



CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE
NAME

CLASS

2T

CHEMISTRY

Paper 2 Structured Questions

9647/02

Monday 26 August 2013

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 on both sides of the paper. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]

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 of the question.

	For Examiner's Use	
Paper 1		40
Paper 2	Q 1	12
	Q 2	15
	Q 3	4
	Q 4	11
	Q 5	17
	Q 6	13
Paper 3	Q 1	20
	Q 2	20
	Q 3	20
	Q 4	20
	Q 5	20
Total		192

This document consists of **17** printed pages and **1** blank page.

[Turn over

1 Planning (P)

Natural water that contains calcium and magnesium ions is said to be 'hard'. Tap water in England is hard water, which is evident from the limescale found in kettles.

The main source of calcium and magnesium ions in hard water is limestones. However, neither calcium carbonate nor magnesium carbonate is appreciably soluble in water. It is said that the solubility is partly the result of carbon dioxide present in rain water.

You are to design an experiment to investigate whether the presence of carbon dioxide in water, indeed, increases the solubility of magnesium carbonate.

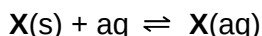
In addition to the standard apparatus available in a school laboratory, you are provided with the following materials,

- magnesium carbonate
- distilled water
- distilled water saturated with carbon dioxide
- methyl orange indicator
- phenolphthalein indicator
- standard hydrochloric acid

- (a) Write an expression for the solubility product, K_{sp} , of magnesium carbonate, stating its units.

.....[1]

- (b) When a solution is saturated, the undissolved solid is in equilibrium with its aqueous solution.



Describe briefly how you would prepare a saturated solution of magnesium carbonate at room temperature.

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.....[3]

(c) The concentration of a saturated solution of magnesium carbonate may be determined by titration with standard hydrochloric acid.

(i) Given that, at room temperature, K_{sp} of magnesium carbonate has a numerical value of 6.82×10^{-6} , suggest an appropriate concentration of the standard hydrochloric acid to be prepared. Show your working.

(ii) Name the indicator used in this titration.

..... [4]

(d) Describe what further experiments you would carry out to show that solubility of magnesium carbonate is increased by the presence of carbon dioxide in water. State clearly the volume of solution used and the expected results.

[3]

(e) Recently phenolphthalein is classified as a carcinogen and is banned from use in the school laboratory. Suggest a suitable replacement for phenolphthalein indicator from the list below.

indicator	colour (lower pH)	pH range	colour (upper pH)
congo red	blue	3.0 – 5.0	red
methyl red	red	4.8 – 6.0	yellow
phenol red	yellow	6.4 – 8.2	red-violet
cresol red	yellow	7.1 – 8.8	violet

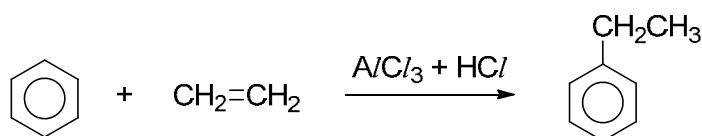
..... [1]

[Total: 12]

- 2 Ethylbenzene is a highly flammable and colourless liquid. It is important in the petrochemical industry as an intermediate in the production of styrene which is a precursor for polystyrene, a common plastic material.

Ethylbenzene has a characteristic gasoline odour with an odour threshold, which is the lowest concentration of a compound detectable by smell, of 2.3 parts per million (ppm). It also has density of 0.866 g cm^{-3} and boiling point of 136°C .

- (a) Ethylbenzene can be produced by combining ethene with benzene in an acid-catalysed reaction as shown below.



- (i) Name the mechanism for this reaction.

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- (ii) The first step of the mechanism involves the reaction between AlCl_3 and HCl . Show clearly how ethene interacts with the species formed from the first step to generate the attacking species for subsequent reaction with benzene. You should include in your answer curly arrows to depict electron movement and all charges.

- (iii) Suggest why 1,4-diethylbenzene is also formed in the overall reaction.

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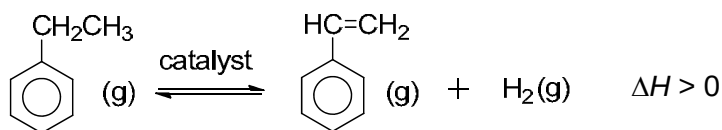
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- (iv) If a room has dimensions of $5 \text{ m} \times 4 \text{ m} \times 3 \text{ m}$, calculate the minimum mass of ethylbenzene that would be present before its odour is detected.

[6]

- (b) Ethylbenzene can reversibly undergo catalytic dehydrogenation at 600 °C and 0.5 bar in the presence of a solvent to form styrene. [1 bar = 1×10^5 Pa]



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

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- (ii) Under the conditions used for the reaction, 0.0200 g of the equilibrium mixture occupies 38.0 cm³. Calculate the average relative molecular mass of the gaseous mixture, giving your answer to 1 decimal place.

- (iii) Assuming the mole fraction of styrene and hydrogen gas is the same at equilibrium, and using your answer in (b)(ii), calculate the proportion of ethylbenzene, styrene and hydrogen gas present in the equilibrium mixture.

(iv) Hence, calculate the value of K_p for the dehydrogenation of ethylbenzene at 600 °C, giving its units.

(v) State and explain the effect of an increase in temperature on the K_p for the dehydrogenation of ethylbenzene.

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[9]

[Total: 15]

- 3 “Every drop of Evian Natural Spring Water begins as rain and snow falling high in the pristine and majestic French Alps.”

Bottled water has become big business due to a growing number of consumers preferring bottled water to tap water. Statements advertising bottled water tends to convey images of purity and natural processes.

The label of an Evian mineral water bottle shows the following:

pH = 7.1	
Mineral content	Amount per L (mg dm ⁻³)
Aluminium	trace
Calcium	80
Magnesium	26
Potassium	1
Bicarbonate	360
Chloride	6.8
Nitrate	3.7
Sulfate	35

- (a) Suggest the ions which will be precipitated when excess alkali is added to the mineral water.

..... [1]

- (b) Describe, with the use of suitable equations, what happens to the aluminium ions in the water sample as alkali is added slowly until in excess.

[2]

- (c) A student carried out an electrolysis using a sample of Evian water. Write an ion-electron equation for the reaction at the cathode assuming an inert electrode was used.

..... [1]

[Total: 4]

- 4 Chlorine containing inorganic compounds have often been used as bleaching or disinfecting agent. An example is chlorine dioxide, ClO_2 .

(a) Chlorine dioxide can exist in both the anionic form, ClO_2^- , as well as the cationic form, ClO_2^+ .

(i) Calculate the oxidation state of chlorine in each of the species.

ClO_2 : ClO_2^+ : ClO_2^- :

(ii) Given that chlorine is the central atom, draw the dot-and-cross diagram for each of the species. For ClO_2 and ClO_2^+ , predict the $\text{O}-\text{Cl}-\text{O}$ bond angle.

	ClO_2	ClO_2^+	ClO_2^-
Dot-and-cross diagram			
Bond angle			105°

[6]

(b) When a sample of solid sodium chlorite, NaClO_2 , is dissolved in water, the cations and anions are each surrounded by water molecules.

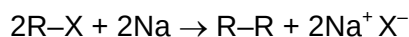
Draw suitable diagrams to illustrate how a water molecule is attached to a sodium ion and a chlorite ion. Include labels in your answer to show the types of interaction involved.

Na^+	ClO_2^-

[2]

Organic compounds containing halogen atoms such as chlorine are very useful in organic reactions.

- (c) Halogenoalkanes can undergo the Wurtz reaction, a coupling reaction where two halogenoalkanes are reacted with sodium to form a new carbon-carbon bond.



- (i) Explain why the reaction does not occur readily when chlorobenzene is used.

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- (ii) When a 1:1 molar mixture of 2-chloropropane and chloroethane is reacted in the presence of sodium, a mixture of three alkanes is formed.

Suggest the structures of these alkanes and the ratio in which they are formed.

Alkane formed			
Ratio			

[3]

[Total: 11]

- 5 Methanoic acid can be oxidised by bromine to form carbon dioxide gas.



A student carried out an experiment to determine the rate of this reaction using a large excess of methanoic acid. During the reaction, reddish-brown colour of bromine fades as it is used up. The change in colour intensity, measured by a colorimeter, can be used to determine the concentration of bromine.

The experimental data obtained is shown in the table below

Time / min	0	1	2	3	4	6	8	10
$[\text{Br}_2] / \text{mol dm}^{-3}$	0.010	0.008	0.007	0.0054	0.0046	0.0029	0.0020	0.0013

- (a) In the experiment, the initial concentration of methanoic acid used was 0.50 mol dm^{-3} . Explain why a large amount of methanoic acid was used in the experiment.

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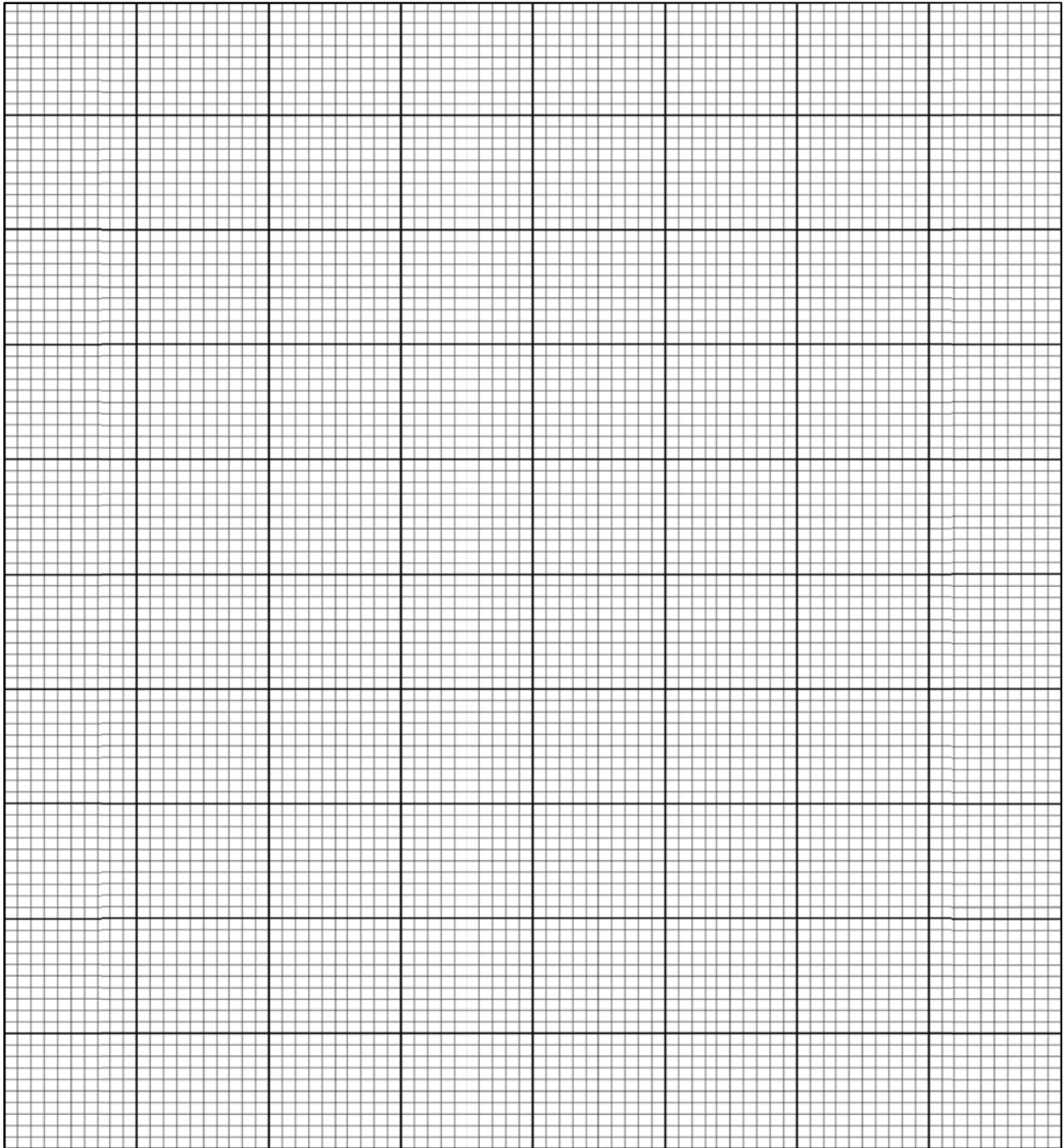
 [1]

- (b) (i) On the grid provided on the next page, plot a suitable graph which you can use to determine the order of reaction with respect to bromine.

- (ii) Using the graph you have drawn in (b)(i), determine the order of reaction with respect to bromine and the initial rate of the reaction. All relevant working should be shown on the graph or in the space provided below.

Order of reaction with respect to Br_2 :

Initial rate of reaction:



[4]

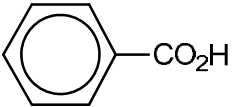
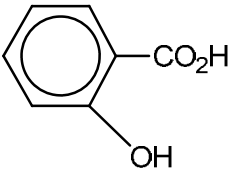
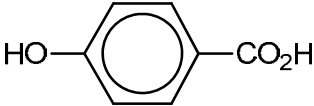
- (c) Write the rate equation for the reaction between bromine and methanoic acid given that the overall order of reaction is 2. Hence, calculate the rate constant for the reaction including its units.

[2]

- (d) Suggest an alternative method which can be used to determine the order of reaction with respect to bromine.

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..... [1]

(e) The following table gives the pK_a values of some carboxylic acids.

Carboxylic Acids	Formula	pK_{a1}	pK_{a2}
ethanoic acid	CH_3CO_2H	4.74	-
2-fluoroethanoic acid	FCH_2CO_2H	2.65	-
2-chloroethanoic acid	$ClCH_2CO_2H$		-
benzoic acid		4.20	-
2-hydroxybenzoic acid		2.97	13.40
4-hydroxybenzoic acid		4.48	9.32

(i) Suggest a value for the pK_a of 2-chloroethanoic acid.

pK_a of 2-chloroethanoic acid is

(ii) With the aid of equations, explain why 2-hydroxybenzoic acid has a higher pK_{a2} than 4-hydroxybenzoic acid.

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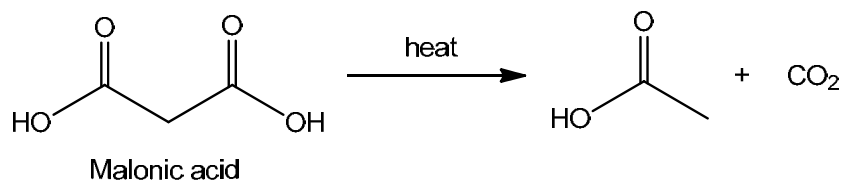
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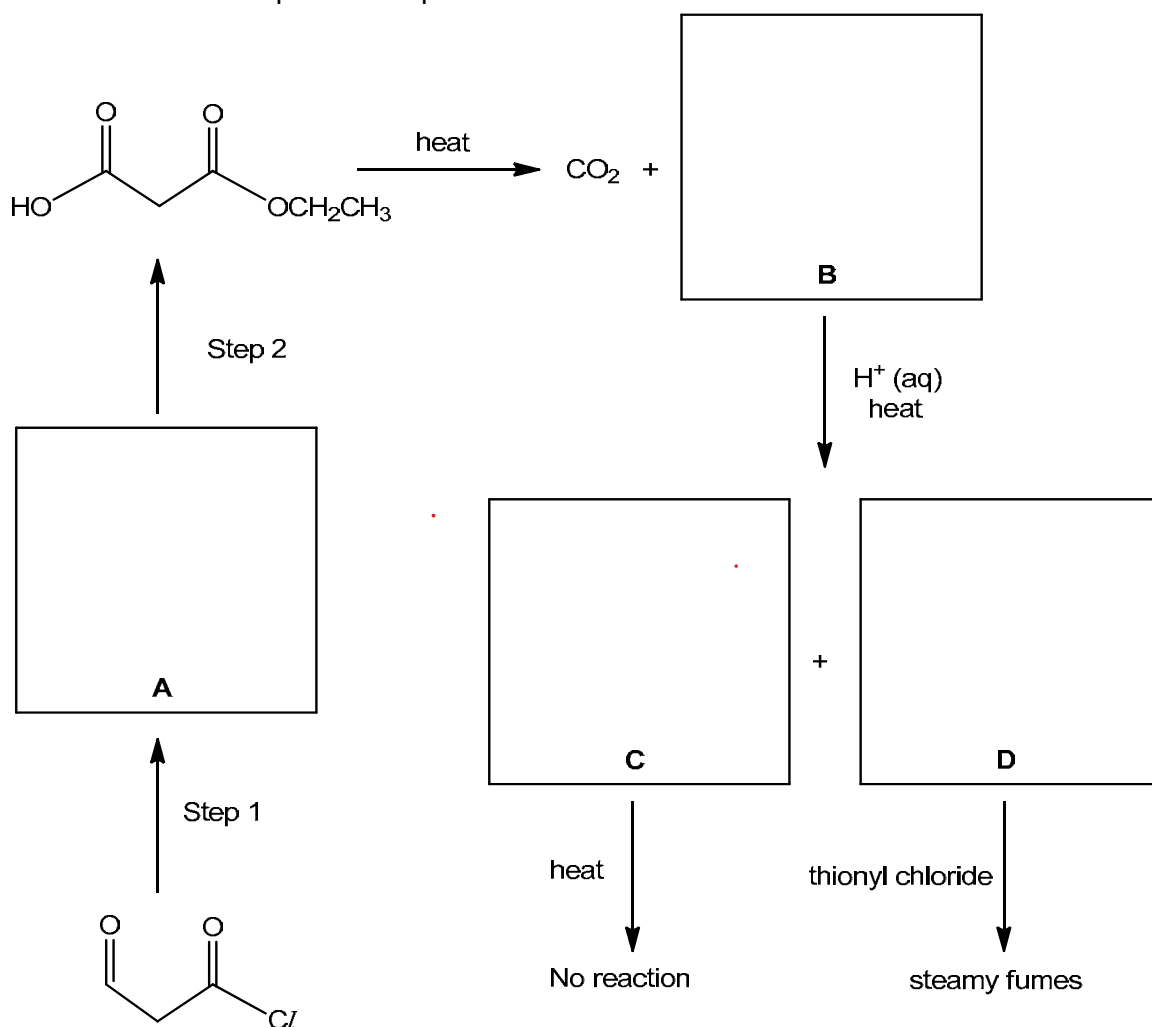
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- (f) Oxidation of carboxylic acids involves the removal of the carbonyl carbon atom as carbon dioxide in a process known as decarboxylation.

Carboxylic acids with a carbonyl carbon at position 3 readily undergo thermal decarboxylation as illustrated by malonic acid.



Simple carboxylic acids such as ethanoic acid rarely undergo such decarboxylation. By using this information and your knowledge of the reactions of carboxylic acids and its derivatives, complete the reaction scheme shown below by drawing the structures of compounds **A** to **D** in the boxes provided. State the reagents and conditions for step 1 and step 2.



Step 1: Reagents:

Conditions:

Step 2: Reagents:

Conditions:

[6]

[Total: 17]

6 Chromium is a typical transition element and it forms many stable coloured complexes that are capable of exhibiting various types of isomerism.

(a) Chromium(III) chloride with the general formula $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ can exist as hydrated isomers which differs in the number of water molecules attached as ligands to the metal ion.

(i) One of the hydrated isomers is $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$. Explain why an aqueous solution of this isomer is green.

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(ii) Suggest the formulae of **two** other possible hydrated isomers of chromium(III) chloride.

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(iii) When aqueous ammonia is added gradually to a solution containing $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$, a grey-green precipitate is formed. When aqueous ammonia is added in excess, the precipitate dissolves to give a purple solution. Explain the observations with the aid of relevant equations, including state symbols.

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[8]

- (b) Certain octahedral transition metal complexes are able to exhibit both geometric (*cis-trans*) and optical isomerism.

Cis-trans isomers are isomers which differ in the arrangement of two ligands.

Cis- isomers are isomers where the two ligands are 90° apart from one another in relation to the central metal ion, whereas *trans*-isomers are isomers where the two ligands are 180° apart in the complex.

- (i) Select a suitable hydrated isomer of chromium(III) chloride which contains a complex ion capable of exhibiting *cis-trans* isomerism. Draw the structures of the two isomers and label clearly which is the *cis*- and *trans*- isomers.

- (ii) Another chromium-containing complex, $[\text{CrCl}(\text{NH}_3)(\text{en})_2]^{2+}$, exists as three isomers. [en: ethylenediamine, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$]

Isomer **A** rotates plane-polarised light to the right.

Isomer **B** rotates plane-polarised light to the left.

Isomer **C** has no effect on the plane-polarised light.

Draw the structures of isomers **A** to **C**.

You may use  to represent ethylenediamine.

A	B
C	

[5]

[Total: 13]