NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **9729/02**
Paper 2 Structured Questions **29 August 2022**
2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

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

For Examiner's Use	
1	/15
2	/22
3	/15
4	/11
5	/12
Paper 2 Total	/75

	Marks	**Weightings**
Paper 1	/30	**15%**
Paper 2	/75	**30%**
Paper 3	/80	**35%**
Paper 4	/55	**20%**

Overall Percentage	
Grade	

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

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

1 **(a)** Chemists have recently established that four molecules of water are required for the dissociation of a single molecule of HC*l* (reported in *Science*, 2009).

Given that 1.00 dm^3 of water contains 55.6 mol of H_2O, calculate the number of molecules of hydrogen chloride, HC*l*, that should therefore dissociate in 1.00 dm^3 of water.

[1]

(b) Commercial concentrated hydrochloric acid, HC*l*, fumes strongly on exposure to moist air and thus is known as 'fuming hydrochloric acid'.

1.00 cm^3 of fuming hydrochloric acid was transferred with a graduated pipette to a 100 cm^3 volumetric flask. The volume was made up to 100 cm^3 with deionised water and the solution was labelled **F**. 10.0 cm^3 of solution **F** was neutralised by 24.75 cm^3 of 0.0500 mol dm^{-3} of aqueous sodium hydroxide.

Calculate the concentration of HC*l* in the fuming hydrochloric acid in mol dm^{-3}.

[2]

(c) **(i)** The halide ions, X^- (where X = C*l*, Br, I), show clear trends in their physical and chemical properties.

State and explain the relative thermal stabilities of the hydrogen halides, HX.

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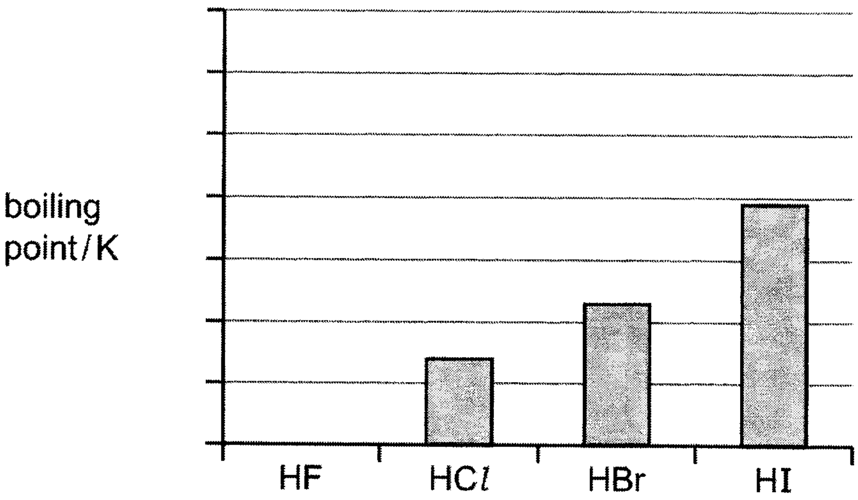
[2]

The bar chart below shows the boiling points of HC*l*, HBr and HI. The boiling point of HF is not shown.



(ii) Explain why HI has a higher boiling point than HC*l* and HBr.

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[1]

(iii) Complete the bar chart above to show the boiling point of HF.
Explain your answer.

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[2]

(d) Indium and aluminium are elements in Group 13 of the Periodic Table. Indium has very similar chemical properties to aluminium.

- Indium reacts vigorously with hydrochloric acid to form a colourless gas and a soluble salt.
- Indium oxide, In_2O_3, is amphoteric. In_2O_3 is a white solid which dissolves in excess aqueous NaOH.
- Gaseous indium bromide, In_2Br_6, contains coordinate bonds.

(i) Identify the formula of the salt formed when indium reacts with hydrochloric acid.

.... [1]

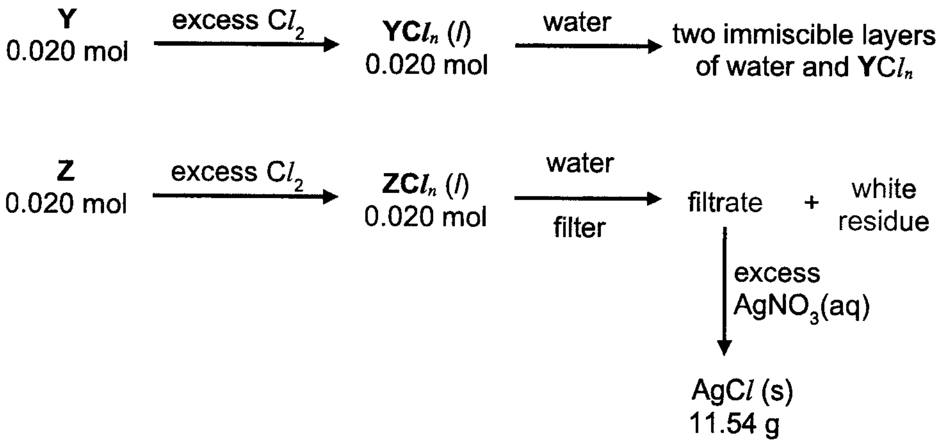
(ii) Construct an equation for the reaction of In_2O_3 with excess aqueous NaOH.

.... [1]

(iii) Draw a diagram that clearly shows the types of bonds in a molecule of In_2Br_6 (g).

[1]

(e) In the periodic table, element **Y** is above element **Z** in the same group. Elements **Y** and **Z** are subjected to a series of reactions in the flowchart below.



(i) Calculate the value of n in ZCl_n.

[1]

(ii) Suggest the identities of elements **Y** and **Z** and explain why YCl_n and ZCl_n react differently with water.

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.... [2]

(iii) Write a balanced equation for the reaction of ZCl_n with water.

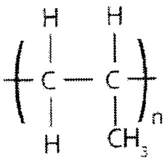
.... [1]

[Total:15]

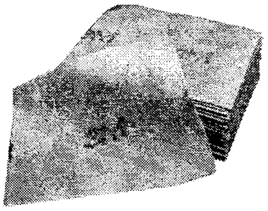
2 **(a)** Oil spills are hazardous as it affects the marine ecosystem, and the marine life-forms existence gets threatened. It becomes increasingly important to employ various clean up methods for tackling the menace that oil spills pose to the marine ecosystem.

(i) Oil consists mainly of hydrocarbons. Sheets of sorbents, usually made of materials like polypropene, can be used to absorb oil.

The structure of polypropene is given below.



Structure of polypropene



Sorbent sheets

Suggest how sorbents are able to absorb and effectively remove oil from water.

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[2]

(ii) Another method of removing oil floating on the sea surface is to ignite and burn it off. Such burning of oil will cause an increase in temperature of the sea.

One of the major components of oil is decane, $C_{10}H_{22}$. A simulation was done where 500 g of decane floating over 200 dm^3 of water was burnt off.

Given that the enthalpy change of combustion of decane is -300.9 kJ mol^{-1}, determine the rise in temperature of the body of water.

[3]

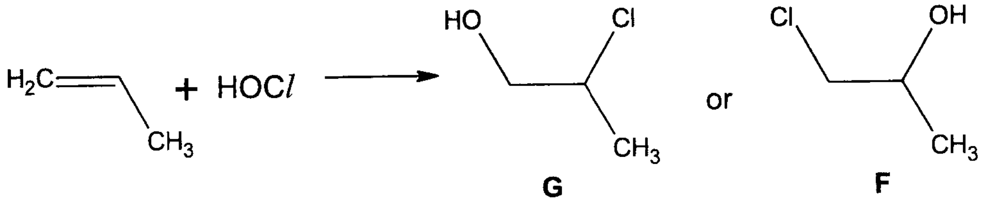
(iii) The actual temperature rise differs from the calculated value in **(a) (ii)**. Suggest a reason for the discrepancy.

....

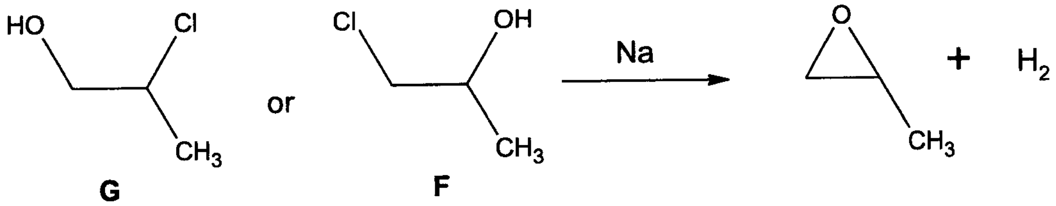
[1]

(b) Propene is the second most important starting material in the petrochemical industry. It is involved in a two-step synthesis to make a class of compounds known as epoxides.

Step **1**: Propene is reacted with HOC*l* to give two possible products, **G** or **F**.



Step **2**: The mixture of **G** and **F** is treated with Na to give the epoxide.



(i) State the type of isomerism between **G** and **F**.

.... [1]

(ii) Determine the type of reaction that occurs in **each step**.

Step **1**: ....

Step **2**: .... [2]

(iii) Outline the mechanism for formation of **F** in step 1.
In your answer, show any relevant charges, lone pairs of electrons and movement of electrons.

[2]

(iv) Hence explain why **F** is the major product in step 1.

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[2]

(v) Suggest the importance of Na in the formation of epoxide.

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[1]

(c) Allyl chloride, $ClCH_2CH=CH_2$, is produced by the chlorination of propene at high temperatures

equation 1 $CH_3CH=CH_2 + Cl_2 \rightarrow ClCH_2CH=CH_2 + HCl$

(i) At lower temperatures, the main product is 1,2-dichloropropane.
Explain why the formation of allyl chloride, $ClCH_2CH=CH_2$, occurs at high temperatures.

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....

[1]

[Turn over

(ii) $ClCH_2CH=CH_2$ contains a C=C bond.
Draw labelled diagrams to show how orbitals overlap to form

- a σ (sigma) bond
- a π (pi) bond.

[2]

(iii) Describe the mechanism for the formation of $ClCH_2CH=CH_2$ in equation 1.

[3]

(iv) Other than $ClCH_2CH{=}CH_2$, two other mono-substituted chloropropenes can also be formed by the same mechanism in **(c) (iii)**.

Complete Table 2.1 with

- the structures of the two other chloropropenes
- the expected ratio in which the three chloropropenes will be formed.

Table 2.1

chloropropene	$ClCH_2CH{=}CH_2$		
ratio			

[2]

[Total:22]

3 Vanadium is a transition metal that forms stable coloured ions of various oxidation states in aqueous solutions. Some of the ions of vanadium and their corresponding colours are shown in the table below.

formula of vanadium ion	VO_2^+	VO^{2+}	V^{3+}	V^{2+}
colour of aqueous solution	yellow	blue	green	violet

(a) Explain why vanadium can form ions of variable oxidation states.

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[1]

(b) Data about calcium and vanadium are given below.

	calcium	**vanadium**
relative atomic mass	40.1	50.9
electronic configuration	$[Ar]4s^2$	$[Ar]3d^34s^2$
atomic radius (metallic) /nm	0.197	0.122
density / g cm^{-3}	1.54	6.07

Using the data provided, explain why the density of vanadium is significantly greater than that of calcium. (No calculations are required.)

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[2]

(c) Predict, by calculating $E^\ominus_{cell}$ values, the reaction(s) that occur in each experiment. State the observation(s) that would be made in each experiment.

(i) Experiment **A**:
Excess acidified hydrogen peroxide is added to an aqueous solution containing VO^{2+} ion.

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[2]

(ii) Experiment **B**:
Excess tin is added to an acidic aqueous solution containing VO^{2+} ion.

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[3]

(d) The vanadium-containing ion in 50 cm^3 of a 0.800 mol dm^{-3} solution of ammonium metavanadate, NH_4VO_3, reacts with 506 cm^3 of sulfur dioxide gas measured at 20.0 °C and 98.0 kPa. In the reaction, sulfur dioxide is oxidised according to the equation given below.

$$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$$

(i) Calculate the final oxidation state of the vanadium ion in the solution.

[2]

(ii) Hence, write a balanced equation for the reaction between VO_3^- and SO_2.

....

[1]

(e) Vanadium(V) oxide, V_2O_5, is obtained by the action of heat on ammonium metavanadate, NH_4VO_3. V_2O_5 is an orange-coloured solid that catalyses the Contact process:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

(i) State the type of catalysis involved.

.... [1]

(ii) Explain briefly how V_2O_5 catalyses the Contact process.

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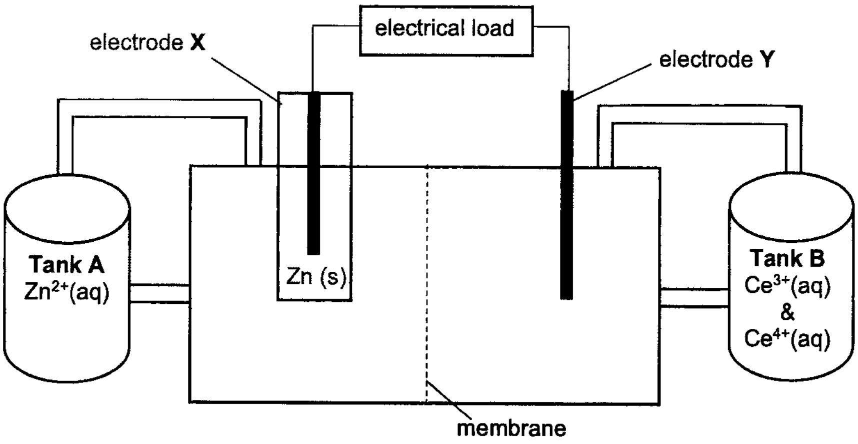
[3]

[Total: 15]

4 (a) Flow batteries are one of the most viable technologies for larger scale energy storage. Zinc–cerium battery is a flow battery with graphite electrodes where the electrolytes can be pumped from separate storage tanks into the cell. A thin membrane, separating the two electrolytes, allows selected ions to flow through it.



(i) During discharging, electrons flow from electrode **X** to electrode **Y**.
Write the equation for the reaction that occurs at the cathode and the anode respectively.

cathode: ……………………………………………………………………………………

anode: ……………………………………………………………………………………

[2]

(ii) Given the standard cell potential, $E^\ominus_{cell}$, of the Zn-Ce battery is 2.2 V, calculate the standard free energy change, $\Delta G^\ominus$, and state its units.

[1]

(iii) Explain why it is necessary to have a membrane that allows selected ions to flow through it in the Zn-Ce battery.

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[1]

(iv) The Zn-Ce battery can be recharged by applying current across the two electrodes. How long would it take, in hours, to recharge a Zn-Ce battery at a current of 2 A to deposit 6.1 g of Zn?

[2]

(v) During the charging process, a side reaction occurs at electrode **Y** that requires the electrode to be replaced periodically.

Identify the side reaction and give a reason why electrode **Y** needs replacement.

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[2]

(b) Supercapacitors are gaining attention in wearable and lightweight electronic devices due to its fast charging–discharging capacity and long lifespans compared to a typical battery. The cathode electrode material for supercapacitors must have high temperature stability.

Using relevant data from the *Data Booklet*, describe and explain which compounds, manganese(II) carbonate, $MnCO_3$, or magnesium carbonate, $MgCO_3$, is more suited for use as the cathode electrode in supercapacitors.

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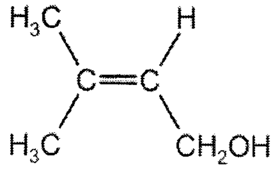
[3]

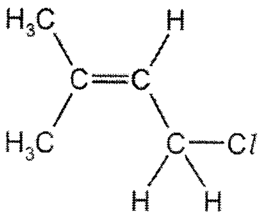
[Total: 11]

5 Prenol is a naturally occurring organic molecule found in many fruits. It contains both an alkene and an alcohol functional group.

Prenol



G



(a) State the reagents and conditions to convert **G** to prenol.

.... [1]

(b) Prenol reacts with steam to form a mixture of three isomers, **J**, **K** and **L**, with molecular formula $C_5H_{12}O_2$.

(i) When **J** is heated with excess acidified potassium manganate(VII), it forms an organic product which does not react with 2,4-dinitrophenylhydrazine.

Suggest a structure of **J**.

[1]

K and **L** are stereoisomers. **K** and **L** both react when heated with excess acidified potassium manganate(VII) to form **M**, $C_5H_8O_3$. **M** forms an orange precipitate on reaction with 2,4-dinitrophenylhydrazine.

(ii) Name the type of stereoisomerism shown by **K** and **L**, and draw structures to illustrate the stereoisomerism.

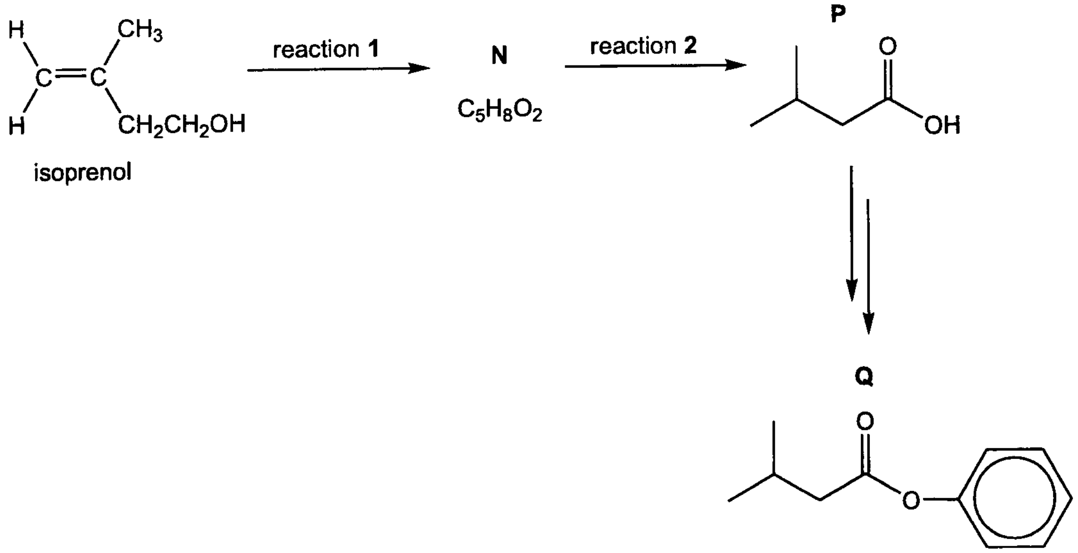
....[2]

(iii) Write a balanced equation to represent the reaction of **K**, $C_5H_{12}O_2$, with acidified potassium manganate(VII), to form **M**, $C_5H_8O_3$.

Use [O] to represent an atom of oxygen provided by the oxidising agent.

....[1]

(c) Isoprenol is a structural isomer of prenol. The series of reactions below shows how isoprenol can be used to form **Q**, a sweet-smelling liquid.



(i) Suggest the structure of **N**.

[1]

(ii) Suggest the reagents and conditions for reactions **1** and **2**.

reaction **1**: ....

reaction **2**: ....

[2]

(iii) Suggest the step(s) to convert **P** to **Q**, showing the structure of any intermediate formed.

[3]

(iv) Compound **S**, a structural isomer of isoprenol, gives a brick-red precipitate when treated with alkaline solution of copper(II) tartrate. **S** gives only one mono-chlorinated product when reacted with chlorine gas under ultraviolet light.

Suggest the structure of **S**.

[1]

[Total: 12]

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NATIONAL JUNIOR COLLEGE
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Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **9729/03**

Paper 3 Free Response

13 September 2022

2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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	
Section A	
1	**/18**
2	**/19**
3	**/23**
Section B (*circle the question you attempt)	
4	**/20**
5	**/20**
Paper 3 Total	**/80**

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

Section A

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

1 **(a)** Amines can be synthesised from methylbenzene, shown by the following steps.

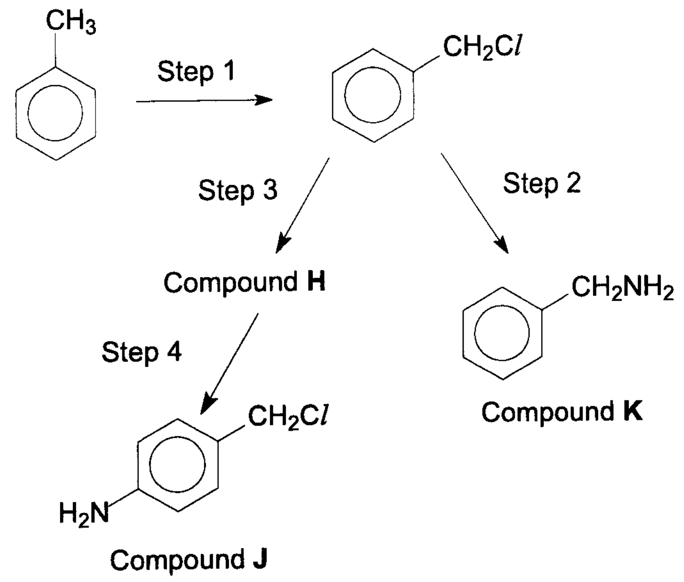

Fig. 1.1

(i) Suggest the structure for compound **H**. [1]

(ii) Suggest reagents and conditions for steps 1, 2, 3 and 4 in Fig. 1.1. [4]

(iii) Suggest why the yield for step 2 is not high. [1]

The K_b values of three bases, at 25 °C, are shown in Table 1.2.

Table 1.2

base	K_b/mol dm^{-3}
ammonia	1.8×10^{-5}
compound **K**	4.5×10^{-4}
compound **J**	7.4×10^{-10}

(iv) Explain the relative magnitudes of the K_b values in Table 1.2. [2]

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(b) The rate of reaction for step 2 in Fig. 1.1 can be followed by measuring the change in concentration of C_7H_7Cl with time. The reaction was carried out with the other reactant in large excess.

Fig. 1.2 shows the concentration of C_7H_7Cl monitored against time for step 2.

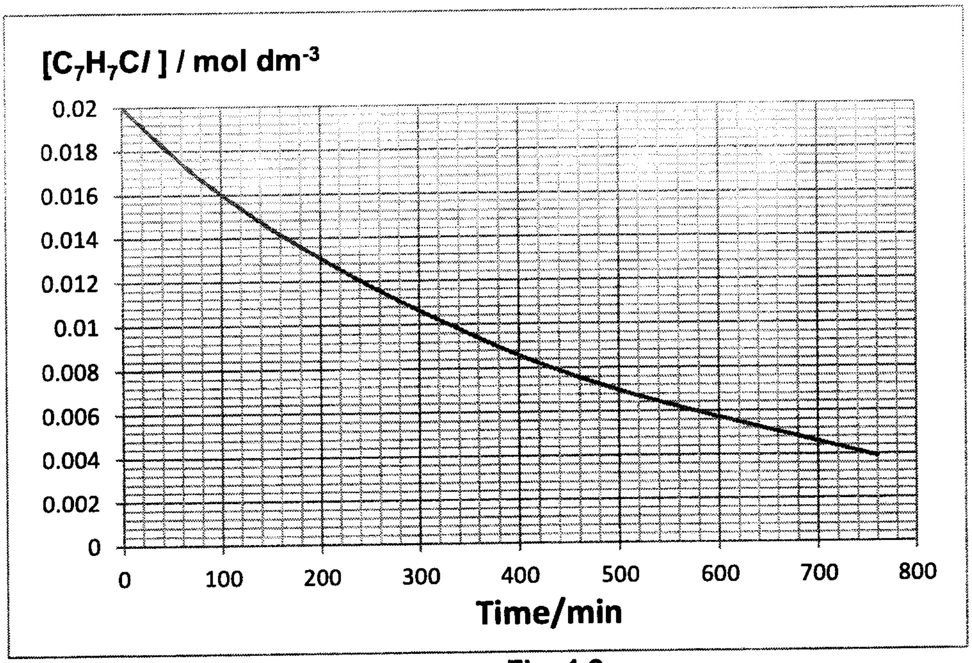

Fig. 1.2

Showing all your working and drawing clearly any construction lines, use Fig.1.2 to determine:

(i) The order with respect to C_7H_7Cl. Explain your reasoning. [2]

(ii) The initial rate, in mol dm^{-3} min^{-1} [1]

Given that the half-life magnitude of C_7H_7Cl is not affected by the change in concentration of the other reactant.

(iii) Write the rate equation for step 2 in Fig.1.1, and calculate a value for the rate constant, stating its units. [2]

(iv) Hence, outline a mechanism for step 2 in Fig.1.1 to form all the products.

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

(v) Explain why step 2 proceeds via the mechanism you describe in **b(iv)**. [1]

(vi) Suggest and explain the difference in reactivity when 4-bromomethylbenzene undergoes the same reaction. [1]

[Total : 18]

PLEASE TURN OVER

2 Hydrogen cyanide, HCN, is extremely toxic and with sufficient concentrations it leads to rapid death. During the Second World War, a form of hydrogen cyanide known as *Zyklon B* was used in the Nazi gas chambers.

(a) **(i)** Draw a dot–and–cross diagram to illustrate the bonding in HCN. [1]

HCN can be oxidised to cyanogen, C_2N_2.

$$C_2N_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons 2HCN(g) \quad E^\ominus = +0.37\ V$$

(ii) Suggest a suitable oxidant to oxidise HCN to C_2N_2 in acidic solution, using the *Data Booklet*.

Write an equation for the reaction and calculate the $E^\ominus_{cell}$. [2]

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(b) The synthesis of HCN was developed in the early 1900s. The most commonly used procedure is the *Andrussow* process. A less common method is the *BMA* process.

Andrussow process:

$CH_4\,(g) + NH_3\,(g) + \frac{3}{2}O_2\,(g) \longrightarrow HCN\,(g) + 3H_2O\,(l) \qquad \Delta H = -\,506\text{ kJ mol}^{-1}$

BMA process:

$CH_4\,(g) + NH_3\,(g) \longrightarrow HCN\,(g) + 3H_2\,(g)$

(i) Using information from the *Data Booklet*, calculate the enthalpy change of reaction for the *BMA* process given above. [2]

(ii) By considering the spontaneity of reaction, suggest why the *Andrussow* process is the preferred procedure at low temperature. [2]

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(c) The *BMA* process is a reversible reaction at 500 °C. Starting with equal amounts of CH_4 and NH_3, the reaction is allowed to reach equilibrium at 500 °C under a constant pressure of 1 atm.

BMA process: $CH_4\,(g) + NH_3\,(g) \rightleftharpoons HCN\,(g) + 3H_2\,(g)$

(i) Write an expression for the K_p of *BMA* process, stating its units. [1]

(ii) Given that the equilibrium partial pressure of H_2 is 0.3 atm, calculate the value of K_p at 500 °C. [2]

(iii) Discuss the effect of increase in total pressure on

- the proportion of HCN,
- K_p value,
- rate of reaction .

[3]

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(d) HCN (aq) has pK_a = 4.79 at 25 °C.

(i) Calculate the concentration of CN^- ion at pH 4, when the concentration of HCN(aq) is 0.06 mol dm^{-3}. [1]

Zinc cyanide, $Zn(CN)_2$, is sparingly soluble in water.
The numerical value of K_{sp} is 8.0×10^{-12} at 25°C.

(ii) Write an expression for the K_{sp} of $Zn(CN)_2$, stating its units. [1]

(iii) By considering your answer to **(d)(i)**, determine the minimum concentration of Zn^{2+} required to cause precipitation of $Zn(CN)_2$ at pH 4. [2]

(iv) Describe and explain how the solubility of $Zn(CN)_2$ is affected:

- by adding HC*l*(aq)
- by adding concentrated ZnCl_2(aq)

. [2]

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[Total:19]

3 **(a)** GABA, a naturally occurring neurotransmitter, has the condensed formula of $HOOCCH_2CH_2CH_2NH_2$. It can be synthesised from 2-bromoethanal, CH_2BrCHO, shown by the following steps.

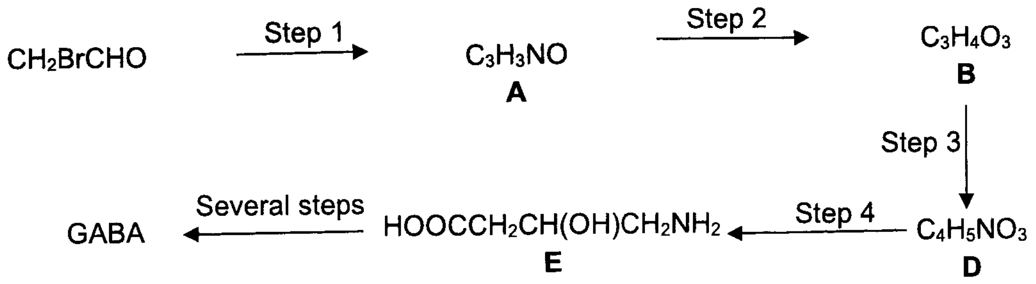


Fig. 3.1

Compound **B** gives effervescence with $Na_2CO_3(aq)$ and it gives a brick red precipitate with warm Fehling's solution.

(i) Suggest what these observations indicate about the functional groups in **B**. [1]

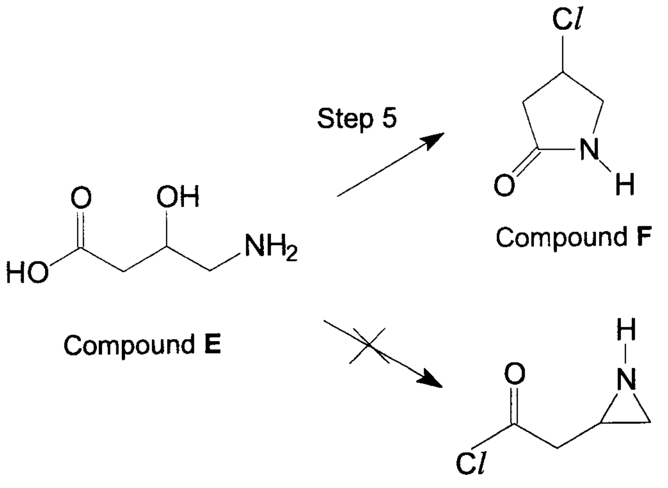
(ii) Give the structures for compounds **A** and **D**. [2]

(iii) Suggest reagents and conditions for steps 1, 2, 3 and 4 in Fig. 3.1. [4]

(iv) Suggest why the yield for step 3 is very low. [1]

(v) The conversion of **B** to **D** involves a nucleophilic addition. Suggest why only 50% of compound **D** can be used in drug synthesis. [2]

(b) Compound **E** undergoes intramolecular condensation reaction under suitable conditions. Isomer **F** is produced instead of isomer **G**.



Compound **E**

Compound **F**

Compound **G**

Fig. 3.2

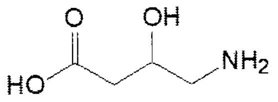
(i) Suggest the reagents and conditions for step 5 in Fig. 3.2. [1]

(ii) Give two reasons why isomer **F** is preferentially formed. [2]

(iii) Explain why compound **F** is neutral. [2]

(c) Table 3.3 shows the pK_a values of different functional groups present in compound **E** and GABA.

Table 3.3

	pK_{a1} of carboxyl group	pK_{a2} of amino group
$HOOCCH_2CH_2CH_2NH_2$ GABA	2.45	9.10
 Compound **E**	2.05	9.80

(i) Suggest a reason why pK_{a1} value of compound **E** is of lower value than pK_{a1} of GABA. [1]

(ii) Calculate the initial pH of 25.0 cm^3 of 0.050 mol dm^{-3} of compound **E**. [1]

(iii) Calculate the volumes of 0.10 mol dm^{-3} of NaOH required to form a buffer mixture with compound **E** at pH 2.05 and 9.80 respectively. [2]

(iv) Sketch the pH-volume added curve you would expect when compound **E** is titrated against 0.10 mol dm^{-3} of NaOH. Include the volume and pH values given or calculated in **(c)(ii)** and **(c)(iii)** as well as the volumes required for each equivalence point.

You may assume that the graph tends towards pH 13 upon addition of excess NaOH. [2]

(v) The working range for thymolphthalein is 9.3 to 10.5, comment on whether thymolphthalein is a suitable indicator for identifying the first endpoint. [1]

(vi) Write two equations to describe how the buffer mixture at pH 9.80 from **(c)(iii)** can act as a buffer when small amounts of H^+ or OH^- is added. [1]

[Total: 23]

[Turn over

PLEASE TURN OVER

Section B

Answer **one** question from this section.

4 **(a)** State the electronic configuration of chromium. [1]

....

(b) Chromium(VI) ions commonly exist as oxo-anions such as CrO_4^{2-}, which is yellow in color and $Cr_2O_7^{2-}$,which is orange.

(i) Explain why chromium(VI) ions exist as oxo-anions instead of $[Cr(H_2O)_6]^{6+}$. [1]

(ii) Write the equation for the conversion of CrO_4^{2-} to $Cr_2O_7^{2-}$ in acidic medium. Predict the observation when NaOH is added to this solution at equilibrium. [2]

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(c) **E** is a hydrated salt containing 13.0 % of Cr, 27.0 % of H_2O and 60.0 % of Br by mass. When 0.400 g of **E** is dissolved in water, an octahedral complex cation is formed. When treated with aqueous silver nitrate, this solution **immediately** gives 0.188 g of cream precipitate.

(i) Calculate the mole ratio of Cr: H_2O: Br in the hydrated salt **E**. [1]

(ii) Identify the cream precipitate and hence, determine the formula of the complex cation formed when **E** is dissolved in water.

[2]

(iii) Draw the structure of the complex cation present in **E**, showing clearly how the ligands are arranged around chromium cation. Indicate the overall charge of this complex ion. [1]

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(d) When a current of 1.0 A was passed through aqueous potassium maleate ($KO_2CCH{=}CHCO_2K$) for 15 minutes, it was found that 110 cm^3 H_2, measured at r.t.p, was collected at the cathode. The following reaction took place.

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$$

Ethyne, C_2H_2, and CO_2 gas were produced at the anode. In order to determine the stoichiometry of the anode reaction, the volume of the gases collected at the anode was measured. The anode gas was first passed through aqueous NaOH before being collected in a gas syringe. The following data was collected :

- mass of bottle containing NaOH before experiment = 10.501 g
- mass of bottle containing NaOH after experiment = 10.904 g
- initial reading on syringe = 10.0 cm^3
- final reading on syringe = 120.0 cm^3

(i) Using the data *obtained from the cathode* and the *Data Booklet*, calculate a value for Faraday constant. [2]

(ii) Calculate the volume of CO_2 produced at the anode, assuming r.t.p conditions. [2]

(iii) State the volume of ethyne gas and hence suggest an ion-electron equation for the reaction that occurred at the anode. [2]

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(e) Ethanal used to be manufactured from ethyne. These days, ethene is being used as the reactant instead. Widely known as the Wacker-Tsuji Oxidation, ethene and oxygen are bubbled together through an aqueous solution containing $CuCl_2$ and $PdCl_2$ catalysts:

$$CH_2{=}CH_2 + \tfrac{1}{2}O_2 \xrightarrow[CuCl_2]{PdCl_2} CH_3CHO$$

The Wacker-Tsuji Oxidation is also useful for the synthesis of ketone:

$$RCH{=}CH_2 + \tfrac{1}{2}O_2 \xrightarrow[CuCl_2]{PdCl_2} RCOCH_3$$

Compound **A**, C_9H_{10}, is used as a reactant in the Wacker-Tsuji oxidation reaction to give compound **B**, $C_9H_{10}O$. **B** gives a yellow precipitate when warmed with aqueous alkaline I_2. When **B** is reacted with LiA/H_4 in dry ether, compound **C** is formed. **A**, **B** and **C** all reacted with hot acidified $KMnO_4$ to give compound **D**, $C_7H_6O_2$.

Suggest the structures of compounds **A** to **D** and explain the reactions described.

[6]

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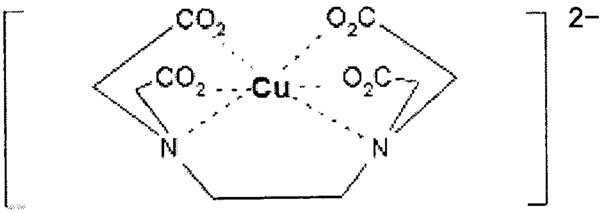
[Total: 20]

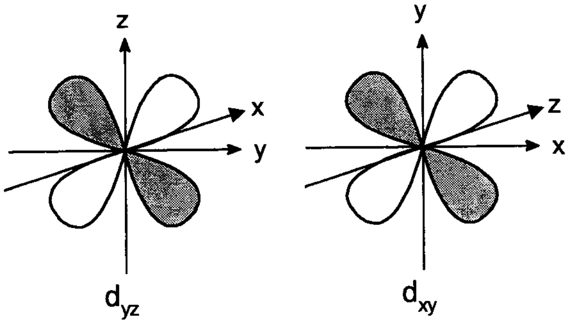
5 (a) Copper and its compounds have a wide variety of uses.
Copper-EDTA complexes are commonly used in cosmetics and it gives the blue colour in many shampoos.

The structure of the copper-EDTA complex is given below.



(i) State the electronic configuration of the copper ion in the copper-EDTA complex. [1]

(ii) Two of the d orbitals are given below. Sketch the shapes of the other three d orbitals present in copper, labelling your orbitals clearly.



[2]

(iii) Explain why the copper-EDTA complex is blue. [3]

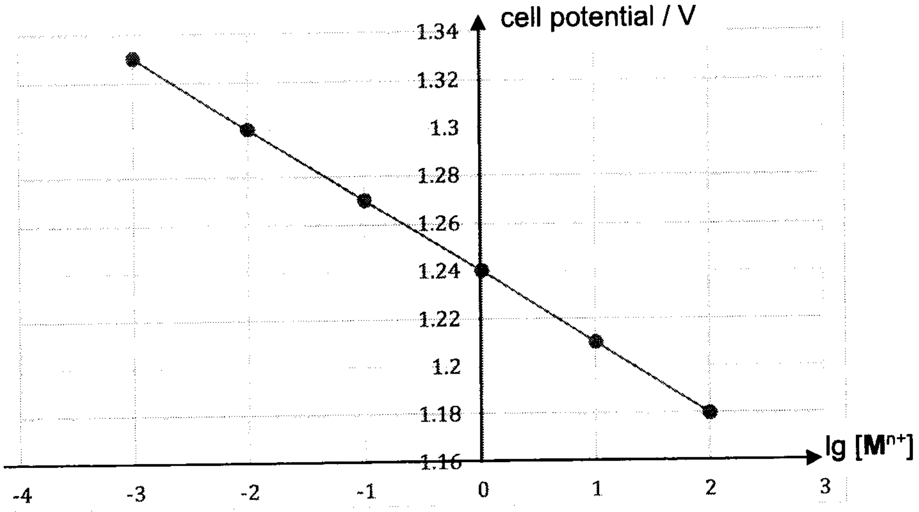
(iv) Cobalt and copper are both common transition elements.

Comment on the similarity of the atomic radii between cobalt and copper. [1]

(b) An experiment was set up to investigate how the cell potential of a cell containing a metal, **M**, in contact with an aqueous solution of its ions, $\mathbf{M}^{n+}$(aq), changed as $\mathbf{M}^{n+}$(aq) was diluted.
As a Standard Hydrogen Electrode was not available, a half-cell consisting of Cl^-/ClO^- in alkaline medium under standard conditions was used to connect to the half-cell with **M** in contact with $\mathbf{M}^{n+}$(aq).

(i) Draw a fully labelled diagram of the electrochemical cell set-up as described above, in order to measure the changes in cell potential. [3]

(ii) The cell potential was measured for various concentrations of $\mathbf{M}^{n+}$(aq) and the results of cell potential against lg [$\mathbf{M}^{n+}$] obtained are plotted in the graph as shown below.



Given that the cell potential of a cell, E_{cell}, is related to the standard electrode potential, $E^{\ominus}_{cell}$, by the equation:

$E_{cell} = E^{\ominus}_{cell} - \frac{0.06 \lg[M^{n+}]}{n}$, use your graph to determine

(I) the charge, n, of the $\mathbf{M}^{n+}$ ions

(II) the $E^{\ominus}_{cell}$ [2]

(iii) Given that the standard electrode potential for Cl^-/ClO^- in alkaline conditions is +0.80 V, calculate the standard electrode potential of the half cell containing $\mathbf{M}^{n+}$(aq) and **M**(s).
Suggest the identity of **M**. [2]

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(c) In the presence of $HClO_4$, alcohols react with nitriles to form *N*–alkylamides. This is known as the *Ritter reaction*, as shown in Fig. 5.1.

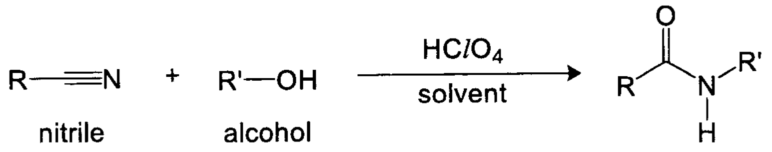

Fig. 5.1

Compounds **A** and **B** react in the presence of $HClO_4$ to give compound **C** via the *Ritter reaction.*

Compound **A** has the molecular formula $C_4H_{10}O$. When heated under reflux with acidified $K_2Cr_2O_7$, it gives a product that gives a yellow precipitate when warmed with aqueous alkaline iodine.

Compound **D** is a 6-membered ring molecule and has the molecular formula $C_7H_{12}O$. When heated with acidified $KMnO_4$, it forms $CH_3COCH_2CH_2COCH_2CO_2H$. **D** reacts with PCl_5 followed by hot ethanolic KCN to give **B**.

Suggest the structures of compounds **A** to **D** and explain the reactions described. [6]

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[Total: 20]

Additional answer space

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

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NATIONAL JUNIOR COLLEGE
SH2 Year-End Practical Examination
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY **9729/04**
Paper 4 Practical **16 August 2022**
Candidates answer on the Question paper **2 hours 30 minutes**
Additional Materials: As listed in the Confidential Instructions

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READ THESE INSTRUCTIONS FIRST

Write your identification number and name.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in 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 22 and 23.

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.

Shift
Laboratory

For Examiner's use	
1	/ 9
2	/ 21
3	/ 17
4	/ 8
Total	/ 55

This document consists of **23** printed pages including this cover page.

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

1 **Determination of the enthalpy change of a reaction, ΔH_r**

FA 1 is 1.00 mol dm^{-3} sodium hydrogen carbonate, $NaHCO_3$ **(to be used for Q3 as well)**
FA 2 is 2.00 mol dm^{-3} sodium hydroxide, NaOH
FA 3 is 2.00 mol dm^{-3} sulfuric acid, H_2SO_4

An acid-base neutralisation reaction involves reacting the two solutions, to produce water molecules. The equation for this neutralisation reaction is given below.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

You will follow the instructions to perform two experiments, **Experiment A** and **Experiment B**. Record your results in **Tables 1.1** and **1.2**.

<u>**Experiment A**</u>

Reaction between **FA 1**, $NaHCO_3$, and **FA 2**, NaOH.

Reaction 1 $NaHCO_3(aq) + NaOH(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$ $\Delta H_{reaction1}$

The molar enthalpy change for **reaction 1**, $\Delta H_{reaction1}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with NaOH.

1 Using a 50 cm^3 measuring cylinder, transfer 30.0 cm^3 of **FA 1** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm^3 glass beaker. Place the lid on the cup.

2 Stir and measure the temperature of this **FA 1**, T_{FA1}.

3 Using another 50 cm^3 measuring cylinder, measure 20.0 cm^3 of **FA 2.**

4 Stir and measure the temperature of this **FA 2**, T_{FA2}.

5 Add **FA 2** from the measuring cylinder to the **FA 1** in the Styrofoam cup. Immediately replace the lid.

6 Using the thermometer, stir the mixture continuously until a maximum temperature is reached. Read and record this temperature T_{max}.

7 Calculate the weighted average initial temperature, $T_{average}$, of **FA 1** and **FA 2** using the formula given below:

$$T_{average} = \frac{(V_{FA1} \times T_{FA1}) + (V_{FA2} \times T_{FA2})}{(V_{FA1} + V_{FA2})}$$

	Experiment A
T_{FA1} /°C	
T_{FA2} /°C	
$T_{average}$ /°C	
T_{max} /°C	
ΔT_{max} /°C	

Table 1.1

Experiment B

Reaction between **FA 1**, $NaHCO_3$, and **FA 3,** H_2SO_4.

Reaction 2 $NaHCO_3(aq) + \frac{1}{2}H_2SO_4(aq) \rightarrow \frac{1}{2}Na_2SO_4(aq) + H_2O(l) + CO_2\,(g)$ $\Delta H_{reaction2}$

The molar enthalpy change for **reaction 2**, $\Delta H_{reaction\ 2}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

1 Using a measuring cylinder, transfer 30.0 cm^3 of **FA 1** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm^3 glass beaker. Place the lid on the cup.

2 Stir and measure the temperature of this **FA 1**, T_{FA1}.

3 Using another measuring cylinder, measure 20.0 cm^3 of **FA 3.**

4 Stir and measure the temperature of this **FA 3**, T_{FA3}.

5 Add **slowly**, the **FA 3** from the measuring cylinder to the **FA 1** in the Styrofoam cup. Immediately replace the lid.

6 Using the thermometer, stir the mixture continuously until a minimum temperature is reached. Read and record this temperature T_{min}.

7 Calculate the weighted average initial temperature, $T_{average}$, of **FA 1** and **FA 3** using the formula given below:

$$T_{average} = \frac{(V_{FA1} \times T_{FA1}) + (V_{FA3} \times T_{FA3})}{(V_{FA1} + V_{FA3})}$$

	Experiment B
T_{FA1} /°C	
T_{FA3} /°C	
$T_{average}$ /°C	
T_{min} /°C	
ΔT_{max} /°C	

Table 1.2

[2]

(a) For the purpose of calculations, you should assume that the mixture has a density of 1.00 g cm^{-3} and specific heat capacity, *c*, of 4.18 J g^{-1} K^{-1}.

(i) Use your results from **Table 1.1** to calculate a value for the molar enthalpy change for **reaction 1**, $\Delta H_{reaction1}$.

$\Delta H_{reaction1}$ = ...

[2]

(ii) Use your results from **Table 1.2** to calculate a value for the molar enthalpy change for **reaction 2**, $\Delta H_{reaction2}$.

$\Delta H_{reaction2}$ = ...

[2]

(b) Ionic equations for neutralisation, **reaction 1**, and **reaction 2** are shown below.

$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$	$\Delta H_{neu} = -57.1$ kJ mol^{-1}
$HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$	$\Delta H_{reaction1}$
$HCO_3^-(aq) + H^+(aq) \rightarrow H_2O(l) + CO_2(g)$	$\Delta H_{reaction2}$

Carbon dioxide reacts with solutions of carbonate ions according to the following equation.

reaction 3 $CO_2(g) + CO_3^{2-}(aq) + H_2O(l) \longrightarrow 2HCO_3^-(aq)$ $\Delta H_{reaction3}$

Using your calculated answers in **(a)**, together with the given value of enthalpy change of neutralisation, ΔH_{neu}, construct an energy cycle to determine a value for the enthalpy change for this reaction, $\Delta H_{reaction3}$.

$\Delta H_{reaction3}$ = ...

[3]

[Total: 9]

2 Qualitative analysis of some organic and inorganic compounds

You are provided with liquids **FA 4**, **FA 5**, **FA 6**, **FA 7**, and **FA 8.**

You are to perform the tests described in **Tables 2.1** and **2.3** and record your observations.

At each stage of any test, you are to record details of the following:
- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test
- if there is no observable change, write **no observable change**

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

In all tests, the reagents should be added gradually until no further change is observed unless you are instructed otherwise. If any solution is warmed, a **boiling tube** must be used. Rinse and reuse test-tubes where possible.

No additional or confirmatory tests for ions present should be attempted.

(a) **FA 4**, **FA 5**, **FA 6** and **FA 7** are organic compounds with the molecular formula shown.

- **FA 4**: C_3H_6O
- **FA 5**: C_3H_6O
- **FA 6**: C_3H_8O
- **FA 7**: $C_3H_6O_2$

You will perform some of the tests described in **Table 2.1**.

Using the observations in **Table 2.1** and the given molecular formula, you will then deduce the identities of **FA 4**, **FA 5**, **FA 6** and **FA 7**.

Perform the tests given in **Table 2.1**. Some of the observations have been completed for you. There is no need to carry out those tests. Record your observations in **Table 2.1**.

Safety: Organic compounds are flammable. Transfer your organic waste into the waste bottle for disposal after the end of the assessment.

Test	Procedure	Observations with **FA 4,** C_3H_6O	Observations with **FA 5,** C_3H_6O	Observations with **FA 6,** C_3H_8O	Observations with **FA 7,** $C_3H_6O_2$
1.	**[2,4-DNPH]** To 1 cm depth of unknown liquid, add 1cm depth of 2,4-dinitrophenylhydrazine solution.		Orange precipitate observed		
2.	To 1 cm depth of unknown liquid, add aqueous sodium carbonate. Test for and identify any gas evolved.	No observable change	No observable change	No observable change	Effervescence produced. White precipitate observed when gas is bubbled into limewater
3.	**[Iodoform Test]** To 1 cm depth of unknown liquid, add 8 drops of aqueous sodium hydroxide followed by iodine solution, dropwise, until a permanent orange/red colour is present. Warm the mixture in a beaker of hot water for two minutes.	No observable change	Yellow precipitate observed		No observable change

4.	**[Tollens' reagent]** To 1 cm depth of aqueous silver nitrate, slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate formed dissolves. You may use a clean glass rod to stir the mixture and help dissolve the precipitate. Add 1 cm depth of unknown liquid to this mixture, shake the tube and let it stand.				

Table 2.1

[4]

(b) Complete **Table 2.2** with the identities of **FA 4, FA 5, FA 6**, and **FA 7**.

Give evidence from the observations in **Table 2.1** to support your conclusions.

	Compound	**Evidence**
FA 4		
FA 5		
FA 6		
FA 7		

Table 2.2

[4]

FA 8 is a mixture of two salts and contains two cations.

You will perform a series of test–tube reactions and use the observations to help you identify the two cations.

(c)	Test	Observation
1.	Test the **FA 8** solution using Universal indicator paper.	
2.	Prepare about 2 cm^3 of dilute sulfuric acid in a clean test tube. Place about 2 cm^3 of **FA 8** into another clean test-tube. Carefully add aqueous sodium hydroxide, dropwise with shaking, until no further change is seen. Swirl and filter the mixture, collecting the filtrate in the test tube containing dilute sulfuric acid. Observe the residue and filtrate until no further change is seen.	
3.	To 1cm^3 of **FA 8**, carefully add aqueous potassium manganate, dropwise with shaking, until no further change is seen.	

Table 2.3

[5]

(d) **(i)** Identify the cations in **FA 8**.

Cation 1: .... **Cation 2:** ....

[2]

(ii) With the aid of an equation, explain the observation for **Test 1** in **Table 2.3**.

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....

....

[2]

(iii) Identify the metal-containing complex formed when excess sodium hydroxide is added to **FA 8**.
Write equations to illustrate the formation of this complex.

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[2]

(iv) **FA 8** contains either the sulfate ion or a halide anion.

Describe two tests, using only the bench reagents provided, which will allow you to identify the anion present.

In each case, state how you will decide if the test result is positive.

[You **DO NOT** need to carry out these tests.]

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[2]

[Total: 21]

3 **To determine the order of reaction with respect to the concentration of iodine in the iodination of propanone reaction**

FA 12 is 1.00 mol dm^{-3} propanone, CH_3COCH_3
FA 13 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4
FA 14 is an aqueous solution of iodine, I_2
FA 15 is 0.0150 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$
FA 1 is 1.00 mol dm^{-3} sodium hydrogen carbonate, $NaHCO_3$ **(same solution used in Q1)**

You are also provided with a starch indicator.

The iodination of propanone, to form iodopropanone, proceeds as shown in the equation below.

Reaction 1: $CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$

This reaction is first order with respect to both CH_3COCH_3 and H^+ ions.

You are to investigate the order of reaction with respect to I_2.

A reaction mixture containing **FA 12**, **FA 13**, and **FA 14** is first prepared. At different chosen times, aliquots (fixed volumes) of this reaction mixture is removed and quenched using excess **FA 1.**

It is necessary that you titrate each aliquot against **FA15** before transferring the next aliquot. I_2 and $S_2O_3^{2-}$ react as shown in **Reaction 2.**

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

The required order of reaction can be obtained by the graphical analysis of your results.

The first aliquot should be removed approximately 4 minutes after the reagents were mixed. You will then remove four further aliquots, at time intervals of your choice, up to a maximum time of 30 minutes.

In an appropriate format in the space provided on **page 14**, prepare a table in which to record for each aliquot

- the time of transfer, *t*, in minutes and seconds,
- the decimal time, t_d, in minutes, to 0.1 min, for example, if t = 4 min 33 s then t_d = 4 min + 33/60 = 4.6 min,
- the burette readings and the volume of **FA 15** added.

Safety: Propanone is flammable. Transfer your titrated solutions into the waste bottle for later disposal.

Keep the conical flask (**reaction mixture**) stoppered except when removing aliquots.

Experiment

NOTE READ THE FULL PROCEDURE BEFORE STARTING YOUR EXPERIMENT

1. Label each of the boiling tubes **1** to **5**.
2. Add approximately 10 cm^3 of **FA 1** to each of these boiling tubes.
3. Fill a burette with **FA 15**

Preparing the reaction mixture

4. Using a 50 cm^3 measuring cylinder, transfer 25.0 cm^3 of **FA 12** into the 100 cm^3 beaker.
5. Using the same 50 cm^3 measuring cylinder, transfer 25.0 cm^3 of **FA 13** into the same 100 cm^3 beaker.
6. Using another 50 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 14** into the 250 cm^3 conical flask, labelled **reaction mixture.**
7. Pour the contents of the 100 cm^3 beaker into this 250 cm^3 conical flask. Start the stopwatch, **insert the stopper** and swirl the mixture thoroughly. Once you have started the stopwatch, allow it to continue running for the duration of the experiment. You must not stop the stopwatch until you have collected all of your aliquots.

Removing aliquots of reaction mixture and titration

8. At approximately 4 minutes, using a 10.0 cm^3 pipette, remove a 10.0 cm^3 aliquot of the reaction mixture.
9. **Immediately** transfer this aliquot into the boiling tube labelled **1** and swirl the mixture. Read and record the transfer time in minutes and seconds, to the nearest second, when half of the reaction mixture has emptied from the pipette. Replace the stopper in the flask.
10. Pour all the contents of **boiling tube 1** into a clean 250 cm^3 conical flask. Wash out the boiling tube and add the washings to the conical flask.
11. Titrate the iodine in this solution with **FA 15**. Add about 1 cm^3 of starch indicator when the colour of the solution turns pale yellow. The solution will turn blue–black. The end–point is reached when the dark blue–black colour just disappears. Record your results.
12. Empty the contents of this conical flask into the waste bottle. Wash this conical flask thoroughly with water.
13. At approximately 8 minutes, repeat points **8** to **12**. Transfer this aliquot into the boiling tube labelled **2.**
14. Repeat point **8** to **12** for the remaining boiling tubes at about four-minute intervals.

(a) Results

[4]

(b) **(i)** On **Fig 3.1**, plot a graph of **volume of sodium thiosulfate, FA 15**, on the y–axis, against decimal time, ***t***$_d$, on the x–axis. Start the x–axis at ***t***$_d$ = 0. You should choose a scale which will allow you to extrapolate your graph back to ***t***$_d$ = 0.

Draw the most appropriate best–fit line taking into account all of your plotted points.

Fig 3.1

[3]

(ii) Deduce the order of reaction with respect to the I_2 in reaction **1**. Explain your answer.

order...

explanation...

....

.... [1]

(c) **(i)** Write the rate equation for the iodination of propanone.

.... [1]

(ii) Calculate the gradient of the line you have drawn in **Fig 3.1**, showing clearly how you did this.

gradient = ... $cm^3 min^{-1}$ [1]

(iii) Use your answer from **(c)(ii)** to determine the rate of change of amount of $S_2O_3^{2-}$ ions required in mol min^{-1}.

rate of change of amount of $S_2O_3^{2-}$ ions required = ... mol min^{-1} [1]

(iv) Hence, deduce the rate of disappearance of I_2 in mol min^{-1}.

rate of disappearance of I_2 = ... mol min^{-1} [1]

(v) Use your answer from **(c)(iv)** to calculate the rate of change of $[I_2]$ in the reaction mixture.

rate of change of $[I_2]$ in the reaction mixture = ... mol dm^{-3} min^{-1} [1]

(vi) Hence, calculate the value of the rate constant for this reaction, giving its units.

rate constant = ... [2]

(d) **Step 7** requires you to mix each aliquot immediately with an excess of sodium hydrogencarbonate solution, **FA 1**. Suggest a clear explanation for this requirement.

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.... [1]

(e) Explain why the concentration of iodine in **FA 14** used is very much lower than the concentrations of propanone in **FA 12** and of H^+ ions in **FA 13**.

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.... [1]

[Total: 17]

4 **Planning – Extension to Q3**

You are to plan a series of experiments to verify that the order with respect to propanone in the iodination of propanone is 1.

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I\,(aq) + HI(aq)$$

This investigation can be carried out by monitoring the time taken for the colour of a limited amount of iodine to be discharged when reacting with varying concentrations of propanone.

You may assume that it takes approximately 1 minute for the iodine colour to be discharged when a mixture of 20 cm^3 of 2.00 mol dm^{-3} of propanone, CH_3COCH_3 and 10 cm^3 of 1.00 mol dm^{-3} sulfuric acid, H_2SO_4 is reacted with 10 cm^3 of 1.00 mol dm^{-3} iodine, I_2.

, You may assume that you are provided with:

- **Only 60 cm^3** of 2.00 mol dm^{-3} propanone, CH_3COCH_3
- 1.00 mol dm^{-3} sulfuric acid, H_2SO_4
- 1.00 mol dm^{-3} solution of iodine, I_2
- 100 cm^3 volumetric flasks
- starch indicator
- stopwatch
- the equipment normally found in a school or college laboratory.

(a) **Serial dilution**

Suggest how propanone of concentrations 1.00 mol dm^{-3}, 0.50 mol dm^{-3} 0.25 mol dm^{-3} and 0.125 mol dm^{-3} can be prepared from the 2.00 mol dm^{-3} propanone provided.

Clearly outline the procedure for the dilution.

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[2]

(b) Plan a procedure to collect sufficient data to allow a graph to be plotted to verify the order of reaction with respect to propanone.

You are to use the 1.00 mol dm^{-3}, 0.50 mol dm^{-3}, 0.25 mol dm^{-3} and 0.125 mol dm^{-3} propanone solutions you have prepared in **(a)** in your procedure.

In your plan you should include brief details of:

- the apparatus you would use,
- the quantity of the different solutions you would use,
- the procedure you would follow,
- how you would verify that the order with respect to propanone is 1.

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[4]

(c) A student suggested that preparing individual solutions of propanone of varying concentrations for use in this analysis is very time consuming and not necessary.

Suggest how the above procedure can be modified to investigate the order with respect to propanone by just using 2.00 mol dm^{-3} propanone.

You may find it helpful to use of a table to illustrate your answer.

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[Total: 8]

Qualitative Analysis Notes
[*ppt. = precipitate*]

(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	**NH_3(aq)**
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

anions	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)
bromide, $Br^-(aq)$	gives pale cream ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives yellow ppt. with $Ag^+(aq)$ (insoluble in $NH_3(aq)$)
nitrate, $NO_3^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	SO_2 liberated by dilute acids; gives white ppt. with $Ba^{2+}(aq)$ (soluble in dilute strong acids)

(c) Tests for gases

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

(d) Colour of halogens

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

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