	Cla	ISS	Reg Number
Candidate Name			



Meridian Junior College JC2 Prelim Examination 2008

H2 Chemistry 9746

10 September 2008

2 hours

Paper 3 Free Response

Additional Materials Data Booklet Writing Paper Graph Paper

INSTRUCTION TO CANDIDATES

Write your name, class and register number in the spaces provided at the top of this page.

Answer any 4 out of 5 questions.

Fasten the writing papers behind the given **Cover Page for Questions 1 & 2** and **Cover Page for Questions 3, 4 & 5** respectively.

Hand in Questions 1 & 2 and 3, 4 & 5 separately.

You are advised to spend about 30 min per question.

INFORMATION FOR CANDIDATES

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

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

This question paper consists of <u>14</u> pages.

Answer any 4 out of 5 questions.

Begin each question on a fresh page of writing paper.

- **1(a)** Hydrazine, N₂H₄, has an ammonia-like odor, and is derived from the same industrial chemistry processes that manufacture ammonia. In some cases, hydrazine behaves like ammonia in chemical reactions. For example, hydrazine is able to form a product when it reacts with boron trifloride, BF₃, in a molar ratio of 1:1.
 - (i) Draw a 'dot-and-cross diagram' to show the electronic structure of a molecule of N_2H_4 . Use the electron repulsion theory to pedict the shape of this molecule and state its bond angle.

[2]

- (ii) Explain why hydrazine form a product with BF_3 when they react in a molar ratio of 1:1.
- (iii) Draw a diagram to show the likely shape of the product formed.

[1]

[1]

(b) Hydrazine is used as rocket fuel and to prepare gas precursors used in air bags. Approximately 260 thousand tonnes of hydrazine are manufactured annually.

Liquid hydrazine undergoes combustion according to the following equation:

 $N_2H_4(I)$ + $O_2(g) \rightarrow N_2(g)$ + $2H_2O(I)$

A chemist conducted an experiment to determine the standard enthalpy change of combustion of hydrazine. In the experiment, 0.210g of hydrazine was burnt as fuel to heat up a beaker containing 200 cm³ of water. The temperature of water rose by 4 °C. You may assume the process has 80 % efficiency.

(i) Explain what is meant by standard enthalpy change of combustion of hydrazine.

[1]

[2]

- (ii) Calculate the standard enthalpy change of combustion of hydrazine.
- (iii) Given the following data:

Enthalpy change of formation of steam = - 242 kJ mol⁻¹ Enthalpy change of vapourisation of water = + 44 kJ mol⁻¹

and using the value you have calculated in *b(ii)*, draw an appropriate energy cycle to determine the standard enthalpy of formation of hydrazine.

[3]

- (c) The standard enthalpy change of formation of hydrazine gas is +235 kJ mol⁻¹.
 - (i) Using appropriate data from the *Data Booklet*, draw an energy level diagram to calculate the average bond energy of N-H bond in hydrazine.

[3]

(ii) Suggest a reason for the difference in the N-H bond energy value obtained from (c)(i) with the value given in the Data Booklet.

[1]

[3]

(d)(i) When sodium thiosulphate is reacted separately with bromine and iodine, different products are formed. Using the following data, and data from the Data Booklet, describe and explain the difference.

(ii) Describe and explain why the trend of boiling points of hydrogen halides differs from the trend of thermal stability of hydrogen halides down Group VII.

[3] [Total : 20] 2 An example of a gas-phase reaction is the decomposition of nitryl chloride NO_2Cl . At 700K, NO_2Cl decomposes according to the following equation.

 $2 \operatorname{NO}_2 \operatorname{Cl}(g) \rightarrow 2 \operatorname{NO}_2(g) + \operatorname{Cl}_2(g)$

The initial pressure of NO₂C*l* is 0.0524 atm. The rate of the reaction is followed by measuring the partial pressure of Cl_2 as it changes with time, t. In such as an experiment, the partial pressure of Cl_2 increased as follows.

Time, t /s	0	300	900	1500	2000	3000
Partial pressure of $Cl_2 / x 10^2$ atm	0	0.48	1.18	1.68	1.94	2.30

(a) (i) When the reaction is complete, the partial pressure of CI_2 is 0.0262 atm. Plot a graph to show how the partial pressure of CI_2 changes during the first 3000s of the reaction and determine the order of reaction with respect to NO_2Cl . Hence, write a rate equation for the decomposition of NO_2Cl .

[4]

(ii) Calculate the rate constant for the above reaction, stating its units.

[1]

(iii) At a certain temperature, the decomposition of NO_2Cl follows a two-step mechanism as shown:

Step 1 : $NO_2Cl \rightarrow NO_2 + Cl$ Step 2 : $NO_2Cl + Cl \rightarrow NO_2 + Cl_2$

The enthalpy change for the overall process is -15 kJ mol^{-1} . For the first step, the activation energy for the forward reaction is 35 kJ mol^{-1} and that of a reverse reaction is 25 kJ mol^{-1} . The activation energy for the reverse reaction of the second step is 35 kJ mol^{-1} . Draw a labelled energy profile diagram based on the above given data.

[2]

(iv) The rate of decomposition of NO₂C*l* is found to increase when temperature is raised. With the aid of a sketch of the Maxwell-Boltzmann distribution curve, explain how a small increase in temperature can lead to a large increase in the rate of decomposition.

[3]

(b) C_4H_8 can exist in 4 non-cyclic isomers forms, **W**, **X**, **Y** and **Z**. **W** has the structure as shown:



W reacts with chlorine under two different conditions.

Reaction I:

In the absence of light, **W** reacts with Cl_2 dissolved in CCl_4 to give an equimolar mixture of two isomers **A** and **B**.

Reaction II:

W reacts with Cl_2 gas under ultraviolet light to give $H_2C=CH(CH_2CH_2Cl)$. However, the presence of trace amount of nitrogen monoxide may decrease the rate of reaction.

(i) Draw the isomeric structures of **X**, **Y** and **Z** and identify the types of isomerism present.

[3]

(ii) Draw the displayed formulae of isomers **A** and **B** in reaction **I**.

[2]

(iii) Explain why the following step rarely occurs in reaction II.

$$H_2C=CH(CH_2CH_3) + CI \bullet \rightarrow H_2C=CH(CH_2CH_2Cl) + H \bullet$$

[1]

(iv) Suggest why the presence of nitrogen monoxide will slow down reaction II.

[1]

(c) Chlorine forms many compounds with different oxidation states. With the aid of balanced equations, explain how different chlorine-containing products are obtained when chlorine reacts with sodium hydroxide under different conditions.

[3] [Total : 20]

- **3(a)** Alloys are mixtures of two or more metals. Transition elements are usually alloyed with one another to enhance their properties. For instance, titanium can be alloyed with iron and copper to form a strong, light-weight and corrosion resistant material for aerospace and automobile.
 - (i) Explain what is meant by the term *transition element*. [1]
 - (ii) When 50g of the titanium-iron alloy is completely oxidized, 35.3g of FeO and a violet oxide of titanium, compound A, is obtained. The mass of oxygen measured in compound A is found to be 11.3g. Determine the molecular formula of this oxide. Hence calculate the oxidation number of titanium.
 - (iii) On strong heating, compound A undergoes disproportionation to form two oxides. One of the oxide is a yellow solid and the other oxide is a white solid, compound B. Write a balanced equation for the disproportionation reaction.
 - (iv) State the full electronic configuration of Ti in compound B. Hence, explain why compound B is a white solid. [1]
 - (v) Explain why complexes of titanium are coloured. [3]
 - (vi) $[Ti(H_2O)_6]^{3+}$ is violet in colour however $[TiF_6]^{3-}$ is pale green. Explain the difference in colour. [2]
- (b) By reference to the *Data Booklet,* predict and describe the observations when $FeCl_3$ (aq) is added to the following compounds. In each case, calculate the E^{θ}_{cell} and write balanced equations for the reactions.
 - (i) $Mn_2(SO_4)_3$
 - (ii) CuI
- (c) Aqueous Fe²⁺ is a good homogeneous catalyst for the decomposition of solution of aqueous hydrogen peroxide.

$$2 H_2O_2 (aq) \rightarrow 2H_2O (l) + O_2 (g)$$

With reference to relevant E^{θ} in the *Data Booklet*, suggest a mechanism for the catalysis of this reaction by aqueous Fe^{2+} .

[3]

[4]

(d) A white powder, anhydrous copper (II) sulphate is added and stirred into a beaker of water. Aqueous ammonia is added dropwise until excess to the solution. Describe and explain what will be observed in the above reactions and support your answers with relevant equations.

[3] [Total : 20] **4(a)** 25 cm³ of 0.50 mol dm⁻³ aqueous barium hydroxide was placed in a conical flask. 1.00 cm³ of 1.00 mol dm⁻³ aqueous sulphuric acid was added at regular intervals, with stirring, from a burette. The electrical conductivity of the mixture was measured after each addition of the acid. The following graph obtained shows the variation of electrical conductivity with volume of acid added.



- (i) Write a balanced equation for the reaction of barium hydroxide and sulphuric acid, including the state symbols.
- (ii) Calculate the volume of acid added at point **v**.

[1]

[1]

(iii) Explain the shape of the graph, stating clearly the species present before and after the addition of v cm^3 of sulphuric acid.

[2]

- (b) X, Y and Z are Group II metals. They formed iodates (V) compounds as shown X(IO₃)₂, Y(IO₃)₂, Z(IO₃)₂. Upon heating, each of these iodates (V) compounds decomposes to yield a metal oxide, a purple gas and a colourless gas that rekindles a glowing splint.
 - (i) Draw a dot-and-cross diagram of X(IO₃)₂. [1]
 - (ii) Write a balanced equation for the decomposition of $X(IO_3)_2$. [1]

(iii) The three graphs below show the change in mass when 2.00g of each iodates (V) compounds from Group II elements (Ca, Sr and Ba) are heated separately at a temperature of T°C.



With the aid of the information from the graphs, state the identity of the $X(IO_3)_2$, $Y(IO_3)_2$ and $Z(IO_3)_2$. [1]

(iv) Arrange the three iodates (V) compound in order of increasing thermal stability and explain the trend as fully as you can.

[3]

(c) Triisopropanolamine (TIPA), $N(C_3H_6OH)_3$, is a monoprotic base which is used as a neutralizing agent in agricultural products. The structure is as shown below.



TIPA

(i) Based on the structure of **TIPA**, explain how **TIPA** can act as a base in neutralizing excess acid in the soil.

[1]

(ii) 20 cm³ of a solution of **TIPA** was exactly neutralized by 25.0 cm³ of 0.05 moldm⁻³ hydrochloric acid. Calculate the concentration of the solution of **TIPA**.

[1]

(iii) The pH of the solution of **TIPA** was found to be lower than 12.0, suggest with a reason, the strength of **TIPA** as a base.

[1]

(iv) When 12.50 cm³ of the same hydrochloric acid was added to the solution of TIPA, the resulting pH was 9.6. Calculate the value of K_b, base dissociation constant for TIPA.

[1]

(v) Hence, determine the initial pH of the solution of **TIPA**.

[2]

- (d) It was found that besides the pH condition of soil, magnesium ion deficiency in the soil decreases the grain quality and protein content of the rice crop cultivated. Two soil samples with different amount of TIPA added were then analysed for their suitability in rice crop cultivation.
 - (i) In the first sample, the pH of the soil is 8.7 and the concentration of Mg^{2+} aqueous ions in the soil is found to be 0.0717 mol dm⁻³. Write the K_{sp} expression of Mg(OH)₂ and calculate its K_{sp}, including the units.

[2]

(ii) In the second sample, the pH of the soil is 12. Calculate the concentration of Mg²⁺ ions in the soil.

[1]

(iii) Deduce which soil samples, first or second, favours good cultivation of rice crop.

[1] [Total : 20] **5(a)** Amino acids are the basic structural building units of proteins. Beyond the amino acids that are found in all forms of life, many non-natural amino acids play vital roles in technology and industry.

Three amino acids with their R groups and isoelectric points are given in the table below.

Amino acid	R group	Isoelectric point
Histidine	HN N	7.6
Glutamic acid	-CH ₂ CH ₂ CO ₂ H	3.2
Glycine	-CH ₃	6.0

(i) Draw the structural formula of a tripeptide with the sequence histidineglycine-glutamic acid, showing the form in which it would exist at pH 2.

[1]

- (ii) Amino acids can act as buffer in solutions. By means of equations, show how glycine can act as a buffer when
 - dilute hydrochloric acid and
 - dilute NaOH

is added to separately into its solution.

(iii) Suggest with reasons a suitable pH which can be used to separate a mixture of histidine, glutamic acid and glycine using electrophoresis.

[2]

[2]

(iv) Crystals of the simplest amino acid, glycine, NH₂CH₂COOH, melt between 230°C and 235 °C. Suggest why the melting point of glycine is higher than that of 2-hydroxyethanamide, HOCH₂CONH₂ (m.p. 102-104°C).

[2]

(b) Explain why phenylamine, $C_6H_5NH_2$ is a weaker base than benzylamine, $C_6H_5CH_2NH_2$ but reacts much more readily with aqueous bromine than benzylamine.

[3]

(c) The compounds **P** and **Q** are isomers with the molecular formula $C_9H_8O_2$.

P liberates carbon dioxide with sodium hydrogencarbonate but **Q** does not.

Upon reaction with hot acidified potassium manganate (VII), 1 mole of **P** gives 2 moles of carbon dioxide and $C_7H_6O_2$ while 1 mole of **Q** gives 1 mole of carbon dioxide and $C_8H_6O_3$.

P decolourises aqueous bromine in the dark to form **R**, $C_9H_9O_3Br$. **Q** reacts with aqueous bromine to form white precipitate of **S**, $C_9H_6O_3Br_3$.

Q can be obtained by reacting **T**, $C_9H_{10}O_3$, with excess concentrated sulphuric acid at 170°C. **T** gives a yellow precipitate on reaction with aqueous alkaline iodine solution.

When **Q** reacts with a mixture of NaCN and HCN, **U** is produced.

Suggest the structures of **P**, **Q**, **R**, **S**, **T** and **U**, explaining the chemistry of the reactions described.

[10] [Total : 20]

Cover Page for Question 1 & 2

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Fasten your answers for **Question 1 and 2** behind this Cover Page.

You are advised to spend about **30 min per question**.

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FOR EXAMINER'S USE		
Paper 3	Q1	/ 20
	Q2	/ 20

Cover Page for Question 3, 4 & 5

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	Q4	/ 20
	Q5	/ 20