H

TEMASEK JUNIOR COLLEGE

2023 JC2 PRELIMINARY EXAMINATION

Higher 2

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME		CIVICS CLASS	/22

CENTRE NUMBER	S					INDEX NUMBER				

Chemistry **9729/02**

Paper 2 Structured Questions **23 August 2023**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, name and CG in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** the questions in the spaces provided on the Question Paper.
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		
Paper 1		**/30**
Paper 2	**Q1**	
	Q2	
	Q3	
	Q4	
	Q5	
	Q6	
	Total	**/75**
Paper 3		**/80**
TOTAL (%)		**/100**

This document consists of **17** printed pages and **3** blank page.

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

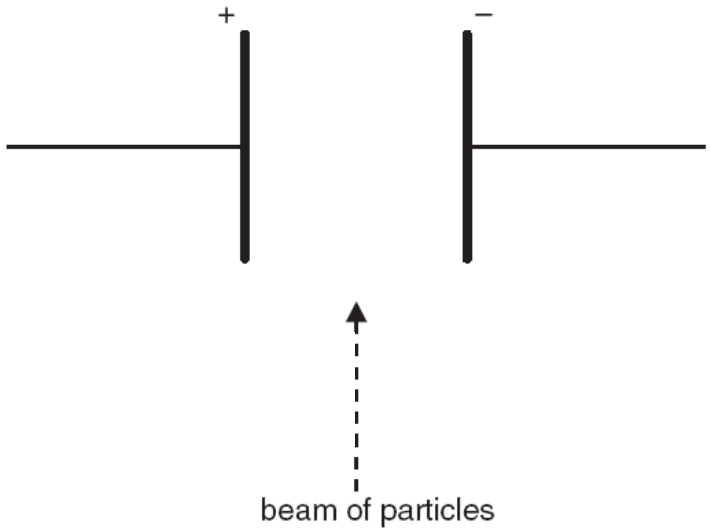
1 Atoms and ions of elements are made up of the three subatomic particles, protons, electrons, and neutrons, in varying amounts.

(a) Complete the following table to show the number of each particle in $^{7}Li^{+}$ and $^{14}C^{2-}$. [2]

Ion	protons	electrons	neutrons
$^{14}C^{2-}$			
$^{7}Li^{+}$			

(b) Separate beams of $^{14}C^{2-}$ and $^{7}Li^{+}$ ions are passed through an electric field in the set-up below. The angle of deflection of the $^{14}C^{2-}$ beam is 7.0°.

Sketch on the diagram below, the paths taken by beams of $^{7}Li^{+}$ and $^{14}C^{2-}$ ions in the presence of an electric field. Label your sketch clearly. [2]



[Total: 4]

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2 **(a)** **(i)** Explain what is meant by the term 'electronegativity', and how it relates to the concept of bond polarity. [2]

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(ii) State and explain the change in electronegativity across a period in the Periodic Table. [2]

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(iii) Explain, in terms of electronegativity why the bonding in NaC*l* is different from the bonding in PCl_5. [1]

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(b) Period 3 elements react with chlorine gas, Cl_2 (g), to form chlorides. The chlorides of the elements in the third period behave in different ways when added to water, depending on their structure and bonding.

The table shows the differences in observations which occur when three Period 3 chlorides are added to water.

Period 3 chloride	Observations when added to excess water	pH of solution formed with water
NaCl	White solid disappears. Colourless solution obtained.	7
PCl_5	Colourless solution obtained.	1
Liquid **Q**	Vigorous reaction with cold water. White solid and pale yellow solution obtained.	1

(i) Explain in terms of bonding, why NaCl and PCl_5 behave differently when added to water. Write equation for any reaction that occurs. [2]

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(ii) PCl_5 also reacts with limited amount of water.

Write the equation for the reaction. [1]

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(iii) State the identity of **Q**. [1]

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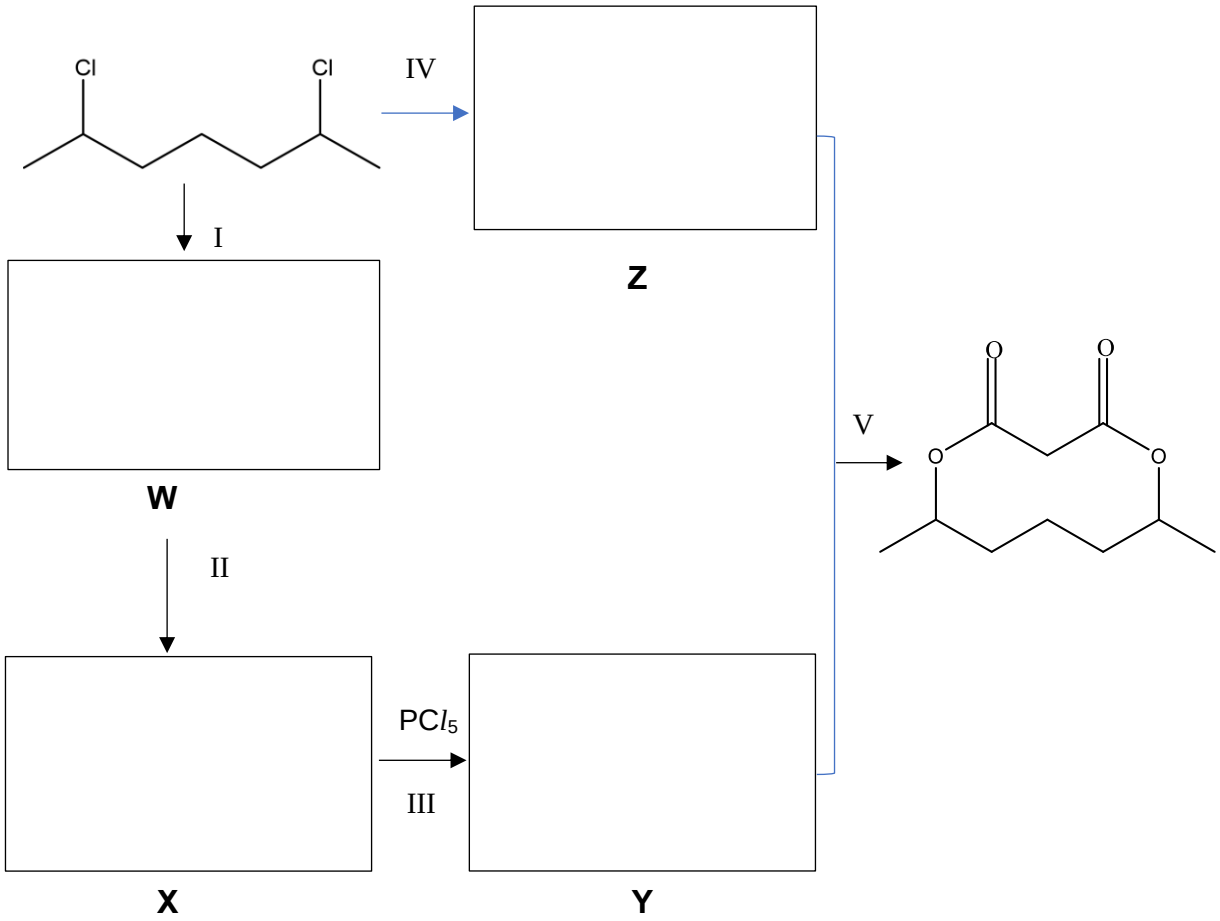
(c) Phosphorus(V) chloride, PCl_5, is involved in the following reaction scheme.

Suggest the reagents and conditions for steps I, II and IV and the products **W** to **Z** below.

[7]



Step I : .....

Step II : .....

Step IV : .....

[Total: 16]

3 Group 2 elements of the Periodic Table are also known as the *alkaline earth metals*. The metals are named after their oxides, the alkaline earths. "Earth" was a term applied by early chemists to non-metallic substances that are insoluble in water and resistant to heating.

Fig. 3.1 shows some reactions of the Group 2 element magnesium and its compounds.

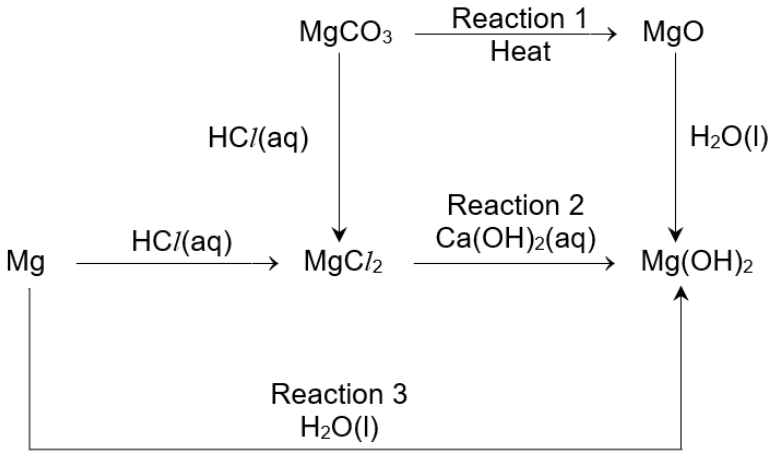


Fig. 3.1

(a) $MgCO_3(s)$ undergoes thermal decomposition in Reaction 1.

Describe and explain the trend in thermal stability of Group 2 carbonates in terms of the charge density of the cation and polarizability of the large anion. [2]

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(b) Write an equation for Reaction 3.

Explain the relative reactivity of the Group 2 elements (magnesium, calcium and barium) with water, and relate this reactivity to relevant $E^{\ominus}$ values. [3]

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(c) In Reaction 2, $Mg(OH)_2(s)$ is precipitated when $Ca(OH)_2(aq)$ is added to $MgCl_2(aq)$. No precipitate is observed when $Ca(OH)_2(aq)$ is added to $BaCl_2(aq)$

Explain the difference in observations in terms of lattice energy. [2]

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(d) Describe and deduce from $E^{\ominus}$ values, the relative reactivity of Group 17 elements (chlorine to iodine) as oxidising agents.

Hence, state the colour of the resultant solution when 1 cm^3 of $MgCl_2(aq)$ is added to 1 cm^3 of $Br_2(aq)$ in a test-tube. [3]

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(e) Element **X** is a Period 5 element.

X reacts with oxygen to form an insoluble white oxide that has a melting point of 1900 °C. The oxide of **X** conducts electricity only when in liquid state.

The chloride of **X** acts as a Lewis acid. It forms an acidic solution when dissolved in water.

(i) Suggest the structure of the oxide of **X**. Explain your answer. [2]

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(ii) Suggest the structure shown by the chloride of **X** and identify **X**. [2]

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[Total: 14]

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4 **(a)** When bromine and sodium hydroxide are mixed, sodium bromide and sodium bromate(V), $NaBrO_3$, are formed.

(i) Write a balanced equation for this reaction. [1]

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(ii) Draw the dot-and-cross diagram for the bromate(V) ion, BrO_3^-. [1]

(b) A student is given three unlabelled bottles separately containing pentane, pent-1-ene and pent-2-ene.

(i) Suggest a chemical test to distinguish between the three compounds. [2]

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(ii) Infra-red absorptions can be used to identify functional groups in organic compounds.

With reference to the table of characteristic infra-red absorption frequencies in the *Data Booklet*, suggest how pentane can be distinguished from the other two compounds. [1]

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(iii) One of the three compounds exhibits cis-trans isomerism.
Draw and label the two cis-trans isomers. [1]

[Total: 6]

5 Monoprotic acids are acids that donate one H^+ per molecule.

(a) Benzoic acid, C_6H_5COOH, is a monoprotic acid, with a pK_a value of 4.20.

Calculate the pH of 0.010 mol dm^{-3} sodium benzoate. [2]

(b) Phenylboronic acid, $C_6H_5B(OH)_2$, can act as an Lewis acid due to the electron deficient B atom.

Define what is meant by a Lewis acid and give the balanced equation which represents phenylboronic acid acting as a Lewis acid in aqueous solution. [2]

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(c) Phenylboronic acid, is a monoprotic acid a with pK_a value of 8.86.
Benzoic acid has a pK_a value of 4.20.

A 10.0 cm^3 sample of **T**, a solution containing both benzoic acid and phenylboronic acid was titrated against 0.050 mol dm^{-3} KOH using a mixture of two indicators, bromothymol blue and phenolphthalein.

It was found that 8.6 cm^3 was needed to change the colour of the first indicator and a **further** 7.1 cm^3 was needed to change the colour of the second indicator.

(i) Sketch the shape of the pH curve during the titration on the given axes.

Label your graph clearly including the information in **(c)** as well as relevant pK_a values and the corresponding volumes. [2]

(ii) Calculate the concentration of **each** of the two acids in sample **T**. [3]

(d) Phenylethanol, $C_6H_5CH_2CH_2OH$, reacts with benzoic acid. However, phenol does not react directly with benzoic acid.

Suggest and explain why phenol does not react with benzoic acid. [2]

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(e) In a separate experiment, 200 cm^3 of sodium hydroxide was added to 800 cm^3 of 0.3 mol dm^{-3} of propanoic acid to make a buffer solution of pH 5.00. The pK_a value of propanoic acid is 4.90.

(i) Explain what is meant by a *buffer* solution. [1]

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(ii) Write an equation to show what happens when a small amount of OH^- is added to the buffer solution. [1]

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(iii) Calculate the concentration of the sodium hydroxide solution added to make the buffer solution. [2]

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[Total: 15]

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6 Ethylamine, $CH_3CH_2NH_2$, is commonly used in the production of herbicides.

(a) To determine the standard enthalpy change of neutralisation, 60 cm^3 of 0.370 mol dm^{-3} aqueous ethylamine was placed in a polystyrene cup. Constant volume of dilute HC*l* was added. The mixture was stirred after each addition and the maximum temperature was recorded.

The following graph of ($V_T \times \Delta T$) against volume of HC*l* added was obtained in Figure 6.1. V_T represents the total volume of the mixture. The intersection of the 2 extrapolated lines corresponds to the equivalence point.

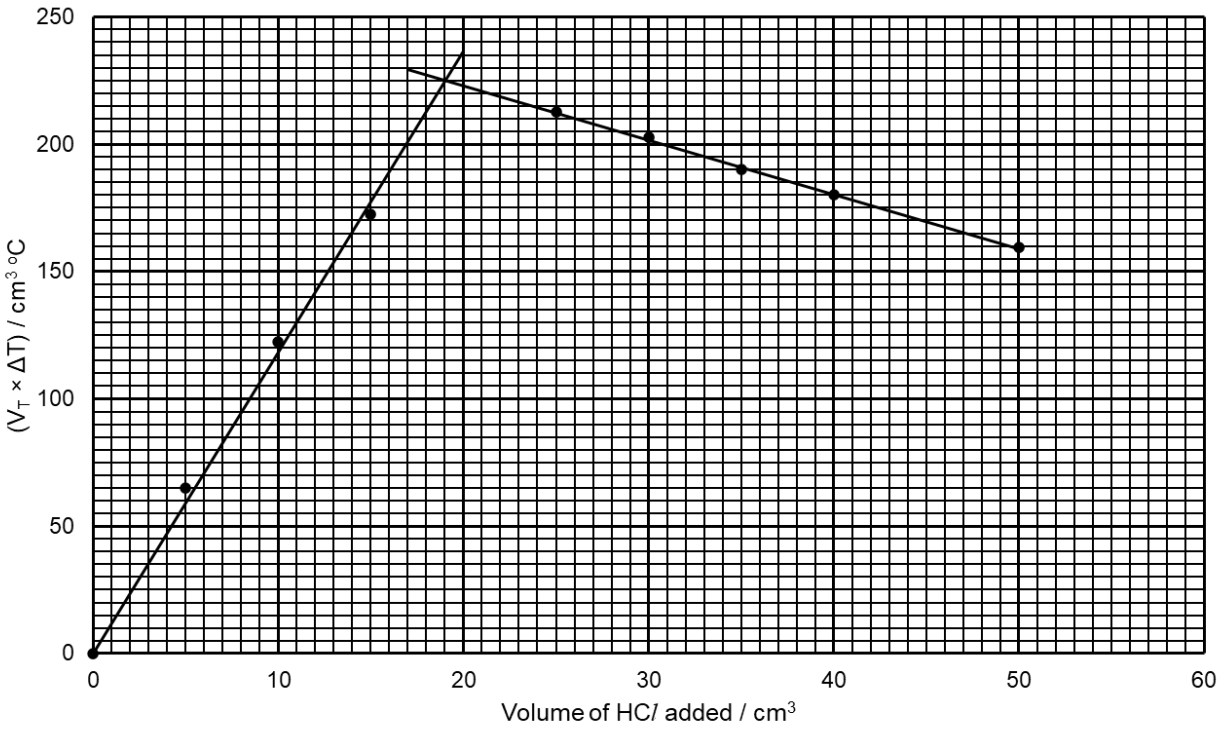

Figure 6.1

(i) Define the term *standard enthalpy change of neutralisation*. [1]

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(ii) Using the definition in **(a)(i)**, show that $\frac{V_T \Delta T}{n_{water}}$ is a constant value before equivalence point, where n_{water} is the amount of water produced during neutralisation.

Hence, explain the shape of the graph in Figure 6.1 before equivalence point. [2]

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(iii) Explain the shape of the graph in Figure 6.1 after equivalence point. [1]

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(iv) Determine the maximum temperature change using relevant data from Figure 6.1. [1]

(v) Calculate the concentration of HC*l* used in the experiment. [1]

(vi) Calculate the enthalpy change of neutralisation, $\Delta H_n^{\ominus}$, for the reaction between HC*l* and ethylamine. [2]

Assuming that the density of all aqueous solution is 1.00 g cm^{-3}.

(b) The experiment was repeated with aqueous KOH and butylamine of identical concentration as ethylamine.

The table below shows the absolute theoretical values of the standard change of neutralisation, $|\Delta H_n^{\ominus}|$ with HC*l* of various bases.

Base	Theoretical $\lvert\Delta H_n^{\ominus}\rvert$
butylamine	*x*
ethylamine	40.7
KOH	57.9

Suggest a value for *x*, and hence explain your answer fully. [3]

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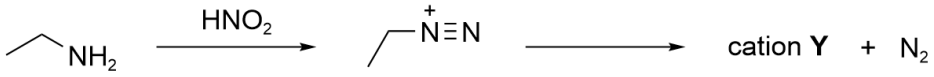
(c) Primary aliphatic amines such as ethylamine react with nitrous acid, HNO_2, to form diazonium salts which *spontaneously decompose* by losing N_2, forming cation **Y**.



diazonium salt

Illustrate, using curly arrows, the formation of cation **Y** and N_2 gas from the diazonium salt. [1]

(d) **(i)** Explain the general unreactivity of alkanes. [2]

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(ii) Alkanes undergo free radical substitution with halogens in ultraviolet light. The propagation step is found to be affected by temperature.

Sketch the Boltzmann distribution and explain how an increase in temperature affects the rate of reaction. [3]

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(e) Alkanes with high number of carbons are produced from the Wurtz reaction, whereby 2 alkyl halides are treated with sodium metal.

$$2\ CH_3–Cl + 2\ Na \rightarrow CH_3–CH_3 + 2NaCl$$

The reaction was first believed to follow a free radical mechanism.

In step 1, alkyl radicals are formed in the presence of sodium. In step 2, the radicals combine to form a larger chain alkane.

(i) Write balanced equations for step 1 and step 2 of the Wurtz reaction, for the formation of ethane using chloromethane. [2]

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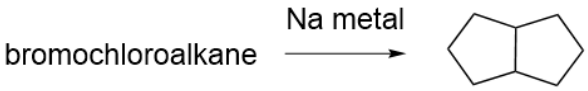
(ii) Bicyclic alkanes such as compound **X**, can be produced from the Wurtz reaction, using a bromochloroalkane.



X

Deduce the structure of the bromochloroalkane used to produce **X**. [1]

[Total: 20]

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