17. Carbonyl compounds

17.1 Aldehydes and ketones

Paper 2

Question Paper

1 Propanone, CH_3COCH_3, is an important organic reagent. Fig. 4.1 shows some reactions of propanone and its derivatives.

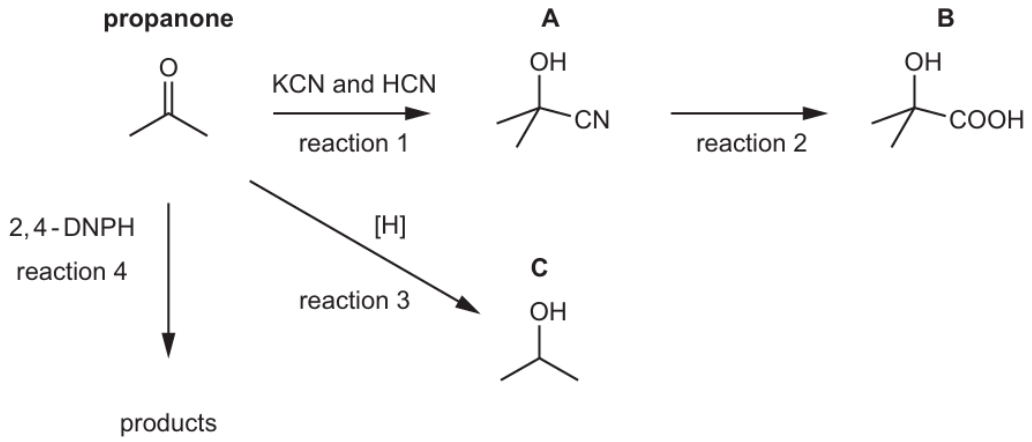


Fig. 4.1

(a) Reaction 1 is a nucleophilic addition reaction.

(i) Complete Fig. 4.2 to show the mechanism for the formation of **A** from propanone.

Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.

Fig. 4.2

[3]

(ii) Explain why **A** does **not** show optical isomerism.

.....

..... [1]

(c) Reaction 3 is a reduction reaction.

(i) Construct an equation to represent reaction 3.

Use [H] to represent one atom of hydrogen from the reducing agent.

..... [1]

(ii) Name **C**.

..... [1]

(d) State what is observed in reaction 4.

..... [1]

(e) Explain why Fehling's reagent does **not** react with propanone.

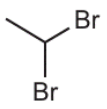
.....

..... [1]

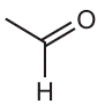
2 **(d)** Compound **E** is the only isomer of 1,2-dibromoethane.

Alkaline hydrolysis of **E** gives compound **F**.

E



F



(iii) Complete Table 4.1 to state what is observed when **F** reacts with the reagents listed.

Table 4.1

reagent	observation with **F**
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	
Tollens' reagent	
alkaline I_2(aq)	

[3]

3 **(b)** **A** and **B** are structural isomers with molecular formula $C_5H_{10}O$.

They are both straight-chained molecules with only one functional group.

Table 5.1 describes observations when separate samples of **A** and **B** are added to different reagents.

Table 5.1

reagent	**A**	**B**
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	orange precipitate appears	orange precipitate appears
Tollens' reagent	silver mirror appears	no reaction
alkaline $I_2(aq)$	no reaction	no reaction

(i) Name the functional group present in both **A** and **B**.

..... [1]

(ii) Draw the structures of **A** and **B** in the boxes.

A

B

[2]

4 Compound **V** is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(c) **W**, **X** and **Y** have the same molecular formula, $C_5H_{10}O$.

W, **X** and **Y** are added separately to different reagents. Observations for these reactions are described in Table 4.1.

Table 4.1

	+ 2,4-dinitrophenylhydrazine	+ alkaline I_2(aq)	+ Fehling's reagent and warm
W	orange precipitate seen	no change	orange-red precipitate seen
X	orange precipitate seen	yellow precipitate seen	no change
Y	orange precipitate seen		

(i) **W**, **X** and **Y** each contain a common functional group.

Name the functional group that is present in all three compounds.

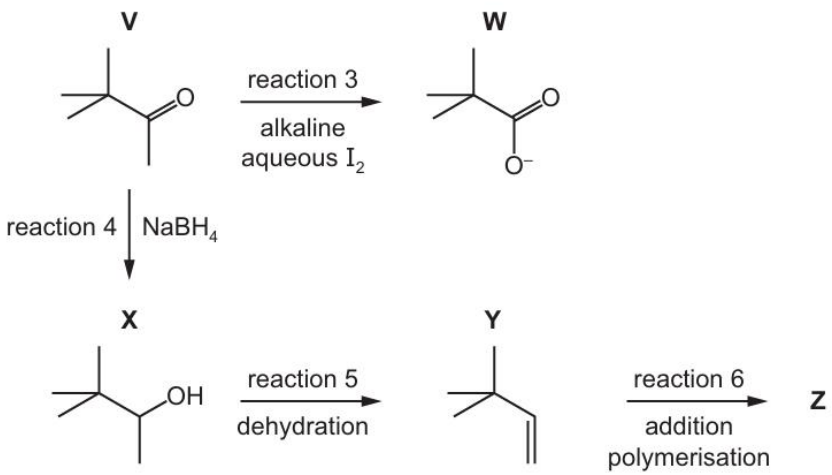
..... [1]

(ii) State the formula of the yellow precipitate produced when **X** is added to alkaline I_2(aq).

..... [1]

5 **(e)** **V** is used in a wide range of organic reactions.

Some reactions of **V** are shown.



(i) **V** and **W** are colourless and soluble in water.

State what you would observe in reaction 3.

..... [1]

(ii) Reaction 3 is a redox reaction.

Identify which of the **reactants** is reduced in this reaction.

..... [1]

(iii) Construct an equation for reaction 4.

Use [H] in the equation to represent an atom of hydrogen from $NaBH_4$.

$C_6H_{12}O$ + ... [1]

6 **(c)** **(i)** Name an organic functional group which reacts with a nucleophile in an addition reaction.

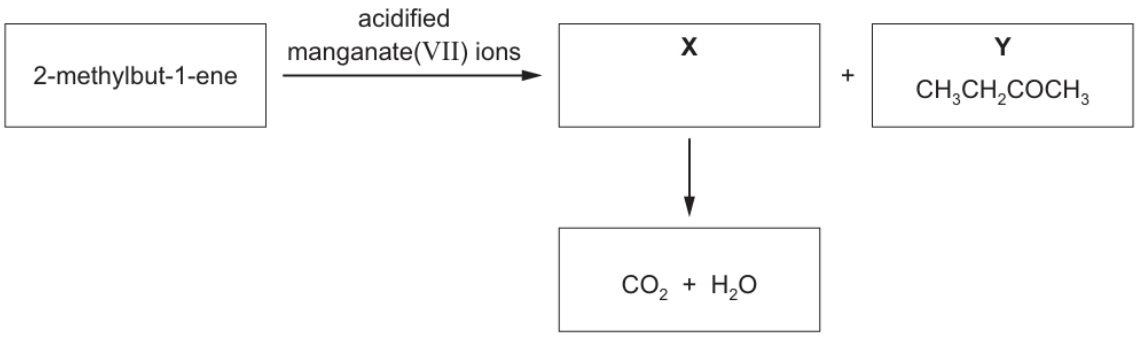
..... [1]

(ii) Name an organic functional group which tends to react with a nucleophile in an S_N1 substitution mechanism.

..... [1]

7 2-methylbut-1-ene reacts with acidified manganate(VII) ions, under specific conditions, to produce two organic compounds **X** and **Y**.

X immediately reacts with the acidified manganate(VII) ions to form carbon dioxide and water. **Y** has the structural formula $CH_3CH_2COCH_3$.

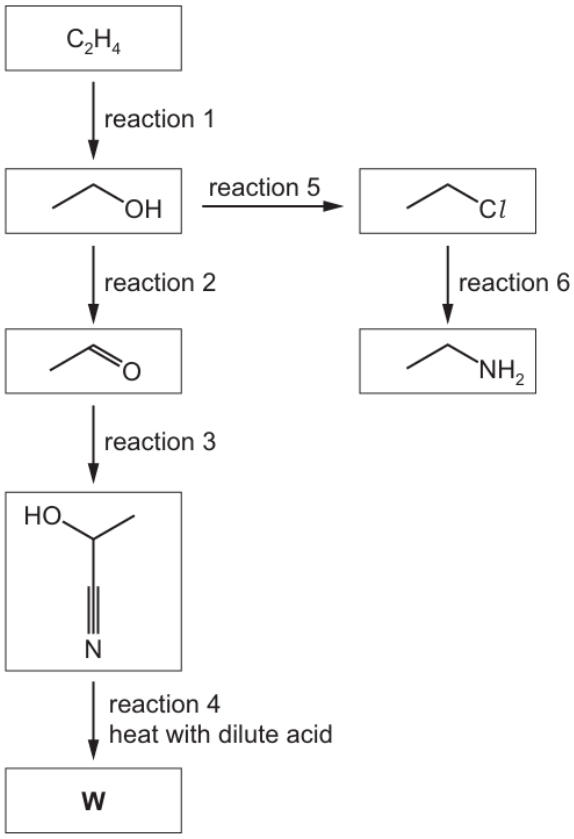


(d) Describe a chemical test and the expected observation(s) to confirm the presence of the carbonyl functional group in **Y**.

.....

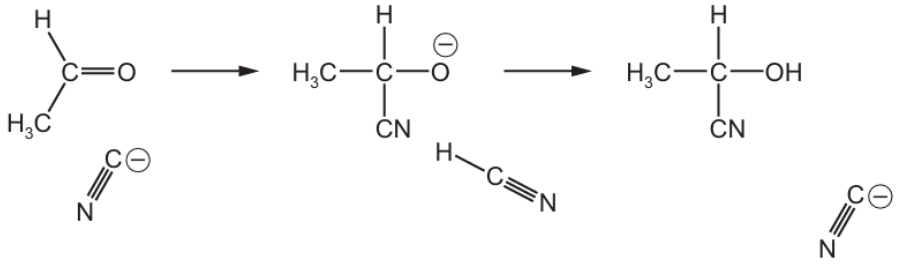
..... [2]

5 The reaction sequence shows how ethene, C_2H_4, can be converted into other organic molecules.



(b) In reaction 3 the organic molecule reacts with HCN and a KCN catalyst.

(i) Complete the diagram to show the mechanism of the reaction occurring.
Include all relevant dipoles, lone pairs and curly arrows in your answer.



[3]

(ii) Name the functional groups present in the product of reaction 3.

..... [2]

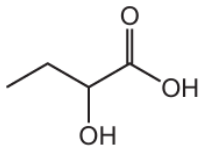
(c) Draw the structure of the organic molecule **W** formed in reaction 4.

[1]

9 The reducing agent $LiAlH_4$ can be synthesised by reacting aluminium chloride with lithium hydride, LiH.

(c) Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

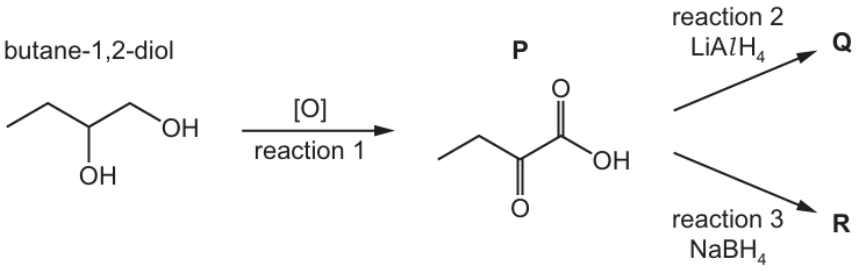
2-hydroxybutanoic acid



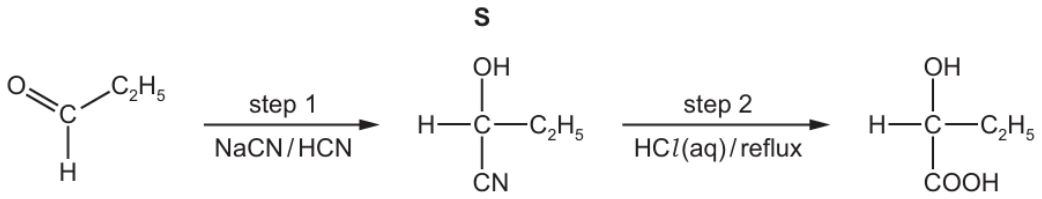
Both students oxidise butane-1,2-diol to form **P** in reaction 1.

One student then reduces **P** using $LiAlH_4$. **Q** is formed.

The other student reduces **P** using $NaBH_4$. **R** is formed.



A third student prepares 2-hydroxybutanoic acid using propanal as the starting material. In step 1 the student reacts propanal with a mixture of NaCN and HCN.

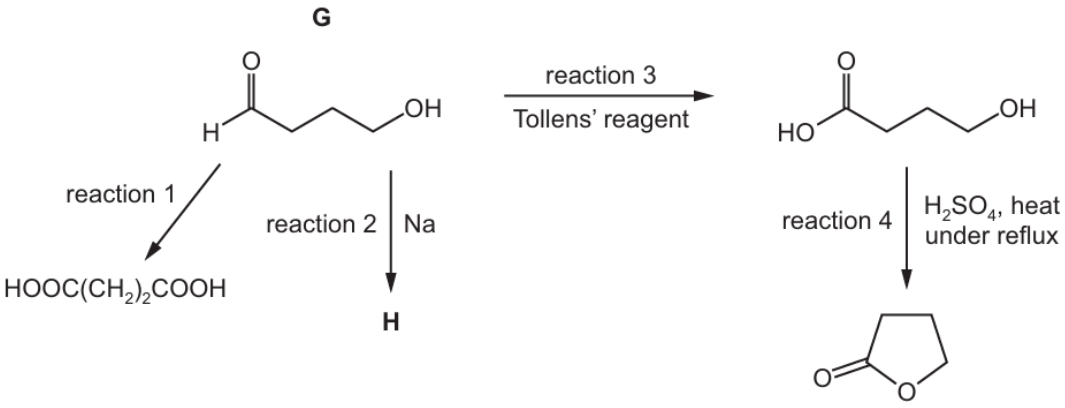


(iii) Draw the mechanism for the reaction of propanal with the mixture of NaCN and HCN to form **S**.

- Identify the ion that reacts with propanal.
- Draw the structure of the intermediate of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

[4]

10 Some reactions of compound **G** are shown.



(a) (iii) Draw the structure of the organic product, **H**, from reaction 2.

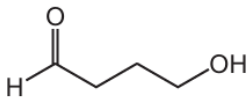
[1]

(iv) State what you would observe in reaction 3.

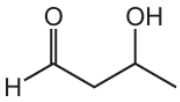
..... [1]

(b) **G** and **J** are structural isomers of each other.

G



J



(ii) Suggest **one** chemical test that can distinguish **G** from **J**. Give the result of the test with each compound.

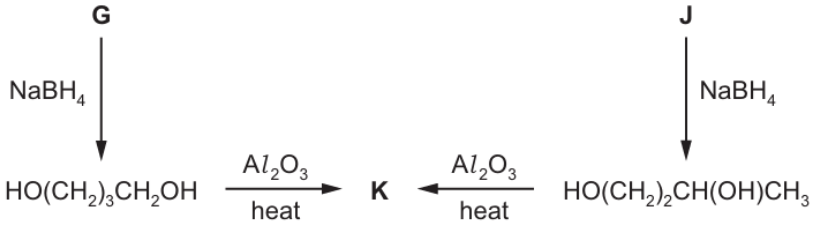
test .....

result with **G** .....

result with **J** .....

[2]

In the reaction schemes below, **G** and **J** are converted into organic compound **K**.

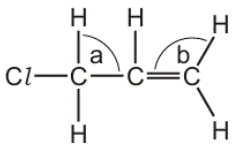


(iii) State the role of $NaBH_4$ in the reactions with **G** and **J**.

..... [1]

11 The structure of compound **Y** is shown.

Y



(d) Samples of organic compounds, **A**, **B**, **C** and **D**, are placed in unlabelled bottles.

A	**B**	**C**	**D**
$CH_3CH_2COCH_3$	$CH_3(CH_2)_2CHO$	CH_3CH_2OH	CH_3CO_2H

(i) Identify all of the compound(s), **A**–**D**, that contain a carbonyl group.

..... [1]

(ii) **A**–**D** are reacted separately with the reagents given in the table.

Complete the table to:
- identify which of the compounds, **A**–**D**, reacts with the reagents
- give an appropriate observation when a reaction occurs.

reagent	compounds identified	observation when a reaction occurs
Tollens' reagent		
alkaline solution of iodine		
sodium metal		

[8]

12 Ethanal reacts with a mixture of HCN and NaCN to make 2-hydroxypropanenitrile, $CH_3CH(OH)CN$.

The reaction mechanism is nucleophilic addition.

(a) Explain the meaning of the term *nucleophile* and identify the species which acts as the nucleophile during this reaction.

.....

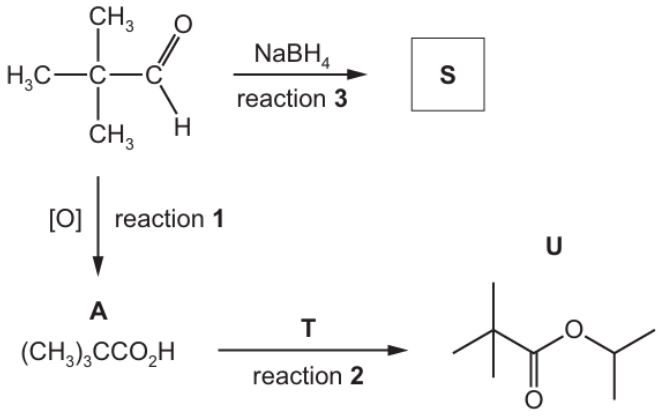
.....

species acting as nucleophile .....

[2]

13 $(CH_3)_3CCHO$ is used in the synthesis of some antibiotics.

(b) Two reaction sequences are shown.



(i) Reaction **1** is an oxidation reaction.

Identify the reagent(s) and conditions for reaction **1**.

..... [1]

(ii) **A**, $(CH_3)_3CCO_2H$, is a solid at room temperature.

B, $CH_3CO_2(CH_2)_2CH_3$, is an isomer of **A**. **B** is a liquid at room temperature.

Explain the difference in the physical states of **A** and **B**, with reference to any intermolecular forces that may exist.

.....

.....

.....

..... [3]

(iii) Give the balanced equation for the reaction of $(CH_3)_3CCHO$ with $NaBH_4$ to form **S**.

Use [H] to represent an atom of hydrogen provided by $NaBH_4$.

..... [1]

(iv) Draw the structure of the organic molecule **T** that reacts with **A**, $(CH_3)_3CCO_2H$, in reaction **2**, to form **U**.

Suggest a catalyst for reaction **2**.

T

catalyst .....

[2]

(c) **X**, **Y** and **Z** are all isomers of $(CH_3)_3CCHO$.

A summary of some of the reactions and properties of **X**, **Y** and **Z** is shown in the table.

compound	observations with 2,4-DNPH	observations with Fehling's solution	principal absorptions in infra-red spectrum
X		no reaction	1715 cm^{-1}
Y		red precipitate	1730 cm^{-1}
Z	no reaction	no reaction	3200–3600 cm^{-1} 1630 cm^{-1} 1050 cm^{-1}

(i) **X** and **Y** each contains a carbonyl group.

Complete the table with the expected observations for the reactions of **X** and **Y** with 2,4-DNPH. [1]

(ii) Identify the functional group present in **Y** that causes the recorded observation with Fehling's solution.

..... [1]

(iii) **Y** has a chiral centre and exists as a pair of optical isomers.

State what is meant by the term *chiral centre*.

.....

..... [1]

(iv) Draw the optical isomers of **Y** using the conventional three-dimensional representation.

[2]

Z, $C_5H_{10}O$, has a branched carbon chain. It shows geometrical isomerism.

(v) Complete the table with the bond responsible for each of the principal absorptions seen in the infra-red spectrum of **Z**.

principal absorptions in infra-red spectrum	bond responsible
3200–3600 cm^{-1}	
1630 cm^{-1}	
1050 cm^{-1}	

[1]

(vi) Draw the skeletal formula of **Z**.

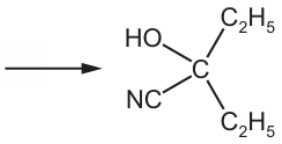
[3]

(vii) **X** contains a carbonyl group. **X** reacts with HCN, in the presence of a small amount of NaCN, to form $(C_2H_5)_2C(OH)CN$ as shown.

$$\mathbf{X} + HCN \rightarrow (C_2H_5)_2C(OH)CN$$

Draw the mechanism of the reaction of **X** with HCN.

- Draw the structure of **X** and the intermediate.
- Include all charges, partial charges, lone pairs and curly arrows.



[3]

(viii) State the role of NaCN in the reaction in **(c)(vii)**.

..... [1]