NATIONAL JUNIOR COLLEGE

SH2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY
Paper 2 Structured

Answer on the Question Paper.

Additional Materials: Data Booklet

9647/02

Wednesday 24 Aug 2016

1½ hours

READ THE INSTRUCTIONS FIRST	**For Examiner's Use**	
Write your name, subject class and registration number on all the work you hand in.	**1**	/7
Write in dark blue or black ink in the spaces provided.	**2**	/8
You may use a soft pencil for any diagrams, graphs or rough working.	**3**	/4
Do not use paper clips, highlighters, glue or correction fluid.	**4**	/12
Answers **all** questions.	**5**	/17
The number of marks is given in brackets [ ] at the end of each question or part question.	**6**	/ 12
	Total	/ 60

This document consists of **15** printed pages.

1 "Lethal Dose", LD, is a means of measuring toxicity. LD_{50} is the amount of a material which causes the death of 50% of a group of test animals. Its value is expressed as the mass of a chemical administered per kg body mass of a test animal.

"Lethal Concentration", LC, is another means of measuring toxicity. The value of LC_{50} is the concentration of a chemical in air that kills 50% of the test animals during the observation period.

The table below shows the values for the LD_{50} and LC_{50} along with the toxicity ratings.

Toxicity rating	Commonly used term	LD_{50}: Oral (mg kg^{-1})	LC_{50}: Inhalation (ppm)
1	Extremely Toxic	1 or less	10 or less
2	Highly Toxic	1 – 50	10 – 100
3	Moderately Toxic	50 – 500	100 – 1000
4	Slightly Toxic	500 – 5000	1000 – 10 000
5	Practically Non-toxic	5000 – 15 000	10 000 – 100 000
6	Relatively Harmless	15 000 or more	100 000 or more

(a) 9.90×10^{-4} mol of a toxic compound, C_4H_5NO, was found to cause death in 50% of the test animals weighing 1 kg.

Calculate the LD_{50} of C_4H_5NO and state its toxicity rating.

[2]

(b) Phosphine, PH_3, is a gas widely used in the semiconductor industries as a dopant and a precursor for the deposition of compound semiconductors.

For safety considerations, the permissible limits of phosphine must not exceed $\frac{1}{10}$ of the LC_{50} value.

When expressing the concentration of a small quantity of gas, parts per million (ppm) can be used. Ppm is usually used for volume of gases and is expressed as shown in the equation below:

$$\text{Concentration of gas (in ppm)} = \frac{\text{volume of gas}}{\text{volume of air}} \times 10^6$$

(i) Given that the LC_{50} for phosphine is 55 mg m^{-3} at room temperature, convert the LC_{50} to ppm and determine its toxicity rating.

[3]

(ii) A semiconductor factory releases 36 g of phosphine in a day.

Using your answer in **(b)(i)**, determine the minimum volume of the factory that will ensure the volume of phosphine is within the permissible limits at room temperature.

[2]

[Total:7]

2 **(a)** Liquefaction of air is done industrially by surrounding pre-cooled high-pressure air in a coil surrounded by cold water. The air cools down by a large amount when it expands into a region of low pressure. This behaviour is **not** exhibited by ideal gases.

(i) State **two** assumptions of the kinetic theory of gases.

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…… [2]

(ii) Suggest why air cools when it expands.

……

…… [1]

(iii) Conversely, gases can be liquefied at room temperature by compressing them under high pressures. Explain why a gas liquefies when compressed.

……

…… [1]

(b) Critical temperature is the maximum temperature at which a gas can be converted into a liquid by an increase in pressure. When the temperature is above the critical temperature, the vapour cannot be liquefied no matter how much pressure is applied.

(i) Draw the dot-and-cross diagram for N_2O, where N is the central atom.

[1]

(ii) Arrange the gases, N_2O, F_2 and H_2O, in an increasing order of their critical temperatures. Explain your answer.

……..……..……...……..… < …..…..…..…..……..… < ……..…..……...…

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……..……..……..……..……..……..……..……..……... [3]

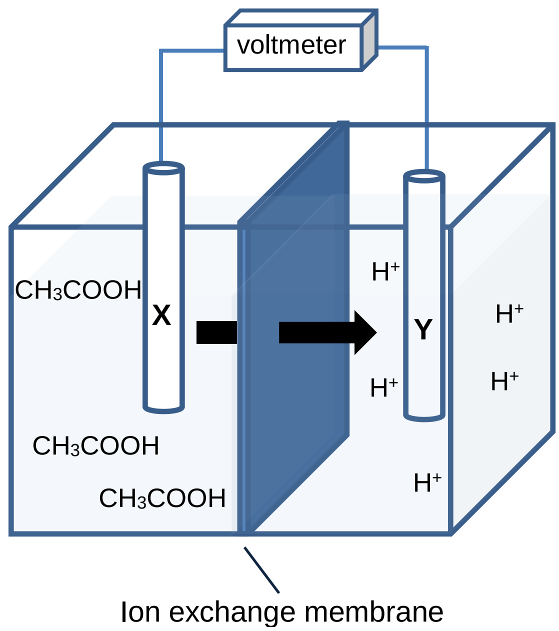
[Total: 8]

3 Hydrogen is a better source of fuel compared to fossil fuels as it is clean and renewable. The conventional method of obtaining pure hydrogen is to electrolyse water. However, many industries still prefer fossil fuel or coal as the main source of energy. One reason is the high cost of electrolysis.

(a) State another reason why the use of hydrogen as a fuel is not popular.

………………………………………………………………………………………………… [1]

(b) The diagram below shows an alternative method of producing hydrogen from organic material where ethanoic acid is converted by bacteria to carbon dioxide.



(i) Complete the table below.

Electrode	Type of reaction	Polarity
X		
Y		

[1]

(ii) Construct an equation for the reaction at each electrode.

Electrode **X**: ……………………………………………………………………………………

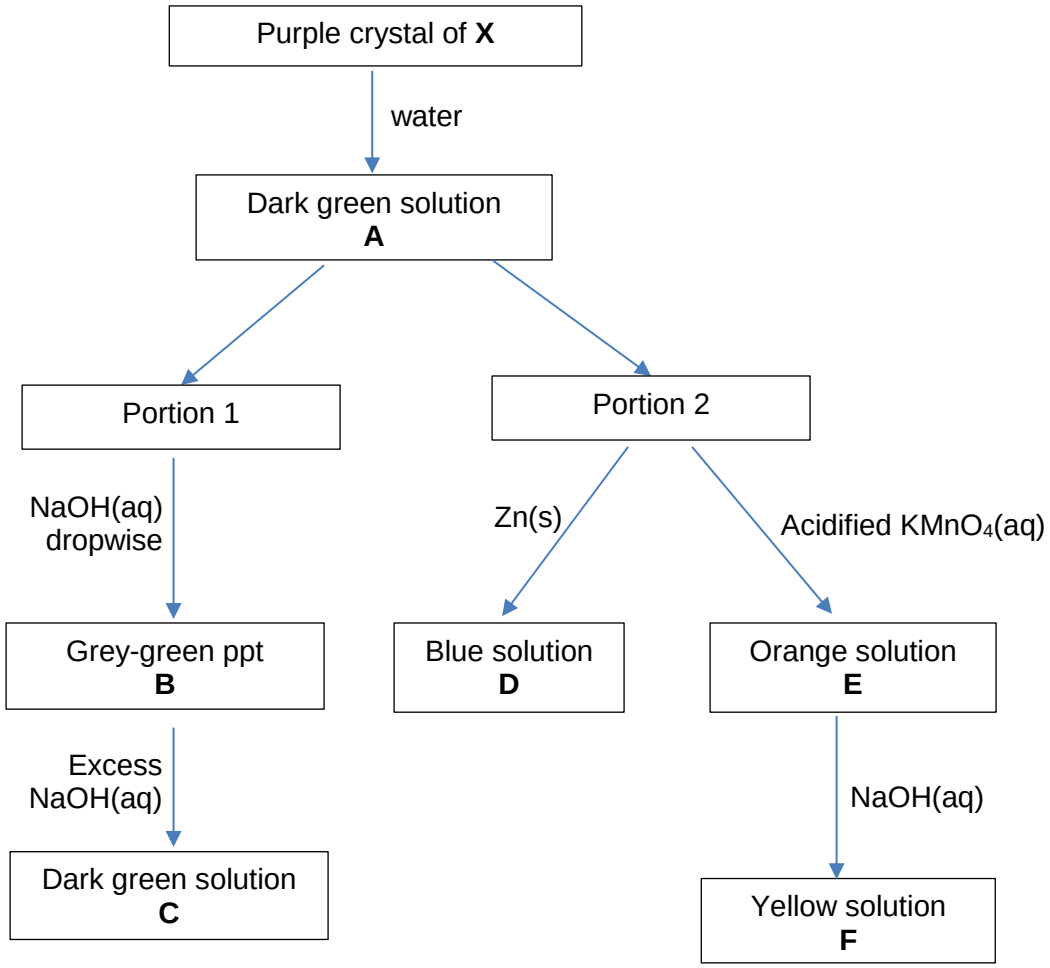
Electrode **Y**: ……………………………………………………………………………………

[2]

[Total: 4]

4 Chromium is a transition element which exhibits more than one oxidation state in its compounds, many of which are coloured.

The flow chart below shows the reaction of a purple chromium(III) compound, **X**, which has a crystalline structure.



(a) **(i)** Write the electronic configuration of the chromium ion in **A**.

[1]

(ii) Suggest an explanation for **A** being coloured.

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……

……

…… [3]

(b) **(i)** Explain why **B** dissolves in excess NaOH(aq) to form **C**. You should use the ideas behind the Le Chaterlier's principle and solubility product, K_{sp}, in your answer.

……

……

……[2]

(ii) Identify the chromium-containing species in **D**.

[1]

(iv) State the type of reaction and write an equation for the conversion of **E** to **F**.

……

…… [2]

(c) Consider the two chromium complexes, $[CrCl(NH_3)_5]SO_4$ and $[CrF(NH_3)_5]Cl_2$.

(i) Describe a chemical test, which does **not** involve silver nitrate, that could distinguish between aqueous solutions of $[CrCl(NH_3)_5]SO_4$ and $[CrF(NH_3)_5]Cl_2$.

……

……

…….. [2]

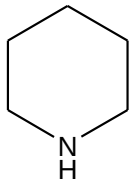
(ii) Explain why the ionic radius of Cr^{2+} is much smaller than that of Ca^{2+}.

……

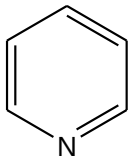
…… [1]

[Total: 12]

5 Piperidines are cyclic amines while pyridines are heterocyclic organic compounds structurally related to benzene.

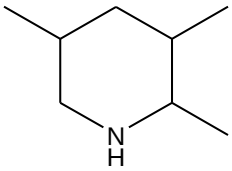


piperidine



pyridine

(a) The structure of 2,3,5–trimethylpiperidine is shown below.



It can be synthesised by reacting ammonia with a dibromo compound **G**.

$NH_3 + C_8H_{16}Br_2 \rightarrow$ 2,3,5–trimethylpiperidine + 2HBr

G

(i) Suggest the structure of compound **G**.

[1]

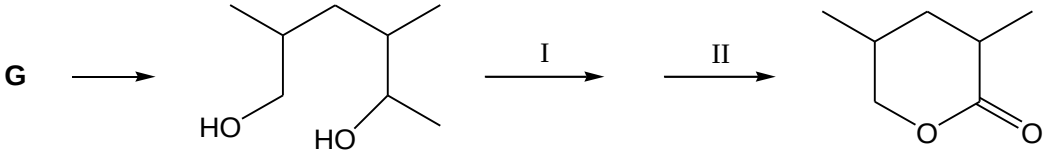
(ii) When compound **G** is reacted with NaOH in ethanol, a mixture of isomeric alkenes with molecular formula C_8H_{14} is formed.

Suggest the structures of all the isomers.

You may use skeletal representations in your answers.

[2]

(iii) Compound **G** can be converted to compound **H** by first converting it to a diol, followed by two more steps as shown.



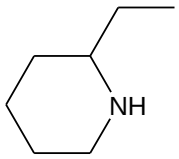
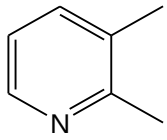
compound **H**

Complete the table below.

Step	Reagents and Conditions	Type of reaction
I		
II		

[4]

(b) The table below shows the pK_b values of three monoprotic bases, ammonia, 2-ethylpiperidine and 2,3-dimethypyridine.

	NH_3 ammonia	 2-ethylpiperidine	 2,3-dimethypyridine
pK_b	4.74	3.55	7.43

(i) Give an equation which represents the reaction of 2-ethylpiperidine with water.

[1]

(ii) Explain why 2-ethylpiperidine has a lower pK_b value than ammonia.

……

…… [1]

A 10.0 cm^3 sample of **J**, a solution containing 2-ethylpiperidine and 2,3-dimethypyridine, was titrated against 0.50 mol dm^{-3} HC*l*(aq) in the presence of two indicators, bromothymol blue and methyl orange.

It was found that 12.20 cm^3 of HC*l*(aq) were needed to change the colour of the first indicator and a ***further 7.80 cm³*** were needed to change the colour of the second indicator.

(iii) Use the data to calculate the concentration of each of the two bases in **J**.

[3]

(iv) Calculate the initial pH of **J**.

[2]

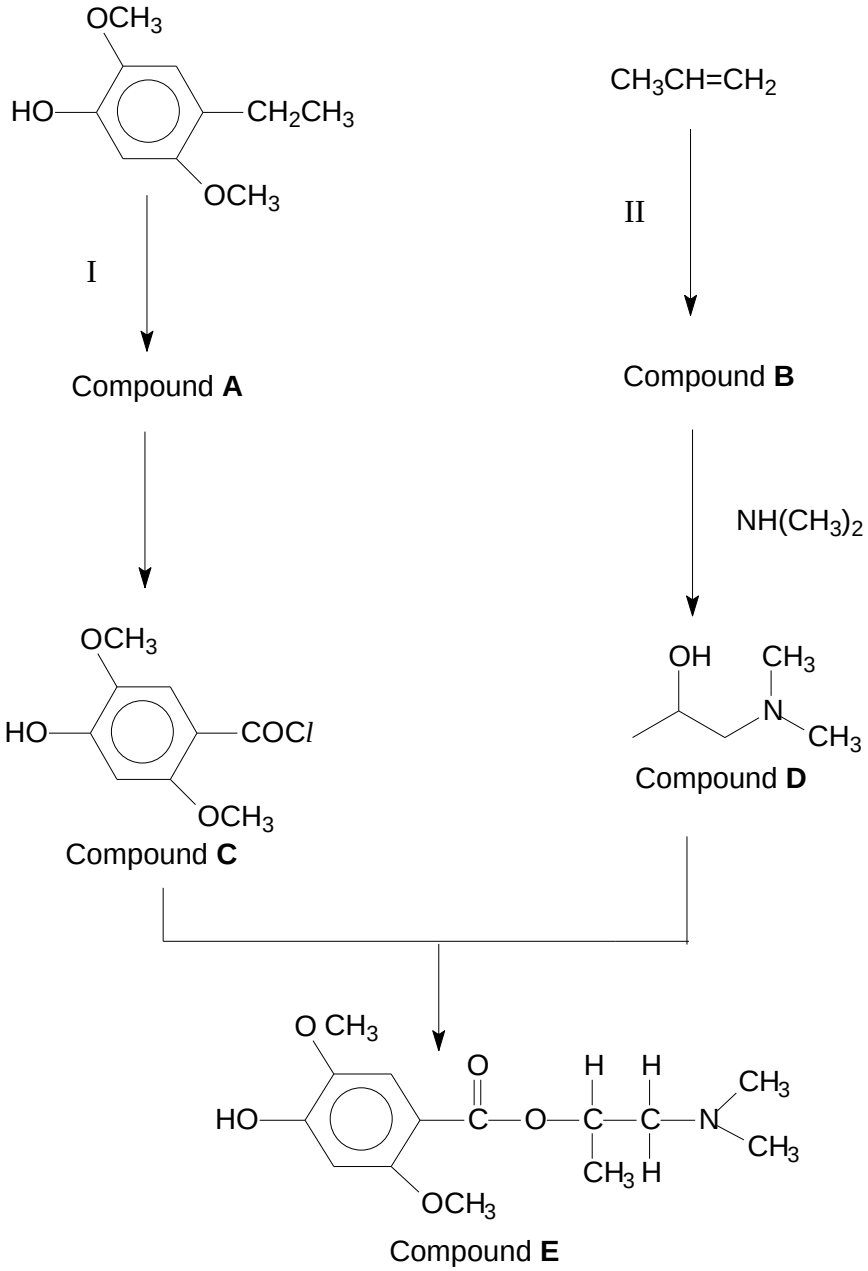
(v) Hence, sketch the shape of the pH curve during this titration, showing the pH values and volumes of HC*l*(aq) at significant points.

[3]

[Total: 17]

6 The reaction scheme below shows the synthesis of compound **E** starting from an alkene and a phenol derivative.

[The CH_3O– group can be considered to be inert.]



(a) **(i)** State reagents and conditions for steps I and II.

Step I: ……..

Step II: ……..……

[2]

(ii) Suggest the identities of compounds **A** and **B**.

Compound **A**	Compound **B**

[2]

(iii) Describe a mechanism for the reaction taking place in step II. In your answers, include all necessary curly arrows, lone pairs and relevant dipoles.

[3]

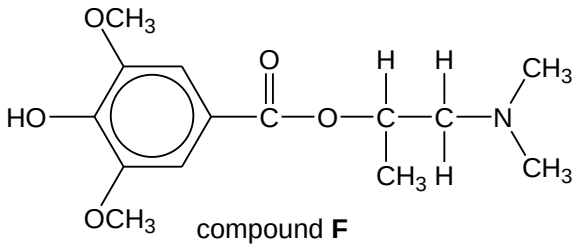
(iv) State the type of stereoisomerism exhibited by **D**. Draw appropriate structures to illustrate your answer.

[2]

(v) Draw the organic product formed when compound **A** reacts with compound **D**.

[1]

(b) Compound **F** is an isomer of **E**.



compound **F**

Describe a simple chemical test to distinguish between compounds **E** and **F**.

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…… [2]

[Total: 12]