Class Adm No

Candidate Name: _____

H

millennia institute

2015 Promotional Examination II
Pre-University 2

H1 CHEMISTRY **8872 / 02**

Paper 2 Structured Questions **16 Sept 2015**

2 hours

Candidates answer Section A on the Question Paper

Additional Materials: Cover page
Data Booklet
Writing paper

READ THESE INSTRUCTIONS FIRST

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** the questions.

Section B
Answer **two** questions on the separate writing papers. Start each new question on a fresh sheet of writing paper.

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				Section B			Total
Question No	**1 (12m)**	**2 (11m)**	**3 (7m)**	**4 (10m)**	**5 (20m)**	**6 (20m)**	**7 (20m)**	
Marks Obtained								**80**

Section A (40 marks)

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

For Examiner's Use

1 Phosphorus is an essential part of life for both human beings and plants. Phosphorus compounds can be found in the minerals in bones and teeth. Phosphorus is also a vital element for plants which is present in the form of phosphates in the fertiliser to maximise the growth of the plant.

(a) Phosphoric acid reacts with potassium hydroxide as shown in the following reaction.

$$H_3PO_4(aq) + 3KOH(aq) \rightarrow K_3PO_4(aq) + 3H_2O(l)$$

Some thermochemical data are shown below.

	ΔH^{θ}/ kJ mol^{-1}
Standard enthalpy change of formation of $H_3PO_4(aq)$	-1277
Standard enthalpy change of formation of KOH(aq)	-482
Standard enthalpy change of formation of $K_3PO_4(aq)$	-1950
Standard enthalpy change of formation of $H_2O(l)$	-286

(i) Define *standard enthalpy change of formation of H_3PO_4* (aq).

……

……

……..[1]

(ii) Calculate the standard enthalpy change for the reaction between phosphoric acid and potassium hydroxide based on the information provided.

[2]

For Examiner's Use

(b) Phosphorus can react with chlorine to form phosphorus pentachloride and phosphorus trichloride.

(i) The boiling points of phosphorus and chlorine are 280 °C and –34 °C respectively.

Explain, in terms of structure and bonding, the difference in boiling points observed in phosphorus and chlorine.

……

……

……

……

……..[2]

(ii) Draw a molecule of phosphorus pentachloride, PCl_5, showing clearly its shape. Indicate the bond angles on the molecule.

[1]

For Examiner's Use

(iii) PCl_3 and PCl_5, both important in the production of other phosphorous compounds, coexist in equilibrium through:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

At 250 °C, 0.289 g of PCl_3 and 2.16 g of Cl_2 were mixed in a 2.50 dm^3 flask. The equilibrium mixture was found to contain 0.105 g PCl_5.

Determine the value of K_c.

[3]

For Examiner's Use

(c) Radioactivity, or radioactive decay, follows first-order kinetics and it involves the emission of a particle or a photon that results from the spontaneous decomposition of the unstable nucleus of an atom. An example of radioactive isotope of phosphorus is ^{32}P which is used as biochemical tracer in the identification of malignant tumours. ^{32}P has a half-life of 14 days.

(i) Define the term *half-life* of a reaction.

……

……..[1]

(ii) If the initial mass of ^{32}P present was 0.0168g, calculate the mass of ^{32}P at the end of 42 days.

[2]

[Total:12]

For Examiner's Use

2 (a) Bauxite is an aluminium ore containing aluminium oxide and other impurities such as silica, iron oxides and titanium dioxide. The Bayer process is an important industrial process to obtain pure aluminium oxide from bauxite.

In the Bayer process, bauxite is first reacted with hot sodium hydroxide. This converts the aluminium oxide in bauxite into a soluble salt, **S**, and water. The solid impurities are then filtered off.

The second step in the process involves bubbling carbon dioxide gas into the products of the earlier step, producing aluminium hydroxide precipitate and sodium carbonate.

In the third step, the precipitate obtained is heated to its decomposition temperature, producing pure aluminium oxide and water vapour.

(i) The soluble salt, **S**, has the following composition by mass:
Na, 28.0%; A*l*, 33.0%; O, 39.0%.
Determine the molecular formula of **S** given that it has a molecular mass of 82.0.

[3]

(ii) Hence using your answer in **(a)(i)**, write balanced equations for the first two steps of the process.

Step 1: …….

Step 2:……[2]

For Examiner's Use

(iii) During an industrial production of aluminium oxide via the Bayer process, a 1 tonne sample of bauxite was used. The aluminium oxide produced reacted completely with 4060 dm^3 solution of 5 mol dm^{-3} of hydrochloric acid.

$$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$$

Calculate the percentage by mass of aluminium oxide in the sample. [1 tonne = 1000 kg]

[2]

(b) Like aluminium oxide, mineral acids are used as catalysts in many reactions.
In one such reaction, sulfuric acid was used to catalyse the reaction of propanone with iodine.

$$CH_3COCH_3 + I_2 \rightarrow CH_2ICOCH_3 + HI$$

The kinetics of the reaction can be investigated experimentally by varying the concentrations of propanone, iodine and sulfuric acid and determining the time for the colour of the iodine to disappear. In this method, the rate of reaction is measured in terms of the rate at which the iodine concentration changes,

$$\text{i.e. rate of reaction} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for colour of iodine to disappear}}$$

For Examiner's Use

The following results were obtained.

Experiment no.	Volume of propanone /cm^3	Volume of iodine /cm^3	volume of sulfuric acid /cm^3	volume of water /cm^3	relative time for colour of iodine to disappear
1	16	8	16	0	1
2	8	8	16	8	2
3	16	8	8	8	2
4	16	4	16	4	*t*

(i) Deduce the order with respect to propanone and hydrogen ions.

[2]

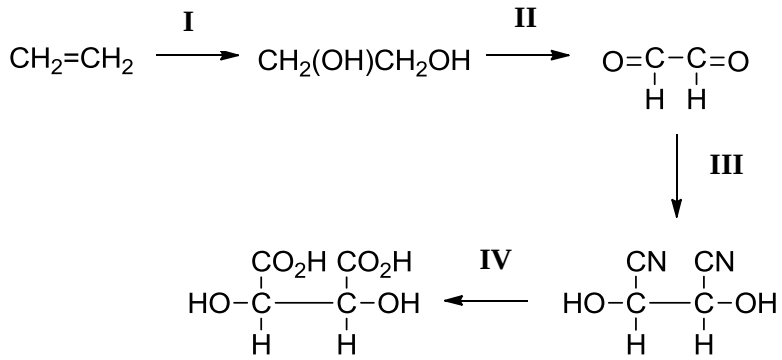
(ii) Given that the order of reaction with respect to iodine is zero, determine the relative time, *t*, for colour of iodine to disappear for **experiment 4**.

[2]

[Total: 11]

For Examiner's Use

3 Tartaric acid can be made from ethene via the synthetic route shown below.



tartaric acid

(a) State the reagents and conditions for each of the following conversions, steps **I** to **IV**.

Step **I**: ……

Step **II**: ……

Step **III**: ……

Step **IV**: ……[4]

(b) Draw the structures of the organic product formed when tartaric acid reacts with each of the following reagents.

(i) Na(s)

(ii) PCl_5

(iii) NaOH(aq)

[3]

[Total:7]

For Examiner's Use

4 3-fluoropropenoic acid, $CHF=CHCO_2H$, is used as building blocks of polymers and it exhibits geometric isomerism.

(a) Draw and label clearly, the geometric isomers of 3-fluoropropenoic acid.

[2]

(b) Suggest how the acidity of $CHF=CHCO_2H$ might compare to that of $CHCl=CHCO_2H$.

……

……

……

……....[2]

(c) Explain why $CHF=CHCO_2H$ is soluble in NaOH(aq).

……

……

……

……....[2]

For Examiner's Use

(d) 0.422 g of an organic compound, $C_3H_xI_y$ (M_r = 422) is subjected to alkaline hydrolysis. After cooling the products, excess dilute HNO_3 (aq) is added followed by the addition of $AgNO_3$ (aq). The mass of the precipitate, AgI formed is 0.705 g.

Determine the values of **x** and **y**.

[4]

[Total:10]

Section B

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

5 **(a)** Liquid propane is commonly found in canisters used for portable gas stoves during camping trips. The enthalpy change of combustion of propane is -2202 kJ mol^{-1}. A camper found a left-over canister of propane and estimates that there was about 60 g of liquid propane.
Calculate the mass of water, at an initial temperature of 25 °C, that he can boil before the canister becomes empty. [2]

(b) Under conditions of insufficient oxygen, propane burns to give carbon monoxide, which is a poisonous colourless and odourless gas.

(i) Construct a balanced equation for this reaction. [1]

(ii) Define *bond energy*. [1]

(iii) Given that the bond energy of C≡O is +740 kJ mol^{-1} and using the bond energy values from the *Data Booklet*, calculate the enthalpy change for the reaction in **(b)(i).** [2]

(c) Explain the following observations, writing balanced equations where appropriate.

(i) Carbon dioxide gas is produced on adding sodium carbonate to aluminium chloride solution, but not on adding sodium carbonate to sodium chloride solution. [3]

(ii) On dissolving silicon tetrachloride in water, the resulting solution turned moist blue litmus paper red. [2]

(iii) In solid state, copper conducts electricity but copper(II) chloride does not. [2]

(iv) Reddish brown NO_2 gas dimerises to give N_2O_4, a colourless gas. The dimerisation process is reversible. A flask containing both gases at equilibrium appeared reddish brown at high temperatures, while the same flask appeared pale brown when the temperature was lowered. [3]

(d) Organic acids are weak acids whereas inorganic acids are generally strong acids.

(i) Define a weak acid. [1]

(ii) Calculate the pH of a solution where the hydrogen ion concentration is 0.04 mol dm^{-3}. [1]

(iii) Calculate the pH of a solution of potassium hydroxide of concentration 0.05 mol dm^{-3}. [2]

[Total: 20]

6 (a) Tin (Sn) exists in two forms. One known as 'white tin', which is a metal and a second form, known as 'grey tin', which has a structure similar to diamond and is more covalent in character.

(i) State the noble gas configuration of tin. [1]

(ii) State two physical properties of white tin which shows it to be a metal. [2]

(iii) Grey tin was boiled under reflux with iodine (I_2) dissolved in tetrachloromethane. Orange crystals of the product, SnI_4, were obtained by filtering the hot reaction mixture followed by cooling the filtrate.

Draw the 'dot-and-cross' diagram of SnI_4, stating clearly its shape and bond angle. [2]

(iv) The following table shows the first ionisation energy of Sn and I.

Element	**1st Ionisation Energy/ kJ mol^{-1}**
Sn	707
I	1010

Explain why the first ionisation energy of I is higher than that of Sn. [2]

(b) Propose a **2-step** synthesis route to show how <u>each</u> of the following conversions can occur. State all reagents and conditions used in each step of the synthesis and draw the intermediates clearly.

(i) $CH_3CH{=}CH_2 \rightarrow CH_3CH(NH_2)CH_3$

(ii) $CH_3CH{=}CH_2 \rightarrow CH_3COCH_3$ [6]

(c) Alcohol **R,** $C_4H_{10}O$, reacts with concentrated sulfuric acid to give three compounds **S, T** and **U**. When compounds **S**, **T** and **U** were separately reacted with hot acidified potassium manganate (VII), the following was observed.

- Compounds **T** and **U** formed the same products.
- Effervescence was observed only for the reaction involving compound **S**.
- All 3 compounds **S**, **T** and **U** formed products that reacted with sodium carbonate.

Deduce the structures of **R**, **S**, **T** and **U**. Explain clearly the chemistry involved in the reactions. [7]

[Total:20]

7 Fuels made from oil mixtures containing large hydrocarbon molecules are not efficient. They do not flow easily and are difficult to ignite. Crude oil often contains too many large hydrocarbon molecules and insufficient small hydrocarbon molecules to meet demand. This is where cracking comes in. Cracking is a process that allows large hydrocarbon molecules to be broken down into smaller, more useful hydrocarbon molecules. One possible cracking reaction involves the hydrocarbon, $C_{15}H_{32}$.

(a) $C_{15}H_{32}$ undergoes cracking to produce ethene, propene and octane (C_8H_{18}) **only**.

(i) Write a balanced equation to illustrate the cracking reaction of $C_{15}H_{32}$. [1]

(ii) Propene can be converted to propane. State the reagents and conditions, and the type of reaction for this reaction. [2]

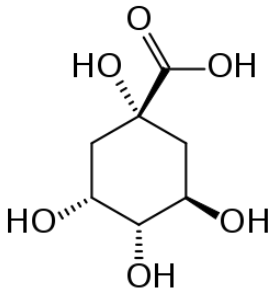
(iii) Suggest a simple chemical test to distinguish between propene and octane. Your answer should include reagents and conditions and expected observations. [2]

(iv) Draw one structural isomer of octane, C_8H_{18}. [1]

(b) An alkane **B** is a component of fuel. When treated with bromine under uv light, it produces a mixture of brominated compounds, including **C**, $C_6H_{12}Br_2$. Dehydrobromination of **C** produces **D**, C_6H_{10}**.** When **D** is oxidised by hot concentrated $KMnO_4$, three compounds, CO_2, CH_3CO_2H and CH_3COCO_2H, are formed in equimolar amounts.

Deduce the structures of **B**, **C** and **D**, explaining clearly the chemistry involved in the reactions. [5]

(c) Quinic acid is a crystalline acid obtained from coffee beans and other plant products. It is responsible for the perceived acidity of coffee. The structure of quinic acid is shown below.



quinic acid

(i) State 2 functional groups present in quinic acid. [2]

(ii) Suggest two simple chemical tests to **confirm** the presence of the two functional groups identified in **(c)(i)**. Your answer should include reagents and conditions and expected observations. [4]

(d) Arrange the following compounds according to **decreasing** K_a values. Explain your answer.

CH_3COOH, $CH_2ClCOOH$, CH_3CH_2COOH

[3]

[Total:20]

END OF PAPER 2

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