PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 1

CANDIDATE NAME								
CT GROUP	1	5				INDEX NUMBER		

CHEMISTRY 8872/02

13 September 2016

2 hours

Additional Materials: Data Booklet
Writing Paper
Cover Page for Section B

READ THESE INSTRUCTIONS FIRST

Write your name, CT group and index number in the spaces provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected where appropriate.

Section A
Answer **all** the questions in the spaces provided.

Section B
Answer **two** questions on separate writing papers. If there is no answer to the question, a *blank sheet* of paper must still be submitted.

You are advised to show all working in calculations.
You may use a calculator.
The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

FOR EXAMINER'S USE			
Paper 1		**Paper 2 Section B**	
Total	/ 30	Total	/ 40
Paper 2 Section A			
1	/ 16	Penalty	s.f. / units
2	/ 11	**TOTAL**	**/ 110**
3	/ 13	**GRADE**	
Total	/ 40		

Section A (40 marks)

Answer **all** questions. Write your answers in the spaces provided.

1 This question is about Period 3 elements and their compounds.

(a) **(i)** Write the full electronic configuration of magnesium.

[1]

(ii) Account for the high melting point of magnesium in terms of its structure and bonding.

[2]

(iii) When a beam of Mg^{2+} particles travels through a uniform electric field which is at right angle to its direction of travel, it is deflected at an angle of +5.0°.

Determine the angle of deflection of a beam of Al^{3+} particles if it travels at the same speed through the same electric field.

[2]

(iv) Suggest the property of magnesium for its use in flares and fireworks.

[1]

(b) Both magnesium and sulfur form oxides.

(i) Construct the dot-and-cross diagram for magnesium oxide.

[1]

(ii) When sulfur dioxide is dissolved in water, an acidic solution is formed.

Write a balanced equation to show the reaction between sulfur dioxide and water.

[1]

(c) Chlorine is a yellow-green diatomic gas which is highly reactive.

(i) In an acidic medium, chlorine reacts with thiosulfate ions, $S_2O_3^{2-}$, to form sulfate ions, SO_4^{2-}.

By means of two half-equations, construct a balanced equation for the reaction.

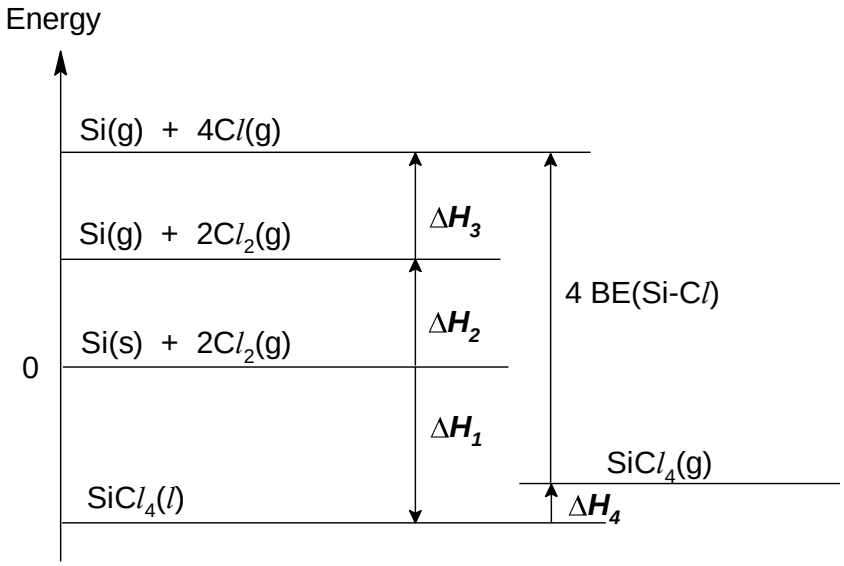
.....

.....

..... [2]

(ii) When chlorine is passed over silicon powder heated in a tube, silicon tetrachloride is produced.

The Si-C*l* bond energy may be calculated using the energy cycle shown below.



(I) Name the enthalpy change represented as ΔH_1.

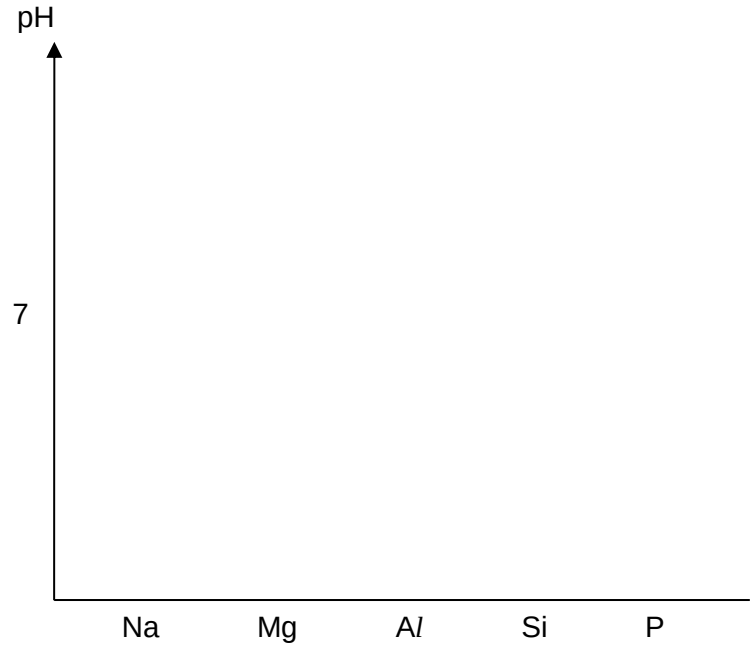
..... [1]

(II) Using relevant information from the *Data Booklet* and the following information, calculate the Si-C*l* bond energy.

$Si(s) + 2Cl_2(g) \rightarrow SiCl_4(s)$	$\Delta H_1 = -692$ kJmol^{-1}
$Si(s) \rightarrow Si(g)$	$\Delta H_2 = +450$ kJmol^{-1}
$SiCl_4(l) \rightarrow SiCl_4(g)$	$\Delta H_4 = +28.7$ kJmol^{-1}

[3]

(d) On the grid below, sketch the graph of the variation in pH of the solutions produced when the chlorides of Period 3 elements are added to water.



[2]

[Total: 16]

2 Benzoic acid is a weak acid which has antifungal abilities and had been used for a long time in preservation of berries in the 19th century.

(a) (i) Explain what is meant by a *weak acid*?

[1]

(ii) Given that a 0.150 mol dm^{-3} of benzoic acid have a pH of 3.1. Calculate the acid dissociation constant, K_a, of benzoic acid.

[2]

(b) In an experiment, 20 cm^3 of 0.01 mol dm^{-3} aqueous benzoic acid is added to 10 cm^3 of 0.01 mol dm^{-3} sodium hydroxide.

Explain, with the aid of **two** equations, how the resultant mixture can act as a buffer upon addition of small amounts of H^+ and OH^-.

[3]

(c) Benzoic acid reacts with an unknown alcohol, **L**, to give an ester with molecular formula $C_{11}H_{14}O_2$.

$$C_6H_5CO_2H(l) + \mathbf{L}(l) \rightleftharpoons C_{11}H_{14}O_2(l) + H_2O(l)$$

(i) **L** produces a yellow precipitate when warmed with alkaline aqueous iodine.

Suggest a possible structure for **L**. Explain your answer.

[2]

(ii) 0.05 mol of benzoic acid and 0.075 mol of **L** are mixed and shaken for a long time to reach equilibrium. The mixture is titrated quickly with 1.00 mol dm^{-3} of aqueous sodium hydroxide and 24.80 cm^3 of alkali is required.

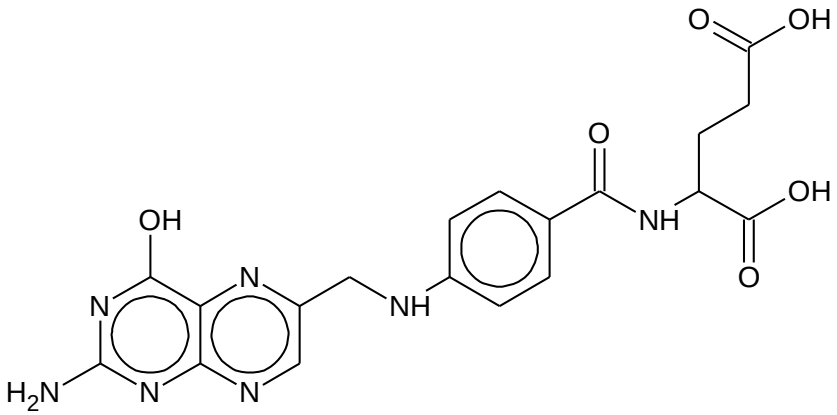
Calculate a value for the equilibrium constant for this reaction.

[3]

[Total: 11]

3 Folic acid, $C_{19}H_{19}N_7O_6$, is a form of vitamin B_9 needed for many functions in the body, especially in rapid cell division and growth. It is important for pregnant women to have enough folic acid to prevent major birth defects.

The structure of the folic acid molecule is



(a) **(i)** State the number of sp^2 hybridised carbons in folic acid.

.....

[1]

(ii) Circle the acidic groups on the structure of the folic acid molecule above. [1]

(b) A pharmaceutical company claims the average mass of folic acid in one tablet indicated in the supplement facts, at 5 mg, is correct to 1%.

Supplement Facts

Serving size:	**1 tablet**	
Serving per container:	**60**	
	Amount Per Serving	**% DV***
Folic Acid	5 mg	1250 %

*Percent Daily Values are based on a 2,000 calorie diet (US).
**Daily Value not established

Other ingredients: Dicalcium Phosphate, Microcrystalline Cellulose, Starch, Stearic Acid, Opadry Clear, Magnesium Stearate Vegetable, Silicon Dioxide.

Label on the folic acid bottle

A student wanted to verify the claim made by the company through volumetric analysis. She prepared the following solutions:

FA 1 is a 250 cm^3 solution containing 15 folic acid tablets.
FA 2 is a 1.50 x 10^{-3} mol dm^{-3} sodium hydroxide solution.

It was found that 25.0 cm^3 of **FA 1** required 22.80 cm^3 of **FA 2** for complete reaction.

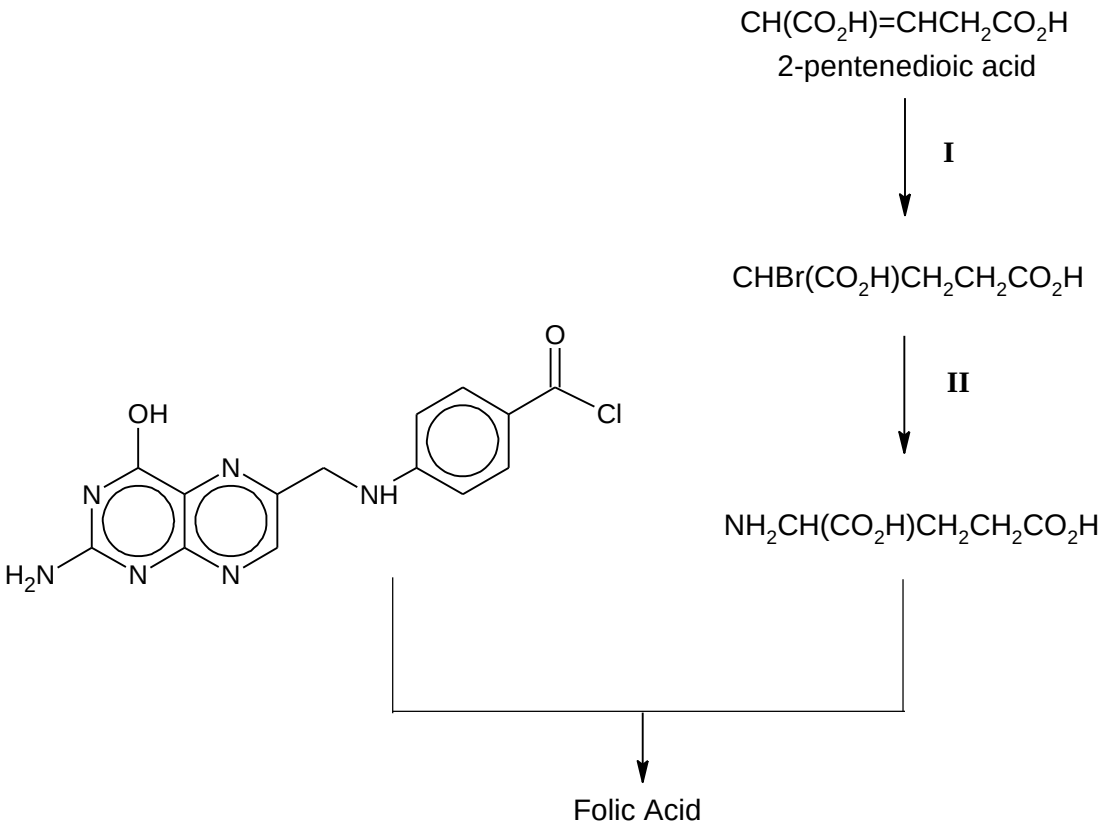
(i) Calculate the average mass of folic acid present in **one** tablet.

[4]

(ii) Explain whether the claim made by the company that the average mass of folic acid in one tablet is correct to 1% is valid.

[2]

(c) The following shows a possible pathway for the synthesis of folic acid.



(i) 2-pentenedioic acid exhibits geometric isomerism. Draw the two isomers of 2-pentenedioic acid.

[2]

(ii) Write an equation for the reaction occurring in step **I**, and state the reagents and conditions necessary for the reaction to occur.

equation: .....

reagents and conditions: .....

[2]

(iii) State the type of reaction in step **II**.

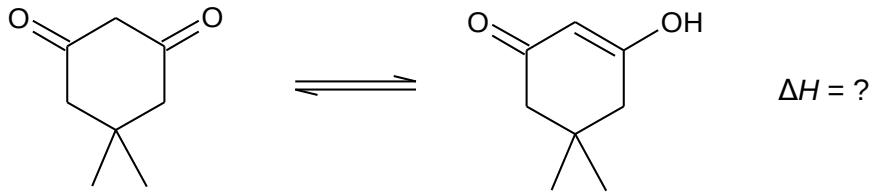
..... [1]

[Total: 13]

Section B (40 marks)

Answer **two** of the three questions in this section on separate paper.

4 **(a)** Dimedone is an important organic precursor for the synthesis of scented compounds used in perfumes. It exists in dynamic equilibrium with its isomer, enol, through a reaction called enol-keto tautomerisation. This reaction is shown in the equation below.



dimedone enol

(i) Define the term *dynamic equilibrium*. [1]

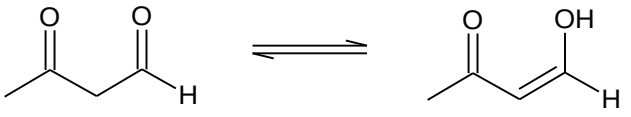
(ii) Write an expression for the equilibrium constant, K_c, for this reaction. [1]

(iii) It was experimentally determined using spectrometric techniques that 33% of dimedone was converted to the enol form at room temperature. Calculate the equilibrium constant, K_c, for this reaction. [2]

(iv) Using suitable bond energy values from the *Data Booklet*, calculate the Δ*H* for the formation of enol from dimedone. [3]

(v) Using the answer obtained in **(iv)**, suggest what will happen to the equilibrium position and composition when the equilibrium mixture is heated. [4]

(b) Acetylacetaldehyde can also undergo enol-keto tautomerisation reaction as shown in the equation below.

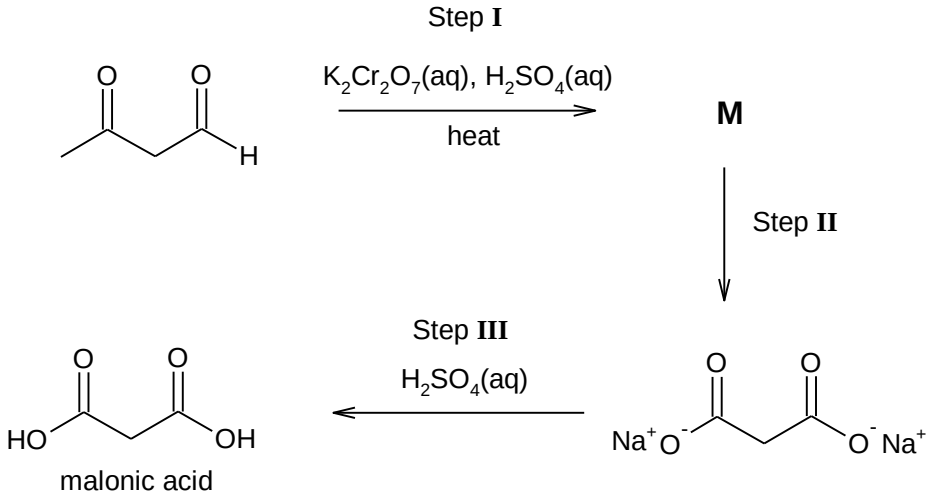


acetylacetaldehyde enol of acetylacetaldehyde

Compared to dimedone, a higher percentage of up to 76% of acetylacetaldehyde was converted to the enol form at room temperature. This can be attributed to the greater stability brought about by the formation of intramolecular hydrogen bonding of the enol of acetylacetaldehyde.

Draw a diagram to show how the intramolecular hydrogen bonding is formed in the enol of acetylacetaldehyde. [2]

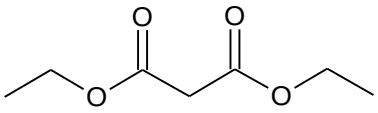
(c) Malonic acid can be synthesised from acetylacetaldehyde by the following reaction scheme.



(i) Draw the intermediate compound **M** and give the reagent and conditions for Step **II**. [2]

(ii) Name the type of reaction which occurred in Step **III**. [1]

(iii) Malonic acid can be converted to diethylmalonate, an ester, which occurs naturally in grapes and strawberries.



diethylmalonate

Name the type of reaction when malonic acid is converted to diethylmalonate. [1]

(d) By means of a simple chemical test, suggest how you would distinguish the two esters, **P** and **Q**.

P **Q**

State clearly the reagents and conditions you would use and the observations you would make. [3]

[Total: 20]

5 (a) Compound **R** has the molecular formula $C_4H_6O_2$.

Data about the reactions of **R** are given in the table.

reaction	reagent	result
1	Br_2(aq)	Aqueous bromine decolourised.
2	Na	1 mol of **R** produced 12 dm^3 of colourless gas, measured at r.t.p.
3	2,4-dinitrophenylhydrazine	Orange solid formed.
4	Hot Tollens' reagent	No visible change observed.
5	Hot acidified $KMnO_4$	Purple $KMnO_4$ decolourised and product **S** formed. When Na_2CO_3(aq) is added to 1 mol of **S**, 24 dm^3 of colourless gas, measured at r.t.p was produced.

(i) Name the functional group that reaction **1** shows to be present in **R**. [1]

(ii) Based on reactions **2**, **3** and **4**, deduce the identity and number of **each** of the functional groups present in **R**. Explain your answer as fully as you can. [5]

(iii) Based only on reaction **5**,
(I) identify the colourless gas
(II) name the type of reaction between **R** and hot acidified $KMnO_4$
(III) deduce the identity and the number of the functional group present in **S**
[4]

(iv) From your answers in **(i)**, **(ii)** and **(iii)**, draw the displayed formula of **R**. [1]

(b) Compound **T**, $CH_3CH{=}CHCO_2H$, is an isomer of compound **R** from **(a)**.

Aqueous solution of **T** reacts with aqueous sodium hydroxide.

(i) Write a balanced equation for the neutralisation reaction between **T**(aq) and NaOH(aq). [1]

(ii) The standard enthalpy change of neutralistion between **T**(aq) and NaOH(aq) was determined experimentally by mixing known volumes of 2.0 mol dm^{-3} **T**(aq) and 1.0 mol dm^{-3} NaOH(aq). The following results were obtained.

Volume of **T**(aq) used = 30.0 cm^3
Volume of NaOH(aq) used = 60.0 cm^3
Change in temperature = +8.4 °C

Calculate the standard enthalpy change of the neutralisation reaction.

[Assume specific heat capacity of the solution to be 4.2 J g^{-1} K^{-1} and its density to be 1 g cm^{-3}] [3]

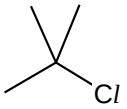
(iii) When the experiment is repeated with 2.0 mol dm^{-3} hydrochloric acid instead of 2.0 mol dm^{-3} **T**(aq), would the enthalpy change of neutralisation be more or less exothermic? Explain your answer. [2]

(iv) With reference to sodium hydroxide, define the term *lattice energy*. [1]

(v) Explain how you would expect the numerical magnitude of the lattice energy of sodium hydroxide to compare with that of magnesium hydroxide. [2]

[Total: 20]

6 **(a)** *t*-butyl chloride is a chloroalkane which is produced industrially as a precursor to other organic compounds.

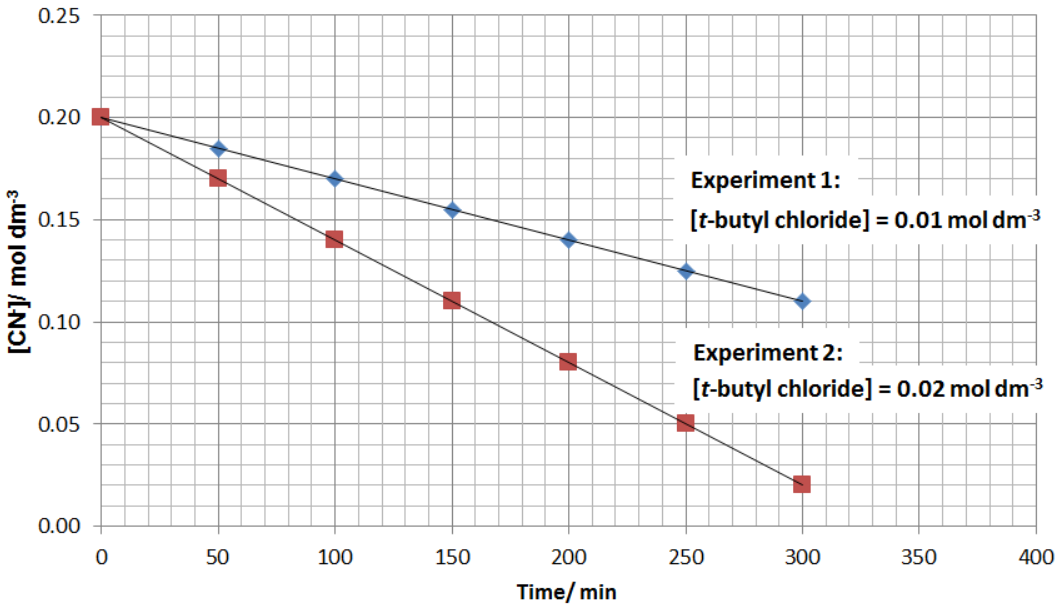


t-butyl chloride

(i) *t*-butyl chloride reacts with sodium cyanide in ethanol solvent.

Write a balanced equation for the reaction and state the type of reaction. [2]

(ii) The kinetics of the reaction in **(i)** can be investigated experimentally. Two separate experiments have been conducted for different concentrations of *t*-butyl chloride and the data collected are used to plot the graphs below.



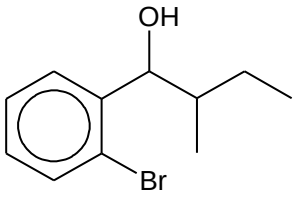
Use the graphs to show that the order of reaction is zero with respect to CN^- ions. [1]

(iii) Use the graphs in **(ii)** to determine the order of reaction with respect to *t*-butyl chloride. Explain your answer fully, showing all appropriate calculation. [3]

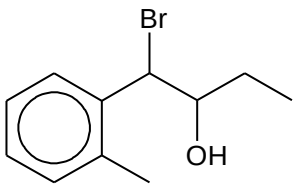
(iv) Hence, calculate the rate constant for the reaction, stating its units. [2]

(v) 1-chlorobutane is an isomer of *t*-butyl chloride. Predict which isomer has a higher boiling point. Explain your answer. [4]

(b) Compounds **V** and **W** are isomers of each other.



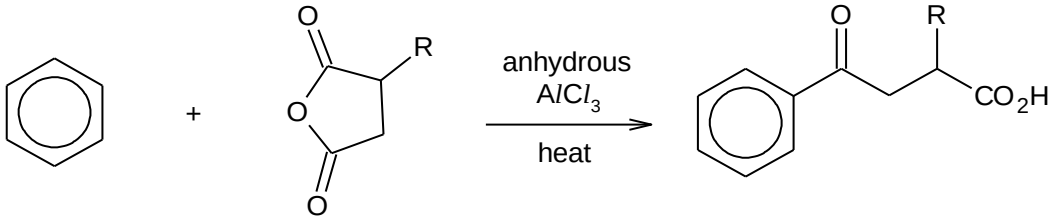
Compound **V**



Compound **W**

Describe a simple chemical test to distinguish **V** and **W**. State any observations clearly. [3]

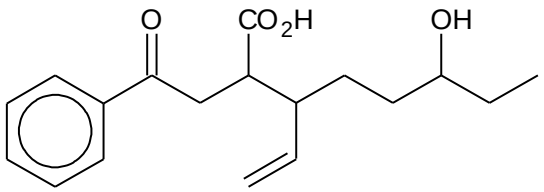
(c) Friedel-Crafts acylation is a reaction developed by Charles Friedel and James Crafts to attach substituents to an aromatic ring. The general reaction scheme is shown below.



(i) Name the type of reaction for Friedel-Crafts acylation. [1]

(ii) 3-(1-vinylhexyl) succinic anhydride reacts with benzene via Friedel-Crafts acylation to form compound **X**.

X is used to produce highly coloured dyes used as biomarkers for livestock exposed to certain carcinogenic pollutants.



X

State the number of sp^2 – sp^3 carbon-carbon overlaps present in **X**. [1]

(iii) Draw the organic compounds formed when **X** reacts with:

(I) H_2, Ni, 200 °C
(II) $LiAlH_4$ in dry ether
(III) cold $KMnO_4$(aq), NaOH(aq)

[3]

[Total: 20]

End of Paper