CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

8872/02

Paper 2

Monday 1st September 2014
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, graphs or rough working.
Do not use staples, paper clips, highlighters, 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	
Paper 1	**/ 30**
Section A	**/ 40**
A1	**/13**
A2	**/14**
A3	**/13**
Section B	**/ 40**
B4	**/20**
B5	**/20**
B6	**/20**
TOTAL	**/ 110**

This document consists of **12** printed pages and **0** blank page.

[Turn over

Section A

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

1 (a) Aluminium oxide, Al_2O_3, is significant in its use as a refractory material due to its high melting point.

(i) Aluminium oxide is said to be *amphoteric*. Write equations to illustrate this fact.

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(ii) Write balanced equations, if any, to illustrate how oxides of elements on either side of aluminium in the third period differ in their behaviour when reacted with

I acids/bases

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……....

II water

……....

……[6]

(b) Unlike aluminium oxide, aluminium chloride cannot be used as a refractory material due to its low melting point.

(i) By considering structure and bonding, explain the difference in melting point between aluminium oxide and aluminium chloride.

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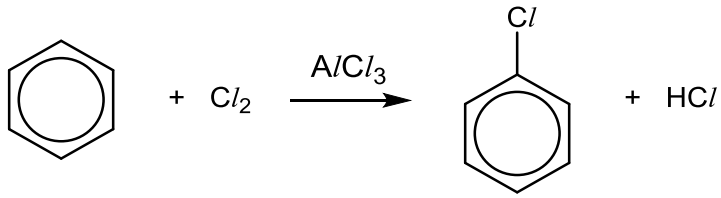
Aluminium chloride is often used as a catalyst in electrophilic substitution reactions. The chlorination of benzene is represented by the following overall equation.



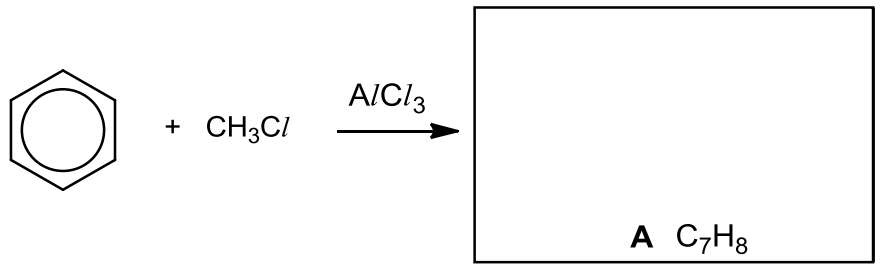
The reaction occurs in two steps.

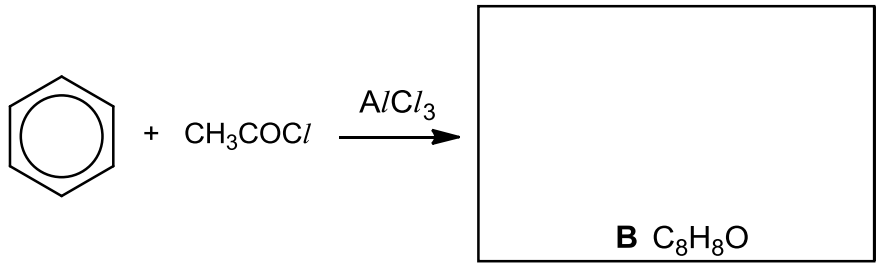
Step 1: The reaction between Cl_2 and $AlCl_3$ generates the Cl^+ electrophile.

Step 2: The benzene ring is then attacked by the electrophile to form the final product.

$AlCl_3$ reacts in a similar way with halogenoalkanes (e.g. CH_3Cl) and acyl chlorides (e.g. CH_3COCl), producing an electrophile that can then attack the benzene ring.

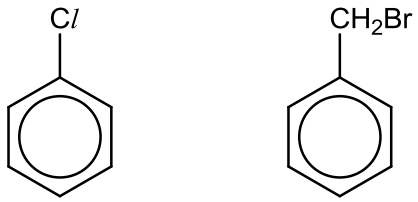
(ii) Predict the structure of the organic products **A** and **B** of each of the following reactions.





[5]

(c) Suggest the reagents and conditions for a simple chemical test that could be used to distinguish between chlorobenzene and (bromomethyl)benzene.



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……[2]

[Total: 13]

2 Benzene can be formed via the reaction between carbon and hydrogen as shown below.

$$6\ C(s) + 3\ H_2(g) \rightarrow C_6H_6(l)$$

Standard enthalpy change of combustion of carbon	- 394 kJ mol^{-1}
Standard enthalpy change of combustion of hydrogen	- 286 kJ mol^{-1}
Standard enthalpy change of combustion of benzene	- 3267 kJ mol^{-1}

(a) (i) Explain what is meant by *standard enthalpy change of combustion.*

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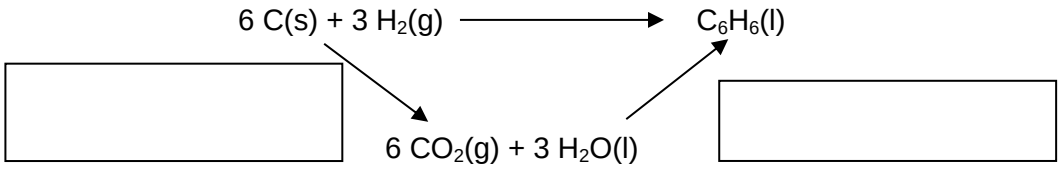
……....

(ii) Given the following energy cycle, fill in the correct enthalpy changes in the boxes and hence calculate the enthalpy change of the above reaction.



(iii) In the space below, draw a fully labelled energy profile diagram for the reaction in **(a)**.

(iv) On the same axes, draw another energy profile diagram, with labels, when the same reaction is catalysed. [6]

(b) When the reaction in part **(a)** was performed at a lower temperature, it was found that the reaction rate changed.

With reference to the Maxwell-Boltzmann distribution curve, explain how this decrease in temperature affected the reaction rate. Label the curves clearly.

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……[4]

(c) 1.17 g of benzene was burnt to heat up 250 g of water in a beaker. The initial temperature of the water was 27.6°C.

(i) Find the amount, in moles, of benzene used.

(ii) Using the information given at the beginning of the question, calculate the total amount of heat evolved.

(iii) Assuming that there is 20% heat loss to the surrounding, calculate the highest temperature reached by the water.

[Specific heat capacity of water is 4.18 J g^{-1} K^{-1}.]

[4]

[Total: 14]

3 Sulfuric acid which is widely used in the manufacturing of fertilisers, explosives and the purification of petroleum, is produced via the Contact process.

In the first step of the Contact Process, sulfur solid is first burnt in excess oxygen to form sulfur dioxide gas.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

The sulfur dioxide gas formed then reacts with excess oxygen at 450°C and 1 atm, in the presence of vanadium(V) oxide catalyst, to form sulfur trioxide gas according the following equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

To prevent formation of a fog of sulfuric acid, sulfur trioxide formed is not directly dissolved in water. Instead, it is dissolved in concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

$$H_2SO_4(l) + SO_3(g) \rightarrow H_2S_2O_7(l)$$

Following which, the oleum that is produce can then be reacted safely with water to produce concentrated acid.

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$$

Sulfuric acid is colourless thick oily liquid without any odour at room temperature. It has to be stored in dry containers.

(a) With the aid of Le Chatelier's Principle, explain why a moderate temperature of 450°C is used in the formation of sulfur trioxide gas.

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……[2]

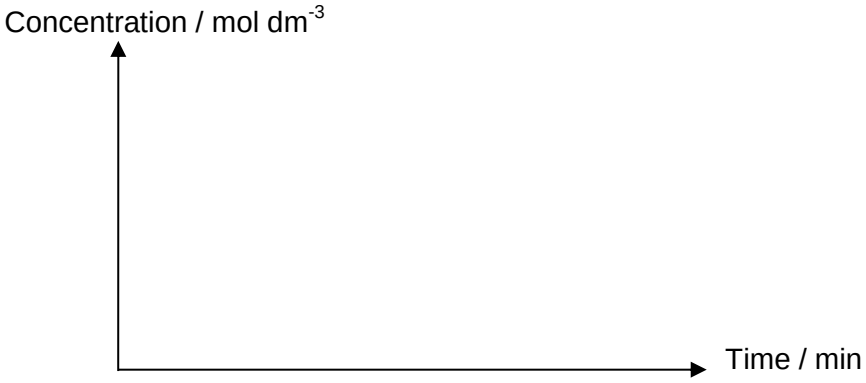
(b) Given that 3 moles of SO_2 and 2 moles of O_2 are allowed to reach dynamic equilibrium in a 2 dm^3 vessel. It is found that the total number of moles of gases present in the vessel at equilibrium is 4.

(i) Write a K_c expression for the equilibrium in the formation of sulfur trioxide.

(ii) Calculate the number of moles of each gas at equilibrium, showing your workings clearly.

(iii) Hence, calculate the equilibrium constant and state its units.

(iv) Using your answer in **(b)(i)**, sketch, on the axes below, the **concentrations** of SO_2 and SO_3 against time for the above equilibrium. Label your graphs clearly.



(v) Sketch, on the axes below, the **rates** of the forward and reverse reactions against time for the above equilibrium. Label your graphs clearly.

[8]

(c) Calculate the mass of oleum required to produce 3 kg of sulfuric acid..

[2]

(d) Suggest why sulfuric acid has to be stored in dry containers.

……....

……[1]

[Total: 13]

Section B

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

4 (a) (i) Using the chlorides of magnesium, silicon and phosphorus as examples, describe the reactions of the chlorides of the third period of the Periodic Table with water. Include in your answer, the pH of the resultant solutions. Write equations where appropriate.

(ii) Draw the dot-and-cross diagrams of the chlorides of magnesium and silicon. [7]

(b) White phosphorus, P_4, is a highly reactive allotrope of phosphorus with a simple molecular structure where each atom is trivalently bonded.

(i) Draw the structure of a molecule of white phosphorus and state the shape about each P atom.

(ii) By considering the **structure** of white phosphorus, suggest the bond angle.

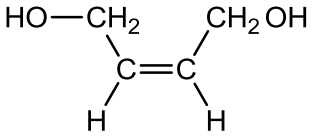
(iii) Hence, suggest why white phosphorus is highly reactive. [4]

(c) Phosphorus trichloride is prepared industrially by heating white phosphorus with chlorine gas.

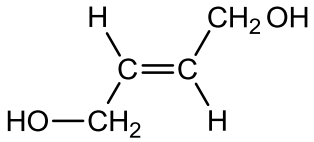
(i) Given that 3.50 tonnes of phosphorus trichloride is produced when 1 tonne of white phosphorus is reacted with excess chlorine, calculate the percentage yield of phosphorus trichloride. (1 tonne = 1×10^6 g)

(ii) Identify one potential safety hazard and state how you would minimise it. [3]

(d) (i) It was observed that the boiling point of cis-but-2-ene-1,4-diol is lower than that of the trans isomer. Suggest a reason for this observation.



cis-but-2-ene-1,4-diol



trans-but-2-ene-1,4-diol

(iii) Suggest a simple chemical test which can be used to distinguish the following.

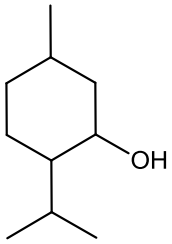
I $(CH_3)_3COH$ and $(CH_3CH_2)_2CO$

II $CH_3CH_2CO_2CH_3$ and $CH_3CH_2OCOCH_2CH_3$

State clearly the reagents used and the observations made. [6]

[Total: 20]

5 Menthol, $C_{10}H_{20}O$, which can be found in peppermint leaves is widely used in the production of medications, candies and beauty products. The skeletal structure of menthol is shown below:



menthol

(a) Draw the structures of all the possible organic products formed when a molecule of menthol is reacted with the following.

(i) Na(s)

(ii) NaBr with concentrated H_2SO_4 with heat

(ii) hot Al_2O_3 [4]

(b) Compound **A**, $C_{14}H_{26}O_3$, produces menthol and compound **B** upon heating with NaOH(aq). Acidification of compound **B** produces compound **C,** $C_4H_8O_3$, which gives effervescence with Na_2CO_3. Compound **C** gives compound **D** when reacted with hot acidified $KMnO_4$. Compound **D** gives yellow crystals with aqueous alkaline iodine but does not produce brick-red precipitate when reacted with Fehling's solution. Upon reacting compound **D** with HCN(aq) in the presence of KCN, compound **E**,$C_5H_7O_3N$, is formed.

Suggest the identities for the compounds **A**, **B**, **C**, **D**, **E** and explain the chemistry of the reactions. [10]

(c) **(i)** Define, with the aid of an equation, the term second ionisation energy with reference to sulfur.

(ii) Describe qualitatively the general trend of second ionisation energy across period 3.

(iii) Write the full electronic configuration of S^+ and Cl^+, and hence explain why the second ionisation energy of chlorine does not follow the general trend across the period. [6]

[Total: 20]

6 In 1669, the German alchemist, Hennig Brand, discovered phosphorus, which has several allotropes. The one of the most common allotropes of elemental phosphorus is white phosphorus, P_4.

(a) Sulfur, like phosphorus, is an element in period 3 of the periodic table. State whether phosphorus or sulfur has a higher boiling point in their elemental state. Explain your answer. [3]

Elemental phosphorus can be used to produce phosphorus-containing acid by first heating phosphorus to form two different phosphorus oxides. These oxides are subsequently dissolved in water to form phosphoric(III) acid and phosphoric(V) acid respectively.

(b) Write equations to illustrate all reactions stated above. [2]

Phosphoric(V) acid is a weak tribasic acid, and it dissociates into PO_4^{3-} in the three steps shown below.

Step 1: $H_3PO_4(aq) \rightleftharpoons H_2PO_4^- + H^+$ $\quad K_{a1} = 7.25 \times 10^{-3}$ mol dm^{-3}

Step 2: $H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-} + H^+$ $\quad K_{a2} = 6.31 \times 10^{-8}$ mol dm^{-3}

Step 3: $HPO_4^{2-}(aq) \rightleftharpoons PO_4^{3-} + H^+$ $\quad K_{a3} = 4.80 \times 10^{-13}$ mol dm^{-3}

(c) **(i)** Write an expression for the first acid dissociation, K_{a1}.

(ii) By considering the K_a values given above, identify the strongest conjugate base. Explain your answer. [3]

(d) A student performed a titration by adding 0.200 mol dm^{-3} H_3PO_4(aq) to a conical flask containing 20 cm^3 of 0.100 mol dm^{-3} NaOH(aq). You may assume that H_3PO_4(aq) behaves as a dibasic acid.

(i) Calculate the pH of solution in the conical flask at the start of the titration.

(ii) Suggest a value for the equivalence point of the above titration.

(iii) Define acidic buffer.

(iv) With the aid of two equations, show how the above mixture acts as a buffer.

(iv) Using answers from **(i)** and **(ii)**, predict if an acidic buffer is formed before or after equivalence point. Explain your answer

(v) Using the answers in part (d), sketch the titration curve of the above reaction. In your sketch, indicate clearly the starting pH of the solution, the equivalence point and the buffer region. [10]

(e) H_3PO_4, heated at 300 °C and 70 atm in the presence of C_6H_{10} and steam, will form only one organic compound, **W**. Draw the structural formula of C_6H_{10} and compound **W**. [2]

[Total: 20]