ST. ANDREW'S JUNIOR COLLEGE

Higher 1

PRELIMINARY EXAMINATION 2009

Name _____ **Class** _____

CHEMISTRY **8872/ 02**

PAPER 2 **15 September 2009**

Candidates answer Section **A** on the Question Paper. **2 hours**

Additional Materials: Writing paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Section **A**
Answer **all** questions.
Section **B**
Answer any **two** questions on separate writing paper.

A Data Booklet is provided.

At the end of the exam, 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	**/ 40**
B9	
B10	
B11	
Total	**/ 80**

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Section A
Answer all questions.

1 The use of the *Data Booklet* is relevant to this question.

(a) **(i)** Define *relative atomic mass*. [1]

(ii) Gallium is in Group III and is found below aluminium in the Periodic Table. Gallium has 2 isotopes. One of the isotopes, ^{69}Ga has a relative abundance of 64.0%. Calculate the relative isotopic mass of the other gallium isotope, to the nearest whole number.

[1]

(b) Acidified potassium manganate(VII) oxidises ethanedioic acid, $H_2C_2O_4$ to form carbon dioxide gas according to the following ionic equation:

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e$$

1.07 g of impure sample of $H_2C_2O_4$ was made up to 250 cm^3 of solution. 25.0 cm^3 of this solution reacted completely with 25.60 cm^3 of 0.02 mol dm^{-3} acidified $KMnO_4$ solution.

(i) Write an overall ionic equation for the reaction between $H_2C_2O_4$ and $KMnO_4$. [1]

1 (b) (ii) Hence, determine the percentage purity of the ethanedioic acid. [2]

[Total: 5]

2 The first 8 ionisation energies of an element, **W**, is shown in the table below.

Electron	1	2	3	4	5	6	7	8
Ionisation energy/ kJ mol^{-1}	572	890	1250	2249	4973	6152	9945	11012

(a) Deduce which group element **W** belongs to. Explain your answer. [2]

(b) (i) Suggest the formula of the oxide of **W** and predict the type of bonding present in the oxide of **W**.

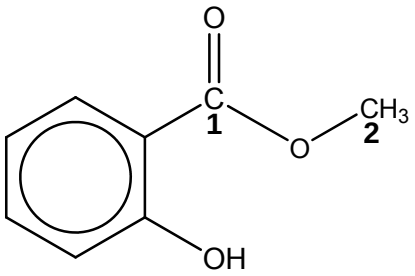
[1]

Formula: _____ **Type of bonding:** _____

(ii) Suggest a pH value for the resulting solution obtained when the oxide of **W** is dissolved in water. [1]

[Total: 4]

3 Oil of wintergreen is a common active ingredient in muscle rubs. It has the following structure.



(a) State the type of hybridisation of the carbon atoms, **C1** and **C2**. [2]

C1: _____ **C2:_____**

(b) State the shape and the bond angle around carbons **C1** and **C2**. [2]

Carbon	Shape	Bond angle
C1		
C2		

(c) Sketch the shape of one hybrid orbital of the carbon **C1**. [1]

[Total: 5]

4 2-methylpropene is a gas used in the manufacture of poly-isobutylene.

(a) **(i)** Define *standard enthalpy change of formation*, with reference to 2-methylpropene.

_____

_____

(ii) Write the equation which represents the standard enthalpy change of formation of 2-methylpropene, showing the structural formula of 2-methylpropene.

[2]

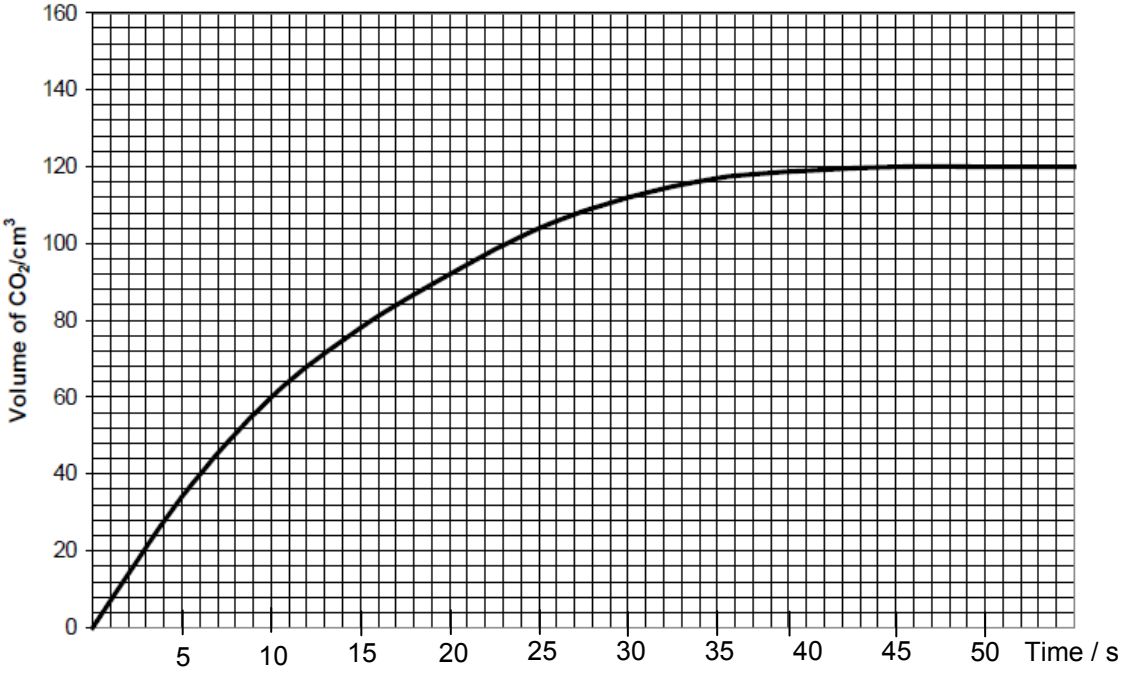
(b) Use the following standard enthalpy changes of combustion, $\Delta H_c°$, to calculate the enthalpy change of formation of 2-methylpropene:

Compound	$\Delta H_c°$/ kJ mol^{-1}
Carbon	-393
Hydrogen	-286
2-methylpropene	-2520

[2]

[Total: 4]

5 An excess of small pieces of calcium carbonate was allowed to react with 100 cm^3 of 0.1 mol dm^{-3} hydrochloric acid. The volume of carbon dioxide formed during the experiment is shown on the graph below.



(a) Determine the order of reaction with respect to hydrochloric acid.

(b) On the axes above, sketch and label the curves for the following experiments that were carried out at the same temperature as the original experiment:

(i) 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid with an excess of small pieces of calcium carbonate.

(ii) 120 cm^3 of 0.1 mol dm^{-3} hydrochloric acid with an excess of small pieces calcium carbonate.

[4]

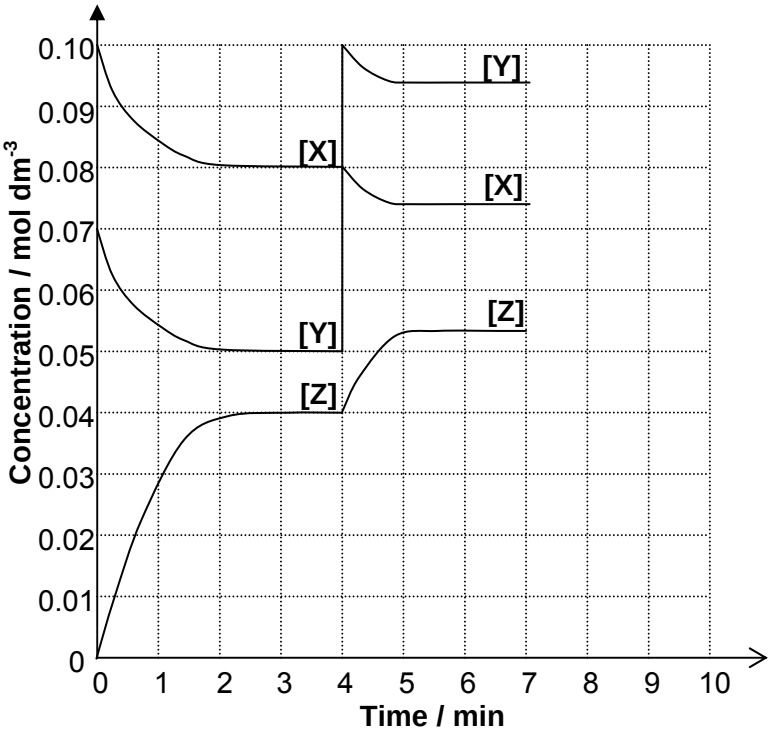
[Total:4]

[Turn Over

6 **X** and **Y** were mixed in a closed vessel and the whole system was allowed to reach equilibrium, as shown in the following equation:

$$\mathbf{X}\,(g) + \mathbf{Y}\,(g) \rightleftharpoons 2\mathbf{Z}\,(g)$$

The concentrations of all gases were measured at one-minute interval for 4 minutes, and then one of the operating conditions were altered. The effects were shown graphically below.



(a) Write an expression for the equilibrium constant, K_C, and hence calculate its value at the 3rd minute.

(b) Suggest the change that could have occurred at the 4th minute.

_____

(c) Sketch on the graph above the changes in the concentrations of **X**, **Y** and **Z** when the pressure of the system is halved at the 7th minute.

[4]

[Total: 4]

7 **(a)** Define the term *buffer solution*. [2]

(b) Given the following reaction:

$$H_2O + H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H_3O^+$$

Explain, with the aid of suitable equations, how the above system acts as a buffer upon the addition of:

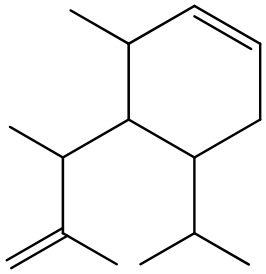
(i) H^+ ions and

(ii) OH^- ions.

[2]

[Total: 4]

8 **(a)** In the spaces provided below, draw the organic product formed when compound **A** is reacted with each of the following reagents.



Compound **A**

	Reagent	**Organic product formed**
(i)	Heat with ammonia dissolved in ethanol in a sealed tube	
(ii)	Acidified potassium dichromate(VI) (aq) with distillation	
(iii)	Hot aqueous sulfuric acid	

[3]

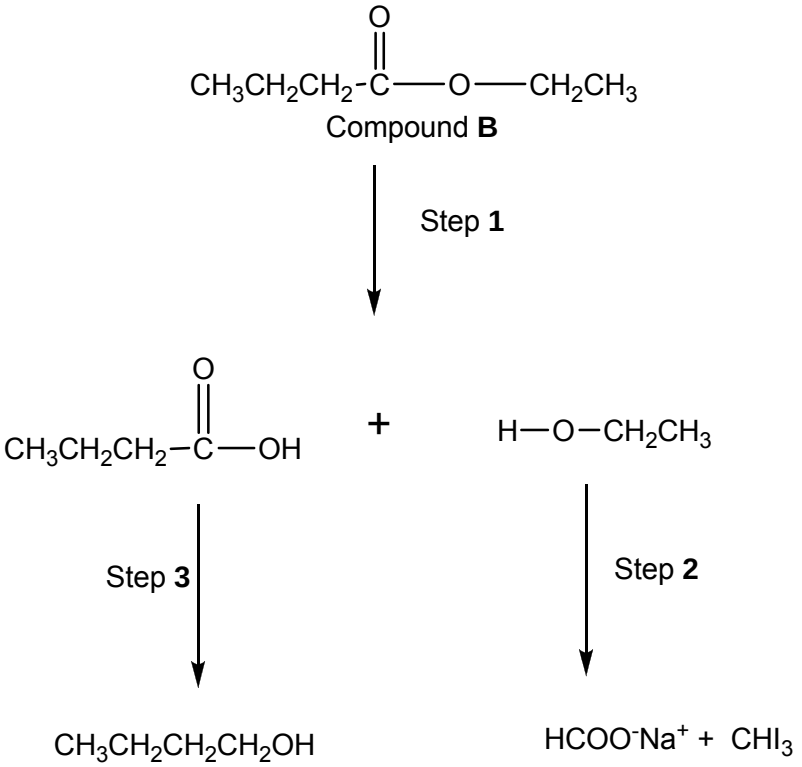
8 **(b)** If the chloro-functional group is replaced with a bromo-functional group in compound **A**, state and explain how the rate of the reaction with potassium hydroxide changes.

[2]

(c) Which is the stronger acid, butan-2-ol or butanoic acid? Justify your answer.

[2]

8 (d) Large molecules are sometimes not particularly useful, and often broken down into simpler and more useful substances. Below is a series of steps used to break down compound **B**. Based on the products formed, state the reagents and conditions to be used.



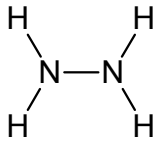
Step	Reagents and conditions
1	
2	
3	

[3]

[Total:10]

Section B
Answer 2 out of 3 questions.

9 Liquid hydrazine is a commonly used rocket fuel and has the following structure:



Hydrazine burns when ignited in air to give nitrogen gas, water vapour and large amounts of energy.

(a) **(i)** Write a balanced equation, with state symbols, which represents the standard enthalpy change of combustion of liquid hydrazine.

(ii) With the use of relevant bond energies from the *Data Booklet*, calculate the standard enthalpy change of combustion of liquid hydrazine.

(iii) Draw a labeled energy profile diagram for the reaction you have written in **(a)(i)**. Label the activation energy and the enthalpy change of combustion of hydrazine in your sketch.

(iv) It is estimated that 10^6 J of energy is needed for a rocket to be launched into space. Using your answer in **(ii)**, calculate the mass of hydrazine required, assuming that the process was 80% efficient?

[9]

9 **(b)** Lactic acid is a weak acid found in soured milk. It has the structural formula $CH_3CH(OH)COOH$.

(i) Write an equation to represent the dissociation of lactic acid. Hence write an expression for the acid dissociation constant, K_a, of lactic acid.

A 10.0 cm^3 sample of lactic acid was titrated against 24.30 cm^3 of 0.025 mol dm^{-3} aqueous sodium hydroxide for complete neutralisation.

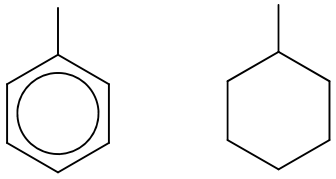
(ii) Write a balanced equation for the reaction between lactic acid and sodium hydroxide. Hence, determine the concentration of lactic acid in the sample.

(iii) Suggest a suitable indicator for the titration between lactic acid and sodium hydroxide.

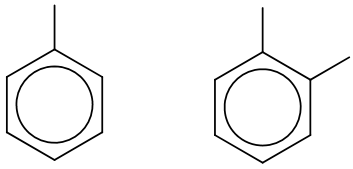
[4]

(c) Suggest chemical tests by which the compounds in the following pairs can be distinguished from each other. You should state the reagents and conditions for each test, and describe how each compound in the pair behaves.

(i)



(ii)



(iii) $CH_3CH_2COOCH(CH_3)_2$ and $CH_3OCOCH(CH_3)_2$

[7]

[Total : 20]

10 (a) Nitrogen monoxide, NO, is a nitrogen-containing compound which can react with hydrogen as follows:

$$2NO\ (g)\ +\ 2H_2\ (g) \longrightarrow N_2\ (g)\ +\ 2H_2O\ (g)$$

An experiment was carried out at 500°C to investigate the rate of this reaction. The results of the experiment are shown below.

Experiment number	Initial concentration of NO / mol dm^{-3}	Initial concentration of H_2 / mol dm^{-3}	Initial rate of reaction / mol dm^{-3} s^{-1}
1	0.0100	0.0200	1.45×10^{-9}
2	0.0300	0.0200	1.30×10^{-8}
3	0.0200	0.0400	1.16×10^{-8}

(i) Use the data above to determine the order of reaction with respect to nitrogen monoxide and hydrogen.

(ii) Hence write a rate equation for the reaction.

(iii) Determine a value of rate constant, *k*, stating its units.

(iv) A fourth experiment was carried at the same temperature with the following initial concentrations:

Gas	*Initial concentration / mol dm^{-3}*
NO	0.0120
H_2	0.0150

Calculate the initial rate of reaction for this experiment.

(v) State and explain how the rate of the reaction would be affected upon addition of a catalyst.

[8]

[Turn Over

10 **(b)** Ammonia is another nitrogen-containing compound which can be synthesized from nitrogen in the Haber process.

(i) Write an equation for the Haber process.

(ii) Nitrogen and hydrogen were mixed in a 2 dm^3 closed vessel and the amount of the three gases at equilibrium are

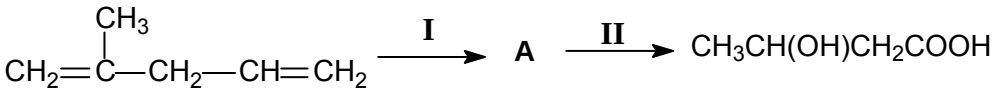
Gas	*Number of moles*
Nitrogen	2.80
Hydrogen	2.56
Ammonia	0.284

Write an expression for the equilibrium constant, K_C, for the Haber process. Calculate K_C from the data above, giving its units.

(iii) State and explain how the yield of ammonia would be affected if there was an increase in temperature.

[6]

(c) 2-hydroxybutanoic acid can be synthesized by a 2-step reaction sequence shown below:



Suggest reagents and conditions used for each step in this synthesis and give the structural formula of compound **A**.

[3]

(d) Give the structural formula(e) of the organic product(s) formed when 2-hydroxybutanoic acid reacts with:

(i) cold sodium hydroxide;

(ii) warm aqueous alkaline iodine.

[3]

[Total: 20]

11 **(a)** **(i)** Draw dot-and-cross diagrams to illustrate the bonding within aluminum chloride, phosphorous trichloride and sodium chloride, stating the bond angle within each molecule, if any.

[4]

(ii) Describe the reaction of each chloride in **(i)** with water. Write relevant equations for the reactions and suggest the pH values of the resulting solutions.

[6]

(iii) Explain why phosphorous trichloride is soluble in chloromethane but aluminium chloride is insoluble in chloromethane.

[3]

(b) Compound **A** has molecular formula of $C_9H_{15}O_2Cl$. 1 mole of compound **A** decolourises 1 mole of aqueous bromine. It forms 2 products, compounds **B** and **C**, upon reaction with acidified potassium manganate(VII) in a ratio of 2 : 1.

Compound **B**, with empirical formula CH_2O, reacts with excess sodium carbonate to form a colourless gas, which forms a white precipitate with limewater.

Compound **C**, with molecular formula $C_5H_9O_3Cl$, reacts with phosphorous trichloride to form compound **D**, with molecular formula $C_5H_7OCl_3$.

Compound **C** can also be formed via the reaction of aqueous chlorine solution with $(CH_3)_2C{=}CHCOOH$.

Suggest the structural formula of compounds **A** – **D**, explaining the chemistry involved.

[7]

[Total: 20]

End of Paper 2