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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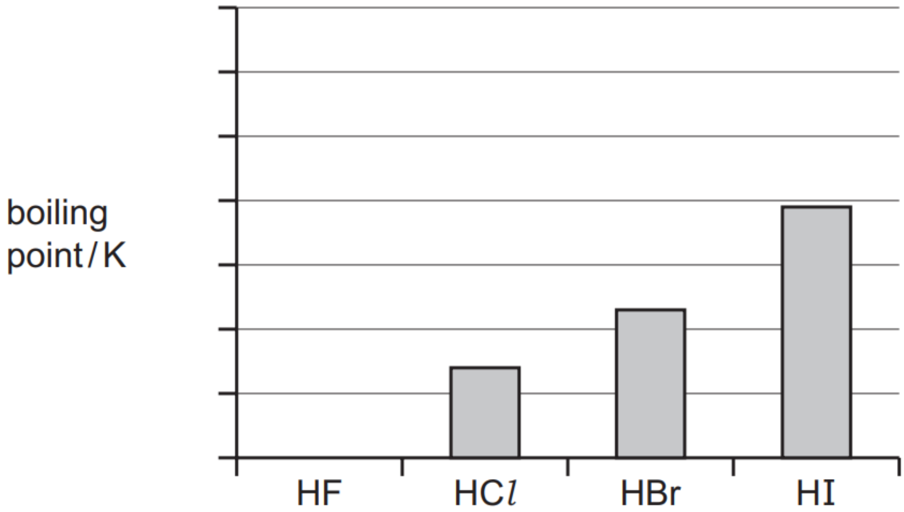
[2]

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.

$$\underset{0.020\text{ mol}}{\mathbf{Y}} \xrightarrow{\text{excess } Cl_2} \underset{0.020\text{ mol}}{\mathbf{Y}Cl_n\,(l)} \xrightarrow{\text{water}} \text{two immiscible layers of water and } \mathbf{Y}Cl_n$$

$$\underset{0.020\text{ mol}}{\mathbf{Z}} \xrightarrow{\text{excess } Cl_2} \underset{0.020\text{ mol}}{\mathbf{Z}Cl_n\,(l)} \xrightarrow[\text{filter}]{\text{water}} \text{filtrate} + \text{white residue}$$

$$\text{filtrate} \xrightarrow{\text{excess } AgNO_3(aq)} \underset{11.54\text{ g}}{AgCl\,(s)}$$

(i) Calculate the value of n in **Z**Cl_n.

[1]

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

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……………………………………………………………………………………………… [2]

(iii) Write a balanced equation for the reaction of **Z**Cl_n with water.

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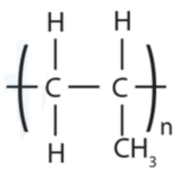
[Total:15]

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.

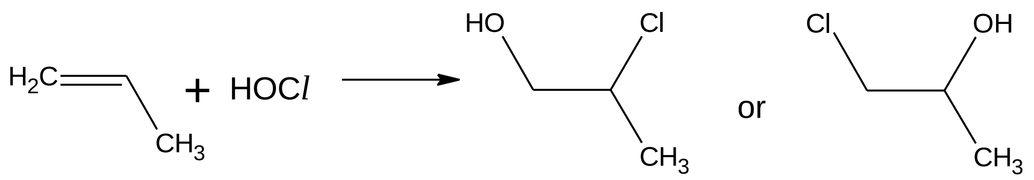
[3]

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

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

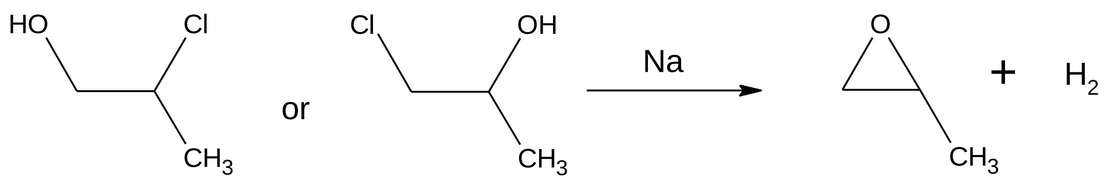
(b) Propene is the second most important starting material in the petrochemical industry. It is involved in a two-step synthesis to make a class of compounds known as epoxides.

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



G **F**

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



G **F**

(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]

(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	$[Ar]4s^2$	$[Ar]3d^3 4s^2$
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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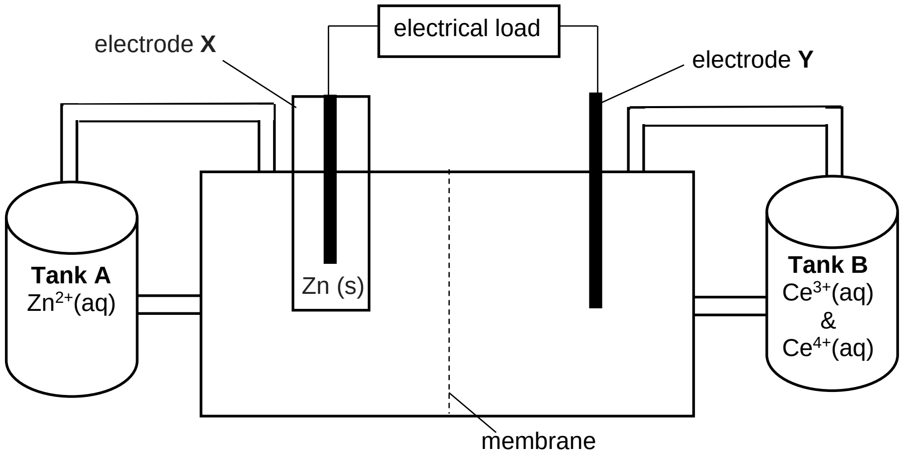
[3]

[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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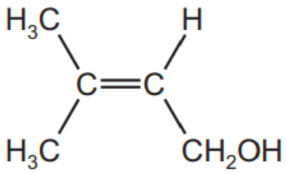
[3]

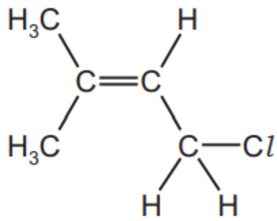
[Total: 11]

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.

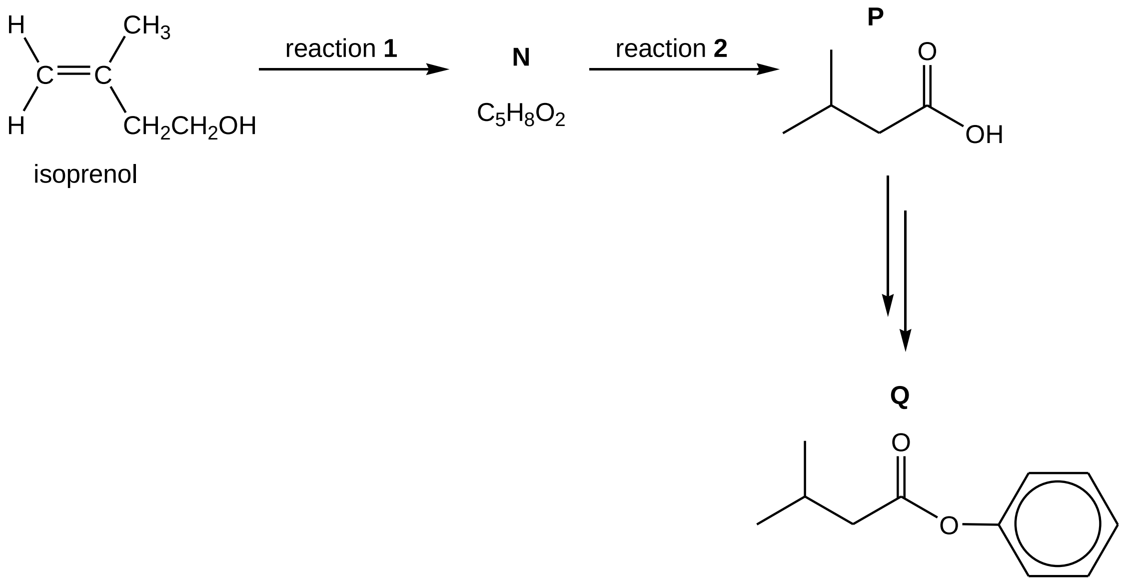
…………………………………………………………………………………………….[2]

(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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