

## PIONEER JUNIOR COLLEGE

# JC2 PRELIMINARY EXAMINATION HIGHER 2

CANDIDATE NAME Suggested Answers	
CT IND GROUP 1 2 NUI	MBER
CHEMISTRY	9647/02
Paper 2 Structured	18 September 2013
Candidates answer on the Question Paper. Additional Materials: Data Booklet	2 hours

### **READ THESE INSTRUCTIONS FIRST**

Write your Centre number, index number and name on all 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 workings. Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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				
Paper 2				
1	/ 12	5		/5
2	/ 10	6		/7
3	/ 14	Penalty	sf	units
4	/ 24	Total		/ 72

This document consists of **20** printed pages.

#### 1 Planning

Heat is absorbed when potassium iodide dissolves in water. Sucrose, on the other hand, does not produce a temperature change when added to water.

By studying the temperature changes when known masses of potassium iodide dissolve, the percentage by mass of potassium iodide in a mixture of potassium iodide and sucrose, **FA 5** can be determined.

You are provided with

- a test tube of FA 1 which contains 2.00 g of potassium iodide
- a test tube of **FA 2** which contains 4.00 g of potassium iodide
- a test tube of **FA 3** which contains 6.00 g of potassium iodide
- a test tube of **FA 4** which contains 8.00 g of potassium iodide
- an empty test tube labelled FA 5
- **FA 5**, a mixture of potassium iodide and sucrose
- a thermometer
- a polystyrene cup
- other common apparatus in the laboratory
- (a) The percentage composition of potassium iodide in the mixture, **FA5**, is estimated to be 50%. Suggest a suitable value for mass of **FA 5** used.

4.00 < mass of **FA 5 (x)** < 16.00

(b) Describe, in a series of numbered steps, how you would measure the temperature changes by dissolving separate samples of FA 1 to FA 5 in water. Hence, determine the mass of potassium iodide in a mixture of FA 5.

Your plan should include the following:

- the apparatus for measurements
- how you would take and record the various measurements
- the tables for recording the data measured
- the graph to be plotted
- 1. <u>Using a weighing balance</u>, weigh out accurately **x** g of **FA 5** in a test tube labelled **FA 5**. Record the mass in the table below.

Mass of test tube + FA 5 / g	
Mass of empty test tube / g	
Mass of <b>FA 5</b> used / g	X

- 2. Measure <u>50 cm<sup>3</sup></u> of deionised water using a (<u>50 / 100 cm<sup>3</sup></u>) measuring <u>cylinder</u> into a styrofoam cup.
- 3. Using a (0.2°C) thermometer measure and record the initial temperature of the water in the cup,  $T_1$  °C.

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- 4. Tip the content of the test tube labelled **FA 1** into the water in the cup. <u>Stir</u> the mixture with a thermometer and record the <u>lowest temperature</u> reached,  $T_2$  °C.
- 5. Discard the solution, rinse and dry the cup. Repeat steps 2 to 4 for **FA 2** to **FA 5**.

Test tube	Mass of KI / g	Initial temperature / °C	Minimum temperature / °C	∆ <b>T / °C</b>
<b>FA 1</b>	2.00			
<b>FA 2</b>	4.00			
<b>FA 3</b>	6.00			
<b>FA 4</b>	8.00			
<b>FA 5</b>				

6. Record all measurements and results in the table below.

- 7. Plot a graph of  $\Delta T$  or  $|\Delta T|$  against mass of KI.
- (c) Sketch the graph you suggested in (b). Show clearly how the percentage by mass of potassium iodide in FA 5 can be determined.

[2]





(d) A second student conducted a similar experiment using the same apparatus and the same volume of water as in your plan in (b) but using twice the mass of FA 1 to FA 5. Suggest whether your experiment or the second student's experiment would result in a more reliable determination of the percentage by mass of potassium iodide in FA 5.

When larger masses of **FA 1** to **FA 5** are used, a <u>larger  $I\Delta TI$ </u> is obtained. This results in a <u>smaller percentage error</u> in temperature measurement in the student's experiment. Thus the second <u>student's experiment</u> would give a more reliable determination of percentage by mass of KI in **FA 5**.

(e) (i) A third student measured a temperature change of 3 °C when he dissolved 12 g of potassium iodide in 100 cm<sup>3</sup> of water. Assume that the specific heat capacity of the final solution is 4.18 J  $g^{-1}$  K<sup>-1</sup>, and that its density is 1.00 g cm<sup>-3</sup>, calculate the enthalpy change of solution of potassium iodide.

Heat absorbed =  $100 \times 4.18 \times 3 = 1254 \text{ J}$ 

Amount of KI dissolved = 12/166.1 = 0.0722 mol

 $\Delta H_{\text{solution}} = +100 \text{ x } 4.18 \text{ x } 3 = +17.4 \text{ kJmol}^{-1}$ 

(ii) The published value for the enthalpy change of solution of potassium iodide is +20.3 kJ mol<sup>-1</sup>. Suggest an explanation for the difference between the published value and the value calculated in (i).

The smaller/lower magnitude of  $\Delta H_{\text{solution}}$  of KI compared to the published value is due to <u>heat gained / absorbed from the surroundings</u> and the Styrofoam cup will cause <u>IATI to be smaller</u>.

[2]

[Total: 12]

2 In a typical iodine clock reaction, solutions of hydrogen peroxide, sulfuric acid, potassium iodide, starch and sodium thiosulfate are mixed. There are two reactions occurring in the reaction mixture.

In the first reaction, iodide ions are oxidised slowly by acidified hydrogen peroxide to form iodine.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$
 reaction I

In the second reaction, iodine is reduced back to iodide ions as they are generated.

 $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^{-}(aq) \qquad \mbox{reaction II}$ 

When all the sodium thiosulfate present has reacted, iodine will appear in the solution producing an immediate deep blue colour with starch indicator.

A series of experiments was carried out using different volumes of the five reagents, each solution being made up to the same total volume with water. The following results were obtained.

expt	volume of	volume	time for the				
no.	0.10	0.100	0.100	0.050	starch	of	appearance
	mol dm⁻³	mol dm⁻³	mol dm⁻³	mol dm⁻³	solution	water	of deep
	$H_2O_2$	KI	HC/	$Na_2S_2O_3$	/ cm <sup>3</sup>	/ cm <sup>3</sup>	blue colour
	/ cm <sup>3</sup>	/ cm <sup>3</sup>	/ cm <sup>3</sup>	/ cm <sup>3</sup>			/ s
1	18	12	6	2	3	59	23
2	6	12	12	2	3	65	70
3	6	18	12	2	3	59	47
4	12	12	12	2	3	59	35

(a) Calculate the relative initial rate of reaction I for each of these experiments.

Experiment	Time for the appearance	Relative rate $\alpha$ 1/t
Number	of blue-black colour	
	/ s	
1	23	0.0435
2	70	0.0143
3	47	0.0213
4	35	0.0286

[1]

(b) Given that the order of reaction with respect to hydrogen peroxide is found to be one, use the results in (a) to deduce the order of reaction with respect to I<sup>-</sup> and H<sup>+</sup> in reaction I. Explain your reasoning.

Since the total volume of reaction mixture is constant (100 cm<sup>3</sup>), the volume of each reagent used is directly proportional to its concentration.

Comparing expt 2 & 3:  $[H_2O_2]$  and  $[H^+]$  are kept constant. When  $[I^-]$  increases by 1.5 times, the initial rate also increases by 1.5 times. Therefore, reaction is first order w.r.t.  $I^-$ .

Let the rate equation be rate =  $k[H_2O_2][I][H^+]^x$ For expt 1: 0.0435 =  $k[18][12][6]^x$ For expt 2: 0.0143 =  $k[6][12][12]^x$ 

 $\frac{0.0435}{0.0143} = \frac{k[18][12][6]^{x}}{k[6][12][12]^{x}}$ 

 $3.0420 = (18/6)(6/12)^{\times}$ (6/12)<sup>×</sup> = 1.014 × lg(1/2) = lg1.014

 $x \approx 0$  Therefore, reaction is zero order w.r.t. H<sup>+</sup>.

[2]

(c) Hence write an overall rate equation for reaction I, stating the units of the rate constant.

Rate =  $k[H_2O_2][I^-]$ Units of k is mol<sup>-1</sup> dm<sup>3</sup> s<sup>-1</sup>

[1]

(d) Suggest, with reasons, which of the following two mechanisms, **A** or **B**, fits the observed kinetics data.

(fast)

(slow)

<u>Mechanism A</u> 2H<sup>+</sup>(aq) + 2I<sup>-</sup>(aq) → 2HI (aq) 2HI(aq) + H<sub>2</sub>O<sub>2</sub> (aq) → I<sub>2</sub>(aq) + 2H<sub>2</sub>O(l)

 $\begin{array}{ll} \underline{\mathsf{Mechanism}\; \textbf{B}} \\ H_2O_2(aq) + I^{-}(aq) \rightarrow H_2O(l) + OI^{-}(aq) & (slow) \\ H^{+}(aq) + OI^{-}(aq) \rightarrow HIO(aq) & (fast) \\ HIO(aq) + I^{-}(aq) + H^{+}(aq) \rightarrow I_2(aq) + H_2O(l) & (fast) \end{array}$ 

#### Mechanism **B**

As rate is proportional to  $[H_2O_2]$  and [I'], only one  $H_2O_2$  molecule and one I' ion are involved in the rate determining step i.e. the slow step.

[2]

(e) With the aid of a sketch of the Boltzmann distribution, explain how an increase in temperature increases the rate of the reaction.

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Increasing temperature increases the average kinetic energy of the reacting particles. Frequency of collision increases. The number of particles with energy  $\ge E_a$  increases. Thus, there is an increase in frequency of effective collision resulting in an increase in rate of reaction.



3 (a) The following diagram shows how the d-orbitals of iron in  $[Fe(H_2O)_6]^{2+}$  complex are split in an octahedral environment.



The arrangement of electrons in the d-orbitals depends on the *spin states* of complexes.

In a 'high spin' state, the electrons occupy all the d-orbitals singly, before starting to pair up in the lower energy d-orbitals.

In a 'low spin' state, the lower energy d-orbitals are filled first, by pairing if necessary, before the higher energy d-orbitals are used.

When the H<sub>2</sub>O ligands in  $[Fe(H_2O)_6]^{2+}$  are changed to CN<sup>-</sup> ligands, the Fe<sup>2+</sup> ion changes its electronic configuration from a 'high spin' state to a 'low spin' state.

(i) Briefly explain why the spin state changes to low spin, when the ligands coordinated to Fe<sup>2+</sup> are changed from H<sub>2</sub>O to CN<sup>−</sup>.

Being a stronger field ligand, the energy gap  $\Delta E$  caused by CN<sup>-</sup> ligands is larger than that of H<sub>2</sub>O. The energy required to overcome the energy gap,  $\Delta E$ , in adding subsequent electrons to the higher energy d-orbitals is greater than that required to overcome inter-electronic repulsion by pairing the electrons in lower energy d-orbitals. Thus, the lower energy d-orbitals are <u>filled first</u>, before higher energy d-orbitals are used (i.e. 'low spin' state).

(ii) Use diagrams to show the electronic distribution in the d-orbitals in the complexes  $[Fe(H_2O)_6]^{2+}$  and  $[Fe(CN)_6]^{4-}$  respectively.



(iii) Many transition elements and their compounds are paramagnetic, which means that they are attracted to a magnetic field. This property is due to the presence of **unpaired electron(s)** in the d–orbitals.

The table below compares the relative paramagnetism of  $[V(H_2O)_6]^{2+}$ ,  $[Fe(H_2O)_6]^{2+}$  and  $[Fe(CN)_6]^{4-}$ .

formula of complex	relative paramagnetism
$[V(H_2O)_6]^{2+}$	3
[Fe(H <sub>2</sub> O) <sub>6</sub> ] <sup>2+</sup>	4
[Fe(CN) <sub>6</sub> ] <sup>4–</sup>	X

With reference to (ii), explain the relative paramagnetism for  $[V(H_2O)_6]^{2+}$  and  $[Fe(H_2O)_6]^{2+}$ . Hence, suggest a value of **x** in the table above, giving your reasoning.

The strength of paramagnetism depends on the <u>total number of unpaired</u> <u>electrons</u>. (The relative paramagnetism in  $[Fe(H_2O)_6]^{2+}$  is 4, when its number of unpaired electrons is 4.)

As the <u>number of unpaired electrons in  $[V(H_2O)_6]^{2+}$  is 3</u>, its relative paramagnetism is thus 3.

The value of x is <u>0</u> because  $[Fe(CN)_6]^{4-}$  has <u>no unpaired electrons</u>, thus its relative paramagnetism is 0.

[6]

(b) A student was given a solution containing iron(II) and zinc(II) ions and was tasked to separate the two cations such that each cation is present in its **solid** state. He proposed and carried out the following reactions.

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To the solution in a test-tube, NaOH(aq) was added in excess. A green precipitate was obtained. Filtering the mixture gave a green residue and a colourless filtrate. When  $HNO_3(aq)$  was added to the colourless filtrate, a white precipitate was obtained.

(i) Suggest the identity of the green precipitate and state the formula of the compound in the colourless filtrate.

identity of green precipitate: Fe(OH)<sub>2</sub>

formula of the compound in the colourless filtrate:  $Na_2[Zn(OH)_4]$ 

(ii) Give the identity of the white precipitate. With the aid of an appropriate equation, explain why the addition of  $HNO_3(aq)$  to the filtrate causes the white precipitate to form.

White precipitate is  $Zn(OH)_2$ .

 $Zn(OH)_2(s) + 2OH^{-}(aq) \rightleftharpoons Zn(OH)_4^{2-}(aq) ----- eqm 1$ 

When  $HNO_3$  is added,  $H^+$  from the acid reacts with  $OH^-$  present, causing the  $[OH^-]$  to decrease. By Le Chatelier's principle, eqm 1 shifts to the left, forming the white precipitate of  $Zn(OH)_2$ .

[4]

(c) Anodising is the process to increase the thickness of the oxide layer on the surface of metal artefacts so as to increase the resistance of the metal to corrosion and to allow the application of dyes.

An aluminium mobile phone casing with a surface area of 200 cm<sup>2</sup> is to be anodised. Given that the density of  $Al_2O_3$  is 4.0 g cm<sup>-3</sup>, calculate the total quantity (in coulombs) of electricity that will be required to increase the thickness of the oxide layer on the casing by 0.2 mm.

Volume of  $Al_2O_3$  deposited = surface area x thickness = 200 x (0.2/10) = 4.00 cm<sup>3</sup> Mass of  $Al_2O_3$  deposited = 4.0 x 4.00 = 16.0 g

Amount of  $Al_2O_3$  deposited = 16.0 / [2(27.0) + 3(16.0)] = 0.1568 mol During anodising,  $2H_2O \rightarrow O_2 + 4H^+ + 4e$   $4Al + 3O_2 \rightarrow 2Al_2O_3$ Hence, 2 mol of  $Al_2O_3 \equiv 3$  mol of  $O_2 \equiv 12$  mol of  $e^-$ 

Amount of e<sup>-</sup> needed to deposit 0.1568 mol of  $Al_2O_3 = 0.1568 \times 6$ = 0.9411 mol

Total charge =  $nF = 0.9411 \times 96500 = 9.08 \times 10^4 C$ 

[4]

[Total: 14]

**4** (a) On heating, a solid sample of phosphorus pentachloride is completely vaporised in a 2 dm<sup>3</sup> vessel. At 227 °C, the following equilibrium is set up:

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

The partial pressure of  $Cl_2$  at equilibrium is found to be 2.00 atm. Given that the equilibrium constant,  $K_p$ , is 1.01 atm,

(i) write an expression for the equilibrium constant,  $K_p$ , for this reaction,

$$\mathcal{K}_{p} = \frac{\left(\mathcal{P}_{PCl_{3}}\right)\left(\mathcal{P}_{Cl_{2}}\right)}{\left(\mathcal{P}_{Cl_{5}}\right)}$$

(ii) calculate the total pressure of the system at equilibrium,

$$\begin{aligned} & \mathcal{K}_{\rm p} = 1.01 \text{ atm} \\ & \frac{(2)(2)}{P_{\rm Cl_5}} = 1.01 \\ & P_{\rm Cl_5} = 3.960 \text{ atm} \end{aligned}$$

Total pressure of system = 3.960 + 2.00 + 2.00 = 7.96 atm

(iii) calculate the mass of the solid  $PCl_5$  placed in the vessel initially.

	$PCl_5(g)$	← PC <i>l</i> <sub>3</sub> (g) +	- Cl <sub>2</sub> (g)	
Initial pressure /atm	X	0	0	
Change in pressure /atm	-2	+2	+2	
Eqm pressure /atm	3.96	2	2	

Initial pressure of  $PCl_5 = x = 3.96 + 2 = 5.96$  atm

Let mass of PCl<sub>5</sub> be m.  

$$pV = nRT = \left(\frac{m}{M_r}\right)RT$$
  
5.96 x 101 x 10<sup>3</sup> x 2 x 10<sup>-3</sup> =  $\left(\frac{m}{208.5}\right)$ x 8.31 x (227 + 273)  
m = 60.4 g  
[5]

- (b) Phosphorus pentachloride is a useful chlorinating agent for organic synthesis. Using phosphorus pentachloride in one of the steps, propose synthetic routes starting from propan-1-ol to the following compounds.
  - (i) propanamide

$$\begin{array}{cccc} \mathsf{CH}_{3}\mathsf{CH}_{2}\mathsf{CH}_{2}\mathsf{OH} & \xrightarrow{\mathsf{KMnO}_{4}, \, \mathsf{H}_{2}\mathsf{SO}_{4}(\mathsf{aq})} \\ & & & & & \\ & & & \\ & & & & \\ & & & & \\ & & & \\ & & & & \\$$

(ii) butanoic acid

$$\begin{array}{cccc} \mathsf{CH}_{3}\mathsf{CH}_{2}\mathsf{CH}_{2}\mathsf{O}\mathsf{H} & \stackrel{\mathsf{PC}l_{5}}{\longrightarrow} & \mathsf{CH}_{3}\mathsf{CH}_{2}\mathsf{CH}_{2}\mathsf{C}l & \stackrel{\mathsf{KCN in}}{\underset{\mathsf{ethanol}}{\overset{\mathsf{ethanol}}{\overset{\mathsf{heat}}{\overset{\mathsf{heat}}{\overset{\mathsf{heat}}{\overset{\mathsf{H}_{2}}{\overset{\mathsf{C}}\mathsf{H}_{2}}\mathsf{CH}_{2}\mathsf{C}\mathsf{H}_{2}}\mathsf{CH}_{3}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{H}_{2}}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{H}_{2}\mathsf{C}\mathsf{O}_{2}}\mathsf{H} \\ \end{array}$$

[5]

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- (c) For **each** of the following pairs of compounds, describe a chemical test which would enable you to distinguish between them. State clearly the observations for each compound.
  - (i)  $CH_3CH_2CONH_2$  and  $CH_3CH_2CO_2^-NH_4^+$

To each compound in separate test tubes, add NaOH(aq) at room temperature and test for any gas liberated with moist red litmus.

For CH<sub>3</sub>CH<sub>2</sub>CONH<sub>2</sub>, no gas liberated. Moist red litmus remains.

For  $CH_3CH_2CO_2^{-}NH_4^{+}$ , gas evolved turns moist red litmus blue.



12

To each compound in separate test tubes, add NaOH(aq) and heat. Add aqueous bromine.

For **P**, orange aqueous bromine decolourises and a white precipitate is observed.

For **Q**, orange aqueous bromine remains.

[6]

(d) Arrange the three compounds: CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>, CH<sub>3</sub>CH<sub>2</sub>CONH<sub>2</sub> and NH<sub>3</sub> in order of decreasing basicity. Explain your answer in terms of their structures.

Base strength:  $CH_3CH_2CH_2NH_2 > NH_3 > CH_3CH_2CONH_2$ 

<u>CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub> is more basic than ammonia</u> due to the presence of <u>an</u> <u>electron-donating propyl group</u> which <u>increases the availability of the lone pair</u> <u>of electrons on N for protonation</u>.

CH<sub>3</sub>CH<sub>2</sub>CONH<sub>2</sub> is not basic <u>because of</u> the strong <u>electron-withdrawing effect</u> <u>of the carbonyl group C=O</u> which <u>reduced the lone pair availability</u>, such that the <u>lone pair of electrons on N is not available to accept a proton H<sup>+</sup></u>. The lone pair of electrons on the N atom can also be <u>delocalised</u> with the  $\pi$  electrons of the C=O double bond.

[3]

(e) Glutamine, H<sub>2</sub>NCH(CH<sub>2</sub>CH<sub>2</sub>CONH<sub>2</sub>)CO<sub>2</sub>H, is a non-essential amino acid as it can be synthesised in the body. The intake of glutamine supplements can help athletes to recover at fast speed from excess of physical stress.

The pH change when 1.0 mol  $dm^{-3}$  of NaOH is added to 25 cm<sup>3</sup> of a 1.0 mol  $dm^{-3}$  solution of **protonated** form of glutamine is shown below.

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(i) State the  $pK_1$  and  $pK_2$  values of glutamine.

 $pK_1 = 2.2 - 2.5$  and  $pK_2 = 9.5 - 9.8$ 

(ii) Use the structure of glutamine, and its  $pK_1$  and  $pK_2$  values to suggest the species present at points **G** and **J** in the graph above.

**G**:  $H_3N^+CH(CH_2CH_2CONH_2)CO_2H$ **J**:  $H_3N^+CH(CH_2CH_2CONH_2)CO_2^-$ 

- (iii) Write ionic equations to show how the solution at point **H** is able to maintain an almost constant pH upon addition of a small amount of
  - I  $H^+(aq)$  ions

 $H_3N^+CH(CH_2CH_2CONH_2)CO_2^- + H^+ \rightarrow H_3N^+CH(CH_2CH_2CONH_2)CO_2H$ 

II OH<sup>-</sup>(aq) ions

 $H_3N^+CH(CH_2CH_2CONH_2)CO_2H + OH^- \rightarrow H_3N^+CH(CH_2CH_2CONH_2)CO_2^- + H_2O$ 

[5]

[Total: 24]

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**5** *Terfenadine* is an antihistamine which was originally used for the treatment of allergies. However, it was withdrawn from the market in 1997 due to its side effect of affecting the heart's rhythm which may result in cardiac arrest.

The structure of the drug is given below.



- (a) Draw the structural formulae of the **organic products** when *Terfenadine* undergoes each of the following reactions.
  - (i) heated over aluminium oxide.



(ii) heated under reflux with hot acidified dichromate(VI) ions.



[2]

(b) Name the type of reaction that occurs in the reaction in (a)(i).

elimination

(c) State the type of isomerism exhibited by *Terfenadine,* and give one further piece of relevant information about it.

**Optical isomerism** 

Requirement for optical isomerism: Presence of <u>at least 1 chiral carbon</u> and <u>absence of plane of symmetry in molecule</u>.

[2]

[Total: 5]

**6** Compound **C** has the molecular formula  $C_8H_6O_4$ . It is an aromatic compound which contains three functional groups.

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

reaction	reagent	result
1	neutral FeCl <sub>3</sub> (aq)	violet complex formed
2	Br <sub>2</sub> (aq) in an excess	Br <sub>2</sub> is decolourised; white solid formed with $M_r$ = 323.8
3	2,4-dinitrophenylhydrazine	orange precipitate formed
4	PCl <sub>5</sub>	white fumes and a neutral cyclic compound <b>D</b> formed with $M_r = 148$
5	Na	colourless gas evolved. When 0.1 mol of <b>C</b> is reacted with excess sodium metal, 2.4 dm <sup>3</sup> hydrogen is formed, measured at room temperature and pressure.

(a) Name the functional group that reaction 1 shows to be present in C. [1]

phenol

(b) Name the functional group that reaction **3** shows to be present in **C**. [1]

aldehyde or ketone

- 16
- (c) Based on reaction 5 and your answer in (a) and (b), deduce the identity of the third functional group present in C.

Amount of  $H_2$  formed from 0.10 mol of C = 0.10 mol

Mole ratio of  $\mathbf{C}$  :  $\mathbf{H}_2 = 1$  : 1

1 mole of **C** reacts with Na to give 1 mole of H<sub>2</sub>, **C** contains 2 OH groups.

**C** contains phenol (1 OH), it must contain <u>either 1 ROH or 1  $CO_2H$ </u> group that reacted with Na.

As **C** contains 4 O atoms, 1 O atom is from phenol, 1 O atom is from aldehyde or ketone, there are <u>2 O atoms left for the third functional group</u>. Thus, the third functional group in **C** is <u>carboxylic acid</u>.

[2]

(d) Deduce the molecular formula of the product formed in reaction 2.

 $C_8H_4O_4Br_2$   $M_r$  of compound **C** = 166  $M_r$  of product = 323.8 Difference in  $M_r$  = 157.8 Number of Br atoms in product = 2



[1]

(e) Draw the fully displayed structures of C and D.



[2]

[Total: 7]

#### End of Paper

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