CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

9647/02

Paper 2 Structured Questions

Monday 22 August 2016
2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do **not** use staples, paper clips, or correction fluid.

Answer **all** questions.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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 1			/40
Paper 2	**Q 1**	/12	
	Q 2	/15	
	Q 3	/15	
	Q 4	/15	
	Q 5	/15	/72
Paper 3	**Q 1**	/20	
	Q 2	/20	
	Q 3	/20	
	Q 4	/20	
	Q 5	/20	/80
Total			/192

This document consists of **16** printed pages.

For Examiner's Use

1 Planning (P)

One method of studying the kinetics of a chemical reaction, to find the order of reaction with respect to a particular reactant, is to measure the initial rates, by using the 'clock experiment'.

To determine the initial rate, we can measure the time taken for a prominent visual change to occur in the course of a reaction.

When aqueous sodium thiosulfate, $Na_2S_2O_3$, is added to a solution containing dilute hydrochloric acid, HC*l*, a fine, pale yellow precipitate of solid sulfur will be formed after a while. This is the prominent visual change that can be clearly identified.

The overall equation for the reaction is represented as follows:

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(g) + H_2O(l)$$

The initial rate of this reaction is determined by measuring the time taken for sufficient precipitate of sulfur to be formed to just obscure a 'cross' marked on a piece of white paper below a reaction container.

A student carried out a series of preliminary experiments, using approximate volumes of the two reactants and each reaction mixture was made up to the same total volume with deionised water. The student found that the time taken for the pale yellow precipitate to appear doubled when the volume of hydrochloric acid added was halved.

(a) (i) State the relationship between the initial rate of reaction and the time taken for the pale yellow precipitate to appear.

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.....[1]

(ii) Explain why it is necessary to top up the reaction mixture with deionised water to the same total volume.

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.....[1]

(b) Hence, based on the results of the student's preliminary experiments, predict the order of the reaction with respect to H^+ ions.

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.....[1]

(c) You are to design an experiment to study the kinetics of the reaction between $S_2O_3^{2-}$ ions and H^+ ions.

The following data in tabulated form is shown below.

experiment	volume of 1.00 mol dm^{-3} $Na_2S_2O_3$ / cm^3	volume of 1.00 mol dm^{-3} HC*l* / cm^3	volume of deionised water / cm^3	time taken for the 'marked cross' to be obscured / s
1	10	20	20	t_1
2		20		t_2
3	10			t_3

(i) Fill in the blanks in the table above, appropriate volumes of the reactants and deionised water to be used in experiments 2 and 3 such that the order of reaction with respect to $S_2O_3^{2-}$ and H^+ ions can be determined and verified. [1]

(ii) Outline in a series of numbered steps, how **experiment 1** could be carried out. Your **plan** should include:

- the **apparatus** used to measure the various volumes,
- the **order** that the various solutions are mixed,
- how the **time** to determine the rate of reaction is measured, and
- other **experimental details** to ensure the **consistency** of the experiment.

Based on the table in **(c)(i)**, explain how the results of any two of the three experiments can be used to determine the order of reaction with respect to $S_2O_3^{2-}$ ions.

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For Examiner's Use

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(d) Identify one potential safety hazard in this experiment and state how you would minimise this risk.

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....[1]

[Total: 12]

For Examiner's Use

2 Silver halides (silver chloride, silver bromide and silver iodide) are useful in qualitative analysis as they are insoluble in water. In qualitative analysis, silver nitrate is added to a test solution to identify the presence of halide ions by forming a precipitate.

(a) (i) When aqueous silver nitrate was added to a test solution which was known to contain a halide ion, a cream precipitate was formed.

Identify the precipitate and deduce the identity of the halide ion present in the solution.

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.....[1]

(ii) To confirm the identity of the halide, aqueous ammonia was added dropwise, and the precipitate remained unchanged at first, but as more ammonia was added, the precipitate dissolved.

With the aid of an equation, briefly explain why the precipitate dissolved.

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.....[2]

(iii) Draw the structure of the silver-containing product in solution after the precipitate dissolved, displaying any lone pair of electrons where appropriate.

[1]

In photography, after an image is developed, sodium thiosulfate, $Na_2S_2O_3$, is used to dissolve any remaining silver halide away, to "fix" the image and ensure that it does not change upon further exposure to light.

(iv) An equal volume of sodium thiosulfate was added to the solution from **(ii)**. State the type of reaction that occurred when sodium thiosulfate was added.

.....[1]

(v) Suggest the identity of the silver-containing product which has a coordination number of 2.

.....[1]

For Examiner's Use

(b) The table below shows data about silver and two other metals, iron and copper.

	silver	iron	copper
electronic configuration	[Kr] $4d^{10}5s^1$	[Ar] $3d^6 4s^2$	[Ar] $3d^{10}4s^1$
conductivity at room temperature/ S m^{-1}	6.3×10^7	1.0×10^7	?

(i) Explain, in terms of structure and bonding, why the three metals have **high** electrical conductivity.

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.....[2]

(ii) Silver and copper are known to be excellent metallic conductors at room temperature. Noting the electronic configuration, suggest the value of the conductivity of copper at room temperature.

..... S m^{-1} [1]

(iii) Iron is used as a catalyst in the synthesis of ammonia in the Haber process. State the type of catalysis and explain clearly how it carries out its function.

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.....[3]

For Examiner's Use

(c) When a jar is filled with gaseous hydrogen iodide, HI, and a red-hot glass rod inserted into the jar, violet fumes are observed.

(i) State the identity of the violet fumes.

.....[1]

(ii) When the same procedure is carried out with HBr instead of HI, no fumes are observed, but on strong heating, reddish-brown vapour is obtained.

With reference to values in the *Data Booklet*, explain the difference in the behaviour of HBr and HI.

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.....[2]

[Total: 15]

For Examiner's Use

3 Methanol is one of the alternative fuels proposed to replace fossil fuels. It has the advantage of more efficient production and ease of storage as compared to other alternatives.

Methanol can be formed from carbon monoxide and hydrogen as shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The reaction was investigated by mixing 3.2 mol of CO and 3.2 mol of H_2 in a 10.0 dm^3 sealed vessel, and equilibrium was established at 120 °C under a pressure of 1.60×10^6 Pa.

(a) (i) Assuming ideal gas behaviour, determine the total amount of gas in moles, at equilibrium.

[2]

(ii) Hence, calculate the amounts of CO, H_2 and CH_3OH in moles, present at equilibrium.

[3]

(iii) Write an expression for the equilibrium constant, K_c for the above reaction, and use your answers in **(a)(ii)** to calculate its value under the stated conditions.

[2]

For Examiner's Use

(b) Standard Gibbs free energy change, $\Delta G^{\ominus}$ is related to K_c by the following equation.

$$\Delta G^{\ominus} = - RT \ln K_c$$

where $\Delta G^{\ominus}$ is in **joules per mole,** T is the temperature at which equilibrium is established and R is the molar gas constant.

(i) Use this equation and your answer in **(a)** to calculate $\Delta G^{\ominus}$ for the formation of methanol from carbon monoxide and hydrogen at 120 °C.

[1]

(ii) With reference to the *Data Booklet*, calculate the enthalpy change of formation of methanol from carbon monoxide and hydrogen. Use 1072 kJ mol^{-1} for the bond energy of C≡O bond.

[2]

(iii) Hence, state briefly why higher temperature is not used industrially for the formation of methanol from carbon monoxide and hydrogen.

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.....[2]

(iv) Use your answers in **(b)(i)** and **(ii)** to calculate the standard entropy change for the reaction at 298 K.

[1]

For Examiner's Use

(v) Explain the significance of the sign of the calculated entropy change and comment if this is expected.

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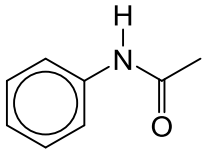
.....[2]

[Total:15]

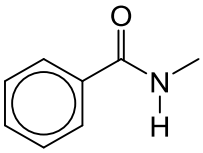
For Examiner's Use

4 **(a)** Acetanilide was the first aniline derivative found to possess analgesic and antipyretic properties. It was introduced into medical practice under the name of the drug, Antifebrin.

Suggest the reagents and conditions that can be used to distinguish acetanilide from compound **X**. State clearly the expected observations for each compound.



Acetanilide



Compound **X**

Reagents and conditions ……..

……..……..……

Observations ……..……

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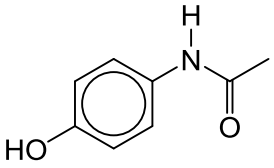
……..……..……[2]

(b) It was later discovered that acetanilide was toxic and thus paracetamol, a derivative of acetanilide, was produced.



Paracetamol

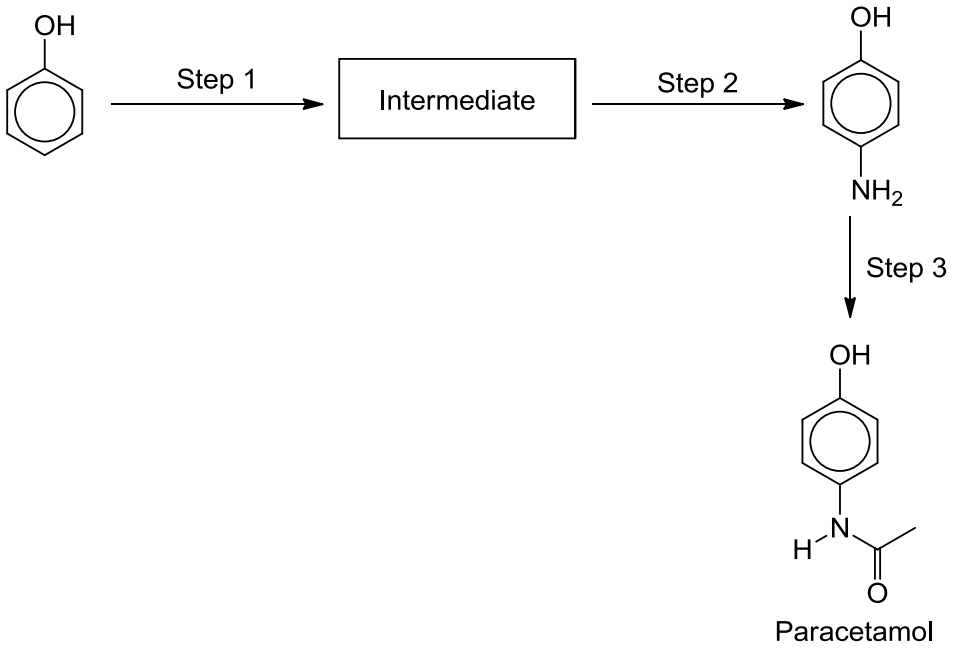
(i) State the shape about N atom in paracetamol and hence identify the type of hybridisation involved.

Shape about N atom ……..

Hybridisation of N …….. [2]

For Examiner's Use

(ii) A reaction scheme was proposed for the synthesis of paracetamol from phenol. Fill in the boxes provided with the reagents, conditions and intermediates for the synthesis.



Reagents and conditions:

Step 1 ……

Step 2 ……

Step 3 ……

Structure of intermediate:

[4]

(iii) In the synthesis of paracetamol from phenol, two possible side-products, compound **Y** and **Z**, are formed. Given that only compound **Y** is a position isomer of paracetamol, suggest the identities of compound **Y** and **Z**.

Compound **Y**

Compound **Z**

[2]

For Examiner's Use

(iv) Predict, with explanation, how the boiling point of paracetamol might compare to that of compound **Y**.

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.....[2]

(c) In a typical pain relief tablet, there are 500 mg of paracetamol.

(i) An adult can consume up to a maximum dosage of 4000 mg of paracetamol within 24 hours. The average adult weight is 62 kg. Calculate the number of tablets a child who weighs 45 kg, can consume within 24 hours. (Maximum dosage is dependent on weight of an individual.)

[2]

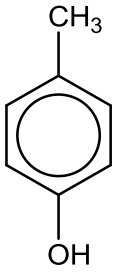
(ii) It was recommended to consume the tablets at 6 hours intervals. Using your answer in **(c)(i)**, calculate the recommended number of tablets the child should take at each interval without exceeding dosage.

[1]

[Total: 15]

For Examiner's Use

5 The compound *p*-cresol is used in the production of antioxidants. It is also used in the fragrance and dye industries.



p-cresol

(a) Draw the displayed formula of a functional group isomer of *p*-cresol, and describe a laboratory test that will distinguish these two compounds. You should state the reagents used and the observations expected.

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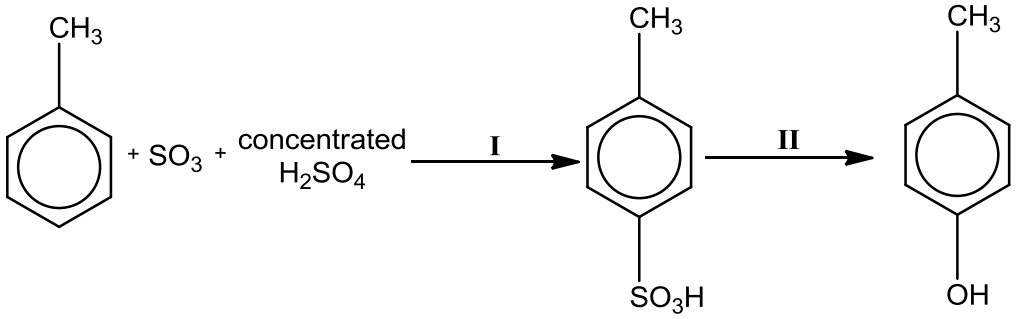
.....[3]

(b) *p*-Cresol can be prepared industrially by a 2-step process as shown below.



p-toluenesulfonic acid *p*-cresol

Reaction **I** involves sulfonation of methyl benzene to give *p*-toluenesulfonic acid. The proposed mechanism of reaction **I** involves electrophilic substitution.

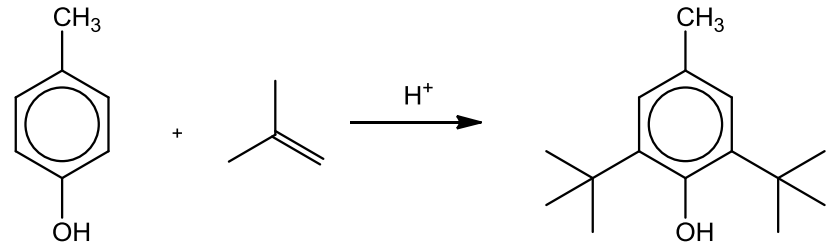
(i) The first step of the proposed mechanism of reaction **I** involves acid-base reaction in the generation of an electrophile, HSO_3^+. Write an equation to show how the electrophile HSO_3^+ is formed.

.....[1]

(ii) Complete the proposed mechanism to produce *p*-toluenesulfonic acid as shown above. In the mechanism, show clearly the curly arrows to indicate the movement of electrons and all charges.

[3]

(c) *p*-Cresol is used in the production of antioxidants such as butylated hydroxytoluene, BHT, which is mainly used as an antioxidant in the food industry. The reaction involves a dialkylation of *p*-cresol with 2-methylpropene in the presence of an acid catalyst given below.



p-cresol 2-methylpropene BHT

(i) Draw a labelled diagram to show how the orbitals overlap to form the C=C bond in 2-methylpropene and state the type of hybridisation involved.

[1]

Type of hybridisation: .....[1]

(ii) Explain why 2-methylpropene cannot exhibit geometric isomerism.

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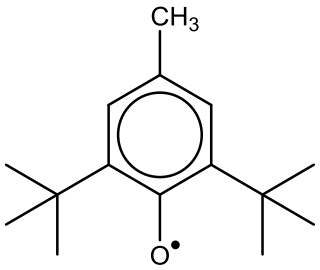
.....[1]

(iii) In order for BHT to act as an antioxidant, it forms a very stable radical on the oxygen atom as shown below. Suggest an explanation why this stable BHT radical is unable to react further with other molecules.



BHT radical

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.....[1]

(iv) Compound **R**, $C_{14}H_{20}O_2$, is a metabolite derived from the biotransformation of BHT. It is structurally related to BHT, $C_{15}H_{24}O$, and is also a cyclic compound.

State the type of reaction and deduction for the following observations.

I 1 mole of Compound **R** will react with 2 moles of 2, 4-DNPH.

Type of reaction:.....

Deduction: .....[1]

II Compound **R** will not react with Tollens' reagent.

Deduction: .....[1]

III 1 mole of compound **R** will decolourise 2 moles of aqueous Br_2 but no HBr is formed.

Type of reaction:.....

Deduction: .....[1]

IV Deduce the structure of compound **R**.

[1]

[Total: 15]