F324: Rings, Polymers and Analysis
4.1.2 Carbonyl Compounds

1. Hydroxyethanal, $HOCH_2CHO$, is sometimes referred to as the 'first sugar' as it is the simplest possible molecule that contains both an aldehyde group and an alcohol group.

A biochemist investigated some redox reactions of hydroxyethanal and found that several different products were produced.

(a) The biochemist reacted hydroxyethanal with Tollens' reagent.

(i) State what the biochemist would see when hydroxyethanal reacts with Tollens' reagent.

.....

[1]

(ii) Write the structural formula of the organic product formed when hydroxyethanal reacts with Tollens' reagent.

[1]

(b) The biochemist also reacted hydroxyethanal with acidified dichromate by heating under reflux.

Write an equation for this oxidation.

Use **[O]** to represent the oxidising agent.

[2]

(c) The biochemist then reduced hydroxyethanal using aqueous $NaBH_4$.

(i) Write the structural formula of the organic product.

.....

[1]

(ii) Outline the mechanism for this reduction.

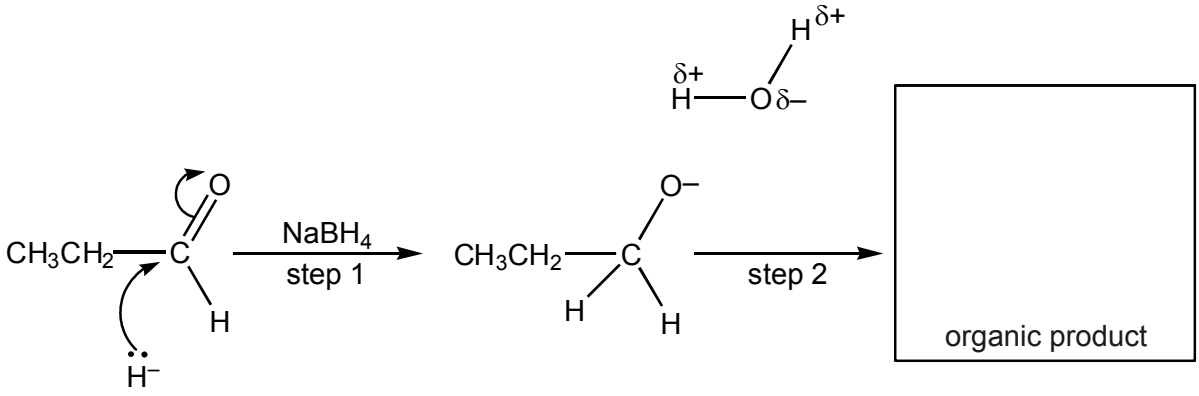
Use curly arrows and show any relevant dipoles.

[4]

[Total 9 marks]

2. Propanal, CH_3CH_2CHO, can be used in the synthesis of organic compounds.

CH_3CH_2CHO reacts with $NaBH_4$ in a nucleophilic addition reaction. The nucleophile can be represented as a hydride ion, H^-. A mechanism for the reaction is shown below.



(i) Add 'curly arrows' to the mechanism to show how the intermediate reacts with the water molecule in **step 2**.

[2]

(ii) Draw the structure of the organic product in the box above.

[1]

(iii) What is meant by the term *nucleophile*?

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[1]

(iv) Describe, in words, exactly what is happening to the electron pairs and bonds in **step 1** of the mechanism above.

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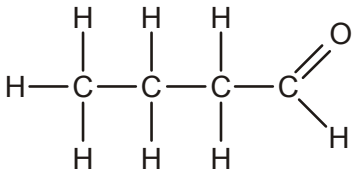
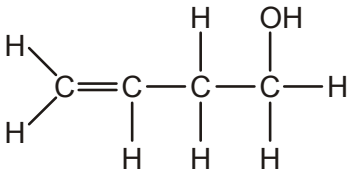
[3]

[Total 7 marks]

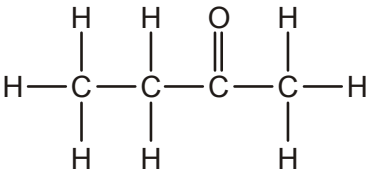
3. An unknown colourless liquid with molecular formula C_4H_8O was thought to be one of butanal, but-3-en-1-ol, or butanone.



butanal



but-3-en-1-ol



butanone

(a) State a simple chemical test that would positively identify:

(i) butanal **only**;

reagent .....

observation .....

organic product .....

[3]

(ii) but-3-en-1-ol **only**.

reagent .....

observation .....

type of reaction .....

[3]

(b) Butanal and butanone both react with 2,4-dinitrophenylhydrazine to produce mixtures containing orange precipitates.

Outline how the mixtures containing these orange precipitates can be used to distinguish between butanal and butanone.

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[3]

[Total 9 marks]

4. But-2-enal, $CH_3CH=CHCHO$, is a pale yellow, flammable liquid with an irritating odour.

(a) (i) Describe a simple chemical test that would show that but-2-enal is an aldehyde.

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[2]

(ii) Explain why this test gives a different result with aldehydes than it does with ketones.

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[1]

(b) But-2-enal also reacts with sodium borohydride, $NaBH_4$.

(i) Identify the organic compound formed in this reaction.

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[1]

(ii) State the type of chemical reaction occurring.

.....

[1]

(c) Precautions must be taken to prevent but-2-enal catching fire.

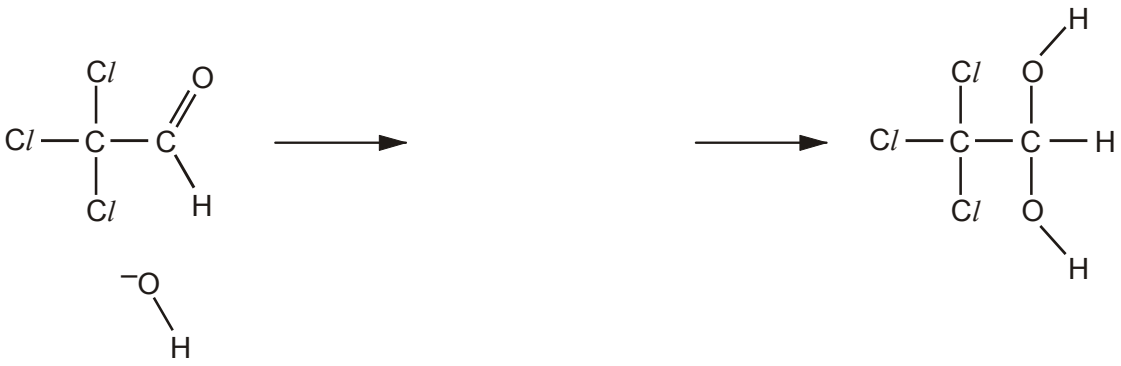
Construct a balanced equation for the complete combustion of but-2-enal, C_4H_6O.

[1]

[Total 6 marks]

5. (a) The reaction of trichloroethanal with water is a nucleophilic addition reaction. It can be catalysed by small amounts of hydroxide ions, OH^-.

Complete the diagram below to suggest a mechanism for this reaction. Show all the relevant dipoles and curly arrows.



[5]

(b) The recommended adult dose of chloral hydrate as a sedative is 250 mg, three times a day.

Calculate the mass of **trichloroethanal** you would need to react with water to make one week's supply of chloral hydrate for an adult, assuming a 60% yield.

M_r: chloral hydrate, 165.5; trichloroethanal, 147.5

mass of trichloroethanal = …… g

[3]

[Total 8 marks]

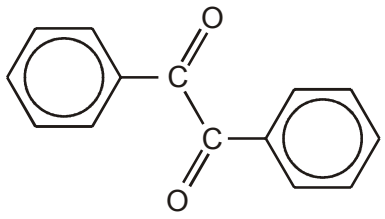
6. Chloral hydrate is broken down in the body after several hours. One reaction is oxidation to trichloroethanoic acid.

Complete the equation for this reaction below.

$Cl_3CCH(OH)_2 \quad + \quad [O] \quad \longrightarrow$

[Total 1 mark]

7. The reducing agent, $NaBH_4$, is used widely in organic chemistry. One example is for the reduction of diphenylethanedione, $C_{14}H_{10}O_2$, shown below.



diphenylethanedione

(i) Draw a displayed formula to show the structure of the organic product that would be formed by reducing diphenylethanedione with excess $NaBH_4$.

[1]

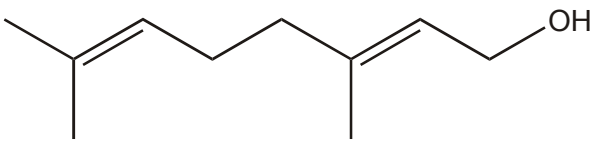
(ii) Complete and balance the equation for this reaction, using [H] to represent the reducing agent.

$C_{14}H_{10}O_2 \quad \longrightarrow$

[1]

[Total 2 marks]

8.



geraniol

Mild oxidation of geraniol gives an aldehyde **Y**.

(i) Draw the skeletal formula of aldehyde **Y** below.

aldehyde **Y**

[2]

(ii) Complete the equation for the oxidation of geraniol to aldehyde **Y**.

$C_9H_{15}CH_2OH + [O] \rightarrow$

[2]

[Total 4 marks]

9. Cinnamaldehyde can be reduced using sodium borohydride, NaBH4.

(i) State which functional group reacts with the sodium borohydride.

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[1]

(ii) Complete and balance the equation for this reaction.

$C_6H_5CH=CHCHO \quad + \quad [H] \quad \rightarrow$

[1]

[Total 2 marks]

10. In this question, one mark is available for spelling, punctuation and grammar.

Tollens' reagent can be used to identify the aldehyde group in cinnamaldehyde.

- Describe how you would make Tollens' reagent and carry out this test in the laboratory.
- Explain what happens to both the Tollens' reagent and the cinnamaldehyde in this reaction. Identify the organic product.

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[7]

Quality of Written Communication. [1]

[Total 8 marks]