Class Adm No

Candidate Name: _____

H

millennia institute

2017 Promotional Examination II

Pre-university 2

H1 CHEMISTRY **8872/02**

Paper 2 **11th Sep 2017**

2 hours

Candidates answer Section A on the Question paper.

Additional materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
You are reminded of the need for good English and clear presentation in your answers.

Section A
Answer **all** the questions.

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

Question	Section A				Section B			Total
	1	2	3	4	5	6	7	
Marks	13	12	5	10	20	20	20	80

Section A

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

1 (a) A sample of lead contains four stable isotopes with the following percentage abundances.

Isotope	Percentage abundance / %
^{204}Pb	1.4
^{206}Pb	24.1
^{207}Pb	22.1
^{208}Pb	**a**

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

……

…… [1]

(ii) Determine the value of **a**. Hence, calculate the relative atomic mass of lead. Give your answer to two decimal places.

[2]

(iii) *Use of the Data Booklet is relevant to this question.*

Determine the number of protons, neutrons and electrons in one particle of $^{206}Pb^{2+}$.

Number of protons: …… Number of neutrons: …… Number of electrons: ……

[1]

(b) Another element in the same group as lead is germanium, Ge, which is chemically similar to silicon, Si. The common oxidation states of germanium in compounds is +2 and +4.

(i) Draw and label the orbital in which electrons are removed from Ge to form Ge^{2+}.

[1]

(ii) Draw and label the orbital in which electrons are removed from Ge^{2+} to form Ge^{4+}.

[1]

(iii) Explain why electrons are removed from the orbital you stated in **(b)(i)** before removing electrons from the orbital in **(b)(ii)** in the ionisation of germanium.

……

……

……

…… [1]

(iv) Describe the structure and bonding in germanium.

……

……

……

…… [2]

(v) Compare and explain briefly how the melting point of germanium differs from that of silicon.

……

……

…… [2]

(c) Pure lithium is highly reactive and reacts readily with water to form lithium hydroxide and hydrogen gas.

Write the ion-electron equations for the redox processes that are occurring in this reaction.

Oxidation: ……..

Reduction: ……

[2]

[Total: 13]

2 **(a)** In 1905, Fritz Haber succeeded in the atmospheric 'fixing' of nitrogen with hydrogen to produce ammonia, which is a precursor in the production of fertilisers. This process is now known as the Haber process, which can be described by the chemical equation below. Haber later went on to receive a Nobel prize in 1918 for this achievement.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Describe the conditions and catalyst used in the Haber process.

……

…… [1]

(ii) Explain how the addition of the catalyst in **(a)(i)** affects the position of the equilibrium for the equation above.

……

……

……

…… [2]

(b) In aqueous solution, ammonia is a *weak Brønsted base*.

Define what is meant by the term *weak Brønsted base.*

……

…… [1]

(c) When excess bromoethane is reacted with limited ammonia, a multi-substituted product is produced.

Write an overall equation to for the reaction when ammonia is reacted with bromoethane in the molar ratio of 1 : 2. [1]

(d) 1,1,2-trichloroethane can undergo elimination to form an alkene which exhibits geometrical isomerism.

(i) Explain how geometrical isomerism arises in alkenes.

……

……

……

…… [2]

(ii) State the reagent and condition required for the elimination reaction.

…… [1]

(iii) Draw and name the structures of the two geometrical isomers.

[3]

(iv) State the number of σ and π bonds in each of the alkenes produced after elimination.

…… [1]

[Total: 12]

3 Use the third period of the modern Periodic Table, sodium to argon, to answer the following questions.

(a) Describe and explain how the atomic radii and first ionisation energies of these elements vary across the period.

……

……

……

……

……

…… [3]

(b) State the structure and bonding present in sodium, magnesium and aluminium. Explain how the bonding present affects the variation in electrical conductivity of these elements.

……

……

……

…… [2]

[Total: 5]

4 Rainwater has a pH of 5.6 instead of 7.0 at 25 °C. This is because carbon dioxide in the atmosphere dissolves in the rainwater and reacts to form an equilibrium with carbonic acid, H_2CO_3, with a K_c of 1.3×10^{-3} mol^{-1} dm^3. The carbonic acid then dissociates, acting as a weak Brønsted acid. Carbonic acid can be assumed to be a monoprotic acid with a K_a value of 4.27×10^{-7}.

Carbonic acid can also be found in the human blood stream as part of an acidic buffer system. When a person undergoes aerobic metabolism, the body uses oxygen to break down glucose to generate carbon dioxide and water as products. However, when a person exercises intensely, there could temporarily be insufficient oxygen for aerobic metabolism, hence producing a by-product called lactic acid, $CH_3CH(OH)COOH$. When lactic acid is built up in the muscles faster than it could be removed by the body, the person can suffer from a condition called lactic acidosis, in which the muscles feel a burning sensation. The lactic acid produced can be removed from the system by reacting with the acidic buffer system present in blood.

(a) Write an expression for the equilibrium constant, K_c, for the dissolution of carbon dioxide in rainwater.

[1]

(b) **(i)** Construct a balanced equation, including state symbols, for the dissociation of carbonic acid in rainwater. Hence, write an expression for the acid dissociation constant of carbonic acid, K_a, and state its units.

[3]

(ii) Calculate the concentration of H^+ ions in rainwater.

[1]

(iii) Using your answers in **(b)(i)** and **(b)(ii)**, calculate the equilibrium concentration of carbonic acid, H_2CO_3, in water. You may assume that the equilibrium concentration of H^+ ions in rainwater is the same as the concentration of HCO_3^- ions.

[1]

(c) Write a balanced equation to show how small amounts of lactic acid, $CH_3CH(OH)COOH$ can be removed by the buffer system present in blood.

…… [1]

(d) Lactic acid can be synthesised in the laboratory from ethanal, CH_3CHO, in two steps.

State the reagents and conditions for both steps and draw the structure of the intermediate organic compound in the space below.

Structure of intermediate:

Reagents and conditions for

Step 1: ……..

Step 2: …… [3]

[Total: 10]

Section B

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

5 (a) The boiling points of the halogens show the following trend.

Element	boiling point / °C
Cl_2	–35
Br_2	59
I_2	184

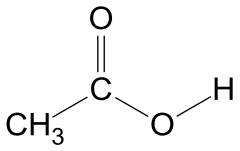
Explain, in terms of structure and bonding, the trend in the boiling point. [2]

(b) The table shows the melting points of magnesium chloride and magnesium oxide respectively.

compound	**melting point / °C**
$MgCl_2$	714
MgO	2852

Account for the difference in the melting point of the two compounds in terms of their structure and bonding. [3]

(c) The structural formula of ethanoic acid is given below.



Explain, with the aid of a diagram, why ethanoic acid has a M_r of 120 in organic solvent. [2]

(d) (i) Define, with the aid of an equation, the standard enthalpy change of combustion of propane, C_3H_8. [2]

(ii) Calculate the enthalpy change of formation of propane, given the following data.

Standard enthalpy change of combustion of propane	–2220 kJ mol^{-1}
Standard enthalpy change of formation of water	–285 kJ mol^{-1}
Standard enthalpy change of formation of carbon dioxide	–394 kJ mol^{-1}

[1]

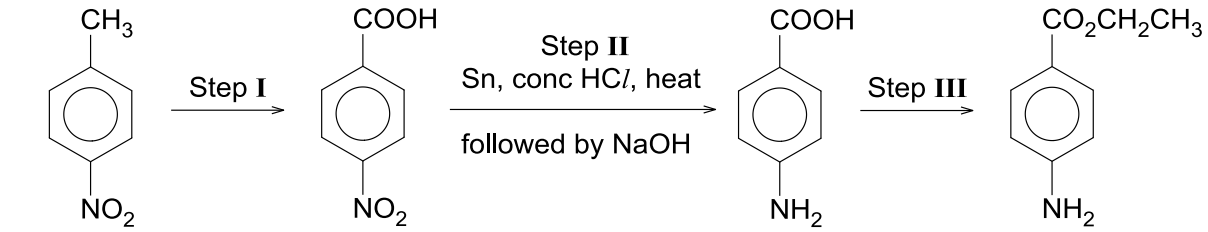
(iii) Propane is combusted under an open copper container with 2 dm^3 of water at 29.0 °C.

Using the data given below and in **(d)(ii)**, calculate the change in temperature of the water if 11.0 g of propane is combusted. Assume that the efficiency of heat transfer is 75%.

Specific heat capacity of water = 4.20 J g^{-1} K^{-1}
Density of water = 1.0 g cm^{-3} [3]

(iv) Suggest a reason to explain why the efficiency of heat transfer is not 100%. [1]

(e) Benzocaine is a topical anaesthetic used in first aid creams and sunburn remedies. It can be produced from 4-nitrotoluene in a series of steps.



4-nitrotoluene Compound **B** Compound **C** Benzocaine

(i) State the reagents and conditions used for steps **I** and **III**. [2]

(ii) State the type of reaction for steps **I** and **III**. [2]

(iii) Explain why the NaOH in step **II** needs to be added carefully in order to obtain compound **C**. [1]

(iv) Write a balanced equation for step **III**. [1]

[Total: 20]

6 **(a)** 2.78 g of a metallic oxide, represented by $\mathbf{M}_2O$ (where **M** is an unknown metal), was added to 43.7 cm^3 of 1.50 mol dm^{-3} hydrochloric acid. The resulting solution then required 13.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide for neutralisation.

Construct two balanced equations for the reactions that occur. Hence, determine the relative atomic mass of **M**. [4]

(b) The reaction of ethanoic anhydride, $(CH_3CO)_2O$, with ethanol, C_2H_5OH, can be represented by the equation:

$$(CH_3CO)_2O + C_2H_5OH \rightarrow CH_3CO_2C_2H_5 + CH_3CO_2H$$

The table below shows the initial concentrations of the two reactants and the initial rates of reaction.

Experiment	**$[(CH_3CO)_2O]$ /mol dm^{-3}**	**$[C_2H_5OH]$ /mol dm^{-3}**	**Initial rate /mol dm^{-3} s^{-1}**
1	0.800	0.400	1.20×10^{-3}
2	0.800	0.800	2.40×10^{-3}
3	1.60	0.800	4.80×10^{-3}

(i) Deduce the order of the reaction with respect to each of ethanoic anhydride and ethanol. [2]

(ii) Write an expression for the rate equation. [1]

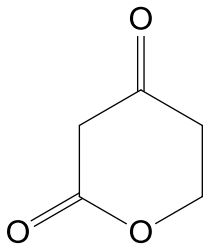
(iii) Calculate the value, with units, for the rate constant, k. [1]

(iv) With the aid of a diagram, explain how a catalyst increases the rate of a chemical reaction. [3]

(c) On heating a neutral compound **D** (shown below) with dilute sulfuric acid, a single compound **E** ($C_5H_8O_4$) is produced. Both compounds **D** and **E** give an orange precipitate with 2,4-dinitrophenylhydrazine but do not react with Fehling's solution.

Upon treating **E** with HCN with a trace of NaCN, **F** ($C_6H_9O_4N$) is produced.

F gives **G** ($C_6H_{15}O_3N$) on reacting with lithium aluminum hydride in dry ether. **G** forms **H** ($Na_2C_6H_9O_5N$) when reacted with hot $KMnO_4$ in dilute NaOH.



Compound **D**

Suggest the structures of **E** to **H**, explaining the chemistry of the reactions described.
Write a balanced equation for the reaction of **D** with 2,4-dinitrophenylhydrazine.

[9]

[Total: 20]

7 **(a)** Bromine trifluoride auto-ionises in the liquid state according to the equation.

$$2BrF_3 \rightleftharpoons BrF_2^+ + BrF_4^-$$

Draw the 'dot-and-cross' diagrams to show the outer shell electron arrangement of BrF_3 and BrF_4^-. Hence, predict the shapes of the two structures. [2]

(b) Boron forms simple trihalides of formula BX_3 with all the halogens. BF_3 and BCl_3 are commonly used as catalyst in chemical reactions since they readily react with electron pair donors.

(i) Using VSEPR theory, explain the shape and state the bond angle of BF_3. [3]

(ii) BF_3 and trimethylamine, $(CH_3)_3N$ react in a 1:1 ratio to give a white crystalline compound. Draw a diagram to illustrate and explain the type of bonding involved in the formation of the compound. [3]

(c) Pure hydrogen iodide, HI, is a gas, which at high temperatures, partially decomposes into hydrogen and iodine, according to the equation:

$$2HI\ (g) \rightleftharpoons H_2\ (g) + I_2\ (g)$$

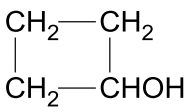
At 500 K, the equilibrium constant, K_c, for the decomposition reaction is 6.25×10^{-3}. Some pure HI is placed into an evacuated 2.0 dm^3 glass tube and heated to 500 K. In the equilibrium sample, the concentration of I_2 is 3.10×10^{-5} mol dm^{-3}.

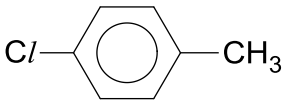
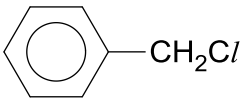
(i) Calculate the concentrations of H_2 (g) and HI (g) in this equilibrium mixture at 500 K. [2]

(ii) Calculate the amount of HI that must have been placed in the 2.0 dm^3 glass tube originally. [2]

(iii) At 600 K, the K_c for dissociation of HI is 1.56×10^{-2}. Deduce whether the forward reaction is endothermic or exothermic. [2]

(d) Suggest simple one-step test-tube reactions by which the following pairs of isomers can be distinguished from each other. You should state the reagents and conditions for each test, and describe the observations for each of the isomers in the pair.

(i)  and $CH_3CH{=}CHCH_2OH$ [2]

(ii)  and  [2]

(iii) $CH_3CH(OH)CH_3$ and $CH_3CH_2CH_2OH$ [2]

[Total: 20]

END OF PAPER 2

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