JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY

8872/02

Paper 2

29 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, class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
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. Start each question on a new sheet of paper.

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use

Section A		/ 40
Section B		
Qn		/ 20
Qn		/ 20
Total		/ 80

This document consists of **12** printed pages.

Section A

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

1. Sulfur can be found in many items used in our daily lives. These include washing detergents, dye, drugs and even explosives. Sulfuric acid is one of the most commonly used form of sulfur.

One of the key manufacturing methods for producing sulfuric acid is the Contact Process, where sulfur dioxide (SO_2) reacts with oxygen gas to form sulfur trioxide (SO_3).

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

(a) **(i)** Draw the dot-and-cross diagram of sulfur dioxide and state its shape.

Shape: …….. [2]

(ii) Explain why sulfur dioxide has a lower boiling point than water.

……..

……..

……..

……..

…….. [1]

(b) In sulfur trioxide, the sulfur atom has more than eight electrons around it. Explain why sulfur is able to expand its octet.

……....

……....

……. [1]

(c) Use Le Chatelier's Principle to predict and explain how the following changes will affect the position of equilibrium in the Contact Process, and state the effect on the equilibrium constant K_c.

(i) a decrease in temperature

……..

……..

……..

……..

…….. [3]

(ii) an increase in total pressure of the system

……..

……..

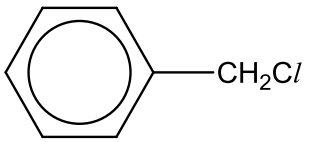
……..

……..

…….. [3]

[Total: 10]

2. **(a)** (Chloromethyl)benzene is highly reactive molecule that is used widely in the synthesis of other organic compounds.



(chloromethyl)benzene

(i) Draw the structure of the organic compound that is produced when (chloromethyl)benzene is heated with potassium manganate (VII) under acidic conditions.

[1]

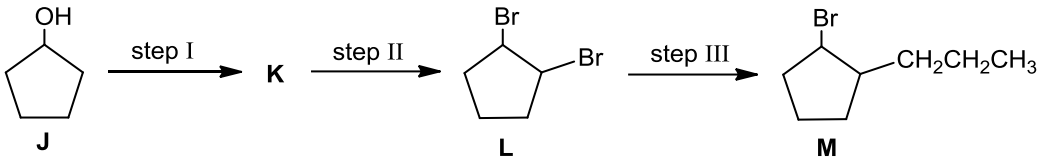
(ii) Ammonia also reacts with (chloromethyl)benzene. Give the conditions necessary and the type of reaction that occurs. State fully which class of organic compound the organic product belongs to.

Conditions: ……..……

Type of reaction: ……..……..

Class of organic compound: …….. [3]

(b) Compound **J** undergoes a series of reactions shown below.



(i) Suggest the structure for **K**.

[1]

(ii) Suggest the reagents and conditions for step **I** and step **II**.

Step **I**:

…… [1]

Step **II**:

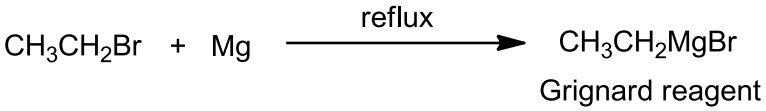
…… [1]

(iii) The following description is with regards to step **III**.

Grignard reagents have the formula of RMg*X* where *X* is a halogen and R is an alkyl group. These reagents can be made by adding halogenoalkane to magnesium in a suitable solvent.

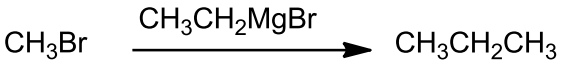
For example,

Reaction **1**:



One of the most common applications of Grignard reagents is in their reaction with halogenoalkanes to extend a carbon chain shown below.

Reaction **2**:



- Suggest the organic compound in step **III** necessary for synthesizing the Grignard reagent to produce **M**.

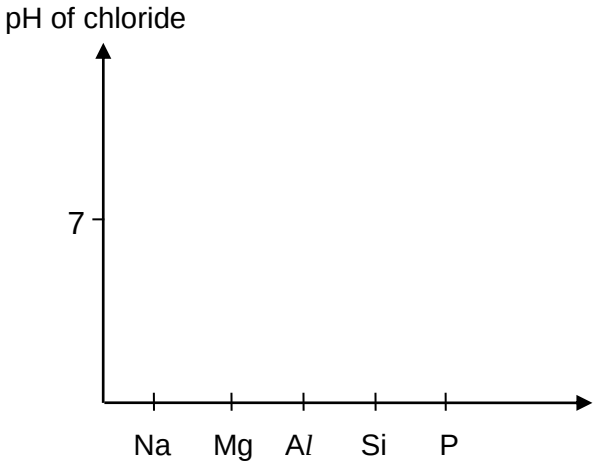
  ……..... [1]

- Suggest the type of reaction in step **III**.

  …….. [1]

[Total: 9]

3. (a) (i) On the axes below, sketch a graph to show the pH of the resultant solutions when period 3 chlorides are dissolved in water.



[1]

(ii) Write equations to show how $SiCl_4$ and PCl_5 react with excess water.

.....

..... [2]

(b) The properties of oxides of the elements of the third period depend on the difference in electronegativity values between the element and oxygen.

The table below shows the electronegativity of elements of the second and third period as proposed by Linus Pauling.

Li	Be	B	C	N	O	F	Ne
0.98	1.57	2.04	2.55	3.04	3.44	3.98	–
Na	Mg	A*l*	Si	P	S	C*l*	Ar
0.92	1.31	1.61	1.90	2.19	2.58	3.16	–

(i) Calculate the difference in electronegativity between the element and oxygen for the oxides BeO, Al_2O_3 and SO_2.

BeO	Na_2O	Al_2O_3	SO_2
	2.52		

[1]

(ii) Hence, use your values in **(b)(i)** to predict the following properties of beryllium oxide, BeO.

- structure and bonding

……... [1]

- acid-base nature

……... [1]

(iii) Write equations to describe how aluminium oxide react with aqueous HC*l* and aqueous NaOH respectively.

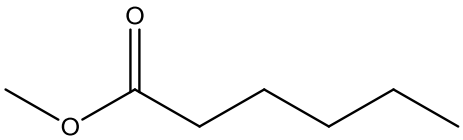
……

……... [2]

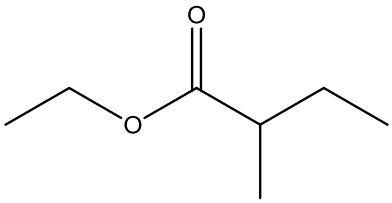
[Total: 8]

4. The pineapple is a fruit which grows in countries that are situated in the tropical and sub-tropical regions. Due to its attractive sweet flavour, pineapple is widely consumed as a fresh and canned fruit, as well as in processed juices.

The characteristic flavour of pineapples is due to esters and other volatile compounds it contains. Two such esters are methyl hexanoate and ethyl-2-methyl butanoate.



Methyl hexanoate



Ethyl-2-methyl butanoate

The human sense of smell can detect numerous different smells (or odours), with some odours more easily detected than others. The *odour detection threshold* is the lowest concentration of a certain odour compound that is perceivable by the human sense of smell. The threshold of a chemical compound is determined in part by its shape, polarity, partial charges and molecular mass. The two esters above have the following values of *odour detection thresholds*:

1 μg = 1 $\times$ 10^{-6} g

	Odour detection threshold (μg kg^{-1})
Methyl hexanoate	70
Ethyl-2-methyl butanoate	0.006

A 150 g serving of pineapple contains the following quantities of the esters:

	Mass (μg)
Methyl hexanoate	3.74
Ethyl-2-methylbutanoate	1.52

Another parameter known as the *odour activity value* (**OAV**) measures the relative importance of a particular compound in a sample to the overall aroma of the sample. It is calculated as the ratio of the concentration of the compound in the sample (measured in μg kg^{-1}), to its odour detection threshold value. The greater the **OAV**, the greater the contribution of the compound to the overall aroma.

(a) (i) State which of the two esters above is more easily detected by smell and explain your answer.

…….

…….

……. [2]

(ii) Calculate the **OAV** of methyl hexanoate and ethyl-2-methyl butanoate. Hence, state which ester contributes more to the overall aroma of pineapple.

[3]

(b) Ethyl-2-methyl butanoate can be produced in the laboratory according to the following chemical equation:

$$C_2H_6O(l) + C_5H_{10}O_2(l) = C_7H_{14}O_2(l) + H_2O(l)$$

(i) Draw the fully displayed structure of the alcohol used in the above reaction and state the *type of reaction* that occurs.

Type of reaction: …… [2]

(ii) The 150 g serving of pineapple contains 0.126 dm^3 of water. Calculate the concentration (in mol dm^{-3}) of ethyl-2-methylbutanoate ($C_7H_{14}O_2$) in the serving.

[2]

(iii) Write an expression for the equilibrium constant, K_c, for the reaction in **(b)**.

[1]

(iv) Equal concentrations of C_2H_6O and $C_5H_{10}O_2$ are reacted to form $C_7H_{14}O_2$.

The value of K_c is 4 at a particular temperature. Calculate the concentrations of C_2H_6O and $C_5H_{10}O_2$ used, such that the concentration of $C_7H_{14}O_2$ formed is the same as that in the 150 g serving of pineapple.

[2]

(v) Concentrated sulfuric acid, a dehydrating agent, is used in the above reaction to increase the yield of the ester. Using Le Chatelier's Principle, explain why this is so.

……

……

…… [1]

[Total: 13]

Section B

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

5. During exercise, muscle cells convert glucose into lactic acid. The lactic acid is used in the *mitochondria*, the energy factories in muscle cells, to produce energy. To help athletes optimize their training regime, sports scientists analyse the lactic acid content in their blood during training to determine how effective their muscle *mitochondria* takes up the lactic acid produced. A sample of blood is taken from the athlete and the monoprotic acid is extracted and subsequently titrated with a base.

(a) Outline the *Brønsted–Lowry* theory of acids and bases. [2]

(b) A solution of lactic acid with concentration 0.10 mol dm^{-3} has a pH of 2.43.

(i) Is lactic acid a strong or weak acid? Explain your answer. [2]

(ii) Use the data given to calculate the value of K_a for lactic acid, stating its units. [3]

(iii) Suggest a suitable indicator for the titration of lactic acid with aqueous calcium hydroxide. [1]

(iv) A sample of lactic acid having a mass of 1.00 g was extracted from a blood sample. It was dissolved in water and titrated with 0.250 mol dm^{-3} calcium hydroxide, $Ca(OH)_2$. It was found that 22.3 cm^3 of $Ca(OH)_2$ was required for neutralisation. Calculate the M_r of lactic acid. [3]

(v) The mass composition of carbon, hydrogen and oxygen in lactic acid is 40.0%, 6.7% and 53.3% respectively. Determine the empirical formula of lactic acid.

Hence, deduce the molecular formula of lactic acid using your answer in **(iv)**. [3]

(vi) When lactic acid reacts with acidified $K_2Cr_2O_7$, it gives an organic product with the same number of oxygen atoms. Draw the structural formula of lactic acid. [1]

(c) State what is meant by a *buffer solution*. [1]

(d) Explain, using equations why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution

(i) on addition of acid, [1]

(ii) on addition of alkali. [1]

You may represent lactic acid as HA and sodium lactate as Na^+A^-.

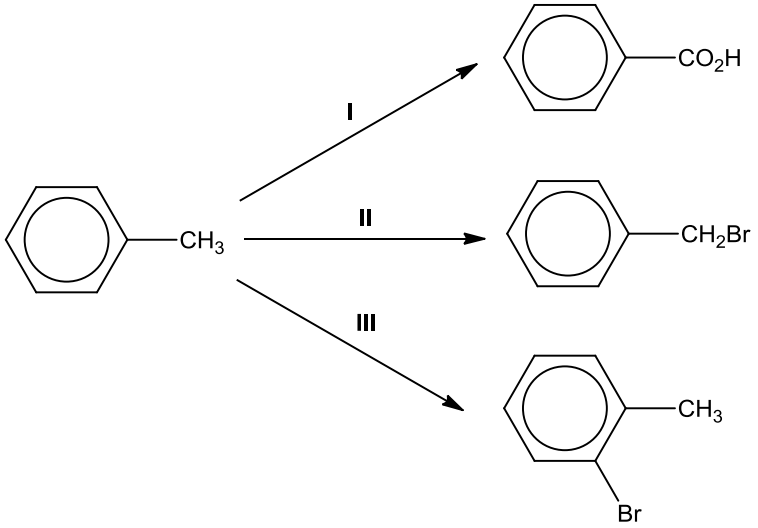
(e) A buffer solution best resists pH changes when the concentrations of lactic acid and that of sodium lactate in the buffer are the same.

Determine the mass of sodium lactate that needs to be added to 500 cm^3 of 0.1 mol dm^{-3} solution of lactic acid to create this buffer solution. [2]

[Total: 20]

6. **(a)** Describe and explain the trends in atomic radius and first ionisation energy across Period 3 of the Periodic Table. [6]

(b) Methylbenzene can be used as an additive in unleaded petrol. Some chemical transformations of methylbenzene are given below.



Compound **A**

(i) Suggest reagents and conditions for each of the reactions **I**, **II** and **III**, and state the *type of reaction* undergone in each case. [6]

(ii) There are two other positional isomers of Compound **A**. Draw their structural formulae. [2]

The progress of reaction **III** can be followed by plotting the concentration of methylbenzene against time.

Data from the experiment are shown in the table.

Time/min	8	11	13	16	21	25
[methylbenzene] / $x10^{-3}$ mol dm^{-3}	65	55	50	38	25	10

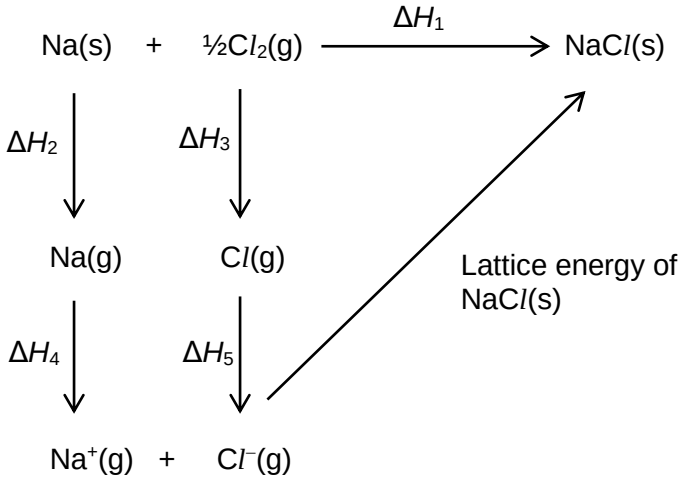
(iii) Plot a graph of these results. [2]

(iv) Explain what is meant by the term *order of reaction*. Use your graph to deduce the order of reaction with respect to methylbenzene. [2]

(v) Describe and explain how the graph would change, if the initial concentration of methylbenzene was doubled. [2]

[Total: 20]

7. **(a)** The diagram below shows a Born-Haber energy cycle for the ionic compound, NaC*l*.



(i) Based on the energy cycle above and the data given below, calculate the lattice energy of NaC*l*.

$\Delta H_1 = -776$ kJ mol^{-1}

$\Delta H_2 = +109$ kJ mol^{-1}

$\Delta H_3 = +244$ kJ mol^{-1}

$\Delta H_4 = +494$ kJ mol^{-1}

$\Delta H_5 = -364$ kJ mol^{-1} [2]

(ii) What enthalpy terms are represented by ΔH_1 and ΔH_4 respectively? [2]

(iii) How would the lattice energy of MgCl_2 compare with that of NaC*l*? Explain your answer. [2]

(b) A compound **P** has the molecular formula C_4H_9Br. Treatment of **P** with warm aqueous sodium hydroxide gives **Q**, which on oxidation gives **R**. **R** forms an orange precipitate with 2,4-dinitrophenylhydrazine. Both **Q** and **R** on treatment with aqueous alkaline iodine, give a yellow precipitate. When **P** is treated with ethanolic sodium hydroxide it forms three isomeric compounds, **V**, **W** and **X**, each of which, on treatment with HBr, is converted back to **P**.

Deduce, with reasoning, the structures of compounds **P**, **Q**, **R**, **V**, **W** and **X**. [10]

(c) For the following pairs of compounds, suggest a simple chemical test to distinguish one compound from the other. You should state the reagents and conditions for each test and the observations seen.

(i) Propanoic acid and propanol

(ii) Chloroethane and bromoethane [4]

[Total: 20]