NATIONAL JUNIOR COLLEGE

SH2 PRELIMINARY EXAMINATION

Higher 1

H

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY 8872/02

Paper 2 Structured Questions

Friday 28 Aug 2015

Answer Section A on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name 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**
Answers **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.

For Examiner's Use	
A1	
A2	
A3	
A4	
B5	
B6	
B7	
Total	

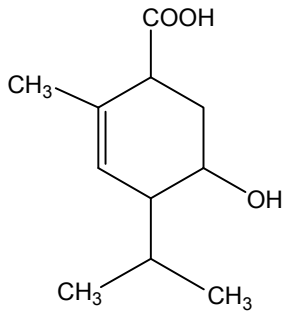
This document consists of **13** printed pages and **0** blank page.

Section A

For Examiner's use

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

1 Menthol is an important compound extracted from the peppermint plant. It has important uses in flavouring. The structure of a derivative of menthol is shown below.



(a) Name **two** other functional groups, other than the carboxylic acid, that are present in the above structure.

…… [1]

(b) State the type of reaction that occurs, if any, and draw the structure of the organic products, when the above compound is added to the following reagents.

	Reagent and conditions	**Structure of organic product(s), if any**
(i)	Acidified $KMnO_4$, heat	
	Type of reaction: ……	
(ii)	H_2, Pt	
	Type of reaction: ……	
(iii)	CH_3CO_2H, conc. H_2SO_4, reflux	
	Type of reaction: ……	

[6]

[Total: 7]

2

For Examiner's use

(a) Sodium, magnesium and phosphorus are all elements in Period 3 of the Periodic Table. What will you see when these elements are burned separately in excess oxygen? Give an equation, with state symbols, for each reaction. [4]

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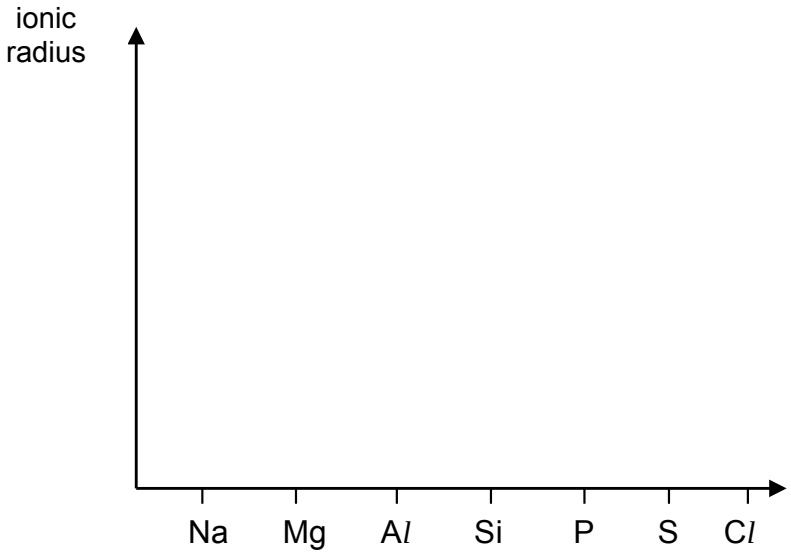
(b) On the axes below, sketch a graph to illustrate the variation of ionic radius of the elements sodium to chlorine.



Explain the shape of your sketch.

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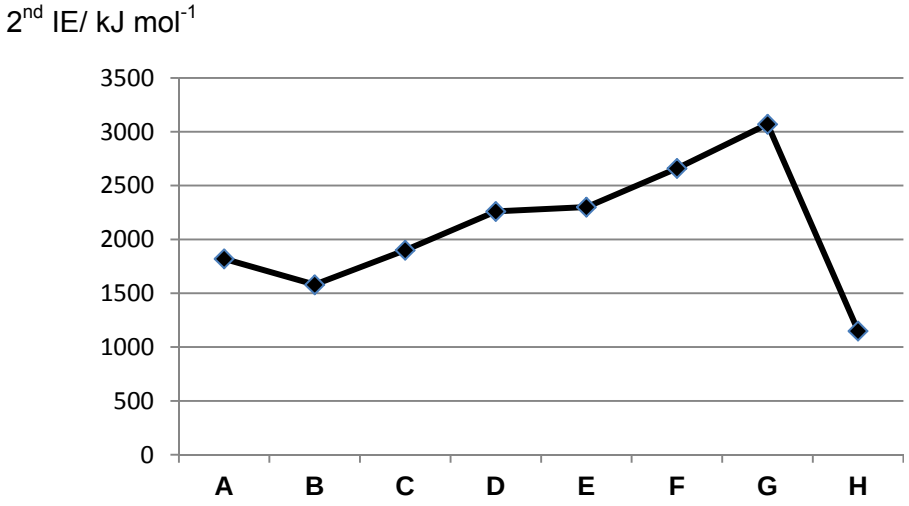
…… [3]

(c) The graph below shows the second ionisation energies of eight consecutive elements **A** to **H** in Period 3 and 4 of the Periodic Table.

For Examiner's use



(i) Deduce which group does element **F** belongs to? Explain your answer.

Group no: ……

Explanation: ……

……

……

……

……..

(ii) Give the formula of the compound formed between elements **A** and **E**.

……

[4]

[Total: 11]

3 The table below gives some information of various organic compounds.

For Examiner's use

Compound	Formula	M_r	K_a / mol dm^{-3}	Boiling point / °C
Propanoic acid	CH_3CH_2COOH	74	1.3×10^{-5}	141
2-chloropropanoic acid	$CH_3CHClCOOH$	108.5	1.5×10^{-3}	172
Methanoic acid	HCOOH	46	1.8×10^{-4}	101
Propanol	$CH_3CH_2CH_2OH$	60	1.0×10^{-18}	97
Methyl ethanoate	CH_3OCOCH_3	74	-	57

(a) Explain the difference in the acid strength of propanoic acid, 2-chloropropanoic acid and methanoic acid.

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…… [4]

(b) Given that propanoic acid dimerises in non-polar solvents, draw the structure of this dimer. [2]

(c) Explain the observed trend for the boiling points of propanol, propanoic acid and methyl ethanoate.

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…… [3]

[Total: 9]

4 Our main source of energy is the combustion of fossil fuels, namely coal, oil and natural gas. They give out large amounts of energy when burned, but there are disadvantages to their use.

For Examiner's use

Natural gas is a combustible mixture of hydrocarbon gases, mainly methane, ethane, propane and butane. Contaminants such as nitrogen and hydrogen sulfide are also present in small amounts. The chart below outlines the typical makeup of natural gas before it is refined.

Typical Composition of Natural Gas (by volume)

Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulfide	H_2S	0-5%
Rare gases	Ar, He, Ne, Xe	trace

Natural gas is usually considered sour if the hydrogen sulfide content exceeds 5.7 milligrams of H_2S per cubic meter of natural gas. The process for removing hydrogen sulfide from sour gas is commonly referred to as 'sweetening' the gas.

In the process of sweetening sour natural gas, the sour gas is run through a tower, which contains an amine solution. The amine solution will absorb hydrogen sulfide from natural gas as it passes through. The effluent gas is virtually free of hydrogen sulfide, and thus loses its sour gas status.

(a) State one disadvantage of the use of fossil fuels as our main source of energy.

……

…… [1]

(b) Determine the maximum percentage by volume of H_2S that can be present in a sample of natural gas in order not for it to be considered sour.
Assume room conditions in your calculations. [2]

(c) During the sweetening of sour natural gas, H_2S acts as a *Bronsted-Lowry* acid. Using RNH_2 to represent the amine, write a balanced equation to show how H_2S reacts with RNH_2.

For Examiner's use

……..[1]

(d) **(i)** Other than using amine solution to remove H_2S from natural gas, another method that could be adopted is by reacting H_2S with methane, as represented by the equation below:

$$CH_4\,(g) + 2H_2S\,(g) \overset{\Delta H_1}{\rightleftharpoons} CS_2\,(g) + 4H_2\,(g)$$

Using the data given below, calculate ΔH_1.

$\Delta H_f(CH_4) = -74.9$ kJ mol^{-1}
$\Delta H_f(H_2S) = -20.6$ kJ mol^{-1}
$\Delta H_f(CS_2) = +116.7$ kJ mol^{-1}

(ii) ΔH_1 can also be calculated using bond energies values. Using appropriate values from the *Data Booklet* as well as the values given below, calculate an alternative value for ΔH_1

Bond energy of C=S = 573 kJ mol^{-1}
Bond energy of H–S = 368 kJ mol^{-1}

(iii) Hence, suggest a reason for the discrepancy between the values in **(i)** and **(ii)**.

……

……...

[5]

(e) Besides methane, many other organic compounds are also used as an energy source, one of which is the use of methanol in spirit lamps.
The standard enthalpy change of combustion of methanol is -715 kJ mol^{-1}.

For Examiner's use

(i) Write a thermochemical equation to represent the *standard enthalpy change of combustion* of methanol.

……

(ii) A student carried out an experiment to find out the minimum mass of methanol required to bring 100 g of water to boil from room temperature, i.e. 25 °C. Assume that the process is 80% efficient and that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}.
Calculate the minimum mass of methanol required.

[4]

[Total: 13]

Section B

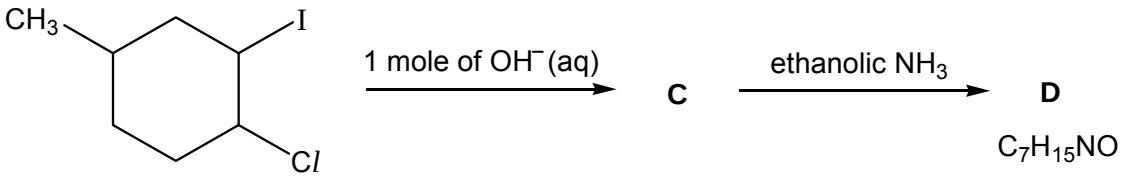
Answer **two** questions from this section on separate answer paper.

5 (a) Describe and explain the relative reactivities of chloropropane and iodopropane with respect to hydrolysis.

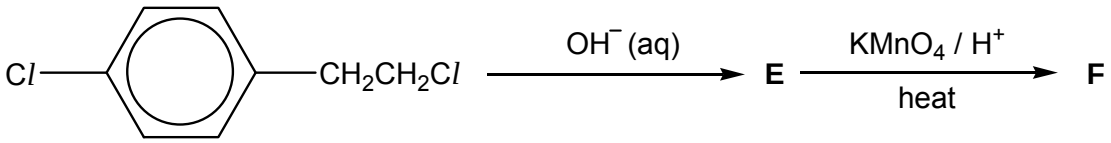
[2]

(b) The different reactivities of organic halogeno compounds can be exploited in successive reactions of dihalogeno compounds.
Predict the outcomes of the following transformations, drawing the structures of the intermediates **C** and **E** and the products **D** and **F**.

(I)



(II)



[4]

(c) Samples of 2-chloropropane were dissolved in dilute aqueous ethanol and reacted with hot sodium hydroxide solution. Two separate experiments with different concentrations of 2-chloropropane, were carried out to study the kinetics of the reaction.

The following results were obtained.

	Experiment 1 **[2-chloropropane] = 0.05 mol dm^{-3}**	**Experiment 2** **[2-chloropropane] = 0.10 mol dm^{-3}**
Time / min	**[NaOH] / mol dm^{-3}**	**[NaOH] / mol dm^{-3}**
0	0.0050	0.0050
15	0.0045	0.0040
30	0.0040	0.0032
45	0.0036	0.0026
60	0.0032	0.0021
75	0.0029	0.0017
90	0.0026	0.0014

(i) The results of **Experiment 1** has been plotted on the **INSERT** provided. On the same **INSERT**, plot a graph for **Experiment 2**.

(ii) Use your graph in **(i)** to deduce the order of reaction with respect to 2–chloropropane and sodium hydroxide solution. Show your working clearly.

(iii) Use your answer in **(ii)** to write a rate equation for the reaction.

(iv) The numerical value of the rate of reaction was measured as 0.048 when [NaOH] = 0.20 mol dm^{-3}, [2-chloropropane] = 0.10 mol dm^{-3}. Determine the rate constant for this reaction and state its units.

(v) Sketch a Maxwell-Boltzmann curve for the reactants and use it to explain the effect of a catalyst on the rate of reaction in **Experiment 2**.

(vi) In the reaction described in **(c)**, suggest why 2-chloropropane is dissolved in dilute aqueous ethanol before it is reacted with hot sodium hydroxide solution.

[14]

[Total:20]

6 (a) The acid-base behaviour of aluminium oxide, Al_2O_3, shows similarities to that of magnesium oxide, MgO on the one hand, and phosphorus(V) oxide, P_4O_{10}, on the other.
Describe what these similarities are, and explain why aluminium oxide occupies this in-between position.
Write equations for all the reactions you choose to illustrate your answer.

[4]

(b) Phosphorus is able to form more than one chloride, PCl_3 and PCl_5.

(i) Draw the lewis structures of PCl_3 and PCl_5, and state their shapes.

(ii) Predict the solubility of PCl_5 in CCl_4. [4]

(c) PCl_5 can be produced by reacting PCl_3 with chlorine gas.

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

The process is carried out in a ***V*** dm^3 reaction vessel. 1.80 mol of PCl_3 and 1.50 mol of Cl_2 are allowed to reach equilibrium at 180 °C.
0.60 mol of PCl_5 is found to be present in the equilibrium mixture.

(i) Given that the value of equilibrium constant, K_c for the reaction is 0.311, determine ***V***.

(ii) The percentage yield of PCl_5 at different temperatures is shown below.

Temperature	Percentage yield
200°C	70%
300°C	65%
400°C	50%

With reference to the data above, deduce whether the production of PCl_5 is an endothermic or exothermic reaction. Explain your answer.

(iii) By making use of your answer in **(ii),** draw a well-labelled reaction profile diagram for the forward reaction.

(iv) State and explain how the position of equilibrium and the equilibrium constant would change when the reaction is carried out in a bigger reaction vessel.

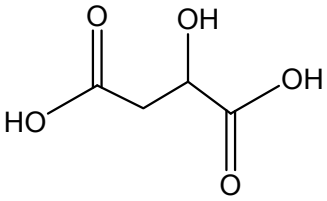
[9]

(d) One of the uses of PCl_5 includes the chlorinating of organic compounds. Propose a synthetic pathway (making use of PCl_5 in one of your steps) for the conversion of butanone to 2-chlorobutane.

[3]

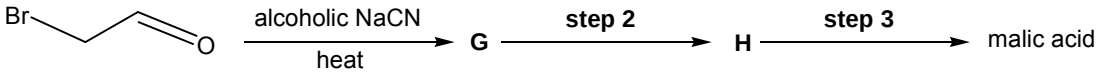
[Total: 20]

7 Malic acid can be found in green apples and grapes. It is often added to beverages and confectionery to confer a sour taste.



Malic acid

(a) Suggest the reagents and conditions you would use in a three-step synthesis of malic acid from bromoethanal, identifying the intermediates **G** and **H**.

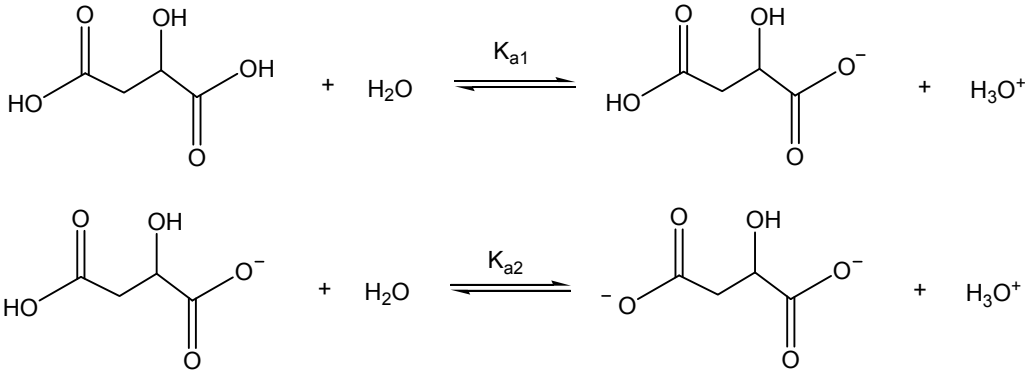


[4]

(b) Malic acid is classified as a *Bronsted-Lowry* acid. It is a dibasic acid.

(i) Explain what is meant by a *dibasic* acid.

(ii) Malic acid dissociates in water according to the equations shown below:

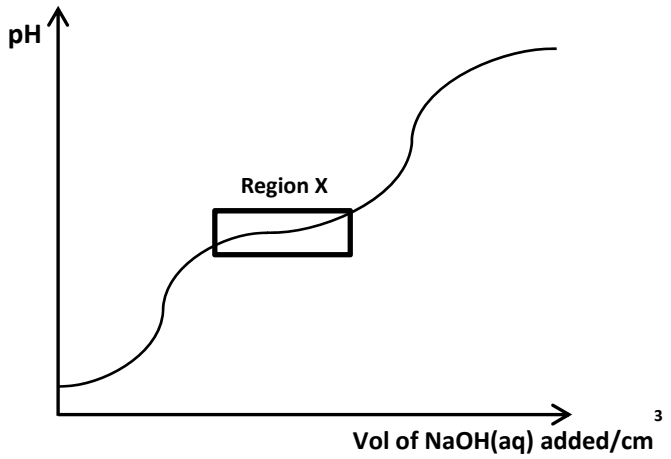


(I) Write the Ka_1 expression.

(II) Given that the Ka_1 value of malic acid is 10^{-3}, calculate the pH of a 0.10 mol dm^{-3} solution of malic acid. Hence, deduce if malic acid is a strong or a weak acid.

(iii) 25.0 cm^3 of a 0.10 mol dm^{-3} solution of malic acid was titrated with 0.20 mol dm^{-3} of aqueous sodium hydroxide. Calculate the total volume of aqueous sodium hydroxide required for complete neutralisation.

(iv)



The above pH curve was obtained in the titration procedure as described in **(iii)**. With the aid of an equation, explain why the pH of the mixture remained fairly constant at region **X** when a small amount of NaOH(aq) is added.

(v) Phenolphthalein was used as the indicator in the titration procedure as described in **(iii).** Explain why is phenolphthalein a suitable indicator and suggest the colour that will be observed at the end of the titration.

[9]

(c) Malic acid can be dehydrated to give a mixture of two geometric isomers of alkenedioic acids with the molecular formula $C_4H_4O_4$.

(i) Suggest reagents and conditions for the dehydration of malic acid.

(ii) Draw the structural formulae of the two geometric isomers, and explain why geometric isomerism arises.

(iii) Explain why the *trans*-isomer has a higher boiling point than the *cis*-isomer.

[7]

[Total:20]