CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

8872/02

Paper 2

Thursday 27 August 2015
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 a soft 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.

You are advised to spend not more than 1 hour for Section B.

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

For Examiner's Use	
Section A	
A1	**/7**
A2	**/14**
A3	**/7**
A4	**/3**
A5	**/9**
Section A	**40**
Section B	
B6	**/20**
B7	**/20**
B8	**/20**
Section B	**40**
P2 Total	**80**
P1 Total	**30**
Overall %	
Grade	

Section A

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

1 **(a)** Potassium manganate(VII), $KMnO_4$, can be reduced by iron(II) sulfate, $FeSO_4$. The relevant half-equations for the reaction are given below:

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$$

Write the balanced equation for the redox reaction which can occur. [1]

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(b) Ketones can be reduced by lithium aluminium hydride, $LiAlH_4$, in dry ether to form secondary alcohols. State **another** set of reagents and conditions that can also be used for the reduction of ketones. [1]

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(c) Ketones are not easily oxidised. However, methyl ketones are a specific class of ketones with the acetyl functional group, $RCOCH_3$, and these can be easily oxidised in the ***triiodomethane test***. State the conditions and reagents necessary for this test and write an equation for the reaction, using $RCOCH_3$. [2]

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(d) Many organic compounds undergo oxidation, albeit to varying degrees. Compare the relative ease of oxidation of benzene and methylbenzene. Write appropriate equations and state reagents and conditions to illustrate your answer. [3]

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[Total: 7]

2 **(a)** Define the term *relative atomic mass* of chlorine. [1]

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(b) Write the *spdf* electronic configuration of a chloride **ion,** Cl^-. [1]

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(c) **(i)** Draw a dot-and-cross diagram to show the bonding in calcium chloride.

(ii) Explain how and why the lattice energies of calcium chloride, $CaCl_2$, and potassium chloride, KCl, have different numerical values. [4]

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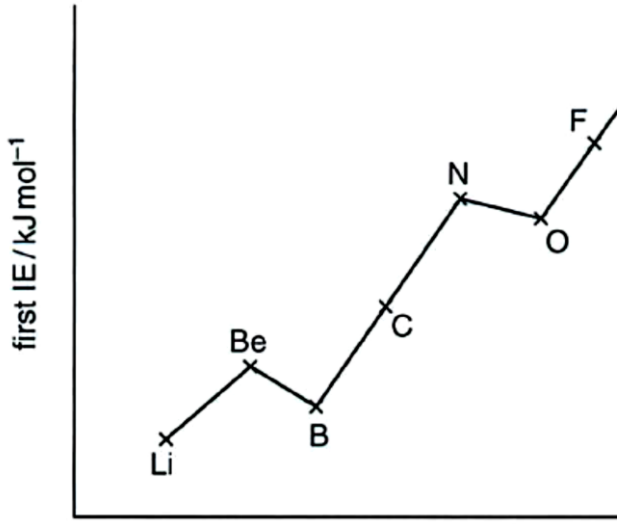
The first ionisation energies of the elements lithium to fluorine is shown below.



(d) **(i)** Describe and explain the **general** trend in first ionisation energies for the elements lithium to fluorine.

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(ii) Describe and explain how the first ionisation energy for chlorine compares to that of fluorine. [4]

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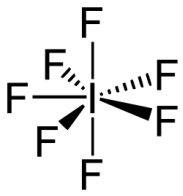
(e) **(i)** Solid iodine burns in fluorine gas to produce iodine pentafluoride which has the chemical formula of IF_5. Draw and state the shape of the IF_5 molecule.

Shape: .....

When liquid IF_5 reacts with fluorine gas, a compound known as iodine (VII) fluoride is formed. This has the formula of IF_7 where all the fluorine atoms are evenly distributed around the central iodine atom as shown in the diagram below:



IF_7

IF_5 and IF_7 differ in their boiling points as shown in this table:

Compound	Boiling point /^oC
IF_5	97.9
IF_7	4.8

(ii) With reference to bonding, suggest an explanation for the difference in boiling points. [4]

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[Total: 14]

3 The hydrolysis of the ester, propyl ethanoate, gives ethanoic acid and propan-1-ol as the products. This hydrolysis is a reversible reaction which, given time, is able to achieve dynamic equilibrium.

$$CH_3CO_2CH_2CH_2CH_3(l) + H_2O(l) \rightleftharpoons CH_3CO_2H(l) + CH_3CH_2CH_2OH(l)$$

propyl ethanoate

(a) (i) Write an expression for the equilibrium constant, K_c of the above reaction.

(ii) State one factor which affects the value of equilibrium constant of the hydrolysis reaction.

……...

(iii) Calculate the concentration of $H_2O(l)$ at equilibrium when the concentrations of $CH_3CO_2CH_2CH_2CH_3(l)$, $CH_3CO_2H(l)$ and $CH_3CH_2CH_2OH(l)$ are 1.357 mol dm^{-3}, 1.505 mol dm^{-3} and 2.353 mol dm^{-3}respectively.

K_c for this reaction is 2.535. [3]

(b) (i) State the catalyst and the conditions that are used for the acidic hydrolysis of the ester.

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(ii) Suggest why the base hydrolysis of esters might give a higher yield of the products compared to the acid hydrolysis of esters. [3]

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(c) Draw another ester that is a structural isomer of the ester, propyl ethanoate. [1]

[Total: 7]

4 Ethene, $H_2C=CH_2$, is able to undergo electrophilic addition with chlorine to form 1,2-dichloroethane.

Eth**y**ne, HC≡CH, is also able to undergo electrophilic addition with chlorine in the same way as eth**e**ne does, but the products are a mixture of 1,2-dichloroeth**e**ne and 1,1,2,2-tetrachloroeth**a**ne.

(a) State the reagent and conditions necessary to have a good yield of 1,2-dichloroeth**e**ne, CHC*l*=CHC*l* from ethyne.

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(b) 1,2-dichloroethene can exhibit geometric isomerism. Draw and label the **two** geometric isomers of 1,2-dichloroethene. [3]

[Total: 3]

5 Honey does not spoil over time, unlike most types of food. In fact, the oldest known sample of honey was found in an Ancient Egyptian tomb and it was still perfectly edible.

A key factor is the low water content of honey. Its water content is too low to support bacteria growth, it dehydrates bacteria and makes honey resistant to spoiling. However, if honey is exposed to moisture in the air, bacteria growth can take place. The sugar in honey will get fermented and honey would taste and smell bad. This is why honey is usually stored in a sealed screw-top jar.

The water content of honey can be estimated by measuring the change in mass of the honey as it dries out. A student took a sample of honey and placed it in a clean and dry Petri dish. She recorded the mass of the dish containing the honey and placed the dish in an oven at about 30°C for 24 hours.

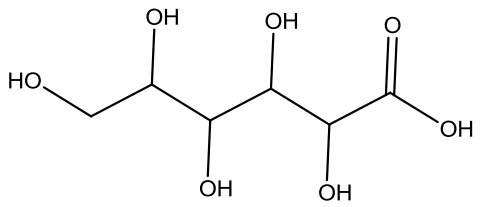
Her results were obtained below:

Mass of empty Petri dish	= 32.34 g
Mass of Petri dish and honey before experiment	= 44.56 g
Mass of Petri dish and honey after experiment	= 42.47 g

(a) Assuming all the water was evaporated from the honey sample at the end of the experiment, calculate the water content in honey. Express your answer as a percentage. [2]

The acidity of honey further boosts honey's antibacterial properties, as many bacteria thrive in neutral rather than acidic conditions. Hence its acidity is another factor that prevents the spoiling of honey. The average pH of honey is 4. The acidity of honey is contributed by a number of acids, including formic acid and citric acid present in honey. However, the dominant acid is gluconic acid which is produced by the action of bee enzymes on some of the glucose molecules in the honey.

The skeletal structure of gluconic acid is given below:



gluconic acid

(b) Calculate the $[H^+]$ concentration in honey. [1]

(c) Apart from the carboxylic acid functional group, state all other functional groups present in a gluconic acid molecule. [2]

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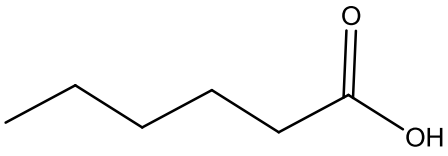
(d) Write balanced equations for the reaction of gluconic acid with

(i) Na

(ii) Na_2CO_3 [2]

(e) Explain in terms of structure why gluconic acid is a stronger acid than hexanoic acid. [2]



hexanoic acid

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[Total: 9]

Section B

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

6 **(a)** Hydrogen peroxide is able to oxidise iodide ions to iodine and this reaction is represented by the following equation:

$$2I^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The rate of this reaction can be followed by monitoring how quickly a specific amount of iodine forms. A small, fixed amount of sodium thiosulfate solution and 1 cm^3 of starch solution are also added to the reaction mixture. Iodine reacts with starch to give a deep blue-black colouration. The ***rate of the reaction*** is inversely proportional to the time taken for the blue-black colour to appear.

The experiment was performed five times, each time with a different initial concentration of iodide ions. The total volume in each experiment is held constant. The results are given below.

Experiment	Initial $[I^-(aq)]$ / mol dm^{-3}	time (t) / s	Relative rate x 10^{-2} (1/t) / s^{-1}
I	0.04	37	0.027
II	0.06	25	0.040
III	0.08	19	***r***
IV	0.10	15	0.067
V	0.12	12	0.083

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

(ii) In the experiments, the concentrations of the acid and hydrogen peroxide are far more concentrated than that of the iodide solution. Explain why this is necessary.

(iii) State the value of ***r***. Hence, plot a graph of the relative rate of reaction (1/t) against the initial iodide concentration.

(iv) Determine the order of the reaction, *n*, with respect to iodide ions. State clearly your reasoning.

(v) Other experiments show that the order of reaction with respect to $[H_2O_2(aq)]$ is 1 and with respect to $[H^+(aq)]$ is zero. Write the rate equation for the reaction and state the units of the rate constant.

(vi) Sketch the shape of the graph of $[H_2O_2(aq)]$ against time. [9]

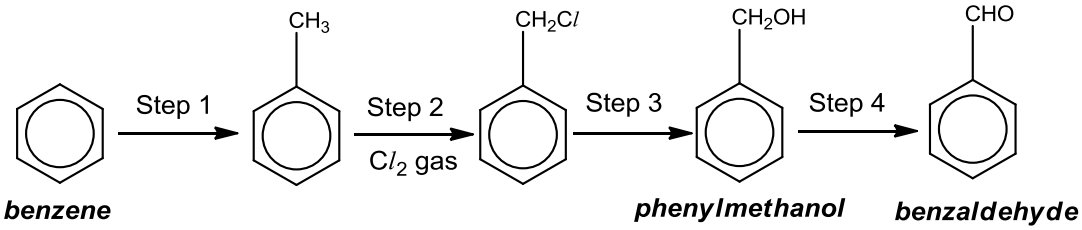
(b) Phosphorus, sulfur and chlorine are consecutive elements in the periodic table. All their oxides, P_4O_{10}, SO_3 and Cl_2O, react with water to form acids. In each reaction, the period 3 elements do not change their oxidation states.

(i) Write balanced equations to show how P_4O_{10} and SO_3 react with water.

(ii) Hence, suggest a balanced equation to show how Cl_2O reacts with water.

[3]

(c) Benzaldehyde is the simplest aromatic aldehyde. It is a colourless liquid with a pleasant almond-like odour. Benzaldehyde can be synthesised from benzene via the following schematic route:



(i) Step 1 is a substitution reaction. Why does benzene undergo substitution reactions instead of addition reactions?

(ii) Write a balanced equation to show benzene undergoing substitution with bromine. State the conditions for the reaction.

(iii) State the condition necessary for Step 2 and identify another possible product that may be formed from Step 2.

(iv) An orange precipitate is formed when benzaldehyde is heated with 2,4-dinitrophenylhydrazine. Draw the molecular structure of the orange precipitate.

(v) Apart from using 2,4-dinitrophenylhydrazine, describe a simple chemical test to show that benzaldehyde is an aldehyde but phenylmethanol is not.

[8]

[Total: 20]

7 **(a)** The Contact Process is one of the most important industrial processes in the modern world due to its production of sulfuric acid which is a common laboratory reagent. One of the steps requires a vanadium catalyst and the equation is shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(i) Explain the effect of increasing the concentration of oxygen on the yield of SO_3.

(ii) The equilibrium amounts in a 1 dm^3 flask consists of 0.65 mol of SO_2, 0.30 mol of O_2 and 5.20 mol of SO_3 at 650 ^oC. Calculate the value for the equilibrium constant, K_c, for the reaction at 650 ^oC.

[4]

(b) **(i)** Ethyl isovalerate, is an ester that is miscible in water and also some non-polar solvents. As this ester has an odour similar to apples, it is commonly used as a favouring agent in beverages and confectionary products.

An experiment was carried out to make ethyl isovalerate in the laboratory. Some ethanol was mixed with 3-methylbutanoic acid and the mixture was heated to 80°C in the presence of a suitable catalyst. The equation for the reaction is shown below.

$$CH_3CH_2OH(l) + (CH_3)_2CHCH_2CO_2H(l) \rightleftharpoons (CH_3)_2CHCH_2CO_2CH_2CH_3(l) + H_2O(l)$$

With the aid of an energy distribution diagram, explain how the catalyst increases the rate of the reaction.

(ii) Using the bond energy values in the *Data Booklet*, calculate the enthalpy change, ΔH, for the esterification reaction between ethanol and 3-methylbutanoic acid.

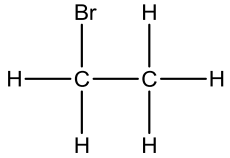
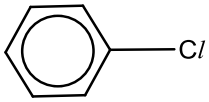
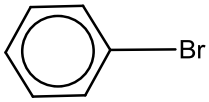
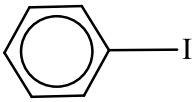
(iii) Using your answer in **b(ii)**, draw an energy profile diagram for the esterification reaction between ethanol and 3-methylbutanoic acid assuming that it is a 1 step reaction.

[6]

(c) Describe the reactions of $AlCl_3$ and PCl_3 with water. State the pH of the resulting solutions formed and write equations for the reactions.

[3]

(d) Compound **Y** has the molecular formula, $C_{10}H_{10}X_2$ (where **X** can be C*l*, Br or I). Equal quantities of each of compound **Y** and 4 other organic halides were treated with excess ethanolic silver nitrate solution and left to stand for 30 min at room temperature conditions. The table below summaries the observations and deductions of the reactions of the above five compounds.

Organic Halide	Observations	Deductions
$C_{10}H_{10}X_2$ Compound **Y**	precipitate was formed after 3 minutes	
 ***Bromoethane***	cream coloured precipitate was formed after 7 minutes	precipitate is silver bromide
 ***Chlorobenzene***	no silver halide precipitate was formed	carbon-halide bonds did not break hence no precipitate was formed in each case.
 ***Bromobenzene***	no silver halide precipitate was formed	
 ***Iodobenzene***	no silver halide precipitate was formed	

Using the information above, suggest the colour of the silver halide precipitate which was formed in the reaction of compound **Y** with ethanolic silver nitrate. Explain your answer.

[2]

(e) *The information in part **(d)** is relevant for solving this question.*

Compound **Z** is an isomer of compound **Y** and can exhibit geometric isomerism. When 1 mole of **Z** reacts with excess KCN in the presence of heat, 1 mole of **A**, $C_{11}H_{10}NX$, is formed.

When aqueous hot NaOH is added to **Z,** compound **B**, $C_{10}H_{11}OX$ is formed. **B** reacts with thionyl chloride, $SOCl_2$, to form steamy fumes of HC*l* and **B** also reacts with aqueous alkaline iodine to form yellow precipitate of CHI_3.

Deduce the structure of compound **Z**. Explain the reactions that occurred.

[5]

[Total: 20]

8 **(a)** The enthalpy change of solution, ΔH_{sol}, is defined as the enthalpy change when one mole of a substance is dissolved in large volume of solvent such that further addition of the solvent produces no more heat changes.

In an experiment to determine the enthalpy change of solution of sodium hydroxide, 2.3 g of sodium hydroxide pellets was dissolved in 200 cm^3 of water. The temperature of water was found to increase by 3.0 ^oC.

(i) Explain in terms of structure and bonding, why sodium hydroxide is soluble in water.

(ii) Calculate the enthalpy change of solution of sodium hydroxide. The specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}. [5]

(b) An acid, HX, was used to determine the concentration of the sodium hydroxide solution which was formed in **(a)**. 25.0 cm^3 of 0.100 mol dm^{-3} of HX was used for the titration. The pH of HX was found to be 3.75.

(i) Show that HX is a weak acid and hence suggest a suitable indicator which can be used for the titration between sodium hydroxide and HX. Explain your choice of indicator.

(ii) The titration was halted after 5 cm^3 of sodium hydroxide was added to the weak acid HX. The pH of the resulting mixture was slightly higher than the initial pH of the weak acid.

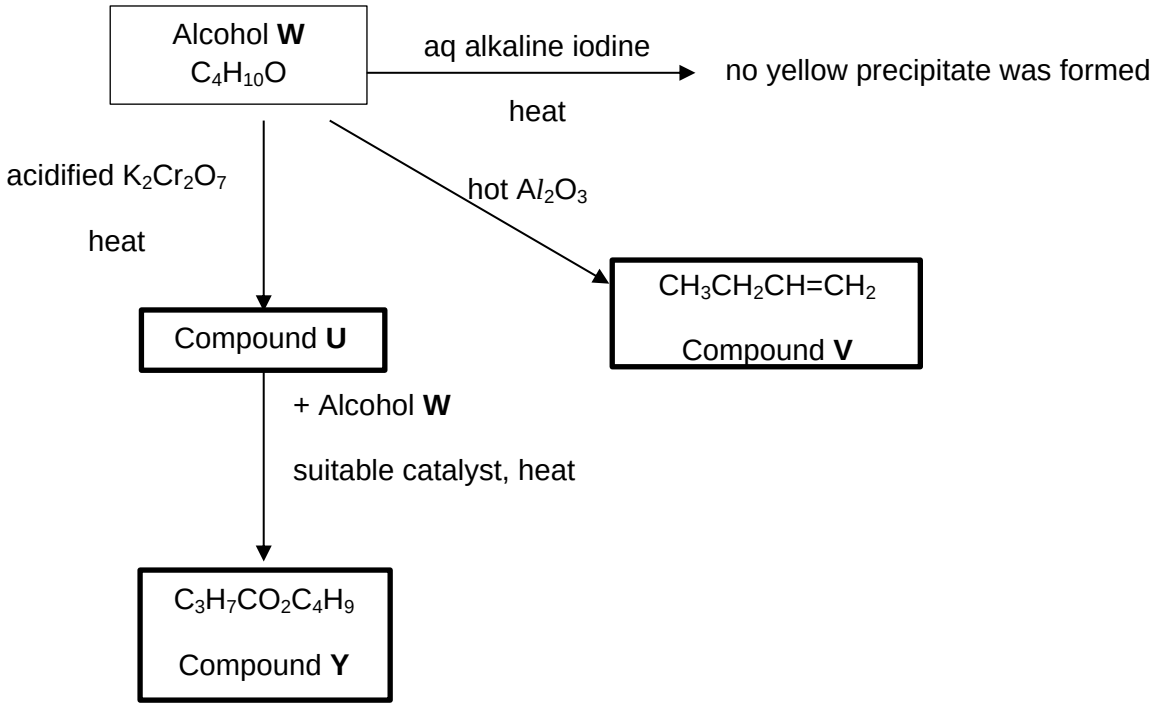
Explain what will happen to the pH of the mixture if 0.1 cm^3 of 0.100 mol dm^{-3} of hydrochloric acid is now added to the mixture. Write an equation for any reaction that occurs. [5]

(c) The oxides, MgO and P_4O_{10}, vary considerably in their physical and chemical properties. Describe the acid-base natures of both oxides and write equations for reactions with acid or base. [2]

(d) **(i)** Alcohols may be used as biofuels to generate energy for locomotion. However due to their high costs, they are more often used as additives in fossil fuels to improve the combustion process.

Give the **environmental advantage** of burning fossil fuels added with biofuels (eg: a mixture of octane and ethanol) compared to burning fossil fuels that contain other anti-knock agents such as Tetraethyl Lead (TEL).

(ii) Alcohols are also widely used in chemical industry as solvents or as precursors (reagents) for synthesis of pharmaceutical products. The flowchart below shows some common reactions of one such alcohol, **W**, that has the molecular formula of $C_4H_{10}O$.



(I) Based on the information presented in the flowchart, deduce the following:

- the name and classification of alcohol **W**
- the names and skeletal structures of compounds **U** and **Y**
- The type of reaction that converts alcohol **W** to compound **V.**

(II) Write an equation for the reaction that occurs when alcohol **W** is heated with acidified potassium dichromate(VI) followed by immediate distillation. [8]

[Total: 20]

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