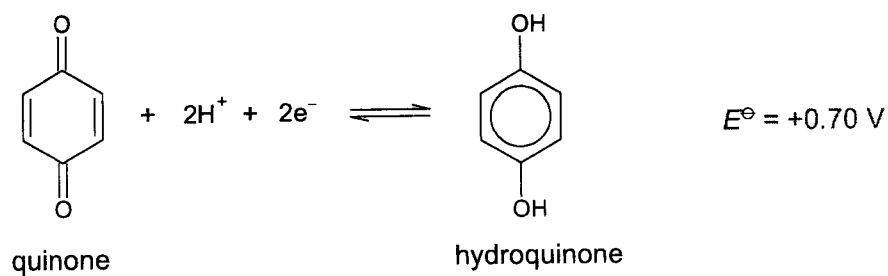
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- (d) Quinone and hydroquinone have similar structures to anthraquinone and anthrahydroquinone respectively.

The standard reduction potential of the quinone–hydroquinone system is +0.70 V.



An electrolytic cell was set up under standard conditions with a mixture of aqueous quinone and dilute sulfuric acid as the electrolyte and platinum rods as electrodes.

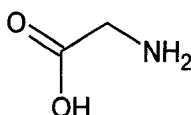
State the products formed at the anode and the cathode.

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[Total: 16]



- 5 (a) Glycine has the following structure.



The  $pK_a$  values of glycine are shown in Table 5.1.

Table 5.1

$pK_a$ of $\alpha$ -carboxyl group	$pK_a$ of $\alpha$ -amino group
2.30	9.60

- (i) Glycine exists as a zwitterion at pH 5.95.

State what is meant by the term *zwitterion*.

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- (ii) A  $15 \text{ cm}^3$  solution of  $0.05 \text{ mol dm}^{-3}$  glycine is prepared in which glycine is fully protonated. The initial pH of this solution is 1.87.

Sketch the pH–volume added curve you would expect to obtain when  $11.25 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  NaOH is added to this solution.

Use the information provided, and data from (a)(i) and Table 5.1 to label the various key points on the curve.

Show your working.

[3]

- (iii) Write an equation to show the reaction occurring when  $1.75 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  NaOH is **further** added to the resulting solution in (a)(ii).

Hence calculate the pH of the solution obtained.

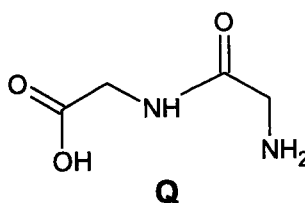
equation .....

[2]

- (iv) Draw the structure of the predominant species of glycine at pH 10.0.

[1]

- (v) Name the type of reaction occurring when **Q** is formed from two glycine molecules.



..... [1]

- (b) The presence of some amino acids has been linked to the precipitation of calcium ethanedioate ( $\text{CaC}_2\text{O}_4$ ), a component of kidney stones, in the body. Research studies have been performed to better understand the effect of pH on the solubility of  $\text{CaC}_2\text{O}_4$ .

- (i) Predict and explain the effect of pH on the solubility of  $\text{CaC}_2\text{O}_4$ .

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One research study on the effect of pH on the solubility of  $\text{CaC}_2\text{O}_4$  involves adding excess powdered  $\text{CaC}_2\text{O}_4$  to water that has its pH value adjusted. The suspension was filtered and the filtrate was titrated against acidified potassium manganate(VII) of a known concentration. The results are shown in Table 5.2.

**Table 5.2**

experiment	pH of filtrate	volume of $\text{KMnO}_4$ added / $\text{cm}^3$
1	1.56	30.00
2	1.76	24.55
3	2.45	13.40
4	3.20	8.00
5	5.37	3.70
6	6.16	3.50

- (ii) Construct balanced ion-electron equations for the reaction between  $\text{CaC}_2\text{O}_4$  and potassium manganate(VII) which produces a gas.

Hence write the overall equation for the reaction.

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(iii) Using the data in Table 5.2, comment on your prediction in (b)(i).

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(iv) In experiment 1, 200 cm<sup>3</sup> of the filtered solution was titrated against 0.00100 mol dm<sup>-3</sup> potassium manganate(VII).

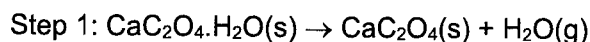
Calculate the mass of Ca<sup>2+</sup>, in mg, present in the filtrate.

[2]

(c) Thermogravimetric analysis is an analytical technique used to determine a substance's thermal stability by monitoring the change in mass that occurs as a sample is heated at a constant rate.

- (i) Calcium ethanedioate monohydrate,  $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ , has been used to calibrate equipment that performs thermogravimetric analysis because of its well-defined three-step decomposition process.

Complete the following equations which describe the decomposition process of  $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ . Include state symbols.



[2]

- (ii) A thermogram from a thermogravimetric analysis plots mass of carbonate against temperature.

Given the same initial mass of carbonate, state and explain how the thermogram of magnesium carbonate will differ from that of calcium carbonate in terms of

- the final mass of carbonate obtained,
- the temperature at which the mass of carbonate starts to change significantly.

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[Total: 21]

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**DUNMAN HIGH SCHOOL**  
**Preliminary Examination**  
**Year 6**

**H2 CHEMISTRY**

Paper 3 Free Response Questions

**9729/03**

**21 September 2022**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your centre number, index number, name and class 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. 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.

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

For Examiner's Use	
<b>Section A</b>	
1	20
2	20
3	20
<b>Section B</b>	
4 / 5	20
<b>Total</b>	<b>80</b>

This document consists of **32** printed pages.

## Section A

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

- 1 (a) Alkynes is a class of organic compounds with the general formula,  $C_nH_{2n-2}$ .
- (i) Describe what is meant by sp hybridisation with reference to one carbon atom in ethyne,  $C_2H_2$ . Draw the hybrid orbitals of the carbon atom. [2]
- (ii) Use relevant radius values from the *Data Booklet* to calculate the bond length of a single carbon-hydrogen bond. Show your working clearly. [1]
- (iii) Table 1.1 shows the carbon-hydrogen bond length in ethene and ethyne.

Table 1.1

molecule	carbon-hydrogen bond length/ nm
ethene	0.109
ethyne	0.106

With reference to Table 1.1, state which carbon-hydrogen bond is stronger. Use the concept of hybridisation to explain the difference in bond length of the carbon-hydrogen bond between these two molecules. [2]

- (iv) Write a balanced equation for the complete combustion of propyne,  $C_3H_4$ . [1]
- (v) A sample of propyne was burned in excess oxygen. When the remaining gases were passed through aqueous sodium hydroxide, the gas volume was reduced by  $0.450 \text{ dm}^3$ . Calculate the mass of propyne in the sample.

Assume all gas volumes were measured at r.t.p. [2]

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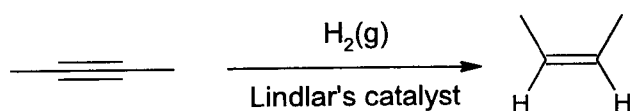
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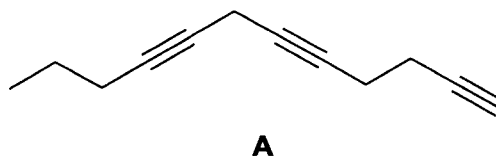


- (b) The use of hydrogen gas with Lindlar's catalyst is a selective method which reduces alkynes to form the *cis*-isomer of alkenes.

As an example, but-2-yne,  $C_4H_6$ , can be reduced to give *cis*-but-2-ene only.



Suggest the structure of the alkene formed when compound **A** is reduced with the use of Lindlar's catalyst.



[1]

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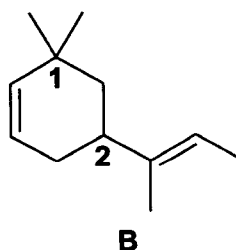
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- (c) Compound **B** has the following structure.

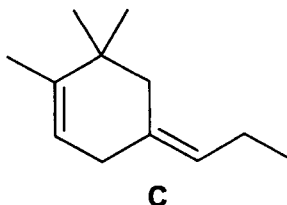


- (i) State the isomeric relationship between **B** and your answer in (b). [1]
- (ii) A student made the following deductions about compound **B**:
- "Since carbon atoms labelled 1 and 2 are chiral and there are two carbon-carbon double bonds, compound B has 16 possible stereoisomers."*
- Explain where the student has gone wrong in his deductions. [3]
- (iii) Draw all the organic products that are formed when compound **B** is heated with acidified potassium manganate(VII). [1]



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(d) Compound **C** is an isomer of compound **B**.



Draw the structure of the major product formed when compound **C** is reacted with excess HBr(g). Explain your answer. [2]

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(e) Lithium aluminium hydride, LiAlH<sub>4</sub>, is a reducing agent commonly used in organic chemistry.

- (i) Assuming LiAlH<sub>4</sub> as a source of hydride (H<sup>-</sup>) ions, suggest why the reduction of alkynes using LiAlH<sub>4</sub> is likely **not** a suitable method. [1]
- (ii) LiAlH<sub>4</sub> can be synthesised from aluminium chloride, which exists as a dimer, Al<sub>2</sub>Cl<sub>6</sub>, at room temperature.

Draw a dot-and-cross diagram to illustrate the bonding present in Al<sub>2</sub>Cl<sub>6</sub>. [1]

- (iii) When heated, LiAlH<sub>4</sub> decomposes to LiAl(s) as one of its products. LiAl(s) has a melting point of 718 °C. It can conduct electricity when in solid and molten states.

Suggest the structure of LiAl(s) and describe the bonding present. [2]



- 2 (a) 1,2-diols are common precursors used in many pharmaceuticals, agrochemicals, and natural products.

Fig. 2.1 shows a *pinacol coupling reaction* which involves the *homo-coupling\** of a carbonyl compound to produce a symmetrically substituted 1,2-diol.

\*Two identical molecules react to form a different one.

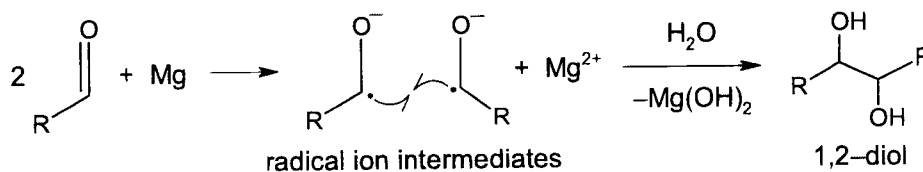


Fig. 2.1

The first step is single electron transfer involving the carbonyl group, which generates radical ion intermediates that couple via carbon-carbon bond formation to give a 1,2-diol.

- (i) State the role of magnesium in the first step of Fig. 2.1 and give a reason for its suitability in this reaction. [2]
- (ii) It is possible to synthesise a desired unsymmetrical diol using methods similar to the *pinacol coupling reaction* but a mixture of diols will be obtained.

Explain why a mixture of diols is formed. Suggest why this is unfavourable other than a low yield of the desired diol. [2]

The *pinacol coupling* can be followed up by a *pinacol rearrangement* to convert the 1,2-diol to a carbonyl compound.

Pinacolone is a carbonyl compound that can be produced via the *pinacol rearrangement*.

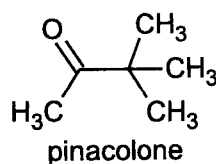


Fig. 2.2 shows the first step of the *pinacol rearrangement* to form pinacolone using pinacol as the starting reactant.

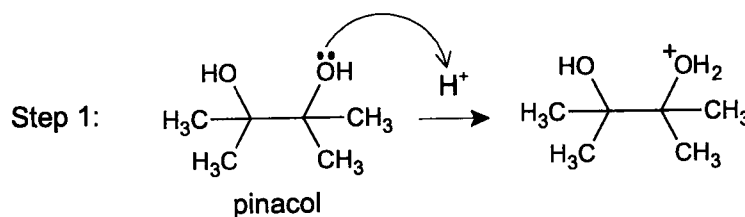


Fig. 2.2



(iii) Below describes the remaining three steps of the *pinacol rearrangement* to form pinacolone.

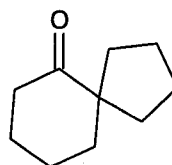
- Step 2 involves the removal of water from the intermediate in Step 1 in Fig. 2.2 to form a carbocation.
- Step 3 involves the shifting of an adjacent methyl group to the positively charged carbon to form another carbocation.
- Step 4 involves the deprotonation of the -OH group in the carbocation in Step 3 to form pinacolone.

Using the information provided, draw Steps 2 to 4 of the mechanism for the formation of pinacolone via *pinacol rearrangement*.

Show all charges and show the movement of electron pairs by using curly arrows. [3]

(iv) Suggest a simple chemical test that you could carry out to confirm the formation of pinacolone from pinacol. State the observations you would make and write a balanced equation for the reaction. [2]

(v) Compound X is a product formed from *pinacol rearrangement*.



compound X

Draw the structure of the 1,2-diol responsible for producing X. [1]

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- (b) A research team in Kanazawa University was successful in selectively synthesising one species of 1,2-diol from an aldehyde and a ketone as the starting materials. The key to the success was a newly developed copper catalyst that could distinguish between the two different carbonyl compounds.

Fig. 2.3 shows the structure of the copper catalyst with N-heterocyclic carbene (NHC) as one of the ligands.

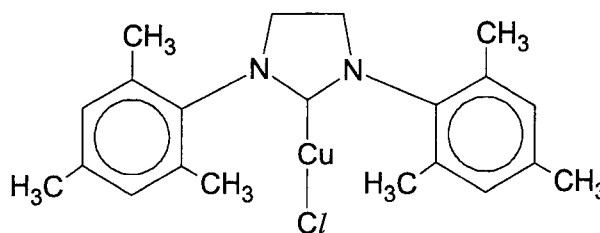


Fig. 2.3

Bases can be used to prepare the NHC ligand, as shown in Fig. 2.4.

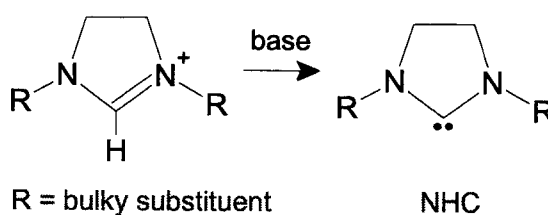


Fig. 2.4

- (i) Define the term *ligand*. [1]
- (ii) State the oxidation number of Cu in Fig. 2.3. [1]
- (iii) Coordination number is defined as the number of dative bonds formed between ligands and the central metal atom or ion.

State the coordination number of Cu in Fig. 2.3. [1]

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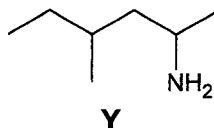
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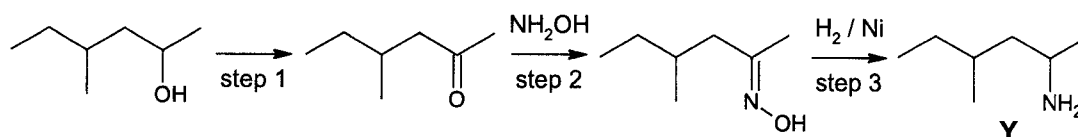
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- 3 (a) Compound Y is a banned performance-enhancing stimulant. Usain Bolt lost one of his three gold medals from the 2008 Olympics because one of his relay team members tested positive for this drug.



Compound Y may be prepared by the three-step synthesis shown in Fig. 3.1. Other products of each step are not shown.



**Fig. 3.1**

- (i) Name the starting organic material in step 1 of Fig. 3.1. [1]
- (ii) Deduce the identity of the other product formed in step 2 of Fig. 3.1. [1]
- .....
- .....
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- .....
- (b) A student suggested that compound Y could be prepared directly from the starting material in step 1 by reacting it with phosphorus pentachloride,  $PCl_5$ , followed by ammonia,  $NH_3$ .
- (i) State the property of ammonia that makes this a possible synthesis route for compound Y. [1]
- (ii) A second student suggested that the first student's proposal might work better if the reaction with ammonia was carried out in the presence of acid.
- Explain if the second student's suggestion is correct. [1]
- (iii) Thionyl chloride,  $SOCl_2$ , can be used as a replacement for  $PCl_5$  in the reaction mentioned in (b).  $SOCl_2$  is difficult to handle safely and is similar to  $PCl_5$  in terms of reactivity and cost.
- Suggest an advantage of using  $SOCl_2$  instead of  $PCl_5$ . [1]
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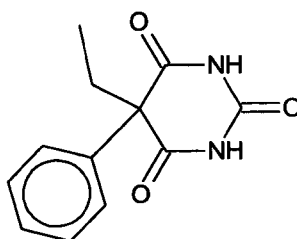
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(c) Phenobarbital is a drug used in the treatment of seizures.



phenobarbital

- (i) Comment on the basicity of phenobarbital. [1]
- (ii) Predict the products of the alkaline hydrolysis of phenobarbital. [2]

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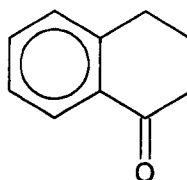
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- (d) 1-tetralone is used in the synthesis of propranolol, a drug used in the treatment of high blood pressure.



1-tetralone

Benzene can be used to make 1-tetralone.

- (i) Suggest the structure of an organic reagent that could form 1-tetralone from benzene in a single step. [1]
- (ii) Explain why benzene does not undergo addition reactions. [1]

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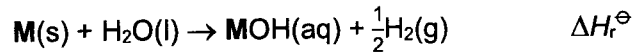
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(e) Organic drug synthesis processes often involve alkali metals.

Alkali metals react with water as shown in the equation, where **M** represents the alkali metal.



For each of the alkali metals, Table 3.1 shows:

- the standard enthalpy change of atomisation,  $\Delta H_{\text{at}}^\ominus$ ,
- the standard enthalpy change of hydration,  $\Delta H_{\text{hyd}}^\ominus$ ,
- the first ionisation energy, 1<sup>st</sup> IE,
- the standard enthalpy change of reaction between alkali metal and water,  $\Delta H_r^\ominus$ .

**Table 3.1**

alkali metal	$\Delta H_{\text{at}}^\ominus (\text{M})$ / kJ mol <sup>-1</sup>	$\Delta H_{\text{hyd}}^\ominus (\text{M}^+)$ / kJ mol <sup>-1</sup>	1 <sup>st</sup> IE (M) / kJ mol <sup>-1</sup>	$\Delta H_r^\ominus (\text{M})$ / kJ mol <sup>-1</sup>
Li	+160	-519	+519	-222
Na	+109	-406	+495	-184
K	+90	-322	+418	-196
Rb	+86	-301	+402	-195
Cs	+79	-276	+376	-203

- (i) Define the term *standard enthalpy change of hydration*. [1]
- (ii) Explain the trend in the standard enthalpy change of hydration,  $\Delta H_{\text{hyd}}^\ominus$ , down the group. [2]

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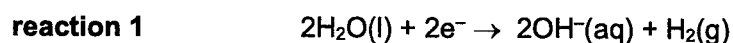
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- (f) (i) Use relevant data from Table 3.1 to calculate the enthalpy change for the following reaction.



- (ii) Using relevant data from Table 3.1 and your answer in (f)(i), draw an energy cycle to determine the enthalpy change of **reaction 1**.



Show your working clearly. [2]

- (iii) There is particular interest in lithium as an energy source due to its low density.

Use relevant data from Table 3.1 to calculate the energy change per gram of lithium for the reaction between lithium and water. [1]

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- (g) Lithium carbonate undergoes thermal decomposition in a similar way to Group 2 carbonates, though a much higher temperature is required.

Explain why the reaction occurs at high temperatures. Refer to the signs of  $\Delta H$ ,  $\Delta S$  and  $\Delta G$  in your answer. [2]

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- (h) Group 2 metals undergo reaction with water in a similar way to alkali metals.

However, magnesium and barium have different reactivities when added separately to water.

Use relevant  $E^\ominus$  values from the *Data Booklet* to explain the difference in the reactivity of magnesium and barium with water. [1]

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[Total: 20]

**Please Turn Over for Section B**

## Section B

Answer **one** question from this section.

- 4 (a) Alcohol is widely used in the preparation of aldehydes and ketones. The electrolysis of alcohols to carbonyl compounds is reported. A simplified diagram of the cell set-up is shown in Fig. 4.1.

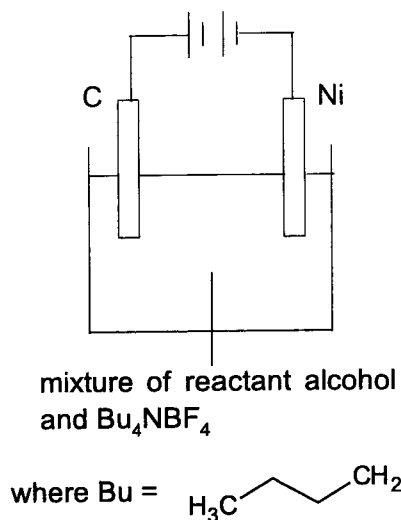
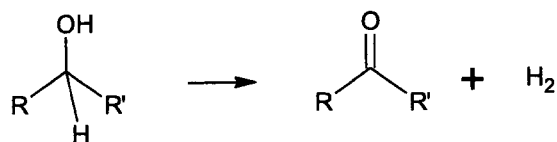


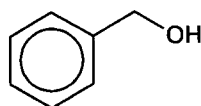
Fig. 4.1

The overall equation for the electrolysis of alcohol is shown.



where R = alkyl or aryl  
R' = H, alkyl or aryl

- (i) Write a balanced equation that shows the complete combustion of benzyl alcohol.



benzyl alcohol

[1]

- (ii) Draw the structure of the product formed when benzyl alcohol is electrolysed. [1]
- (iii) State and explain at which electrode does the conversion of the reactant alcohol take place. You should state the element that the electrode is made of. [2]
- (iv) Suggest the role of  $\text{Bu}_4\text{NBF}_4$  in the set-up in Fig. 4.1. [1]



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**(b)** Iodine-based reagents are commonly used in organic synthesis owing to their unique chemical properties which are linked to their physical properties such as ionic radius and ionisation energy.

- (i)** State what is meant by the *first ionisation energy of iodine*. [1]
- (ii)** State and explain the variation of atomic radius down Group 17. [2]
- (iii)** Hydrofluoric acid and sodium fluoride can be used to form an acidic buffer. Explain how an acidic buffer controls the pH of a solution. [1]
- (iv)** Predict and explain if hydroiodic acid and sodium iodide can be used to form an acidic buffer. [1]

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- 5 (a) Fig. 5.1 shows a hydrogen–halogen fuel cell where  $\text{H}_2$  gas is supplied to the anode while  $\text{Br}_2$ , dissolved in an aqueous solution of  $\text{HBr}$ , is provided to the cathode.

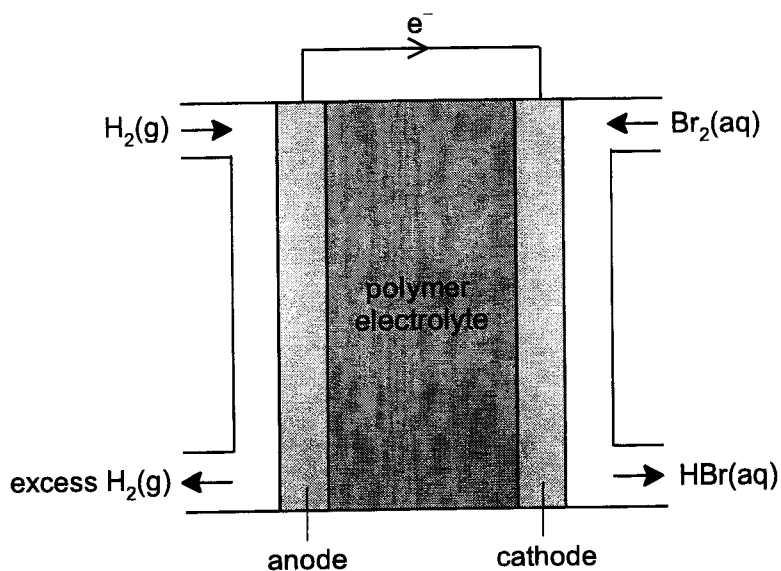


Fig. 5.1

- (i) The polymer electrolyte allows the transfer of a simple ion from the anode to the cathode. Use Fig. 5.1 to suggest the identity of the ion and hence construct balanced equations for the reactions occurring at the electrodes. [2]
- (ii) Use your answer in (a)(i) to write the overall equation when current flows and hence use the *Data Booklet* to calculate the standard cell potential,  $E_{\text{cell}}^{\ominus}$ , for this cell. [2]
- (iii) Use your answer to (a)(ii) to calculate the standard Gibbs free energy change,  $\Delta G^{\ominus}$ , for this electrochemical reaction. [1]
- (iv) A similar hydrogen–halogen fuel cell is set up where  $\text{Cl}_2$ , dissolved in an aqueous solution of  $\text{HCl}$ , is supplied to the cathode.

How would you expect the standard Gibbs free energy change,  $\Delta G^{\ominus}$ , for this electrochemical reaction to compare with your answer in (a)(iii)?

Explain your answer in terms of the difference in relative reactivity of the halogens. [2]

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<b>Name:</b>		<b>Centre/Index Number:</b>		<b>Class:</b>	
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**DUNMAN HIGH SCHOOL**  
**Preliminary Examination**  
**Year 6**

## H2 CHEMISTRY

Paper 4 Practical

**9729/04**

**25 August 2022**  
**2 hours 30 minutes**

Candidates answer on the Question Paper.

### READ THESE INSTRUCTIONS FIRST

- Write your centre number, index number, name and class at the top of this page.  
 Give details of the practical shift and laboratory where appropriate, in the boxes provided.  
 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.

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 19 and 20.

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>

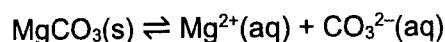
For Examiner's Use	
1	16
2	10
3	14
4	15
<b>Total</b>	<b>55</b>

This question paper consists of **19** printed pages and **1** blank page.

Answer all questions in the spaces provided.

### 1 Determination of solubility product, $K_{sp}$ , of magnesium carbonate

The solubility of solid magnesium carbonate,  $\text{MgCO}_3$ , in water is low. In this experiment, you will determine the solubility product,  $K_{sp}$ , of magnesium carbonate using volumetric analysis.



A saturated solution of magnesium carbonate was prepared by collecting the filtrate after mixing aqueous solutions of magnesium sulfate and sodium carbonate.

You will then determine the amount of carbonate ions left in the filtrate using hydrochloric acid.

**FA 1** is a saturated solution of magnesium carbonate,  $\text{MgCO}_3$ .

**FA 2** is  $0.003 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

methyl orange indicator

#### Note:

- Read the procedures given in part (a) and part (b)(i).
- Part (a) has been done for you. **You are not required to carry out part (a)**, but you will still need to read part (a) to know how **FA 1** is prepared.

#### (a) Preparation of FA 1

1. Use a measuring cylinder to transfer  $20 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$  magnesium sulfate to a clean and dry  $250 \text{ cm}^3$  beaker.
2. Use a measuring cylinder to transfer  $50 \text{ cm}^3$  of  $0.0400 \text{ mol dm}^{-3}$  sodium carbonate to the same beaker. A white precipitate forms.
3. Stir the mixture thoroughly. Leave this mixture to stand for 15 minutes to allow equilibrium to be reached.
4. Filter the reaction mixture into a dry  $250 \text{ cm}^3$  conical flask, using dry filter funnel and filter paper. The filtrate is labelled as **FA 1**. Do not wash the white precipitate with water.

#### (b) (i) Titration of FA 1 against FA 2

1. Fill a burette with **FA 2**.
2. Pipette  $10.0 \text{ cm}^3$  of **FA 1** into a  $100 \text{ cm}^3$  conical flask.
3. Add a few drops of methyl orange indicator to the conical flask.
4. Titrate the solution in the conical flask with **FA 2**. The end-point for this titration is reached when the solution changes colour from yellow to orange.
5. Record all burette readings, to an appropriate level of precision, in the space provided on page 3.
6. Repeat steps 1 to 5 until consistent results are obtained.

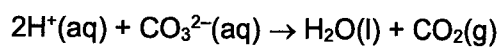
**Titration results**

[3]

- (ii) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 2** = .....cm<sup>3</sup> [4]

- (c) (i) The equation for the reaction in the titration is shown below.



Calculate the concentration of  $\text{CO}_3^{2-}$  ions in **FA 1**.

concentration of  $\text{CO}_3^{2-}$  ions = ..... mol dm<sup>-3</sup> [1]

- (ii) Calculate the total amount of  $\text{CO}_3^{2-}$  ions present in the total volume of filtrate prepared in (a).

total amount of  $\text{CO}_3^{2-}$  ions = ..... mol [1]

- (iii) Hence, calculate the amount of  $\text{CO}_3^{2-}$  ions precipitated as  $\text{MgCO}_3$ .

amount of  $\text{CO}_3^{2-}$  ions precipitated as  $\text{MgCO}_3$  = ..... mol [2]

- (iv) Deduce the amount of  $\text{Mg}^{2+}$  ions removed by precipitation, in step 3 of the procedure in (a). Hence, calculate the amount of  $\text{Mg}^{2+}$  ions left in FA 1.

amount of  $\text{Mg}^{2+}$  ions removed by precipitation = ..... mol

amount of  $\text{Mg}^{2+}$  ions left = ..... mol  
[2]

- (v) Write an expression for the solubility product,  $K_{sp}$ , of magnesium carbonate. Include units in your answer.

$K_{sp}$  of  $MgCO_3$  = .....

units = .....

[1]

- (vi) Calculate a value for the solubility product,  $K_{sp}$ , of magnesium carbonate.

$K_{sp}$  = ..... [1]

- (d) A student follows the procedures described and obtained a higher  $K_{sp}$  value compared to the literature value of  $6.82 \times 10^{-6}$  at 25 °C.

Give a possible explanation for the higher  $K_{sp}$  value obtained.

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.....[1]

[Total: 16]

## 2 Planning

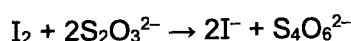
Avogadro's constant,  $L$ , is defined as the number of particles in one mole of a substance. The currently accepted value is  $6.02 \times 10^{23} \text{ mol}^{-1}$ .

The Avogadro's constant,  $L$ , can be determined through the electrolysis of acidified aqueous potassium iodide.

During electrolysis, the amount of material discharged at each of the electrodes depends solely on the amount of current that has passed through the system.

A student conducted the electrolysis experiment. When a current was passed through a solution of acidified aqueous potassium iodide, hydrogen gas was produced at one electrode, while iodine was produced at the other electrode.

The amount of hydrogen produced can be determined from the volume of hydrogen gas collected by downward displacement of water. The amount of iodine produced can be determined by titration of a portion of the resultant solution with aqueous sodium thiosulfate.



- (a) Explain why the volume of gas collected was higher than the theoretical volume of hydrogen gas that can be produced in the electrolysis.

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

- (b) (i) Plan an investigation to determine the amount of iodine produced in the electrolysis of acidified aqueous potassium iodide, if a current of 0.50 A is passed for 10 minutes, and hence determine a value for the Avogadro's constant,  $L$ .

You may assume that you are provided with:

- 500 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> acidified aqueous potassium iodide,
- 0.0100 mol dm<sup>-3</sup> aqueous sodium thiosulfate,
- ammeter (instrument used to measure current)
- wires and crocodile clips
- adjustable DC power source (battery)
- graphite rods
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- a fully labelled diagram of the electrolytic set-up, showing how you would collect and measure the volume of hydrogen gas,
- the apparatus you would use,
- the procedure you would follow for the electrolysis of aqueous potassium iodide.

You need **not** include details of:

- the adjustment of the current setting of the power source to 0.50 A,
- the titration of the resultant solution with aqueous sodium thiosulfate.



- (ii) Table 2.1 gives information about the titration of the resultant solution with aqueous sodium thiosulfate.

Table 2.1

total volume of resultant solution after electrolysis / cm <sup>3</sup>	500
volume of portion of resultant solution used in titration / cm <sup>3</sup>	25.0
volume of sodium thiosulfate used to reach end-point / cm <sup>3</sup>	V

By means of calculations, show how you would use the information in Table 2.1 to determine the Avogadro's constant,  $L$ , in terms of  $V$ . Show your working clearly.

[electronic charge,  $e = -1.60 \times 10^{-19}$  C]

[3]

- (c) A student suggested that the percentage error in titre value can be reduced if 0.0500 mol dm<sup>-3</sup> aqueous sodium thiosulfate was used instead.

Do you agree with this student? Explain your answer.

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.....[1]

[Total: 10]

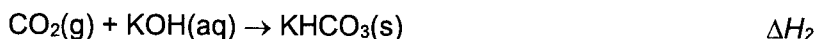


### 3 Determination of a value for the enthalpy change of reaction between $\text{CO}_2$ and $\text{KOH}$ via Hess' Law

The reaction between  $\text{KHCO}_3(\text{s})$  and  $\text{HCl}(\text{aq})$  is an endothermic process.



Using  $\Delta H_1$  and the standard enthalpy change of neutralisation, you will be able to determine the enthalpy change,  $\Delta H_2$ , of the following reaction between  $\text{CO}_2$  and  $\text{KOH}$  via Hess' Law.



**FA 3** is solid potassium bicarbonate,  $\text{KHCO}_3$ .

**FA 4** is  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

#### (a) Determination of $\Delta H_1$

In this experiment, you will be adding  $\text{KHCO}_3(\text{s})$  to  $\text{HCl}(\text{aq})$  in a Styrofoam cup. You will then measure the temperature of the reaction mixture over time. Plotting an appropriate graph using the data obtained will allow you to determine  $\Delta H_1$ .

In an appropriate format in the space provided on page 10, prepare tables in which to record for your experiment:

- all weighings to an appropriate level of precision,
- all values of temperature,  $T$ , to an appropriate level of precision,
- all values of time,  $t$ , recorded to 0.5 min.

It is important that you measure each temperature at the specified time.

#### Procedure

1. Weigh the capped bottle containing solid **FA 3**.
2. Place a clean dry Styrofoam cup inside a second Styrofoam cup, then place these in a glass beaker.
3. Using a measuring cylinder, add  $40 \text{ cm}^3$  of **FA 4** into the first Styrofoam cup.
4. Stir the solution in the cup with the thermometer. Read and record its temperature,  $T$  (time,  $t = 0.0 \text{ min}$ ).
5. Continue to stir the solution. Read and record  $T$  every 0.5 min.
6. At exactly 2.0 minutes, transfer all the solid **FA 3** into the Styrofoam cup in three portions, taking extra care that the mixture that does not overflow. Stir the mixture but do not read  $T$ .
7. Continue to stir the mixture. Read and record  $T$  at  $t = 2.5 \text{ min}$ .
8. Continue stirring and reading  $T$  every 0.5 min until  $t = 7.0 \text{ min}$ .
9. Reweigh the emptied bottle and its cap.

**(i) Results**

[3]

- (ii) Plot a graph of temperature,  $T$ , on the y-axis, against time,  $t$ , on the axis, on the grid in Fig. 3.1.

Draw a best-fit straight line taking into account all of the points before  $t = 2.0$  min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to increase steadily.

Extrapolate both lines to  $t = 2.0$  min.

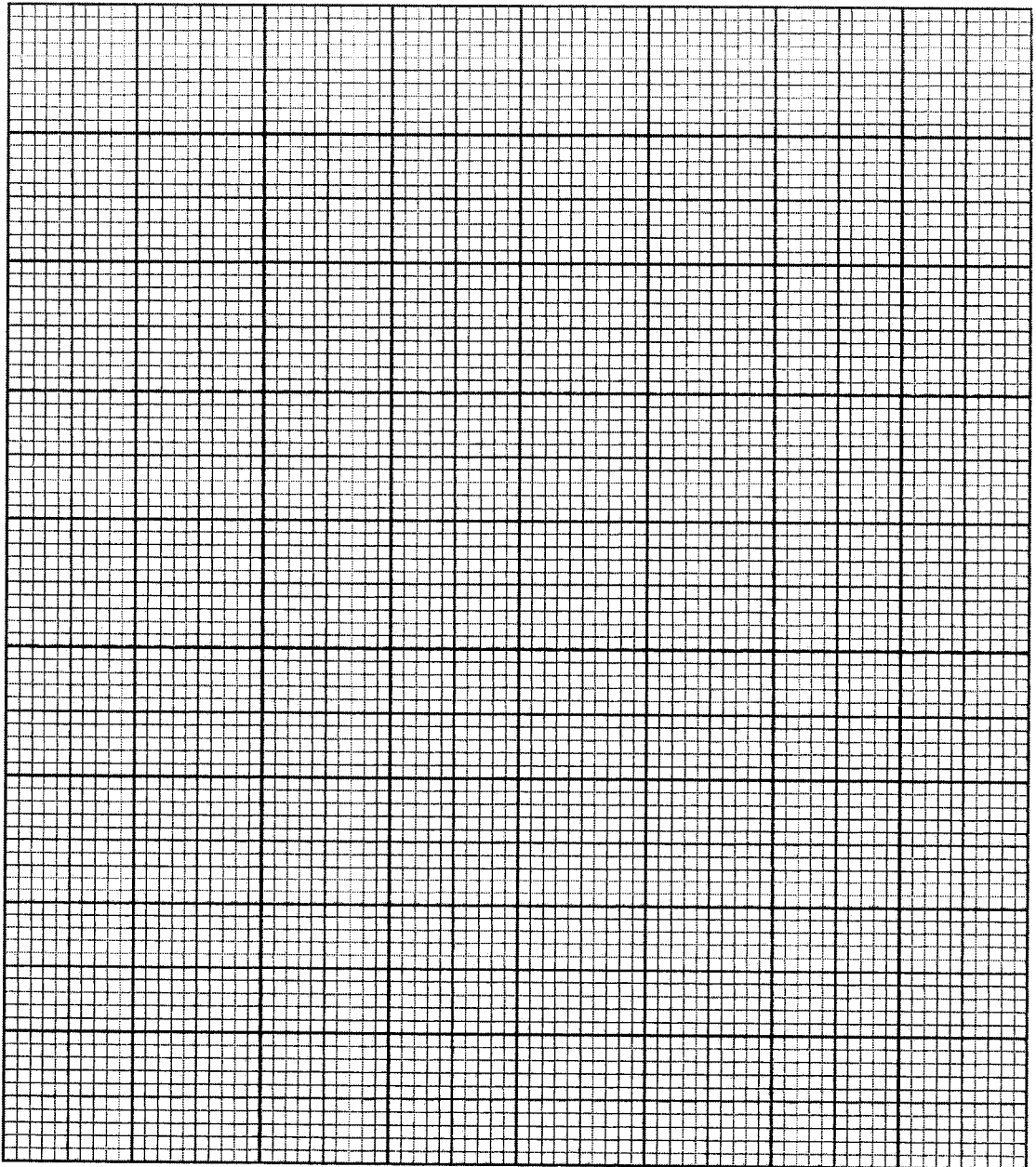


Fig 3.1

[3]

- (iii) From your graph, read the minimum temperature,  $T_{\min}$ , and the maximum temperature  $T_{\max}$ , at 2.0 min. Record these values in the spaces provided below. Deduce the temperature change,  $\Delta T$ , at  $t = 2.0$  min.

$$T_{\min} = \dots\dots\dots$$

$$T_{\max} = \dots\dots\dots$$

$$\Delta T = \dots\dots\dots$$

[1]

- (iv) Calculate the heat change,  $q$ , using the values you deduced in (a)(iii).

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

$$q = \dots\dots\dots [1]$$

- (v) Hence, determine the enthalpy change of reaction,  $\Delta H_1$ .

[A<sub>r</sub>: K, 39.1; H, 1.0; C, 12.0; O, 16.0]

$$\Delta H_1 = \dots\dots\dots [2]$$

- (vi) Calculate the percentage error associated with the measurement of the volume of FA 4.

$$\text{percentage error} = \dots\dots\dots [1]$$

- (vii) Suggest the effect that using 80 cm<sup>3</sup>, rather than 40 cm<sup>3</sup>, of HCl would have on the value for  $\Delta T$ . Hence, deduce and explain the effect this will have on the value for  $\Delta H_1$ .

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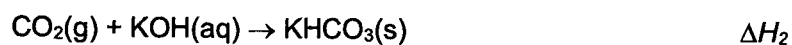
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.....[1]

**(b) Determination of  $\Delta H_2$**

The enthalpy change of neutralisation between a strong acid and a strong base is  $-57.3 \text{ kJ mol}^{-1}$ .

Using this information and your answer in (a)(v), draw an appropriate energy cycle to determine  $\Delta H_2$ , the enthalpy change of following reaction.



$$\Delta H_2 = \dots\dots\dots [2]$$

[Total: 14]

#### 4 Inorganic Analysis

- (a) **FA 5** contains two cations and two anions.  
**FA 6** is a solution of ammonium vanadate(V),  $\text{NH}_4\text{VO}_3$ .

You are to perform the tests described in Table 4.1 and record your observations in the table. Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

In all tests, the reagents should be added gradually until no further change is observed unless you are instructed otherwise.

You should indicate clearly at which stage in a test a change occurs, recording your observations alongside the relevant tests. Your answers should include

- details of colour changes and precipitates formed,
- the identities of gases evolved and details of the test used to identify each gas, **except tests (a)(iv), (vi) and (vii)**.

If there is no observable change, write **no observable change**.

**Table 4.1**

test		observations
(i)	Using a measuring cylinder, add 2 cm <sup>3</sup> of <b>FA 5</b> into a boiling tube.  Add aqueous sodium hydroxide slowly, with shaking, until no further change is seen.	
	Filter the mixture. Retain the filtrate for tests (ii) and (iii). Retain the residue for test (iv).	
(ii)	Add 1 cm depth of the filtrate from test (i) into a boiling tube.  Add one piece of aluminium foil and warm gently.	
(iii)	Add 1 cm depth of filtrate from test (i) into a test-tube.  Add an equal volume of barium nitrate followed by excess dilute nitric acid.	
(iv)	Add 1 cm <sup>3</sup> of hydrogen peroxide to the residue from test (i).	

	test	observations
(v)	<p>Using a measuring cylinder, transfer 2 cm<sup>3</sup> of <b>FA 6</b> into a boiling tube.</p> <p>Add 10 cm<sup>3</sup> of dilute sulfuric acid and swirl the mixture gently.</p> <p>The resultant yellow solution is <b>FA 7</b>, which is an acidified solution of VO<sub>2</sub><sup>+</sup>.</p>	
(vi)	<p>Using a spatula, add a <b>very small quantity</b> of zinc powder to the boiling tube containing <b>FA 7</b> solution from test (v). Swirl the mixture gently and record your observations.</p> <p>Continue to add more zinc powder in small quantities with swirling, until no further colour change is observed. Record all colour changes observed.</p>	
	Filter the mixture and retain the filtrate for test (vii).	
(vii)	To 1 cm depth of the filtrate from test (vi), add an equal volume of aqueous hydrogen peroxide.	

[7]

- (b) (i) Using the results in Table 4.1, deduce the identity of the two cations and two anions present in **FA 5**.

cations .....

anions .....

[2]

(ii) Table 4.2 shows some standard electrode potentials.

**Table 4.2**

electrode reaction	$E^\ominus / V$
$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+1.00
$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$	+0.34
$V^{3+} + e^- \rightleftharpoons V^{2+}$	-0.26
$V^{2+} + 2e^- \rightleftharpoons V$	-1.20
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	-0.76

State and explain which ion is responsible for the final colour of the filtrate in test (a)(vi).

.....

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.....[2]

(c) A student performed an analysis using aqueous cobalt(II) chloride,  $CoCl_2$ . The test and observations are recorded in Table 4.3.

**Table 4.3**

test	observations
To 1 cm depth of $CoCl_2(aq)$ in a test-tube, add aqueous ammonia dropwise, with shaking, until no further change is seen.	Blue-green ppt formed is partially soluble in excess $NH_3(aq)$ to form a pale brown solution.
Then add about 1 cm depth of aqueous hydrogen peroxide and shake the mixture thoroughly.	Blue-green ppt turned brown. Effervescence observed. Gas relights glowing splint. Gas is $O_2$ .

(i) Aqueous  $CoCl_2$  contains  $[Co(H_2O)_6]^{2+}$  ions.

Write an equation for the formation of the blue-green precipitate.

.....[1]



- (ii) Using your answer in (c)(i), account for the partial dissolution of the blue-green precipitate to form a pale brown solution when aqueous ammonia was added in excess.

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

- (iii) With reference to changes in oxidation state, explain the formation of the brown precipitate upon the addition of aqueous hydrogen peroxide.

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

[Total: 15]

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**Qualitative Analysis Notes**

[ppt. = precipitate]

**(a) Reactions of aqueous cations**

<b>cation</b>	<b>reaction with</b>	
	<b>NaOH(aq)</b>	<b>NH<sub>3</sub>(aq)</b>
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**

<i>ion</i>	<i>reaction</i>
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 with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

**(c) Tests for gases**

<i>gas</i>	<i>test and test result</i>
ammonia, $\text{NH}_3$	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 aqueous acidified potassium manganate(VII) from purple to colourless

**(d) Colour of halogens**

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
chlorine, $\text{Cl}_2$	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