Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC 2 Preliminary Exam

Chemistry **9647/02**

Higher 2 **1 September 2015**

Paper 2 **2 hours**

Candidates answer in the spaces provided on the question paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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

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

For Examiner's Use:

Question	Marks
1	
2	
3	
4	
5	
Total (72 marks)	

This document consists of **25** printed pages (including this page) and **1** blank page.

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1 Planning

Calcium hydroxide, $Ca(OH)_2$, is sufficiently insoluble in water such that it forms a saturated $Ca(OH)_2$ solution, as shown in the following equation:

$$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$$

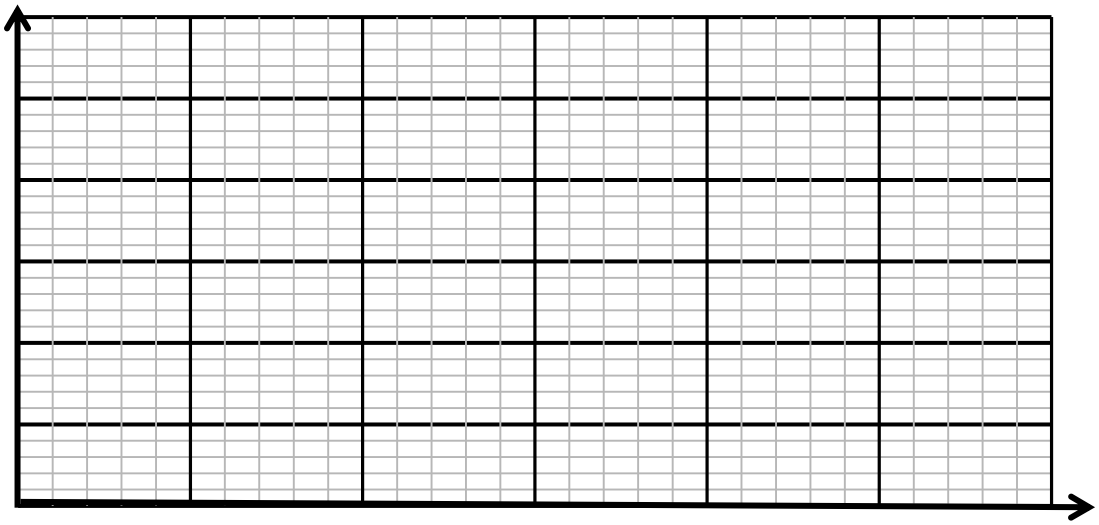
The following experiments were carried out to determine the solubility product of calcium hydroxide. Different volumes of NaOH and water were added separately to different dry conical flasks according to the following table.

Experiment	**Vol of NaOH / cm^3**	**Vol. of water / cm^3**	**[OH^-] in the saturated solution/ mol dm^{-3}**
1	5.00	45.00	0.04
2	10.00	40.00	0.03
3	15.00	35.00	0.02
4	20.00	30.00	0.01
5	25.00	25.00	0.001

Excess solid calcium hydroxide was added to each conical flask before it was stoppered and shaken for a few minutes. The solution was filtered and titrated to determine the concentration of hydroxide ions in the saturated solution.

(a) On the grid provided, plot a graph using the values from the above table. **[1]**

[OH^-] in the saturated solution/ mol dm^{-3}



Volume of NaOH / cm^3

1 (b) Explain why the concentration of hydroxide ions in the saturated solution decreases when more sodium hydroxide is added to the conical flask.

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[1]

(c) Explain why dry conical flasks needs to be used to prepare the saturated solution.

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[1]

(d) Write the K_{sp} expression for $Ca(OH)_2$, stating its units.

[2]

(e) Using the graph plotted, calculate the numerical value of K_{sp} of $Ca(OH)_2$.

[2]

1(f) Using the information above, you are required to write a plan to

- prepare a saturated solution of calcium hydroxide and
- determine the concentration of hydroxide ions in the saturated solution in experiment **1**.

You may assume that you are provided with:

- solid calcium hydroxide
- 1 mol dm^{-3} aqueous hydrochloric acid;
- the apparatus normally found in the college laboratory

Outline how you would carry out experiment **1**.

Your plan should include details of :

- the apparatus you would use, bearing in mind the levels of precision they offer;
- Indicate the colour change at the end point with your chosen indicator.

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1(f) ……

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[5]

[Total: 12 marks]

2 The Cobasys' NiMH batteries supersede the performance of other rechargeable batteries due to its high performance, lighter weight and longer life cycle. It uses a metal hydride alloy as one of the electrode. Today, NiMH batteries are used pervasively in many applications such as cell phones and hybrid cars.

(a) The standard electrode potential of the NiOOH (aq) / $Ni(OH)_2$ (s) system in an alkaline medium is +0.41 V.

Draw a fully labelled diagram of how you would determine the standard electrode potential of the NiOOH (aq) / $Ni(OH)_2$ (s) system.

[3]

(b) The equation at the anode is $MH + OH^- \longrightarrow M + H_2O + e^-$

Construct the half equation that occurs at the cathode in an alkaline medium, and the overall equation for the Cobasys' NiMH cell during discharging.

Cathode: ……

Overall: ……

[2]

2 **(c)** The table below shows the standard electrode potential of different types of metal hydride, **X**H, **Y**H, **Z**H that could possibly be used as an anode in the Cobasys' NiMH cell.

Metal Hydride, MH	E^{θ} value/ V
XH	+ 0.37
YH	+ 0.58
ZH	– 0.42

(i) State which metal hydride is the most effective to be used in the Cobasys' NiMH cell.

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[1]

(ii) Explain your answer in **(c)(i).**

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[1]

(d) Explain the effect, if any, on the e.m.f. of the cell on adding aqueous H_2SO_4 to the anodic half cell during discharging.

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[2]

2 (e) The Cobasys' NiMH cell can be recharged when the power is depleted.

(i) Write the overall equation for the reaction upon charging.

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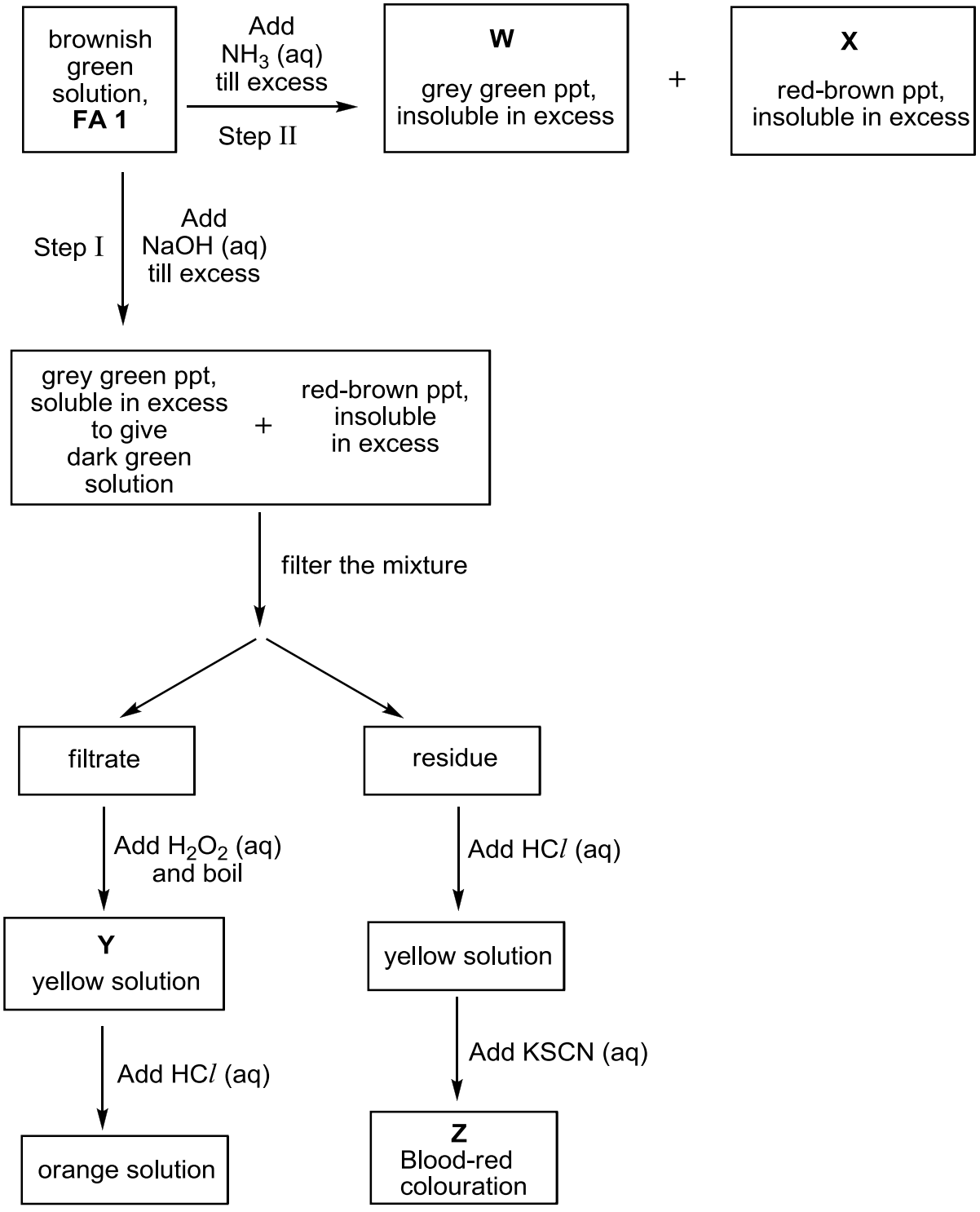
[1]

(ii) To charge the Cobasys' NiMH cell completely, a continuous current of 2.0 A for two hours is required. Calculate the minimum mass of the $Ni(OH)_2$ that would have to be present initially.

[3]

[Total: 13 marks]

3 Two cations and one anion are mixed together to form a brownish green solution, **FA 1**. A series of tests is carried out in the reaction scheme as shown.



3 **(a)** **(i)** State the formulae of the two cations present in **FA 1**.

Cation 1: …….

Cation 2: …….

[2]

(ii) Write the formulae of the species **W, X, Y** and **Z**.

W	
X	
Y	
Z	

[4]

(b) The solution of **FA 1** is acidified with HNO_3. $AgNO_3$ (aq) was subsequently added and a white precipitate formed.

State the anion that was present in **FA 1**.

……. **[1]**

3 (c) **FA 2** contains the same cations but a different anion.

FA 2 undergoes the same reactions as **FA 1** in **(b)** and a cream precipitate was formed instead.

Both precipitates in **(b)** and **(c)** were filtered from the resultant mixtures, washed and separated into two parts. Dilute and concentrated NH_3 was added to each part in separate test tubes.

	Dilute NH_3	Concentrated NH_3
White precipitate in **(b)**	Soluble	Soluble
Cream precipitate in **(c)**	Insoluble	Soluble

With the aid of equation(s), explain fully the difference in the solubility of the precipitates.

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[3]

3 (d) **FA3** is a pink solution that contains Co^{2+}.

A student added NH_3 (aq) to a test tube containing **FA3** and observed a blue precipitate formed. The blue precipitate dissolved when the student added excess NH_3 (aq) to form a yellowish-brown solution.

(i) Explain why aqueous Co^{2+} is pink.

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[3]

(ii) With the aid of equations, explain how the blue precipitate is formed when NH_3 (aq) is added and why the blue precipitate dissolves in excess NH_3 (aq).

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[3]

[Total: 16 marks]

4 **(a)** Sodium carbonate is a compound with a wide variety of uses, such as regulating the pH in swimming pools, and as a softener in laundry.

Aqueous carbonate ion is a diprotic base as shown in the equation below:

$$CO_3^{2-} \xrightarrow[pK_{b1} = 6.3]{+ H^+} HCO_3^- \xrightarrow[pK_{b2} = 10.3]{+ H^+} CO_2 + H_2O$$

(i) Calculate the pH of a 0.1 mol dm^{-3} solution of sodium carbonate. (You may ignore the effect of pK_{b2})

[2]

(ii) 20 cm^3 of 0.1 mol dm^{-3} solution of sodium carbonate was titrated against 50 cm^3 of 0.1 mol dm^{-3} hydrochloric acid. Calculate the final pH of the solution.

[1]

4 **(a)** **(iii)** Sketch a titration curve for the reaction in **(a)(ii)**, labelling clearly any significant pH values and volumes.

[2]

4 (a) (iv) Two indicators are needed for this titration. The table below shows the working ranges and colours of some common indicators:

Indicator	**Colour**		**pH at which colour changes**
	Acid	**Base**	
Methyl violet	Yellow	Blue-violet	0.0 – 2.0
Methyl yellow	Red	Yellow	2.9 – 4.0
Bromothymol blue	Yellow	Blue	6.0 – 7.6
Cresolphthalein	Colourless	Purple	8.2 – 9.8

State the two suitable indicators for the titration above, as well as the colour change observed for each indicator chosen.

First indicator used: ……..

Colour change: ……...

Second indicator used: ……

Colour change: ……..…

[2]

4 **(b)** Sodium hydrogen carbonate is used in baking as a leavening agent. Upon heating, it decomposes, producing sodium carbonate, carbon dioxide and water, causing cakes and other pastries to “rise”.

However, the enthalpy change of the decomposition above must be determined indirectly. Several experiments are carried out to determine related enthalpy changes.

In Experiment 1, 2.0 g of solid sodium carbonate was reacted with 30 cm^3 of 2.0 mol dm^{-3} excess hydrochloric acid in a calorimeter. The temperature increased by 5.2°C.

(i) Write an equation for the reaction that occurs in Experiment 1.

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[1]

(ii) Hence, calculate the enthalpy change of the reaction per mole of sodium carbonate.

Assume that the specific heat capacities of all solutions are 4.2 J g^{-1} K^{-1}.

[2]

4 **(b)** In the Experiment 2, 2.0 g of sodium hydrogen carbonate was reacted with excess HCl, and the enthalpy change for the reaction per mole of hydrogen carbonate was determined to be +23.3 kJ mol^{-1}.

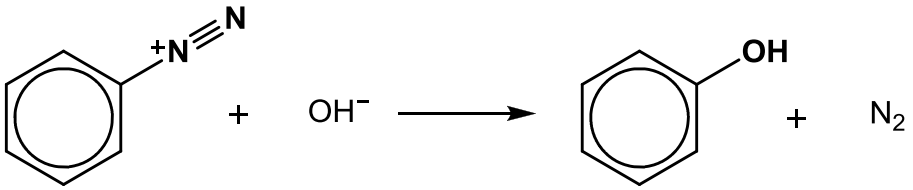
(iii) Using the information above as well as your value in **(b)(ii)**, draw an energy cycle to determine the enthalpy change for the decomposition of one mole of sodium hydrogen carbonate.

[2]

[Total: 12 marks]

5 Benzenediazonium salts are useful compounds in organic synthesis. However, they are unstable.

(a) A simplified equation for the decomposition of benzenediazonium ion, $C_6H_5N_2^+$, is shown below:



benzenediazonium ion

The reaction is known to proceed via an S_N1 mechanism as follows:

- Heterolytic fission of the C–N bond forms a carbocation intermediate and nitrogen.
- The carbocation intermediate is then attacked by a nucleophile to form the product.

Based on the information above, propose a mechanism for the reaction. You should use curly arrows to represent the movement of electrons.

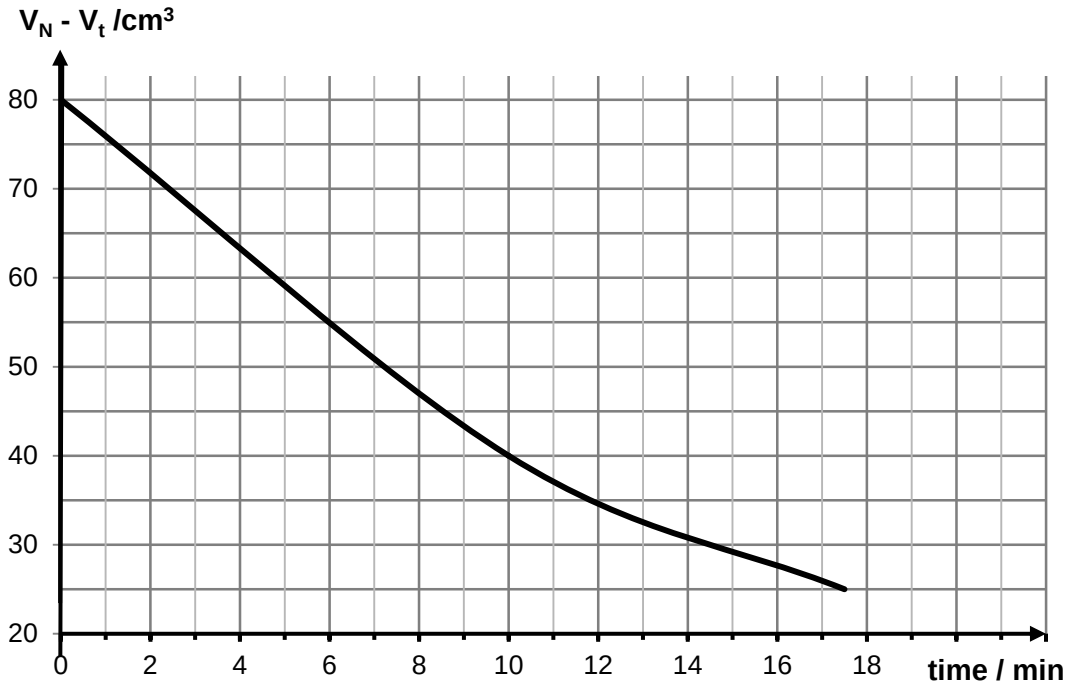
[2]

5 (b) Aqueous benzenediazonium chloride decomposes according to the equation:

$$C_6H_5N_2Cl\,(aq) + H_2O\,(l) \longrightarrow C_6H_5OH\,(aq) + N_2\,(g) + H^+\,(aq) + Cl^-\,(aq)$$

The rate of reaction can be followed by measuring V_t, the volume of nitrogen evolved at different time intervals. The following graph was plotted from the results obtained in the experiment.

V_N is the volume of nitrogen evolved at the end of the reaction.



(i) Why should a large volume of water be used in the experiment?

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[1]

5 (b) (ii) What is the significance of the term $V_N - V_t$?

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[1]

(iii) Using the graph above, deduce the order of reaction with respect to [$C_6H_5N_2Cl$]. Hence, write the rate equation.

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[3]

(iv) In an experiment with [$C_6H_5N_2Cl$] = 0.01 mol dm^{-3}, it was observed that 40% of the $C_6H_5N_2Cl$ decomposed in 9 min. What is the time taken for 40% of $C_6H_5N_2Cl$ to decompose when a concentration of 0.02 mol dm^{-3} is used instead?

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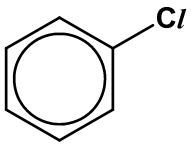
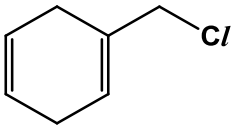
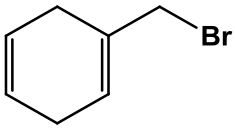
[1]

5 **(c)** Benzenediazonium ions can also be used to synthesise aryl halides such as chlorobenzene.

A student was tasked to investigate the rate of hydrolysis of chlorobenzene and two other organo-halide compounds.

Chlorobenzene	Compound **B**	Compound **C**
		

State and explain the difference in reactivity of the three compounds to hydrolysis.

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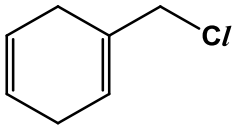
[4]

5 (d) Compound **D**, which is a structural isomer of compound **B**, was investigated in two separate reactions.

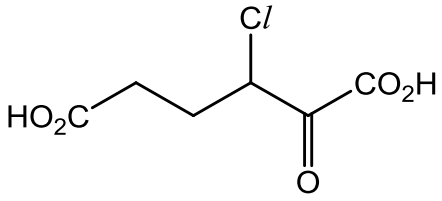


Compound **B**

Reaction 1: 0.1 mol of **D** was found to react with 10.3 cm^3 of Br_2 (*l*) in the dark.

(Density of Br_2 (*l*) = 3.10 g cm^{-3}.)

Reaction 2: Compound **D** was refluxed with acidified potassium manganate, and only one organic product **E,** $C_6H_7O_5Cl$, was obtained.



Compound **E**

(i) Based on the information above, what can you deduce about the functional groups present in **D**? Explain your reasoning clearly and state the type of reaction that occurs.

Reaction 1

Type of reaction: ……..

Deductions: ……..

……

……

5 (d) (i) Reaction 2

Type of reaction: ……..

Deductions: ……..

……

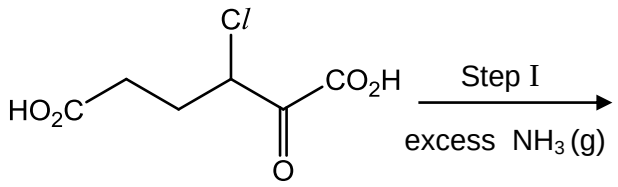
……

[3]

(ii) Hence, deduce a possible structure of compound **D**.

[1]

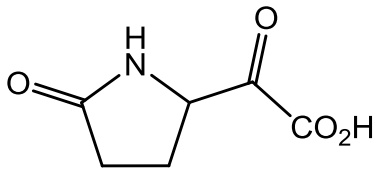
5 **(e)** Compound **E** can be used to synthesise a cyclic compound **G** according to the following synthetic pathway:



Compound **E**

Intermediate **F**

Step II



Compound **G**

(i) Draw the structure of the Intermediate **F** in the space provided above.

[1]

(ii) State the type of reaction and the reagents and conditions needed for Step II.

Type of reaction: ……

Reagents and conditions: ……..

[2]

[Total: 19 marks]

End of Paper