CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

8872/02
Paper 2
Monday 22 August 2016
2 hours

Candidates answer Section A on the Question Paper.
Additional Materials: Answer Paper
Data Booklet
Graph Paper (2 sheets)

READ THESE INSTRUCTIONS FIRST

Write your name and HT group 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.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

You are advised to show all working in calculations.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
Section A	A1	/10	
	A2	/5	
	A3	/4	
	A4	/6	
	A5	/15	/40
Section B	B6	/20	
	B7	/20	
	B8	/20	/40
TOTAL			/80

Section A

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

1 (a) Magnesium, aluminium and sulfur are all elements in Period 3 of the Periodic Table. With reference to their structure and bonding, explain the variation observed in their melting points.

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……...

……[3]

(b) When the oxides of the above three elements are added to water, solutions of different pH values are obtained. State the pH values of the solutions obtained and explain your answer with the aid of relevant equations.

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...…….....[5]

(c) Aluminium oxide is *amphoteric*. Write equations to illustrate this property.

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...…….....[2]

[Total: 10]

2 (a) Using the following $\Delta H^{\ominus}$ values at 298K,

$\Delta H_c^{\ominus}$ of $CH_3CH_3(g)$ = –1560 kJ mol^{-1}

$\Delta H_c^{\ominus}$ of $CH_2{=}CH_2(g)$ = –1411 kJ mol^{-1}

$\Delta H_f^{\ominus}$ of $H_2O(l)$ = –242 kJ mol^{-1}

calculate the enthalpy change of reaction for the reduction of ethene to ethane, $\Delta H_{r1}^{\ominus}$.

$$CH_2{=}CH_2\ (g) + H_2(g) \rightarrow CH_3CH_3(g)$$

[2]

(b) (i) By referring to the bond energy values in the Data Booklet, calculate the enthalpy change of the same reaction for the reduction of ethene to ethane, $\Delta H_{r2}^{\ominus}$.

[2]

(ii) Explain why this calculated value in **(b)(i)** is different from the values obtained from the method using $\Delta H^{\ominus}$ values in **(a)**.

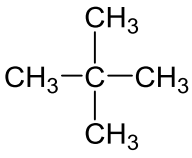
…….....

…….....

…….....[1]

[Total: 5]

3

name	structure	boiling point / °C
Pentane	$CH_3CH_2CH_2CH_2CH_3$	36
2,2-dimethylpropane		10
Propane	$CH_3CH_2CH_3$	– 42

(a) In terms of its bonding, explain why the boiling point of pentane is higher than that of propane.

…….....

…….....

…….....

…….....[2]

(b) In terms of its bonding, explain why the boiling point of pentane is higher than that of 2,2-dimethylpropane.

…….....

…….....

…….....

…….....[2]

[Total: 4]

4 **(a)** But-1-ene is synthesised from butane in a two-step reaction as shown below.

(i) In the space given below, draw the displayed formulae of the two possible structures of intermediate, **X**. Suggest the ratio in which they might be formed. [2]

(ii) State the types of reaction that are taking place in reactions **I** and **II**.

Reaction **I**: ……..

Reaction **II**: …….. [1]

(iii) State the reagents and conditions for reactions **I** and **II**.

Reaction **I**: ……..

Reaction **II**: …….. [2]

(b) Suggest a reason why this synthetic route often results in low yield of but-1-ene

…….....

…….....

…..…….....[1]

[Total: 6]

5 In a healthy human body, oxygen, O_2, is transported around the body by haemoglobin, as represented by Hb, which is present in blood. Oxyhaemoglobin, HbO_2, carry the O_2 to individual cells in the body tissue where the O_2 molecules are then released. This reversible process can be represented by this equation:

$$Hb + O_2 \rightleftharpoons HbO_2 \quad \text{----------} \quad \text{Equilibrium I}$$

Carbon monoxide, CO, is considered a toxic gas as it starves the human body of O_2. CO interferes with the oxygen-carrying capacity of blood by preferentially binding with the haemoglobin according to the following equilibrium:

$$Hb + CO \rightleftharpoons HbCO \quad \text{----------} \quad \text{Equilibrium II}$$

CO can be harmful even at very low concentrations. A concentration of 500 ppm (parts per million) for an hour can be fatal. If a person is suspected of having CO poisoning, he can be treated by being given pure O_2 to breathe.

(a) (i) Write an expression for the equilibrium constant, K_c, for either equilibrium **I** or equilibrium **II**.

[1]

(ii) The values of the equilibrium constants of equilibria **I** and **II** are not given, but based on information given in the passage, state and explain which equilibrium is expected to have a larger K_c value.

$Hb + O_2 \rightleftharpoons HbO_2$ ---------- Equilibrium I

$Hb + CO \rightleftharpoons HbCO$ ---------- Equilibrium II

……

……

……

……[2]

(b) A concentration of 500 ppm of CO is equivalent to 500 cm^3 of CO in 1 million cm^3 of air. Calculate the concentration of CO in terms of mol dm^{-3} at r.t.p.

[2]

(c) **(i)** State Le Chatelier's Principle.

……

……

……[2]

(ii) Using Le Chatelier's Principle and making reference to both equilibria **I** and **II**, explain why pure oxygen is able to treat a person suffering from CO poisoning.

……

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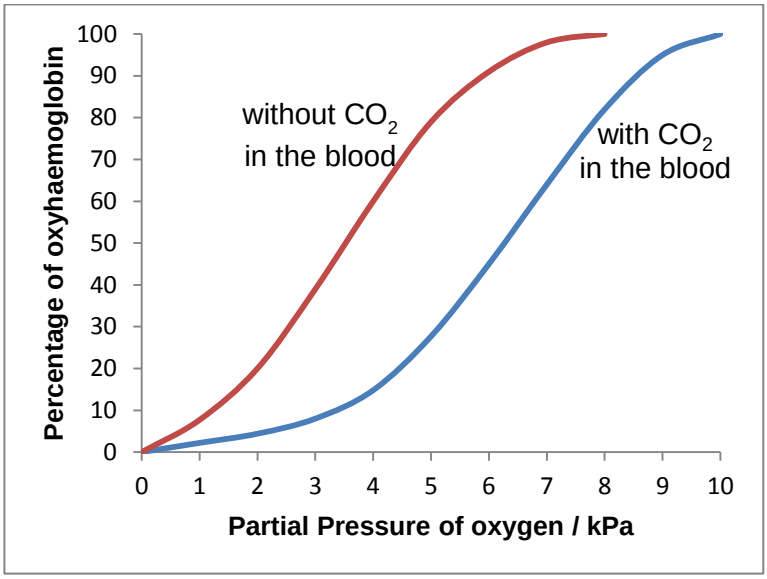
……

……

……[3]

Haemoglobin can also bind to carbon dioxide, CO_2. CO_2 is a waste product of respiration and its concentration is high in respiring cells. However, it is not considered to be toxic.

The graph below has two curves which show how the percentage of oxyhaemoglobin, HbO_2, varies with and without CO_2 as the partial pressure of O_2 in the blood increases. Partial pressure of O_2 is directly proportional to the concentration of O_2 in the blood.



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(d) State the oxidation number of carbon in both CO_2 and CO. [2]

Oxidation number of C in CO_2: …….

Oxidation number of C in CO: ……...

(e) **(i)** With reference to the graph, find the percentage of HbO_2 with and without CO_2 in the blood at 5 kPa of O_2. Give your answer to the nearest 10%.

Percentage of HbO_2 with CO_2 in the blood: ……..

Percentage of HbO_2 without CO_2 in the blood: ……. [1]

(ii) Hence, suggest how the presence of CO_2 affects Equilibrium I. Briefly explain your answer.

……

……

……[2]

[Total: 15]

Section B

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

6 Carboxylic acids are an important class of organic molecules that are used in the production of many chemical compounds. The chemical reactions to form these compounds depend on the acidity of the carboxylic acids chosen, as well as the final intended purposes of the chemical compounds.

(a) (i) Explain, in terms of its structure, why ethanoic acid is acidic. [2]

(ii) Ethanoic acid is described as a *weak acid*. Explain the term *weak acid*. [1]

(iii) When titrating against sodium hydroxide to find out the concentration of a weak acid, state and explain which indicator should be used. [2]

(b) Describe and explain why the acidity of 4-chlorobenzoic acid differs from that of benzoic acid. [2]

(c) Esters are an important class of organic compounds that can be naturally occurring or synthesised in a laboratory. The most distinctive feature is that they are usually sweet smelling, and one of their most important features in modern society is their use in polyester (PET) plastics.

Esters are formed by the reaction between alcohols and carboxylic acids in the presence of concentrated sulfuric acid catalyst. The ester, ethyl decadienoate, is one such example that gives the smell of pears.

(i) Name the alcohol and carboxylic acid used in the production of this ester. [2]

(ii) Construct the equation to represent the esterification reaction, using RCH_2OH as the alcohol and $R'CO_2H$ as the acid. [1]

(iii) Apart from its role as a catalyst, state and explain another effect of concentrated sulfuric acid in the above reaction. [2]

(d) There are multiple pathways to obtain the desired acids for the production of esters.

(i) Given the following half-equation for the oxidation of a primary alcohol to a carboxylic acid, construct the balanced equation when the oxidising agent used is acidified potassium manganate(VII). [1]

$$RCH_2OH + H_2O \rightarrow RCO_2H + 4H^+ + 4e^-$$

If the primary alcohol is not available, a step-up reaction may be used to obtain the acid.

$$ROH \xrightarrow{Step\ 1} RCl \xrightarrow{Step\ 2} RCN \xrightarrow{Step\ 3} RCOOH$$

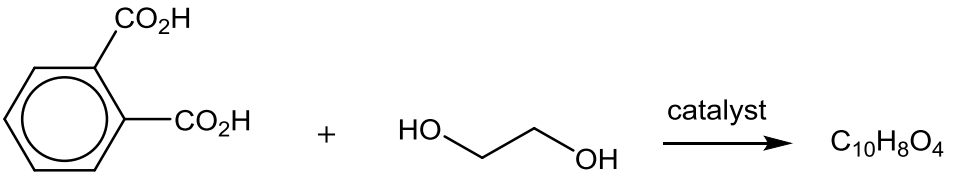
(ii) State the reagents and conditions for Steps 2 and 3. [2]

(iii) State the type of reaction for Step 3. [1]

(e) Benzene-1,2-dicarboxylic acid, although limited in its industrial use, is an important starting material to synthesise phthalic anhydride, a versatile intermediate in organic chemistry.

In a reaction, benzene-1,2-dicarboxylic acid is heated with ethane-1,2-diol in a presence of a suitable catalyst to produce compound **Z**, $C_{10}H_8O_4$.

Given the following reaction scheme,



benzene-1,2-dicarboxylic acid M_r = 166.0

ethane-1,2-diol M_r = 62.0

compound **Z** M_r = 192.0

(i) Predict the structure of compound **Z** [1]

(ii) Calculate the mass of compound **Z** formed if 100 g of each reactant is used in the reaction. You may represent benzene-1,2-dicarboxylic acid as $C_6H_4(COOH)_2$ and ethane-1,2-diol as $C_2H_6O_2$ in your working. [3]

7 (a) Ethyl propanoate, an ester, is found naturally in apple juice and strawberries. Ethyl propanoate can be hydrolysed according to the following equation.

$$C_2H_5OCOCH_2CH_3 + H_2O \rightarrow C_2H_5OH + CH_3CH_2CO_2H$$

The kinetics of the above hydrolysis may be investigated by measuring the concentration of propanoic acid produced. In this investigation, 0.240 moles of the ester was mixed with a suitable catalyst. Sufficient water was then added to raise the total volume to 1 dm^3 and the mixture was kept at a constant temperature of 35 °C.

10 cm^3 samples were withdrawn periodically at hourly intervals and rapidly cooled by the addition of cold water. The resulting solution was then titrated against a solution of standard sodium hydroxide every hour over a period of four hours. The following results were obtained.

Time / h	Concentration of propanoic acid / mol dm^{-3}
0	0.000
1	0.084
2	0.140
3	0.178
4	0.195

(i) Identify the role of the cold water used prior to the titration and explain why it is necessary. [2]

(ii) By using a suitable graphical method, determine the half-life of the reaction and hence show that the hydrolysis reaction is first order with respect to the ester. [4]

(iii) Calculate the rate constant for the above hydrolysis, stating the units clearly. [1]

(iv) Explain the role of catalyst in the experiment with the aid of a Boltzmann distribution curve. [3]

(b) The ester, ethyl propanoate, can also undergo base hydrolysis and the reaction is monitored using the initial rates method. The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in three separate experiments at a constant temperature. The results are obtained below:

Experiment	**Initial [NaOH] / mol dm^{-3}**	**Initial [ester] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.020	0.015	2.70×10^{-3}
2	0.030	0.015	4.05×10^{-3}
3	0.060	0.020	***r***

(i) Use the data above to deduce the order of reaction with respect to NaOH. [2]

(ii) Given that the reaction is first order with respect to the ester, calculate the initial rate of reaction, ***r***, for Experiment **3**. [1]

(c) Compound **A** is an isomer of ethyl propanoate ($C_5H_{10}O_2$). No precipitate is seen when **A** is warmed with Fehling's solution. However, when **A** is warmed with alkaline aqueous iodine, a yellow precipitate of CHI_3 is observed.

Heating **A** with acidified $K_2Cr_2O_7$ followed by immediate distillation gives compound **B**. Tollen's reagent gives a silver mirror when warmed with **B**. When **B** is warmed with 2,4-dinitrophenylhydrazine, an orange precipitate is observed.

(i) Identify and suggest structures for **A** and **B**. Show how you deduced these structures and suggest the types of reactions that are occurring. [6]

(ii) State the type of isomerism present between **A** and ethyl propanoate. [1]

[Total: 20]

8 *Use of the Data Booklet is relevant to this question.*

Some organic compounds contain chlorine, bromine or iodine in addition to carbon and hydrogen. They are classified as halogenoalkanes. One such compound is 2-iodobutane.

(a) 2-iodobutane reacts with ammonia.

(i) State the type of reaction occurring.

(ii) Write a balanced equation for the reaction and;

(iii) State the conditions required for the reaction to occur. [3]

(b) 2-iodobutane also undergoes reaction with potassium hydroxide.

Given that only two geometric isomers are formed

(i) State the type of reaction that occurred [1]

(ii) State the conditions required for the reaction to occur. [1]

(iii) Draw the structural formulae of the products and state how this isomerism arises. [3]

(c) In an experiment, 2-iodobutane was reacted with aqueous silver nitrate at room temperature. A second experiment was carried out using 2-bromobutane instead.

Describe, as much as possible, how the reaction would differ from that of 2-iodobutane. Explain your answer. [4]

(d) In a separate experiment, 2-chlorobutane is reacted to form butan-2-ol. Butan-2-ol is then oxidised to form butanone.

(i) To distinguish between butanone and 2-chlorobutane, a student heated separate samples of each compound with aqueous iodine in the presence of sodium hydroxide. However, this method failed to work. Suggest an explanation why this is so. [2]

(ii) Other than aqueous silver nitrate, suggest a simple chemical test that can be used to distinguish between butanone and 2-chlorobutane. In your answer, state the reagent and conditions used and observations made. [2]

(iii) $KMnO_4$ was used in the oxidation process to form butanone under acidic conditions. Identify the manganese containing species present at the end of the experiment and write its electronic configuration. [2]

(iv) 2-chlorobutane can also be obtained from butan-2-ol by reacting it with anhydrous phosphorous pentachloride. Explain why phosphorous pentachloride must be anhydrous for the reaction to occur. Include in your answer, any equations necessary. [2]

[Total: 20]