Catholic Junior College
JC2 Preliminary Examinations
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

8872/02

Paper 2

Friday 18 August 2017
2 hours

Candidates answer Section A on the Question Paper.
Additional Materials: Data Booklet
Answer paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
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.

Section A – Answer **all** the questions**.**
Section B – Answer **two** questions on separate answer paper.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.

At the end of the examination, fasten all your answer scripts securely together.

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

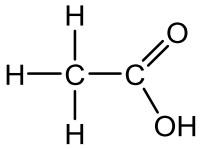
	For Examiner's Use		
Section A	**Q1**	/9	
	Q2	/12	
	Q3	/7	
	Q4	/6	
	Q5	/6	/40
Section B	**Q6**	/20	
	Q7	/20	
	Q8	/20	/40
Total			/80

This document consists of **14** printed pages

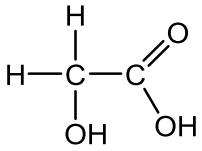
Section A

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

1 Ethanoic acid and 2-hydroxyethanoic acid are weak acids containing two carbons each.



ethanoic acid



2-hydroxyethanoic acid

Ethanoic acid is a component in antiseptic that can be used to treat skin infections, whereas 2-hydroxyethanoic acid is commonly used in skincare products.

(a) Ethanoic acid dissociates according to the following equation:

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

Write an expression for the acid dissociation constant, K_a, of ethanoic acid.

[1]

(b) The K_a of ethanoic acid is 1.74×10^{-5} mol dm^{-3}.
Given that the $[H^+]$ = [conjugate base], calculate the $[H^+]$ and hence the pH of 0.100 mol dm^{-3} of ethanoic acid.

[2]

(c) The K_a of 2-hydroxyethanoic acid is 1.48×10^{-4} mol dm^{-3}.
Explain why 2-hydroxyethanoic acid has a higher K_a value than ethanoic acid.

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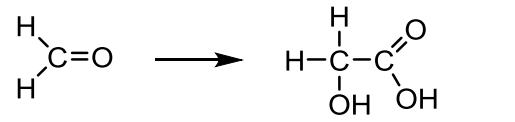
..... [2]

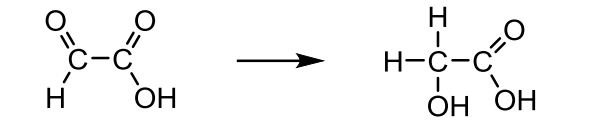
(d) Propose a simple reaction scheme to obtain 2-hydroxyethanoic acid from methanal.



methanal 2-hydroxyethanoic acid

[3]

(e) 2-hydroxyethanoic acid can also be obtained from oxoethanoic acid in a one-step reaction. State the reagents and conditions for this conversion.



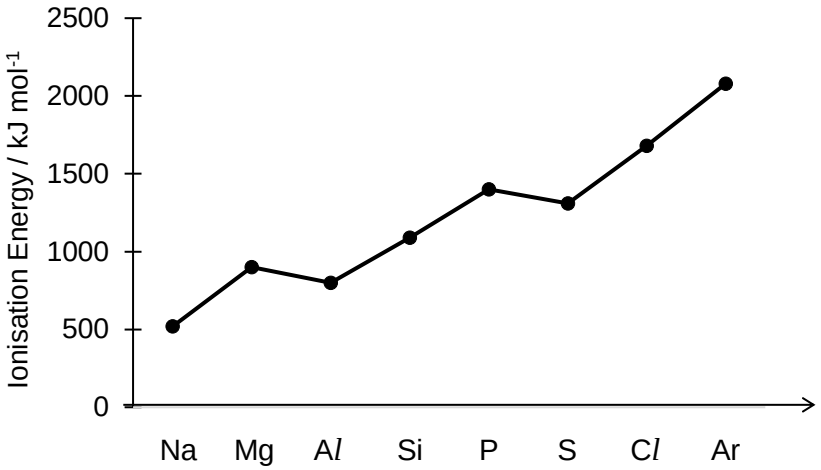
oxoethanoic acid 2-hydroxyethanoic acid

Reagents and conditions:

..... [1]

[Total: 9]

2 **(a)** The diagram below shows the first ionisation energies of the Period 3 elements from Na to Ar.



(i) Write an equation to represent the *first ionisation energy* of S.

.....[1]

(ii) Explain why the first ionisation energy generally increases across Period 3.

.....

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.....[2]

(iii) With the aid of electronic configurations, predict whether the **second** ionisation energy of Si will be higher or lower than the second ionisation of A*l*. Give your reasoning.

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.....[2]

(b) Sodium and magnesium are elements from Period 3 of the Periodic Table.

(i) State and explain two reasons why the melting point of magnesium is higher than that of sodium.

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..……[2]

Magnesium can react with oxygen gas to form magnesium oxide, MgO, which is often used as a refractory material in the lining of furnaces.

(ii) Draw a dot-and-cross diagram to show the bonding in MgO.

[1]

(iii) Explain why the lattice energy of MgO is less exothermic than that of Mg_3N_2.

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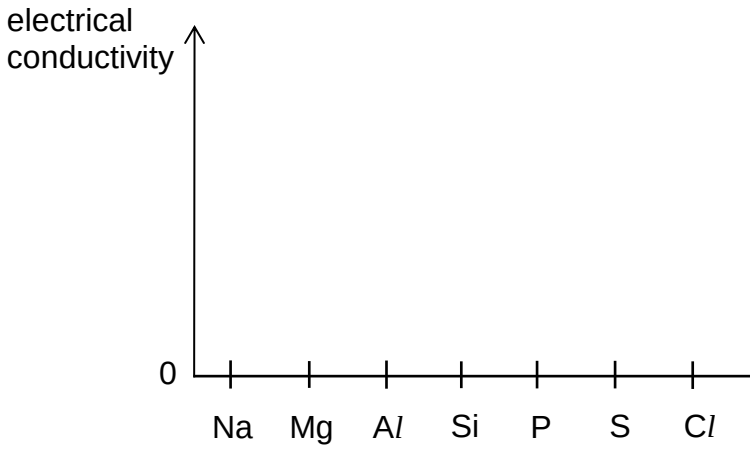
..……[3]

(c) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to C*l*.



[1]

[Total: 12]

3 An aromatic ester with the molecular formula $C_8H_8O_2$ was synthesised in the laboratory using suitable reactants and heated under reflux with concentrated sulfuric acid catalyst for about 6 hours.
The enthalpy change for this esterification reaction can be regarded as 0 kJ mol^{-1}.

(a) Draw a Boltzmann distribution curve for the reactants at this temperature and use it to explain why the reaction is significantly slower when the catalyst is removed.

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..... [3]

(b) The esterification reaction is reversible and hence has an equilibrium constant, K_c. Explain briefly how the equilibrium position and K_c are expected to change when the temperature is increased.

…….....

..... [2]

(c) When the aromatic ester is hydrolysed with H_2SO_4(aq), methanoic acid, HCO_2H, is not among the products.
Suggest two possible structural formulae for the ester.

[2]
[Total: 7]

4 **(a)** Hexa-1,4-diene, $CH_2CHCH_2CHCHCH_3$, has geometrical isomers.

(i) Draw the structural formula of each of the isomers so as to identify this isomerism and label each structure. [2]

(ii) Explain how this isomerism arises.

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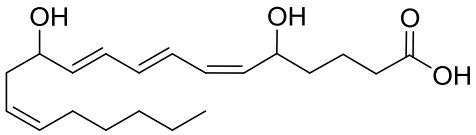
……

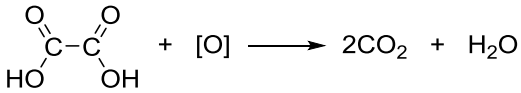
……[1]

(b) Leukotriene B4 is a biomolecule in the human body.



Leukotriene B4

Draw **all possible organic products** formed when leukotriene B4 is subjected to heating under reflux in the presence of acidified $KMnO_4$(aq). Note that any ethanodioic acid formed is further oxidised according to the following equation.



[3]

[Total: 6]

5 In March 2017, residents in a small town in Alberta, Canada, received a shock when pink coloured water flowed from their taps. The colour was due to potassium manganate(VII), $KMnO_4$, used in the early stages of water treatment to remove pathogens and metal ions such as iron and manganese ions. $KMnO_4$ should have been removed before the treated water reached the homes of the consumers, but a water treatment valve malfunctioned which caused the incident to happen.

$KMnO_4$ has a relative formula mass of 158 and it exists as black crystals at room condition. When dissolved in water, small quantities of the solid are sufficient to give very intense shades of pink and purple solutions.

(a) Define the term *relative formula mass*.

.....

..... [1]

$KMnO_4$ is used to remove Mn^{2+} present in water. $KMnO_4$ will oxidise Mn^{2+} to MnO_2 precipitate which can easily be filtered from the water.

The half equation that shows the reduction of MnO_4^- under the treatment conditions is:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

(b) With reference to the *Data Booklet*, write down the oxidation half equation.

..... [1]

(c) Hence, give the overall equation that shows the removal of Mn^{2+} during the treatment of water.

..... [1]

(d) During treatment, the concentration of $KMnO_4$ used is 1 mg dm^{-3}. Convert this concentration value into mol dm^{-3} and hence calculate the maximum mass of MnO_2 that can be precipitated per cubic metre of water.
(1 g = 1000 mg; 1 cubic metre = 1000 dm^3)

[3]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

6 Hydrogen peroxide and acidified potassium iodide can react according to the equation below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated.

In one such study, the following reaction mixture was prepared.

initial $[H^+] = 0.200$ mol dm^{-3}
initial $[I^-] = 0.200$ mol dm^{-3}
initial $[H_2O_2] = 0.0200$ mol dm^{-3}

The table below shows $[H_2O_2]$ at various times.

time / s	$[H_2O_2] \times 10^{-3}$ / mol dm^{-3}
0	20.0
80	16.7
183	13.5
315	10.3
490	7.10
760	3.90

(a) **(i)** Explain the term *rate of reaction*. [1]

(ii) Explain why the initial concentration of H_2O_2 used is much lower than the concentrations of H^+ and I^- used. [1]

(iii) Plot a graph of the above results. [2]

(iv) Use your graph to determine:

I the order of reaction with respect to $[H_2O_2]$,

II the initial rate, in mol dm^{-3} s^{-1}.

Show all working and construction lines clearly on your graph. [4]

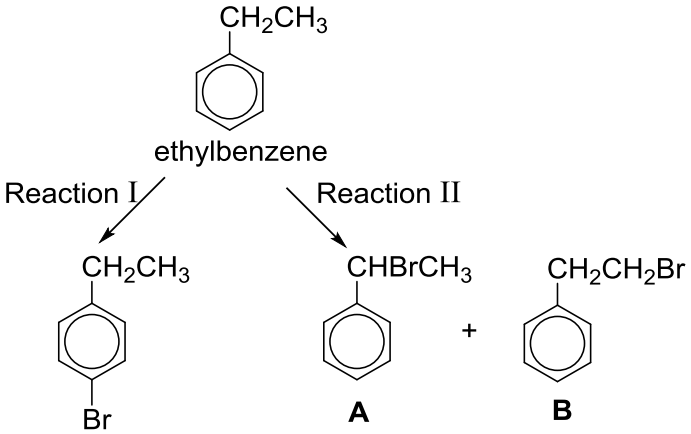
(v) Further experiments were carried out by changing $[H^+]$ and $[I^-]$, but keeping the initial $[H_2O_2]$ constant. The following results were obtained.

Experiment	initial $[H^+]$ / mol dm^{-3}	initial $[I^-]$ / mol dm^{-3}	initial rate/ mol dm^{-3} s^{-1}
1	0.400	0.200	1.0×10^{-4}
2	0.200	0.100	2.5×10^{-5}
3	0.100	0.200	2.5×10^{-5}

Determine the orders with respect to $[H^+]$ and $[I^-]$. Explain your reasoning. [2]

(b) Describe the reactions, if any, of the oxides P_4O_{10} and SiO_2 with water. State the approximate pH values of the resulting solutions and explain your answer with the aid of relevant equations for any reactions that occur. [3]

(c) Ethylbenzene can undergo substitution reactions to give three different products as shown in the scheme below.



(i) Explain why ethylbenzene does not undergo addition reactions readily. [1]

(ii) State the reagents and conditions for reactions **I** and **II**. [2]

(iii) Suggest the ratio in which **A** and **B** might be formed, assuming that the ease of substitution of H is the same for the formation of both compounds. [1]

(d) An alkaline solution of $Cu^{2+}(aq)$ is used in organic chemistry to test for a particular functional group.

(i) Describe the appearance of a positive result of this test. [1]

(ii) Compounds **X** and **Y** both have the molecular formula $C_5H_{10}O$ and give an orange precipitate with 2,4-dinitrophenylhydrazine. However, compound **X** shows a positive result in the test in **(d)(i)** while compound **Y** does not. Suggest a possible structure for compound **X** and for compound **Y**, showing the skeletal formula in your answers. [2]

[Total: 20]

7 **(a)** Ethanol, CH_3CH_2OH, is manufactured in the industry by reacting ethene with steam in the presence of a catalyst. The reaction is reversible and the equation is as follows:

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

(i) Draw a labelled reaction pathway diagram for this reaction. [2]

For every 1.0 mol dm^{-3} of ethene and 0.6 mol dm^{-3} of steam reacted and allowed to reach equilibrium, only 5% of the ethene is converted into ethanol at each pass through the reactor. To increase the overall yield of ethanol, ethanol is regularly removed from the equilibrium mixture as it is formed, and more ethene is added into the reaction mixture.

(ii) Using the information given above, calculate K_c (including units) at this temperature. [2]

(iii) Calculate the amount, in moles, of ethene (in every dm^3) that must be added to increase the equilibrium concentration of ethanol to 0.20 mol dm^{-3}. [2]

(iv) State the catalyst used for the reaction. [1]

(v) Apart from the methods mentioned above, suggest one other method which will result in an increase in the conversion of ethene into ethanol without changing the temperature and without adding more steam. Explain your answer briefly. [2]

(b) Ethanol is one of several compounds used as an ‘anti-knock’ agent that is added to unleaded petrol to prevent damage to car engines. Prior to the use of ethanol as an anti-knocl

To prevent accumulation of lead deposits in the engines, a small quantity of 1,2-dichloroethane was added to the gasoline to form $PbCl_2$ that can be flushed from the engine and into the air, but the compound quickly solidifies at atmospheric temperature. The accumulation of toxic lead compounds in the environment quickly resulted in a worldwide ban of leaded petrol.

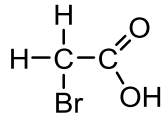
(i) Catalytic converters were fitted in cars to minimise the emissions of undesirable exhaust gases emitted such as carbon monoxide, oxides of nitrogen and unburnt hydrocarbons. State the environmental damage of one of the gases listed. [1]

(ii) The oxidation state of Pb in $PbCl_2$ is +2. What is the maximum oxidation state Pb is able to obtain and explain why this is so. [1]

(iii) Write an equation to show how the chloride of lead (where lead is at its maximum oxidation state) reacts with water. [1]

(iv) Explain why the reaction stated in **(b)(iii)** proceeds with greater ease than a similar reaction involving the chloride of silicon. [1]

(c) Ethene can be used as a starting material to synthesise 2-bromoethanoic acid.



2-bromoethanoic acid

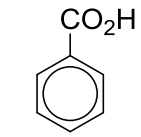
(i) Propose a reaction scheme that will convert ethene to 2-bromoethanoic acid, bearing in mind that each step should result in a fairly good yield of products. [3]

(ii) State the functional groups present in 2-bromoethanoic acid. [2]

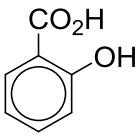
(iii) Describe a simple chemical test to show the presence of bromine in 2-bromoethanoic acid. [2]

[Total: 20]

8 **(a)** Benzoic acid and salicylic acid are both important precursors for the industrial synthesis of many other organic substances.



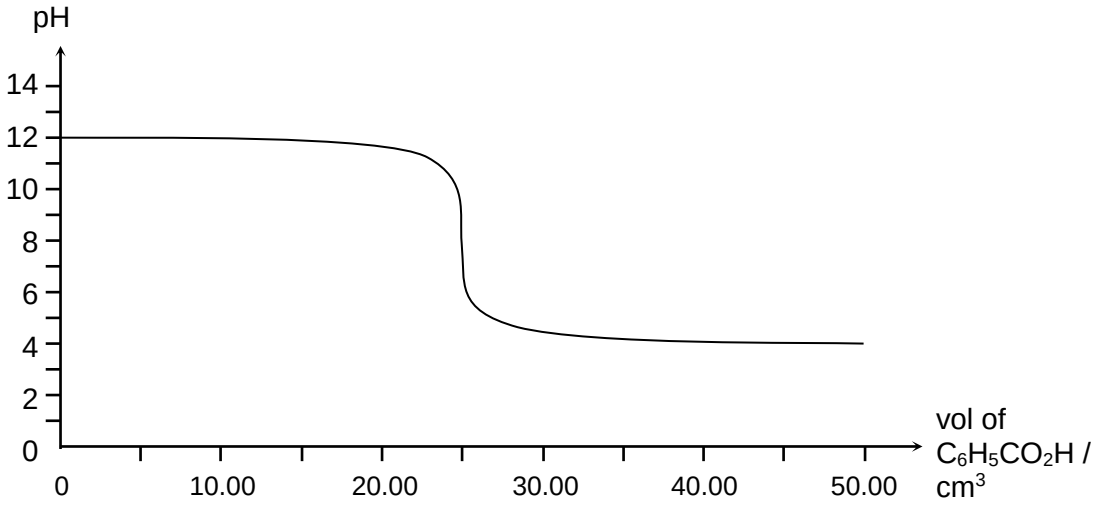
benzoic acid



salicylic acid

It was observed that salicylic acid has a lower solubility in water compared to benzoic acid in water. This is due to salicylic acid forming less extensive hydrogen bonding with water molecules. With the aid of a labelled diagram, suggest a reason for this observation. [2]

(b) In a titration carried out under standard conditions, a solution of benzoic acid is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction. [1]

(ii) Suggest a suitable indicator for the above reaction, stating the expected colour change. [2]

(iii) Explain your choice of indicator. [1]

(iv) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid. [2]

(c) *Use of Data Booklet is relevant to this question.*

In another experiment, 60.00 cm^3 of 0.600 mol dm^{-3} benzoic acid is added to 40.00 cm^3 of 0.800 mol dm^{-3} aqueous sodium hydroxide and the increase in temperature is measured.

Given that the enthalpy change of this reaction is –56.9 kJ mol^{-1}, calculate the increase in temperature. [3]

(d) In the 1940s, it was difficult to oxidise methylbenzene to benzoic acid using the oxygen present in air. Many methods resulted in incomplete oxidation or produced low yields of benzoic acid. It was later discovered that aluminium oxide is able to support controlled oxidation of methylbenzene to benzoic acid in the presence of air.

Aluminium oxide is amphoteric. Write balanced equations to illustrate this fact. [2]

(e) Compound **X** is a four carbon organic molecule. Upon addition of aqueous silver nitrate, a yellow precipitate was observed almost immediately. The yellow precipitate was then filtered off and the solution was left to stand. After a period of time, white precipitate was observed in the filtrate.

In a separate experiment, compound **X** was heated under reflux with aqueous sodium hydroxide to give compound **Y**. When compound **Y** was reacted with phosphorus(V) chloride, steamy fumes were observed. When one mole of compound **Y** was reacted with alkaline aqueous iodine, only one mole of yellow precipitate **Z** was produced.

Using the information given, deduce the structures of **X**, **Y** and **Z**. In your answer, state clearly the types of reactions that occurred. [7]

[Total: 20]