Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

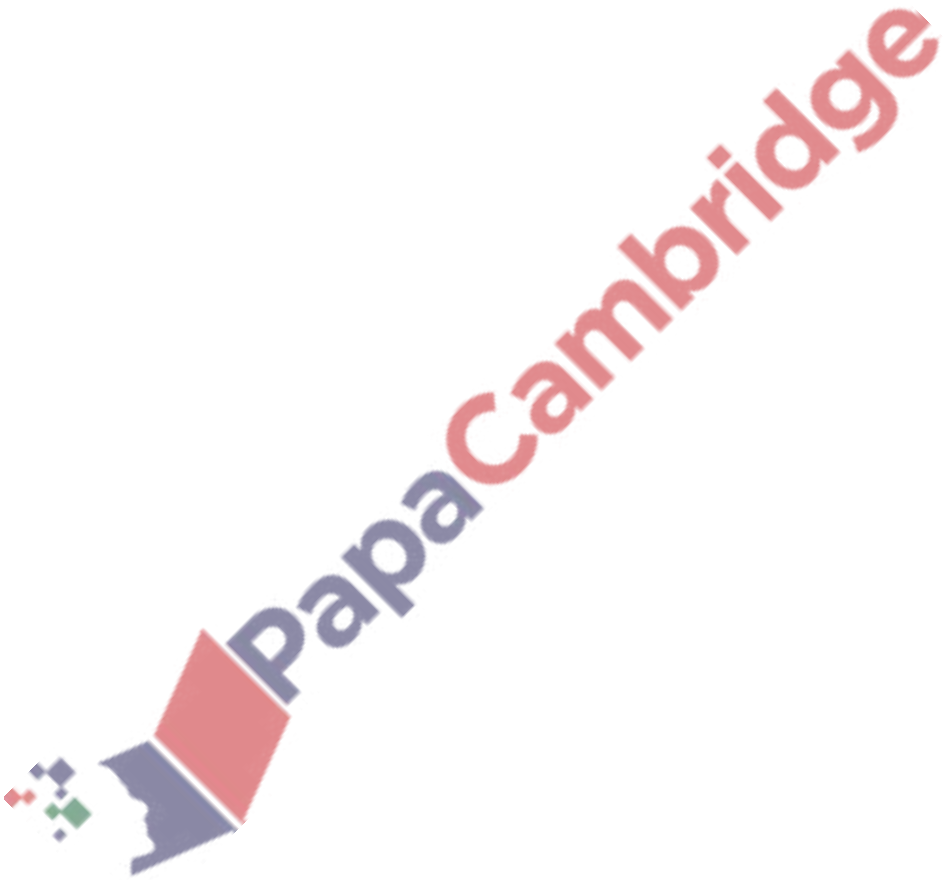
+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 17

Carbonyl compounds

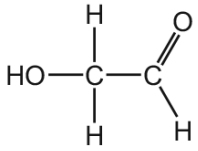


17.1 Aldehydes and ketones

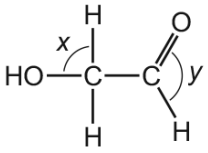
134. 9701_m21_qp_22 Q: 4

Hydroxyethanal, $HOCH_2CHO$, has been observed in dust clouds near the centre of our galaxy.

hydroxyethanal



(a) Predict the bond angles labelled *x* and *y* in the diagram of hydroxyethanal.



x = ... °

y = ... °

[2]

(b) Hydroxyethanal reacts separately with 2,4-dinitrophenylhydrazine (2,4-DNPH) and with Tollens' reagent.

State what you would observe in each reaction.

reaction with 2,4-DNPH .....

reaction with Tollens' reagent .....

[2]

(c) Hydroxyethanal is converted to ethanedioic acid, $(CO_2H)_2$, when it reacts with excess acidified dichromate(VI) ions, $Cr_2O_7^{2-}$.

(i) State the role of acidified $Cr_2O_7^{2-}$ in this reaction.

..... [1]

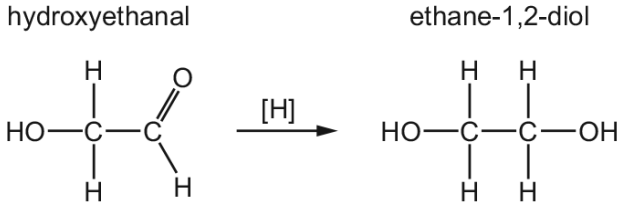
(ii) State and explain any other necessary conditions for this reaction to be successful.

.....

.....

..... [2]

(d) Hydroxyethanal can be reduced to ethane-1,2-diol, $(CH_2OH)_2$, as shown.



(i) Write an equation for the reduction of hydroxyethanal to $(CH_2OH)_2$.

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

..... [1]

(ii) Identify a reagent for this reduction reaction.

..... [1]

(iii) $(CH_2OH)_2$ also forms when an alkene **A** reacts with cold, dilute, acidified manganate(VII) ions.

Name **A**.

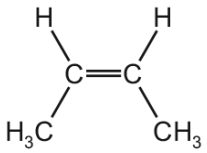
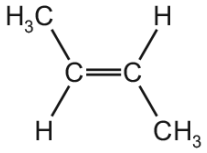
..... [1]

[Total: 10]

135. 9701_s21_qp_22 Q: 4

(a) The table shows the structural formulae of four compounds, **A**, **B**, **C** and **D**, with molecular formula C_4H_8.

(i) Complete the table by giving the systematic name of **A**, **B**, **C** and **D**.

	structural formula	name
A	$CH_3CH_2CH{=}CH_2$	
B		
C		
D	$CH_2{=}C(CH_3)_2$	

[4]

(ii) Explain what is meant by *stereoisomerism*.

.....

..... [1]

(b) **W** is an alkene with formula C_4H_8. It reacts with HBr to form two possible carbocations, $CH_3C^+(H)(CH_2CH_3)$ and $H_2C^+CH_2CH_2CH_3$.

(i) Identify **W** as compound **A**, **B**, **C** or **D**.

..... [1]

(ii) Draw the skeletal formula of the major organic product formed when HBr reacts with **W**. Explain why this is the major organic product.

.....

.....

.....

[3]

(c) A sample of propan-1-ol reacts with concentrated sulfuric acid to form propene.

Identify the role of concentrated sulfuric acid in this reaction.

..... [1]

(d) Alcohol **Y** reacts completely when warmed with acidified $Cr_2O_7^{2-}$ to form **Z**.

Z is distilled from the reaction mixture as soon as it is made.

Tollens' reagent is added to a sample of **Z** and warmed. A silver mirror forms.

(i) Name the type of reaction that occurs when **Y** reacts to form **Z**.

..... [1]

(ii) Identify with a tick (✓) the functional group(s) present in **Z**.

functional group	present in **Z**
aldehyde	
ketone	
carboxylic acid	

[1]

[Total: 12]

136. 9701_w21_qp_21 Q: 3

Phosphorus is a reactive Period 3 element.

(a) Phosphorus has several allotropes. Details of two allotropes are given.

allotrope of phosphorus	formula	melting point / °C
white	P_4	44
red	P	590

(i) White phosphorus and red phosphorus both have covalent bonding.

Suggest the types of structure shown by white phosphorus (P_4) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus (P_4).

structure of P_4 .....

structure of P .....

explanation .....

.....

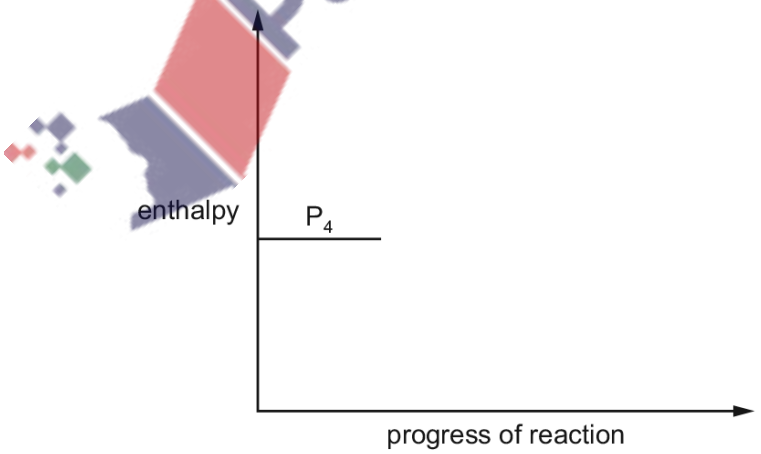
.....

[3]

(ii) Red phosphorus (P) forms when white phosphorus (P_4) is exposed to sunlight.

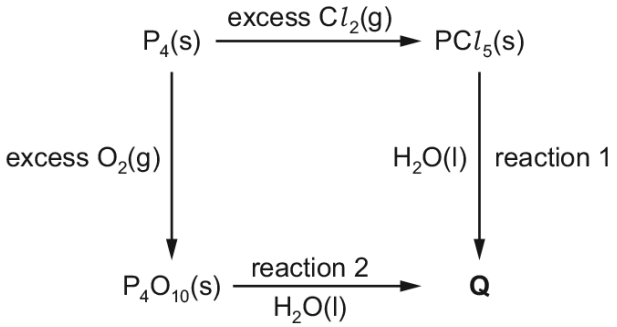
$$\underset{\text{white}}{\tfrac{1}{4}P_4(s)} \rightarrow \underset{\text{red}}{P(s)} \qquad \Delta H = -17.6\,\text{kJ mol}^{-1}$$

Use this information to draw a reaction pathway diagram to show the formation of red phosphorus (P) from white phosphorus (P_4).



[1]

(b) Some reactions of $P_4(s)$ are shown in the reaction scheme.



(i) State the oxidation number of phosphorus in P_4O_{10}.

..... [1]

(ii) Deduce the identity of **Q** and hence construct chemical equations for reactions 1 and 2.

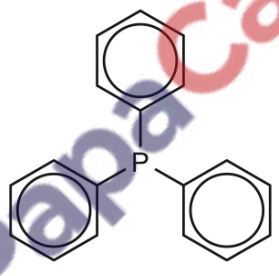
reaction 1 PCl_5 + ...H_2O → .....

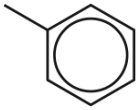
reaction 2 P_4O_{10} + ...H_2O → .....

[2]

(c) Triphenylphosphine is used in a type of reaction known as a *Wittig reaction*.

triphenylphosphine

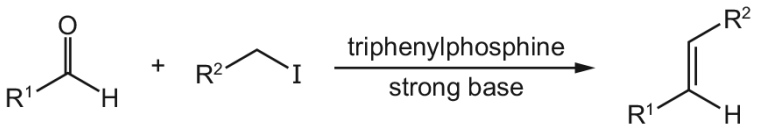


where  = $-C_6H_5$

(i) Give the empirical formula of triphenylphosphine.

..... [1]

In a Wittig reaction, an aldehyde reacts with a halogenoalkane to form an alkene. The conversion is shown in the following unbalanced equation.



Compound **H** can be made from propanal, C_2H_5CHO. Stage 3 in the reaction scheme is a Wittig reaction.

stage 1 $C_2H_5CHO \xrightarrow{NaBH_4}$ **G**

stage 2 **G** $\xrightarrow{\text{red phosphorus and } I_2}$ $C_2H_5CH_2I$

stage 3 (Wittig reaction) $C_2H_5CH_2I + C_2H_5CHO \xrightarrow[\text{strong base}]{\text{triphenylphosphine}}$ **H**

(ii) State the types of reaction that occur in stages 1 and 2.

stage 1 .....

stage 2 .....

[2]

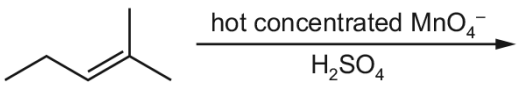
(iii) Draw the structures of **G** and **H** in the boxes provided.

G	**H**

[2]

(d) Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate(VII) ions.

J



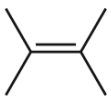
[2]

[Total: 14]

137. 9701_w21_qp_22 Q: 3

Compound **T** is an isomer of C_6H_{12}.

T



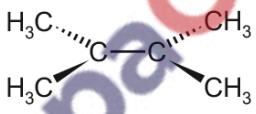
(a) Name **T**.

..... [1]

(b) Draw the skeletal formula of a structural isomer of **T** that shows *cis-trans* (geometrical) isomerism.

[1]

(c) Each carbon atom in **T** forms a sigma (σ) bond to at least one other carbon atom, as shown.

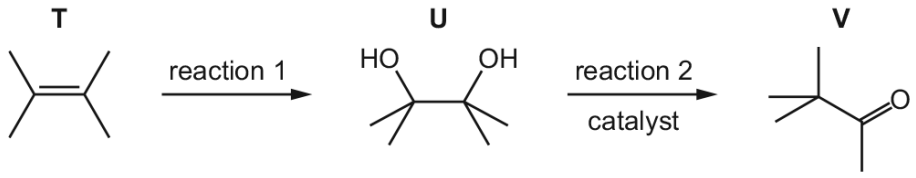


(i) On the diagram, draw the orbitals that represent the pi (π) bond that is also present in **T**. [1]

(ii) State the hybridisation of the two carbon atoms between which the pi (π) bond forms.

..... [1]

(d) A reaction scheme starting with **T** is shown. Reaction 2 occurs in the presence of a catalyst; knowledge of the mechanism for this reaction is not required.



(i) Give the reagent(s) and conditions for reaction 1.

..... [1]

(ii) State and explain how 2,4-dinitrophenylhydrazine (2,4-DNPH) can be used to detect the presence of **V** as a product of reaction 2.

.....

.....

..... [2]

(iii) The progress of reaction 2 can be monitored by infrared spectroscopy.

The absorption caused by O–H bonds is always present because water is used as a solvent.

Identify two absorptions, and the bonds responsible for these absorptions, whose appearance will change significantly during the reaction.

1 .....

.....

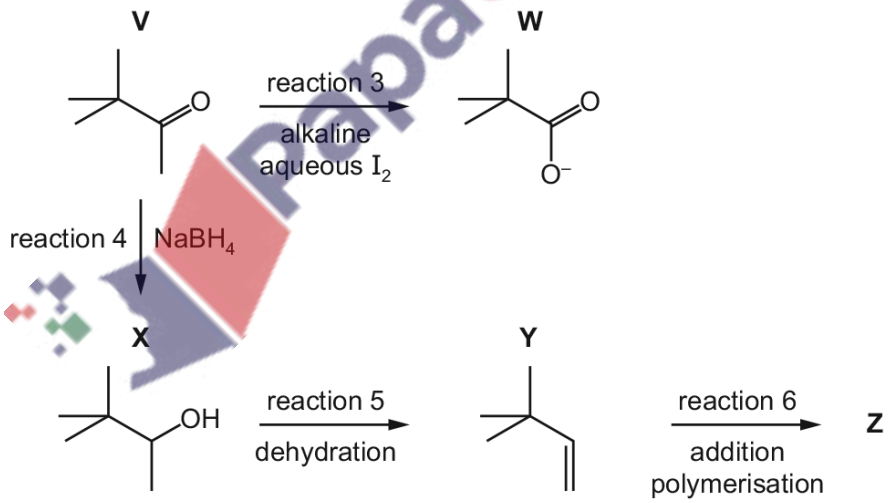
2 .....

.....

[2]

(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]

(iv) **X** is a mixture of two optical isomers.

Draw the two optical isomers in the boxes provided.

[2]

(v) Both optical isomers of **X** can be dehydrated to form a single product, **Y**.
Give the reagent(s) and conditions required for reaction 5.

..... [1]

(vi) **Y** can form an addition polymer **Z**.

Draw one repeat unit of **Z**.

[1]

vii) Reaction 6 does not proceed quickly at room temperature.

Suggest why this is the case.

.....

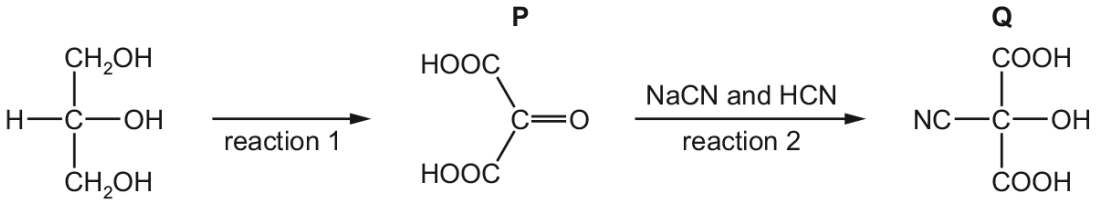
..... [1]

[Total: 17]

138. 9701_m20_qp_22 Q: 3

Glycerol, $CH_2(OH)CH(OH)CH_2OH$, is widely used in the food industry and in pharmaceuticals.

(a) A series of reactions starting from glycerol is shown.



(i) Suggest the reagent(s) and conditions for reaction 1.

.....

..... [2]

(ii) Name the reaction mechanism for reaction 2.

..... [1]

(iii) Give the observation you would make when 2,4-dinitrophenylhydrazine is added to **P**.

..... [1]

(iv) **Q** does **not** show optical isomerism.

Explain why.

.....

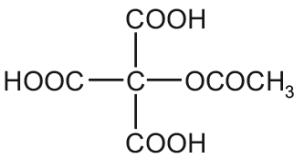
.....

.....

..... [1]

(v) When **Q** is heated with excess aqueous ethanoic acid in the presence of a catalytic amount of sulfuric acid, two reactions take place to form compound **R**.

R



Identify the two types of reaction that occur.

1 .....

2 .....

[2]

(b) Glycerol can be used as a starting material in the manufacture of nitroglycerine, $C_3H_5N_3O_9$.

Nitroglycerine decomposes rapidly on heating to form a mixture of gases.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

A sample of nitroglycerine decomposes, releasing 1.06 dm^3 of $O_2(g)$ at 850 K and 1.00×10^5 Pa.

(i) Calculate the mass of nitroglycerine that decomposes.

mass of nitroglycerine = ... g [3]

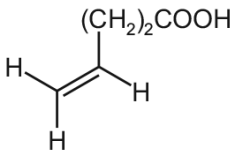
(ii) Calculate the total volume of gas released by this decomposition at 850 K and 1.00×10^5 Pa.

total volume of gas = ... dm^3 [1]

(c) Fats are compounds made from glycerol and unsaturated carboxylic acids.

4-pentenoic acid is an example of an unsaturated carboxylic acid.

4-pentenoic acid



(i) Give the molecular formula of 4-pentenoic acid.

..... [1]

(ii) Draw the repeat unit of the addition polymer that can be formed from 4-pentenoic acid.

[1]

(iii) Unsaturated acids are often brominated before being added to soft drinks.

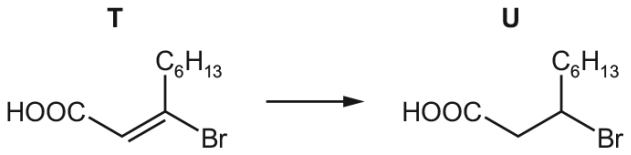
Complete the mechanism for the addition of Br_2 to 4-pentenoic acid.

- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

In the mechanism, R has been used to represent $(CH_2)_2COOH$.

[4]

(d) A reaction of another unsaturated carboxylic acid, **T**, is shown.



(i) **T** is one of a pair of geometrical (*cis-trans*) isomers.

Draw the other geometrical isomer of **T** and explain why the molecules exhibit this form of isomerism.

.....

.....

.....

[3]

(ii) Identify the reagent used to convert **T** to **U**.

..... [1]

(iii) The C–Br bond has an absorption between 500 cm^{-1} and 600 cm^{-1} in an infrared spectrum.

The infrared spectra for both **T** and **U** have absorptions between 2850 cm^{-1} and 2950 cm^{-1}. These correspond to C–H bonds.

Identify:

- two other absorptions that would be seen in the infrared spectra of both **T** and **U**
- one other absorption that would **only** be seen in the infrared spectrum of **T**.

For each absorption, give the range of the absorption and the bonds that correspond to these absorptions.

absorption 1 present in both spectra .....

.....

.....

absorption 2 present in both spectra .....

.....

.....

absorption **only** present in spectrum of **T** .....

.....

.....

[3]

[Total: 24]

139. 9701_s20_qp_21 Q: 5

(a) Below is a list of species which can react with organic compounds.

CN^- HCl Cl H_2O CO_3^{2-}

(i) From the list, identify a species which can react with ethane.

..... [1]

(ii) From the list, identify **two** species which can attack the π bond in ethene.

..... [1]

(iii) From the list, identify a species which can be used to distinguish between solutions of propanoic acid and propan-1-ol. Describe any relevant observations.

.....

.....

..... [2]

(b) Cl(g) can be made from Cl_2(g).

(i) Describe the conditions required for this process.

..... [1]

(ii) Name this process.

..... [1]

(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]

(d) But-1-ene reacts with steam in the presence of concentrated phosphoric acid to form two isomers of molecular formula $C_4H_{10}O$.

Each reaction occurs via a different intermediate ion.

(i) Draw the structure of both intermediate ions.

[2]

(ii) Circle the more stable intermediate ion drawn in **(d)(i)**. Explain your answer.

.....

.....

..... [2]

[Total: 12]

140. 9701_w20_qp_22 Q: 3

PCl_5, PCl_3 and NCl_3 are halides of Group 15 elements.

(a) PCl_5 can be formed from the reaction of phosphorus with chlorine. PCl_5 has a melting point of 161 °C.

(i) Write an equation for the formation of PCl_5 from the reaction of phosphorus and chlorine.

..... [1]

(ii) State the type of structure and bonding shown by liquid PCl_5.

..... [1]

(b) A small amount of PCl_5 is added to excess water. The PCl_5 reacts vigorously to form a colourless solution.

(i) Give **one** other observation you would make when PCl_5 reacts with excess water.

..... [1]

(ii) Write the equation for the reaction of PCl_5 with excess water.

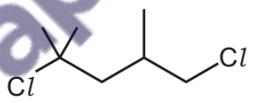
..... [1]

(iii) Estimate the pH of the resulting solution.

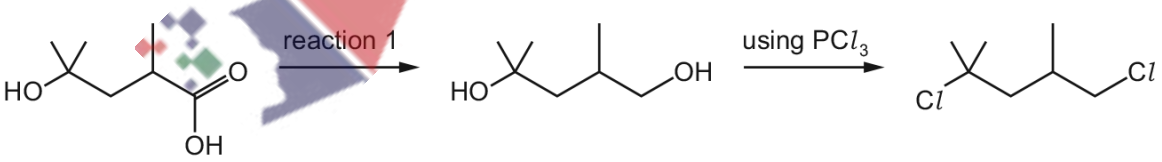
..... [1]

(c) PCl_3 is used to convert alcohols to chloroalkanes, such as compound **T**.

T



A possible synthesis of **T** is shown.



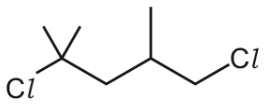
(i) Identify a reagent that could be used in reaction 1.

..... [1]

(ii) **T** exhibits optical isomerism.

Explain what is meant by the term *optical isomer* and circle any atom(s) in **T** that give rise to optical isomerism.

T



.....

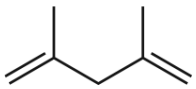
.....

.....

[2]

(iii) **T** is a **minor** product in the reaction of compound **S** with excess HCl.

S



Draw the structure of the **major** product of the reaction of **S** with excess HCl.

[1]

(d) NCl_3 is a yellow liquid that can be used to bleach flour.

(i) Predict the shape of the NCl_3 molecule and the C*l*–N–C*l* bond angle.

shape .....

bond angle .....
[2]

(ii) NCl_3 reacts with water to form HOC*l*, a weak Brønsted-Lowry acid.

Explain fully what is meant by the term *weak Brønsted-Lowry acid*.

.....

.....

..... [2]

(iii) NCl_3(l) decomposes according to the equation shown.

$$2NCl_3(l) \rightarrow N_2(g) + 3Cl_2(g)$$

A sealed container of volume 250 cm^3 contains an unreactive gas at a pressure of 1.00×10^5 Pa.

0.241 g of NCl_3(l) was injected into the sealed container.

The sealed container was heated to make the NCl_3(l) decompose fully and then cooled to 20 °C.

Calculate the final **total** pressure inside the sealed container at 20 °C after the NCl_3(l) has fully decomposed.

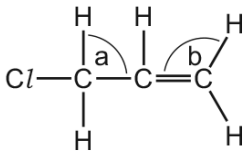
final **total** pressure = ... Pa
[4]

[Total: 17]

141. 9701_s19_qp_21 Q: 4

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

Y



(a) Give the systematic name for **Y**.

..... [1]

(b) Predict the values for the bond angles a and b shown in the diagram.

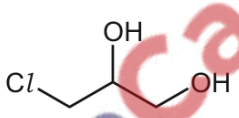
a .....

b .....

[2]

(c) When **Y** reacts with cold, dilute, acidified manganate(VII) ions, compound **Z** is produced.

Z



(i) State the molecular formula of **Z**.

..... [1]

(ii) Name the type of reaction occurring when **Y** is converted into **Z**.

..... [1]

(iii) Alcohols can be classified as primary, secondary or tertiary.

Identify with a tick (✓) the alcohol group(s) present in **Z**.

	alcohol group present in **Z**
primary	
secondary	
tertiary	

[1]

(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]

[Total: 15]

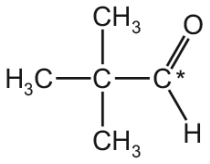
142. 9701_w19_qp_21 Q: 4

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

(a) (i) Give the name of $(CH_3)_3CCHO$.

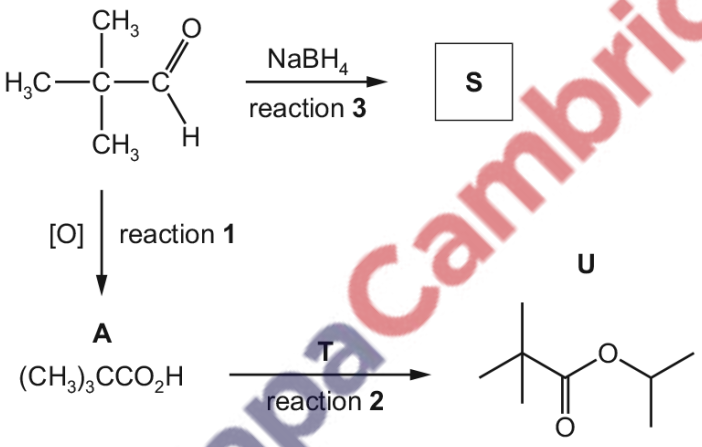
..... [1]

(ii) State the hybridisation of the carbon atom labelled with an asterisk, *.



..... [1]

(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]

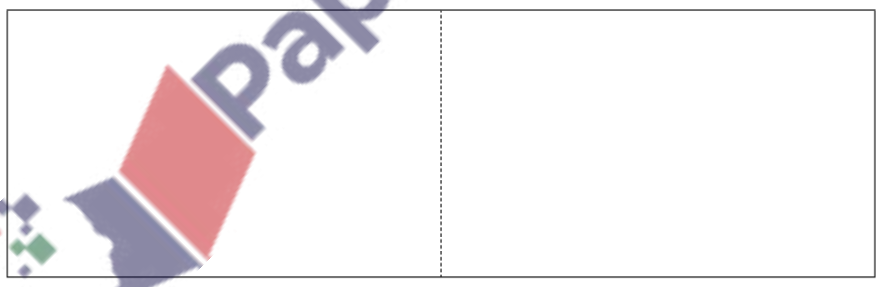
(iii) **Y** has a chiral centre and exists as a pair of optical isomers.

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**.

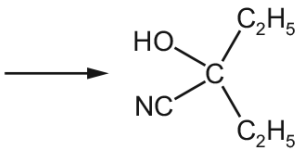
[3]

(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]

[Total: 22]

143. 9701_m18_qp_22 Q: 3

Calcium and its compounds have a large variety of applications.

(a) Calcium metal reacts readily with most acids.

(i) Write an equation for the reaction of calcium with dilute nitric acid. State symbols are **not** required.

..... [1]

(ii) When calcium metal is placed in dilute sulfuric acid, it reacts vigorously at first.

After a short time, a crust of calcium sulfate forms on the calcium metal and the reaction stops. Some of the calcium metal and dilute sulfuric acid remain unreacted.

Suggest an explanation for these observations.

.....

.....

.....

..... [2]

(b) Calcium ethanedioate is formed when calcium reacts with ethanedioic acid, $(CO_2H)_2$. The compound contains one cation and one anion.

(i) Draw the 'dot-and-cross' diagram of the cation present in calcium ethanedioate. Show **all** electrons.

[1]

(ii) Draw the displayed formula of the anion present in calcium ethanedioate.

[2]

(c) Calcium chlorate(I), $Ca(ClO)_2$, is used as an alternative to sodium chlorate(I), $NaClO$, in some household products.

(i) Suggest a use for calcium chlorate(I).

..... [1]

(ii) The chlorate(I) ion is formed when cold aqueous sodium hydroxide reacts with chlorine.

Write an **ionic** equation for this reaction. State symbols are **not** required.

..... [1]

(iii) The chlorate(I) ion is unstable and decomposes when heated as shown.

Deduce the oxidation number of chlorine in each species. Complete the boxes.

$$3ClO^- \rightarrow 2Cl^- + ClO_3^-$$

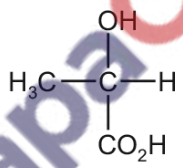
oxidation number of chlorine:	+1		

[1]

(iv) In terms of electron transfer, state what happens to the chlorine in the reaction in **(iii)**.

..... [1]

(d) Calcium lactate is used in some medicines. It forms when lactic acid (2-hydroxypropanoic acid) reacts with calcium carbonate.

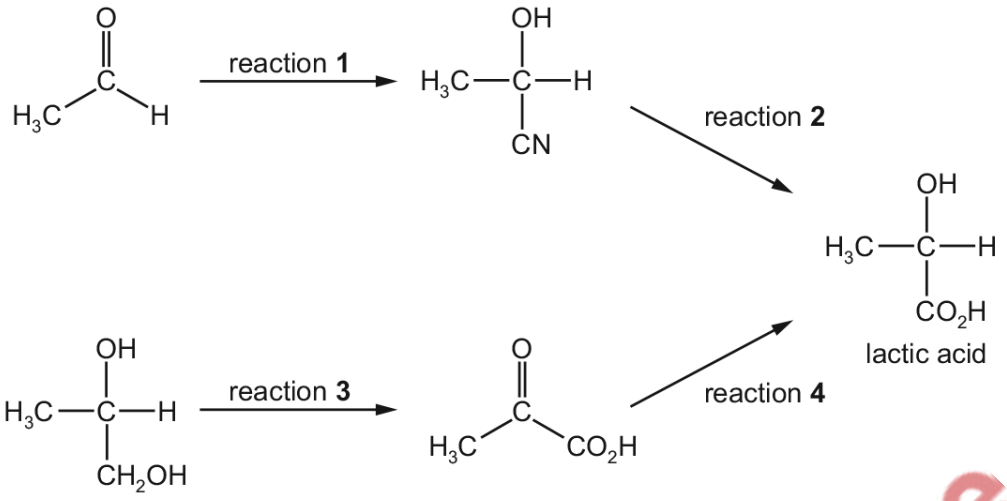


lactic acid

(i) Identify the **two** other products of the reaction of lactic acid with calcium carbonate.

..... [1]

Two possible methods of making lactic acid are shown.



(ii) State suitable reagents and conditions for reactions **1** and **3**.

reaction	reagents and conditions
1	
3	

[4]

(iii) Name the type of reaction that occurs in reaction **2**.

..... [1]

(iv) Reaction **4** uses $NaBH_4$.

Identify the role of $NaBH_4$ in this reaction.

..... [1]

(v) Lactic acid has a chiral centre.

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

.....

.....

..... [1]

[Total: 18]

144. 9701_s18_qp_22 Q: 4

W is $CH_3COCH_2CH_3$.

(a) The reaction between **W** and alkaline aqueous iodine produces a yellow precipitate.

(i) Give the name of the compound formed as a yellow precipitate in this reaction.

..... [1]

(ii) Give the name of **W**.

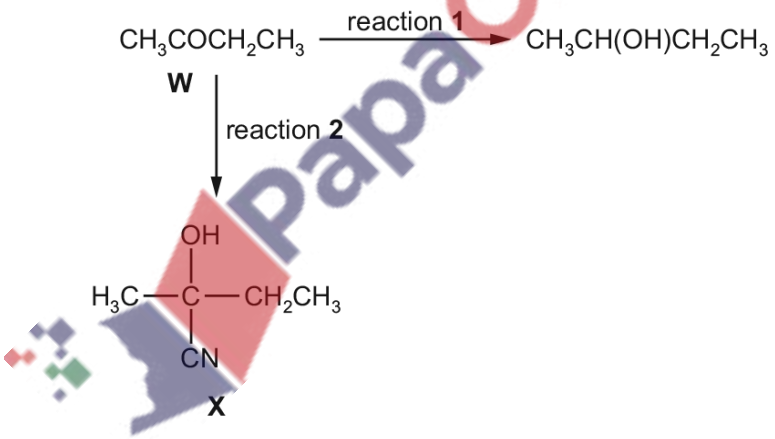
..... [1]

(b) There are two structural isomers of **W** that are also carbonyl compounds.

Draw the structures of these two isomers of **W**.

[2]

Two reactions of **W** are shown.



(c) **(i)** Identify the type of reaction occurring in reaction **1**.

..... [1]

(ii) Identify the reagent for reaction **1**.

..... [1]

(d) Reaction **2** is carried out by adding a mixture of HCN and NaCN to **W**.
The product, **X**, is formed as a mixture of two isomers.

(i) Complete the mechanism for this reaction.

Include the structure of the intermediate formed and all necessary charges, dipoles, lone pairs and curly arrows.

W 

[4]

(ii) State the name of the type of isomerism shown by **X**.

..... [1]

(iii) Explain fully why **X** shows this type of isomerism.

.....

.....

.....

..... [2]

(e) If **X** is treated with ammonia and the product hydrolysed, a compound, **Y**, is obtained that contains 51.3% C, 9.40% H, 12.0% N and 27.3% O by mass.

(i) Show that the empirical formula of **Y** is $C_5H_{11}NO_2$.

[2]

(ii) The empirical formula of **Y** is $C_5H_{11}NO_2$ and the M_r of **Y** is 117.

Deduce the molecular formula of **Y**. You **must** explain your reasoning.

molecular formula = ...

.....

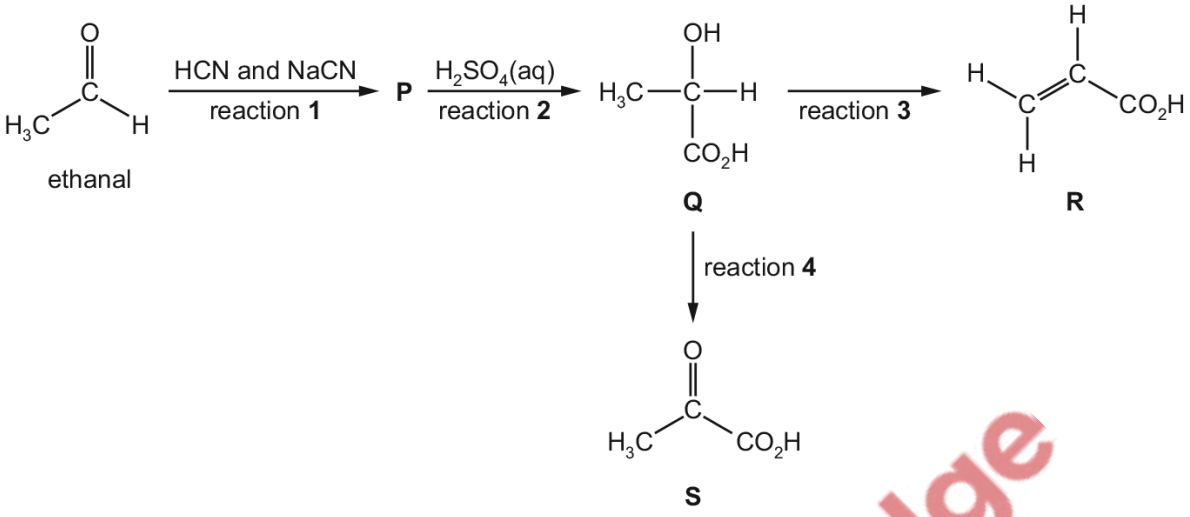
.....

[1]

[Total: 16]

145. 9701_w18_qp_22 Q: 4

The diagram shows a reaction sequence starting from ethanal.



(a) (i) Draw the **displayed** formula of **P**.

[1]

(ii) Name the type of chemical reaction that occurs in reaction **3**.

..... [1]

(iii) Write an equation to represent reaction **4**.

Use [O] to represent the oxidising agent.

..... [1]

(iv) State the reagents and conditions for reaction **4**.

..... [1]

(b) Compound **Q** is formed as a mixture of two optical isomers.

(i) Explain what is meant by the term *optical isomers*.

.....

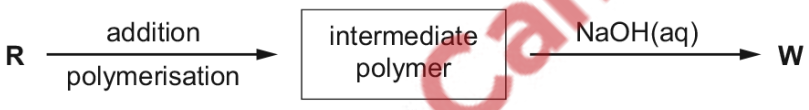
.....

..... [1]

(ii) Draw the **two** optical isomers of **Q**, showing clearly their three-dimensional structures.

[2]

(c) **R** can be used to make a polymer, **W**, in two steps.



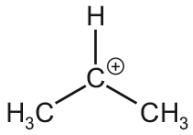
Draw one repeat unit of **W**.

[3]

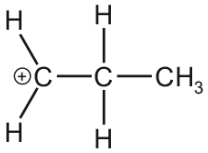
(d) Compound **Z**, $H_2C{=}CHCH_3$, is produced from **R**.

Z can be used in a two-step process to produce 2-aminopropane.

(i) In the first step, **Z** reacts with HBr to form two products. The structure of the product depends on which intermediate is formed, intermediate **I** or intermediate **II**.



intermediate **I**



intermediate **II**

Explain why intermediate **I** is more likely to form than intermediate **II**.

.....

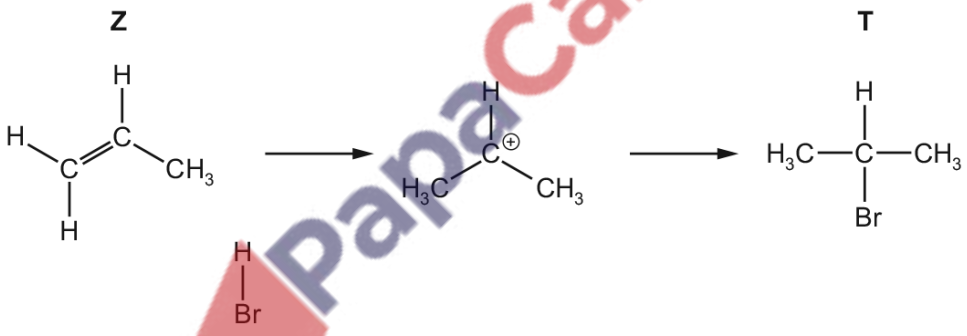
.....

.....

..... [2]

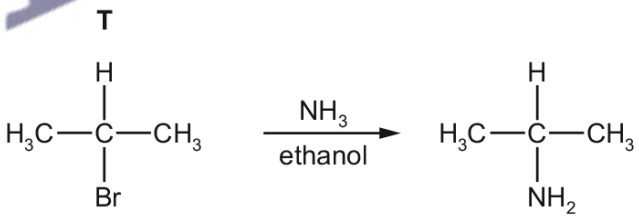
(ii) When intermediate **I** forms, the product of the first step is **T**.

Complete the diagram to show the mechanism for the conversion of **Z** to **T**.
Include all relevant charges, partial charges, curly arrows and lone pairs.



[3]

(iii) **T** can then be converted to 2-aminopropane.



2-aminopropane

Name the mechanism for this conversion.

..... [1]

(e) (i) Compound **S**, CH_3COCO_2H, can be reduced by $LiAlH_4$.

Complete the equation using structural formulae to represent this reaction.
Use [H] to represent the reducing agent.

CH_3COCO_2H + ... [2]

Other reducing agents containing Group 1 metal cations include $LiBH_4$, $NaBH_4$ and KBH_4.
The strength of the reducing agent depends on the size of its cation.

(ii) Give the electronic configuration of the Na^+ cation.

$1s^2$ ..... [1]

(iii) Suggest why ionic radius increases down Group 1.

.....

.....

..... [1]

[Total: 20]

146. 9701_s17_qp_21 Q: 4

P, **Q** and **R** all have the molecular formula C_3H_6O. They are all structural isomers of each other.

P and **Q** each contain an oxygen atom bonded directly to a carbon atom that is sp^2 hybridised.
R contains an oxygen atom bonded directly to a carbon atom that is sp^3 hybridised.

(a) (i) Explain the meaning of the term *structural isomers*.

.....

.....

.....

..... [2]

(ii) Explain how sp^2 and sp^3 hybridisation can occur in carbon atoms.

sp^2 hybridisation .....

.....

sp^3 hybridisation .....

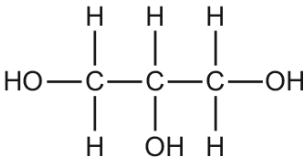
.....
[2]

(iii) State the bond angles normally associated with each type of hybridisation in carbon atoms.

sp^2 .....

sp^3 .....
[2]

(b) **R** contains two different functional groups, one of which is an alkene group.
R reacts with cold, dilute, acidified manganate(VII) ions to form propane-1,2,3-triol.



propane-1,2,3-triol

(i) Give the displayed formula of **R**.

[1]

(ii) State the type of reaction and what you would observe when **R** reacts with bromine water.

.....

..... [2]

(iii) Draw the structure of the product formed when **R** reacts with bromine water.

[1]

(iv) Identify the gaseous product formed when **R** reacts with hot, concentrated, acidified manganate(VII) ions.

..... [1]

(c) **P** and **Q** (C_3H_6O) both form an orange precipitate when reacted with 2,4-DNPH. Only **Q** produces a yellow precipitate when reacted with alkaline aqueous iodine.

(i) Name **P** and **Q**.

P .....

Q .....

[2]

(ii) Identify the yellow precipitate formed by the reaction of **Q** with alkaline aqueous iodine.

..... [1]

(d) **P** and **Q** each react with hydrogen cyanide to form a single product.
The product formed from **P** exists as a pair of optical isomers.
The product formed from **Q** does not exhibit optical isomerism.

(i) Explain the meaning of the term *optical isomers*.

.....

.....

.....

..... [2]

(ii) Ethanal, CH_3CHO, also reacts with hydrogen cyanide. The product of this reaction is $CH_3CH(OH)CN$.

Draw the mechanism of this reaction.
Include all necessary charges, dipoles, lone pairs and curly arrows.

[3]

[Total: 19]

147. 9701_m16_qp_22 Q: 3

Over one million tonnes of hydrogen cyanide, HCN, are produced each year using the Andrussow process. The overall equation for the reaction is shown.

$$CH_4(g) + NH_3(g) + 1\tfrac{1}{2}O_2(g) \rightleftharpoons HCN(g) + 3H_2O(g)$$

(a) (i) Draw a dot-and-cross diagram to represent the bonding in a molecule of ammonia, NH_3, and state the shape of the molecule.

shape of molecule .....

[3]

(ii) A molecule of hydrogen cyanide, HCN, is shown.

$$H—C\equiv N$$

The bonding between the carbon and nitrogen atoms consists of one sigma (σ) bond and two pi (π) bonds.

Sketch the shape of the sigma bond and one of the pi bonds in the space below.
Show clearly the position of the atomic nuclei in each diagram.

sigma (σ)

pi (π)

[2]

(b) The reaction exists as a dynamic equilibrium.

(i) Explain what is meant by the term *dynamic equilibrium*.

.....

..... [1]

(ii) State and explain how the amounts of the chemicals present in the equilibrium mixture will change when the pressure is increased.

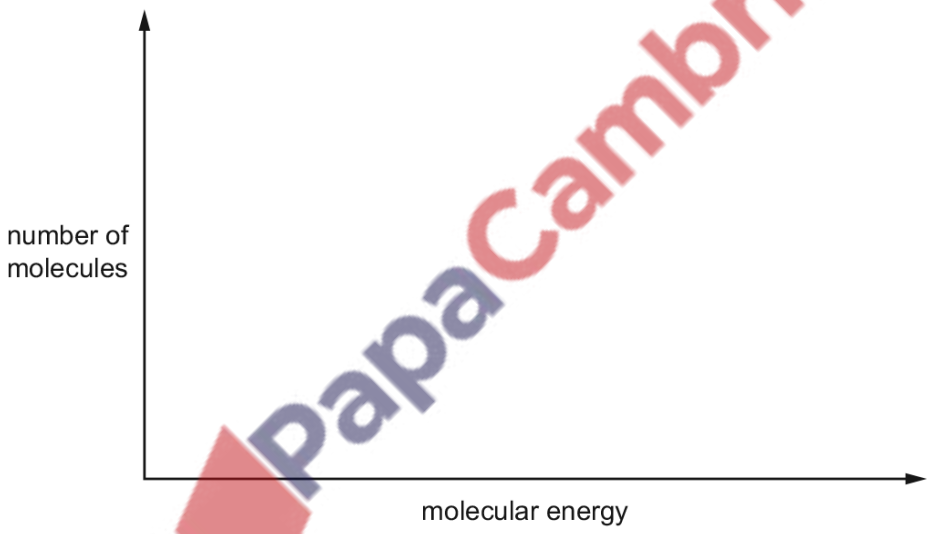
.....

.....

..... [2]

(c) The process uses a platinum catalyst, which increases the rate of reaction.

Sketch a Boltzmann distribution on the axes given below and use your diagram to explain how the platinum catalyst increases the rate of the reaction.



.....

.....

.....

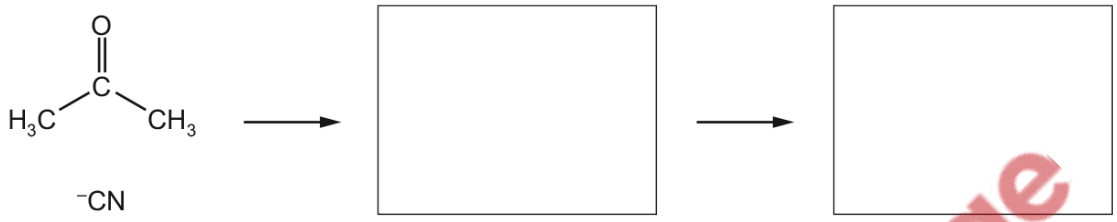
..... [3]

(d) The reaction of hydrogen cyanide with propanone is an important first step in many organic syntheses.

(i) Give the full name of the mechanism of this reaction.

..... [1]

(ii) Complete the diagram to show the mechanism of the reaction of hydrogen cyanide with propanone.
Draw the structure of the intermediate and the product of the reaction.
Include all relevant charges, partial charges, curly arrows and lone pairs.

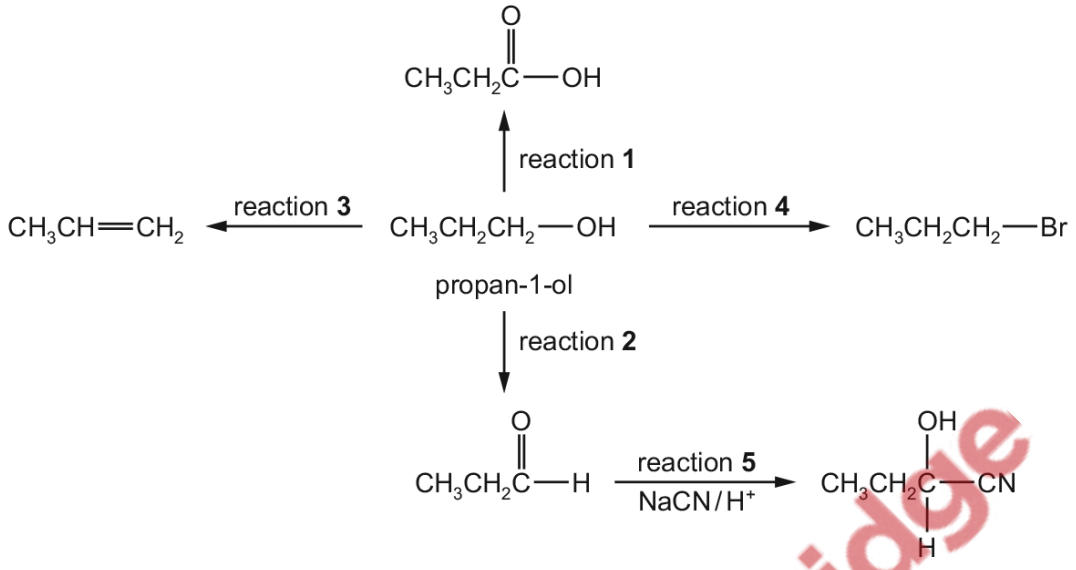


[5]

[Total: 17]

148. 9701_s16_qp_22 Q: 5

A reaction sequence based on propan-1-ol is shown.



(a) Reactions **1** and **2** can both be carried out using the same reagents.

(i) Identify suitable reagents for reactions **1** and **2**.

.....

..... [1]

(ii) State and explain how the reaction should be carried out to ensure that reaction **2** rather than reaction **1** occurs.

.....

.....

.....

..... [2]

(b) Identify the necessary reagents and conditions for each of reactions **3** and **4**.

reaction **3** .....

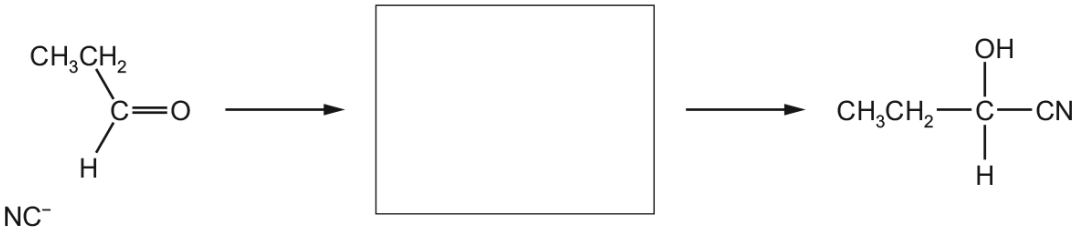
.....

reaction **4** .....

.....

[2]

(c) (i) Complete the reaction mechanism for reaction **5**. Include all relevant lone pairs, curly arrows, charges and partial charges.



[4]

The product of reaction **5** exhibits stereoisomerism.

(ii) Draw the two stereoisomers in the conventional way.

[2]

(iii) Suggest why a mixture of the two stereoisomers is formed by reaction **5**.

.....

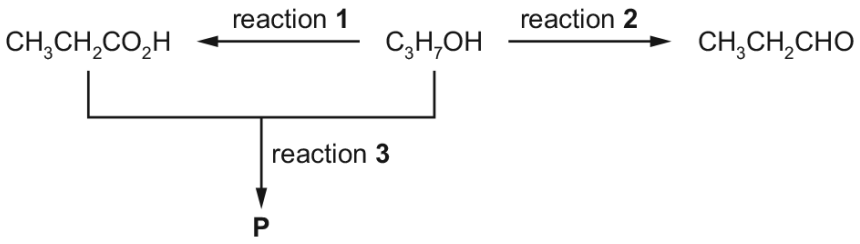
.....

..... [2]

[Total: 13]

149. 9701_w16_qp_21 Q: 5

A sequence of reactions is shown starting with an alcohol, C_3H_7OH.



(a) Draw the skeletal formula of the alcohol C_3H_7OH.

[1]

(b) State the reagents and conditions needed for reaction **1**.

.....

..... [2]

(c) State the reagents and conditions needed for reaction **2**.

.....

..... [2]

(d) Name **P**, the organic product of reaction **3**.

..... [1]

[Total: 6]

150. 9701_w16_qp_22 Q: 5

In each section of this question choose the answer or answers from the options listed.

(a) Six particles are listed.

H• H^+ Cl• Cl^- $\bullet CH_3$ $^+CH_3$

(i) Identify **two** particles produced during the reaction of methane and chlorine in the presence of UV light.

..... [1]

(ii) Identify the **two** particles produced by the heterolytic fission of a bond in chloromethane.

..... [1]

(b) Seven reaction types are listed.

addition substitution oxidation elimination

hydrolysis condensation reduction

(i) Name the type of reaction involved when Tollens' reagent is used to identify an aldehyde.

..... [1]

(ii) Name the type of reaction involved in the test for a carbonyl group using 2,4-DNPH.

..... [1]

(iii) Name the type of reaction involved in the reaction of a ketone with $NaBH_4$.

..... [1]

(iv) Name the type of reaction involved in the reaction of an aldehyde with HCN.

..... [1]

[Total: 6]

151. 9701_S15_qp_21 Q: 3

Ethanal reacts with hydrogen cyanide, in the presence of a small amount of NaCN, as shown.

$$CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$$

(a) Use bond energies from the *Data Booklet* to calculate the enthalpy change for this reaction. Include a sign with your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [3]

(b) The product of this reaction shows stereoisomerism as it contains a chiral centre. This reaction produces an equimolar mixture of two optical isomers.

(i) Explain the meanings of the terms *stereoisomerism* and *chiral centre*.

stereoisomerism .....

.....

.....

chiral centre .....

.....

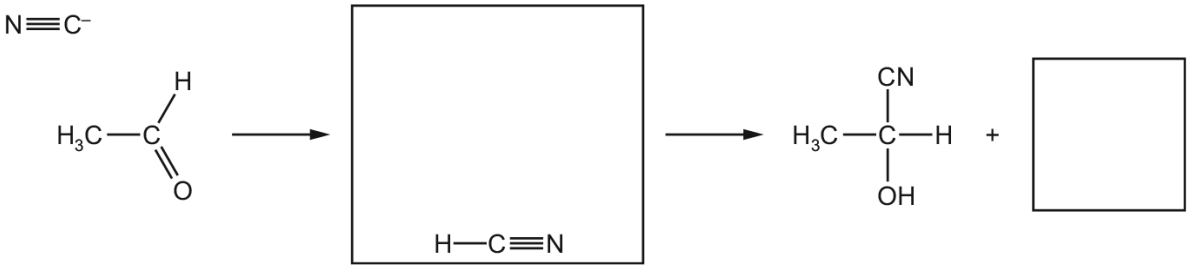
[2]

(ii) Suggest why the two optical isomers are produced in equal amounts by this reaction.

.....

..... [1]

(c) (i) Complete the diagram to show the mechanism of this reaction. Include all necessary charges, partial charges, lone pairs and curly arrows and show the structure of the intermediate.



[5]

(ii) With reference to your mechanism in **(i)**, explain the role of the NaCN in this reaction.

.....

..... [1]

[Total: 12]

152. 9701_S15_qp_22 Q: 4

There are seven structural isomers with the molecular formula $C_5H_{10}O$ that are carbonyl compounds. Four of these are aldehydes.

These four aldehydes, **A**, **B**, **C** and **D**, have the following properties.

- Aldehyde **A** has a straight chain while **B**, **C** and **D** are branched.
- Aldehyde **B** is the only one of the four isomers with a chiral centre and it exists as a pair of optical isomers.
- Aldehyde **C** has two methyl groups in its structure but **D** has three.

(a) (i) Give the structure of each of the four isomers.

A

B

C

D

[4]

(ii) Draw the three-dimensional structures of the two optical isomers of **B**.

[2]

(b) (i) Describe a chemical test that would allow you to distinguish between any of the four isomers **A** to **D** and any of the other three structural isomers of $C_5H_{10}O$, that are carbonyl compounds.

In your answer you should describe any necessary reagents and conditions as well as explaining what you would **see** in each case.

.....

.....

.....

.....

..... [3]

(ii) Describe a test that would give the same result with all seven carbonyl isomers of $C_5H_{10}O$.

.....

.....

..... [2]

[Total: 11]

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A, **B**, **C**, **D**, **E** and **F** are all structural isomers with the molecular formula C_4H_8O.

(a) **A**, **B** and **C** all give an orange precipitate when treated with 2,4-DNPH but only **A** and **B** give a brick-red precipitate when warmed with Fehling's solution.

(i) Draw the **skeletal** formulae of **A**, **B** and **C**.

A	B	C

[3]

(ii) Name the type of structural isomerism shown by **A** and **B**.

..... [1]

(iii) State what you would **see** when a sample of **A** is warmed with Tollens' reagent.

..... [1]

(b) **D**, **E** and **F** all decolourise bromine and effervesce slowly with sodium metal.

E shows geometrical isomerism. Only **D** has a branched chain.

None of these isomers contains an oxygen atom bonded to a carbon atom involved in π bonding.

None of these isomers contains a chiral centre.

(i) Give the structures of **D**, **E** and **F**. Show the two stereoisomers of **E** and label the stereoisomerism shown.

D	
E	**E** .....
F	

[5]

(ii) Identify the gas produced during the reaction of each of these isomers with sodium metal.

..... [1]

(c) Another compound, **G**, C_3H_6O, contains the same functional group as **A**.

Give equations for the reactions of **G** with each of acidified potassium dichromate(VI) and sodium tetrahydridoborate, $NaBH_4$, using [O] or [H] as appropriate.

(i) reaction with acidified potassium dichromate(VI)

C_3H_6O + ... → ..... [1]

(ii) reaction with $NaBH_4$

C_3H_6O + ... → ..... [1]

[Total: 13]