JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY

8872/02

Paper 2

29 August 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, 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.

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	
B5	
B6	
B7	
Total	

This document consists of **13** printed pages and **1** blank page.

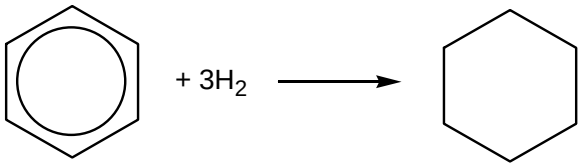
Section A

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

1. This question is about benzene, C_6H_6 and acrolein, CH_2=CHCHO, both of which are found in car exhausts and cigarette smoke.

(a) Benzene can undergo hydrogenation under suitable conditions to give cyclohexane.

The equation for the hydrogenation of benzene is as follows.



(i) Using the enthalpy change of combustion data in the following table, calculate the enthalpy change of hydrogenation of benzene.

Substance	**ΔH_c/ kJ mol^{-1}**
benzene, $C_6H_6(l)$	–3268
cyclohexane, $C_6H_{12}(l)$	–3920
hydrogen, $H_2(g)$	–286

(ii) Use relevant bond energy values from the *Data Booklet* to calculate another value for the enthalpy change of hydrogenation of benzene.

(iii) Suggest a reason for the discrepancy between the values calculated in **(i)** and **(ii)**.

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……

……

[5]

1. **(b)** Acrolein, CH_2=CHCHO, is the simplest unsaturated aldehyde that is formed when glycerol in meat breaks down on heating. It contributes to the smell of burnt fat that is produced by cooking meat on barbecue.

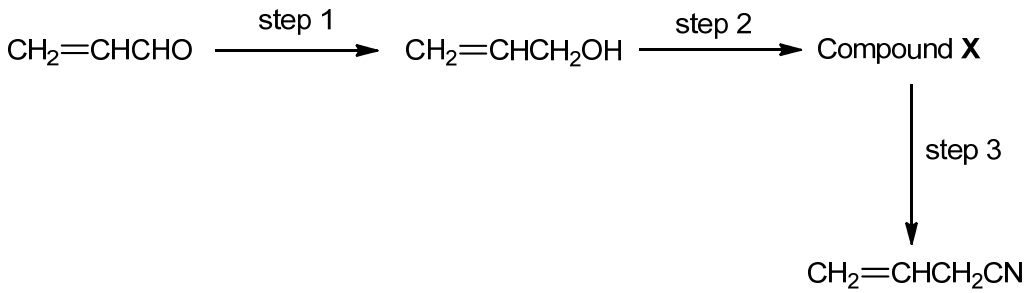
Draw the structural formula of the organic product formed when acrolein is separately reacted with

(i) aqueous bromine;

(ii) acidified $K_2Cr_2O_7$, heat under reflux

[2]

(c) Acrolein can be converted to allyl cyanide, CH_2=$CHCH_2CN$, via the following reaction scheme.



(i) Suggest the structure of compound **X**.

(ii) For the reactions shown in the reaction scheme, state

- the type of reaction in step 1,

……

- the reagents and conditions for step 2,

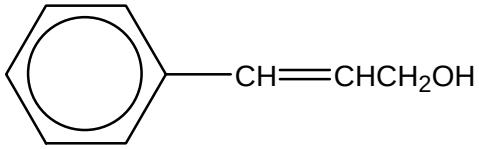
……

- the reagents and conditions for step 3.

……

1. (c) (iii) The product formed in step 1, $CH_2=CHCH_2OH$, is very soluble in water because it can form hydrogen bonds with water molecules. Draw the displayed formula of $CH_2=CHCH_2OH$ and use it to illustrate hydrogen bonding with water.

(iv) In contrast, cinnamyl alcohol is only slightly soluble in water.



cinnamyl alcohol

Suggest a reason why cinnamyl alcohol is only slightly soluble in water.

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……

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[6]

[Total: 13]

2. Hydrochloric acid and sulfuric acid are common reagents found in the laboratory.

(a) A student carried out an experiment to measure the standard enthalpy change of neutralisation.

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

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……

The student added 40.0 cm^3 of 3.00 mol dm^{-3} hydrochloric acid to 60.0 cm^3 of 1.40 mol dm^{-3} potassium hydroxide in a polystyrene cup. The maximum temperature rise recorded is 8.2 °C. Assume the specific heat capacity of the solution is 4.2 J g^{-1} K^{-1}.

(ii) Given that the neutralisation process was 80 % efficient, calculate the standard enthalpy change of neutralisation for the reaction between hydrochloric acid and potassium hydroxide.

(iii) Hydrochloric acid was replaced with ethanoic acid, CH_3COOH, and the experiment was repeated. State and explain how you would expect the standard enthalpy of neutralisation of CH_3COOH with potassium hydroxide to differ from that calculated in **(ii)**.

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…… [6]

2. **(b)** In the manufacture of sulfuric acid, SO_2 is converted into SO_3 in the presence of vanadium(V) oxide catalyst in one of the steps.

$$SO_2(g) + \frac{1}{2}O_2(g) = SO_3(g)$$

The K_c value for this reaction is 9.8 at 1000 K. A mixture of sulfur dioxide of initial concentration 2.0 mol dm^{-3} and oxygen of initial concentration x mol dm^{-3} are allowed to reach equilibrium at 1000 K. The concentration of sulfur trioxide at equilibrium is found to be 1.6 mol dm^{-3}.

(i) Explain what is meant by the terms, *catalyst* and *activation energy*.

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(ii) Write an expression for the equilibrium constant, K_c, for this reaction.

(iii) Calculate the initial concentration, x mol dm^{-3}, of oxygen used.

[5]

[Total: 11]

3. Elements and compounds which have small molecules usually exist as gases or liquids.

(a) These molecules can vary in polarity.

State which of the molecules shown below are polar and explain your choice clearly.

SF_4 $BeCl_2$

……

……

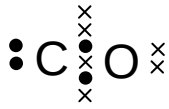
……

……

……

[3]

(b) A dot–and–cross diagram of a CO molecule is shown below. Only electrons from outer shells are represented. On the structure, circle the pair of electrons that represent a co-ordinate bond.



[1]

(c) Chlorofluorocarbons, CFCs, were once used as refrigerants and aerosol propellants due to their low boiling points and non–toxicity. However, they have now been banned.

(i) Explain why CFCs have been banned.

……

……

(ii) Suggest why fluoroalkanes such as CH_2FCF_3 are used as replacements for CFCs.

……

……

[2]

[Total: 6]

4. Methanoic acid, HCO_2H, is the main defence mechanism of an ant, squirted at potential intruders and injected in 'ant bites'. The common name for methanoic acid is *formic acid* because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

When an ant bites, it injects a 6.0×10^{-3} cm^3 of a solution containing 50 % by volume of pure methanoic acid. In one bite, the ant only injects 80 % of the total volume of methanoic acid solution present in it.

One of the most common uses of methanoic acid solution is its application on bee hives infested with mites. A typical methanoic acid solution used for destroying mites has a concentration of 8.9×10^{-2} mol dm^{-3} and a pH of 2.4.

Since methanoic acid can be produced from renewable sources such as wood, direct oxidation of methanoic acid in a fuel cell has also been explored as a potentially efficient method of obtaining useful energy from a renewable fuel. In the methanoic acid fuel cell, the electrodes are coated with palladium or platinum. At one electrode, methanoic acid is oxidised to carbon dioxide and at the other electrode, oxygen is reduced to water. Relevant half equations are shown below.

$$CO_2 + 2H^+ + 2e^- = HCO_2H$$

$$O_2 + 4H^+ + 4e^- = 2H_2O$$

(a) **(i)** Calculate the volume, in cm^3, of pure methanoic acid in one ant.

(ii) Hence, calculate how many ants would have to be distilled to produce 1 dm^3 of pure methanoic acid. Leave your answer to **two** significant figures.

(iii) Given that the density of pure methanoic acid is 1.2 g cm^{-3}, determine the amount in moles of methanoic acid injected to the victim in one ant bite.

4. **(a)** **(iv)** Sodium hydrogencarbonate, $NaHCO_3$, can be used to treat an ant bite. Calculate the mass of sodium hydrogencarbonate, in mg, needed to completely neutralise the sting from one ant bite.

[6]

(b) **(i)** Write an expression for the acid dissociation constant, K_a, for methanoic acid.

(ii) Calculate the concentration of hydrogen ions present in the methanoic acid solution used to destroy mites in a bee hive.

(iii) Hence, calculate a value for the K_a of methanoic acid.

[3]

(c) Use the half–equations given to construct an equation for the overall reaction that takes place in the methanoic acid fuel cell.

…..…… [1]

[Total: 10]

Section B

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

5. **(a)** **(i)** Define the term *first ionisation energy*.

(ii) Sketch a graph of the first ionisation energies of the elements sodium to potassium against proton number.

Using the graph, explain the difference between the values of their first ionisation energies for **each** of the pairs of elements listed below. You should use a different explanation for each pair.

- sodium and potassium
- magnesium and aluminium [4]

(b) Magnesium, aluminium and sulfur react with oxygen to form oxides which differ in their acid/base behaviour.

(i) State the formulae of the oxides formed in their maximum oxidation states for the elements Mg, A*l* and S.

(ii) For **each** oxide, write a balanced equation for its reaction with either hydrochloric acid or sodium hydroxide. [5]

(c) The oxides of sodium and phosphorus differ in their reactions with water. Describe what happens when separate samples of sodium oxide and phosphorus(V) oxide are added to water, relating them to the structure and bonding in each oxide. Write equations for any reactions that occur. [4]

(d) Write an equation to represent the *lattice energy of calcium oxide* and explain why the magnitude of the lattice energy of calcium oxide is greater from that of calcium chloride. [2]

(e) Ozone, O_3, is formed when oxygen is exposed to ultraviolet radiation or to an electric discharge. Ozone is a blue gas whereas oxygen is colourless. When the two gases are mixed, an equilibrium is established as shown in the following equation.

$$3O_2(g) = 2O_3(g)$$

(i) When the temperature of the blue equilibrium mixture is decreased at constant volume, the blue colour fades. Use Le Chatelier's Principle to explain if the forward reaction is endothermic or exothermic.

The concentration of O_3 in the equilibrium mixture can be determined by its reaction with aqueous KI.

$$O_3 + 2KI + H_2O \rightarrow I_2 + O_2 + 2KOH$$

The iodine formed can be estimated by its reaction with sodium thiosulfate.

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$$

When 500 cm^3 of an oxygen/ozone gaseous mixture at s.t.p. was passed through an excess of aqueous KI, and the iodine titrated, 15.0 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$ was required to discharge the iodine colour.

(ii) Calculate the amount in moles of iodine produced.

(iii) Hence calculate the percentage of O_3 in the gaseous mixture. [5]

[Total: 20]

6. **(a)** Carbon exists in two allotropic forms, diamond and graphite.

(i) Explain, in terms of structure and bonding, why diamond and graphite have very high melting points.

(ii) State one physical property in which diamond and graphite differ, and account for this difference. [3]

(b) Like carbon, phosphorus has different allotropes, exhibiting different colours and properties. Phosphorus reacts with chlorine to produce two chlorides, PCl_3 and PCl_5, depending on the amount of chlorine present during the reaction.

(i) Draw and name the shapes of the two phosphorus chlorides.

(ii) At 298 K, PCl_5 is a solid, while PCl_3 is a liquid.

Account for the difference in physical states of the two phosphorus chlorides at room temperature.

(iii) Describe the reactions of PCl_5 and $MgCl_2$ with water, stating the pH of the resulting solutions. Write equations for all the reactions that occur. [8]

(c) Organic compounds that contain carbon and bromine are called bromoalkanes.

A sample of bromoalkane, R–Br, was reacted with aqueous sodium hydroxide in an experiment. The rate of reaction was followed by measuring the concentration of R–Br remaining at various times.

The following reaction mixture was prepared.

initial [R–Br] = 0.0100 mol dm^{-3}

initial [NaOH] = 0.150 mol dm^{-3}

The following table shows [R–Br] at various times.

time /min	[R–Br] /mol dm^{-3}
0	0.0100
40	0.0070
80	0.0049
120	0.0034
160	0.0024
200	0.0017
240	0.0012

Plot these data on suitable axes and, showing all your working and drawing clearly any construction lines on your graph, use your graph to determine:

(i) the order of reaction with respect to [R–Br],

(ii) the initial rate, in mol dm^{-3} min^{-1}.

6. (c) Two further experiments were carried out with different concentrations of NaOH, but keeping the initial [R–Br] the same as before. The following results were obtained.

[NaOH] / mol dm^{-3}	Initial rate / mol dm^{-3} min^{-1}
0.300	1.9×10^{-4}
0.500	3.2×10^{-4}

(iii) Determine the order of reaction with respect to [NaOH], explaining your answer.

(iv) Hence, write a rate equation for this reaction and calculate a value for the rate constant, including units in your answer. [9]

[Total: 20]

7. **(a)** **(i)** Explain what is meant by the terms *Brønsted–Lowry acid* and *conjugate acid–base pair*.

(ii) Identify the Brønsted acid and Brønsted base, and their conjugate base and conjugate acid, in the following equilibrium.

$$H_2PO_4^-(aq) + OH^-(aq) = HPO_4^{2-}(aq) + H_2O(l)$$ [3]

(b) Explain what is meant by an *acidic buffer solution*. Use blood as an example to illustrate your answer. [3]

(c) Hydrogen chloride is an acidic gas. Describe, in terms of orbital overlap, the bonding in a HC*l* molecule. Draw a clearly labelled diagram to illustrate your answer. [2]

(d) On treatment with an excess of hot concentrated manganate(VII) ions, **A** forms two products **B** and **C**.

$$\underset{\textbf{A}}{C_7H_{12}O} \xrightarrow{MnO_4^-} \underset{\textbf{B}}{C_3H_6O} + \underset{\textbf{C}}{C_4H_6O_3}$$

All the three compounds **A**, **B** and **C** give orange precipitates with 2,4-dinitrophenylhydrazine, but only **A** gives a red-brown precipitate with Fehling's solution. **B** and **C** give a yellow precipitate with alkaline aqueous iodine, but **A** does not. Only **C** evolves CO_2 with Na_2CO_3(aq). Treatment of **C** with $NaBH_4$ gives compound **D**.

(i) Use the information given to deduce the structures of **A**, **B**, **C** and **D**. Clearly show all of the deductions that you make from the information you have been given and suggest the types of reactions that are occurring.

(ii) Heating **D** with Al_2O_3 gives a mixture of three isomeric compounds, two of which are stereoisomers of each other. Suggest the structures of the two stereoisomers and state the type of stereoisomerism shown. [12]

[Total: 20]

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