TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **15 September 2020**

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **one** question only.

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

For Examiner's Use		
Paper 1	**MCQ**	**/ 30**
Paper 2	**Q1**	**/ 14**
	Q2	**/ 11**
	Q3	**/ 10**
	Q4	**/ 13**
	Q5	**/ 12**
	Q6	**/ 20**
	Q7	**/ 20**
		/ 80
Percentage		**/ 100**
Grade		

This document consists of **28** printed pages including **1** blank page.

Section A

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

1 **(a)** Sulfur is in the p block while calcium is in the s block of the Periodic Table.

(i) State the electronic configuration of a Ca^+ ion.

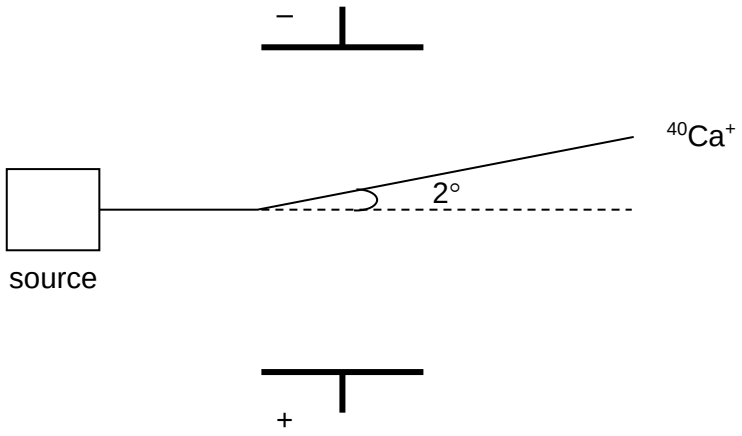
Ca^+ : ……..……..……

[1]

(ii) Draw and label the shape of a $3p_x$ orbital.

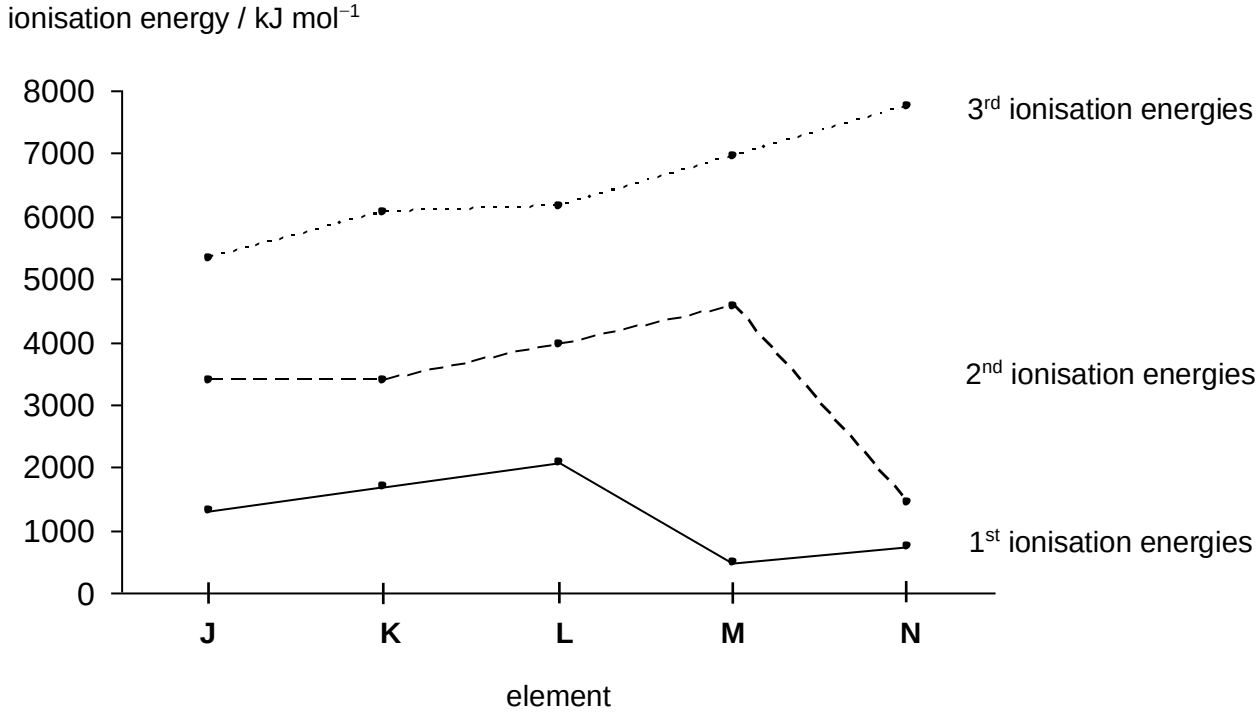
[1]

(iii) Beams of $^{40}Ca^+$ ions and $^{32}S^{2-}$ ions were passed through an electric field. It was observed that a beam of $^{40}Ca^+$ ions gives an angle of deflection of 2° as shown below.



Sketch the path of the beam of $^{32}S^{2-}$ ions in the diagram above. Include the angle of deflection in your answer. [2]

(b) The diagram below gives the ionisation energies of five consecutive unknown elements **J** to **N** with atomic numbers less than 20.



(i) Explain the increasing trend of the 1st ionisation energies from elements **J** to **L**.

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…… [2]

(ii) State, with reasoning, which Group element **M** belongs to.

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…… [2]

(c) The oxides, Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10} and SO_3, differ considerably in their chemical properties.

(i) Describe the difference in the acid-base nature of these oxides with reference to the chemical bonding in these oxides.

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…… [2]

(ii) Write an equation for the reaction of Al_2O_3 with aqueous sodium hydroxide.

…… [1]

(d) The table below shows some physical properties of oxides of elements **W**, **X**, **Y** and **Z**.

formula of oxide	melting point / ^oC	appearance at room temperature	conductivity in molten state
WO_2	1700	White solid	None
X$_2$O	0	Colourless liquid	None
YO	2850	White solid	Good
ZO_2	-78	Colourless gas	None

(i) Explain the difference in melting points between **W**O_2 and **Z**O_2 in terms of structure and bonding.

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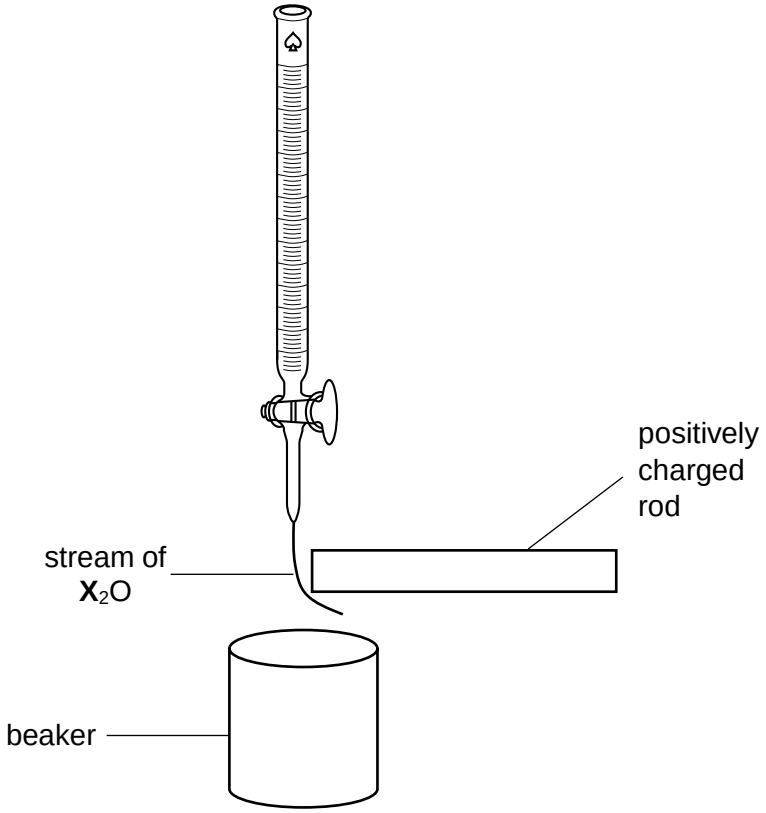
…… [2]

(ii) When a positively charged poly(ethene) rod is held near $\mathbf{X}_2O$ which is released from a burette in a slow steady stream, the stream is deflected towards the rod.



Explain why the stream experiences a deflection.

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…… [1]

[Total: 14]

2 Cinnamon is used as a condiment in various cuisines. The aroma of cinnamon is derived from its principal component, *cinnamaldehyde*, as well as numerous other constituents, including *terpineol*.

(a) *Cinnamaldehyde*, $C_6H_5CH{=}CHCHO$ is able to exhibit *cis-trans* isomerism.

Explain why *cinnamaldehyde* exhibits *cis-trans* isomerism and draw the structure of the *cis-trans* isomers.

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………………………………………………………………………………………………… [3]

(b) Describe the bonding in C=C of $C_6H_5CH{=}CHCHO$ in terms of orbital overlap.

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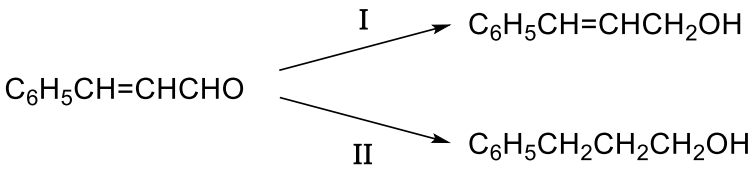
(c) *Cinnamaldehyde* can be converted into the following compounds.



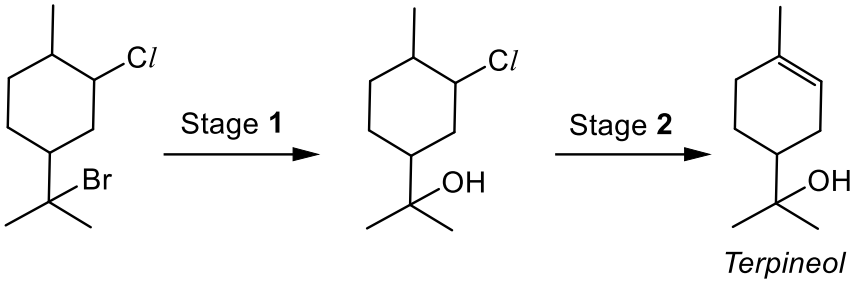
State the reagents and conditions required for reactions **I** and **II**.

I: ……..……..……..……..

II: ……..……..……..……..

[2]

(d) *Terpineol* can be synthesised from a two-stage process as shown below.



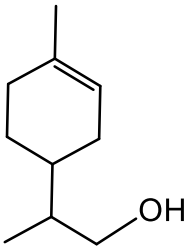
Terpineol

(i) State the reagents, conditions and types of reaction for stages **1** and **2**.

Stage	Reagents and conditions	Type of reaction
1		
2		

[2]

(ii) Suggest a suitable chemical test to distinguish *terpineol* from Compound **L**, an isomer of *terpineol*.



Compound **L**

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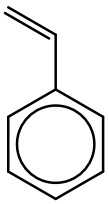
…… [2]

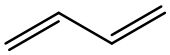
[Total: 11]

3 Synthetic polymers are macromolecules which have many uses.

(a) Styrene-Butadiene Rubber (SBR) is a synthetic copolymer that is synthesised from two different monomers, styrene and 1-3-butadiene. It is durable and has good abrasion resistance allowing it to be used for the soles of shoes and tyres.



styrene



1,3-butadiene

(i) State the type of polymerisation used to form SBR. Substantiate your answers with **two** reasons.

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…… [2]

(ii) Assuming that the monomers join together in a 1:1 ratio, draw a repeating unit of the styrene-butadiene rubber.

[1]

(iii) The styrene / butadiene ratio influences the properties of the SBR polymer. With high styrene content, the rubbers are significantly harder and less flexible.

Explain your answer in terms of the structure and bonding in the polymer.

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…… [1]

(iv) Like natural rubber, SBR is also vulcanised, a chemical process, which involves the formation of cross-links between the rubber and polymeric chains.

State the effect of vulcanisation on the strength and softening behavior of SBR. Explain your answer with reference to its structure and bonding after SBR is vulcanised.

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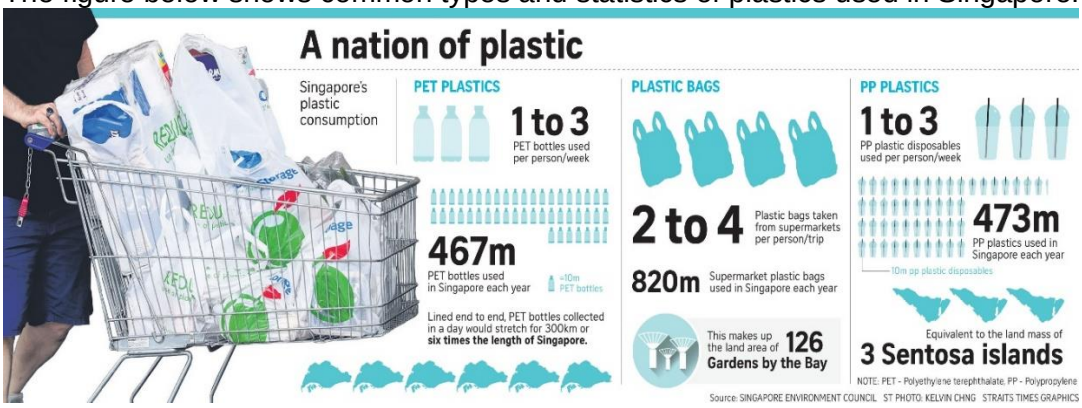
…… [2]

(b) In 2018, Singapore uses at least 1.76 billion plastic items a year, roughly equivalent to one plastic item per person per day, but fewer than 20% of these plastic items used are recycled, according to the Singapore Environment Council (SEC).

The figure below shows common types and statistics of plastics used in Singapore:



Info-graphics: A nation of plastics, The Straits Times, Aug 1, 2018

(i) Poly(propene) (PP) are used in reusable food storage container as well as in bottles storing pickles in acidic vinegar. On the other hand, poly(ethylene terephthalate) (PET) are more commonly used as single-use food packaging.

Explain why PET are unsuitable for use in bottles storing pickles in terms of its structure and bonding.

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…… [1]

(ii) The plastic bags from supermarkets are typically made of low–density poly(ethene) (LDPE) and not high–density poly(ethene) (HDPE).

Comparatively, LDPE is much softer and more flexible. Explain these properties of LDPE in terms of its structure and bonding.

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…… [2]

(iii) State one negative impact from the use of non-recyclable plastics.

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…… [1]

[Total: 10]

4 **(a)** One of the nitrogen compounds, hydrazine, N_2H_4, is used as rocket fuel. Pure hydrazine can be prepared by the reaction of ammonia with hypochlorite ion in aqueous solution.

(i) Draw a dot-and-cross diagram of hydrazine, N_2H_4, and suggest the shape around the nitrogen atom.

[2]

(ii) Predict the solubility of hydrazine in water. Explain your answer briefly.

……

…… [1]

(iii) The following table shows the boiling points of N_2H_4, NH_3 and PH_3.

Compound	N_2H_4	NH_3	PH_3
Boiling Point / °C	114	– 33	– 88

Compare and contrast the difference in boiling points in terms of structure and bonding present in the three compounds.

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…… [3]

Porous ceramics containing phosphate ions, PO_4^{3-}, have recently increased their use as artificial teeth and bones.

(iv) Explain why nitrogen does not form a similar anion, NO_4^{3-}.

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…… [2]

(b) Hydrogen halides (HX) are formed from the reaction of hydrogen with one of the Group 17 elements.

$$X_2 + H_2 \longrightarrow 2HX \text{ , where X represent Group 17 elements}$$

Upon dissolving the hydrogen halides in water, acids of varying pH are formed.

(i) With reference to the *Data Booklet*, explain and rank the pK_a of the following acids: HI, HBr and HC*l*.

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…… [3]

Group 1 elements can also react with water. Their reactions with water are observed to become more vigorous down the group.

(ii) Account for the increase in reactivity of Group 1 elements down the group.

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…… [2]

[Total: 13]

5 **(a)** Buckminsterfullerene, C_{60}, is the third allotrope of carbon along with graphite and diamond.

A molecule of buckminsterfullerene has sixty carbon atoms joined by covalent bonds. It has a cage-like fused-ring structure that resembles a soccer ball, made of twenty hexagons and twelve pentagons as shown in Fig. 5.1.

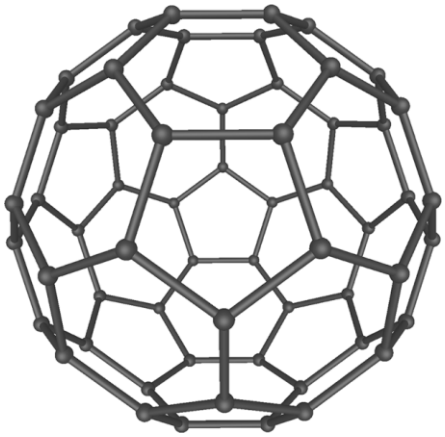

Fig. 5.1

The table below shows the melting points of the three allotropes of carbon.

allotrope	melting point / °C
C_{60}	600
diamond	3550
graphite	3730

(i) Explain, in terms of structure and bonding, the difference in melting point between C_{60} and diamond.

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…… [2]

(ii) State and explain, in terms of structure and bonding, one difference in the physical property of diamond and graphite.

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……

…… [2]

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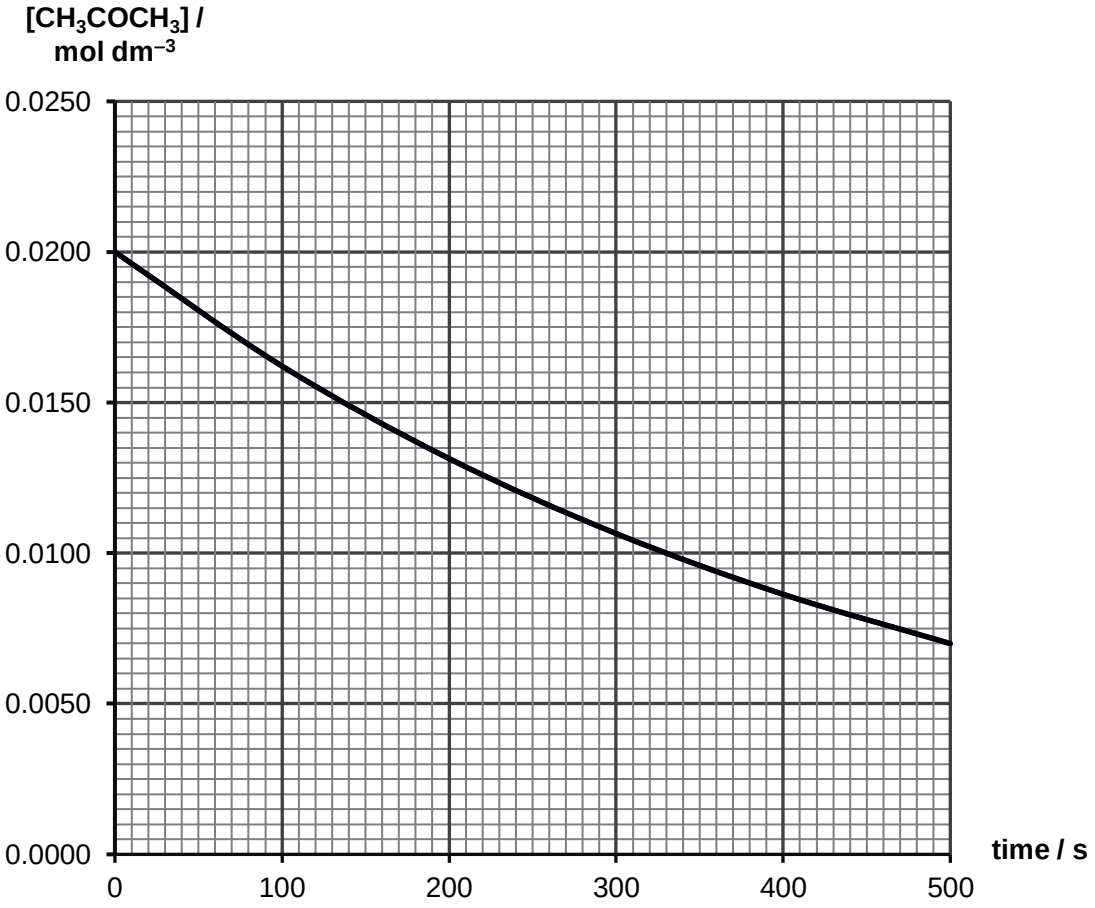
(b) When bromine reacts with propanone in the presence of an acid catalyst, bromopropanone is formed.

$$Br_2 + CH_3COCH_3 \xrightarrow{H^+} CH_3COCH_2Br + HBr$$

A chemist performs several experiments, at 25 ºC, to determine the order of reaction with respect to Br_2, CH_3COCH_3 and H^+.

In experiment 1, the chemist monitored the concentration of CH_3COCH_3 over time while keeping the concentrations of Br_2 and H^+ constant at 1 mol dm^{-3}.



Graph 5.1

(i) Define *order of reaction*.

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…… [1]

(ii) Determine the order of reaction with respect to CH_3COCH_3.

[2]

The chemist then carried out experiments 2 to 4 by varying the concentrations of the three reactants and measuring the initial rate of reaction.

experiment	$[CH_3COCH_3]$ / mol dm^{-3}	$[Br_2]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
2	0.100	0.100	0.100	1.02×10^{-3}
3	0.100	0.100	0.200	2.03×10^{-3}
4	0.150	0.200	0.150	2.30×10^{-3}

(iii) Determine the order of reaction with respect to H^+ and Br_2.

[2]

(iv) Hence, write the rate equation for the reaction.

…… [1]

(v) Calculate the rate constant *k*, for this reaction, and state the units.

k = ……

units = ……..... [2]

[Total: 12]

Section B

Answer **one** question from this section in the spaces provided.

6 Industrially, alcohols are commonly used as chemical feedstock in the synthesis of plastics and other organic compounds.

(a) 10 cm^3 of alcohol **W**, C_xH_yO, was combusted with 100 cm^3 of oxygen in excess. After cooling to room temperature and pressure, the residual gas occupied a volume of 75 cm^3 and after passing through an excess of aqueous potassium hydroxide, KOH, the volume was reduced to 25 cm^3.

(i) Write a balanced equation for the complete combustion of alcohol **W**, C_xH_yO.

……..……..……..…… [1]

(ii) Determine the volume of the gas that reacted with KOH and hence, determine the formula of alcohol **W**.

[3]

(b) Propanol is commonly used as a disinfectant. Hand sanitisers and rubbing alcohol often contain propanol as a main ingredient.

(i) Define the term *standard enthalpy change of combustion of propanol*.

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……

…… [1]

(ii) 1.00 g of propanol, $CH_3CH_2CH_2OH$, was burned under a beaker containing 120 cm^3 of seawater, raising its temperature from 15 °C to 55 °C. This process was known to be only 70 % efficient. Calculate the enthalpy change of combustion of propanol, given that the specific heat capacity of seawater is 3.99 J g^{-1} K^{-1} and the density of seawater is 1.02 g cm^{-3}.

[4]

(iii) Other than heat loss to the surroundings, state an assumption made in the calculations above.

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…… [1]

(iv) The actual values of the standard enthalpy change of combustion of propanol, carbon and hydrogen are given in the table below.

standard enthalpy change of combustion	kJ mol^{-1}
propanol	−2020
carbon	−394
hydrogen	−286

Using the values in the table, calculate the enthalpy change of formation of propanol.

[2]

(v) By considering relevant bond energy values in the *Data Booklet*, explain qualitatively why the combustion of propanol is an exothermic process.

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…… [1]

(vi) The standard enthalpy change of combustion of propanol calculated using bond energy values is −1888 kJ mol^{-1}. Suggest why this value differs from the actual value given in **(b)(iv)**.

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…… [1]

(c) Methanol is often preferred as a fuel compared to methane. Conventionally, the conversion of methane into methanol occurs in a two-step process as shown below.

step 1 : CH_4 (g) + H_2O (*l*) $\rightleftharpoons$ CO (g) + $2H_2$ (g) $\quad \Delta H_1$

step 2 : CO (g) + $2H_2$ (g) $\rightleftharpoons$ CH_3OH (*l*) $\quad \Delta H_2 < 0$

(i) Suggest why methanol is preferred as a fuel compared to methane.

……

…… [1]

(ii) The equilibrium in *step 2* is shown below.

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (l)$$

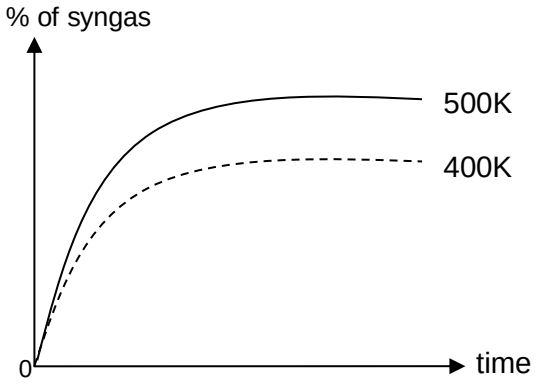
2.00 mol of carbon monoxide and 4.00 mol of hydrogen were mixed and heated to a high temperature in a vessel of capacity 3.00 dm^3. The equilibrium yield of methanol was found to be 1.60 mol.

Write the equilibrium constant for the equilibrium in *step 2* and calculate the equilibrium constant for this reaction, stating its units.

[3]

(iii) The following graph shows the percentage of syngas (CO and H_2) which are the products from *step 1.*

step 1 : CH_4 (g) + H_2O (*l*) $\rightleftharpoons$ CO (g) + $2H_2$ (g) $\quad \Delta H_1$



Deduce whether ΔH_1 is endothermic or exothermic. Explain your answer.

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…… [2]

[Total: 20]

7 Carbonic acid, H_2CO_3 is a weak acid formed from dissolving carbon dioxide in water. With its conjugate base, HCO_3^-, both H_2CO_3 and HCO_3^- play important roles in different aspects.

(a) Amid the COVID-19 pandemic, baking soda is an item that has experienced a major surge in popularity among shoppers. It is also known as sodium bicarbonate, $NaHCO_3$.

A hydrogen carbonate salt of a Group 1 metal, **M**HCO_3 (where **M** is the Group 1 metal) and some impurities were accidentally mixed together. The impurities are insoluble and do not react with acid.

This sample mixture labelled **X** was then dissolved in 45.0 cm^3 of 1.0 mol dm^{-3} hydrochloric acid. The solution is filtered into a 250 cm^3 graduated flask. Deionised water is added so that the total volume of the solution is 250 cm^3.

When 25.0 cm^3 of this diluted acidic sample was titrated with 0.20 mol dm^{-3} sodium hydroxide, 15.60 cm^3 was required for complete neutralisation.

(i) Construct a balanced equation for the reaction between **M**HCO_3 and hydrochloric acid.

……..…..……..…….…… [1]

(ii) Calculate the number of moles of HC*l* that reacted with sodium hydroxide.

[1]

(iii) Calculate the number of moles of **M**HCO_3 in **X**.

[3]

(iv) It was found that the mass of **M**HCO_3 in **X** is approximately 1.16 g.

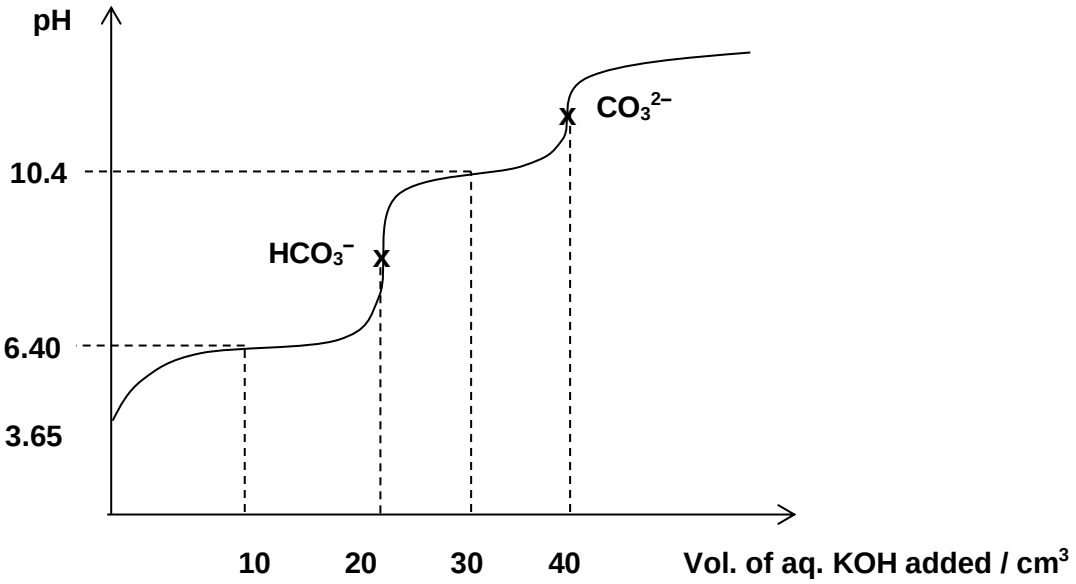
Hence, using your answer in part **(a)(iii)** deduce whether hydrogen carbonate salt of a Group 1 metal is baking soda.

[1]

(b) In an experiment, 25 cm^3 of 0.100 mol dm^3 H_2CO_3 is titrated with aqueous potassium hydroxide. The titration curve is shown below. The acid dissociation of H_2CO_3 is as shown in the following equations.

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \quad \textbf{(1)}$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+ \quad \textbf{(2)}$$



(i) State the difference between a strong and weak acid based on their extent of dissociation of H^+ ions.

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…… [1]

(ii) Define a Bronsted-Lowry base, and hence state the identities of the Bronsted-Lowry acid and base in equation **(2)**.

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…… [2]

(iii) Calculate the concentration of KOH, in mol dm^{-3}, used in the titration.

[1]

(iv) Suggest, with a reason, a suitable indicator for the first end point of this titration.

Indicator	pH range at which colour change occurs
Methyl violet	0.5 – 1.5
Phenolphthalein	8.2 – 10.0
Alizarin Yellow	10.1 – 12.0

……

…… [1]

(c) Blood plasma is a biological fluid that plays an important role in maintaining pH in the body.

In the blood plasma, the equilibrium between carbonic acid, $H_2CO_3(aq)$, and hydrogencarbonate ion, $HCO_3^-(aq)$, buffers pH changes.

(i) Explain what is a buffer solution.

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…… [1]

(ii) Explain with equations to show how blood plasma can be used to maintain the pH level.

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…… [2]

(d) Calcium oxalate, often accumulated in plants, is chemically highly stable. However, it is readily oxidized by bacteria, with alkalinisation to form calcium carbonate, which eventually accumulates in soil as shown in the reaction.

$$CaC_2O_4 + \tfrac{1}{2}O_2 \longrightarrow CaCO_3 + CO_2 \qquad \Delta H < 0$$

(i) State the changes in oxidation number of carbon that occur during this reaction.

……..…..……..……

……..…..……..…… [1]

(ii) Draw a reaction pathway diagram to represent this reaction. Label the activation energy, E_a, of the reaction clearly.

On the same diagram, draw another reaction pathway to represent the catalysed reaction. Label the activation energy, E_a(catalysed), of the reaction clearly.

[2]

(iii) Explain with the aid of a Maxwell-Boltzmann distribution diagram, the effect of adding catalyst on the rate of reaction.

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…… [3]

[Total: 20]

End of Paper 2