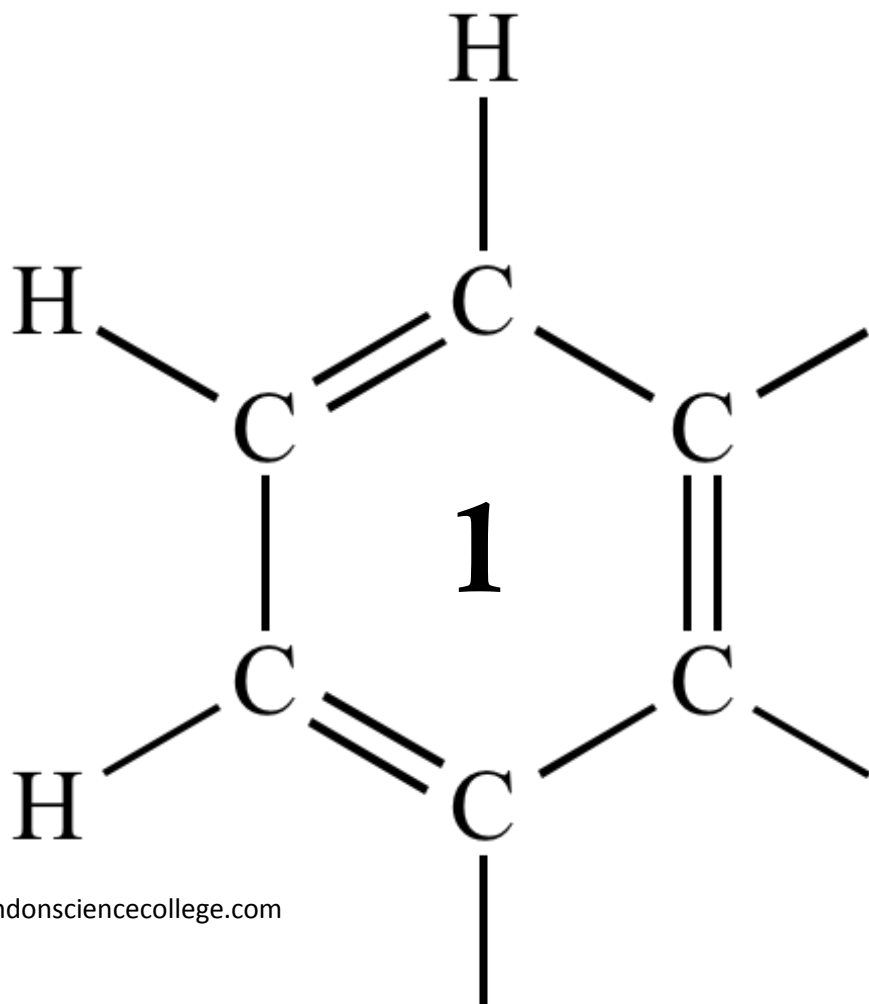


OCR AS CHEMISTRY

MODULE 4

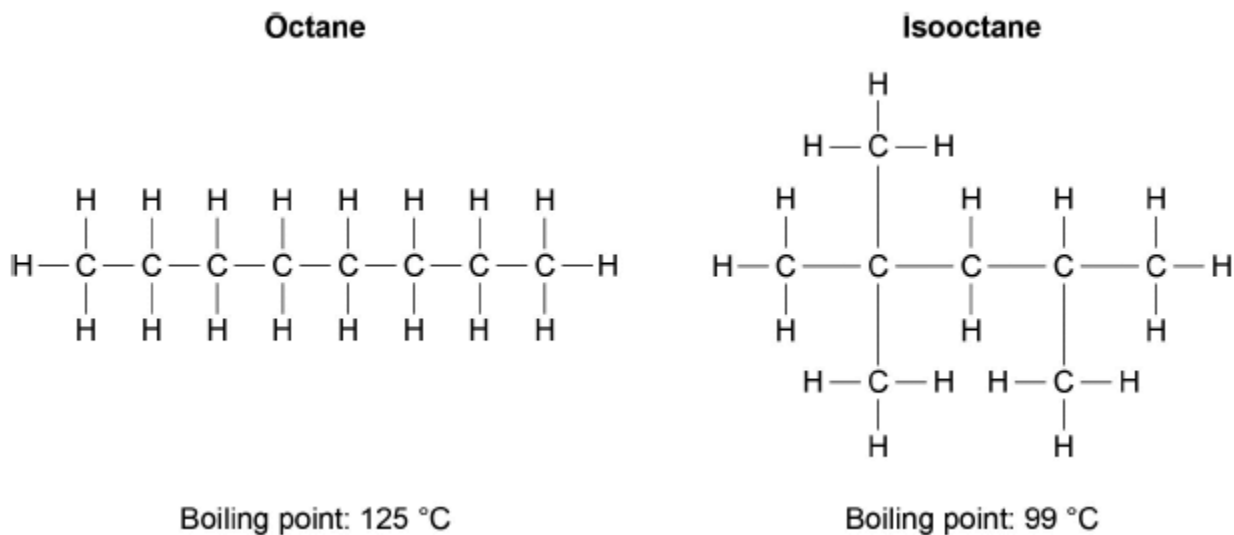
ORGANIC
REACTION OF ALKANES / ALKENES



1

Octane and isooctane are structural isomers with the molecular formula C_8H_{18} . The displayed formulas and boiling points of octane and isooctane are shown in **Figure 1**.

Figure 1



(a) Give the IUPAC name for isooctane.

.....

(1)

(b) Octane and isooctane can be separated in the laboratory.

Name a laboratory technique that could be used to separate isooctane from a mixture of octane and isooctane.

Outline how this technique separates isooctane from octane.

Name

Outline

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.....

.....

.....

(3)

(c) Isooctane is added to petrol to increase its octane rating. Some high-performance engines require fuel with a higher octane rating.

Write an equation for the complete combustion of isooctane. Use the molecular formula (C_8H_{18}) of isooctane in your equation.

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(1)

(d) Explain, in general terms, how a catalyst works.

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(2)

(e) Carbon monoxide is produced when incomplete combustion takes place in engines. Nitrogen monoxide is another pollutant produced in car engines.

Write an equation to show how these pollutants react together in a catalytic converter.

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(1)

(f) Platinum, palladium and rhodium are metals used inside catalytic converters. A very thin layer of the metals is used on a honeycomb ceramic support.

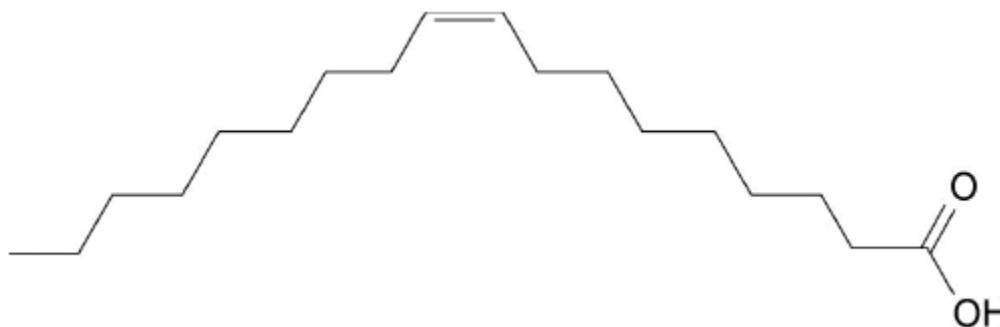
Explain why a thin layer is used in this way.

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(2)

- (g) Oleic acid ($C_{18}H_{34}O_2$) is a straight-chain fatty acid obtained from plant oils. Isooctane can be made from oleic acid. The skeletal formula of oleic acid is shown in **Figure 2**.

Figure 2



Identify a reagent that could be used in a chemical test to show that oleic acid is unsaturated.

State what would be observed in this test.

Reagent

Observation.....

.....

(2)
(Total 12 marks)

2

The compounds in the table all have a relative molecular mass of 58.0

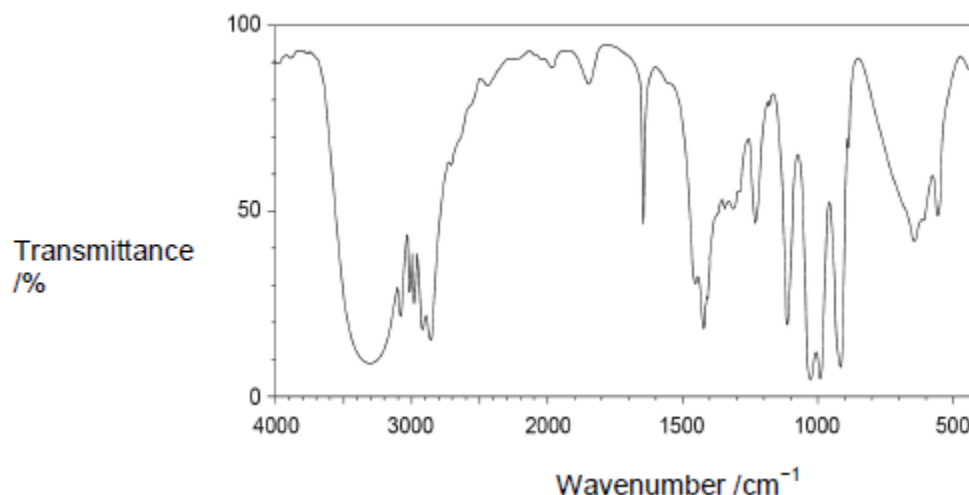
Name	Propanal	Prop-2-en-1-ol	Butane
Structure	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{C}=\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$

- (a) Explain why determining the precise relative molecular mass of propanal and prop-2-en-1-ol by mass spectrometry could not be used to distinguish between samples of these two compounds.

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(2)

(b) The infrared spectrum of one of these three compounds is shown below.



Use the spectrum to identify the compound.
 State the bond that you used to identify the compound and give its wavenumber range.
 You should only consider absorptions with wavenumbers greater than 1500 cm⁻¹.

Compound

Bond used to identify compound.....

Wavenumber range of bond used to identify compound cm⁻¹

(2)

(c) Predict the relative boiling points of these three compounds from the highest to the lowest boiling points.

Justify this order in terms of intermolecular forces.

(6)

(Total 10 marks)

3

Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

(a) Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

1

2

(2)

(b) Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

(1)

(c) 1,1,1-trifluoroethane (CF_3CH_3) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

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(1)

(d) One of the steps in the synthesis of 1,1,1-trifluoroethane (CF_3CH_3) is the reaction of 1,1-difluoroethane (CHF_2CH_3) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of CHF_2CH_3 into CF_3CH_3

Propagation step 1

.....

Propagation step 2

.....

(2)

- (e) A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane (CF₃CH₃).

Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator.

Give your answer to an appropriate number of significant figures.

(The Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$)

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(2)

- (f) There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

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(1)

(Total 9 marks)

4 Propane-1,2-diol has the structure CH₂(OH)CH(OH)CH₃. It is used to make polyesters and is one of the main substances in electronic cigarettes (E-cigarettes).

A sample of propane-1,2-diol was refluxed with a large excess of potassium dichromate(VI) and sulfuric acid.

- (a) Draw the skeletal formula of propane-1,2-diol.

(1)

- (b) Write an equation for this oxidation reaction of propane-1,2-diol under reflux, using [O] to represent the oxidizing agent.

Show the displayed formula of the organic product.

.....

(2)

- (c) Draw a labelled diagram to show how you would set up apparatus for refluxing.

(2)

- (d) Anti-bumping granules are placed in the flask when refluxing.
Suggest why these granules prevent bumping.

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(1)

- (e) Draw the structure of a different organic product formed when the acidified potassium dichromate(VI) is not in excess.

(1)

(Total 7 marks)

5

The alkene 3-methylpent-2-ene ($\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$) reacts with hydrogen bromide to form a mixture of 3-bromo-3-methylpentane and 2-bromo-3-methylpentane.

- (a) The alkene 3-methylpent-2-ene ($\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$) exists as *E* and *Z* stereoisomers.

Draw the structure of *Z*-3-methylpent-2-ene.

(1)

- (b) Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

Explain why more 3-bromo-3-methylpentane is formed in this reaction than 2-bromo-3-methylpentane.

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(7)
(Total 8 marks)

- 6** Which of the following compounds would form an orange-red precipitate when heated with Fehling's solution?

A $\text{CH}_3\text{CH}_2\text{CN}$

B $\text{CH}_3\text{CH}_2\text{COOH}$

C CH_3CHO

D CH_3COCH_3

(Total 1 mark)

7

Pentanenitrile can be made by reaction of 1-bromobutane with potassium cyanide.

Which of these is the correct name for the mechanism of this reaction?

- A Electrophilic addition
- B Electrophilic substitution
- C Nucleophilic addition
- D Nucleophilic substitution

(Total 1 mark)

8

Propene can be made by the dehydration of propan-2-ol.

What is the percentage yield when 30 g of propene ($M_r = 42.0$) are formed from 50 g of propan-2-ol ($M_r = 60.0$)?

- A 60%
- B 67%
- C 81%
- D 86%

(Total 1 mark)

9

Sulfur dioxide (SO_2) is produced when some fossil fuels are burned.

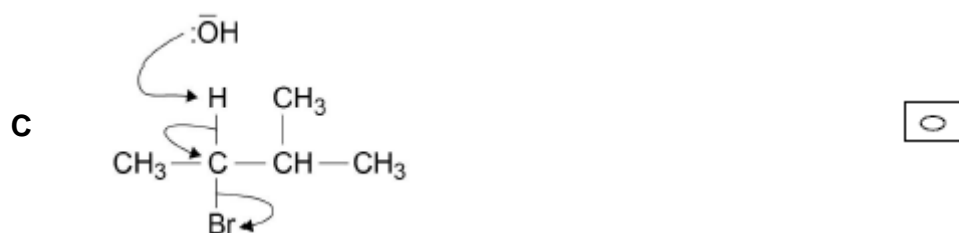
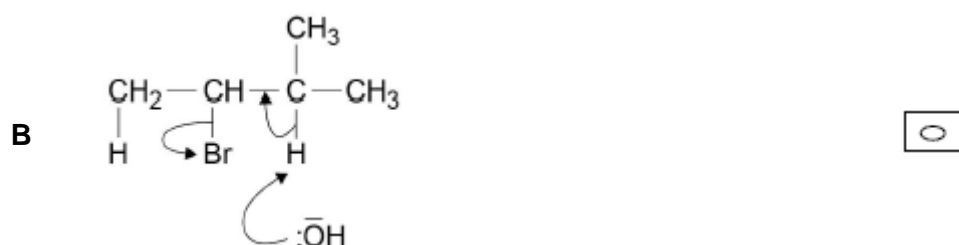
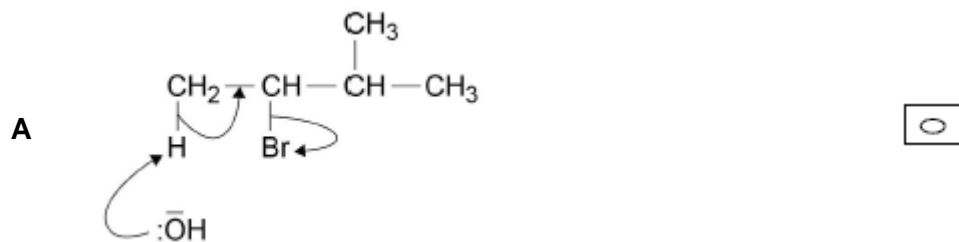
Which of the following statements is true?

- A Sulfur dioxide can be removed from waste gases in a power station by an acid-base reaction with calcium oxide.
- B Sulfur dioxide is insoluble in water.
- C Sulfur dioxide is a basic oxide.
- D Sulfur dioxide is an ionic compound.

(Total 1 mark)

10

Which of the following is a correct mechanism for the formation of 2-methylbut-2-ene from 2-bromo-3-methylbutane?



(Total 1 mark)

11

An organic compound is found to contain 40.0% carbon, 6.7% hydrogen and 53.3% oxygen.

Which of the following compounds could this be?

A Ethanol

B Ethanoic acid

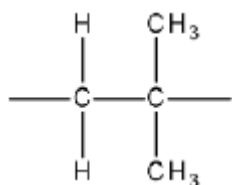
C Methanol

D Methanoic acid

(Total 1 mark)

12

The repeating unit of a polymer is



Which of the following molecules would form a polymer containing this repeating unit?

- A But-1-ene
- B *E*-but-2-ene
- C *Z*-but-2-ene
- D Methylpropene

(Total 1 mark)

13

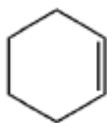
Tetradecane ($\text{C}_{14}\text{H}_{30}$) is an alkane found in crude oil. When tetradecane is heated to a high temperature, one molecule of tetradecane decomposes to form one molecule of hexane and three more molecules.

Which of the following could represent this reaction?

- A $\text{C}_{14}\text{H}_{30} \rightarrow \text{C}_6\text{H}_{14} + \text{C}_4\text{H}_8 + 2\text{C}_2\text{H}_4$
- B $\text{C}_{14}\text{H}_{30} \rightarrow \text{C}_6\text{H}_{14} + \text{C}_6\text{H}_{12} + \text{C}_2\text{H}_4$
- C $\text{C}_{14}\text{H}_{30} \rightarrow \text{C}_5\text{H}_{12} + 3\text{C}_3\text{H}_6$
- D $\text{C}_{14}\text{H}_{30} \rightarrow \text{C}_6\text{H}_{14} + \text{C}_2\text{H}_6 + 2\text{C}_3\text{H}_6$

(Total 1 mark)

14 The structure of cyclohexene is shown.



Which of the following is the general formula of cyclic alkenes such as cyclohexene?



(Total 1 mark)

15 (a) Octane (C_8H_{18}) is an important compound in petrol.

(i) Identify the homologous series to which octane belongs.

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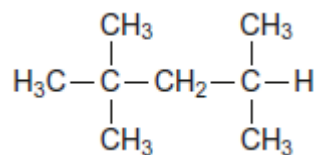
(1)

(ii) Write an equation to show the complete combustion of C_8H_{18}

.....

(1)

(iii) An isomer of octane used to improve the performance of car engines is shown.

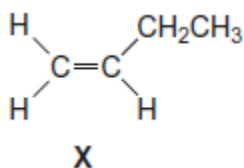


Give the IUPAC name of this isomer.

.....

(1)

(b) Compound **X** is produced when an alkane is cracked.



(i) Give the IUPAC name for compound **X**.

.....

(1)

(ii) One molecule of an alkane is cracked to produce one molecule of compound **X**, one molecule of octane and one molecule of ethene.

Deduce the molecular formula of this alkane.

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(1)

(iii) Name the type of cracking that produces a high yield of compound **X**.
Give **two** conditions required for this process.

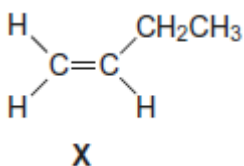
Type of cracking

Conditions

.....

(2)

(iv) Compound **X** has several isomers. The structure of **X** is repeated here.



Draw the displayed formula of a chain isomer, a position isomer and a functional group isomer of compound X.

Type of isomer	Displayed formula of isomer of compound X
Chain	
Position	
Functional group	

(3)
(Total 10 marks)

Haloalkanes are used as refrigerants, solvents and anaesthetics.

- (a) Trichloromethane (CHCl_3) is a haloalkane that can be formed by heating a mixture of chloromethane (CH_3Cl) and chlorine.

- (i) Write an overall equation for the formation of trichloromethane by the reaction of chloromethane with chlorine.

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(1)

- (ii) Name the mechanism for this formation of trichloromethane.

.....

(1)

- (iii) Dichloromethane (CH_2Cl_2) is an intermediate in this formation of trichloromethane.

Write an equation for each of the following steps in the mechanism for the reaction of dichloromethane with chlorine.

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step leading to the formation of a compound with formula $\text{C}_2\text{H}_2\text{Cl}_4$

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(4)

- (b) Chlorotrifluoromethane (CClF_3) is used as a refrigerant, but is being phased out due to concerns about ozone depletion in the upper atmosphere. In the upper atmosphere, CClF_3 decomposes in the presence of UV light forming a reactive intermediate that catalyses the decomposition of ozone.

- (i) Write an equation to show how CClF_3 decomposes to form the reactive intermediate.

.....

(1)

- (ii) Write two equations to show how this reactive intermediate is involved in catalysing the decomposition of ozone.

1

2

(2)

(Total 9 marks)

17

Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula $C_4H_{10}O$. They all have a broad absorption in their infrared spectra in the range $3230\text{--}3550\text{ cm}^{-1}$.

- (a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

.....

(1)

- (b) Compounds **A** and **B** are both straight-chain compounds.

A can be oxidised to form **P**.

B can be oxidised to form **Q**.

P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in the table are obtained.

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**. Explain your answer with reference to the functional groups in **P** and **Q**.

Identity of **A**

Identity of **B**

Explanation

.....

.....

.....

(3)

- (c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1} .

State the bond that causes the absorption in the range 1620–1680 cm^{-1} .

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

Bond

Displayed formula of **C**

Reagent

Condition

(4)

- (d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.
- (i) Compound **S** is obtained by distilling it off as it forms during the oxidation. Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

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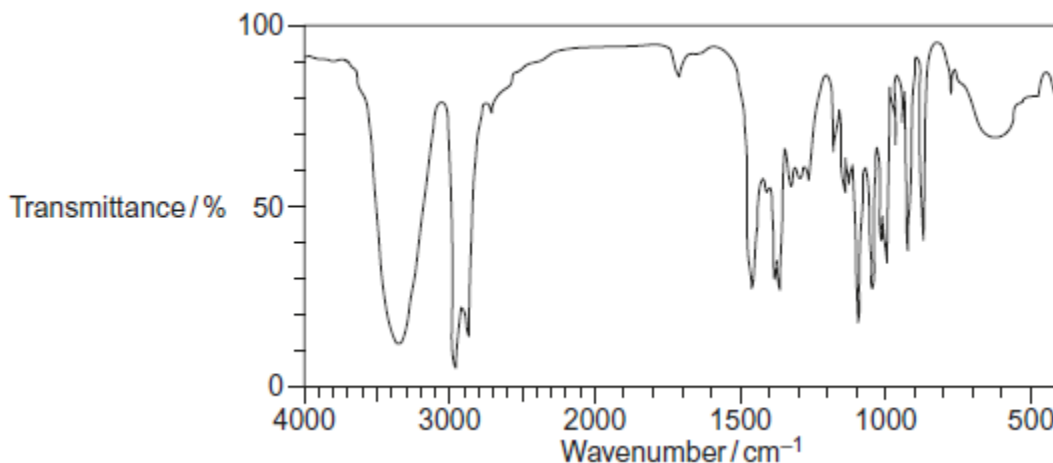
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(3)

- (ii) A student claims to have oxidised compound **D**. The infrared spectrum of the product obtained by the student is shown.



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

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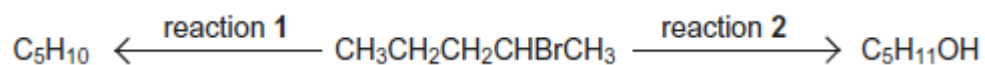
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(2)
(Total 13 marks)

18

Two reactions of 2-bromopentane, (CH₃CH₂CH₂CHBrCH₃) are shown.



The C₅H₁₀ formed in reaction 1 exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

- (a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction 1 and reaction 2.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction 1 for the formation of pent-1-ene.

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(8)

(b) All three isomers of C_5H_{10} contain the same functional group.

Draw the displayed formula of pent-1-ene.

Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

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(5)

- (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

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(4)
(Total 17 marks)