Candidate Name: _____

Class	Adm No

H

millennia institute

2014 Promotional Examination II
Pre-university 2

H1 CHEMISTRY **8872 / 02**

Paper 2 Structured Questions

15 September, Monday

Candidates answer Section A on the Question Paper.

2 hours

Additional Materials: Data Booklet, Writing Paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name, index number and class on all the work you hand in.
Write in dark blue or black pen on both sides of the writing paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluids.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **two** questions on separate answer paper.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, arrange your answers in numerical order and fasten all your work securely together.

FOR EXAMINER'S USE	
SECTION A	
Q1	**/ 10**
Q2	**/ 10**
Q3	**/ 14**
Q4	**/ 6**
SECTION B	
Q__	**/ 20**
Q__	**/ 20**
Total	**/ 80**

This question paper consists of **14** printed pages and **2** blank pages.

[Turn over

Section A

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

For Examiner's Use

1 Ethanedioic acid, $H_2C_2O_4$, is a dicarboxylic acid and it is widely used in the dye industry as a cleaning agent. It is naturally occurring in molds as CaC_2O_4.

(a) Draw the Lewis structure of ethanedioic acid **and** state the hybridisation around each carbon atom.

Hybridisation around each C atom: ……..

[2]

(b) Ethanedioic acid can be reacted with Na_2CO_3.

(i) State the observations for the reaction.

……

……

(ii) Write a balanced equation for the reaction.

……**[2]**

(c) When CaC_2O_4 is dissolved in water, the anions and cations are each surrounded by a number of water molecules. The formation of these hydrated ions is an exothermic process.

Draw simple diagrams to show how a water molecule can be attached to a calcium cation, and to an ethanedioate ion. Label each diagram to show the type of interaction involved.

[2]

For Examiner's Use

(d) Suggest how the magnitude of lattice energy of CaC_2O_4 compares with that of SrC_2O_4. Explain your answer.

……

……

……**[2]**

(e) The decomposition of calcium ethanedioate is as follows.

$$CaC_2O_4(s) \rightarrow CaO(s) + CO(g) + CO_2(g)$$

Calculate the oxidation numbers of the relevant elements on each side of the equation and hence, state the type of reaction that has occurred.

……

……

……**[2]**

[Total: 10]

For Examiner's Use

2 Sodium azide, NaN_3, found in air-bags in cars can be produced by reacting nitrous oxide and sodium amide according to the equation below.

$$N_2O(g) + NaNH_2(s) \rightarrow NaN_3(s) + H_2O(l)$$

When a car undergoes head-on collision, the decomposition of sodium azide is triggered, forming nitrogen gas which fills the air bag.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

(a) An inflated airbag can contain a maximum of 720 cm^3 of nitrogen gas at r.t.p. Calculate the maximum mass of sodium amide that could be used before the airbag bursts.

[3]

(b) Sodium burns in air to form Na_2O.
Suggest why Na_2O is a solid with high melting point (1280ºC) while N_2O exists as a gas. Explain your answer.

……

……

……

……

……**[3]**

For Examiner's Use

(c) **(i)** Define the term *relative atomic mass*.

……

……

……

(ii) The relative isotopic mass values and percentage abundances of the isotopes of a sample of an element **X** are shown in the table below.

Relative isotopic mass	% abundance
32.0	95.02
33.0	0.75
34.0	4.21
36.0	0.02

Based on these figures, calculate the relative atomic mass of element **X**.

(iii) Compound **A** contains element **X**. It has the following composition by mass: **X**, 37.3%; O, 18.6%; F, 44.1%. It has a relative molecular mass of 86.1. Using your answer in **(c)(ii)**, determine the molecular formula of compound **A**.

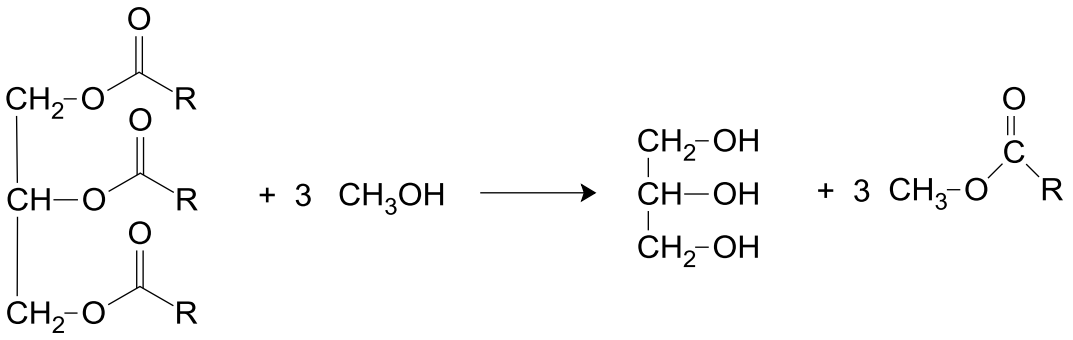
[4]

[Total: 10]

For Examiner's Use

3 Biodiesel is one of the fuels that are being considered as an alternative to fossil fuels. Biodiesel can be made from vegetable oils, animal fats, or grease (used cooking oil from restaurants).

Biodiesel can be produced from transesterification of oil samples in the presence of NaOH as shown in the reaction below.



Oil sample Methanol Glycerol Biodiesel

where R: long-chain hydrocarbon group

(a) For small scale production of biodiesel, 10 cm^3 of cooking oil was heated to 50°C and mixed with 1.5 cm^3 of methanol and NaOH. NaOH acts as a catalyst. After reaction, it was observed that there were two distinct layers in the reaction mixture. Using this method, an 80% yield of biodiesel can be obtained. The densities and M_r of the various compounds used in the reaction are given in the table below.

Compound	Density (g/cm^3)	M_r
cooking oil	0.92	896.0
methanol	0.79	32.0
glycerol	1.26	92.0
biodiesel	0.88	312.0

(i) Determine the limiting reagent in the reaction. Show your working.

For Examiner's Use

(ii) Calculate the volume of biodiesel obtained in the reaction.

(iii) Explain why two distinct layers were observed in the reaction mixture.

……

……

……

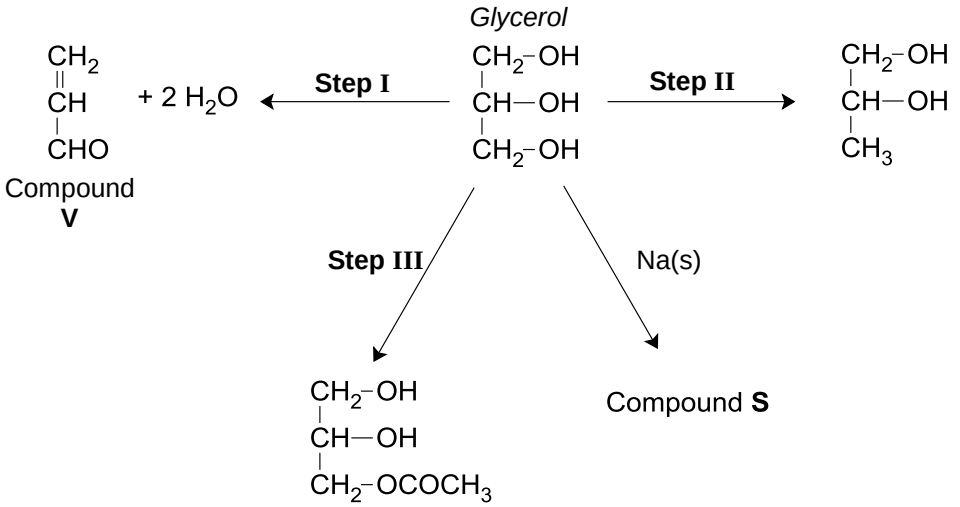
……

(iv) State the organic compounds present in the two layers.

Top layer: ……

Bottom layer: ……..**[7]**

(b) Glycerol, which is a by-product of biodiesel production, has many commercial uses in the pharmaceutical, food and personal care industry. Glycerol is used as a chemical intermediate to produce other useful chemicals.



(i) State the type of reaction for the following steps.

Step I: ……..

Step II: ……..

(ii) Suggest the reagents and conditions for **Step III**.

……

(iii) Draw the structure of compound **S**.

For Examiner's Use

(iv) State the two functional groups which are present in compound **V**. Suggest two simple chemical tests which would enable you to identify the two functional groups in compound **V**. You should state the reagents, conditions and observations for each test.

Functional Group: …….

Reagents and conditions: ……..

Observation: …….

…….

Functional Group: ……

Reagents and conditions: ……..

Observation: …….

…….**[7]**

[Total: 14]

For Examiner's Use

4 An organic compound **P** has molecular formula, C_7H_7CI. When **P** is refluxed with aqueous NaOH, **Q** is formed. Controlled oxidation of **Q** gives **R**. **R** gives a silver mirror with Tollen's reagent but does not react with Fehling's reagent. Continued oxidation of **R** gives **S**, a white solid.

Deduce the structures of **P** – **S**. Explain your reasoning and the chemistry of the reactions involved.

P	**Q**
R	**S**

[Total: 6]

Section B

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

5 **(a)** The elements **X** and **Y** can be one of the following Period 3 elements: Na, Mg, A*l* and Si.

Element **X** has an oxide that does not dissolve in water. Its chloride hydrolyses readily in water, forming a strongly acidic solution.

Element **Y** has a crystalline solid oxide with a high melting point. This oxide dissolves in water to form an alkaline solution. Its chloride is soluble in water to give a neutral solution.

Identify the elements **X** and **Y**. Explain the observations with the aid of relevant balanced equations where necessary.

[4]

(b) Phosphorus is another Period 3 element. It has two forms of chlorides, PCl_3 and PCl_5. PCl_5 can be prepared by chlorination of PCl_3.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad (\Delta H_{rxn} = -124\ kJmol^{-1})$$

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

(ii) 1.0 mol of PCl_3 and 1.0 mol of Cl_2 were mixed in a 1 dm^3 closed vessel at 250^{o}C. At equilibrium, 40% of PCl_3 and Cl_2 remained. Calculate the K_c for the above reaction.

(iii) State *Le Chatelier's* Principle.

(iv) Predict the effect of an increase in temperature on the value of K_c. Explain your answer.

(v) Use the bond energies given in the *Data Booklet* and the enthalpy change of reaction for chlorination of PCl_3 to calculate a value for the bond energy of P-C*l*.

[9]

(c) **(i)** Explain why nitrogen forms only one chloride, NCl_3, whereas phosphorus forms two chlorides PCl_3 and PCl_5.

(ii) PCl_5 undergoes autoionisation in polar solvents to form PCl_4^+. Draw the dot-and-cross diagram for both species and state their shapes.

[4]

(d) PCl_5 is used as a reagent in organic reactions with alcohols. It was used in the first step of the following reaction.

$$CH_3CH_2CH_2OH \xrightarrow[\textbf{Step I}]{PCl_5} \textbf{A} \xrightarrow[\textbf{Step II}]{} CH_3CH{=}CH_2$$

(i) Draw the structure of **A** and state the type of reaction taking place in **Step I**.

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

[3]

[Total: 20]

6 (a) The following table shows the acid dissociation constant, K_a, for some weak acids.

acid	formula	K_a/ mol dm^{-3}
benzoic acid	C_6H_5COOH	6.3×10^{-5}
carbonic acid	H_2CO_3	4.5×10^{-7}
ethanoic acid	CH_3COOH	1.8×10^{-5}
methanol	CH_3OH	3.0×10^{-16}

(i) Define the term *weak acid*.

(ii) When 1 mol of each of the acids was dissolved in 1 dm^3 of water, which of the acids would give the lowest pH value? Explain your answer.

(iii) Explain, in terms of their molecular structures, why methanol has a significantly different K_a value as compared to the other acids?

(iv) Define the term *acidic buffer*. Illustrate the principles of how acidic buffer solutions work by referring to the role of H_2CO_3/HCO_3^- in blood.

[10]

(b) Using **not more than 3 steps**, draw a reaction scheme to show how the following conversion can be made. Suggest the reagents and conditions required for each step and draw all intermediates formed.

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CH(OH)COOH$$

[5]

(c) Ethylamine, $CH_3CH_2NH_2$, is a foul smelling liquid. It is a weak base that reacts with hydrochloric acid at room temperature.

(i) Write a balanced equation for the reaction between ethylamine and hydrochloric acid.

(ii) State how the enthalpy change of neutralisation of ethylamine and hydrochloric acid would compare to that of sodium hydroxide and hydrochloric acid. Explain your answer.

(iii) State reagents and conditions for the preparation of ethylamine from the following compounds:

I. CH_3CH_2Br

II. CH_3CN

[5]

[Total: 20]

7 **(a)** Ethanal can be manufactured by passing ethanol vapour and air over a heated copper catalyst at 300 ^oC.

$$CH_3CH_2OH(g) + ½\ O_2(g) \rightarrow CH_3CHO(g) + H_2O(g) \qquad \Delta H_{rxn}^{\theta} = -182\ kJ\ mol^{-1}$$

The standard enthalpy change of formations of $CH_3CH_2OH(g)$ and $H_2O(g)$ is $-238\ kJ\ mol^{-1}$ and $-242\ kJ\ mol^{-1}$ respectively.

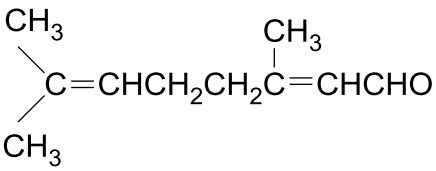
(i) Define the term *standard enthalpy change of formation*.

(ii) Using the information given above, calculate a value for the enthalpy change of formation of $CH_3CHO(g)$.

(iii) With the help of suitable diagram, explain how copper affects the rate of reaction.

[6]

(b) Citral is a pheromone produced by honey bees to attract other bees toward itself. The structure of citral is shown below.



Citral

Draw the structures of the organic products formed and state any observations seen when citral reacts with the following reagents.

(i) Br_2 in CCl_4

(ii) hot acidified concentrated $KMnO_4(aq)$

(iii) 2,4-dinitrophenylhydrazine

[7]

(c) Butyl ethanoate is an ester that gives the odour of banana. It is commonly used as a solvent. Acid hydrolysis of butyl ethanoate gives butan-1-ol and ethanoic acid.

$$CH_3COOCH_2CH_2CH_2CH_3 + H_2O \rightleftharpoons CH_3CH_2CH_2CH_2OH + CH_3COOH$$

The kinetics of this reaction was investigated and the following data was obtained.

Experiment	[ester] / mol dm^{-3}	[HC*l*] / mol dm^{-3}	Relative initial rate / mol dm^{-3} s^{-1}
1	0.040	0.040	1.00
2	0.050	0.040	1.25
3	0.020	0.020	0.25

(i) Use the data given above to deduce the order of reaction with respect to the ester and hydrochloric acid.

(ii) Write a rate equation for the reaction. State the units of the rate constant.

(iii) Using your answer in **(c)(i)**, sketch a graph showing how the rate of reaction varies with [HC*l*] if butyl ethanoate is used in large excess.

(iv) Butan-2-ol is an isomer of butan-1-ol.

Suggest how you would distinguish between butan-2-ol and butan-1-ol using a suitable chemical test. State clearly the reagents and conditions used as well as the observations for each of the compounds.

[7]

[Total: 20]

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