

Cambridge AS & A Level

CHEMISTRY

Paper 2

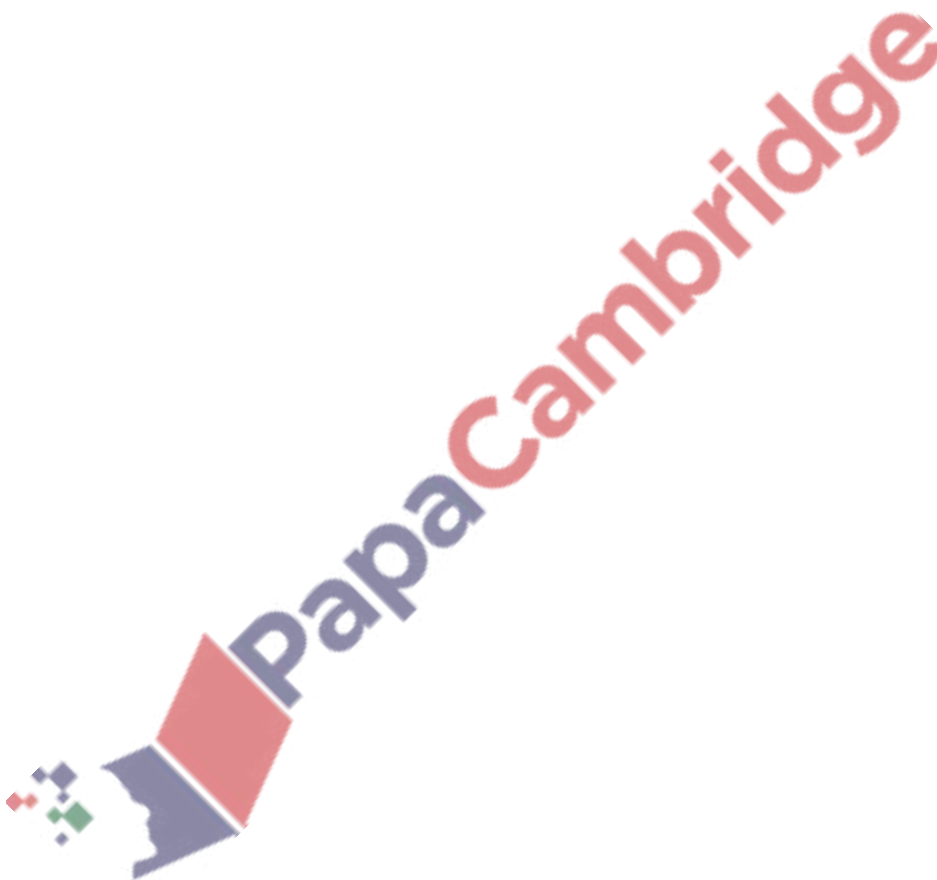
Topical Past Paper Questions
+ Answer Scheme

2015 - 2021



Chapter 19

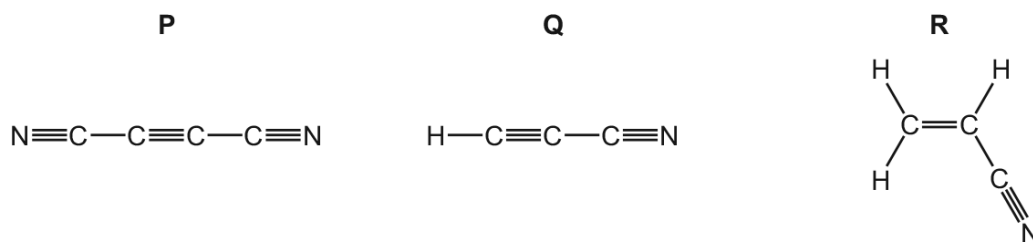
Analytical techniques



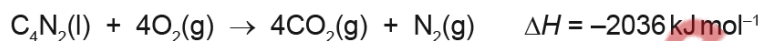
19.1 Infra-red spectroscopy

160. 9701_m21_qp_22 Q: 3

Compounds **P**, **Q** and **R** have all been found in the atmosphere of one of Saturn's moons.



(a) The equation for the complete combustion of **P**, $\text{C}_4\text{N}_2(\text{l})$, is shown.



(i) The enthalpy change of formation, ΔH_f , of $\text{CO}_2(\text{g})$ is -384 kJ mol^{-1} .

Calculate the enthalpy change of formation, ΔH_f , of **P**, in kJ mol^{-1} .

ΔH_f of **P** = kJ mol^{-1} [2]

(ii) One of the products of the complete combustion of **P** is nitrogen gas, $\text{N}_2(\text{g})$.

Explain the lack of reactivity of nitrogen.

..... [1]

(b) **Q** forms when HCN reacts with ethyne, $\text{H}-\text{C}\equiv\text{C}-\text{H}$.

(i) Ethyne, HCN and **Q** are all weak Brønsted–Lowry acids.

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

.....
.....
..... [2]

(ii) Ethyne, HCN and **Q** all contain triple bonds between two atoms.

A triple bond consists of one sigma (σ) and two pi (π) bonds.

Draw a labelled diagram to show the formation of one pi (π) bond.

[2]

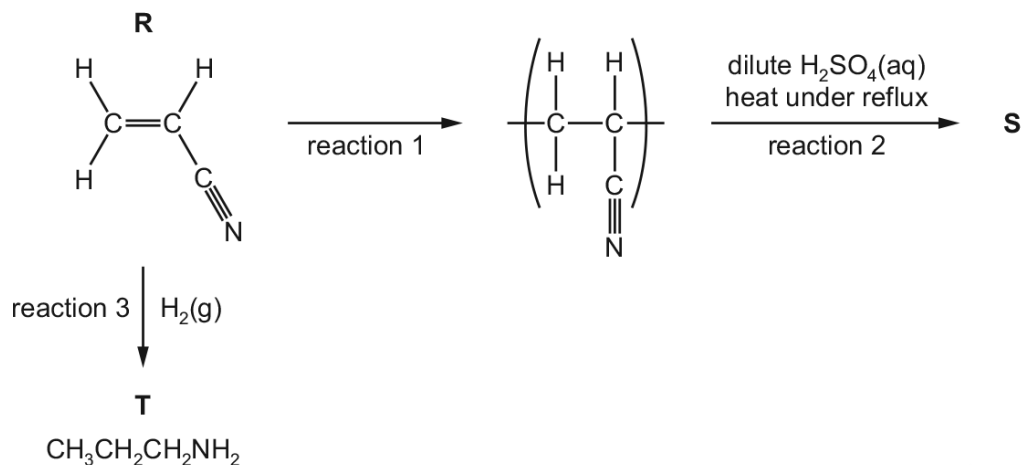
(c) **P** and **Q** can be detected in the atmosphere by infrared spectroscopy.

Identify **two** absorptions, and the bonds that correspond to these absorptions, that will appear in the infrared spectra of both **P** and **Q**.

1
.....
2
.....

[2]

(d) The flow chart shows some reactions of **R**.



(i) Name the type of reaction shown in reaction 1.

..... [1]

(ii) Draw the structure of **S**, the organic product of reaction 2.

[1]

(iii) Name **T**.

..... [1]

(iv) **T** can also be formed by the reaction of CH₃CH₂CH₂Br with ammonia.

State the necessary conditions of this reaction.

..... [1]

[Total: 13]

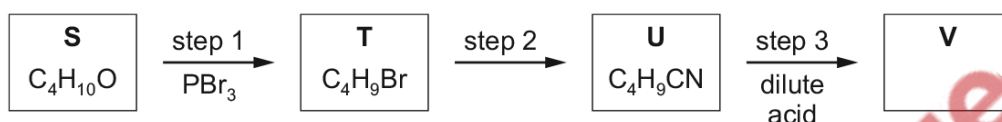
161. 9701_s21_qp_22 Q: 5

S is a secondary alcohol with molecular formula $C_4H_{10}O$.

(a) Draw the displayed formula of **S**.

[1]

(b) **S** is converted to **V** in a three-step reaction sequence.



In step 1, the secondary alcohol **S** reacts with PBr_3 to produce **T**, which has molecular formula C_4H_9Br .

(i) Give the systematic name of **T**.

..... [1]

(ii) Name the type of reaction that occurs in step 1.

..... [1]

(iii) State the reagent(s) and conditions for step 2.

.....
..... [2]

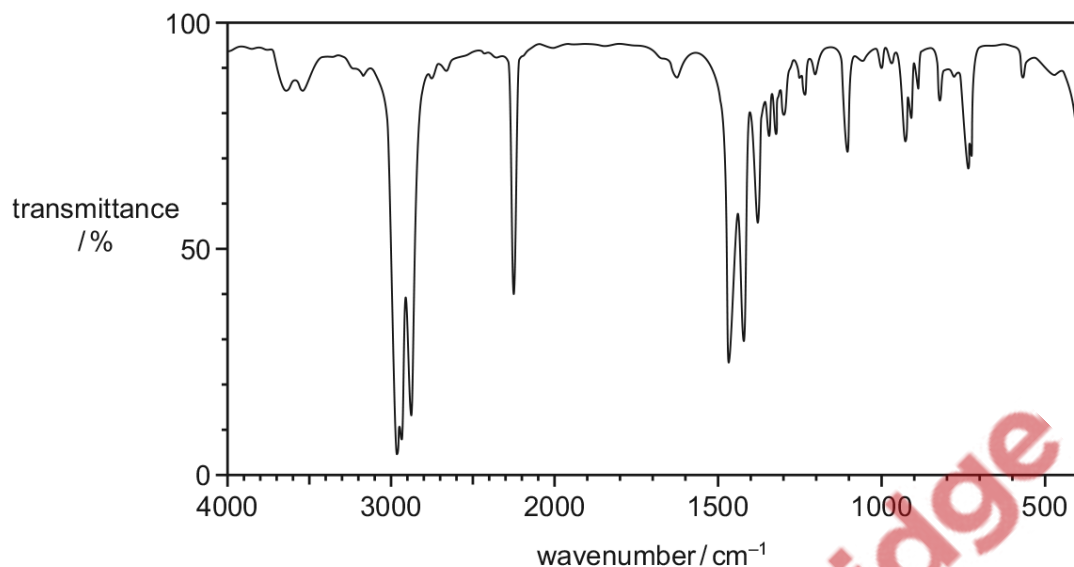
(iv) Step 3 involves heating C_4H_9CN with dilute acid to form **V**.

Complete the equation for this reaction.



(v) An unlabelled sample contains either **S**, **T** or **U**.

The sample produces the infrared spectrum shown.



Explain how this spectrum confirms that the unknown sample contains **U**.

In your answer identify **one** relevant absorption in the infrared spectrum and the bond that corresponds to this absorption in the region above 1500 cm^{-1} .

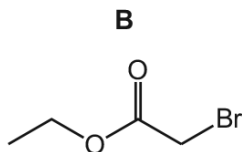
.....
 [1]

[Total: 8]

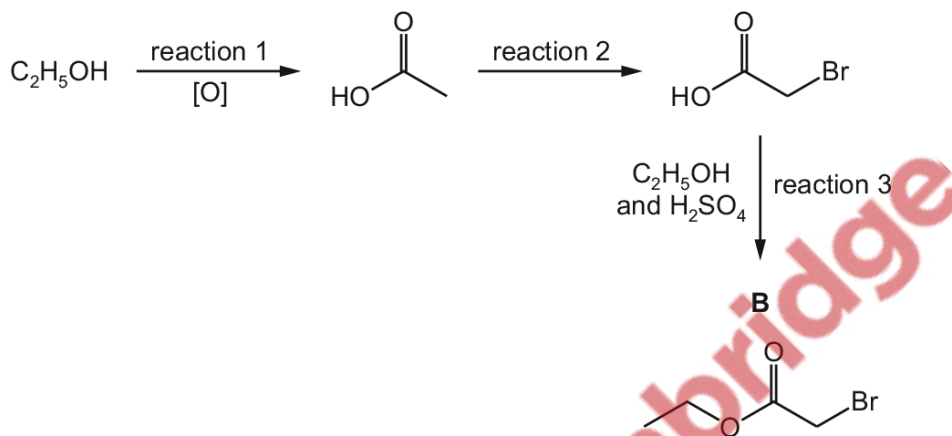


162. 9701_w21_qp_21 Q: 4

Compound **B** is a liquid with a fruity smell.



The reaction scheme shows how **B** can be made from ethanol, C_2H_5OH .



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

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

reagent(s)

conditions

[2]

(ii) Construct an equation to represent reaction 1.

Use [O] to represent an oxygen atom from the oxidising agent in this reaction.

..... [1]

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

..... [1]

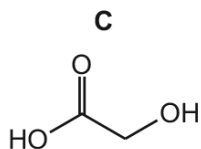
(iv) H_2SO_4 acts as a homogeneous catalyst in reaction 3.

Explain why H_2SO_4 is described as *homogeneous*.

.....

..... [1]

(b) Reaction 2 needs to take place in the absence of water to prevent formation of compound **C**.



If **C** is present in the reaction mixture of reaction 3, a different compound, compound **D**, will also form. Compound **D** has two identical functional groups.

The infrared spectrum of **D** shows strong absorptions at 1100cm^{-1} and 1720cm^{-1} , but no absorption due to O–H bonds.

Use the *Data Booklet* to identify the functional group present in **D**.

Explain your answer as fully as you can.

.....

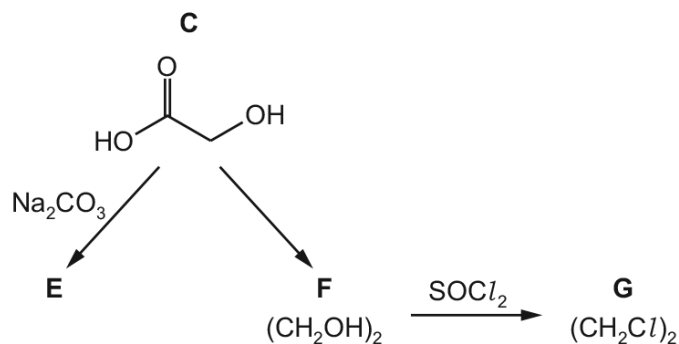
.....

.....

..... [3]

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(c) Some other reactions of **C** are shown.



(i) Draw the structure of **E**.

[1]

(ii) Suggest why NaBH_4 is not a suitable reagent to make **F**, $(\text{CH}_2\text{OH})_2$, from **C**. Explain your answer.

.....
..... [1]

(iii) Construct an equation for the reaction of $(\text{CH}_2\text{OH})_2$ with SOCl_2 to form **G**, $(\text{CH}_2\text{Cl})_2$.

..... [1]

(d) Explain why **C** is very soluble in water.

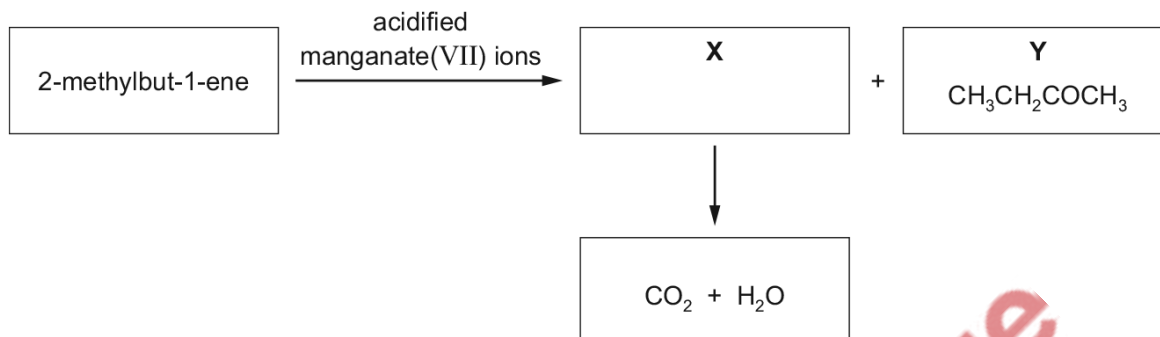
.....
.....
..... [1]

[Total: 12]

163. 9701_s20_qp_21 Q: 6

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 $\text{CH}_3\text{CH}_2\text{COCH}_3$.



(a) Draw the skeletal formula of 2-methylbut-1-ene.

[1]

(b) (i) State the specific conditions required for the acidified manganate(VII) ions to react with 2-methylbut-1-ene in this way.

..... [1]

(ii) Name the type of reaction occurring to the functional group in 2-methylbut-1-ene in the reaction in (b)(i).

..... [1]

(c) Draw the structural formula of **X**.

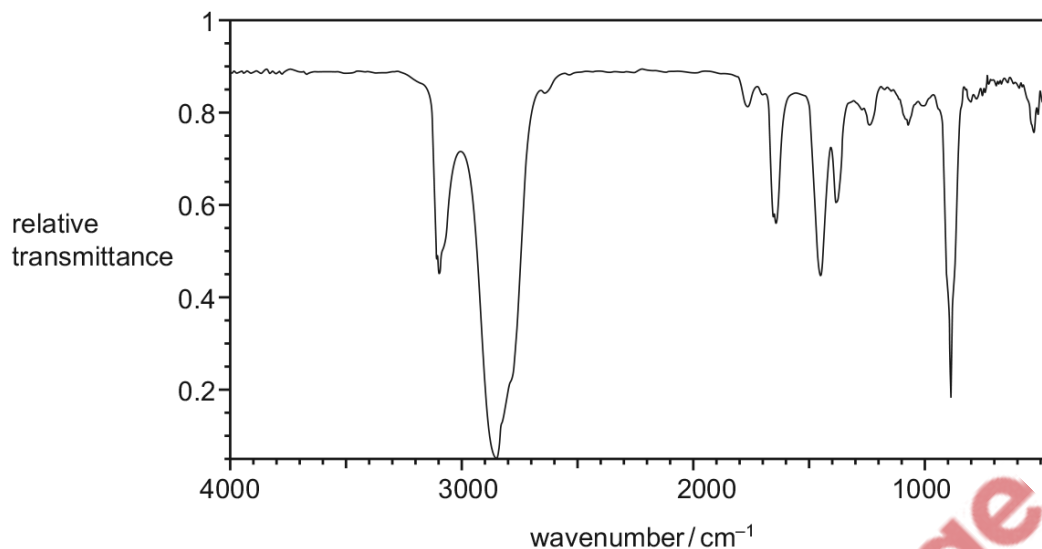
..... [1]

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

.....

..... [2]

(e) The infra-red spectrum of 2-methylbut-1-ene is shown.



Predict two main differences that would be seen between the spectra of Y, $\text{CH}_3\text{CH}_2\text{COCH}_3$, and of 2-methylbut-1-ene. Give reasons for your predictions.

Your answer should refer only to the region of each spectrum **above** 1500 cm^{-1} .

.....

.....

.....

.....

..... [2]

(f) Propanoic acid, $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$, is reduced by LiAlH_4 .

(i) Write an equation to show this reaction. Use [H] to represent an atom of hydrogen from the reducing agent.

..... [1]

(ii) Name the organic product formed in this reaction.

..... [1]

(g) Organic compound **W** is an ester which is a structural isomer of propanoic acid.

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

..... [1]

(ii) Draw a possible structure of **W**.

[1]

[Total: 12]

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164. 9701_w20_qp_21 Q: 3

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

(a) (i) At 200°C , aluminium chloride exists as $\text{Al}_2\text{Cl}_6(\text{g})$.

Draw the structure of $\text{Al}_2\text{Cl}_6(\text{g})$, showing fully any coordinate (dative covalent) bonds in the molecule.

[2]

(ii) At 1000°C , aluminium chloride exists as $\text{AlCl}_3(\text{g})$.

State the bond angle in $\text{AlCl}_3(\text{g})$.

..... $^\circ$ [1]

(iii) Lithium hydride contains the ions Li^+ and H^- .

State the electronic configuration of these two ions.

Li^+ H^- [1]

(iv) LiAlH_4 decomposes slowly to form $\text{LiAl}(\text{s})$ and $\text{H}_2(\text{g})$.



$\text{LiAl}(\text{s})$ shows metallic bonding.

Describe metallic bonding.

.....

 [1]

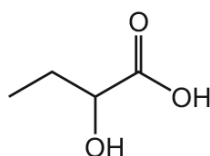
- (b) LiAlH_4 cannot be used in aqueous solution because it reacts with water to produce LiOH(aq) , $\text{H}_2(\text{g})$ and a white precipitate which is soluble in excess sodium hydroxide.

Identify the white precipitate.

..... [1]

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

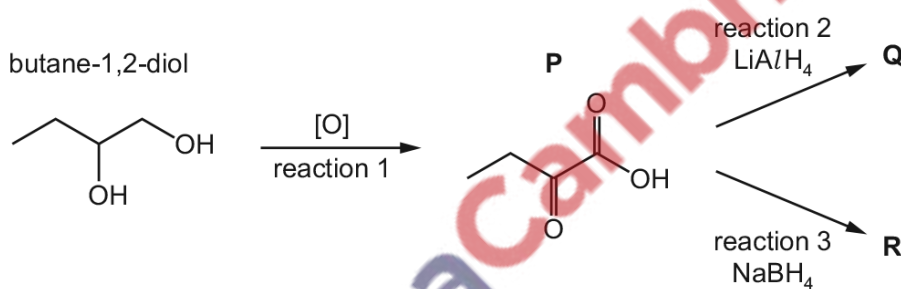
2-hydroxybutanoic acid



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.



- (i) State the reagents and conditions required for reaction 1.

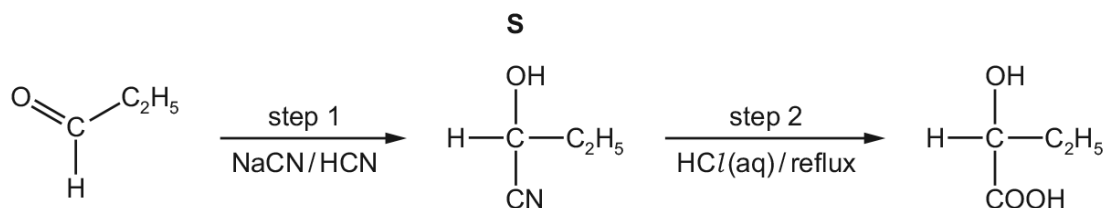
.....
..... [2]

- (ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which of **Q** or **R** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

.....
.....
..... [2]

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**.

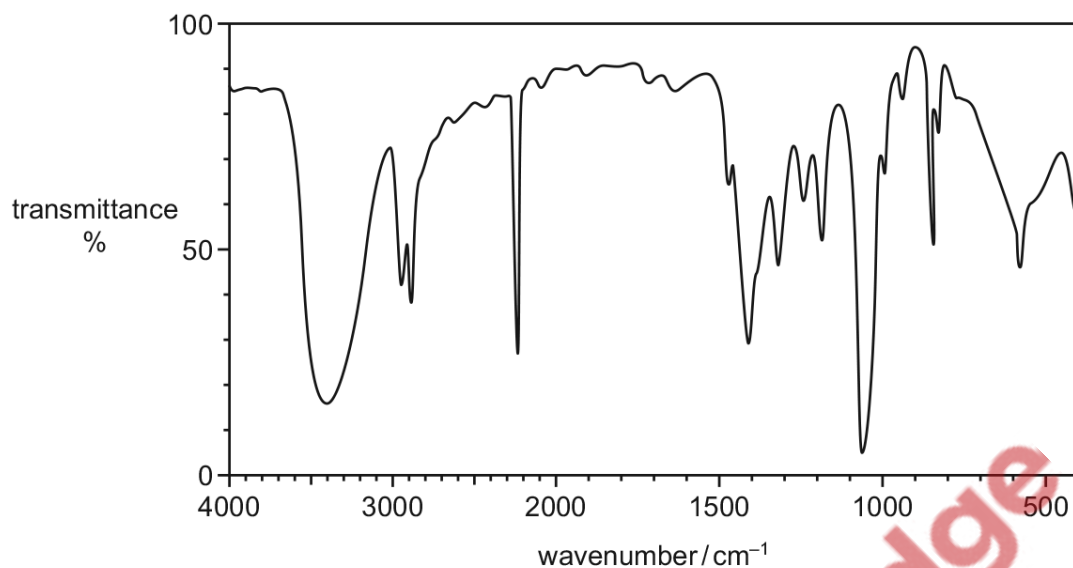
- Identify the ion that reacts with propanal.
- Draw the structure of the intermediate of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.



(iv) Complete the equation for the reaction in step 2, when **S** is heated under reflux with HCl(aq).



- (v) The infrared spectrum of an organic compound is shown. The organic compound is either S or 2-hydroxybutanoic acid.



Deduce the identity of the compound. Give **two** reasons for your answer.

In your answer, identify any relevant absorptions **above** 1500 cm^{-1} in the spectrum and the bonds that correspond to these absorptions.

.....

.....

.....

.....

.....

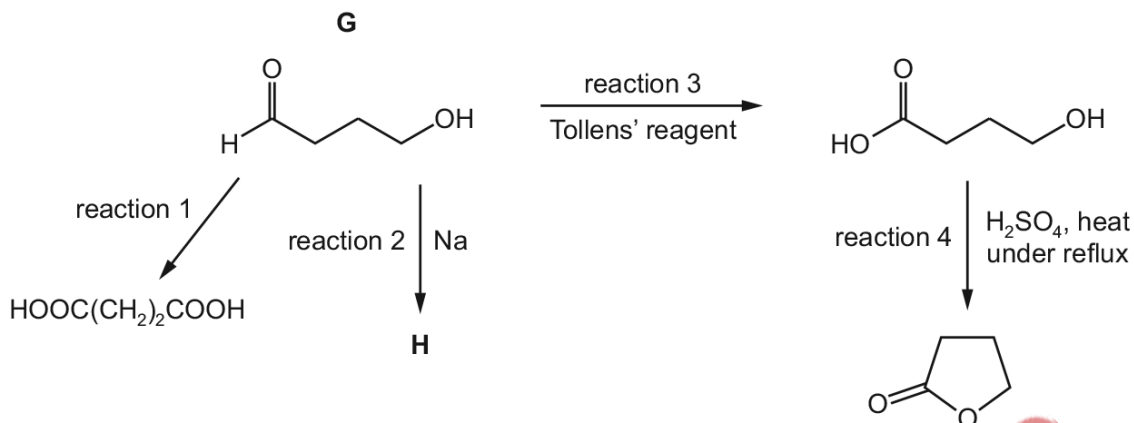
..... [2]

[Total: 17]



165. 9701_w20_qp_22 Q: 4

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



(a) (i) State the type of reaction that occurs in reaction 1.

..... [1]

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

..... [2]

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

..... [1]

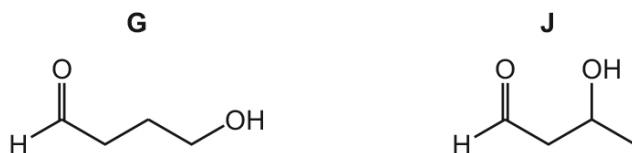
(iv) State what you would observe in reaction 3.

..... [1]

(v) Give the type of reaction shown by reaction 4.

..... [1]

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



(i) Name the type of structural isomerism shown by **G** and **J**.

..... [1]

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

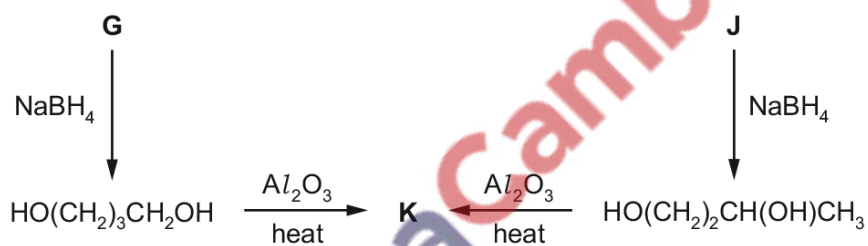
test

result with **G**

result with **J**

[2]

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



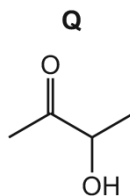
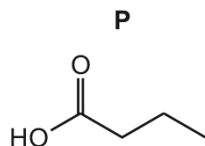
(iii) State the role of NaBH₄ in the reactions with **G** and **J**.

..... [1]

(iv) Identify the organic product **K**.

..... [1]

(c) **P** and **Q** have the same molecular formula as **G**.



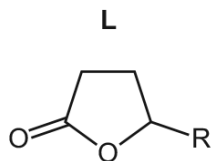
Complete the table with the expected observations for the reactions of **P** and **Q** with the named reagents.

reagent	result with P	result with Q
Br ₂ (aq)		
2,4-dinitrophenylhydrazine		
aqueous sodium carbonate		

[3]

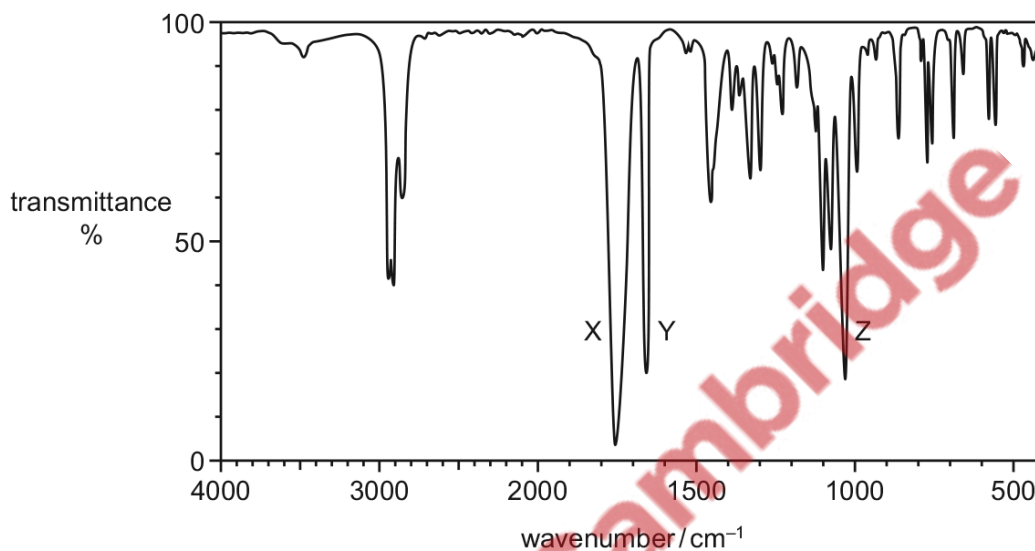
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(d) The structure of compound **L** is shown. R represents a hydrocarbon chain.



A student was asked to deduce the full structure of **L**.

The student analysed **L** using infrared spectroscopy. The following spectrum was obtained.



(i) Identify the bonds responsible for the absorptions marked X and Z.

X

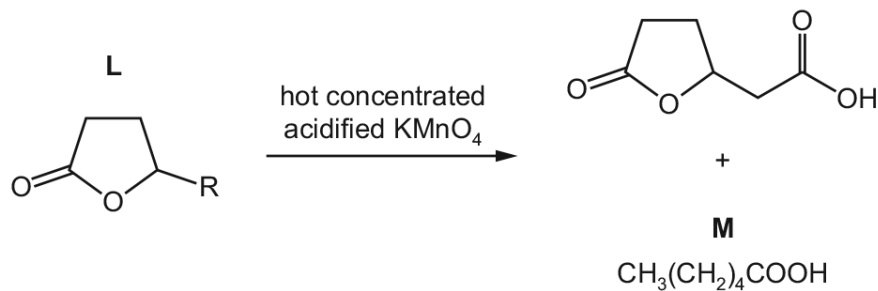
Z

[1]



Absorption Y shows that **L** has a C=C bond present in the R group.

The student decided to treat **L** with hot concentrated acidified potassium manganate(VII). The products of the reaction are shown.



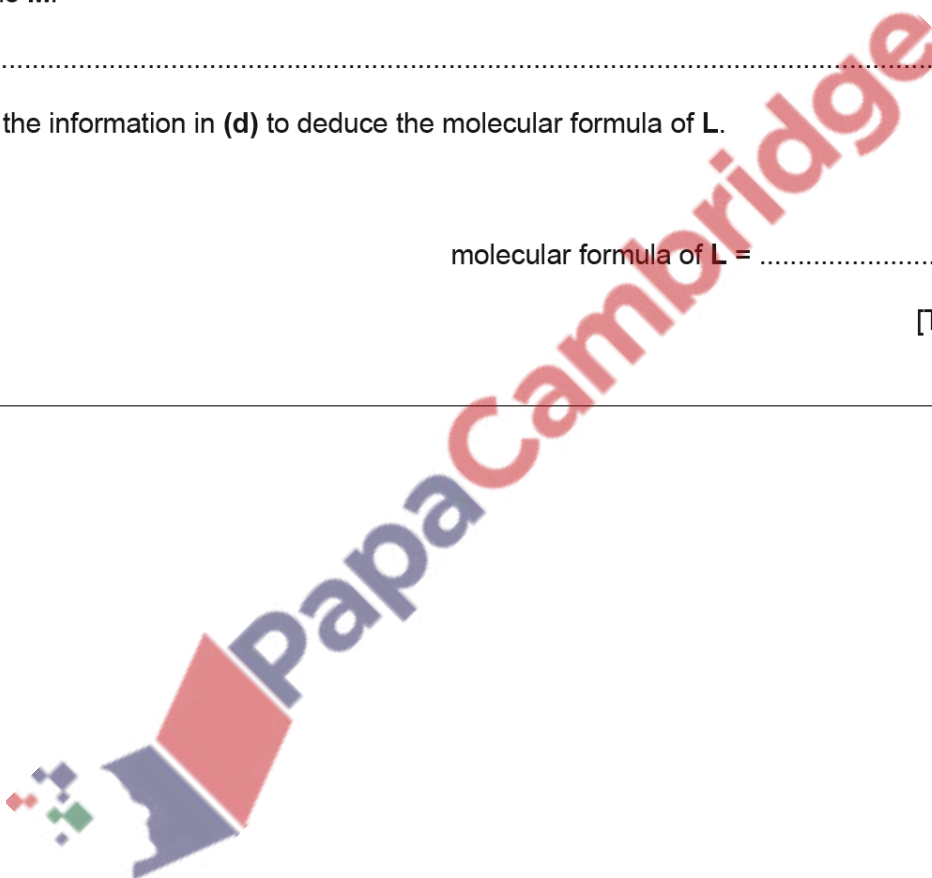
(ii) Name **M**.

..... [1]

(iii) Use the information in (d) to deduce the molecular formula of **L**.

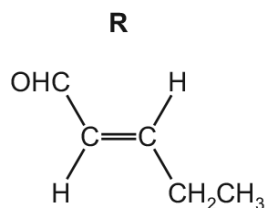
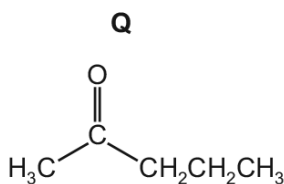
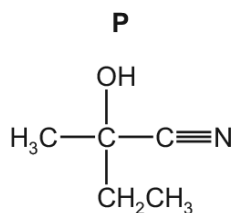
molecular formula of **L** = [1]

[Total: 17]



166. 9701_m19_qp_22 Q: 3

P, Q and R all contain five carbon atoms.



A student carries out several tests to distinguish between P, Q and R.

- (a) Complete the table, identifying any observations for the reaction of each reagent with P, Q and R.

If no reaction occurs, write 'no reaction'.

reagent	observations with		
	P	Q	R
Na(s)			
2,4-DNPH	no reaction		
acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$	no reaction		

[3]

- (b) Q is reduced by NaBH_4 .

 Write an equation for the reaction of Q with NaBH_4 .

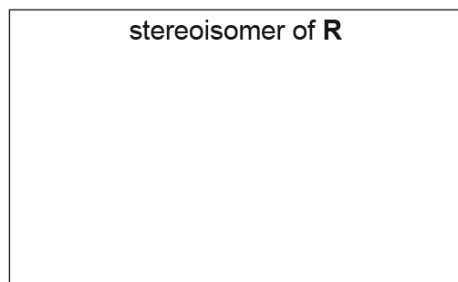
 In your answer, use [H] to represent NaBH_4 .

 $\text{C}_5\text{H}_{10}\text{O} + \dots\dots\dots$ [1]

(c) **R** exists as a pair of stereoisomers.

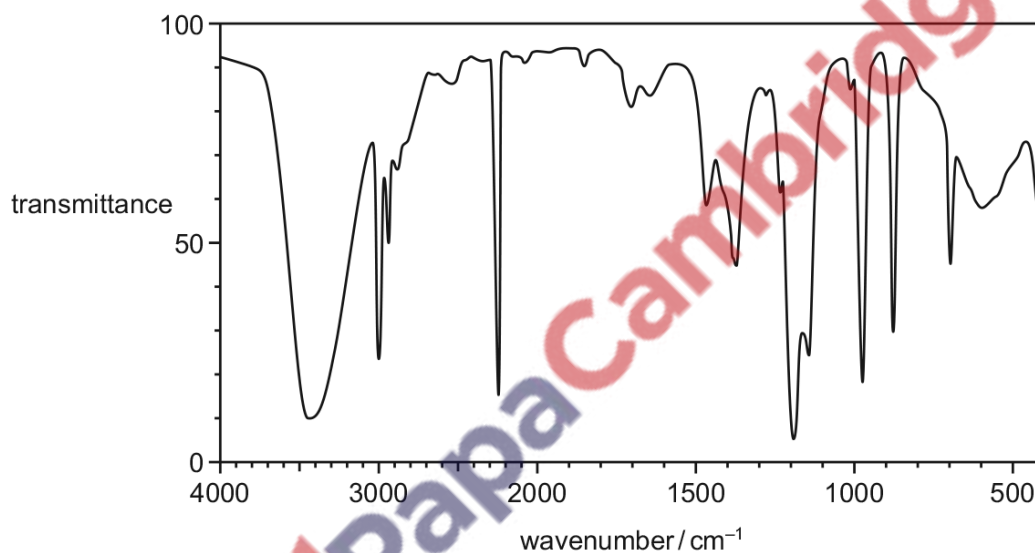
Identify the type of stereoisomerism shown by **R** and draw the structure of the other stereoisomer.

type of stereoisomerism



[2]

(d) The infra-red spectrum shown corresponds to one of **P**, **Q** or **R**.



Deduce which of the compounds, **P**, **Q** or **R**, produces this spectrum. Explain your reasoning.

In your answer, identify any relevant absorptions in the infra-red spectrum and the bonds that correspond to these absorptions in the region above 1500 cm⁻¹.

compound

explanation

.....

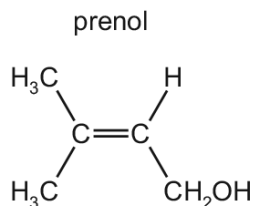
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[3]

[Total: 9]

167. 9701_w19_qp_22 Q: 4

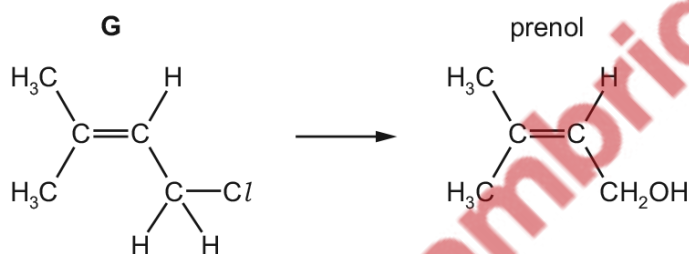
Prenol is a naturally occurring organic molecule found in many fruits. It contains both an alkene and an alcohol functional group.



- (a) Prenol can be formed by the reaction of **G** with NaOH(aq).

Complete the diagram to show the mechanism of the reaction between **G** and NaOH(aq) to form prenol.

Include all relevant charges, partial charges, lone pairs and curly arrows.



[2]

- (b) Prenol reacts with steam to form a mixture of three isomers, **J**, **K** and **L**, of molecular formula $\text{C}_5\text{H}_{12}\text{O}_2$.

- (i) When **J** is heated with excess acidified potassium dichromate(VI) it forms an organic product which shows no reaction with 2,4-DNPH.

Draw the structure of **J**.



[1]

K and **L** are stereoisomers with molecular formula $C_5H_{12}O_2$.

K and **L** both react when heated with excess acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

M forms an orange precipitate on reaction with 2,4-DNPH.

(ii) Give the structural formula of **K** and **L**.

..... [1]

(iii) Name the type of stereoisomerism shown by **K** and **L**.

..... [1]

(iv) Give the balanced equation to represent the reaction of **K**, $C_5H_{12}O_2$, with acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

Use [O] to represent an atom of oxygen provided by the oxidising agent.

..... [1]

(c) (i) Prenol contains an alkene functional group.

Describe a chemical test to confirm the presence of an alkene functional group. Give the result of the test.

.....
..... [1]

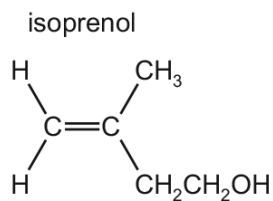
(ii) Prenol can be polymerised to form poly(prenol).

Draw **one** repeat unit of poly(prenol).

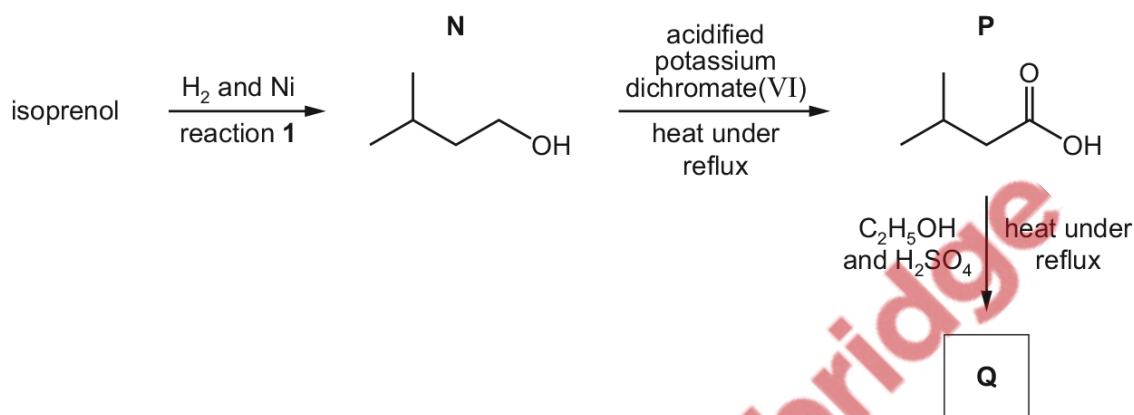


[1]

(d) Isoprenol is a structural isomer of prenol.



The series of reactions shows how isoprenol can be used to form **Q**, a sweet-smelling liquid.



(i) Give the name of **N**.

..... [1]

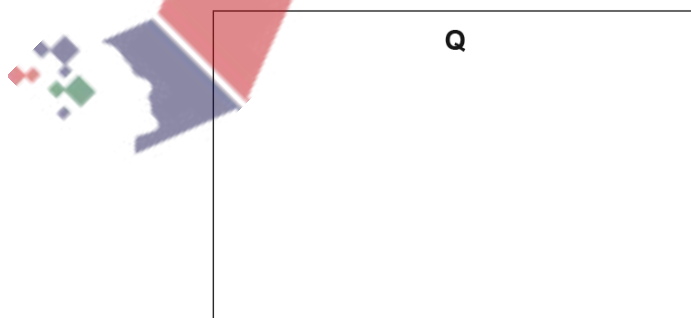
(ii) Isoprenol is a liquid.

Ni acts as a catalyst for reaction 1.

Identify the type of catalysis shown by Ni in reaction 1.

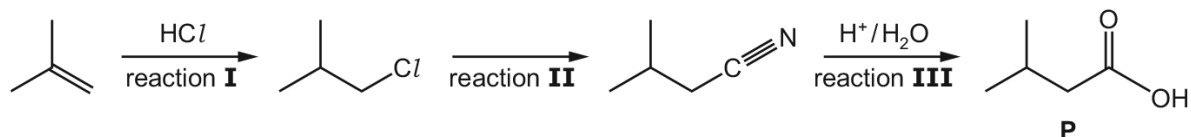
..... [1]

(iii) Draw the **skeletal** formula of **Q** and suggest one commercial use of **Q**.



commercial use [2]

(e) **P** can be produced as shown.



(i) The progress of reaction **I** can be monitored using infra-red spectroscopy.

One absorption that can be used to monitor the progress of this reaction is that of C–Cl at 730cm^{-1} .

Identify another absorption that can be used to monitor the progress of this reaction. In your answer, you should refer to the specific bond and its corresponding absorption range in wavenumbers.

.....
..... [1]

(ii) State the reagent(s) needed for reaction **II**.

..... [1]

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

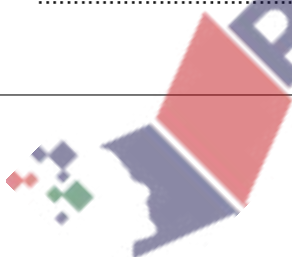
..... [1]

(iv) The yield of reaction **I** is very low.

Explain why.

.....
.....
..... [2]

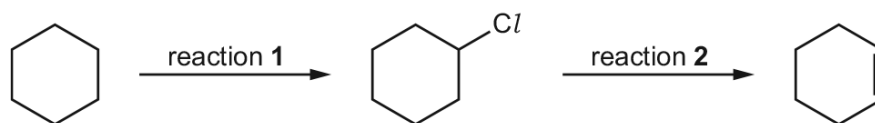
[Total: 17]



168. 9701_m18_qp_22 Q: 4

Cyclohexane is a colourless liquid used in industry to produce synthetic fibres.

A reaction scheme involving cyclohexane is shown.



(a) Reaction 1 involves a free radical substitution mechanism.

(i) State the essential condition required for reaction 1 to occur.

..... [1]

(ii) Complete the table to give details of the mechanism in reaction 1.

name of step	reaction
.....	$Cl_2 \longrightarrow 2Cl\cdot$
propagation	 <chem>C1CCCCC1.[Cl]>>[C1CCCCC1]C.[H]</chem>
.....	 <chem>[C1CCCCC1]C.ClCl>>ClC1CCCCC1.[Cl]</chem>
termination	 <chem>[C1CCCCC1]C.[Cl]>>C1CCCCC1</chem>

[4]

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

..... [1]

(c) The product of reaction 2 is cyclohexene.

Cyclohexene can be converted into adipic acid (hexanedioic acid), $\text{HO}_2\text{C}(\text{CH}_2)_4\text{CO}_2\text{H}$.

(i) Identify the reagents and conditions for the conversion of cyclohexene into adipic acid.

.....
..... [2]

(ii) Suggest **three** main differences between the infra-red spectra of cyclohexene and adipic acid.

In each case, identify the bond responsible and its characteristic absorption range (in wavenumbers).

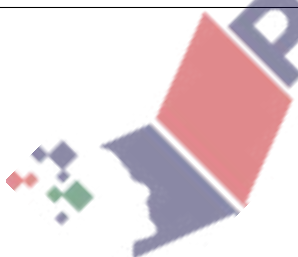
1
.....
.....

2
.....
.....

3
.....
.....

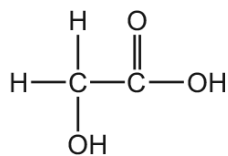
[3]

[Total: 11]



169. 9701_w18_qp_21 Q: 4

The structure of glycolic acid is shown.



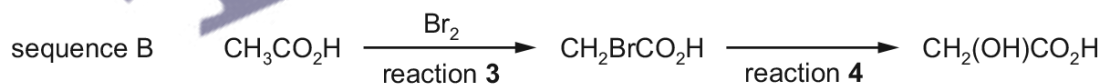
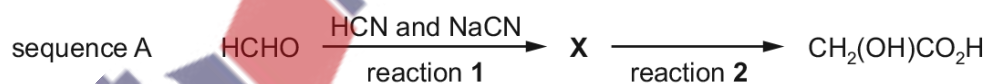
glycolic acid

- (a) Complete the table to show what you would **observe** when an aqueous solution of glycolic acid is added separately to each of the reagents. If a reaction occurs, state the functional group of glycolic acid that is responsible for the reaction.

reagent	observation with glycolic acid	does a reaction occur? ✓ / X	functional group
$\text{Na}_2\text{CO}_3(\text{aq})$			
2,4-DNPH			
acidified $\text{Cr}_2\text{O}_7^{2-}$			

[4]

- (b) Two reaction sequences to make glycolic acid are shown.



- (i) Draw the structure of X.

[1]

(ii) Name the reagent for reaction 2.

..... [1]

(iii) Name the mechanism of reaction 3.

..... [1]

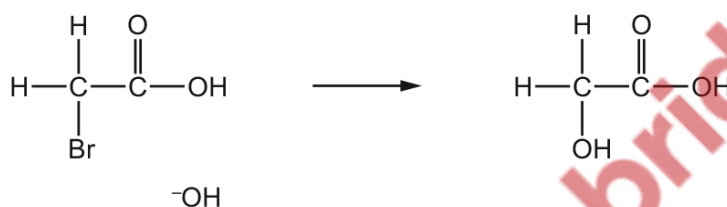
(iv) Suggest the essential condition for reaction 3.

..... [1]

(v) Reaction 4 occurs via an S_N2 mechanism.

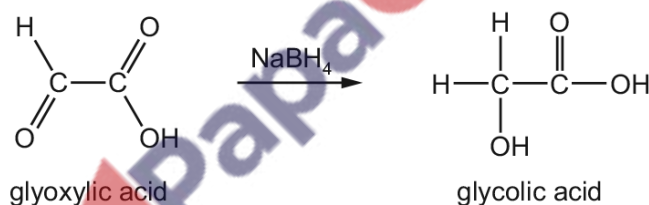
Complete the diagram for the mechanism for reaction 4.

Include all relevant charges, partial charges, curly arrows and lone pairs.



[2]

(c) Glycolic acid can also be made by reacting glyoxylic acid with NaBH₄.



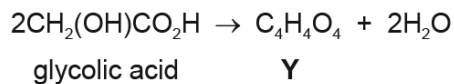
(i) State the role of NaBH₄ in this reaction.

..... [1]

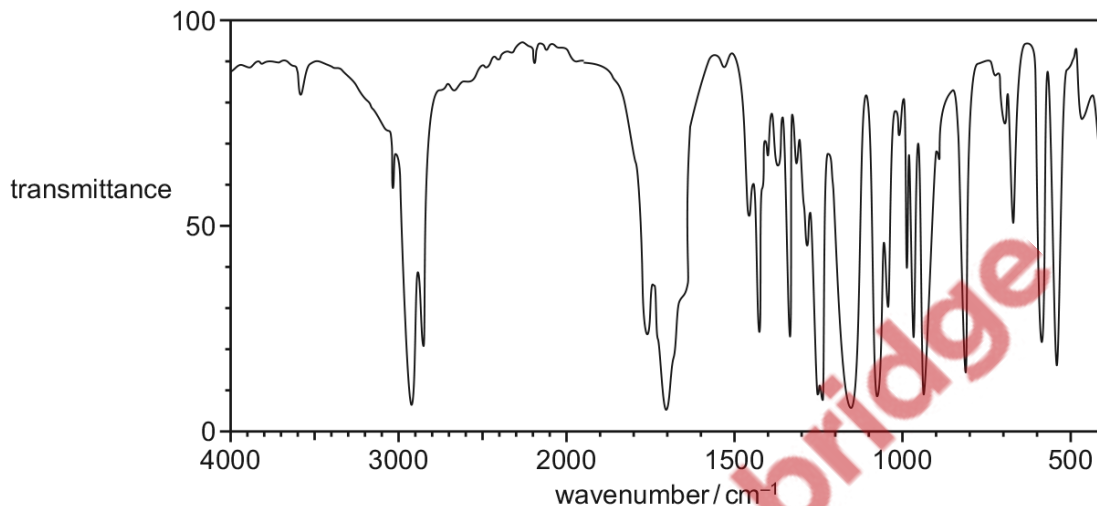
(ii) Write an equation for this reaction using molecular formulae.
Use [H] to represent NaBH₄.

..... [2]

- (d) When glycolic acid is heated in the presence of a sulfuric acid catalyst, a new compound, Y, $C_4H_4O_4$, is formed.
The equation for the reaction is given.



- (i) The infra-red spectrum of Y is shown.



State how this spectrum differs from an infra-red spectrum of glycolic acid. Explain your answer with particular reference to the peaks within the range $1500-4000\text{ cm}^{-1}$.

.....

.....

..... [2]

- (ii) Suggest a structure for Y.



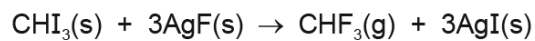
[2]

[Total: 17]

170. 9701_w18_qp_22 Q: 3

Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHF_3 .

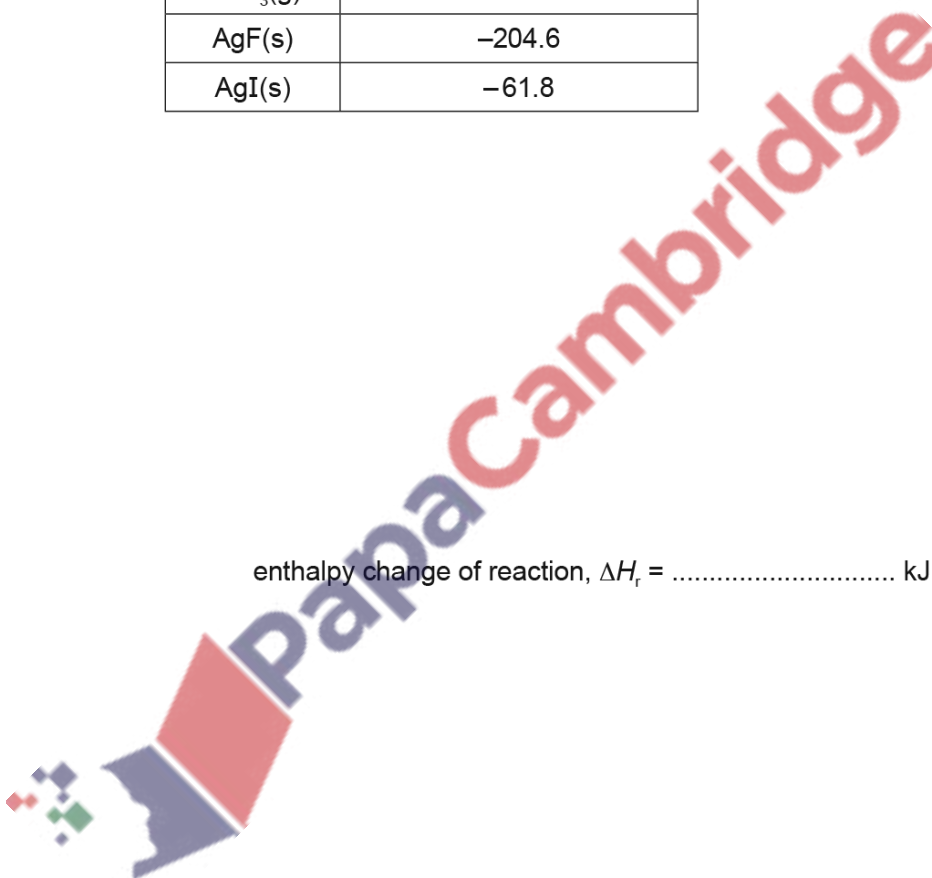
(a) The equation shows a reaction to produce CHF_3 .



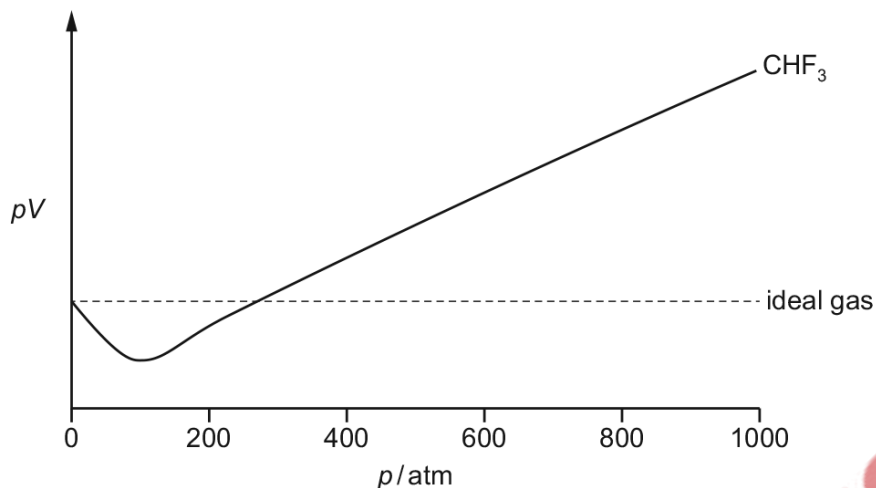
Use the data to calculate the enthalpy change of reaction, ΔH_r , for this formation of CHF_3 .

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
$\text{CHI}_3(\text{s})$	-182.1
$\text{CHF}_3(\text{g})$	-692.9
$\text{AgF}(\text{s})$	-204.6
$\text{AgI}(\text{s})$	-61.8

enthalpy change of reaction, $\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$ [3]



- (b) The graph shows the relationship between pV and p at a given temperature for CHF_3 and an ideal gas.



- (i) CHF_3 is not an ideal gas.

State **three** basic assumptions that scientists make about the properties of ideal gases.

1

2

3

[3]

- (ii) Explain why CHF_3 deviates from the properties of an ideal gas at pressures greater than 300 atm.

.....

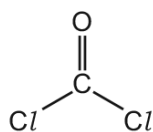
.....

.....

..... [2]



- (c) A different trihalomethane, CHCl_3 , reacts with O_2 to produce carbonyl dichloride. HCl(g) is also released as a product of this reaction.

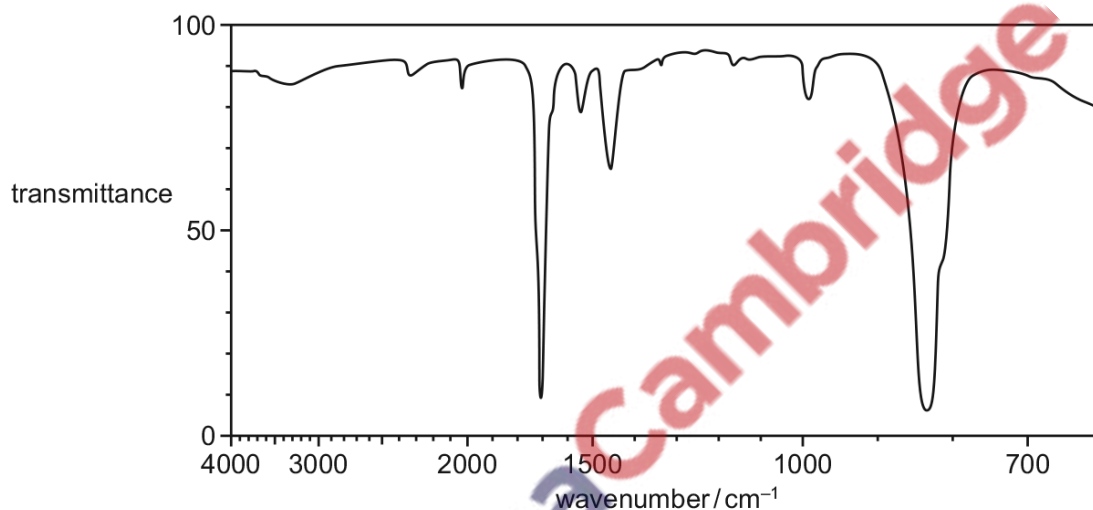


carbonyl dichloride

- (i) Write an equation for this reaction of CHCl_3 with O_2 .

..... [1]

- (ii) The conversion of CHCl_3 to carbonyl dichloride can be monitored by infra-red spectroscopy. The infra-red spectrum of carbonyl dichloride is shown.



On the infra-red spectrum of carbonyl dichloride identify with an **X** the absorption that would **not** be present in an infra-red spectrum of CHCl_3 .

Explain your answer.

.....
..... [2]

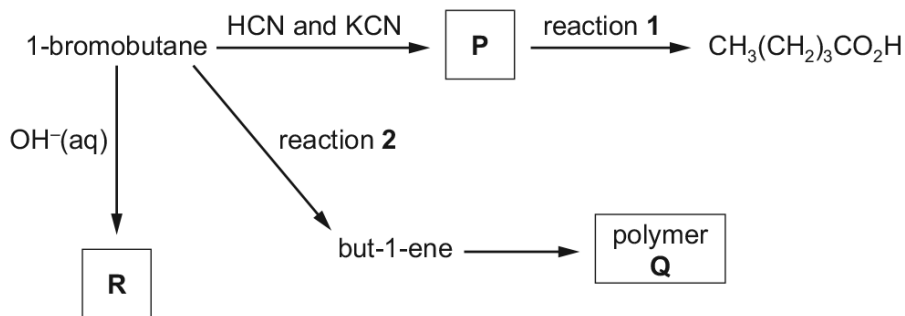
- (iii) Suggest another difference between the infra-red spectra of CHCl_3 and carbonyl dichloride.

.....
..... [1]

[Total: 12]

171. 9701_m17_qp_22 Q: 3

(a) A series of reactions starting from 1-bromobutane is shown.



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

[1]

(ii) Identify the reagent(s) and conditions for reactions 1 and 2.

reaction 1

reaction 2

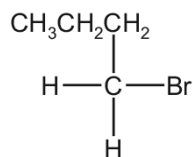
[2]

(iii) Draw the structure of the repeat unit of polymer **Q**.

[2]

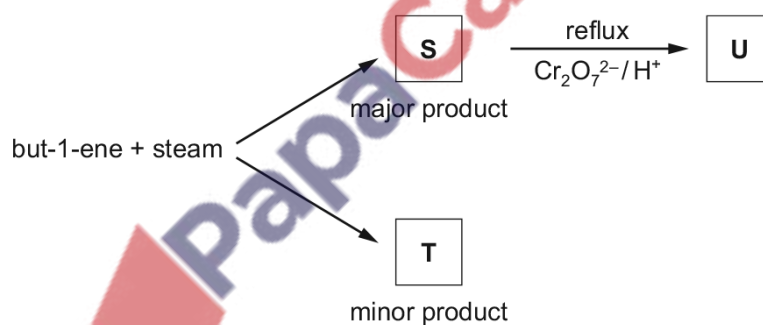
- (b) Complete the reaction scheme to show the mechanism of the reaction of 1-bromobutane with $\text{OH}^-(\text{aq})$ to produce **R**.

Include all necessary charges, dipoles, lone pairs and curly arrows and the structure of **R**.



[3]

- (c) But-1-ene reacts with steam as shown to form a mixture of two structural isomers, **S** and **T**.



S can be oxidised with acidified potassium dichromate(VI) to form compound **U**.
S and **U** both react with alkaline aqueous iodine.

- (i) Identify the *type of reaction* that occurs when but-1-ene reacts with steam.

..... [1]

- (ii) State what can be deduced about the structure of **S** from its reaction with alkaline aqueous iodine.

..... [1]

(iii) Explain why **S** is the major product of the reaction of but-1-ene with steam.

.....

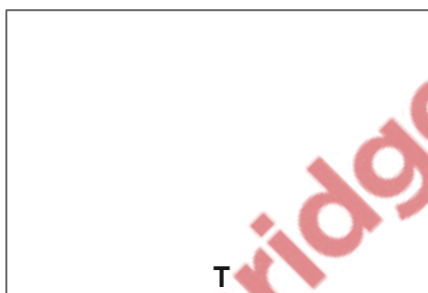
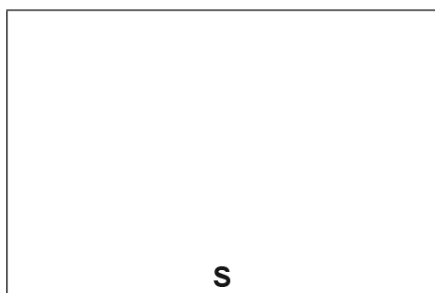
.....

.....

.....

..... [2]

(iv) Draw the skeletal formulae of **S**, **T** and **U**.



[3]

(v) Write an equation to represent the oxidation of **S** to **U** by acidified potassium dichromate(VI).

You should use [O] to represent the oxidising agent.

..... [1]

(d) $\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$ is a colourless liquid with an unpleasant odour.

It reacts with methanol in the presence of an acid catalyst to produce an organic product **V**, which has a pleasant fruity smell.

(i) Name **V**.

..... [1]

(ii) A student analysed $\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$, methanol and **V** using infra-red spectroscopy. The spectra were returned to the student without labels.

Identify which of the infra-red spectra, X, Y or Z, corresponds to **V**.

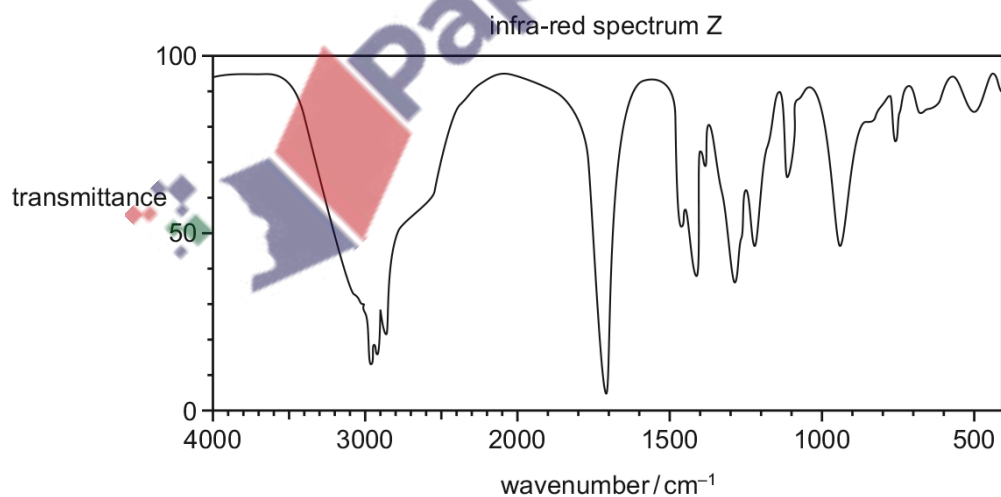
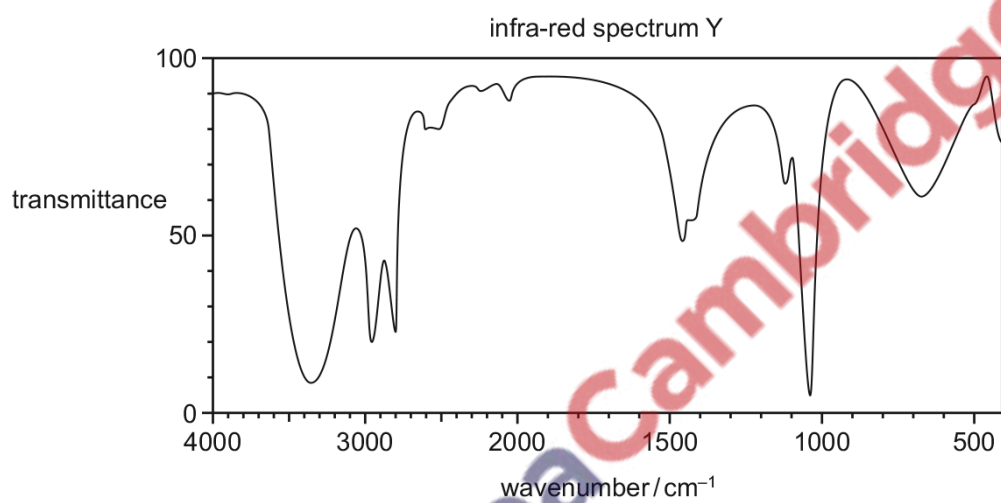
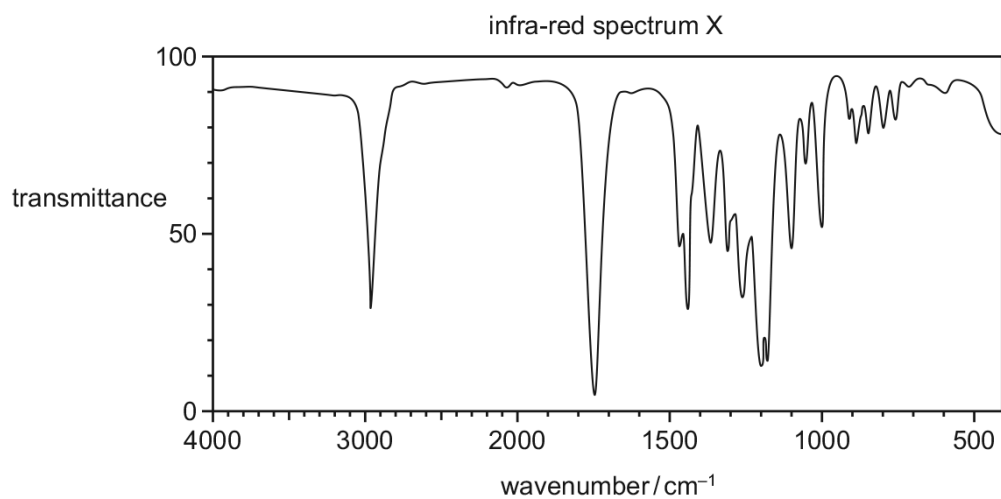
compound	$\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$	methanol	V
spectrum			

Explain your answer with reference to relevant features of the **three** spectra in the region above 1500 cm^{-1} .

.....

 [4]





[Total: 21]

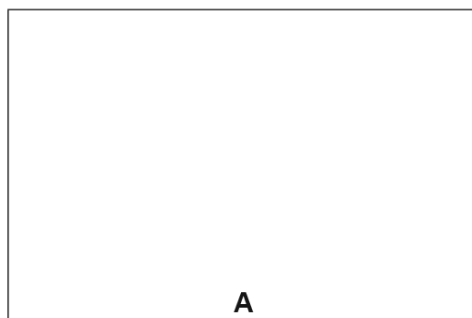
172. 9701_s17_qp_22 Q: 4

(a) The hydrocarbons **A**, C_4H_{10} , and **B**, C_4H_8 , are both unbranched.

A does **not** decolourise bromine.

B decolourises bromine and shows geometrical isomerism.

(i) Draw the skeletal formula of **A**.



[1]

(ii) The hydrocarbon **A**, C_4H_{10} , has a branched isomer.

Suggest why unbranched **A** has a higher boiling point than its branched isomer.

.....

.....

.....

.....

.....

..... [2]

(iii) Give the structural formula of **B**.

..... [1]

(iv) Explain why **B** shows geometrical isomerism.

.....

.....

.....

..... [2]

- (v) Draw the mechanism of the reaction of **B** with bromine, Br_2 .
Include all necessary charges, dipoles, lone pairs and curly arrows.

[4]

- (vi) Explain the origin of the dipole on Br_2 in this mechanism.

.....

 [1]

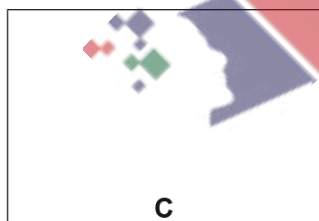
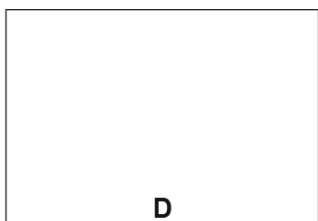

- (b) The alcohols **C** and **D** are isomers of each other with molecular formula $\text{C}_4\text{H}_{10}\text{O}$. Both isomers are branched.

When **C** is heated under reflux with acidified potassium dichromate(VI) no colour change is observed.

When **D** is heated under reflux with acidified potassium dichromate(VI) the colour of the mixture changes from orange to green and **E**, $\text{C}_4\text{H}_8\text{O}_2$, is produced.

E reacts with aqueous sodium carbonate to form carbon dioxide gas.

- (i) Identify **C**, **D** and **E**.

 C	 D	 E
---	---	--

[3]

- (ii) Write the equation for the reaction between **E** and aqueous sodium carbonate.

..... [1]

(c) The isomers **F** and **G**, $C_5H_{10}O$, both form an orange precipitate when reacted with 2,4-DNPH.

F is unbranched and reacts with alkaline aqueous iodine to produce a yellow precipitate.

G does not react with alkaline aqueous iodine. It contains a chiral centre and produces a silver mirror when warmed with Tollens' reagent.

(i) Name the yellow precipitate produced by the reaction between **F** and alkaline aqueous iodine.

..... [1]

(ii) Give the structural formula of **F** and of **G**.

F

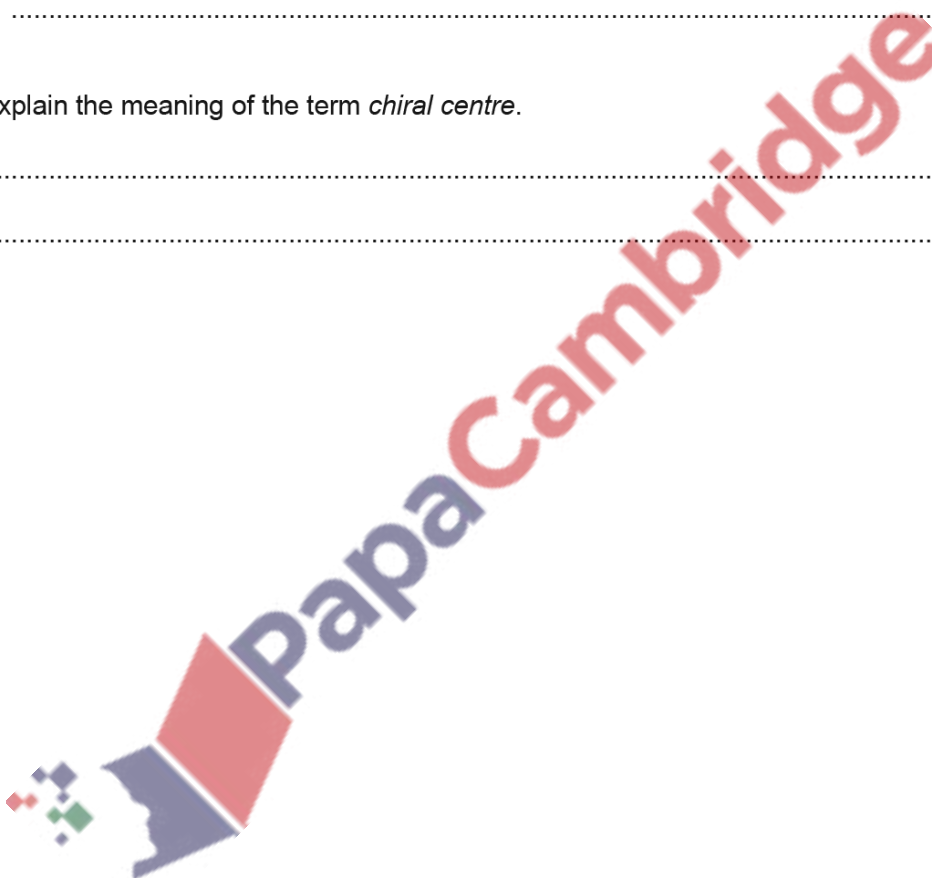
G

[2]

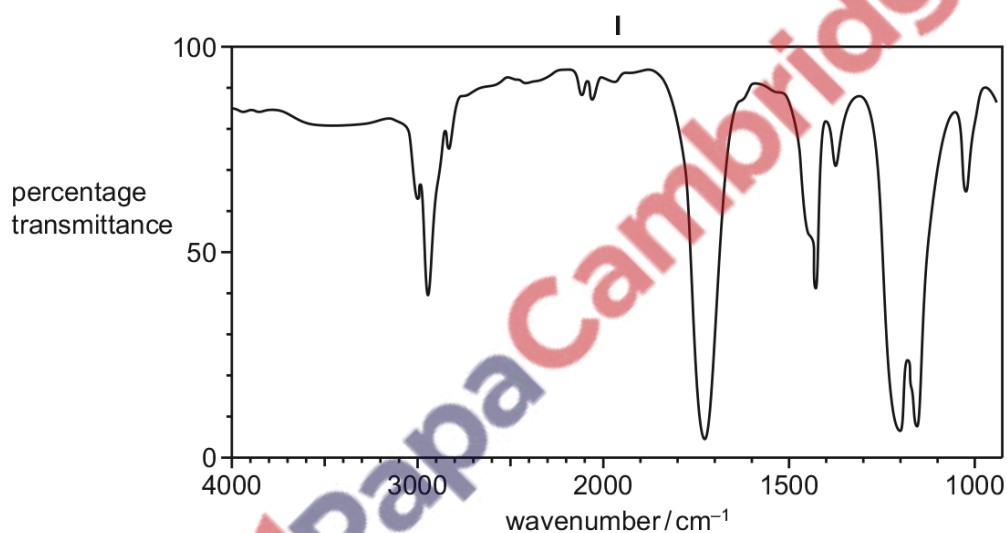
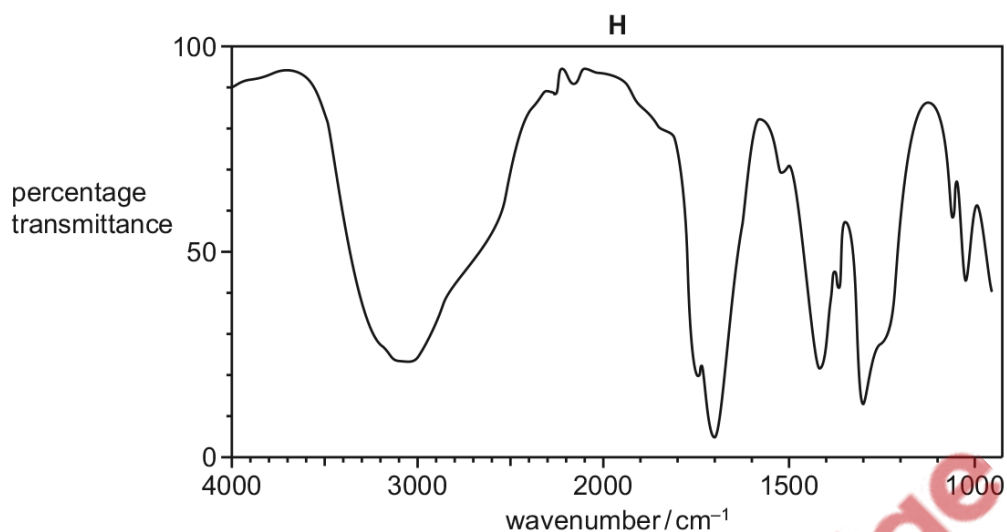
(iii) Explain the meaning of the term *chiral centre*.

.....

..... [1]



(d) H and I are isomers with molecular formula $C_2H_4O_2$. The infra-red spectra of isomers H and I are shown.



(i) Identify the bonds responsible for the principal peaks above 1500 cm^{-1} in each spectrum.

spectrum of H

.....

spectrum of I

.....

[2]

(ii) Name H and I.

H

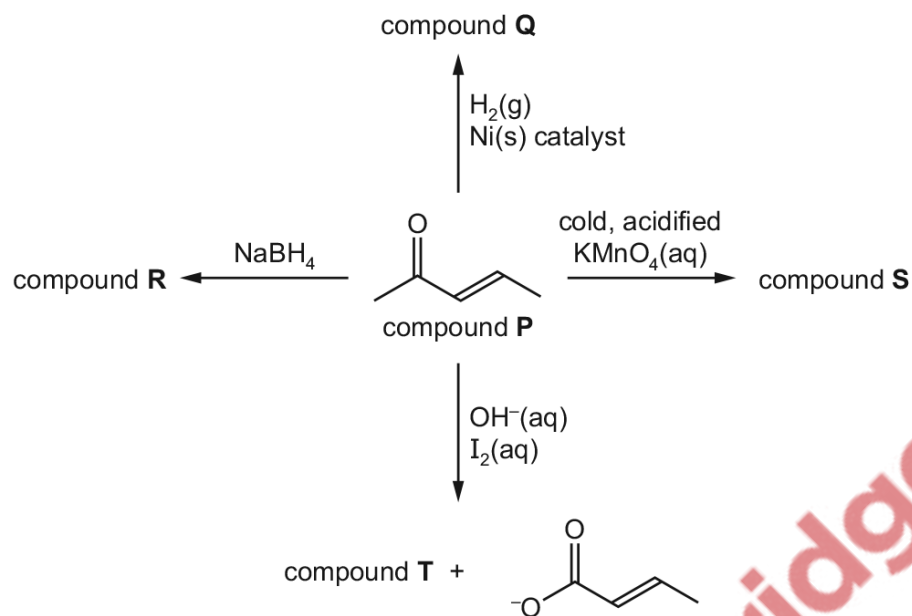
I

[2]

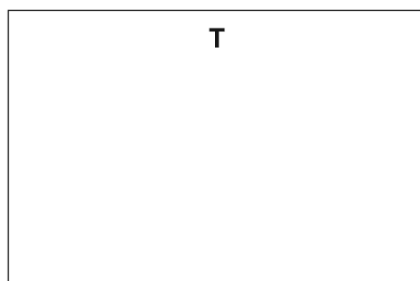
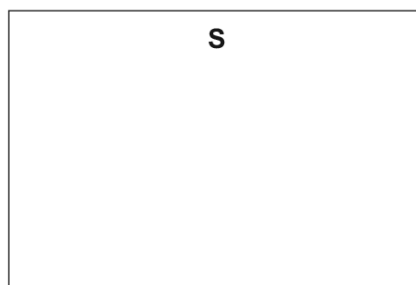
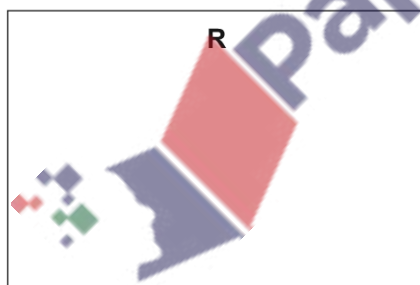
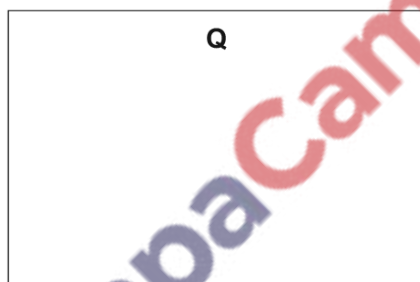
[Total: 23]

173. 9701_m16_qp_22 Q: 5

Some reactions of compound **P**, C_5H_8O , are shown.



(a) (i) Give the structures for organic compounds **Q**, **R**, **S** and **T**.



[4]

(ii) Give the systematic name of compound **P**.

..... [1]

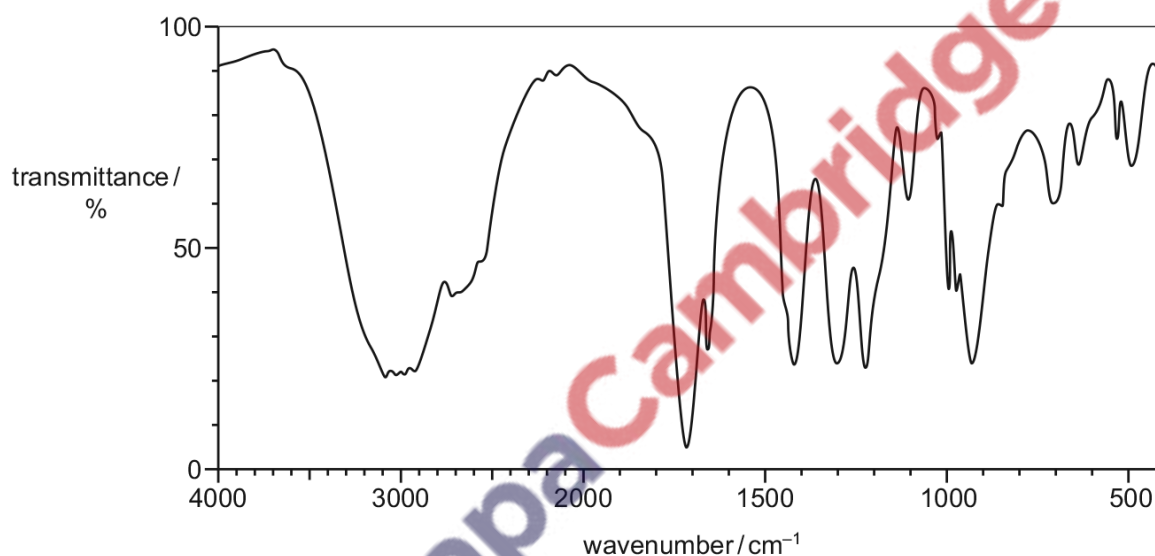
(iii) What would you observe when compound **P** is reacted with 2,4-dinitrophenylhydrazine (2,4-DNPH)?

..... [1]

(b) Compound **U** contains a chiral centre and has the same molecular formula as compound **P**, C_5H_8O .

- Compound **U** readily decolourises a sample of bromine water.
- Compound **U** does not show cis-trans isomerism.
- When compound **U** is heated under reflux in the presence of excess acidified potassium dichromate(VI), the organic product gives the infra-red spectrum shown.

infra-red spectrum of product



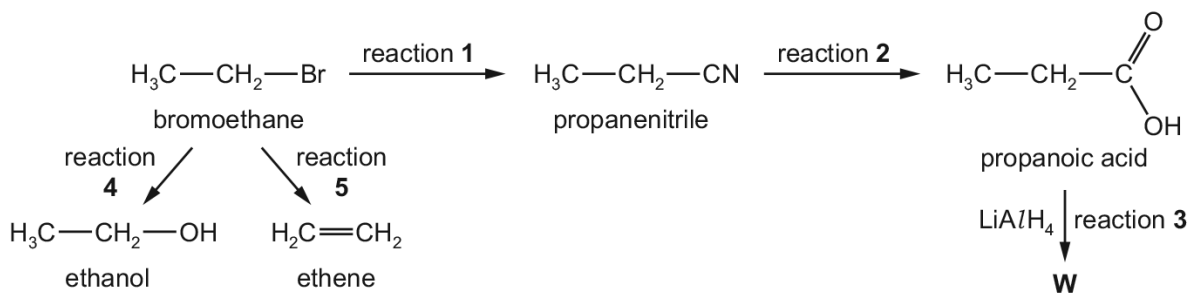
Use the information given to suggest a structure for compound **U**.
Explain your answer.

[4]

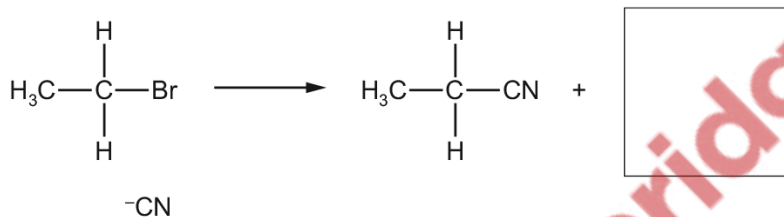
[Total: 10]

174. 9701_s16_qp_21 Q: 5

A reaction sequence is shown.



- (a) Complete the diagram to show the mechanism of reaction 1. Include all necessary charges, partial charges, lone pairs and curly arrows.

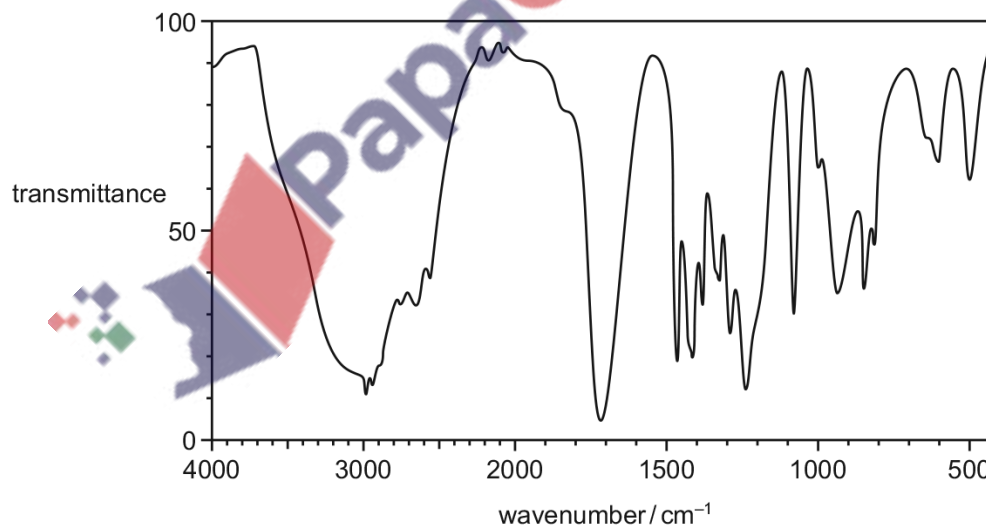


[2]

- (b) (i) Give the name of the type of reaction involved in reaction 3.

..... [1]

The infra-red spectrum of the propanoic acid produced by reaction 2 is shown.



- (ii) Describe and explain the main difference between the infra-red spectrum of **W** and that of propanoic acid.

.....
 [2]

(c) (i) Reactions 4 and 5 use the same reagent.

Give the reagent and conditions needed for reaction 4.

reagent

conditions [2]

(ii) Give the conditions needed for reaction 5.

..... [1]

(d) Under appropriate conditions, ethanol and propanoic acid undergo a condensation reaction.

(i) State the condition necessary for the reaction.

..... [1]

(ii) Draw the skeletal formula of the organic product of this reaction.

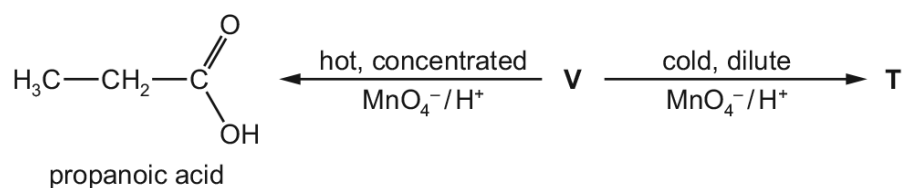
[1]

(iii) Name the organic product of this reaction.

..... [1]



- (e) **V** reacts with acidified manganate(VII) ions in two different ways depending on the conditions, as shown in the reaction sequence below.



V decolourises bromine water.

When the acidified manganate(VII) is hot and concentrated, propanoic acid is the only organic product.

When the acidified manganate(VII) is cold and dilute, the organic product is **T** which has two chiral centres.

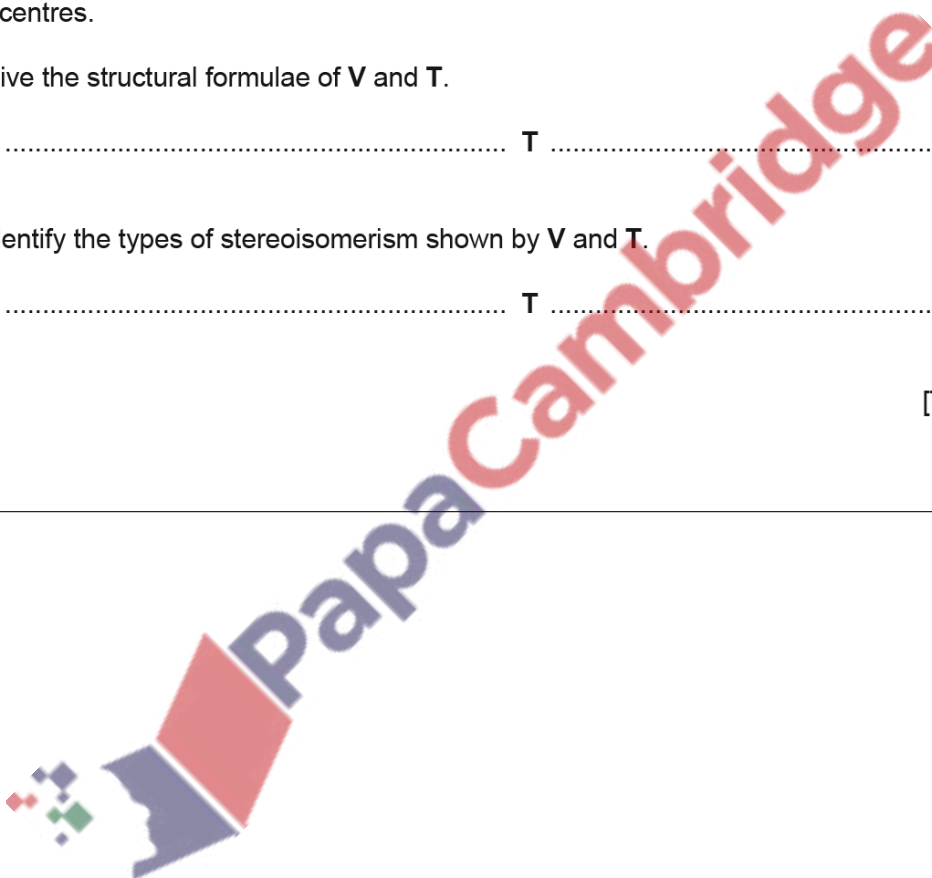
- (i) Give the structural formulae of **V** and **T**.

V **T** [2]

- (ii) Identify the types of stereoisomerism shown by **V** and **T**.

V **T** [2]

[Total: 15]



175. 9701_s16_qp_22 Q: 4

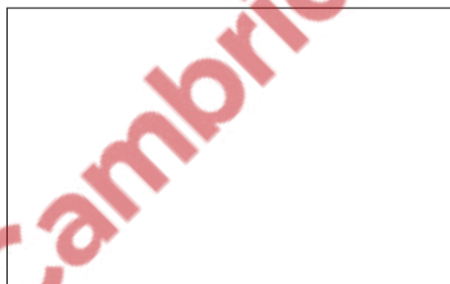
This question is about molecules with molecular formula $C_4H_8O_2$.

- (a) Give the structural formulae of the pair of **chain** isomers with the formula $C_4H_8O_2$ that are carboxylic acids.



[2]

- (b) (i) Give the structural formulae of a pair of **positional** isomers with the formula $C_4H_8O_2$ that are esters.

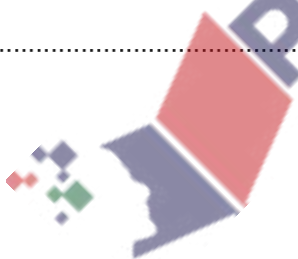


[2]

- (ii) Give the reagents and conditions needed to produce one of your esters in (i).

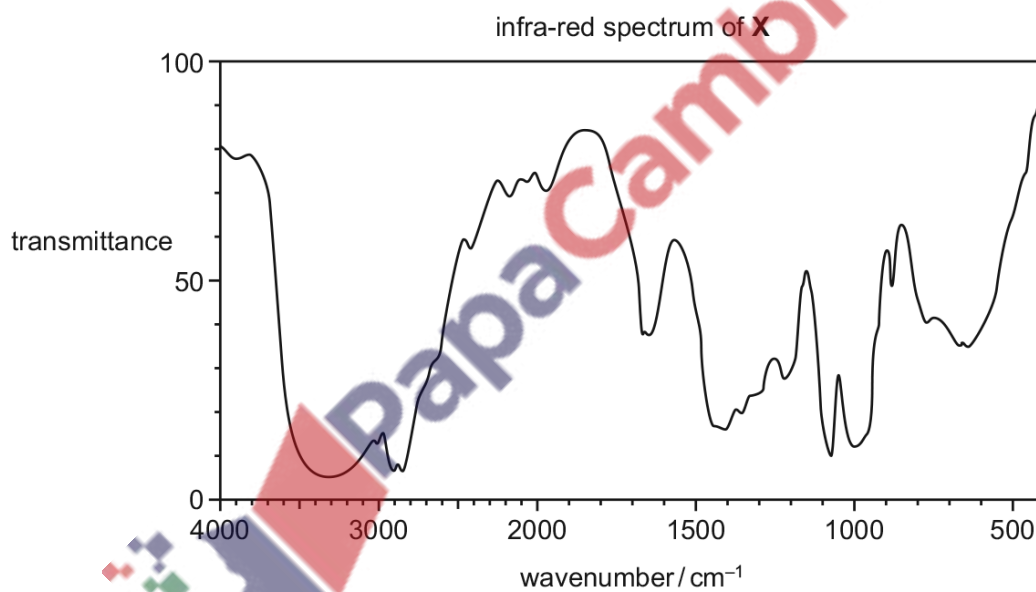
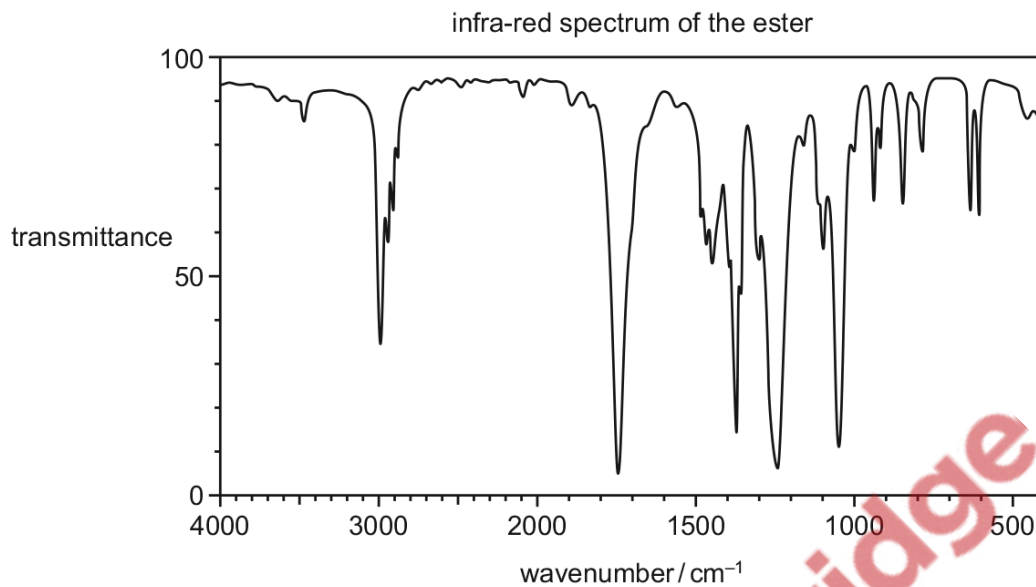
.....

..... [2]



(c) The infra-red spectra of one of the esters and of another isomer, X, are shown.

X decolourises bromine water and is not an ester or an acid.



Explain the differences between these two spectra, with particular reference to the peaks with wavenumbers above 1500 cm^{-1} .

.....

.....

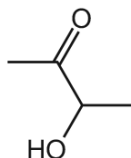
.....

..... [3]

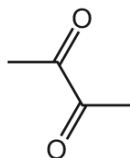
[Total: 9]

176. 9701_s16_qp_23 Q: 4

Acetoin, $\text{CH}_3\text{COCH}(\text{OH})\text{CH}_3$, and diacetyl, $\text{CH}_3\text{COCOCH}_3$, are two of the compounds that give butter its characteristic flavour. Their skeletal formulae are shown.



acetoin



diacetyl

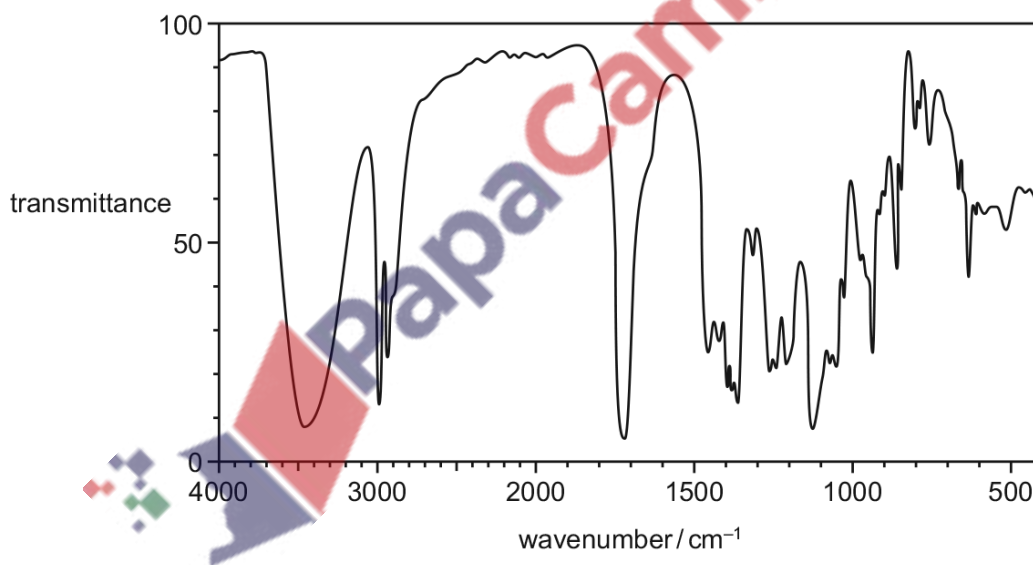
(a) Give the systematic name for acetoin.

..... [1]

(b) Identify the reagents and conditions necessary for the conversion of acetoin into diacetyl.

.....
 [2]

(c) The infra-red spectrum for acetoin is shown.



(i) Explain the main features of this spectrum, with reference to the peaks with wavenumbers greater than 1500 cm^{-1} .

.....

 [3]

- (ii) State and explain how the infra-red spectrum for diacetyl would differ from the infra-red spectrum for acetoin.

.....
.....
..... [2]

- (d) If a sample of acetoin is reacted with concentrated sulfuric acid, a single product is formed that does **not** exhibit stereoisomerism.

However, if a sample of acetoin is reacted with HBr, a mixture of a pair of stereoisomers is produced.

- (i) Give the structural formula of the product of the reaction of acetoin with concentrated sulfuric acid.

..... [1]

- (ii) Explain why the product in (i) does **not** exhibit stereoisomerism.

.....
.....
..... [2]

- (iii) Explain why the product of reaction of acetoin with HBr **does** exhibit stereoisomerism.

.....
.....
..... [1]

- (iv) Draw the two stereoisomers from (iii) using the conventional representation.



[2]

[Total: 14]

19.2 Mass spectrometry

177. 9701_w18_qp_22 Q: 1

The model of the nuclear atom was first proposed by Ernest Rutherford. He developed this model on the basis of results obtained from an experiment using gold metal foil.

(a) Complete the table with information for two of the particles in an atom of ^{197}Au .

particle	relative mass	relative charge	location within atom	total number in an atom of ^{197}Au
electron	0.0005	-1		79
neutron			nucleus	

[4]

(b) State the type of bonding in gold.

..... [1]

(c) A sample of gold found in the earth consists of only one isotope.

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

.....

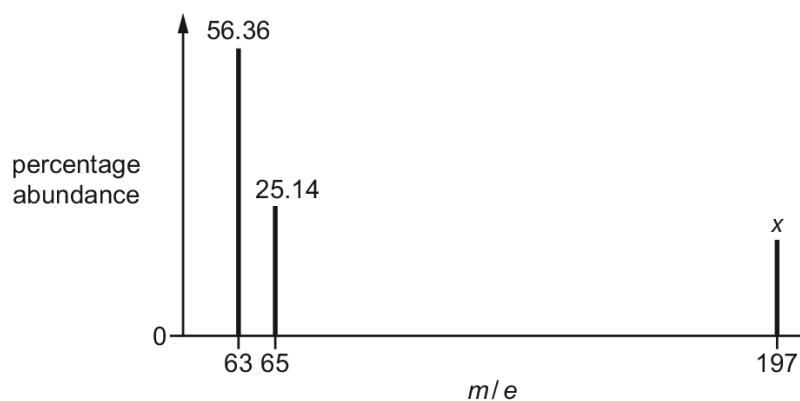
 [2]

(ii) A different sample of gold contains more than one isotope.

Suggest why this different sample of gold has the same **chemical** properties as the sample found in the earth.

.....
 [1]

- (d) *Tumbaga* is an alloy of copper and gold. A sample of *tumbaga* was analysed. The mass spectrum of the sample is shown.



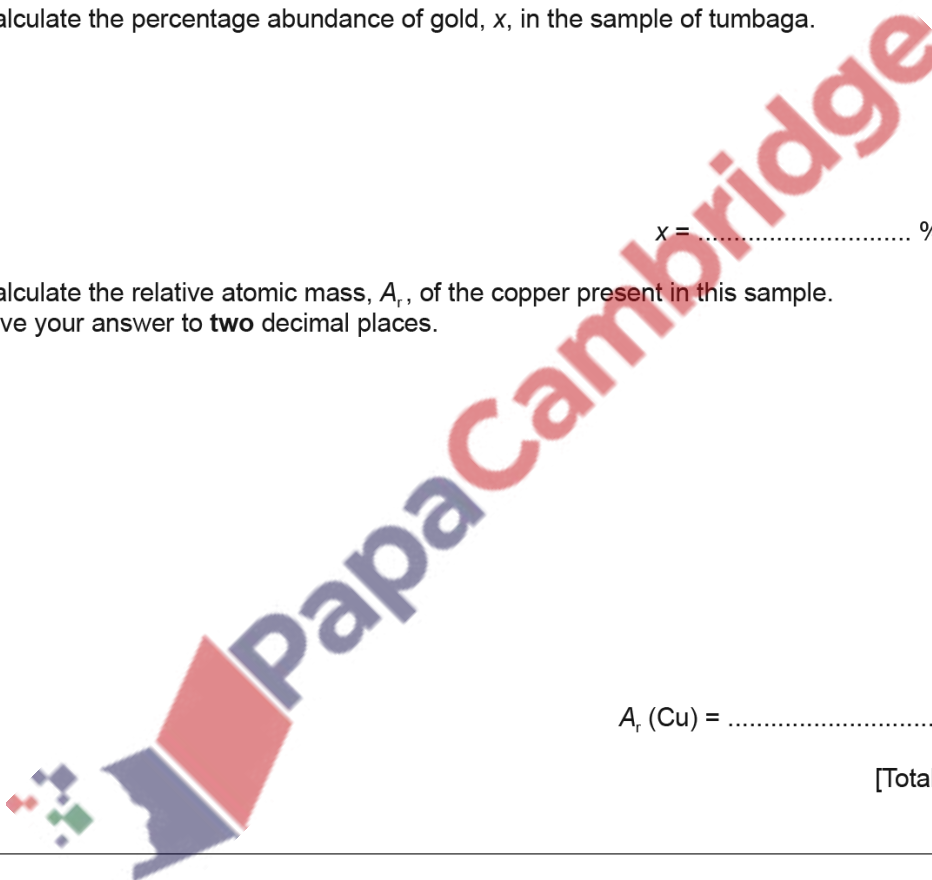
- (i) Calculate the percentage abundance of gold, x , in the sample of *tumbaga*.

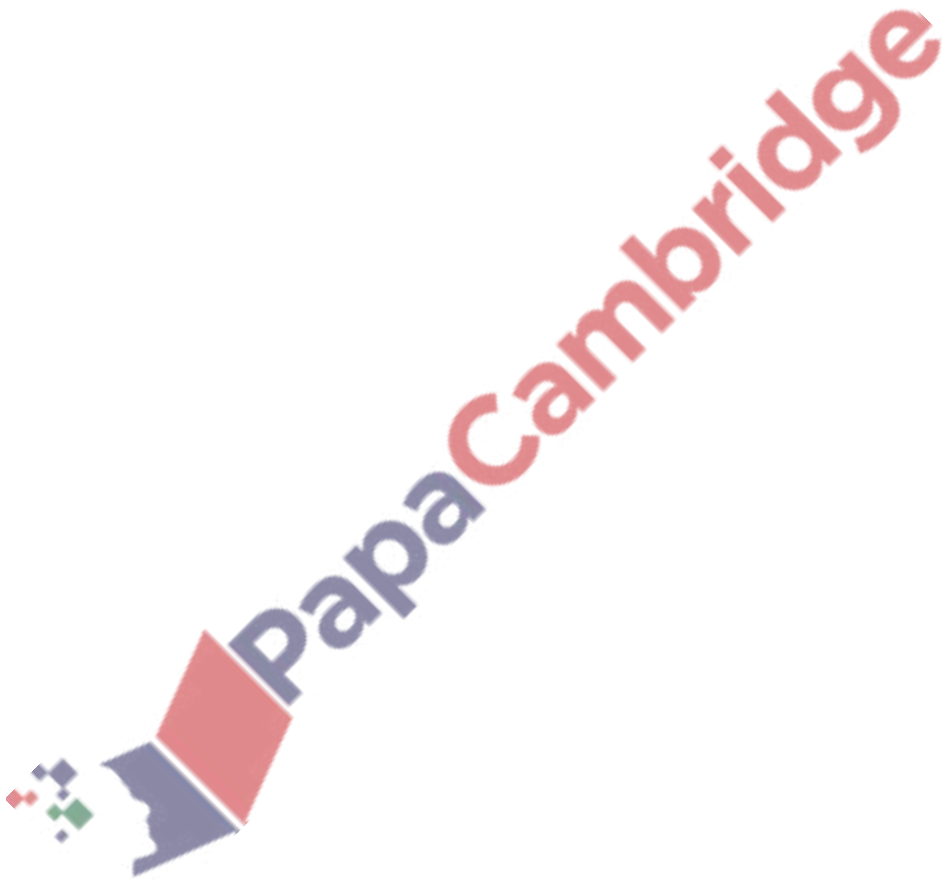
$x = \dots\dots\dots\%$ [1]

- (ii) Calculate the relative atomic mass, A_r , of the copper present in this sample. Give your answer to **two** decimal places.

$A_r(\text{Cu}) = \dots\dots\dots$ [2]

[Total: 11]



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