JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY

8872/02

Paper 2 Structured Questions

27 August 2012

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

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** 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

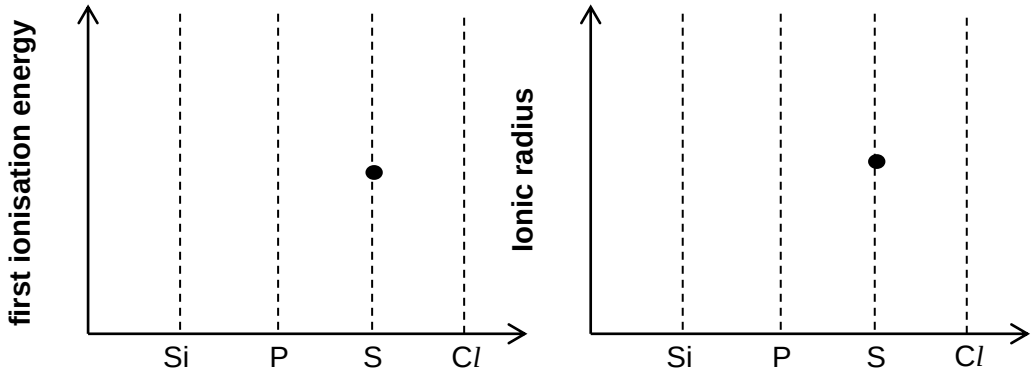
Section A	
B6	
B7	
B8	
Total	

This document consists of **14** printed pages.

Section A

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

1. **(a)** **(i)** On the following diagrams, plot points to show the variation in the named property of some Period 3 elements. Your points should indicate for each element, the relative position of first ionisation energy/ ionic radius with respect to other elements. The point for sulfur has already been plotted in each case.



(ii) Briefly explain the following trends:

the difference in first ionisation energy between phosphorus and sulfur.

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the trend in ionic radius from silicon to chlorine.

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…… [5]

(b) **(i)** Describe what you would observe when a few drops of water is added to phosphorus(III) chloride, PCl_3. Write an equation for this reaction.

……

……

1. (b) (ii) When microwave radiation is passed through phosphorus(III) chloride, PCl_3, at low pressure, a new chloride of phosphorus, **A**, is formed.

A contains 69.6% by mass of chlorine and 30.4% by mass of phosphorus, and its M_r is 200.

Calculate the empirical and molecular formulae of **A**.

(iii) Assuming phosphorus and chlorine show their typical valencies, draw the displayed formula of **A**, showing all bonds and lone pairs.

[5]

[Total: 10]

2. **(a)** Ethanolamine is an organic base that is industrially important. The following table lists some of the properties of ethanolamine and propylamine.

compound	formula	M_r	boiling point/°C	solubility in water
propylamine	$CH_3CH_2CH_2NH_2$	59	48	fairly soluble
ethanolamine	$HOCH_2CH_2NH_2$	61	170	very soluble

(i) Suggest why the boiling point of ethanolamine is much higher than that of propylamine.

…...……

……

……

(ii) Draw a labelled diagram, showing lone pairs of electrons and dipoles, to illustrate why ethanolamine is very soluble in water.

[2]

(b) Write an equation to show how ethanolamine acts as a weak *Bronsted base* in water.

…...…… [1]

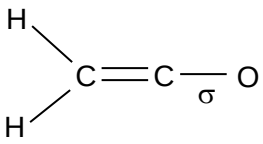
[Total: 3]

3. **(a)** Ketene, C_2H_2O, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds. The structure of ketene is given below.

$CH_2{=}C{=}O$

ketene

The bonding in ketene may be described as a mixture of σ and π bonding. The σ bond between the carbon atom and the oxygen atom is shown in the following diagram. **Complete the diagram** to show orbital overlap that illustrates the π bonding between the *carbon* and *oxygen* atoms in a ketene molecule.



[1]

(b) Ketene burns completely in oxygen to form carbon dioxide and water.

(i) Construct a balanced equation for the above reaction.

…...…….

(ii) Define the term *bond energy*.

…...……

……

(iii) Use relevant bond energy values from the *Data Booklet* to calculate the enthalpy change of combustion of ketene.

[4]

[Total: 5]

4. Blood plasma is a biological fluid that plays an important role in maintaining pH in the body.

In the blood plasma, the equilibrium between carbonic acid, $H_2CO_3(aq)$, and hydrogencarbonate ion, $HCO_3^-(aq)$, buffers pH changes.

$$H_2CO_3(aq) = H^+(aq) + HCO_3^-(aq)$$

The K_a value for this equilibrium is 7.90×10^{-7} mol dm^{-3}.

At body temperature, the pH of the arterial blood plasma is 7.40. The concentration of $H_2CO_3(aq)$ in blood plasma is controlled by respiration through the lungs. $H_2CO_3(aq)$ is in equilibrium with dissolved $CO_2(aq)$.

$$H_2CO_3(aq) = CO_2(aq) + H_2O(l)$$

In the lungs, excess dissolved $CO_2(aq)$ is exhaled as $CO_2(g)$.

$$CO_2(aq) = CO_2(g)$$

During heavy exercise, lactic acid, $CH_3CH(OH)COOH$, is released into the blood and is buffered by the blood plasma. This eventually leads to an increase in the concentration of $CO_2(aq)$ and stimulates increased breathing.

(a) **(i)** Explain what is meant by the term *buffer solution*.

…….

…….

(ii) Write an expression for the acid dissociation constant, K_a, of $H_2CO_3(aq)$ and use it to calculate the mole ratio of HCO_3^- and H_2CO_3 in arterial blood plasma at body temperature.

(iii) Hence, explain whether blood plasma has a greater capacity for absorbing H^+ or OH^- ions.

…….

…….

(iv) Write an equation to show how blood plasma can buffer the pH change when lactic acid is released into the blood.

…….

4. **(a)** **(v)** By applying Le Chatelier's principle, explain why the rate of breathing increases during the process of removing lactic acid.

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…...

…...

…...

…... [8]

(b) During exercise, lactic acid is produced in our muscles from pyruvic acid, CH_3COCO_2H. This reaction occurs in the presence of the enzyme lactic acid dehydrogenase.

(i) Name the reaction that occurs when pyruvic acid is converted to lactic acid.

…...

(ii) Suggest suitable reagents and conditions that can be used to convert pyruvic acid into lactic acid in a college laboratory.

…...

(iii) How would you detect a small quantity of pyruvic acid in a sample of lactic acid? State the reagent(s) you would use and what would be seen in your test.

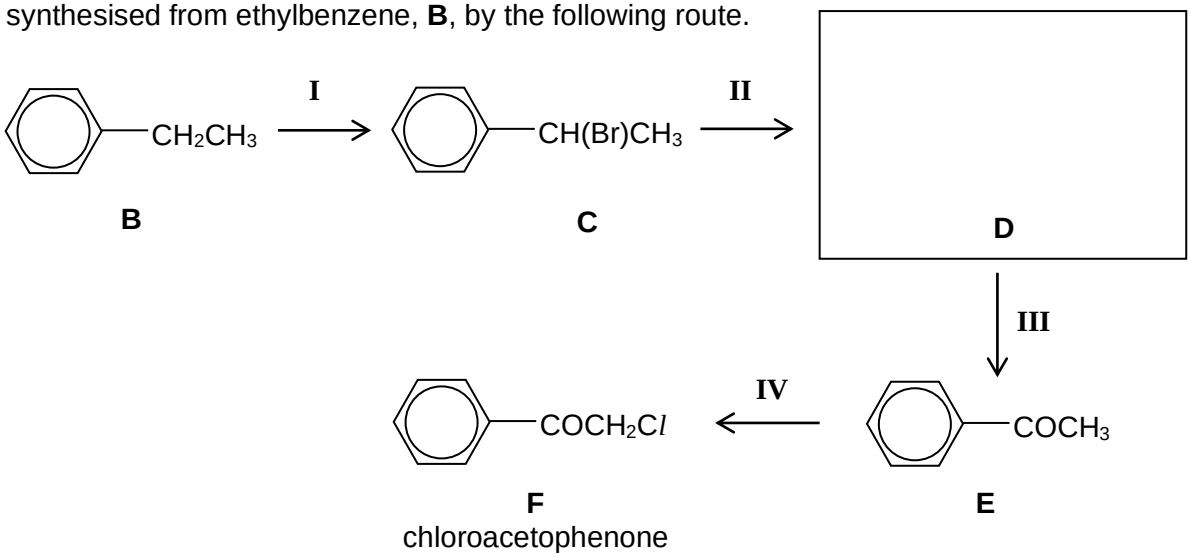
…...

…...

…... [4]

[Total: 12]

5. Chloroacetophenone (compound **F**) was formerly the most widely used tear gas, under the codename *CN*. It was used in warfare and in riot control. It can be synthesised from ethylbenzene, **B**, by the following route.



B **C** **D**

F
chloroacetophenone

E

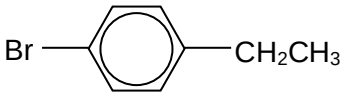
(a) Draw the structure of compound **D** in the box provided above. [1]

(b) State the reagents and conditions for steps **II** and **III**.

Step **II**: ……

Step **III**: …….…….. [2]

(c) Suggest reagents and conditions for converting ethylbenzene into compound **G**, an isomer of **C**.



G

……..... [1]

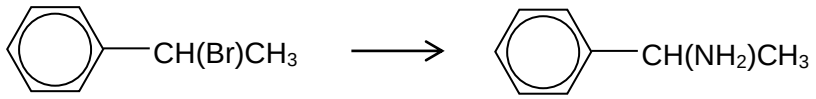
(d) The efficiency of a tear gas is expressed by its 'intolerable concentration', I.C. The I.C. of the tear gas *CN* has been measured as 0.030 ppm of air.

How many molecules of chloroacetophenone need to be sprayed into a room of volume 60 m^3 in order to achieve this concentration?

[1 ppm = 1 g m^{-3}]

[3]

5. **(e)** Compound **C** reacts with NH_3 in ethanol under pressure to give 1-phenylethylamine.



C 1-phenylethylamine

(i) Compounds **H** and **J** can also react with NH_3 under similar conditions to give 1-phenylethylamine.

H **J**

Arrange the three compounds, **C**, **H** and **J** in order of increasing ease of reaction with NH_3.

……

(ii) With the aid of the *Data Booklet*, explain your reasoning behind your choice in **(e)(i)**.

……

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…… [3]

[Total: 10]

Section B

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

6. This question is about the reactions of some oxides of Period 2 and Period 3 elements.

(a) Carbon monoxide is a useful reagent used in many industrial processes. In the manufacture of methanol, carbon monoxide is first formed in **stage I** through the reaction of methane and steam. In **stage II**, the carbon monoxide formed reacts with hydrogen to produce methanol.

stage I: $CH_4(g) + H_2O(g) = CO(g) + 3H_2(g)$ $\Delta H = +210$ kJ mol^{-1}

stage II: $CO(g) + 2H_2(g) = CH_3OH(g)$ $\Delta H = -91$ kJ mol^{-1}

With reference to **stage I**, state and explain the effect of increasing temperature on

- the equilibrium yield of carbon monoxide and
- the rate of production of carbon monoxide respectively.

Include suitable diagram(s) to support your explanations where appropriate. [5]

(b) In **stage I**, methane and steam are heated over nickel catalyst.

(i) Draw a labelled reaction pathway diagram for the *uncatalysed* reaction.

(ii) On the same axes of your answer for **(b)(i)**, draw a reaction pathway diagram for the reaction in the presence of nickel catalyst. Label this line as 'catalysed reaction'. [3]

(c) In **stage II**, one mole of CO was heated with two moles of H_2 in a 2 dm^3 vessel to 550 K at a pressure of 10 MPa. At equilibrium, it was found that only 10% of the carbon monoxide had reacted.

(i) Deduce the number of moles of CO, H_2 and CH_3OH present at equilibrium at 550K.

(ii) Hence, calculate the value of K_c for the equilibrium in **stage II** at 550 K. [3]

(d) Chlorine dioxide, ClO_2, is a liquid at room temperature and pressure. In aqueous solution, chlorine dioxide reacts with hydroxide ions, OH^-. This reaction is carried out three times using different concentrations of the two reactants. The initial rate of each reaction is determined and the results are shown below.

experiment number	[ClO_2(aq)] / mol dm^{-3}	[OH^-(aq)] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.010	0.030	6.00×10^{-4}
2	0.010	0.075	1.50×10^{-3}
3	0.030	0.030	5.40×10^{-3}

6. **(d)** **(i)** Use the data given in the table to deduce the order of reaction with respect to each reactant. Show your reasoning clearly.

(ii) Hence, write a rate equation for the reaction. [3]

(e) Sodium, aluminium and phosphorus are elements in the third period of the Periodic Table. Their oxides have different acid/base properties. For each oxide, state its acid/base nature and write suitable ionic equations to illustrate these properties. [6]

[Total: 20]

7. This question is about some Group II elements.

(a) Describe and explain the trend in the first ionisation energies of the elements down Group II. [2]

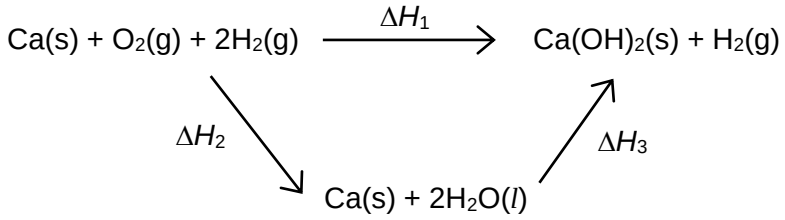
(b) When calcium is placed in water, calcium hydroxide and hydrogen are formed.

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$$

(i) Draw a dot-and-cross diagram to illustrate the bonding in $Ca(OH)_2$.

(ii) In an experiment, 1.00 g of calcium was placed in 180 g of water. The temperature of the solution increased by 13.6 °C after the reaction had completed. Calculate the enthalpy change of the reaction between calcium and water. Assume that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}. [4]

(c) The diagram below shows an energy cycle involving calcium.



(i) In the energy cycle above, what enthalpy change is represented by ΔH_1?

(ii) Given that the standard enthalpy change of combustion of hydrogen gas is −286 kJ mol^{-1}, use your answer in **(b)(ii)** and the above energy cycle to calculate ΔH_1. [3]

(d) Magnesium and sulfur are both Period 3 elements. Describe what you would observe when separate samples of magnesium and sulfur are burnt in oxygen. Write an equation for each reaction. [3]

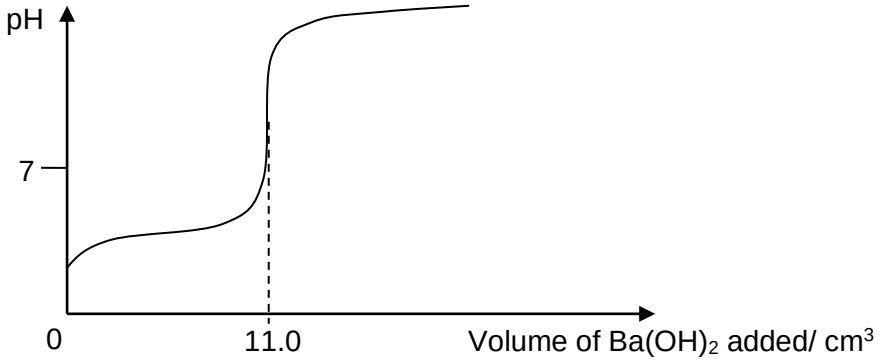
(e) On heating, magnesium nitrate decomposes to give magnesium oxide, nitrogen dioxide gas and oxygen gas.

(i) Write an equation, including state symbols, for the above reaction.

(ii) The lattice energies of sodium bromide is −736 kJ mol^{-1} and that for magnesium oxide is −3800 kJ mol^{-1}. Explain why the two ionic compounds have different magnitude of lattice energies. [3]

7. (f) Glycolic acid, $HOCH_2COOH$, is a compound often found in skincare products. A student pipetted 25.0 cm^3 of 0.125 mol dm^{-3} glycolic acid into a conical flask. Aqueous barium hydroxide, $Ba(OH)_2(aq)$, was gradually added from a burette to the glycolic acid. The pH of the contents was continuously measured using a pH meter.

The pH curve that the student obtained is shown below.



The equation for the reaction between aqueous barium hydroxide and glycolic acid is given below.

$$Ba(OH)_2(aq) + 2HOCH_2COOH(aq) \rightarrow (HOCH_2COO)_2Ba(aq) + 2H_2O(l)$$

(i) Use the titration curve to determine the concentration, in mol dm^{-3}, of the $Ba(OH)_2(aq)$ solution provided.

(ii) Hence, calculate the pH of the $Ba(OH)_2(aq)$ solution provided.

(iii) This titration could be carried out using an indicator. The pH ranges of colour changes of four indicators are shown below.

indicator	**pH range of colour change**
clayton yellow	12.2 – 13.2
thymol blue	8.0 – 9.6
brilliant yellow	6.6 – 7.8
resazurin	3.8 – 6.4

State which of the four indicators is most suitable for this titration. [5]

[Total: 20]

8. **(a)** When **P**, $C_7H_{12}O_2$, is heated under reflux with dilute sulfuric acid, **Q**, $C_4H_6O_2$, and **R**, C_3H_8O, are produced.

When **Q** is reacted with aqueous sodium carbonate, effervescence is observed and the gas evolved forms a white precipitate with aqueous calcium hydroxide. **Q** decolourises a solution of bromine in tetrachloromethane. On heating **Q** with acidified potassium manganate(VII), ethanoic acid is the only organic product formed.

When treated with hot acidified potassium manganate(VII), **R** forms **S**. Both **R** and **S** give a pale yellow precipitate and a product **T** when heated separately with a solution of iodine in aqueous sodium hydroxide.

(i) Suggest structures of **P**, **Q**, **R**, **S** and **T**. Show how you deduce these structures and suggest the types of reactions that occur.

(ii) Write a balanced equation for the reaction when **P** is heated under reflux with dilute sulfuric acid to give **Q** and **R**. [11]

(b) Halogen, $\mathbf{X}_2$, reacts with hydrogen peroxide, H_2O_2, according to the following equation.

$$\mathbf{X}_2(aq) + H_2O_2(aq) \rightarrow O_2(g) + 2H^+(aq) + 2\mathbf{X}^-(aq)$$

In an experiment, 45.0 cm^3 of 0.100 mol dm^{-3} acidified hydrogen peroxide was added to 35.0 cm^3 of 0.200 mol dm^{-3} of $\mathbf{X}_2(aq)$. The resulting solution was found to contain excess $\mathbf{X}_2(aq)$. The amount of excess $\mathbf{X}_2(aq)$ was determined by titrating the resulting solution with aqueous sodium thiosulfate, $Na_2S_2O_3$. 16.60 cm^3 of 0.300 mol dm^{-3} $Na_2S_2O_3(aq)$ was needed for complete reaction.

(i) State the role of hydrogen peroxide in the reaction with $\mathbf{X}_2(aq)$.

(ii) Calculate the number of moles of thiosulfate ions that reacted with the excess $\mathbf{X}_2(aq)$.

(iii) Calculate the number of moles of $\mathbf{X}_2(aq)$ that reacted with hydrogen peroxide.

(iv) Calculate the number of moles of excess $\mathbf{X}_2(aq)$ that reacted with thiosulfate ions.

(v) Calculate the number of moles of thiosulfate ions that reacted with one mole of $\mathbf{X}_2(aq)$.

(vi) $S_2O_3^{2-}(aq)$ reacts with $\mathbf{X}_2(aq)$ to form **<u>one</u>** of the following sulfur-containing species. Calculate the oxidation number of sulfur in each of the sulfur-containing species given in the table below.

$SO_4^{2-}(aq)$	$H_2S(g)$	$S_4O_6^{2-}(aq)$	$S_2O_8^{2-}(aq)$

(vii) Given that $\mathbf{X}_2(aq)$ is reduced to $\mathbf{X}^-(aq)$, identify the sulfur-containing product from the table given in **(b)(vi)**. [9]

[Total: 20]