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Name	:		

Class: _____

Reg Number: ____



Meridian Junior College 2009 JC2 Preliminary Examination Answers H1 Chemistry 8872

14 September 2009

2 hours

Paper 2

Candidates to answer Section **A** on the Question Paper and Section **B** on separate writing paper.

Additional Materials: Data Booklet Writing paper

INSTRUCTION TO CANDIDATES

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

Section A

Answer all questions.

Section B

Answer any two questions.

At the end of the examination, fasten your answers for Section **B** behind Section **A**.

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.

Examiner's Use		
Paper 1	MCQ	/ 30
Paper 2 Section A	Q1	/ 7
	Q2	/ 8
	Q3	/ 10
	Q4	/ 15
Paper 2 Section B	Q5	/ 20
	Q6	/ 20
	Q7	/ 20
Total		/ 110

This question paper consists of Page 1 to 19.

Section A

- **1(a)** Magnesium bromide, MgBr₂, is a white solid that readily absorbs moisture from the atmosphere. It is often used as a mild sedative.
 - (i) Using magnesium bromide as an example, explain what is meant by the term *lattice energy*.

Lattice energy is the energy released when one mole of $MgBr_2$ is formed from gaseous Mg^{2+} and Br^- ions at standard conditions.

(ii) Use the energy level diagram, together with the given data, determine the lattice energy of magnesium bromide.



Enthalpy change of hydration of magnesium ion, $\Delta H_{hyd(Mg2+)}$	-1921 kJ mol⁻¹
Enthalpy change of hydration of bromide ion, $\Delta H_{hyd(Br-)}$	-336 kJ mol⁻¹
Enthalpy change of solution of magnesium bromide, $\Delta H_{soln}(MgBr_2)$	-186 kJ mol⁻¹

 $\Delta H_{latt}^{\theta}(MgBr2) = + (-1921) + 2(-336) - (-186)$

ΔH_{latt}^θ(MgBr2) =<u>- 2407 kJ mol⁻¹</u>

(iii) Explain how you would expect the numerical magnitude of the lattice energy of MgBr₂ to compare with that of sodium fluoride, NaF.

Charge of cation q_+ : Na⁺ < Mg²⁺ Ionic radius of cation: Mg²⁺ < Na⁺ & Ionic radius of anion: F⁻ < Br⁻ $|\Delta H_{latt}|$: MgBr₂> NaF

[4]

(b) (i) With the aid of an equation, define the first ionisation energy of iodine.

 $I(g) \rightarrow I^+(g) + e$

(ii) State and explain how you would expect the first ionisation energy of iodine to compare with that of fluorine.

[3] 1st I.E of iodine < 1st I.E of fluorine

Down the group, significant increase in screening effect outweighs increase in nuclear charge, hence effective nuclear charge of I < F . The size of the iodine atom is larger hence its valence electrons are further away from the nucleus. There is thus weaker electrostatic attraction between nucleus and the valence electrons of I. Less amount of energy required to remove the valence electron of I.

[Total : 7]

2 Early Periodic Tables, such as that devised by Mendeleev, listed the then known elements in order of their relative atomic mass.

		Ti = 50	Zr = 90	? = 180
		V = 51	Nb = 94	Ta = 182
		Cr = 52	Mo = 96	W = 186
		Mn = 55	Rh = 104.4	Pt = 197.4
		Fe = 56	Ru = 104.4	lr = 198
		Ni = Co = 59	Pd = 106.6	Os = 199
		Cu = 63.4	Ag = 108	Hg = 200
Be = 9.4	Mg = 24	Zn = 65.2	Cd = 112	
B = 11	Al = 27.4	? = 68	Ur = 116	Au = 197?
C = 12	Si = 28	? = 70	Sn = 118	
N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
O = 16	S = 32	Se = 79.4	Te = 128?	
F = 19	Cl = 35.5	Br = 80	l = 127	
Na = 23	K = 39	Rb = 85.4	Cs = 133	Ti = 204
	Ca = 40	Sr = 87.6	Ba = 137	Pb = 207
	? = 45	Ce = 92		
	?Er = 56	La = 94		
	?Yt = 60	Di = 95		
	?In = 75.6	Th = 118?		
	Be = 9.4 B = 11 C = 12 N = 14 O = 16 F = 19 Na = 23	$Be = 9.4 \qquad Mg = 24 \\B = 11 \qquad Al = 27.4 \\C = 12 \qquad Si = 28 \\N = 14 \qquad P = 31 \\O = 16 \qquad S = 32 \\F = 19 \qquad Cl = 35.5 \\Na = 23 \qquad K = 39 \\Ca = 40 \\? = 45 \\?Er = 56 \\?Yt = 60 \\?ln = 75.6 \\\end{array}$	$\begin{array}{c c} Ti = 50 \\ V = 51 \\ Cr = 52 \\ Mn = 55 \\ \hline Fe = 56 \\ Ni = Co = 59 \\ \hline Cu = 63.4 \\ \hline Be = 9.4 & Mg = 24 & Zn = 65.2 \\ \hline B = 11 & Al = 27.4 & ? = 68 \\ \hline C = 12 & Si = 28 & ? = 70 \\ \hline N = 14 & P = 31 & As = 75 \\ \hline O = 16 & S = 32 & Se = 79.4 \\ \hline F = 19 & Cl = 35.5 & Br = 80 \\ \hline Na = 23 & K = 39 & Rb = 85.4 \\ \hline Ca = 40 & Sr = 87.6 \\ \hline ? = 45 & Ce = 92 \\ \hline ?Er = 56 & La = 94 \\ \hline ?Yt = 60 & Di = 95 \\ \hline ?ln = 75.6 & Th = 118? \\ \end{array}$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

(a) When Mendeleev created the table, there were uncertainties regarding the relative atomic mass of tellurium. It is now known that there are eight isotopes of tellurium. Complete the following table. Give your answers to **four** significant figures.

isotope	percentage abundance	isotopic mass x percentage abundance
tellurium-120	0.09	11
tellurium-122	2.46	300
tellurium-123	0.87	107
tellurium-124	4.61	572
tellurium-125	6.99	874
tellurium-126	18.71	2357
tellurium-128	31.79	4069
tellurium-130	34.48	4482

Hence, calculate the relative atomic mass of tellurium to 1 decimal place.

Relative atomic mass of Te

 $= \frac{11 + 300 + 107 + 572 + 874 + 2357 + 4069.12 + 4482.40}{100}$

3

= <u>127.7</u>

(b) Tellurium (IV) chloride, $TeCl_4$, is a pale yellow solid at room temperature with a melting point and boiling point of 224°C and 380°C respectively. In the molten state, $TeCl_4$ dissociates into $TeCl_3^+$ and $Te_2Cl_{10}^{2^-}$. Gaseous tellurium (IV) chloride, $TeCl_4$, has a structure similar to sulphur tetrafluoride, SF_4 .

Explain in terms of structure and bonding, the relative electrical conductivity of $TeCl_4$ in the molten and gaseous state.

Electrical conductivity of gaseous $\text{TeC}I_4$ < molten $\text{TeC}I_4$. This is because gaseous $\text{TeC}I_4$ has a simple molecular structure and thus lacks free mobile ions or delocalised electrons to conduct electricity. Molten $\text{TeC}I_4$ can conduct electricity because of the presence of free mobile ions.

[2]

- (c) Tellurium resembles silicon in many aspects. For example, both are metalloids and are used as semiconductors. Tellurium (IV) oxide, TeO₂, reacts with concentrated strong bases in the same way as silicon (IV) oxide, SiO₂.
 - (i) Write a balanced equation for the reaction between TeO_2 and NaOH.

 $TeO_2 + 2NaOH \rightarrow Na_2TeO_3 + H_2O$

(ii) Predict the pH of the solution formed when gaseous tellurium tetrachloride, $TeCl_4$, is bubbled into water. Suggest an equation for this reaction.

pH of solution : Between 1.5 - 2.5

Equation: $TeCl_4 + 2H_2O \rightarrow TeO_2 + 4HCl$

[3]

[Total : 8]

3 The following shows a series of reactions that compound **Z** can undergo.



(a) Draw the structures of compounds **A** to **F** in the boxes provided below.





[6]

(b) When treated with NaOH in ethanol, compound Z produces a mixture of isomers, G and H.

Draw the full structural formulae of **G** and **H**.



(c) State the reagents and conditions required in Steps I and II.

Step I

Reagents: I₂ in NaOH (aq) Conditions: heat Step II Reagents: ... Steam, concentrated H₃PO₄..... Conditions:300°C, 65 atm ...

[2]

[Total: 10]

4 Sulphur compounds occur naturally in petrol. The presence of such compounds gives rise to the emission of toxic oxides of sulphur from car exhausts. One such pollutant produced from car emissions is the gas sulphur dioxide, SO₂. Sulphur dioxide reacts with water and oxygen in the atmosphere to produce 'acid rain', a dilute solution of sulphuric acid, resulting in further damage to urban architecture.

One process used to remove sulphur compounds from petroleum and diesel is called "hydroprocessing". This process uses catalysts consisting of metals deposited as thin layers on porous aluminium supports.

Hydroprocessing converts the sulphur compounds in the fuel to the gas hydrogen sulphide, H_2S . Some of the hydrogen sulphide produced is oxidised to sulphur dioxide and water as shown in equation **1**.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$
 (1)

The sulphur dioxide produced is then reacted with the remaining hydrogen sulphide to produce solid sulphur as follows.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(l)$$
 (2)

Sulphur dioxide also dissolves in water to form sulphurous acid, H_2SO_3 . Unlike sulphuric acid, sulphurous acid is a weak acid and dissociates partially to form hydrogen sulphites and protons, as shown in equation **3**.

$$H_2SO_3(aq) \implies H^+(aq) + HSO_3^-(aq)$$
 (3)

While sulphuric acid in the environment is harmful, a mixture of hydrogensulphites and sulphurous acid is widely used in the food industry as an "acidity regulator".

(a) (i) Draw the dot-and-cross diagram as well as the displayed formula showing the shape of a molecule of sulphurous acid.



(ii) Using the Valence Shell Electron Pair Repulsion Theory, explain the shape around the sulphur atom in a molecule of sulphurous acid.

To minimise repulsion, the 4 electron pairs are directed to the corners of a tetrahedron. Bond pair – lone pair repulsion > bond pair – bond pair repulsion. Shape is trigonal pyramidal.

[4]

(b) A student titrated a 25.0 cm³ solution of 0.0125 mol dm⁻³ potassium hydroxide with 0.010 mol dm⁻³ sulphurous acid solution. The reaction occurring in this titration is

$$KOH(aq) + H_2SO_3(aq) \rightarrow KHSO_3(aq) + H_2O(l)$$

A total of 40.0 cm^3 of acid was added. The following graph shows the variation of pH against the volume of acid added.



(i) Determine the pH at point **a** on the curve.

pOH = -lg (0.0125) = 1.90

pH = 14 – 1.90 = <u>12.1</u>

(ii) Calculate the equivalence volume of H_2SO_3 required in this titration.

Volume of acid needed = $\frac{3.125 \times 10^{-4}}{0.010} = \frac{31.3 \text{ cm}^3}{0.010}$

(iii) The student is provided with some acid-base indicators.

Indicator	pH range at which colour change occurs
Methyl violet	0.5 – 1.5
Chlorophenol red	4.8 - 6.4
Alizarin Yellow	10.1 – 12.0

His classmate suggested that they could use chlorophenol red to detect the end-point of this titration.

Explain whether chlorophenol red is a suitable indicator for this titration.

No. Since this is a strong base – weak acid titration, the pH at equivalence point is basic. The pH transition range of chlorophenol red does not lie within the range of rapid pH change over the equivalence point.

(iv) A mixture of sulphurous acid and hydrogen sulphite based on equation3 works as an "acidity regulator" in foodstuff.

$$H_2SO_3(aq) \longrightarrow H^+(aq) + HSO_3^-(aq)$$
 (3)

In this titration, such a mixture is produced.

Mark with a cross (\mathbf{x}) on the titration curve where you would expect this mixture to be formed.



(v) Explain, with the aid of equations, how the mixture in c(iv) as an "acidity regulator".

When a small amount of acid, H^+ is added: HSO₃⁻ (aq) + H^+ (aq) $\rightarrow H_2SO_3$ (aq) Hence [H⁺] remain unchanged and pH remains fairly constant.

When a small amount of base, OH^- is added: $H_2SO_3 (aq) + OH^- (aq) \rightarrow HSO_3^- (aq) + H_2O (l)$ Hence [OH⁻] remain unchanged and pH remains fairly constant.

(c) During hydroprocessing, the reaction in equation (1) is carried out in the presence of metal catalysts.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$
 (1)

[7]

On the grid below, sketch and label a Maxwell-Boltzmann distribution curve to show how the presence of a catalyst increases the rate of reaction.



(d) (i) The enthalpy change for the reaction in equation (1) is -486 kJ mol^{-1} .

With the aid of the *Data Booklet*, calculate an average value for the S=O bond in SO_2 . Give youhanswer to three significant figures.

-486 = 4(347) + 3(496) - 4BE(S=O) - 4(460)

BE(S=O) = <u>+381 kJ mol⁻¹</u>

(ii) The enthalpy change given in **d**(i) is not identical to the standard enthalpy change for the same reaction.

Suggest one reason for the difference in values.

There is a difference in the state of water between the two conditions. If the reaction is carried out under standard condition, water is a liquid. The given value is obtained when water reacts as steam.

[2]

[Total: 15]

Section B

- **5(a) (i)** Rate equation relates the rate of reaction to the concentration of reactants raised to the appropriate power.
 - (ii) By measuring the time taken for the disappearance of the reddishbrown colour of bromine.
 - (iii) Orders of reaction with
 - 1 Propanone

Comparing experiments 3 and 4, when the [propanone] is increased by 4 times, the rate of reaction increased by 4 times.

Order of reaction with respect to propanone is **1**.

2 Bromine

Comparing experiments 4 and 5, when the $[Br_2]$ is doubled, , the rate of reaction remained constant.

Order of reaction with respect to Br₂ is **0**

3 H⁺

Comparing experiments 1 and 4, when the $[H^+]$ is doubled, the rate of reaction approximately doubled.

Order of reaction with respect to H⁺ is **1**

- (iv) Catalyst. The rate of reaction increases in the presence of high $[H^+]$ or at low pH.
- (v) Rate = k [propanone] $[H^+]$

 $2.94 \times 10^{-6} = k (0.400) (0.202)$

[8]

- (b) (i) Chlorine, uv light.
 - (ii) Substitution
 - (iii) The C-X bond strength of C-Cl (340 kJ mol⁻¹) > C-Br (280 kJ mol⁻¹). The reactivity of R-Cl < R-Br. Hence, rate of formation of AgX : AgCl < AgBr.

(ii)

(i)



Step II : $K_2Cr_2O_7$ in dilute H_2SO_4 , heat under distillation

Step III: HCN with trace amounts of NaOH, cold

[8]

[Total: 20]

6(a) Standard enthalpy change of formation (ΔH_f^{θ}) of MTBE is the energy change when one mole of MTBE is formed from its elements at 298K at 1 atm.

5 C (s) + 6 H₂ (g) + ½ O₂ (g)
$$\xrightarrow{\Delta H^{\theta}_{f(C_{5}H_{12}O)}} C_{5}H_{12}O(I)$$

[2]

(b) Quantity of heat absorbed by water = $500 \times 4.18 \times (95.5 - 28.0)$

Quantity of heat released by combustion of MTBE = $\frac{141075}{70}$ x 100 = 201535.71 J

No. of mol of MTBE used =
$$=\frac{5.5}{88} = 0.0625$$

$$\Delta H_{c} (MTBE) = -\frac{201535.71}{0.0625}$$

= $-\frac{3.22 \times 10^{6} \text{ J mol}^{-1} \text{ OR}_{-} - 3.22 \times 10^{3} \text{ kJ mol}^{-1}}{3.22 \times 10^{6} \text{ J mol}^{-1} \text{ OR}_{-} - 3.22 \times 10^{3} \text{ kJ mol}^{-1}}$

[4]

[1]

(c) ΔH_{f} (MTBE) = <u>-461kJ mol⁻¹</u>

- (d) (i) Functional group isomerism
 - (ii) K undergoes acid-metal displacement with sodium
 → K is an alcohol

K undergoes oxidation with warm alkaline iodine \rightarrow K has structure CH₃-CH(OH)

L undergoes oxidation with acidified KMnO₄ to produce N \rightarrow N is a carbonyl compound.

Since N undergoes condensation with 2,4-DNPH, but does not undergo oxidation with Tollen's reagent,

➔ N is a ketone





L





Ν

(iii) Any 2 isomers as follows:

CH₃CH₂CH₂CH₂CH₂CH₂OH CH₃CH₂CH₂CH(OH)CH₃

CH₃CH₂CH(OH)CH₂CH₃







 $\begin{array}{c} \mathsf{CH}_3 & -\!\!\!-\!\!\!-\!\!\mathsf{CH}_2 -\!\!\!-\!\!\mathsf{CH}_2 -\!\!\!-\!\!\mathsf{CH}_2 -\!\!\!-\!\!\mathsf{OH} \\ & \mid \\ & \mathsf{CH}_3 \end{array}$

(e) (i) $X + \frac{3}{2}O_2 \rightarrow XO_3$ $X \equiv XO_3$ $\frac{35.55}{x} = \frac{57.15}{16(3) + x}$ x = 79

Thus, X is Se.

- (ii) pH = accept any value between 1 to 2
- (iii) SeO₃ + 2NaOH \rightarrow Na₂SeO₄ + H₂O
- (iv) Oxide of Y has a higher boiling point than X. Oxide of Y is an amphoteric, giant ionic oxide. A higher amount of energy is required to overcome the stronger electrostatic forces of attraction between oppositely charged ions in oxide of Y, compared to the weaker intermolecular van der Waals forces of attraction in XO₃.

[3]

[Total: 20]

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[7]

7(a) (i) Cis-trans isomerism in butenedioic acid arises when there is restricted rotation about the C=C.

(ii)



Cis-butenedioic acid is capable of intramolecular hydrogen bonding Hence the cis-isomer possesses less extensive intermolecular hydrogen bonding.

More energy is required to overcome the more extensive hydrogen bonds between the trans-butenedioic acid molecules.

(iii) A from B

Add Br₂ in CCl₄ into each compound separately at r.t.p

For A: Reddish brown Br₂ decolourizes.

A from C

Add Na_2CO_3 (aq) into each compound separately at r.t.p. For **A**: Effervescence of CO_2 gas which forms white ppt when gas is bubbled into $Ca(OH)_2$.

[9]

(b) (i) Concentrated H_2SO_4 , $180^{\circ}C$ / heat.

- (ii) Dynamic equilibrium is a state achieved in a reversible reaction when the rate of forward reaction = rate of backward reaction. The substances are still reacting together although the concentration of the reactants and products remain constant. 16
- (iii) By Le Chatelier's Principle, the equilibrium position will shift right Concentration of CH₃OCOCH=CHCOOCH₃ and H₂O increases and butenedioic acid and methanol.

(iv)

Let the volume of the vessel be \mathbf{V} dm³.

$$K_{c} = \frac{[CH_{3}OCOCH=CHCOOCH_{3}][H_{2}O]^{2}}{[HOOCCH=CHCOOH][CH_{3}OH]^{2}}$$
$$= \frac{\left[\frac{0.38}{V}\right]\left[\frac{0.76}{V}\right]^{2}}{\left[\frac{0.62}{V}\right]\left[\frac{0.24}{V}\right]^{2}}$$
$$= \frac{6.15 \text{ (no units)}}$$

(c) (i) No. of moles of $IO_3^- = \frac{18.85}{1000} \times 0.200$ No. of moles of SO_3^{2-} reacted $= \frac{31.40}{1000} \times 0.300$ Hence <u>2.50 moles</u> of SO_3^- react with 1 mole of IO_3^{2-} .

(ii)
$$2IO_3^{-} + 12H^{+} + 10e \rightarrow I_2 + 6H_2O$$

 \therefore change in oxidation number of sulphur = +2

- (iii) Product is Na_2SO_4 17
- (iv) Overall: $5SO_3^{2-} + 2IO_3^{-} + 2H^+ \longrightarrow 5SO_4^{2-} + I_2 + H_2O$

[4] [Total: 20]

[7]