PRELIMINARY EXAMINATIONS

HIGHER 2

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME										
CIVICS GROUP			/							
CENTER NUMBER	S					INDEX NUMBER				

CHEMISTRY **9729/02**

Paper 2 Structured Questions **24 August 2021**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name 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** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **20** printed pages.

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

1 **(a)** Excited states can be studied to gain information about the energies of orbitals that are unoccupied in an atom's ground state. The excited state of an element, **Q**, is represented by the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2 4p^1$.

(i) Identify the element **Q**.

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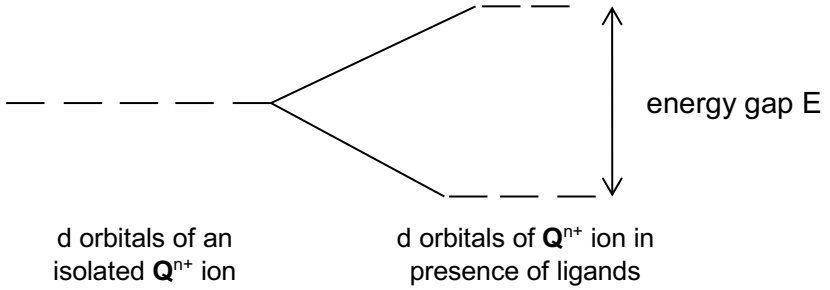
[1]

(ii) Draw the energy level diagram showing the electronic configuration of element **Q** in its ground state.

[2]

(iii) The arrangement of electrons in the d orbitals depends on the spin states of complexes. The following diagram shows how the d orbitals are split in an octahedral environment for the ion $\mathbf{Q}^{n+}$.



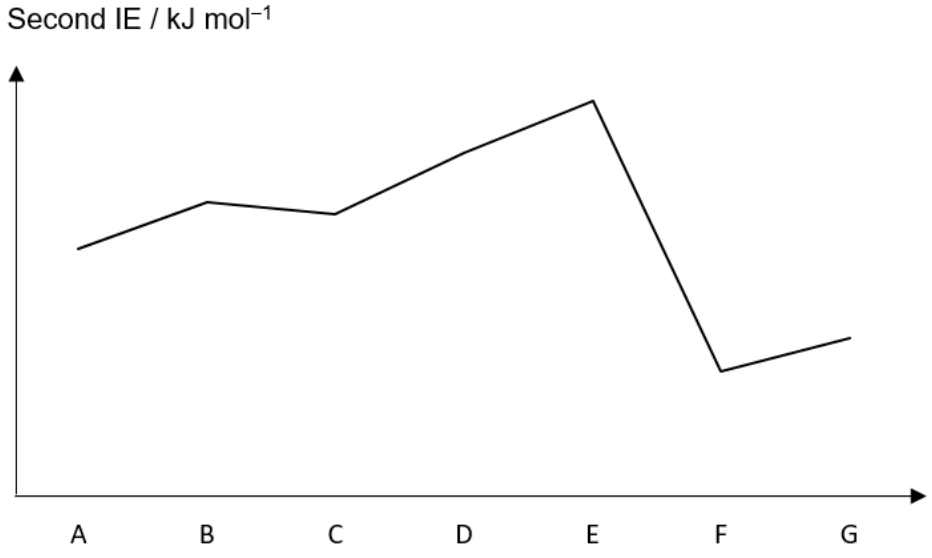
In a 'high spin' state, the electrons occupy all the d orbitals singly, before starting to pair up in the lower energy d orbitals.

In a 'low spin' state, the lower energy d orbitals are filled first, by pairing up if necessary, before the higher energy d orbitals are used.

Use diagrams like the one given to show the electronic configuration of a ground state $\mathbf{Q}^{2+}$ ion in low spin state.

[1]

(b) The second ionisation energies of seven consecutive elements **A** to **G** in the Periodic Table are shown below.



(i) Write an equation for the second ionisation energy of oxygen.

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[1]

[Turn over

(ii) Explain the discontinuity in second ionisation energies between **E** and **F**, and between **B** and **C**. Hence deduce which element **A** to **G** is oxygen.

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..... [3]

(c) **(i)** State and explain the variation in bonding in Period 3 oxides in terms of electronegativity.

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..... [2]

W, **X**, **Y**, and **Z** are four consecutive elements in the fourth period of the Periodic Table. The letters are not the actual symbols of the elements.

W forms an oxide that reacts with both acids and bases.

Z is a solid that can exist as several different allotropes. **Z** burns in air to form $\mathbf{Z}O_2$ which dissolves in water to form an acidic solution. This solution reacts with sodium hydroxide to form the salt $Na_2\mathbf{Z}O_3$.

(ii) Suggest the identities of **W** and **Z**.

.....[1]

(iii) Write equations for the reactions of oxide of **W** with sodium hydroxide and hydrochloric acid respectively.

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.....[2]

(iv) Write an equation for the formation of an acidic solution when $\mathbf{Z}O_2$ dissolves in water.

.....[1]

[Total: 14]

2 **(a)** Chlorine reacts with iodine to form a compound **T**, ICl_7. When dissolved in an excess of aqueous potassium iodide, **T** liberates iodine, I_2, which is the only iodine-containing product in the reaction.

(i) State the oxidation number of iodine in ICl_7.

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[1]

(ii) Write the equation for the reaction between **T** and potassium iodide.

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[1]

(iii) Calculate the amount of iodine liberated when 1.00 g of **T** reacts with an excess of aqueous potassium iodide.

[1]

(iv) Sodium thiosulfate is a common reagent used for the reaction with iodine.

Write a balanced equation for the reaction between sodium thiosulfate and iodine and calculate the volume of 1.00 mol dm^{-3} sodium thiosulfate, in cm^3, required to react with all the iodine liberated in **(a)(iii)**.

[2]

(b) Chlorine is produced together with carbon monoxide when phosgene, $COCl_2$, undergoes dissociation according to the equation below:

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g)$$

The above reaction takes place in a 2 dm^3 reaction vessel. At the start of the reaction, there was 4.0 mol of phosgene in the vessel. When dynamic equilibrium was established, only 1.6 mol of phosgene was left.

(i) Write the K_c expression for the above reaction, stating its units.

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..... [2]

(ii) Calculate the equilibrium amounts of CO and Cl_2, and hence, determine the value of K_c for the above reaction, showing your working clearly.

[2]

(iii) In the same reaction vessel, calculate the amount of phosgene to be removed from the equilibrium mixture in **(b)(ii)** in order to reduce the equilibrium amount of Cl_2 to 2.0 mol.

[2]

(iv) State *Le Chatelier's Principle*.

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..... [1]

(v) State and explain how the equilibrium composition might change if the above reaction is subjected to a decrease in pressure.

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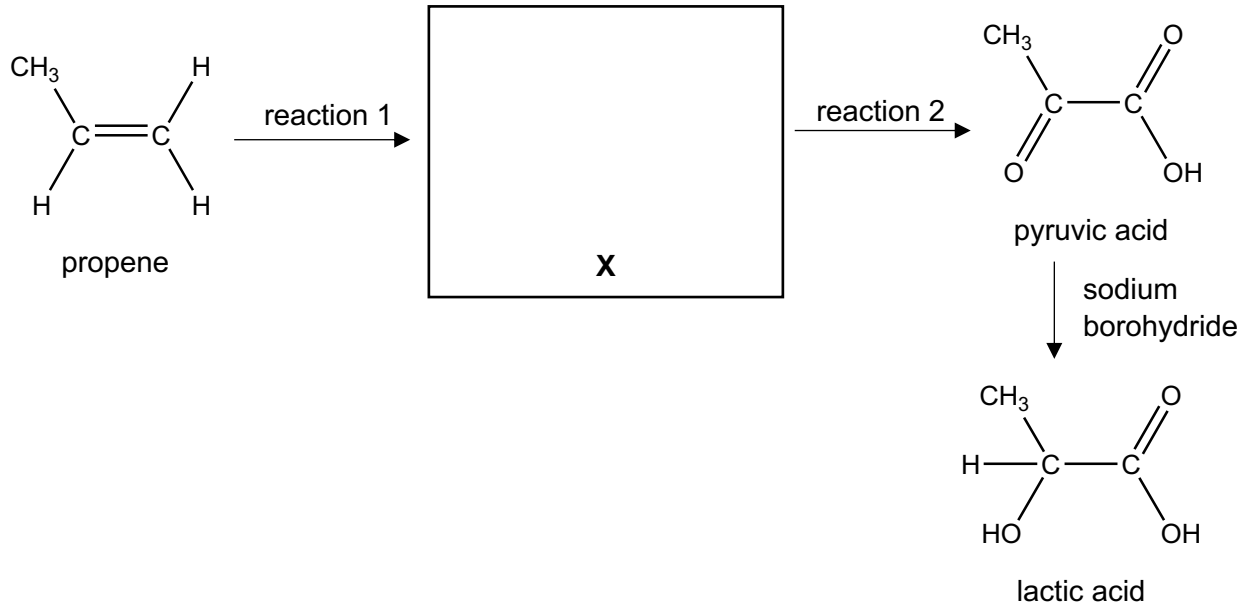
..... [2]

[Total: 14]

3 Propene and lactic acid are commonly used as feedstock for polymers.



(a) **(i)** Suggest reagents and conditions for reaction 1 and 2.

Reaction 1: .....

Reaction 2: .....

[2]

(ii) Suggest the structure of compound **X** in the box above. [1]

(b) Explain why sodium borohydride can reduce the carbonyl C=O bond in pyruvic acid but not C=C bond in propene.

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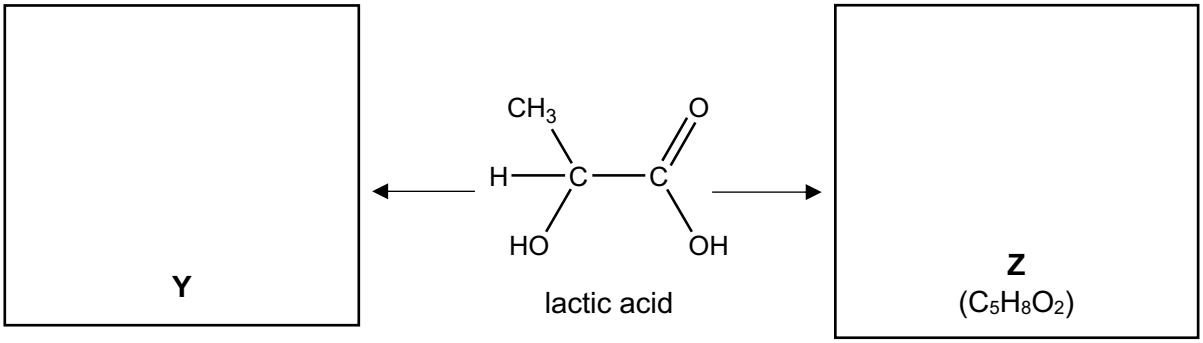
..... [2]

(c) The condensation of two molecules of lactic acid produces compound **Y** and **Z**.



(i) Compound **Y** is a cyclic ester derived from the condensation of two molecules of lactic acid.

Show the skeletal structure of compound **Y** in the box above. [1]

(ii) Explain why compound **Y** have low solubility in methanol.

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..... [1]

(iii) The condensation of two lactic acid molecules also produces compound **Z** with the elimination of carbon dioxide and water.

Compound **Z** reacts with 2 moles of 2,4-dinitrophenylhydrazaine. It forms 1 mole of CHI_3 upon reaction with aqueous alkaline iodine and does not give silver mirror with Tollen's reagent.

Suggest the structure of compound **Z** in the box above. [1]

(iv) Explain why compound **Z** has a lower boiling point than lactic acid.

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..... [2]

[Total: 10]

4 **(a)** Nitrogen monoxide, NO(g), is a colourless, toxic gas that is formed by the oxidation of nitrogen. It can be reduced by hydrogen, $H_2(g)$, under certain conditions to form harmless products.

$$2NO(g) + 2H_2(g) \longrightarrow N_2(g) + 2H_2O(l)$$

(i) Define the term 'rate of reaction'.

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..... [1]

(ii) Identify a change in the reaction mixture that would allow the rate of reaction to be measured.

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..... [1]

A series of experiments was conducted to determine the rate equation for the above reaction. The following data was obtained.

Experiment	Initial [NO] / mol dm^{-3}	Initial [H_2] / mol dm^{-3}	Initial Rate / mol dm^{-3} s^{-1}
1	2.50×10^{-3}	2.50×10^{-3}	1.27×10^{-3}
2	2.50×10^{-3}	4.60×10^{-3}	2.34×10^{-3}
3	5.00×10^{-4}	7.50×10^{-3}	1.52×10^{-4}

(iii) Determine the order of reaction with respect to NO and H_2. Hence state the rate equation.

[3]

(iv) Using the data from Experiment 2, calculate the rate constant, k.

[1]

The reaction was believed to proceed in three steps.

Step 1 : $2NO \rightarrow N_2O_2$

Step 2 : $N_2O_2 + H_2 \rightarrow N_2O + H_2O$

Step 3 : $N_2O + H_2 \rightarrow N_2 + H_2O$

(v) Deduce which of the 3 steps is the rate-determining step.

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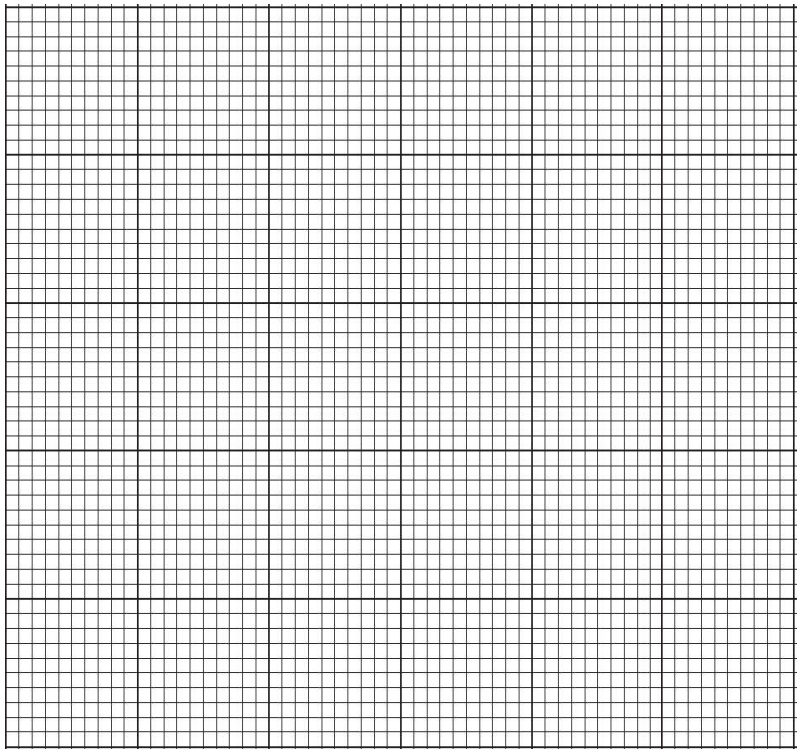
..... [1]

(b) Another experiment was conducted using 2.00 mol dm^{-3} of NO and 0.020 mol dm^{-3} H_2. The experiment was found to have a half-life of 2 s.

(i) Use the axes below to construct a graph of the variation in the concentration of 0.020 mol dm^{-3} $H_2(g)$ under the conditions specified.



[1]

(ii) Determine the half-life if the experiment was repeated using

(I) 0.040 mol dm^{-3} H_2 and same concentration of NO

(II) 0.020 mol dm^{-3} H_2 and concentration of NO doubled.

Show clearly how you arrive at your answer.

[2]

(iii) NO can be easily oxidised to NO_2 which can act as a catalyst in the oxidation of atmospheric sulfur dioxide.

Write equations to show how NO_2 acts as a catalyst in this process.

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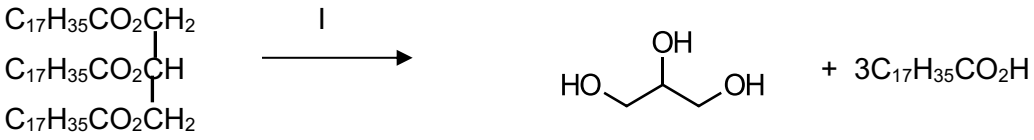
..... [2]

(c) Recently much interest has been shown in the production of the fuel biodiesel from algae. 50% of the mass of the dried algae are triglycerides. To convert triglycerides into biodiesel, the following processes are carried out.



Triglyceride, M_r = 890 glycerol

Biodiesel, M_r = 298

(i) State the reactants and conditions for reactions I and II.

Reaction I : .....

Reaction II : .....

[2]

(ii) Calculate the mass of biodiesel that can be produced from 1000 kg of dried algae.

[2]

(iii) The production of biodiesel is at present an expensive process. Suggest a reason why the development of biodiesel as an alternative to fossil fuels is important.

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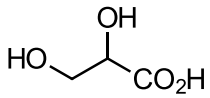
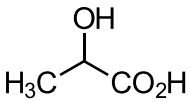
..... [1]

Glycerol, a by-product of biodiesel production, can be selectively oxidised to glyceric acid and lactic acid which have widespread applications. The table below shows the pK_a values of the acids.

Acid	pK_a
 Glyceric acid	3.42
 Lactic Acid	3.86

(iv) Explain the difference in the relative acidity of the two acids.

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..... [2]

(v) 20 cm^3 of 0.20 mol dm^{-3} glyceric acid is added to 40 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution. Calculate the pH of the resultant solution.

[3]

[Total: 22]

5 **(a)** Hydrazine, N_2H_4, was first used as a component in rocket fuel in World War 2.

(i) Using the VSEPR theory, state and explain

- the shape of hydrazine around each N atom;
- the H-N-H bond angle.

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..... [3]

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(ii) Hence, draw the structure of hydrazine, showing clearly the shape around one nitrogen atom.

[1]

When combined with hydrogen peroxide, the reaction produced nitrogen gas and water vapour, and released a large amount of energy that propelled the rocket to space.

$$N_2H_4 + 2H_2O_2 \rightarrow N_2 + 4H_2O \qquad \Delta H_r$$

(iii) What do you understand by the term *bond energy* of a covalent bond.

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..... [2]

(iv) Calculate the enthalpy change, ΔH_r, of the gaseous reaction between hydrazine and hydrogen peroxide.

[2]

(b) When two pure liquids, A and B, which do not react, are mixed together, heat may be absorbed or released depending on the relative strength of intermolecular forces of attraction formed in the mixture.

$$A(l) + B(l) \rightarrow A\text{---}B\ (l) \qquad \Delta H_{mix}$$

--- refers to the intermolecular forces of attraction between liquids A and B.

Enthalpy change of mixing, ΔH_{mix}, is the enthalpy change when 1 mole each of pure A and pure B are added to form a binary A---B solution.

The enthalpy change of mixing of ethyl ethanoate and trichloromethane is determined experimentally in an insulated calorimeter and the following data is collected.

	ethyl ethanoate	trichloromethane
Molar mass / g mol^{-1}	88.0	119.5
Mass / g	8.80	–
Specific heat capacity / J g^{-1} K^{-1}	1.92	0.96
Initial temperature / °C	31.2	31.2
Final temperature / °C	40.7	40.7

(i) Calculate the heat change of ethyl ethanoate during the mixing process.

[1]

[Turn over

(ii) The heat change for an equimolar of trichloromethane at the same initial temperature is 109 J.

Calculate the heat change of the mixture and hence the enthalpy change of mixing, ΔH_{mix}, of ethyl ethanoate and trichloromethane.

[2]

(iii) A student claimed that the heat change was due to the formation of intermolecular forces of attraction between ethyl ethanoate and trichloromethane molecules.

Comment on the student's claim and explain your answer.

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..... [1]

(iv) With reference to structure and bonding, explain the significance of the sign of ΔH_{mix} in **(b)(ii)** and hence, predict the observation of mixing ethyl ethanoate and trichloromethane.

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..... [3]

[Total: 15]