CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

9647/02
Paper 2 Structured Questions
Monday 24th August 2015
2 hours

Candidates answer on the Question Paper
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces provided above.
Write in dark blue or black pen in the spaces provided, on the Question 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	/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

1 Planning (P)

For Examiner's Use

Cream of tartar (potassium hydrogen tartrate, $KHC_4H_4O_6$) is one of the ingredients in baking powder which is used to make cakes rise. Potassium hydrogen tartrate is a weak acid that is not very soluble in water.

$$KHC_4H_4O_6(s) \rightleftharpoons K^+(aq) + HC_4H_4O_6^-(aq)$$

The $HC_4H_4O_6^-(aq)$ ion contains one acidic hydrogen, so the quantity of potassium hydrogen tartrate in solution can be determined by titration with a base.

$$HC_4H_4O_6^-(aq) + OH^-(aq) \rightarrow H_2O(l) + C_4H_4O_6^{2-}(aq)$$

You are to design an experiment to determine the solubility of potassium hydrogen tartrate in two solvent systems: pure water and 0.100 mol dm^{-3} potassium chloride.

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

- potassium hydrogen tartrate
- distilled water
- methyl orange indicator
- phenolphthalein indicator
- standard sodium hydroxide solution

(a) Write an expression for the solubility product, K_{sp}, of potassium hydrogen tartrate, stating its units.

……

[1]

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

$$\mathbf{X}(s) + aq \rightleftharpoons \mathbf{X}(aq)$$

Describe how you would prepare a saturated solution of potassium hydrogen tartrate at room temperature.

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[3]

[Turn over

(c) The concentration of a saturated solution of potassium hydrogen tartrate may be determined by titration with standard sodium hydroxide.

For Examiner's Use

(i) Given that, at room temperature, K_{sp} of potassium hydrogen tartrate has a numerical value of 6.27×10^{-4}, suggest an appropriate concentration of the standard sodium hydroxide solution to be prepared. Show your working.

(ii) Name the indicator used in this titration.

……..
[3]

(d) Describe what further experiments you would carry out to determine the solubility of potassium hydrogen tartrate in 0.100 mol dm^{-3} potassium chloride. State clearly the volume of solution used and the expected observation.

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State and explain how the titration result of this further experiment would compare with that of the solution prepared in **(b).**

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[5]

[Total: 12]

[Turn over

For Examiner's Use

2 Carbon is the fourth most abundant element in the universe by mass after hydrogen, helium and oxygen. It is present in all forms of carbon-based life, and in the human body. This abundance, together with the unique diversity of organic compounds, makes this element the chemical basis of all known life.

(a) (i) Organic compound **P** contains only the elements carbon, hydrogen and oxygen in the following composition by mass: C, 40 %; H, 6.7 %.
Calculate the empirical formula of **P**.

(ii) When a 0.102 g sample of compound **P** was vapourised in a suitable apparatus, the vapour occupied 59 cm^3 at 150 °C and 101 kPa.

Calculate the relative molecular mass of compound **P**, and hence determine its molecular formula.

(iii) Compound **P** gives a silver mirror with Tollens' reagent. Draw the displayed formula of compound **P**.

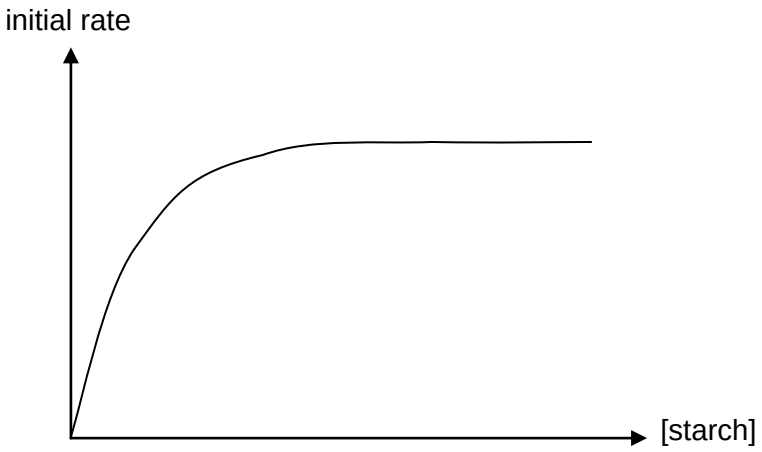
[5]

(b) Starch is another organic compound consisting of carbon, hydrogen and oxygen. The hydrolysis of starch into simpler sugars can be catalysed by the enzyme amylase. Amylase is present in the saliva of humans and acts as a biological catalyst in the digestion of starch.

For Examiner's Use

(i) A few experiments are carried out with different concentrations of starch solution and the initial rates of hydrolysis in the presence of the enzyme, amylase, are measured.

The graph below shows how the initial rates of the hydrolysis reaction in the presence of amylase vary with the concentrations of starch solution.



Explain the relationship between the concentration of substrate and the initial rate of reaction, making reference to the order of reaction with respect to the substrate concentration.

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(ii) On the same graph in **(b)(i)**, sketch another graph to show how the initial rates will vary with the concentrations of starch solution if the concentration of amylase is halved. Label this graph as **(ii)**.

[3]

(c) Allotropes are pure forms of the same element that differ in structure. There are several allotropes of carbon such as graphite and diamond.

For Examiner's Use

A mixture of carbon dioxide reacts with hot graphite according to the equation below:

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \qquad \Delta H = +170 \text{ kJ mol}^{-1}$$

The mixture was allowed to reach dynamic equilibrium at 817 °C in a 2 dm^3 closed vessel. The amount of CO_2, C and CO at equilibrium is given below.

	CO_2	C	CO
Equilibrium amount / mol	0.1	0.7	1.7

(i) What do you understand by the term *dynamic equilibrium*?

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(ii) Write an expression for the equilibrium constant, K_c, of this reaction, stating the units.

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(iii) Use the data given and your answer to **(c)(ii)** to calculate a value for K_c of this reaction.

(iv) State, with reasoning, the effect on the position of equilibrium if

For Examiner's Use

(I) the total volume of the system is increased at 817 °C.

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(II) some of the graphite is removed from the equilibrium mixture.

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(v) The activation energy for the forward reaction is 370 kJ mol^{-1}. Calculate the activation energy, in kJ mol^{-1}, for the reverse reaction.

[7]

[Total: 15]

For Examiner's Use

3 **(a)** Manganese sulfate, $MnSO_4$, which is soluble in water, is commonly used to make fungicide. When the sulfate has dissolved, the anions and cations are each surrounded by a number of water molecules.

(i) Draw a simple diagram to show how a water molecule can be attached to a sulfate anion. Label the type of interaction involved.

The aqueous solution of $MnSO_4$ is pale pink in colour due to the presence of complex ion, $[Mn(H_2O)_6]^{2+}$.

(ii) Draw the structure of the complex ion, $[Mn(H_2O)_6]^{2+}$.

(iii) State the coordination number of the complex ion, $[Mn(H_2O)_6]^{2+}$.

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(iv) Explain why $[Mn(H_2O)_6]^{2+}(aq)$ is pale pink in colour.

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[6]

For Examiner's Use

(b) When aqueous ammonia is added gradually to a pale pink solution of $[Mn(H_2O)_6]^{2+}$, an off-white precipitate is observed which rapidly turns brown on contact with air.

(i) Suggest the identity of the off-white precipitate.

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(ii) Write relevant equations to explain the formation of the off-white precipitate.

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[3]

(c) MnO_2 acts as a heterogeneous catalyst in the decomposition of H_2O_2.

$$2H_2O_2(l) \longrightarrow 2H_2O(l) + O_2(g) \qquad \Delta H^{\ominus} = -196 \text{ kJ mol}^{-1}$$
$$\Delta G^{\ominus} = -224 \text{ kJ mol}^{-1}$$

(i) Use the data to calculate $\Delta S^{\ominus}$ for this reaction and comment on its sign with respect to the equation for the reaction.

(ii) Draw the displayed formula to show the bonding in a hydrogen peroxide molecule. Predict and indicate clearly the bond angle in your diagram.

[3]

[Turn over

(d) Alkaline batteries are often used in portable radios and electric torches. In an alkaline battery, the reaction at the cathode involves the reduction of MnO_2 to Mn_2O_3 while the reaction at the anode is as follows:

For Examiner's Use

$$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$$

(i) State the oxidation number of manganese in Mn_2O_3.

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(ii) Write a half-equation for the reaction that occurs at the cathode.

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(iii) Hence, construct the equation for the overall reaction.

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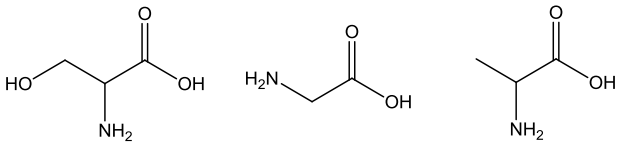
[3]

[Total: 15]

For Examiner's Use

4 **(a)** Silk emitted by the silkworm consists mainly of the insoluble protein fibroin surrounded by a layer of glue-like substance. The protein secondary structure of fibroin consists mostly of layers of anti-parallel beta-pleated sheets and its primary structure is a recurrent 6-amino acid residue sequence consisting of only serine, glycine and alanine.



Partial hydrolysis of fibroin results in the following fragments.

ala-gly-ala , ser-gly-ala, gly-ser

(i) Using the same 3-letter abbreviations as above, write out the recurrent 6-amino acid residue sequence of fibroin based on the information provided.

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(ii) From your answer in **(a)(i)** and the proportion of individual amino acids in the protein structure, suggest why close packing is possible in the polypeptide chain.

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(iii) With reference to the secondary structure of fibroin, describe what is meant by denaturation, clearly making reference to any bonding or interaction involved.

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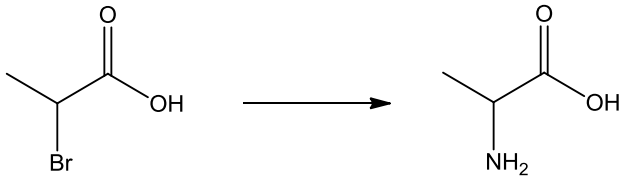
[3]

[Turn over

For Examiner's Use

(b) Alanine is a non-essential amino acid and can be manufactured by the human body. Alanine can also be chemically synthesised from 2-bromopropanoic acid.



2-bromopropanoic acid alanine

(i) State the reagents required to synthesise alanine from 2-bromopropanoic acid.

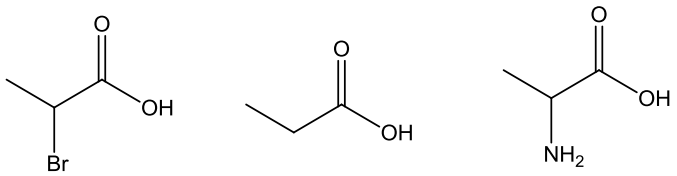
Reagents: ……...

(ii) Identify the inorganic by-product from the reaction shown above.

By-product: ……

The pK_a associated with 2-bromopropanoic acid is 3.00. The two pK_a associated with alanine are 2.35 and 9.69 and its isoelectric point is 6.01.

(iii) Arrange the following compounds in order of decreasing acidity. Explain your answer in terms of their structural properties.



2-bromopropanoic acid propanoic acid alanine

Order of decreasing acidity: ……..……..

Explanation:

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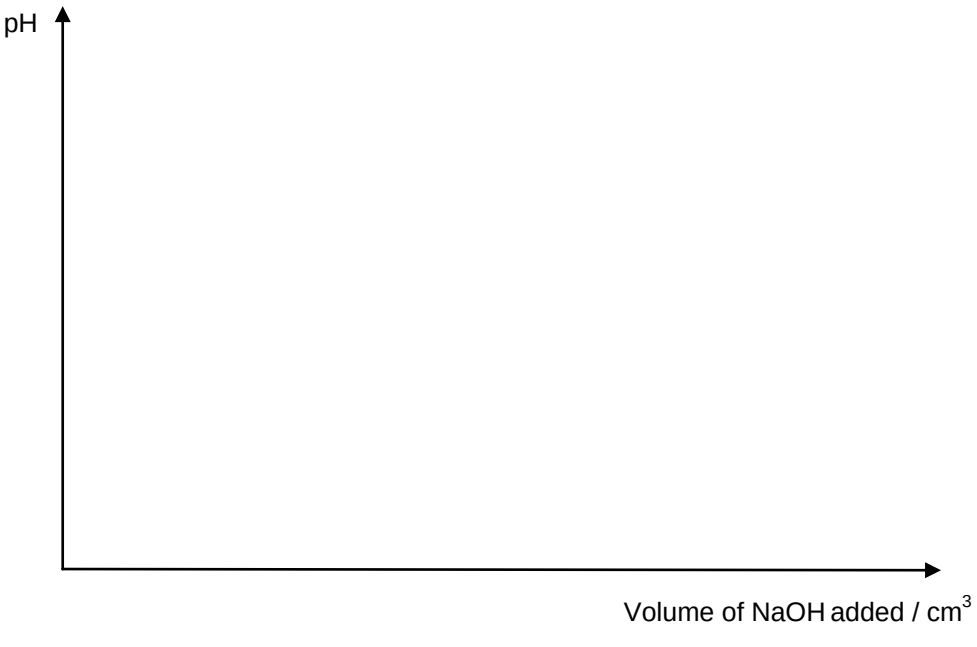
For Examiner's Use

(iv) Write an equation to show how alanine can act as a buffer when a small amount of $OH^-(aq)$ is added at pH 2.35.

(v) Calculate the pH of the resulting solution when 7.5 cm^3 of 0.10 mol dm^{-3} NaOH is added to 10.0 cm^3 of 0.100 mol dm^{-3} of the protonated form of alanine.

(vi) Sketch the pH-volume curve you would expect to obtain when 30 cm^3 of 0.10 mol dm^{-3} NaOH is added to 10 cm^3 of 0.10 mol dm^{-3} of the protonated form of alanine. Show clearly on your curve where the two pK_a values occur and the isoelectric point.



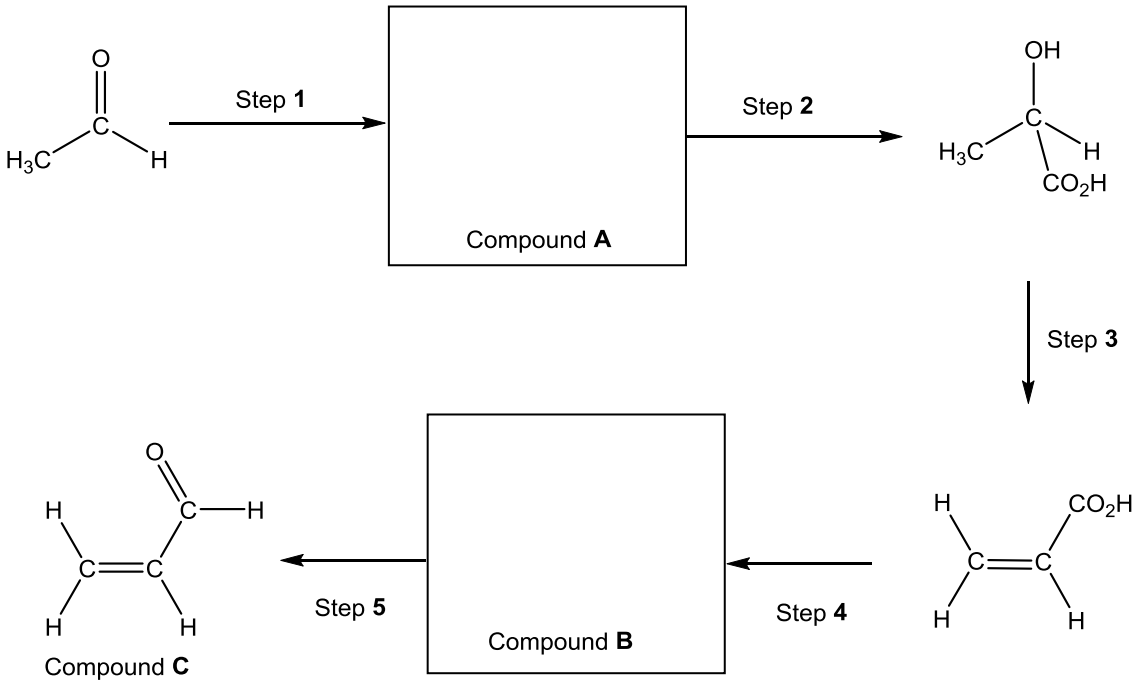
[12]

[Total: 15]

[Turn over

For Examiner's Use

5 **(a)** Compound **C** may be synthesised from ethanal as follows:



State the reagents and conditions required for Steps **3** – **5** and give the structures of the intermediate organic compounds **A** and **B** in the boxes provided.

Reagents and conditions

Step **3** .....

Step **4** .....

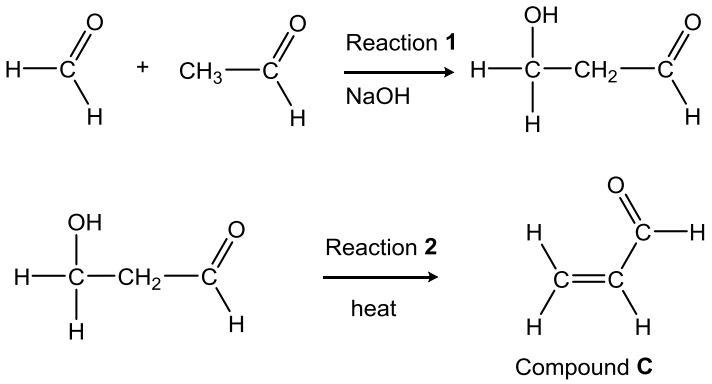
Step **5** .....

[5]

For Examiner's Use

(b) Aldol condensation reaction is a useful method for making new carbon–carbon bonds in organic chemistry. In the presence of a strong base, two carbonyl compounds can undergo the aldol condensation reaction.

The same product, compound **C**, from part **(a)** can also be obtained from ethanal and methanal via the aldol condensation. The reaction proceeds as follows.



(i) Identify the type of reaction occurring in Reaction **2**.

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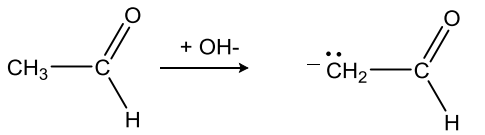
Reaction **1** of the aldol condensation consists of three steps. The first step involves the removal of hydrogen from the alpha carbon of one carbonyl compound to form an enolate ion. The alpha carbon is the carbon adjacent to the carbonyl group.

Step **I**:



(ii) State the type of reaction occurring in Step **I**.

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[Turn over

(iii) Steps **II** and **III** are as follows:

Step **II**: nucleophilic attack on methanal to form an alkoxide ion

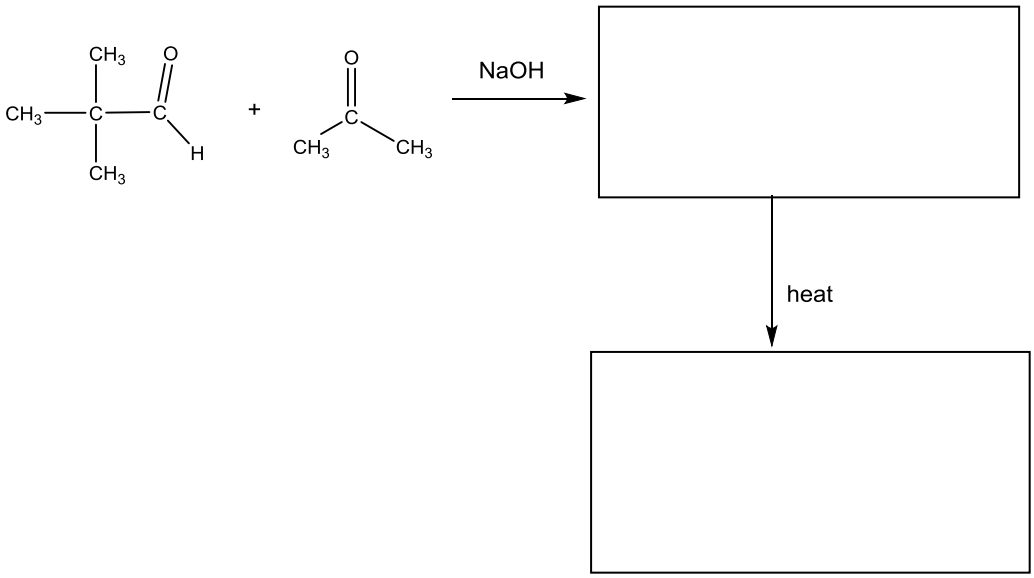
Step **III**: protonation of the alkoxide ion by water

Using the above information, suggest the mechanism for Steps **II** and **III**, showing all charges and using curly arrows to show the movement of electron pairs.

(iv) Given that the negative charge on the enolate ion can be delocalised, draw another possible structure in which the enolate ion can exist as.

For Examiner's Use

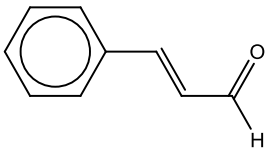
(v) Complete the reaction sequence for the following aldol condensation, by giving the structural formulae for the compounds involved in the boxes provided.



[8]

For Examiner's Use

(c) Cinnamaldehyde is an organic compound that gives cinnamon its flavour and odour. Cinnamaldehyde can also be synthesised in the laboratory via the aldol condensation reaction.



cinnamaldehyde

(i) State the type of stereoisomerism that cinnamaldehyde can exhibit.

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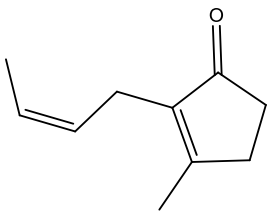
(ii) Jasmone is the active ingredient in jasmine which is used in the perfume industry. The structure of jasmone is shown below.



State the reagents and conditions for a simple chemical test that could be used to distinguish between cinnamaldehyde and jasmone.

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[2]

[Total: 15]