

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

1. Question part 1/2 | 9701 May-June 2016 P2 V1 Q4

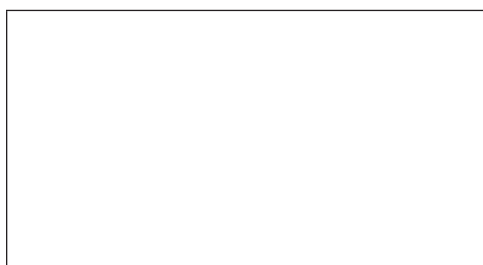
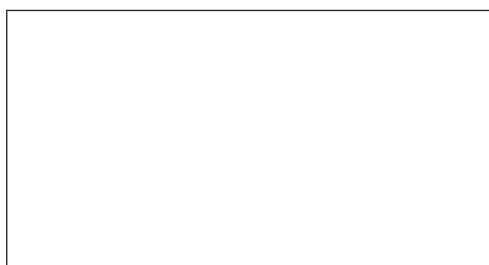
4 This question is about molecules with molecular formula C_4H_8 .

(a) Give the structures of a pair of **positional** isomers with the formula C_4H_8 .



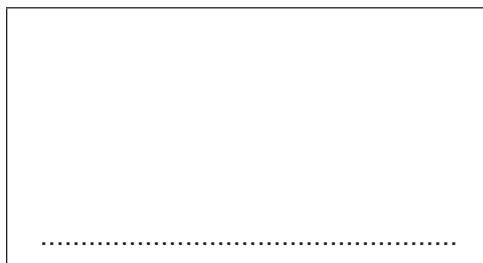
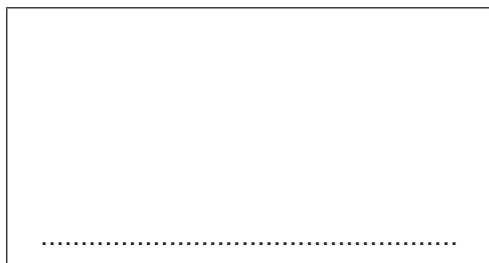
[1]

(b) Give the structures of a pair of **chain** isomers with the formula C_4H_8 , that do **not** exhibit stereoisomerism.



[1]

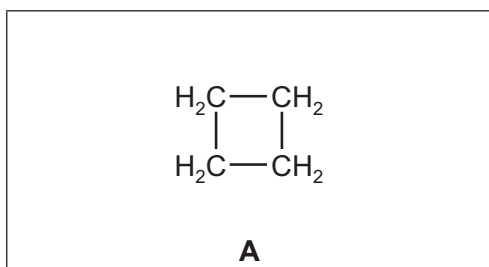
(c) Give the structures and full names of a pair of **stereoisomers** with the formula C_4H_8 .



[2]

(d) The structure of a molecule, **A**, of formula C_4H_8 is shown.

Draw a functional group isomer of molecule **A** in box **B**. Explain how molecules **A** and **B** could be distinguished by a chemical test.



.....
.....
..... [3]

[Total: 71]

9701 Chemistry Paper 2 - Hydrocarbons

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1. Question part 2/2 | 9701 May-June 2016 P2 V1 Q4

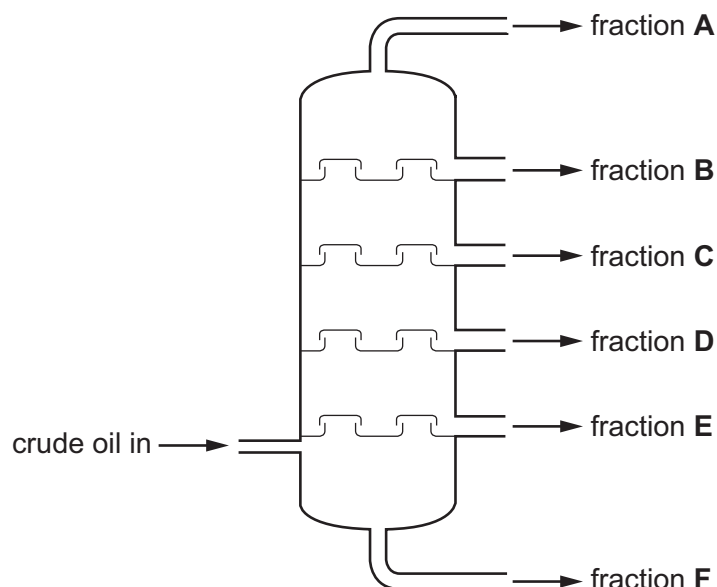
Question 5 starts on the next page.

2. Question part 1/2 | 9701 May-June 2016 P2 V3 Q3

- 3 Crude oil is a mixture of hydrocarbons and provides many useful chemicals when processed.

Two of the stages involved in the processing of crude oil are fractional distillation and cracking.

- (a) The diagram is a simplified representation of a fractional distillation column.



- (i) What has to be done to the crude oil before it enters the column?

..... [1]

- (ii) What trend in **structure** is there from fraction A to fraction F?

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

- (iii) State the trends in **two** properties of the fractions from A to F.

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

- (b) The naphtha fraction from fractional distillation of crude oil is used as a starting material for cracking.

- (i) Write an equation for the cracking of $C_{12}H_{26}$ to form the products ethene and one other hydrocarbon in a 2:1 mole ratio.

..... [1]

- (ii) Suggest a use for each of the products from your equation in (i). Explain what makes each product from (i) suitable for the use you suggest.

use of ethene

.....

explanation

.....

use of other product

.....

explanation

.....

[4]

- (c) Burning hydrocarbons can cause a number of environmental problems.

The products of internal combustion engines can include oxides of nitrogen and oxides of carbon.

Sulfur dioxide is a by-product of burning coal in power stations.

- (i) Explain how and why oxides of nitrogen are produced in internal combustion engines.

.....

.....

..... [2]

- (ii) Write an equation for the reaction between nitrogen monoxide and carbon monoxide in a catalytic converter.

..... [1]

- (iii) Write equations to show the involvement of nitrogen monoxide in the formation of acid rain from atmospheric sulfur dioxide.

.....

.....

..... [3]

- (iv) Describe two of the problems associated with acid rain.

.....

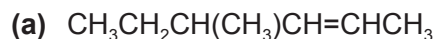
.....

..... [2]

[Total: 17]

3. Question part 1/2 | 9701 Oct-Nov 2016 P2 V1 Q4

- 4 In each section of this question an organic compound is shown. For each compound give its name and answer the questions about it.



(i) name [1]

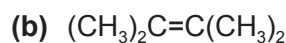
(ii) This compound shows stereoisomerism.

Define *stereoisomerism*.

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

(iii) State and explain how many stereoisomers of this structure there are.

.....
.....
.....
.....
.....
..... [4]



(i) name [1]

(ii) Draw the **skeletal** formula of the organic product of the reaction of this compound with cold, dilute, acidified manganate(VII) ions.

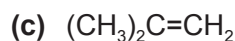
[1]

(iii) Name the organic product of the reaction of this compound with hot, concentrated, acidified manganate(VII) ions.

..... [1]

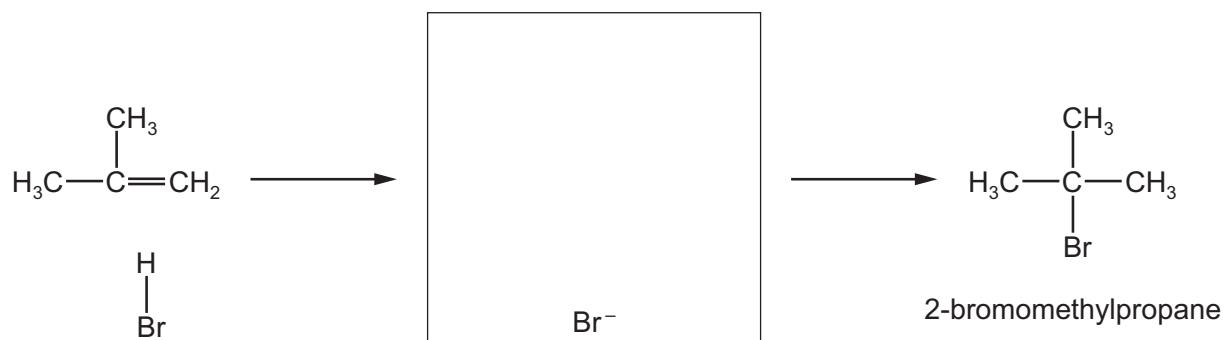
(iv) Draw the structure of part of a molecule of the addition polymer formed from this compound, showing exactly **three** repeat units.

[1]



(i) name [1]

(ii) Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



[4]

(iii) Explain fully why 2-bromomethylpropane is the major product of this reaction while only relatively small amounts of 1-bromomethylpropane are produced.

.....

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.....

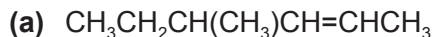
.....

..... [3]

[Total: 18]

4. Question part 1/2 | 9701 Oct-Nov 2016 P2 V3 Q4

- 4 In each section of this question an organic compound is shown. For each compound give its name and answer the questions about it.



(i) name [1]

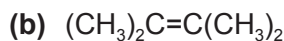
(ii) This compound shows stereoisomerism.

Define *stereoisomerism*.

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

(iii) State and explain how many stereoisomers of this structure there are.

.....
.....
.....
.....
.....
..... [4]



(i) name [1]

(ii) Draw the **skeletal** formula of the organic product of the reaction of this compound with cold, dilute, acidified manganate(VII) ions.

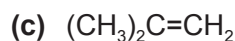
[1]

(iii) Name the organic product of the reaction of this compound with hot, concentrated, acidified manganate(VII) ions.

..... [1]

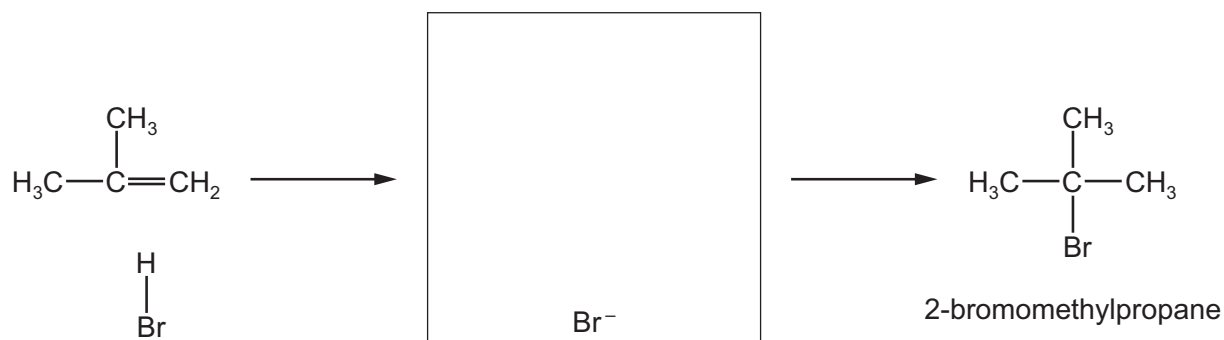
(iv) Draw the structure of part of a molecule of the addition polymer formed from this compound, showing exactly **three** repeat units.

[1]



(i) name [1]

(ii) Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



[4]

(iii) Explain fully why 2-bromomethylpropane is the major product of this reaction while only relatively small amounts of 1-bromomethylpropane are produced.

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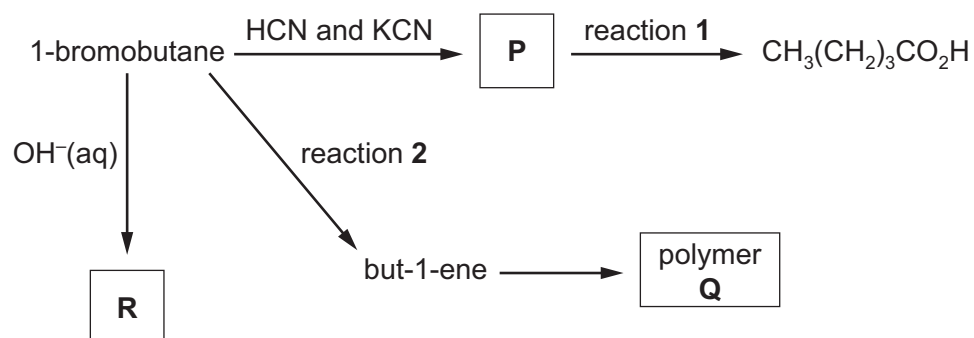
.....

..... [3]

[Total: 18]

5. Question part 1/5 | 9701 Feb-March 2017 P2 V2 Q3

- 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]

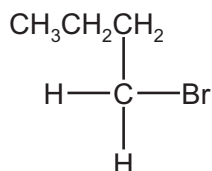
- (iii) Draw the structure of the repeat unit of polymer **Q**.

[2]

5. Question part 2/5 | 9701 Feb-March 2017 P2 V2 Q3

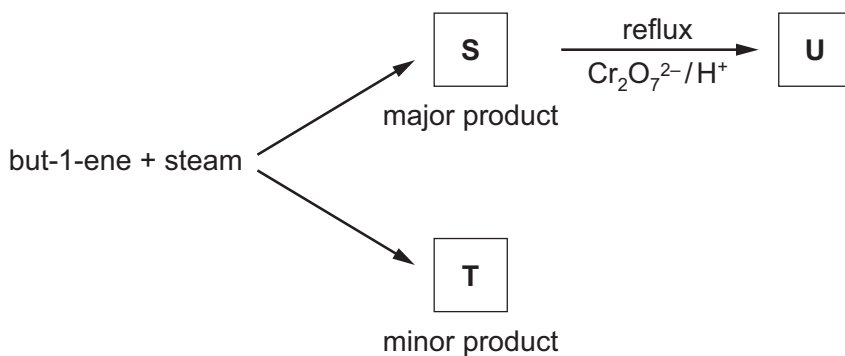
- (b) Complete the reaction scheme to show the mechanism of the reaction of 1-bromobutane with $\text{OH}^-(\text{aq})$ to produce **R**.

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.

.....

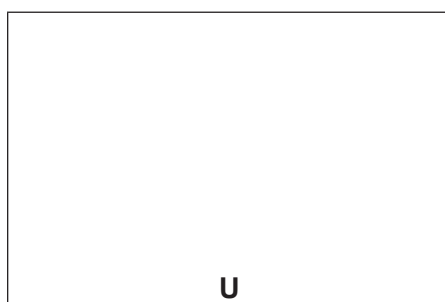
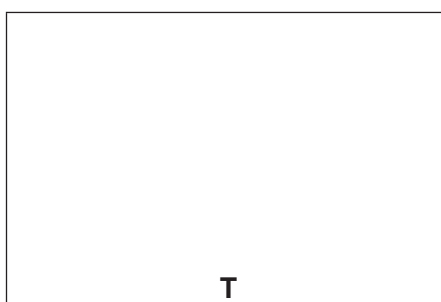
.....

.....

.....

..... [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**.

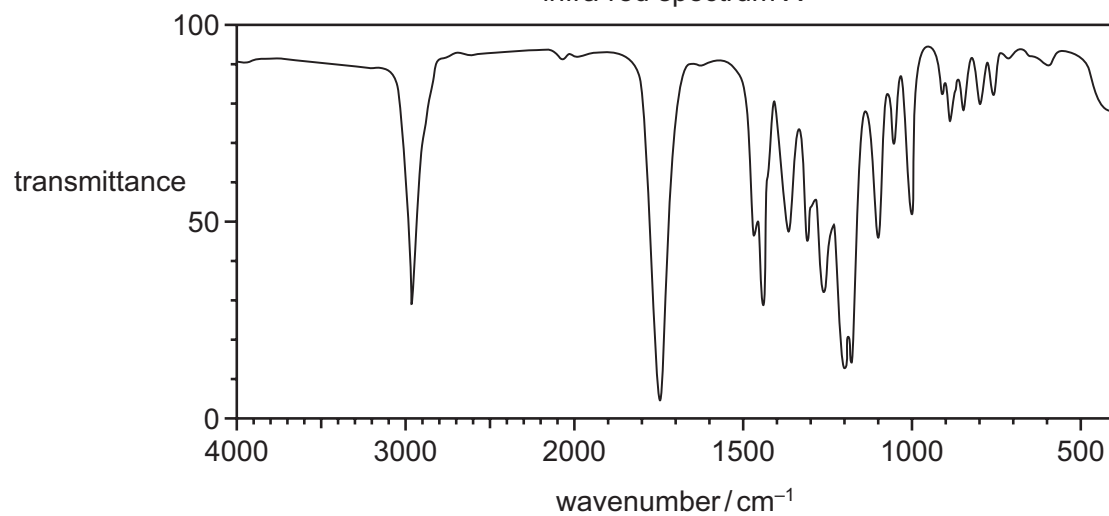
compound	$\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$	methanol	V
spectrum			

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

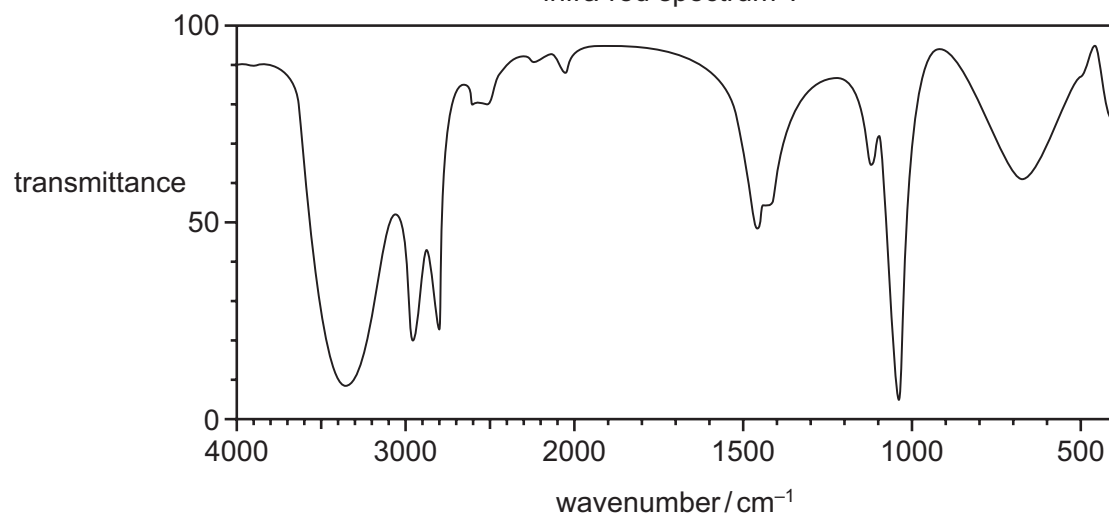
.....
.....
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.....
.....
..... [4]

5. Question part 5/5 | 9701 Feb-March 2017 P2 V2 Q3

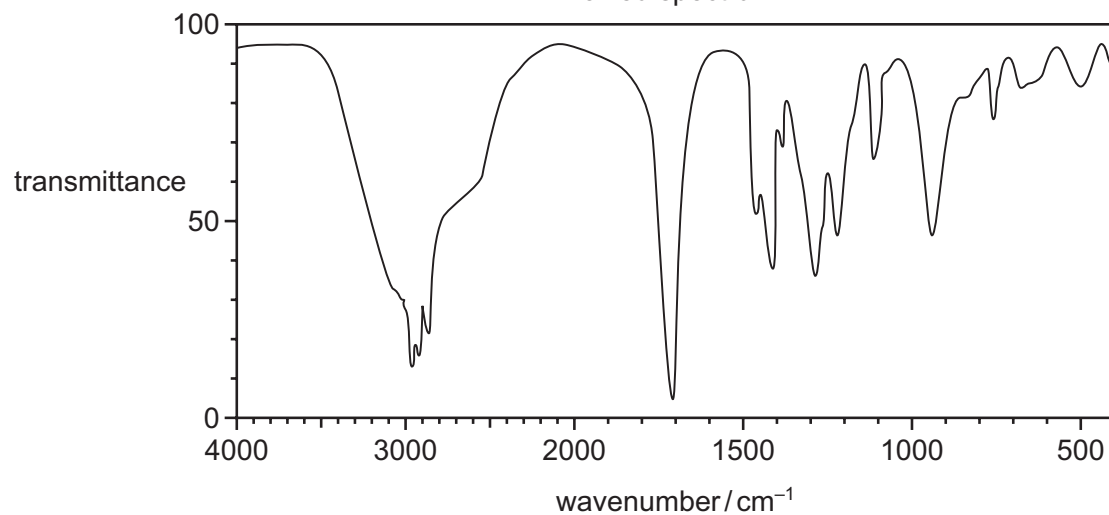
infra-red spectrum X



infra-red spectrum Y



infra-red spectrum Z



[Total: 21]

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6. Question part 1/4 | 9701 May-June 2017 P2 V2 Q4

- 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]

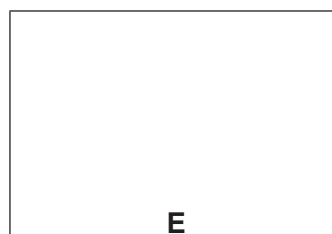
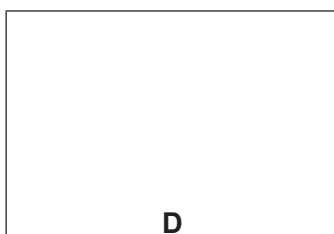
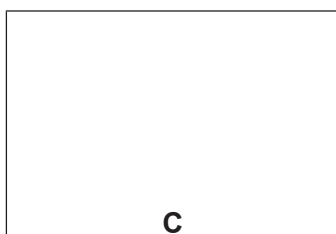
- (b) The alcohols **C** and **D** are isomers of each other with molecular formula $\text{C}_4\text{H}_{10}\text{O}$. Both isomers are branched.

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**.



[3]

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

..... [1]

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Topical questions | 43 questions

6. Question part 3/4 | 9701 May-June 2017 P2 V2 Q4

(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

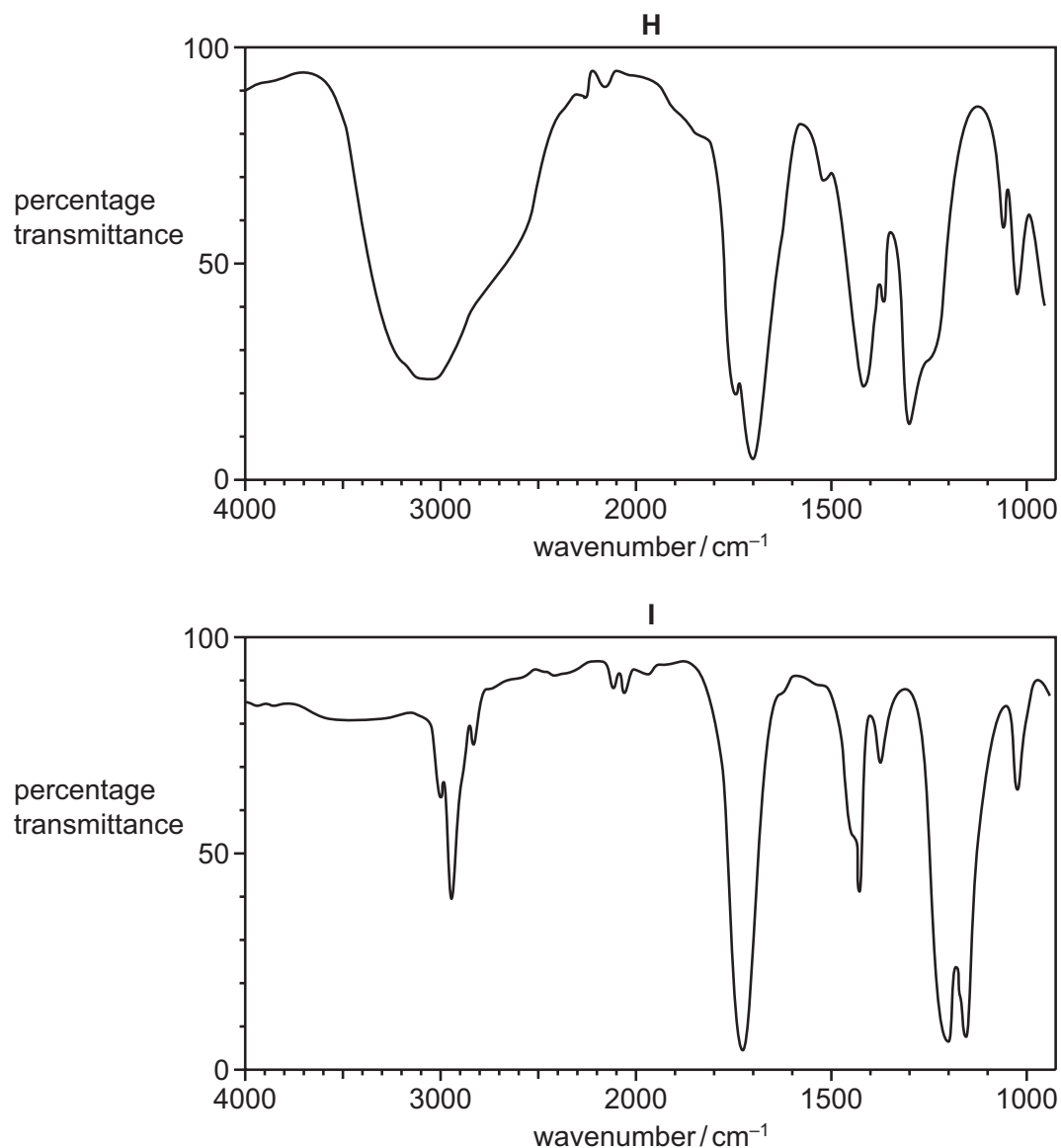
G [2]

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

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

6. Question part 4/4 | 9701 May-June 2017 P2 V2 Q4

- (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]

7. Question part 1/3 | 9701 May-June 2017 P2 V3 Q4

- 4 **A**, **B** and **C** all have the formula C_4H_8 . They all decolourise bromine and are structural isomers of each other.

(a) State the name of the process by which **A**, **B** and **C** could be obtained from $C_{10}H_{22}$.

..... [1]

(b) Draw the structures of these three **structural** isomers.

--	--	--

[1]

(c) Only **A** shows geometrical isomerism.

(i) Explain the meaning of the term *geometrical isomerism*.

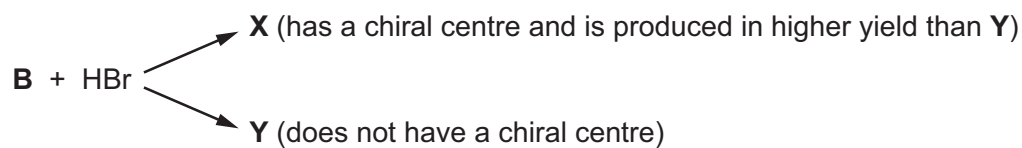
.....
.....
.....
..... [2]

(ii) Draw the displayed formula of **A** and use it to show the mechanism of the reaction of **A** with HBr. Include all necessary charges, dipoles, lone pairs and curly arrows.

[4]

(d) **B** does **not** show geometrical isomerism.

B reacts with HBr to form a mixture of two structural isomers, **X** and **Y**.



(i) State the meaning of the term *chiral centre*.

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

(ii) Name **B**.

..... [1]

(iii) **X** exists as a pair of optical isomers.

Draw these isomers using the conventional three-dimensional representation.



[2]

(iv) Explain why **X** is produced in higher yield than **Y**.

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

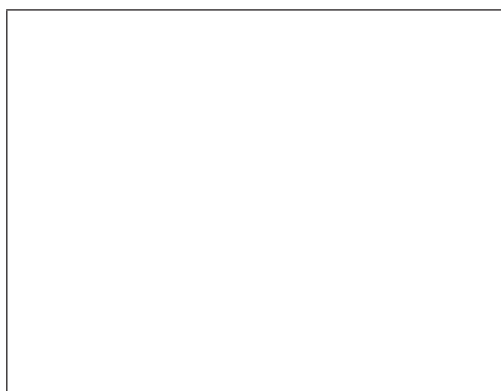
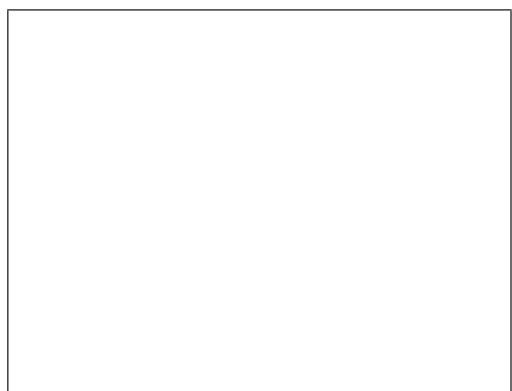
(e) **C** does **not** show geometrical isomerism.

C reacts with HBr to form a mixture of two structural isomers, neither of which has a chiral centre.

(i) Name **C**.

..... [1]

(ii) Draw the **displayed** formula of each of the structural isomers produced by the reaction of **C** with HBr.



[2]

[Total: 17]

8. Question part 1/3 | 9701 Feb-March 2018 P2 V2 Q2

2 Carbon and silicon are elements in Group 14.

(a) C_{60} and diamond are allotropes of carbon.

(i) Describe the lattice structure of solid C_{60} .

.....

.....

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at about 800 K. Diamond also sublimes but only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) State what is meant by the term *hydrocarbon*.

.....

..... [1]

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8. Question part 2/3 | 9701 Feb-March 2018 P2 V2 Q2

- (ii) Describe a test to indicate the presence of double bonds between carbon atoms in $C_{60}H_{18}$. Give the result of the test.

test

.....

result

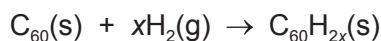
.....

[2]

- (c) 0.144 g of C_{60} was placed in a 100 cm^3 container of hydrogen gas at 20°C and $1.00 \times 10^5\text{ Pa}$.

The container was heated to make the C_{60} and hydrogen gas react.

The reaction occurred as shown in the equation.



After the reaction, the container was allowed to cool to 20°C . The pressure decreased to $2.21 \times 10^4\text{ Pa}$. All of the C_{60} had reacted.

- (i) Name the type of reaction that occurred.

..... [1]

- (ii) Calculate the amount, in moles, of C_{60} that reacted.

amount of C_{60} = ... mol [1]

- (iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60} .

amount of hydrogen gas = ... mol [2]

- (iv) Use your answers from (ii) and (iii) to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacted. This is **not** the correct value for the amount of hydrogen gas that reacted.

molecular formula = ... [2]

(d) Silicon shows the same kind of bonding and structure as diamond.

(i) State the type of bonding and structure shown by silicon.

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

(ii) When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion.

State the full electronic configuration of the Si^{4-} ion.

$1s^2$ [1]

(iii) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction of solid Mg_2Si with dilute hydrochloric acid.

Include state symbols.

..... [2]

(iv) Predict the shape of the SiH_4 molecule.

..... [1]

(v) SiH_4 reacts spontaneously with oxygen to produce a white solid and a colourless liquid that turns anhydrous copper(II) sulfate blue. No other products are formed.

Write an equation for the reaction of SiH_4 with oxygen.

State symbols are **not** required.

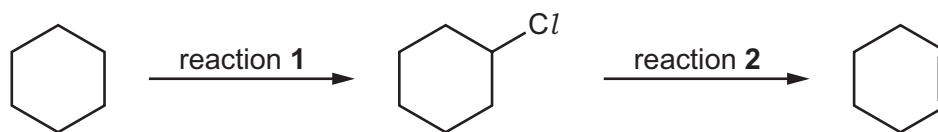
..... [1]

[Total: 22]

9. Question part 1/2 | 9701 Feb-March 2018 P2 V2 Q4

- 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
.....	$\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$
propagation	
.....	
termination	

[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]

2 Crude oil is a complex mixture of hydrocarbon molecules.

The hydrocarbon molecules in crude oil are separated by fractional distillation. Fractional distillation is used because the different hydrocarbon molecules in crude oil have different boiling points.

(a) Explain why the hydrocarbon molecules in crude oil have different boiling points.

.....

.....

.....

.....

.....

.....

..... [2]

(b) Some of the hydrocarbon molecules obtained from crude oil are processed further by cracking.

Suggest why some hydrocarbon molecules are processed further by cracking.

.....

.....

..... [1]

(c) Cracking one mole of dodecane, $C_{12}H_{26}$, produces two moles of ethene and one mole of another hydrocarbon molecule.

(i) Write the equation for this cracking reaction.

..... [1]

The ethene can be used in the production of poly(ethene).

(ii) Give the full name of the process used to produce poly(ethene) from ethene.

..... [1]

10. Question part 2/2 | 9701 May-June 2018 P2 V1 Q2

- (iii) Give **two** reasons why poly(ethene) should be reused or recycled rather than just thrown away.

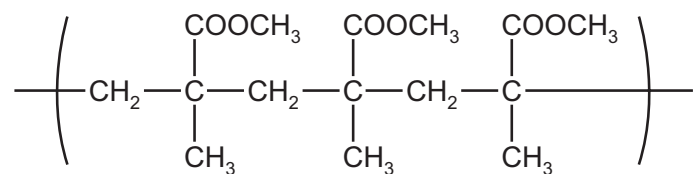
.....

.....

.....

..... [2]

- (iv) Part of a polymer chain, produced by the same type of process as poly(ethene), is shown.



Give the **displayed** formula of the monomer used to produce this polymer.

[2]

[Total: 9]

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11. Question part 1/2 | 9701 May-June 2018 P2 V2 Q3

3 Most vehicle fuels contain hydrocarbons obtained from crude oil.

(a) (i) State the name of the type of reaction that hydrocarbons undergo when being used as fuels.

..... [1]

(ii) Write an equation for the reaction of octane, C_8H_{18} , as a fuel, as in **(a)(i)**.

..... [2]

(b) The supply of material suitable for use as fuels directly from crude oil is **not** sufficient to meet demand. A process is carried out to make some of the larger hydrocarbon molecules more useful.

(i) Name this process.

..... [1]

As well as producing fuels, this process produces compounds suitable for use in the production of polymers. An example of such a compound is but-2-ene, $CH_3CH=CHCH_3$.

(ii) Draw the repeat unit of the polymer that is produced from but-2-ene.

[2]

(iii) Name the type of polymerisation that occurs during the production of the polymer in **(ii)**.

..... [1]

11. Question part 2/2 | 9701 May-June 2018 P2 V2 Q3

- (c) Gases produced in internal combustion engines include carbon monoxide, oxides of nitrogen such as NO_2 , and unburnt hydrocarbons.

These gases are removed from the exhaust before they can enter the atmosphere.

- (i) State what is used to remove these gases from the exhaust.

..... [1]

- (ii) Write **one** equation to show how both carbon monoxide, CO , and nitrogen dioxide, NO_2 , are removed from the exhaust.

..... [1]

- (iii) State the environmental consequence of allowing unburnt hydrocarbons to enter the atmosphere.

..... [1]

- (d) Vehicle fuels are treated to remove sulfur. If sulfur is present in a fuel when it is burned, SO_2 is produced and may be released into the atmosphere where it can form acid rain.

- (i) Acid rain can contribute to breathing difficulties.

Identify **two** other consequences of acid rain in the atmosphere.

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

- (ii) NO_2 is involved in the production of acid rain from SO_2 .

Give **two** equations which describe how acid rain is formed by the action of NO_2 with SO_2 .

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

- (iii) NO_2 is described as a catalyst during this process.

Explain, with the use of an appropriate equation, why NO_2 is described as a catalyst.

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

[Total: 16]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

12. Question part 1/2 | 9701 May-June 2018 P2 V3 Q2

- 2** One reason for the wide variety of organic compounds is isomerism, either structural isomerism or stereoisomerism.

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

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

(ii) Explain the meaning of the term *stereoisomerism*.

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

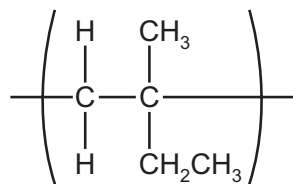
(b) Pent-1-ene, $\text{CH}_2=\text{CH}(\text{CH}_2)_2\text{CH}_3$, does not show stereoisomerism.

(i) Give **two** reasons why pent-1-ene does **not** show stereoisomerism.

reason 1
.....
reason 2
..... [2]

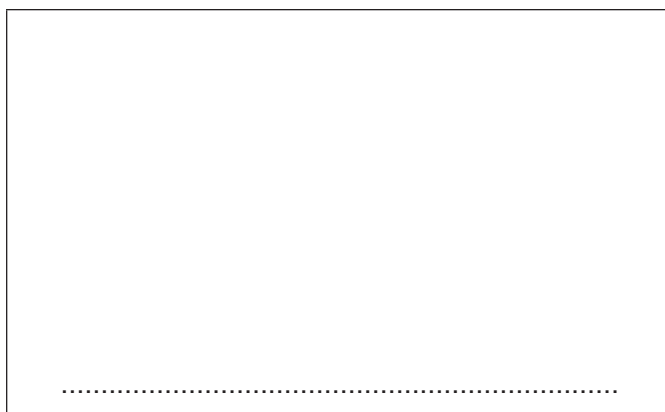
12. Question part 2/2 | 9701 May-June 2018 P2 V3 Q2

- (ii) A structural isomer of pent-1-ene is used as the monomer to form a polymer. The repeat unit of this polymer is shown.



Draw the **displayed** formula of the monomer used to make this polymer.

Give the name of the monomer.

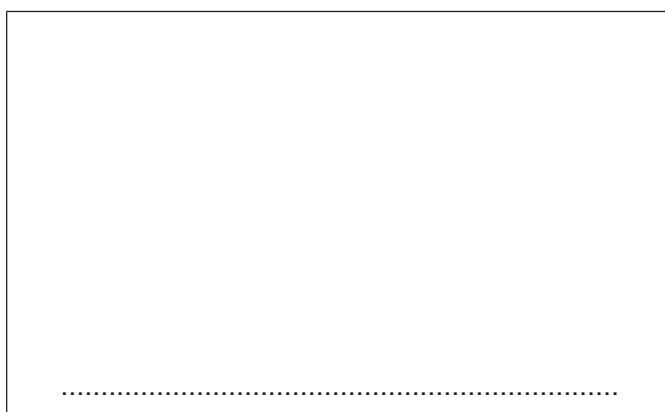


[2]

- (iii) A different structural isomer of pent-1-ene shows geometrical isomerism.

Draw the structure of **one** of the two geometrical isomers with the formula C_5H_{10} .

Give the full name of this isomer.



[2]

[Total: 10]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

13. Question part 1/2 | 9701 May-June 2019 P2 V2 Q4

4 There are many different types of aliphatic and aromatic hydrocarbons.

- (a)** Name a naturally occurring source of aliphatic and aromatic hydrocarbons and outline how different hydrocarbons are separated from this source.

name of source

outline of separation of hydrocarbons

..... [2]

- (b)** When alkanes are heated to high temperatures, in the absence of air, the molecules can break into smaller molecules.

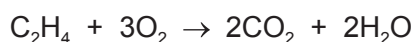
- (i)** Identify the type of reaction occurring.

..... [1]

- (ii)** Write an equation which describes the reaction occurring when heptane, C_7H_{16} , is heated in the absence of air, to form hexane, butane and ethene only.

..... [1]

- (c)** The equation for the complete combustion of ethene is shown.



Calculate the volume, in dm^3 , of carbon dioxide formed in the complete combustion of 1.00g of ethene at room temperature and pressure.

volume of CO_2 = ... dm^3 [3]

(d) The table compares the reactivity of alkanes and alkenes with chlorine.

	alkanes	alkenes
name of the type of reaction with chlorine	substitution	addition and substitution
name of the type of reacting species	free radical	electrophile and free radical

(i) During the first stage in the substitution reaction chlorine forms chlorine free radicals.

Explain what is meant by the term *free radical*.

..... [1]

(ii) Name and explain the type of bond breaking which occurs to form chlorine free radicals.

.....
 [2]

(iii) Name the stage of the reaction mechanism which occurs when a methane molecule reacts with a chlorine free radical.

..... [1]

(iv) Complete the equation for the reaction which occurs when a methane molecule reacts with a chlorine free radical.



[1]

(v) Carbon atoms can form σ and π bonds within hydrocarbon molecules.

Explain the following statement with reference to σ and π bonds.

Alkenes react with electrophiles but alkanes do not.

.....

 [2]

[Total: 14]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

14. Question part 1/2 | 9701 May-June 2019 P2 V3 Q6

6 (a) Three alkenes, **X**, **Y** and **Z**, have the same molecular formula.

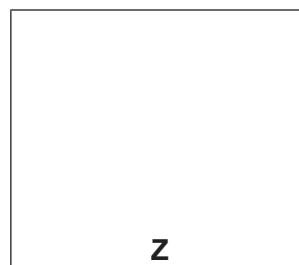
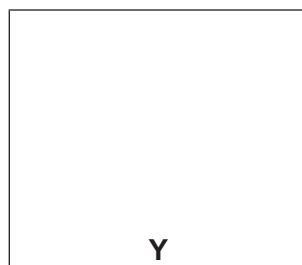
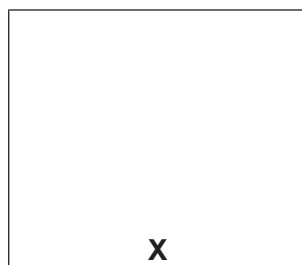
(i) Describe what is seen when aqueous bromine is added to **X**.

..... [1]

X, **Y** and **Z** are reacted separately with hot, concentrated, acidified manganate(VII) ions until no further reaction occurs. The carbon-containing products are shown in the table.

alkene	carbon-containing products
X	$\text{CO}_2 + (\text{CH}_3)_2\text{CO}$
Y	$\text{CO}_2 + \text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
Z	$\text{CH}_3\text{CO}_2\text{H}$

(ii) Draw the structures of **X**, **Y** and **Z**.

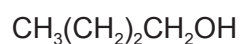


[3]

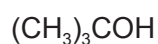
(iii) Deduce the molecular formula of **X**, **Y** and **Z**.

..... [1]

(b) The structures of **V** and **W** are shown.



V



W

(i) Name the class of compound that **V** and **W** each belong to.

V

W

[2]

(ii) **V** and **W** both react with sodium metal.

Write an equation for the reaction of **V** with sodium metal.

..... [1]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

14. Question part 2/2 | 9701 May-June 2019 P2 V3 Q6

(iii) Name a reagent used to distinguish **V** from **W**. Describe any observations.

reagent

observations with **V**

observations with **W**

[3]

[Total: 11]

3 Crude oil is a natural source of hydrocarbons that are used as fuels.

- (a)** Hydrocarbons with low relative molecular mass, M_r , are used as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r .

- (i)** Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

..... [1]

- (ii)** Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

..... [1]

- (iii)** Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butene, C_4H_8 .

..... [1]

- (iv)** Identify an analytical technique that can be used to monitor the levels of CO in the atmosphere.

Outline how this analytical technique may be used to monitor the levels of CO.

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

- (b)** Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

- (i)** Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

..... [2]

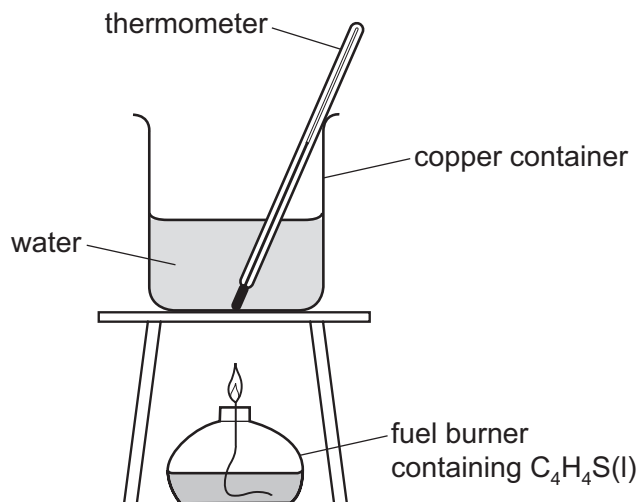
- (ii)** A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

Explain the meaning of the term *enthalpy change of combustion*.

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

15. Question part 2/2 | 9701 Oct-Nov 2019 P2 V1 Q3

(iii) The student uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm³ of water by 1.0 °C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

(iv) The student used 0.63 g of C₄H₄S(l) in the experiment.Calculate the enthalpy change of combustion of thiophene, ΔH_c(C₄H₄S(l)). Include a sign in your answer.

ΔH_c(C₄H₄S(l)) = ... kJ mol⁻¹
[2]

[Total: 13]

3 Crude oil is a natural source of hydrocarbons that are used as fuels.

- (a)** Hydrocarbons with low relative molecular mass, M_r , are used as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r .

- (i)** Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

..... [1]

- (ii)** Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

..... [1]

- (iii)** Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butene, C_4H_8 .

..... [1]

- (iv)** Identify an analytical technique that can be used to monitor the levels of CO in the atmosphere.

Outline how this analytical technique may be used to monitor the levels of CO.

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

- (b)** Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

- (i)** Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

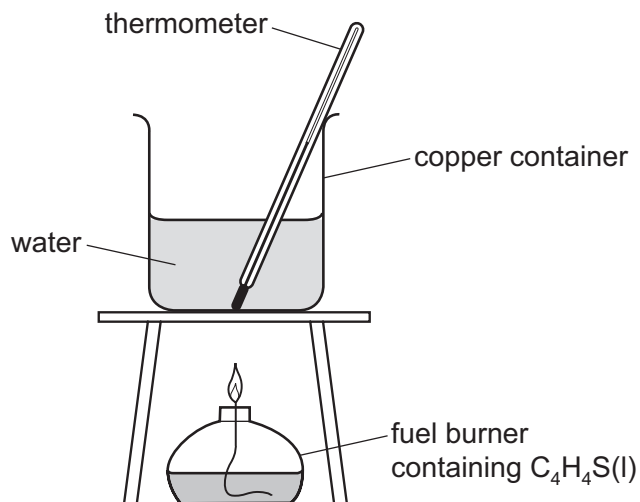
..... [2]

- (ii)** A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

Explain the meaning of the term *enthalpy change of combustion*.

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

(iii) The student uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm³ of water by 1.0 °C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

(iv) The student used 0.63 g of C₄H₄S(l) in the experiment.

Calculate the enthalpy change of combustion of thiophene, $\Delta H_c(\text{C}_4\text{H}_4\text{S(l)})$. Include a sign in your answer.

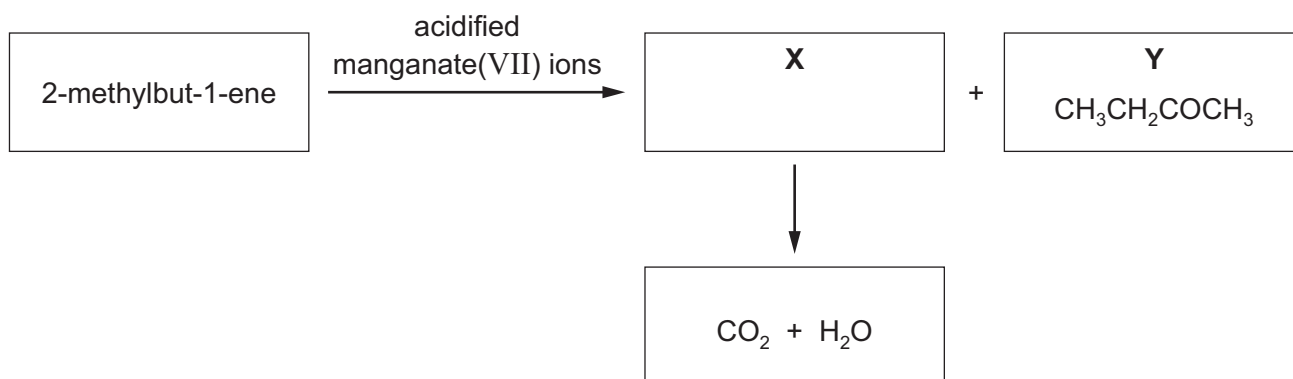
$\Delta H_c(\text{C}_4\text{H}_4\text{S(l)}) = \dots\dots\dots \text{kJ mol}^{-1}$
[2]

[Total: 13]

17. Question part 1/3 | 9701 May-June 2020 P2 V1 Q6

- 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**.

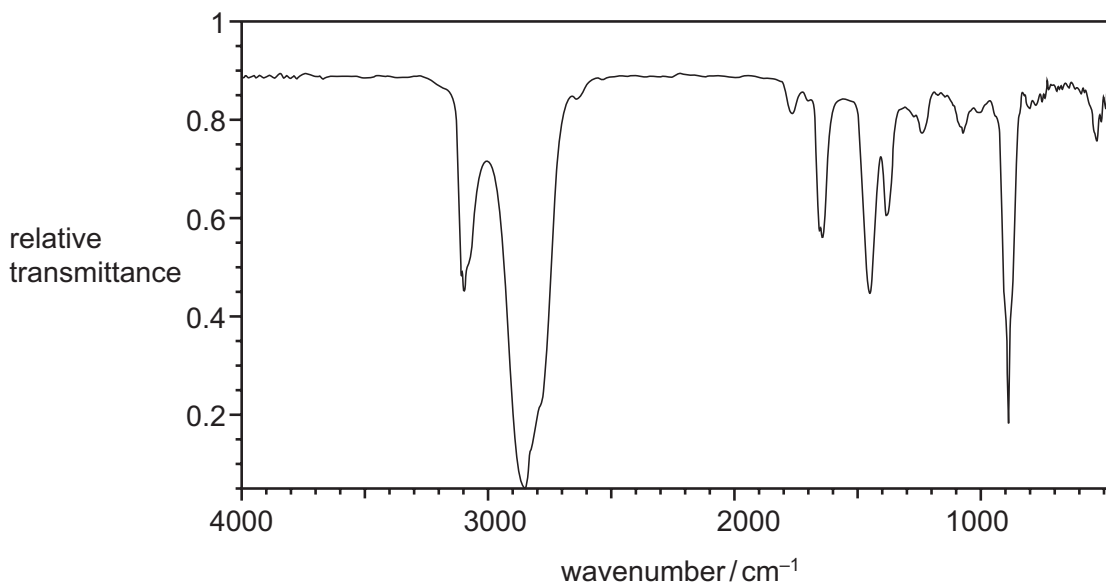
..... [1]

- (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 $[\text{H}]$ to represent an atom of hydrogen from the reducing agent.

..... [1]

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

..... [1]

17. Question part 3/3 | 9701 May-June 2020 P2 V1 Q6

(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]

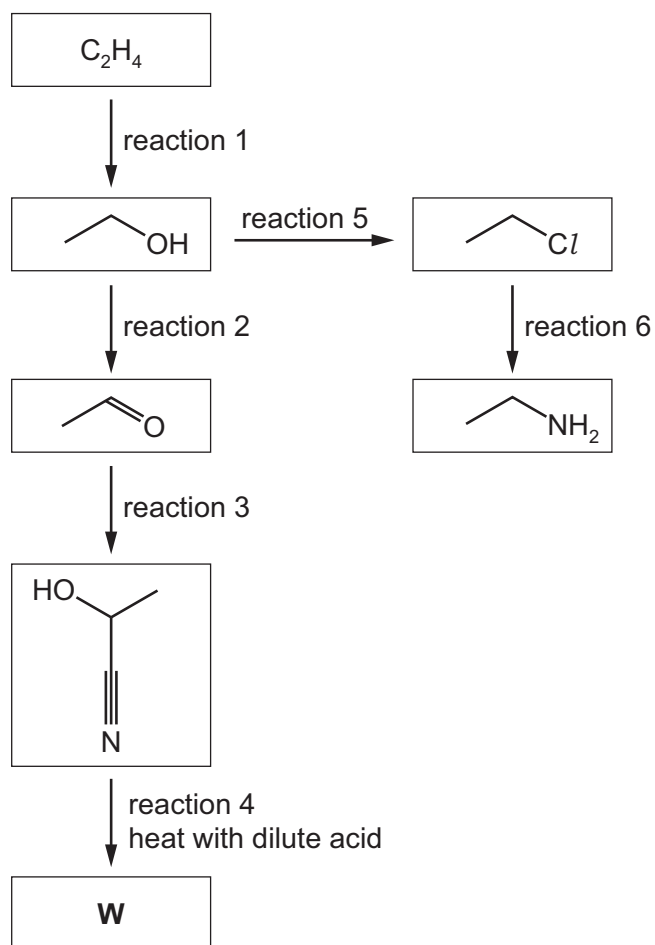
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18. Question part 1/2 | 9701 May-June 2020 P2 V2 Q5

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



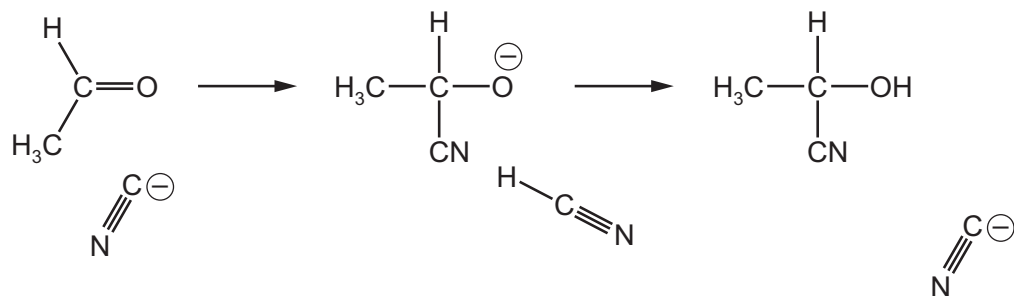
(a) Complete the table to give

- the name of the reaction mechanisms of reactions 1 and 6
- the reagents and conditions required for reactions 1, 2 and 6.

reaction	name of mechanism	name of reagents and conditions
1		
2		
6		

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

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



[3]

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

..... [2]

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

[1]

[Total: 12]

19. Question part 1/2 | 9701 May-June 2020 P2 V3 Q4

- 4 Hexane, C_6H_{14} , is a colourless liquid.
Two test-tubes contain equal amounts of hexane. 1 cm^3 of bromine, $\text{Br}_2(\text{aq})$, is added to both test-tubes. One test-tube is kept in the dark and the other is exposed to sunlight.

The table describes the appearance of each test-tube after one hour.

test-tube conditions	observations
in the dark	no change, mixture remains orange
in sunlight	colour of mixture fades to pale yellow

- (a) The test-tube in the dark is kept cool and is not exposed to ultraviolet light.

Explain the observations for the test-tube kept in the dark.

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

- (b) In sunlight, bromine reacts with hexane by a mechanism which occurs via a series of steps.

- (i) State the name of the mechanism of the reaction that occurs.

..... [1]

- (ii) Give an equation which shows a propagation step in this reaction in which hexane produces $\cdot\text{C}_6\text{H}_{13}$.

..... [1]

- (iii) Give an equation which shows a propagation step in this reaction that produces 1-bromohexane.

..... [1]

- (iv) Give an equation which shows a termination step in this reaction that produces 1-bromohexane.

..... [1]

(c) **A** and **B** are different straight chain alkenes with molecular formula, C_6H_{12} .

A does not show stereoisomerism.

A reacts with potassium manganate(VII) to form hexane-1,2-diol.

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

[1]

(ii) State the conditions needed for this reaction of **A**.

..... [2]

(d) **B** reacts with hydrogen gas in the presence of a platinum catalyst to produce hexane.

(i) Name the type of reaction occurring.

..... [1]

(ii) In terms of σ and π bonds, describe any similarities and differences in the type of carbon-carbon bonds in **B** and the type of carbon-carbon bonds in hexane.

.....

.....

..... [2]

[Total: 12]

5 (a) Naphtha is a mixture which contains only hydrocarbon molecules.

(i) What is meant by the term *hydrocarbon*?

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

(ii) Name the raw material that is used to produce a sample of naphtha.

..... [1]

(b) Compound **V** is found in naphtha. It has a molecular formula $C_{10}H_{22}$.

When **V** is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and **W** are made. **W** is a compound made of straight chain, saturated molecules.

(i) Name the process that describes this reaction.

..... [1]

(ii) Deduce the structure of **W**. Draw its structure below.

[1]

(c) Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to **X**, which contains two functional groups.

(i) Effervescence is seen when $Na_2CO_3(aq)$ is added to **X**.

Identify the functional group present in **X** which is responsible for this observation.

..... [1]

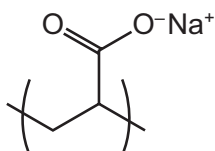
(ii) Identify a reagent which could be used to show that **X** contains a $C=C$. Include relevant observations.

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

(d) **X** reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

repeat unit of polymer **Z**



Draw the structural formula of monomer **Y**.

[1]

(e) Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

(i) Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect.

..... [1]

(ii) Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.

gas

consequence

[1]

[Total: 10]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

21. Question part 1/2 | 9701 May-June 2021 P2 V1 Q6

- 6 Propene, C_3H_6 , reacts with H_2O in the presence of an acid catalyst to form an alcohol with molecular formula $\text{C}_3\text{H}_8\text{O}$.

(a) Name this type of reaction.

..... [1]

(b) Name the catalyst used and state the conditions needed for this reaction to occur.

catalyst

conditions [2]

(c) Complete the table to show the numbers of sigma (σ) bonds and pi (π) bonds present in propene, C_3H_6 , and $\text{C}_3\text{H}_8\text{O}$.

	σ	π
C_3H_6		
$\text{C}_3\text{H}_8\text{O}$		

[2]

(d) The reaction of propene, C_3H_6 , with H_2O occurs in a two-step mechanism. In step 1 C_3H_6 reacts with the catalyst, H^+ , to form a carbocation.

(i) Draw structures to identify the more stable and less stable carbocations which can form in step 1. Explain your answer.

more stable carbocation	less stable carbocation

explanation
.....
.....
.....
.....

[3]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

21. Question part 2/2 | 9701 May-June 2021 P2 V1 Q6

(ii) Name the major organic product formed from the reaction of propene, C_3H_6 , with H_2O .

..... [1]

(e) 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

(i) Name this type of reaction.

..... [1]

(ii) Describe the reagents and conditions needed to favour this reaction.

reagents

conditions

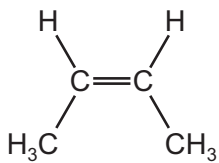
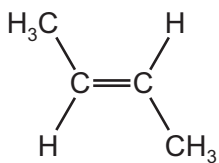
[2]

[Total: 12]

22. Question part 1/2 | 9701 May-June 2021 P2 V2 Q4

- 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 $\text{Cr}_2\text{O}_7^{2-}$ 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**.

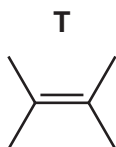
functional group	present in Z
aldehyde	
ketone	
carboxylic acid	

[1]

[Total: 12]

23. Question part 1/3 | 9701 Oct-Nov 2021 P2 V2 Q3

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



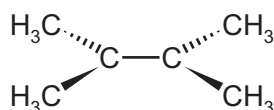
- (a) Name **T**.

..... [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.

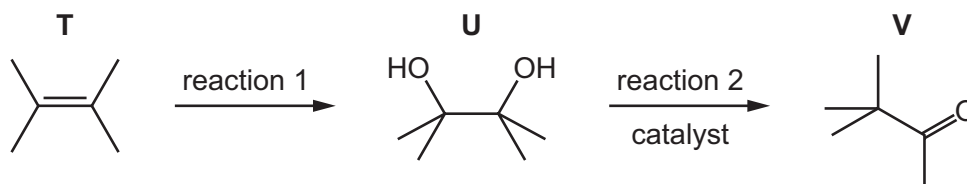


- (i) On the diagram, draw the orbitals that represent the pi (π) bond that is also present in **T**. [1]

- (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.

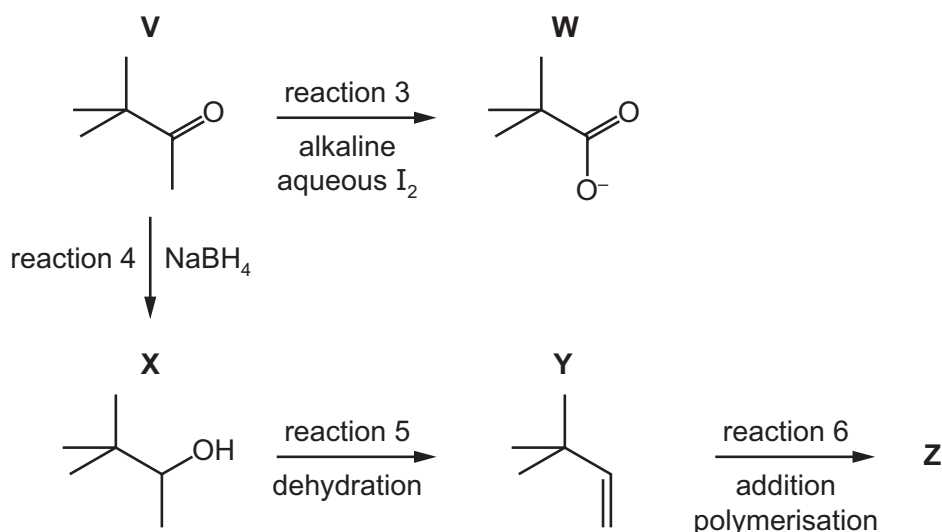
Identify two absorptions, and the bonds responsible for these absorptions, whose appearance will change significantly during the reaction.

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]

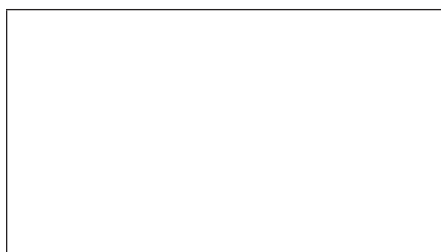
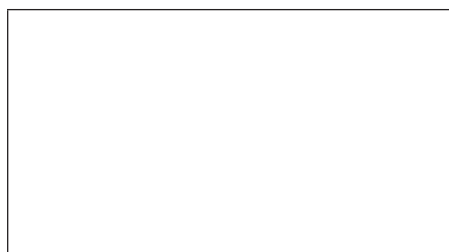
- (iii) Construct an equation for reaction 4.

Use [H] in the equation to represent an atom of hydrogen from NaBH₄.

C₆H₁₂O + ... [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]

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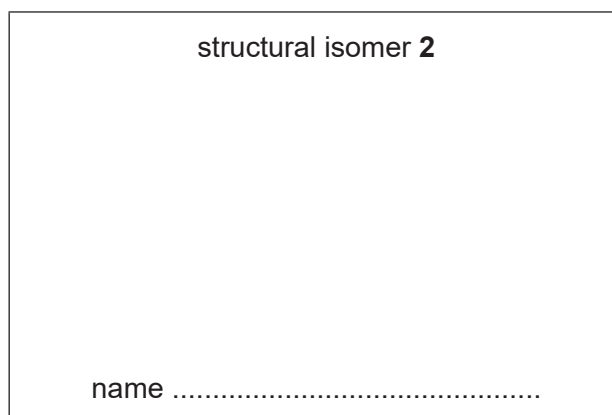
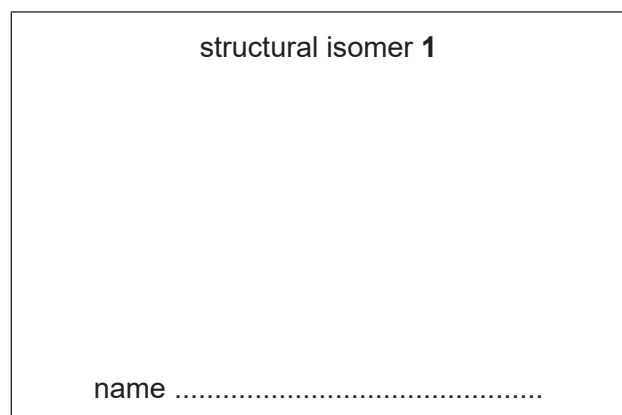
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24. Question part 1/2 | 9701 May-June 2022 P2 V2 Q4

- 4 (a)** Bromine reacts with butane in the presence of ultraviolet light to form bromobutane.

Two structural isomers with the molecular formula C_4H_9Br are produced during this reaction.

- (i)** Draw the two structural isomers and state the systematic name of each isomer.



[2]

- (ii)** Identify the type of structural isomerism shown in **(a)(i)**.

..... [1]

- (b)** Halothane is an anaesthetic.

halothane

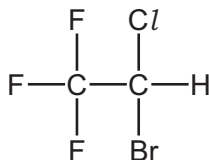


Fig. 4.1

- (i)** Identify the chiral centre in halothane and mark it with an asterisk (*). [1]

When halothane reacts in ultraviolet light, homolytic fission occurs and the C–Br bond is broken.

- (ii)** Construct an equation to show the homolytic fission of halothane, $CF_3CHBrCl$.

..... [1]

- (iii) Complete Fig. 4.2 to show the arrangement of electrons in a bromine atom using the electrons in boxes notation.

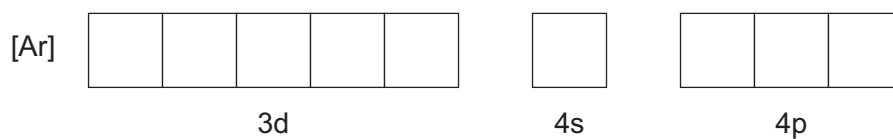


Fig. 4.2

[1]

- (c) **X** is an addition polymer.

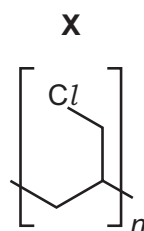


Fig. 4.3

- (i) Draw the monomer of **X**.

[1]

- (ii) Suggest **one** reason why the disposal of items made from **X** is difficult.

..... [1]

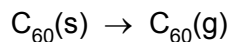
[Total: 8]

2 Carbon and silicon are elements in Group 14.

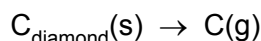
(a) (i) Describe in simple terms the structure of solid C_{60} .

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

(ii) C_{60} sublimes (turns directly from solid to gas) at approximately 800 K.



Diamond also sublimes but only above 3800 K.



Explain why C_{60} and diamond sublime at such different temperatures.

.....
.....
.....
.....
.....
.....
.....
..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) Define hydrocarbon.

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

9701 Chemistry Paper 2 - Hydrocarbons

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25. Question part 2/3 | 9701 Specimen 2022 P2 Q2

- (ii) $C_{60}H_{18}$ is an alkene.

State a test to indicate the presence of double bonds between carbon atoms in alkene molecules.

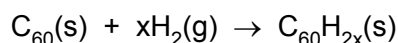
.....
..... [1]

- (iii) State the observations seen when the test in (b)(ii) is carried out on an alkene.

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

- (c) 0.144 g of C_{60} is placed in a 100 cm^3 container of hydrogen gas at a temperature of 20°C and a pressure of $1.00 \times 10^5\text{ Pa}$.

The container is heated to make the C_{60} and hydrogen gas react. The reaction occurs as shown in the equation.



After the reaction, the container is allowed to cool to 20°C . The pressure decreases to $2.21 \times 10^4\text{ Pa}$. All of the C_{60} has reacted.

- (i) Name the type of reaction that occurs.

..... [1]

- (ii) Calculate the amount, in moles, of C_{60} that reacts.

amount of C_{60} = ... mol [1]

- (iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60} .
Show your working.

amount of hydrogen gas = ... mol [3]

9701 Chemistry Paper 2 - Hydrocarbons

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25. Question part 3/3 | 9701 Specimen 2022 P2 Q2

- (iv) Use your answers from (c)(ii) and (c)(iii) to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

(If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacts. This is **not** the correct value.)
Show your working.

molecular formula = ... [2]

- (d) Silicon shows the same type of bonding and structure as diamond.

Silicon reacts with magnesium to form Mg_2Si .

Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

- (i) Construct an equation for this reaction. Include state symbols.

..... [2]

- (ii) Predict the shape of the SiH_4 molecule.

..... [1]

[Total: 19]

26. Question part 1/2 | 9701 Specimen 2022 P2 Q4

- 4 A reaction scheme involving cyclohexane is shown in Fig. 4.1.

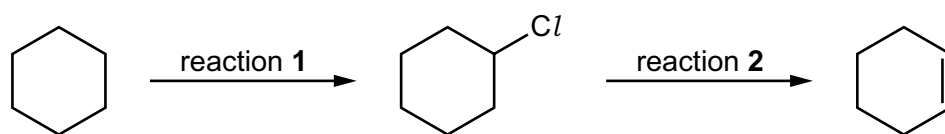


Fig. 4.1

Reaction 1 involves a free radical substitution mechanism.

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

..... [1]

- (b) Complete Table 4.1 to give details of the mechanism in reaction 1. Include curly arrows to show the movement of electrons occurring in the termination step.

Table 4.1

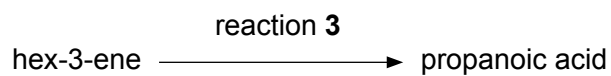
name of step	equation
.....	$Cl_2 \longrightarrow 2Cl\cdot$
propagation	$+ Cl\cdot \longrightarrow$ $+ \dots$
.....	$+ Cl_2 \longrightarrow$ $+ Cl\cdot$
termination	 $\longrightarrow$

[5]

- (c) Deduce the type of reaction that occurs in reaction 2.

..... [1]

(d) Hex-3-ene is an isomer of cyclohexane. Hex-3-ene can be converted into propanoic acid.



Deduce the reagents and conditions for reaction **3**.

.....

..... [2]

[Total: 9]

27. Question part 1/4 | 9701 Feb-March 2023 P2 V2 Q3

- 3 Alkenes undergo an addition reaction with a 1:1 mixture of CO and H₂ to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H₂.

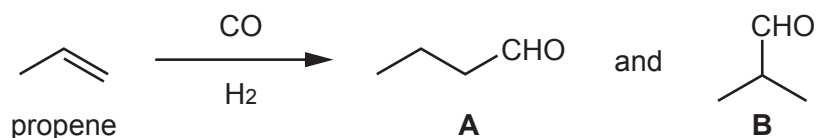


Fig. 3.1

- (a) (i) Define addition reaction.

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

- (ii) Aldehydes **A** and **B** are structural isomers.

State the type of structural isomerism shown by **A** and **B**.

..... [1]

- (iii) Name **A**.

..... [1]

- (iv) The complete reaction of propene with a 1:1 mixture of CO and H₂ produces **A** and **B** only. The product mixture contains 96% **A** and 4% **B**.

Calculate the mass of **A** produced in this reaction when 5.00×10^3 kg of propene is used.

mass of **A** = ... kg [1]

(b) **A** and **B** show reactions typical of aliphatic aldehydes.

- (i) **A** undergoes a nucleophilic addition reaction with a mixture of HCN and KCN, forming compound **C**.

Complete the diagram to show the mechanism for this reaction.

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

Draw the structure of the organic intermediate.



[4]

- (ii) Table 3.1 shows information about three experiments involving **B**.

Complete Table 3.1.

Table 3.1

experiment	reagents	observation with B
1		solution turns from orange to green
2		a silver mirror forms on the sides of the reaction vessel
3	$\text{Br}_2(\text{aq})$	

[3]

- (iii) **B**, $\text{C}_4\text{H}_8\text{O}$, is oxidised by acidified potassium manganate(VII).

Complete the equation for this reaction. Use [O] to represent one atom of oxygen from the oxidising agent.



- (iv) **C** is a chiral molecule.

Circle any chiral centres in the structure of **C** shown in Fig. 3.2.

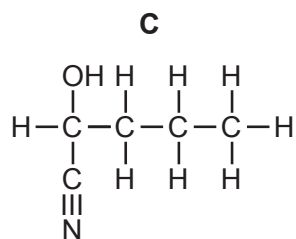


Fig. 3.2

[1]

- (c) When propene reacts with CO and an excess of H_2 , an alkane and a mixture of alcohols are formed instead. The alcohols are isomers of each other.

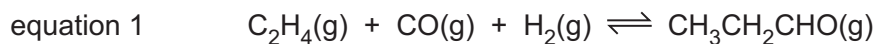
Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions.

molecular formula of alkane

molecular formula of alcohols

[2]

- (d) The reaction of ethene, C_2H_4 , with a 1:1 mixture of CO and H_2 is shown in equation 1.



At atmospheric pressure a cobalt-based catalyst is used in this reaction.

- (i) State and explain the effect of using a catalyst on this reaction.

.....

.....

.....

..... [2]

- (ii) Explain why the yield of $\text{CH}_3\text{CH}_2\text{CHO}(\text{g})$ increases when the overall pressure of the reaction mixture is increased.

.....
 [1]

- (iii) Use the information in Table 3.2 to calculate the enthalpy change, ΔH_r , of the reaction in equation 1.



Table 3.2

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
$\text{C}_2\text{H}_4(\text{g})$	+52
$\text{CO}(\text{g})$	−111
$\text{CH}_3\text{CH}_2\text{CHO}(\text{g})$	−187

$$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- (iv) The reaction mixture is cooled to collect $\text{CH}_3\text{CH}_2\text{CHO}$ as a liquid.

Identify all types of van der Waals' forces that are present between molecules of $\text{CH}_3\text{CH}_2\text{CHO}$.

.....
 [1]

[Total: 21]

9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

28. Question part 1/7 | 9701 May-June 2023 P2 V1 Q5

- 5 (a)** Molecule **M** is present in petrol, a fuel used in cars. **M** is a saturated, non-cyclic hydrocarbon. **M** contains eight carbon atoms.

- (i)** Construct an equation for the complete combustion of **M**.

..... [2]

- (ii)** Describe how the composition of products differs when incomplete combustion of **M** occurs.

.....

..... [2]

- (b)** When petrol is burned in an internal combustion engine, oxides of nitrogen are released into the atmosphere. Oxides of nitrogen are responsible for the formation of acid rain.

- (i)** Suggest the conditions required for the production of oxides of nitrogen during combustion of **M** in an internal combustion engine. Use an appropriate equation in your answer.

.....

.....

.....

..... [2]

- (ii)** Describe how acid rain is formed in the atmosphere in the presence of oxides of nitrogen and SO_2 . Identify the role of the oxides of nitrogen in this process. Include **all** relevant equations.

.....

.....

.....

..... [3]

- (iii)** State **one** other type of air pollution that is caused by the production of oxides of nitrogen in an internal combustion engine.

..... [1]

- (c) Biodiesel **T** is a fuel made from vegetable oil **R**. Fig. 5.1 shows the production of **T** from **R** in a two-step process.

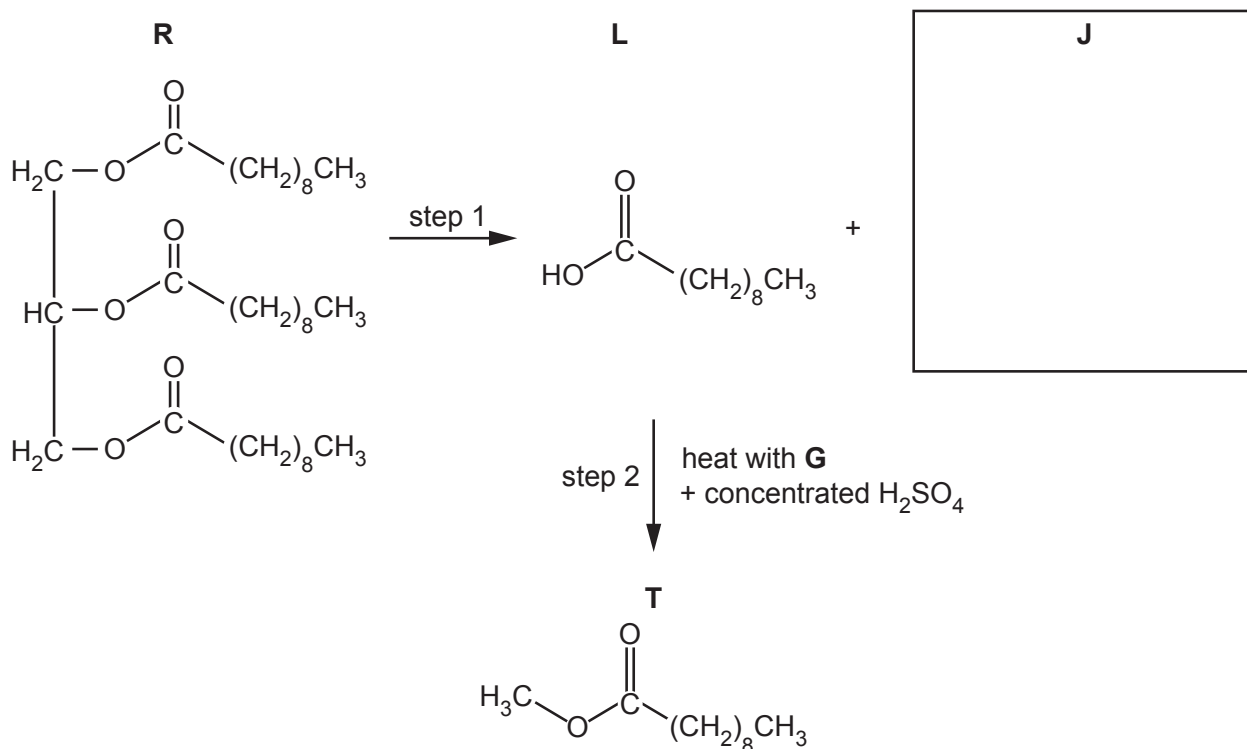


Fig. 5.1

- (i) In step 1 all three ester groups in **R** react. Suggest a suitable reagent and conditions for step 1.
 [1]
- (ii) Draw the structural formula of **J** in the box in Fig. 5.1. [1]
- (iii) Name the type of reaction that occurs in step 2.
 [1]
- (iv) Name organic reagent **G** used in step 2.
 [1]
- (v) **L** is called decanoic acid. Use systematic nomenclature to deduce the name of **T**.
 [1]

[Total: 15]

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28. Question part 5/7 | 9701 May-June 2023 P2 V1 Q5

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28. Question part 6/7 | 9701 May-June 2023 P2 V1 Q5

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

Topical questions | 43 questions

28. Question part 7/7 | 9701 May-June 2023 P2 V1 Q5

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.4	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	euroium	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	yterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	merendeium	—	102	No	nobelium	—	103	Lr	lawrencium	—

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29. Question part 1/9 | 9701 May-June 2023 P2 V3 Q6

- 6 Compound **W**, $\text{CH}_2=\text{CHCN}$, is used to make an addition polymer which is present in carbon fibres.

(a) Draw **one** repeat unit of the addition polymer of **W**.

[1]

- (b) CH_3CHO is used in a two-step synthetic route to form **W**, as shown in Fig. 6.1.
In step 1, CH_3CHO is heated with HCN in the presence of KCN .

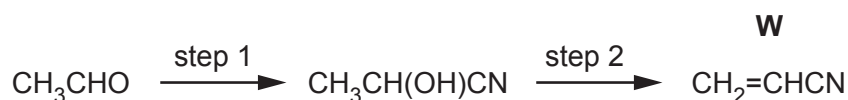


Fig. 6.1

- (i) Name the mechanism for the reaction in step 1 in Fig. 6.1.

..... [1]

- (ii) Complete Fig. 6.2 to show the mechanism for the reaction in step 1.
Include all products, charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

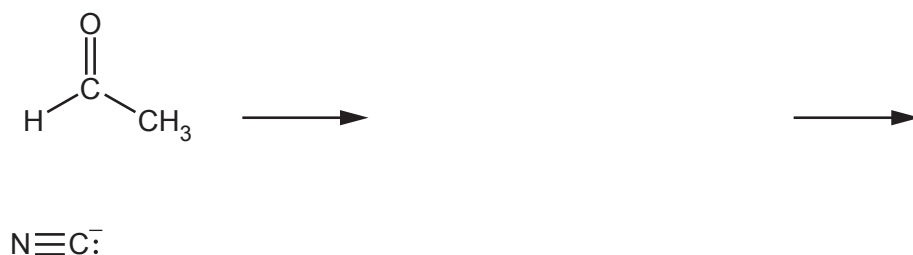


Fig. 6.2

[3]

- (iii) Suggest a suitable reagent and conditions for step 2 in Fig. 6.1.

..... [1]

(iv) Fig. 6.3 shows the infrared spectrum of **W**, $\text{CH}_2=\text{CHCN}$.

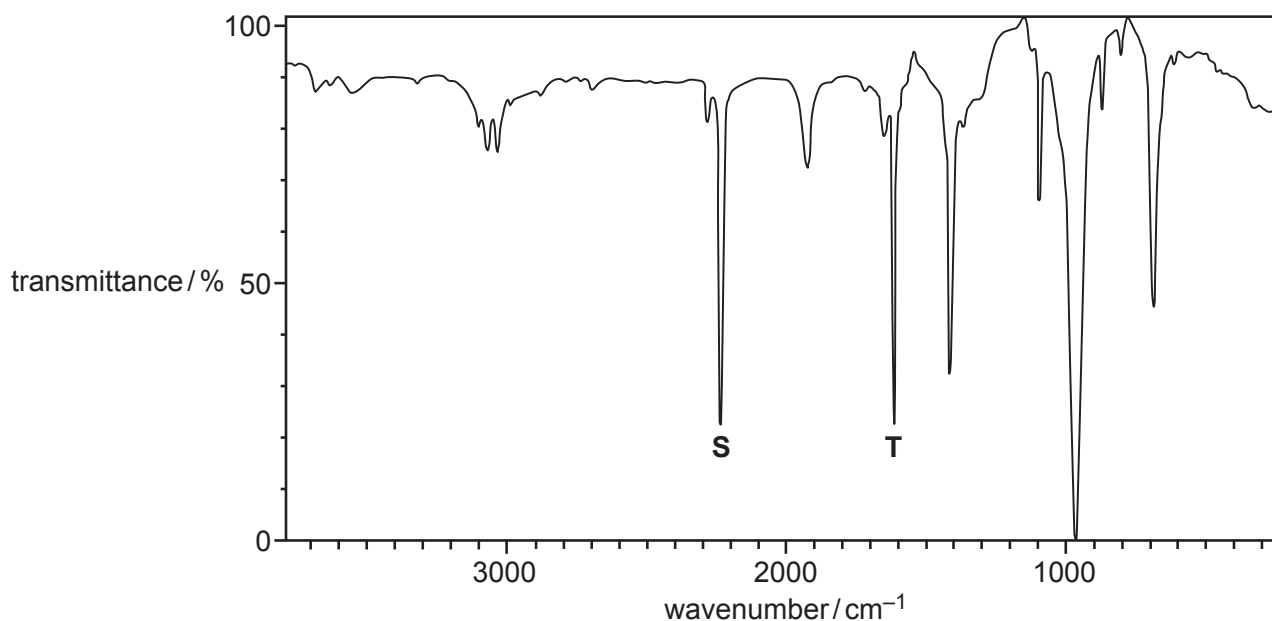


Fig. 6.3

Table 6.1

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/ cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

Use Table 6.1 to identify the bonds responsible for the absorptions marked **S** and **T** on Fig. 6.3.

S

T

(c) Molecules of **W**, $\text{CH}_2=\text{CHCN}$, do **not** show stereoisomerism.

(i) Describe stereoisomerism.

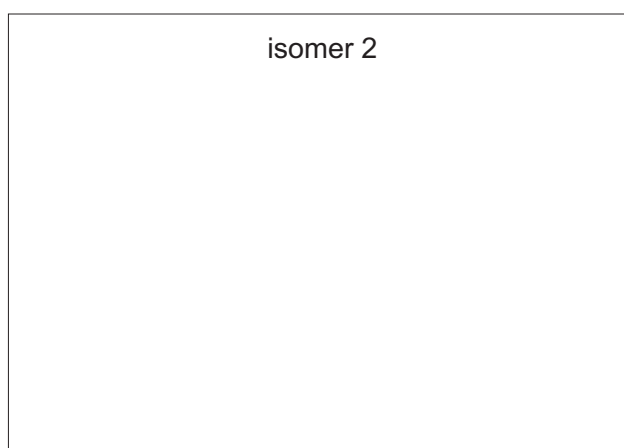
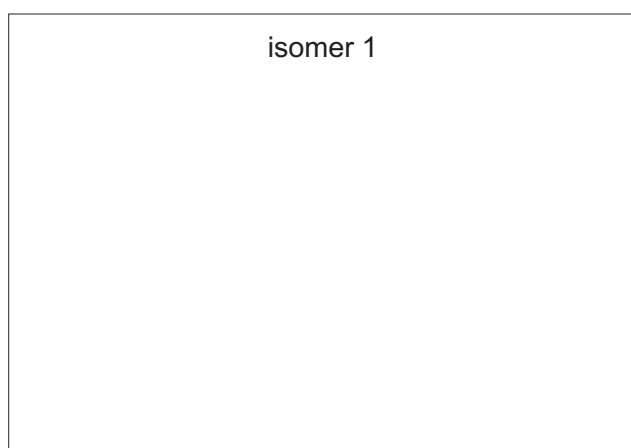
.....
..... [1]

(ii) Describe the **two** essential features of an alkene molecule that cause it to show geometrical stereoisomerism.

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

(d) Molecules of $\text{CH}_3\text{CH}(\text{OH})\text{CN}$ exist as a pair of optical isomers.

Draw three-dimensional diagrams in the boxes to show the optical isomers of $\text{CH}_3\text{CH}(\text{OH})\text{CN}$.



[1]

(e) Propanenitrile is heated with hydrogen gas and a platinum catalyst. The only product is propylamine.

Construct an equation for this reaction.

..... [1]

- (f) Propylamine can also be formed in a two-step synthesis from propan-1-ol, as shown in Fig. 6.4.

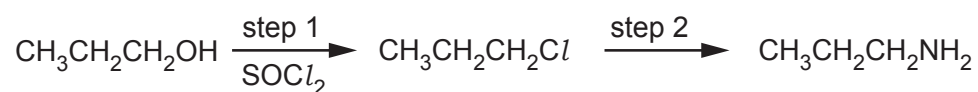


Fig. 6.4

- (i) Name the type of reaction in step 1 in Fig. 6.4.

..... [1]

- (ii) Identify the reagent and conditions for step 2 in Fig. 6.4.

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

[Total: 15]

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29. Question part 5/9 | 9701 May-June 2023 P2 V3 Q6

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29. Question part 8/9 | 9701 May-June 2023 P2 V3 Q6

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

Topical questions | 43 questions

29. Question part 9/9 | 9701 May-June 2023 P2 V3 Q6

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.4	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	euroium	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	yterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	merendeium	—	102	No	nobelium	—	103	Lr	lawrencium	—

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30. Question part 1/9 | 9701 Oct-Nov 2023 P2 V1 Q4

- 4 Compounds **C** and **D** are alkenes with the same molecular formula, C_5H_{10} .



Fig. 4.1

- (a) (i) Give the systematic name of **D**.

..... [1]

- (ii) Explain why **C** and **D** do not show geometrical (*cis/trans*) isomerism.

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

- (iii) Draw the structure of a molecule that is a positional isomer of **C** and **D**.

[1]

- (iv) Give the structural formula of the compound formed when **D** reacts with $H_2(g)$ in the presence of a Pt catalyst.

..... [1]

- (v) **C** can form an addition polymer.

Draw the structure of **one** repeat unit of this addition polymer.

[1]

- (b) The mass spectrum of **C** shows a molecular ion peak at $m/e = 70$. This peak has a relative intensity of 48.7.

The relative intensity of the $[M+1]$ peak is 2.7.

Show that this information is consistent with the molecular formula of **C**.

[2]

- (c) **C** and **D** both react with HBr.

- (i) **C** reacts with HBr to form **E**.

Complete the diagram in Fig. 4.2 to show the mechanism for this reaction.

Draw the structure of the organic intermediate.

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

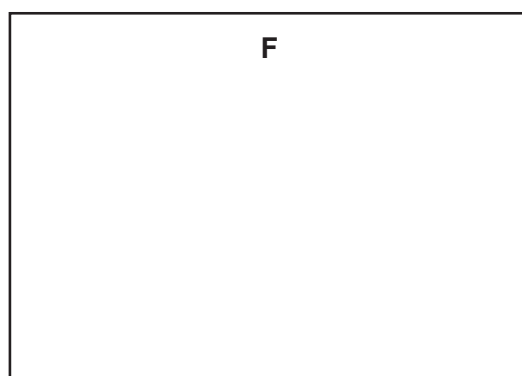


Fig. 4.2

[3]

- (ii) **D** reacts with HBr to produce **F**, a chiral bromoalkane.

Draw the structure of **F**.



[1]

(iii) Explain why the reaction of HBr with **C** and **D** produces different major products.



Fig. 4.3

.....

.....

.....

..... [2]

(d) **C** can be used to form **H**.

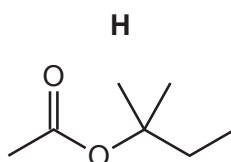


Fig. 4.4

One possible synthesis of **H** is shown in Fig. 4.5. Different portions of **C** are used in reactions 1 and 3. Some of the products are then combined to produce **H**.

Fig. 4.5 does not show any of the inorganic products of the reactions.

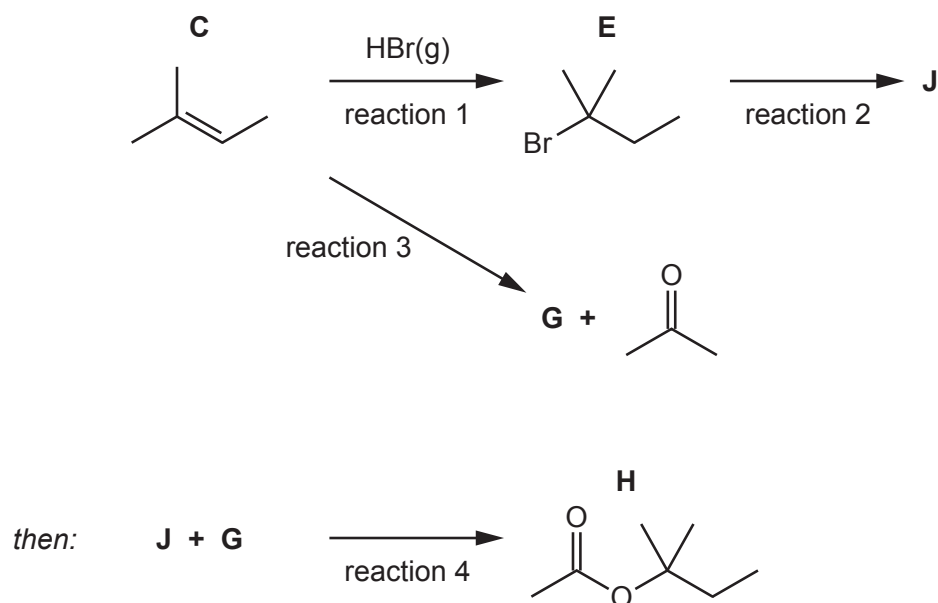


Fig. 4.5

Complete Table 4.1 with the reagents and conditions required for each of the reactions shown in Fig. 4.5.

Table 4.1

	reagent and conditions
reaction 1 C → E	HBr(g)
reaction 2 E → J	
reaction 3 C → G + 	
reaction 4 J + G → H	

[3]

[Total: 16]

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9701 Chemistry Paper 2 - Hydrocarbons

Topical questions | 43 questions

30. Question part 8/9 | 9701 Oct-Nov 2023 P2 V1 Q4

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

The Periodic Table of Elements

Group																						
1	2													13	14	15	16	17	18			
		1 H hydrogen 1.0																				
		Key atomic number atomic symbol name relative atomic mass																				
3	4													5	6	7	8	9	10	11	12	
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2			
11	12													13	14	15	16	17	18			
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9			
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36					
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8					
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54					
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3					
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86				
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —				
87	88	89–103 actinoids		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118				
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —				

lanthanoids

actinoids

57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.4	61	Pm promethium	62	Sm samarium 150.4	63	Eu europium 152.0	64	Gd gadolinium 157.3	65	Tb terbium 158.9	66	Dy dysprosium 162.5	67	Ho holmium 164.9	68	Er erbium 167.3	69	Tm thulium 168.9	70	Yb ytterbium 173.1	71	Lu lutetium 175.0
89	Ac actinium	90	Th thorium 232.0	91	Pa protactinium 231.0	92	U uranium 238.0	93	Np neptunium	94	Pu plutonium	95	Am americium	96	Cm curium	97	Bk berkelium	98	Cf californium	99	Es einsteinium	100	Fm fermium	101	Md mendelevium	102	No nobelium	103	Lr lawrencium

31. Question part 1/9 | 9701 Oct-Nov 2023 P2 V3 Q4

- 4 Compounds **C** and **D** are alkenes with the same molecular formula, C_5H_{10} .



Fig. 4.1

- (a) (i) Give the systematic name of **D**.

..... [1]

- (ii) Explain why **C** and **D** do not show geometrical (*cis/trans*) isomerism.

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

- (iii) Draw the structure of a molecule that is a positional isomer of **C** and **D**.

[1]

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Draw the structure of **one** repeat unit of this addition polymer.

[1]

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[2]

- (c) **C** and **D** both react with HBr.

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Complete the diagram in Fig. 4.2 to show the mechanism for this reaction.

Draw the structure of the organic intermediate.

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

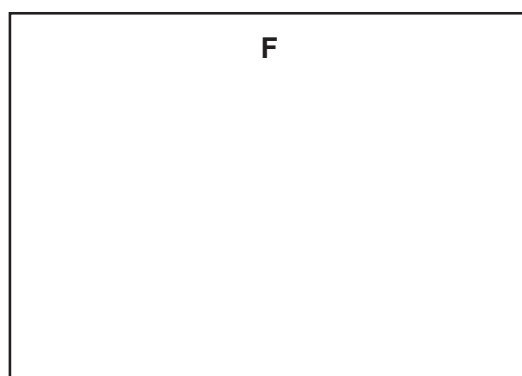


Fig. 4.2

[3]

- (ii) **D** reacts with HBr to produce **F**, a chiral bromoalkane.

Draw the structure of **F**.



[1]

(iii) Explain why the reaction of HBr with **C** and **D** produces different major products.



Fig. 4.3

.....

.....

.....

..... [2]

(d) **C** can be used to form **H**.

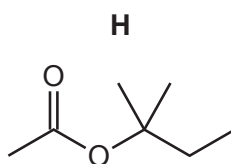


Fig. 4.4

One possible synthesis of **H** is shown in Fig. 4.5. Different portions of **C** are used in reactions 1 and 3. Some of the products are then combined to produce **H**.

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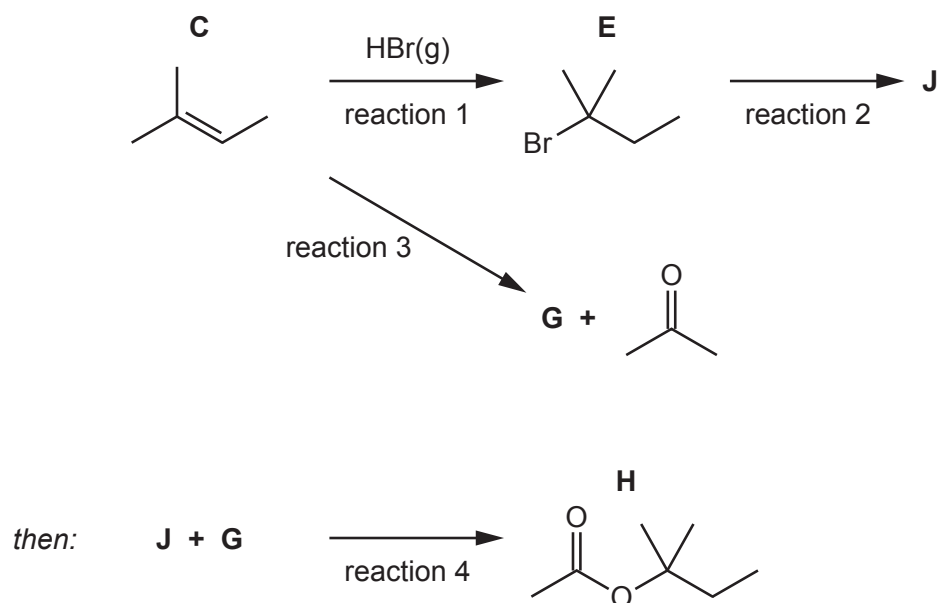


Fig. 4.5

Complete Table 4.1 with the reagents and conditions required for each of the reactions shown in Fig. 4.5.

Table 4.1

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reaction 2 E → J	
reaction 3 C → G + 	
reaction 4 J + G → H	

[3]

[Total: 16]

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31. Question part 8/9 | 9701 Oct-Nov 2023 P2 V3 Q4

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The Periodic Table of Elements

Group																						
1	2	1												13	14	15	16	17	18			
		Key																				
3	4	atomic number atomic symbol name relative atomic mass												5	6	7	8	9	10	11	12	
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2			
11	12													13	14	15	16	17	18			
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9			
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36					
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8					
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54					
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3					
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86					
Cs caesium 132.9	Ba barium 137.3	lanthanoids	Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —					
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118					
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —					

lanthanoids	57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.4	61	Pm promethium	62	Sm samarium 150.4	63	Eu europium 152.0	64	Gd gadolinium 157.3	65	Tb terbium 158.9	66	Dy dysprosium 162.5	67	Ho holmium 164.9	68	Er erbium 167.3	69	Tm thulium 168.9	70	Yb ytterbium 173.1	71	Lu lutetium 175.0
actinoids	89	Ac actinium	90	Th thorium 232.0	91	Pa protactinium 231.0	92	U uranium 238.0	93	Np neptunium	94	Pu plutonium	95	Am americium	96	Cm curium	97	Bk berkelium	98	Cf californium	99	Es einsteinium	100	Fm fermium	101	Md mendelevium	102	No nobelium	103	Lr lawrencium

32. Question | 9701 May-June 2024 P2 V1 Q5

5 Hydrocarbon molecules contain covalent bonds.

(a) Define covalent bond.

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

(b) A C=C bond in an alkene is made from a σ bond and a π bond.

(i) Identify the hybridisation of the carbon atoms in a C=C bond in an alkene.

..... [1]

(ii) Draw labelled diagrams to show, in terms of orbital overlap, how the σ and π bonds are made in a C=C bond.

σ bond

π bond

[2]

(c) In electrophilic reactions involving alkenes the π bond of C=C is broken.

(i) Suggest **one** difference between σ and π bonds that explains why the π bond is broken in electrophilic addition reactions involving alkenes.

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

(ii) Complete Fig. 5.1 to show the mechanism for the electrophilic addition of hydrogen bromide to 2-methylpropene to produce the major organic product.

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



Fig. 5.1

[4]

[Total: 9]

33. Question part 1/7 | 9701 Oct-Nov 2024 P2 V2 Q4

- 4 Bromoalkanes are used widely in industry, although there is increasing concern about their environmental impact.

Fig. 4.1 shows a reaction scheme involving 1,2-dibromoethane.

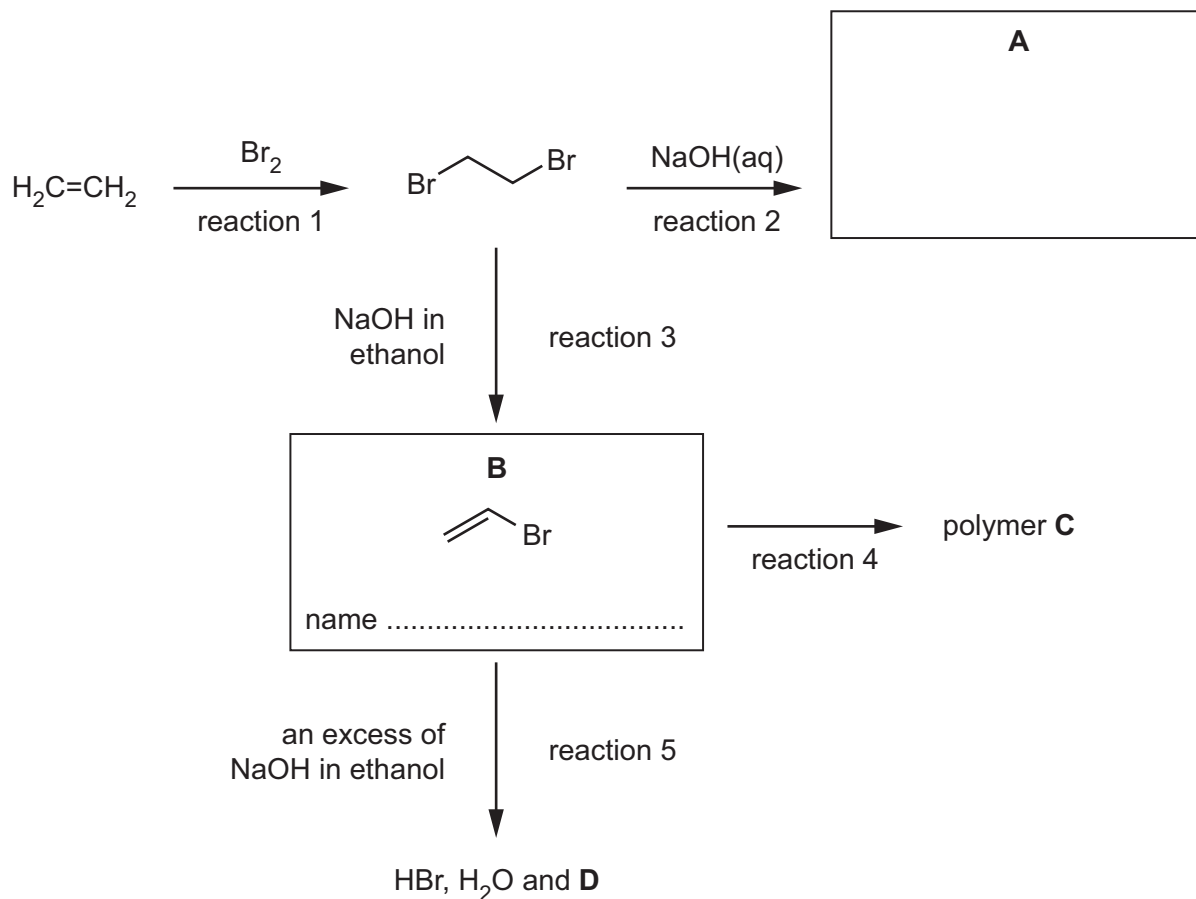


Fig. 4.1

- (a) Complete Fig. 4.2 to show the mechanism for the formation of 1,2-dibromoethane in reaction 1.

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

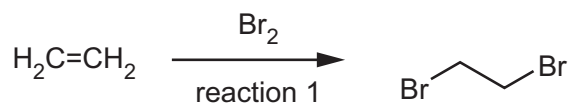


Fig. 4.2

33. Question part 2/7 | 9701 Oct-Nov 2024 P2 V2 Q4



(b) The enthalpy change of reaction 1, $\Delta H_r = -90.0 \text{ kJ mol}^{-1}$.



The enthalpy change of formation of ethene, $\Delta H_f = +52.2 \text{ kJ mol}^{-1}$.

Calculate the enthalpy change of formation of 1,2-dibromoethane.

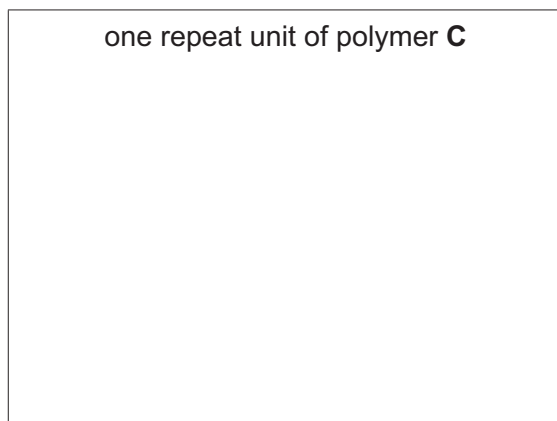
ΔH_f of 1,2-dibromoethane = ... kJ mol^{-1} [1]

(c) (i) Complete Fig. 4.1 to:

- draw the structure of compound **A**
- name compound **B**.

[2]

(ii) Draw the structure of one repeat unit of polymer **C** in the box.



[1]

(iii) In reaction 5, compound **B** reacts with an excess of NaOH dissolved in ethanol. The products are HBr, H_2O and an unsaturated hydrocarbon **D**.

Suggest the identity of **D**.

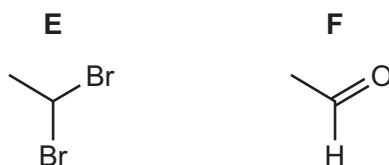
..... [1]

33. Question part 3/7 | 9701 Oct-Nov 2024 P2 V2 Q4



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

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



(i) Identify the type of isomerism shown by **E** and 1,2-dibromoethane.

..... [1]

(ii) Name the homologous series that **F** belongs to.

..... [1]

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

Table 4.1

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

[3]

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33. Question part 4/7 | 9701 Oct-Nov 2024 P2 V2 Q4



Question 4 continues on page 14.

33. Question part 5/7 | 9701 Oct-Nov 2024 P2 V2 Q4



(e) Compound **F** reacts with reagent **G** to form compound **H**.



The infrared spectrum of **H** is shown in Fig. 4.3.

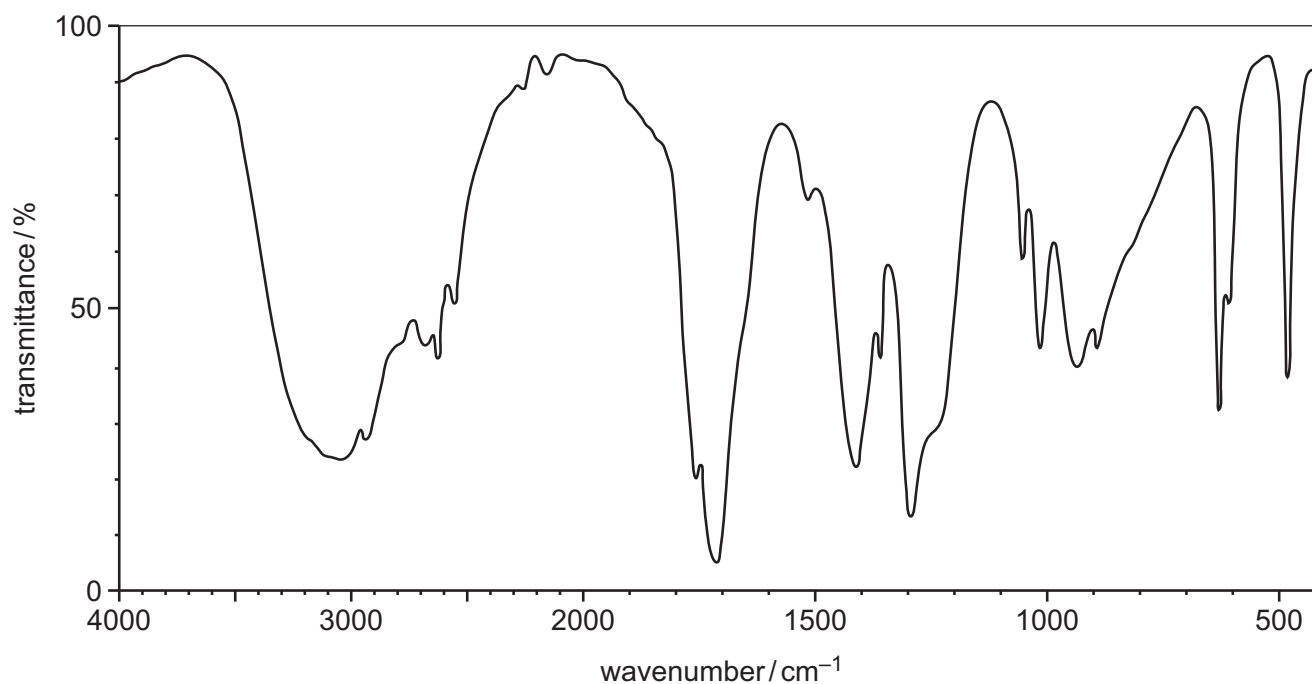


Fig. 4.3

Table 4.2

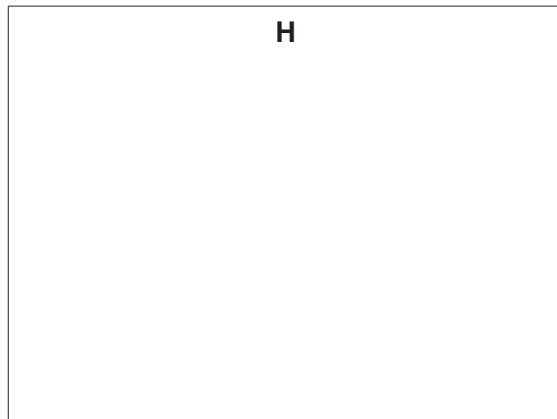
bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

33. Question part 6/7 | 9701 Oct-Nov 2024 P2 V2 Q4



H also shows a molecular ion peak at $m/e = 60$ in its mass spectrum.

- (i) Use the information in (e), Fig. 4.3 and Table 4.2 to deduce the structure of **H**. Explain your answer fully.



.....

.....

.....

[3]

- (ii) Suggest the role of reagent **G**.

.....

[1]

[Total: 17]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
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33. Question part 7/7 | 9701 Oct-Nov 2024 P2 V2 Q4



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Group																					
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Key																					
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11 Na sodium 23.0	12 Mg magnesium 24.3													13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8				
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3				
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —				
87 Fr francium —	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —				

lanthanoids	57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.2	61	Pm promethium —	62	Sm samarium 150.4	63	Eu europium 152.0	64	Gd gadolinium 157.3	65	Tb terbium 158.9	66	Dy dysprosium 162.5	67	Ho holmium 164.9	68	Er erbium 167.3	69	Tm thulium 168.9	70	Yb ytterbium 173.1	71	Lu lutetium 175.0
	89	Ac actinium —	90	Th thorium 232.0	91	Pa protactinium 231.0	92	U uranium 238.0	93	Np neptunium —	94	Pu plutonium —	95	Am americium —	96	Cm curium —	97	Bk berkelium —	98	Cf californium —	99	Es einsteinium —	100	Fm fermium —	101	Md mendelevium —	102	No nobelium —	103	Lr lawrencium —
	actinoids																													

34. Question part 1/4 | 9701 May-June 2025 P2 V2 Q3

3 (a) C_3H_6 reacts with HBr(g) in an addition reaction.

(i) Define addition reaction.

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

(ii) Complete Fig. 3.1 to show the mechanism for the addition reaction between C_3H_6 and HBr to produce 2-bromopropane. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Fig. 3.1

[4]

(iii) Explain why the major product of this reaction is 2-bromopropane rather than 1-bromopropane.

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

34. Question part 2/4 | 9701 May-June 2025 P2 V2 Q3



- (b) $\text{H}_2(\text{g})$ and nickel are added to alkene **X**. Fig. 3.2 shows how the concentration of **X** changes with time.

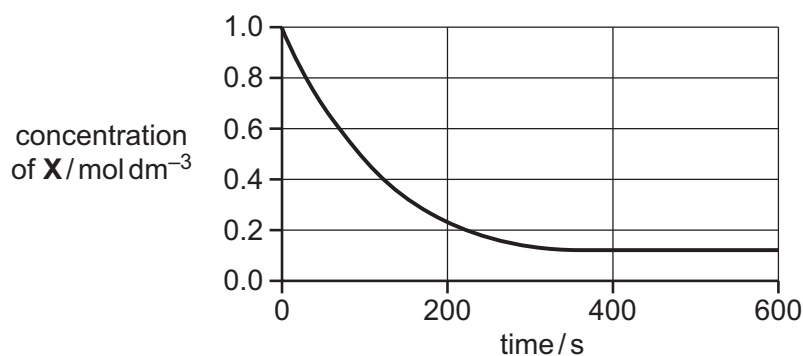


Fig. 3.2

- (i) Use Fig. 3.2 to identify the limiting reagent in this reaction. Explain your answer.

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

- (ii) Use Fig. 3.2 to describe how the gradient changes as the reaction proceeds. State what this shows about the rate during this reaction.

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

34. Question part 3/4 | 9701 May-June 2025 P2 V2 Q3



(c) Hydrocarbon **Y** contains two C=C groups. There are no other functional groups present.

Y reacts with an excess of $\text{H}_2(\text{g})$ to produce hexane, C_6H_{14} .

Table 3.1

bond	energy / kJ mol^{-1}
C–C	350
C=C	610
C≡C	840
H–H	436
C–H	410

Use Table 3.1 to calculate the enthalpy change per mole of C_6H_{14} produced in this reaction.

enthalpy change = ... kJ mol^{-1} [2]

34. Question part 4/4 | 9701 May-June 2025 P2 V2 Q3



(d) Hydrocarbon **Y** reacts with $\text{H}_2(\text{g})$.

Fig. 3.3 shows the distribution of energies of $\text{H}_2(\text{g})$ at temperature T .

Area **A** represents the number of molecules with energy greater than or equal to the activation energy, E_{A} , at temperature T .

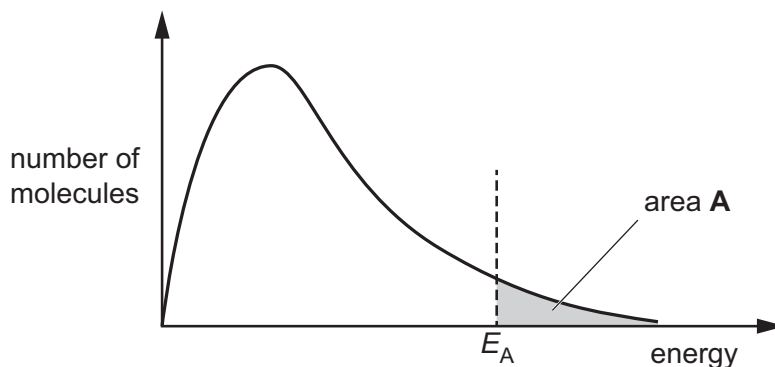


Fig. 3.3

(i) Annotate Fig. 3.3 to show the effect of adding nickel to **Y** and $\text{H}_2(\text{g})$ at temperature T . [1]

(ii) Area **B** (not labelled on Fig. 3.3) represents the number of molecules with energy greater than or equal to the activation energy when nickel is added at temperature T .

State the difference, if any, between areas **A** and **B**. Explain the significance of your answer on the rate of hydrogenation of **Y**. Give your answer in terms of collisions.

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

(e) Alkene **Z** contains two $\text{C}=\text{C}$ bonds. **Z** reacts with an excess of hot concentrated acidified KMnO_4 to produce **only** CH_3COCH_3 , $\text{HOOCCH}_2\text{COOH}$, CO_2 and H_2O .

Suggest the structure of **Z**.

[2]

[Total: 16]

35. Question | 9701 May-June 2025 P2 V3 Q3

- 3 (a) Different hydrocarbon mixtures produced from fractional distillation of crude oil have different uses.

- (i) State the compound that is heated with long-chain hydrocarbons to produce more useful smaller alkanes and alkenes.

..... [1]

- (ii) Describe how photochemical smog is produced during the combustion of petrol in an internal combustion engine.

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

- (b) C_4H_8 reacts with an excess of H_2 to produce C_4H_{10} .



- (i) Name a catalyst for reaction 1.

..... [1]

- (ii) Define activation energy, E_A .

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

- (iii) The Boltzmann distribution for the reaction mixture in reaction 1 is shown in Fig. 3.1. Use the Boltzmann distribution to explain the effect of adding a catalyst on the rate of reaction.



Fig. 3.1

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

[Total: 7]

36. Question part 1/5 | 9701 May-June 2025 P2 V3 Q6

6 (a) HOCl reacts with $\text{CH}_2=\text{CH}_2$ to produce $\text{HOCH}_2\text{CH}_2\text{Cl}$ in an electrophilic addition reaction.

(i) Define addition reaction.

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

(ii) Describe how Cl_2 is used to produce HOCl .

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

(iii) State **one** use for HOCl .

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

(b) Complete Fig. 6.1 to show the mechanism for the reaction between HOCl and $\text{CH}_2=\text{CH}_2$ to produce $\text{HOCH}_2\text{CH}_2\text{Cl}$.

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

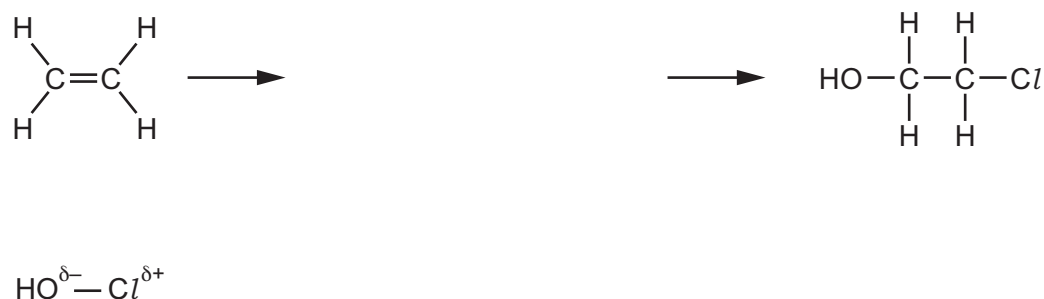


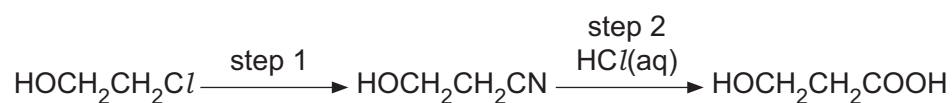
Fig. 6.1

[4]

36. Question part 2/5 | 9701 May-June 2025 P2 V3 Q6



- (c) $\text{HOCH}_2\text{CH}_2\text{Cl}$ reacts in a two-step synthesis to produce $\text{HOCH}_2\text{CH}_2\text{COOH}$, as shown in Fig. 6.2.

**Fig. 6.2**

- (i) State the reagent and conditions for step 1.

..... [1]

- (ii) Identify the type of reaction that occurs in step 2.

..... [1]

- (iii) Complete the equation to show the reaction in step 2.

$\text{HOCH}_2\text{CH}_2\text{CN} + \dots\dots\dots$ [1]

[Total: 10]

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36. Question part 3/5 | 9701 May-June 2025 P2 V3 Q6



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36. Question part 4/5 | 9701 May-June 2025 P2 V3 Q6



Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

Topical questions | 43 questions

36. Question part 5/5 | 9701 May-June 2025 P2 V3 Q6



Group																	
1	2	1 H hydrogen 1.0 Key atomic number atomic symbol name relative atomic mass															
3 Li lithium 6.9	4 Be beryllium 9.0																
11 Na sodium 23.0	12 Mg magnesium 24.3	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9										
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	lanthanoids		73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —
87 Fr francium —	88 Ra radium —	actinoids		105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	europlum	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	ytterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	merendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—

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37. Question part 1/2 | 9701 May-June 2025 P2 V4 Q5

- 5 The skeletal formula of **W** is shown in Fig. 5.1.

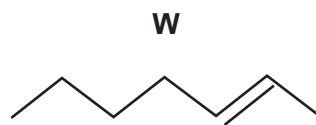
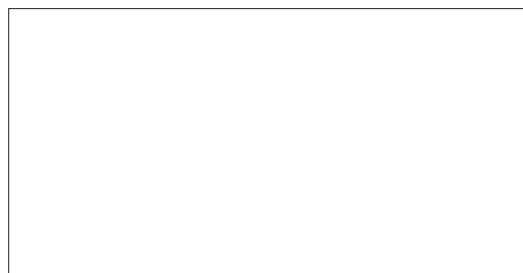
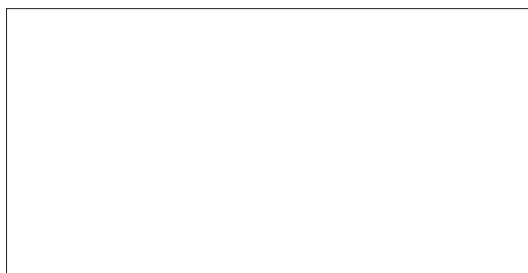


Fig. 5.1

- (a) **W** has two positional isomers. Only one shows stereoisomerism.

Draw the structures of the **two** positional isomers of **W** in the boxes.



[2]

- (b) (i) Describe the origin of stereoisomerism in **W**.

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

- (ii) State why **W** shows stereoisomerism but one of the positional isomers in (a) does **not**.

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

- (c) Draw the skeletal structure of the stereoisomer of **W**.

[1]

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37. Question part 2/2 | 9701 May-June 2025 P2 V4 Q5



(d) **W** reacts with reagent **X** to produce ethanoic acid and pentanoic acid.

(i) State the role of **X** in this reaction.

..... [1]

(ii) Identify **X** and state the conditions used for this reaction.

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

[Total: 7]

38. Question part 1/4 | 9701 Oct-Nov 2025 P2 V1 Q3

- 3 Cycloalkanes show similar chemical properties to alkanes but have the same empirical formula as alkenes.

(a) Define empirical formula.

..... [1]

- (b) Cyclopentane, C_5H_{10} , has four cyclic structural isomers. One of these isomers is **C**, shown in Fig. 3.1.

Complete Fig. 3.1 to show two other cyclic structural isomers of C_5H_{10} .

cyclopentane			C
			

Fig. 3.1

[2]

- (c) Cyclopentane reacts with Cl_2 in the presence of ultraviolet light to form C_5H_9Cl .

- (i) The reaction is initiated by the bond fission of Cl_2 .

State the type of bond fission shown in the initiation step.

..... [1]

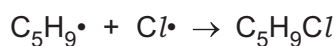
- (ii) Complete the equations to show the two propagation steps that follow the initiation step.

propagation 1 $C_5H_{10} + \dots \rightarrow C_5H_9\cdot + \dots$

propagation 2 $C_5H_9\cdot + \dots \rightarrow \dots$

[2]

- (iii) The final step is shown.



Give the name for this step in the reaction.

..... [1]

38. Question part 2/4 | 9701 Oct-Nov 2025 P2 V1 Q3



(d) Fig. 3.2 shows a reaction cycle involving cyclopentane, cyclopentene and $\text{C}_5\text{H}_9\text{Cl}$.

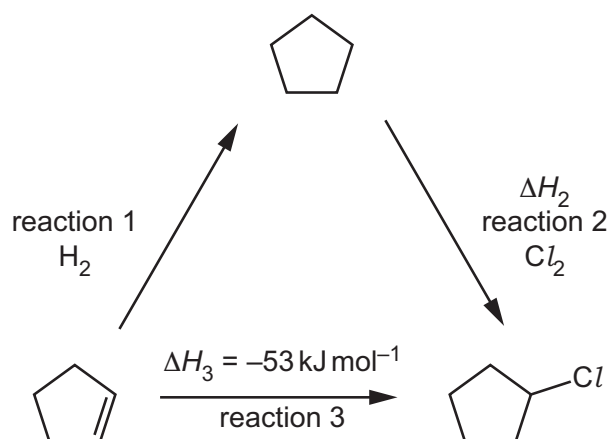


Fig. 3.2

(i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2 .

Table 3.1

compound	enthalpy change of combustion, $\Delta H_c / \text{kJ mol}^{-1}$
	-3292
	-3115
H_2	-286

$\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

38. Question part 3/4 | 9701 Oct-Nov 2025 P2 V1 Q3



(e) Cyclopentene, C_5H_8 , reacts with hot concentrated acidified $KMnO_4$ to form compound **W**, $C_5H_8O_4$.

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

[1]

(ii) The infrared spectrum of **W** is shown in Fig. 3.3.

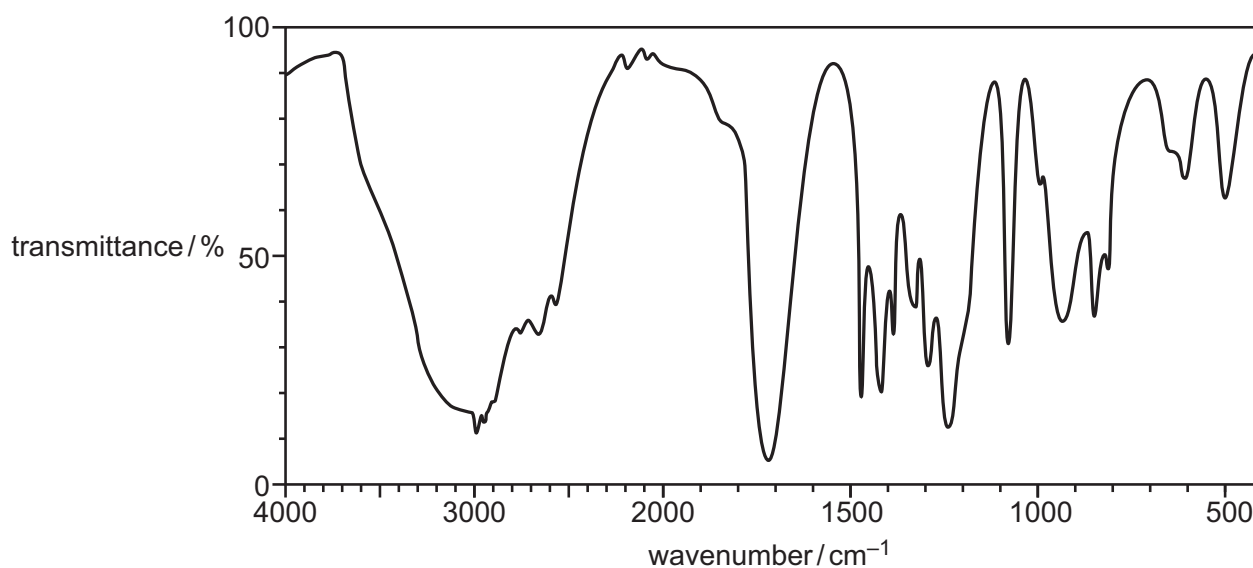


Fig. 3.3

Identify **two** absorptions in the infrared spectrum of **W** that would **not** be present in the infrared spectrum of cyclopentene.

- Write **1** or **2** on Fig. 3.3 against each of these two absorptions.
- Complete Table 3.2 to show which bond is responsible for each absorption that you have identified in Fig. 3.3.

Table 3.2

absorption	1	2
bond responsible		

[2]

38. Question part 4/4 | 9701 Oct-Nov 2025 P2 V1 Q3

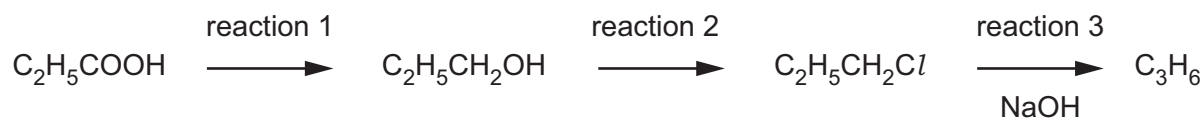
**Table 3.3**

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

[Total: 13]

39. Question part 1/5 | 9701 Oct-Nov 2025 P2 V1 Q4

- 4 Fig. 4.1 shows a possible synthesis of propene, C_3H_6 .

**Fig. 4.1**

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

..... [1]

- (ii) Suggest a suitable reagent for reaction 2.

..... [1]

- (iii) Reaction 3 is an elimination reaction.

Write an equation for this reaction and identify the solvent and conditions used.

equation

solvent and conditions [2]

- (iv) $C_2H_5CH_2OH$ can be directly converted to C_3H_6 .

Suggest the reagent and conditions for this conversion.

..... [1]

- (b) Under suitable conditions, propene polymerises to form poly(propene).

Poly(propene) exhibits stereoisomerism.

- (i) Identify the type of polymerisation that forms poly(propene) from propene.

..... [1]

- (ii) Define stereoisomerism.

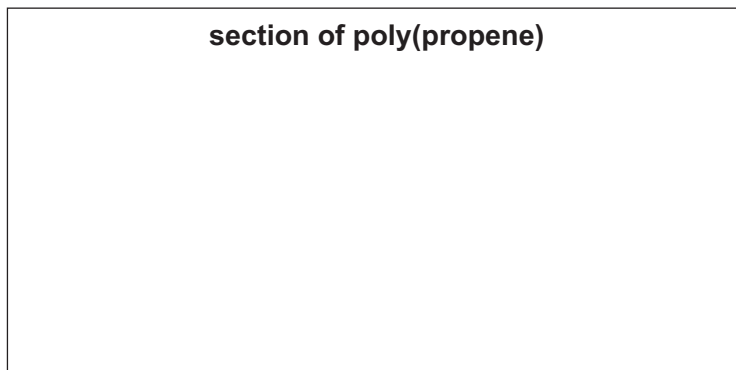
..... [2]

39. Question part 2/5 | 9701 Oct-Nov 2025 P2 V1 Q4



(iii) Draw a section of poly(propene), showing **two** repeat units.

Use your diagram to identify the type of stereoisomerism shown by poly(propene).
Explain your answer.



.....
.....
.....
.....

[3]

(iv) State **two** difficulties associated with the disposal of poly(propene).

1

2

[2]

39. Question part 3/5 | 9701 Oct-Nov 2025 P2 V1 Q4



(c) Under different conditions, two molecules of propene can combine to form compounds **X** and **Y**.



(i) Name **X**.

..... [1]

(ii) Fig. 4.2 shows the mass spectrum of either compound **X** or compound **Y**.

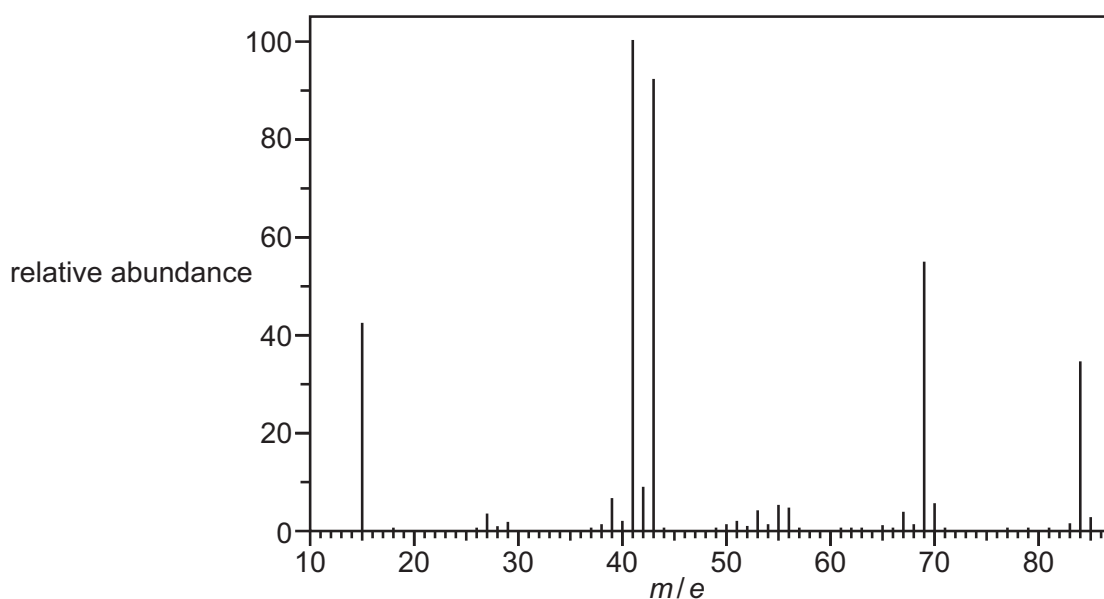


Fig. 4.2

Identify which of **X** and **Y** gives this mass spectrum.

Give **one** reason for your answer, referring to the fragmentation pattern.

.....

 [1]

(iii) The molecular ion peak in the spectrum in Fig. 4.2 has relative abundance 34.7.

Calculate the relative abundance of the $[M+1]^+$ peak in this spectrum.

relative abundance of $[M+1]^+$ peak = ... [1]

[Total: 16]

9701 Chemistry Paper 2 - Hydrocarbons

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39. Question part 4/5 | 9701 Oct-Nov 2025 P2 V1 Q4



Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)



Group																																									
1	2	1 H hydrogen 1.0														17	18																								
		Key																																							
3	4	atomic number atomic symbol name relative atomic mass																																							
Li lithium 6.9	Be beryllium 9.0																																								
11	12																																								
Na sodium 23.0	Mg magnesium 24.3	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36																
Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9	K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8	Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3
55	56	lanthanoids		57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86																						
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —																							
87	88	89–103 actinoids		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118																							
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —																							

lanthanoids	57La lanthanum 138.9	58Ce cerium 140.1	59Pr praseodymium 140.9	60Nd neodymium 144.2	61Pm promethium —	62Sm samarium 150.4	63Eu europium 152.0	64Gd gadolinium 157.3	65Tb terbium 158.9	66Dy dysprosium 162.5	67Ho holmium 164.9	68Er erbium 167.3	69Tm thulium 168.9	70Yb ytterbium 173.1	71Lu lutetium 175.0
actinoids	89Ac actinium —	90Th thorium 232.0	91Pa protactinium 231.0	92U uranium 238.0	93Np neptunium —	94Pu plutonium —	95Am americium —	96Cm curium —	97Bk berkelium —	98Cf californium —	99Es einsteinium —	100Fm fermium —	101Md mendelevium —	102No nobelium —	103Lr lawrencium —

40. Question part 1/2 | 9701 Oct-Nov 2025 P2 V2 Q3

- 3 The alkanes are a homologous series of organic molecules. Alkanes are generally unreactive and are commonly used as fuels.

(a) Define homologous series.

.....
 [2]

(b) Give two reasons to explain the general unreactivity of alkanes.

1
 2 [2]

(c) Alkanes with low relative molecular mass, M_r , are more useful than those found in heavier crude oil fractions.

Name the process that is used to obtain alkanes with low M_r from heavier crude oil fractions.

..... [1]

(d) Hexane, C_6H_{14} , has four structural isomers.

Fig. 3.1 shows hexane and two of its structural isomers.

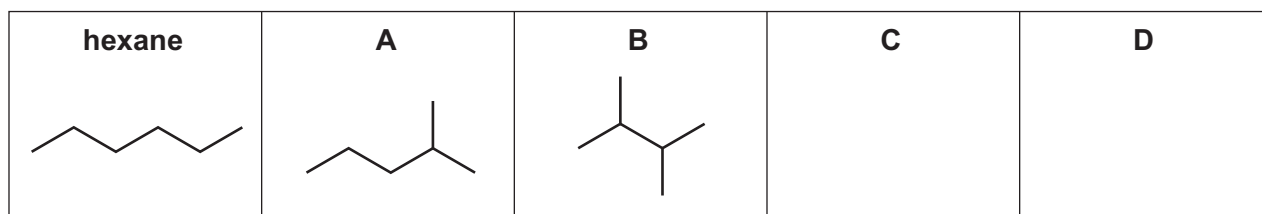


Fig. 3.1

(i) Complete Fig. 3.1 by drawing structures for **C** and **D**, the other two structural isomers of hexane. [2]

(ii) **A**, **B** and hexane have different boiling points.

Arrange **A**, **B** and hexane in order of increasing boiling point.

Explain your answer.

lowest < < highest

.....

 [3]

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- (e) Hexane can be converted into compounds **E** and **F** at high temperature and pressure. Fig. 3.2 shows the reaction scheme involving hexane, **E** and **F**.

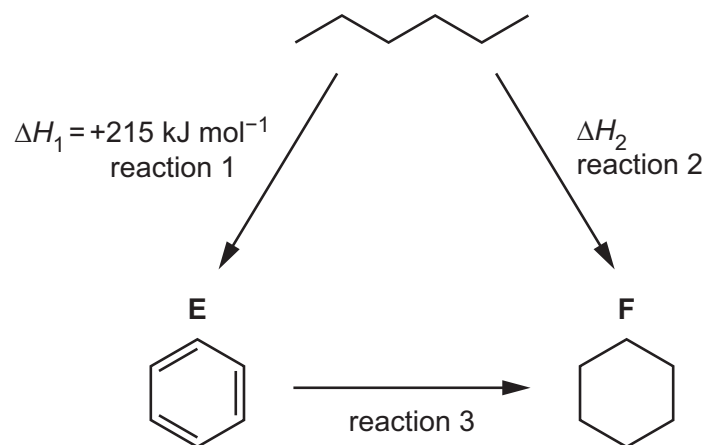


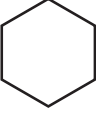
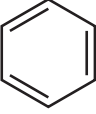
Fig. 3.2

- (i) Identify a suitable reagent for reaction 3.

..... [1]

- (ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2 .

Table 3.1

compound	enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$
	-156
	+48

$\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

- (iii) Write an equation for the complete combustion of hexane.

..... [1]

[Total: 14]

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- 4 Fig. 4.1 shows how propane, C_3H_8 , can be converted to propanoic acid, CH_3CH_2COOH .

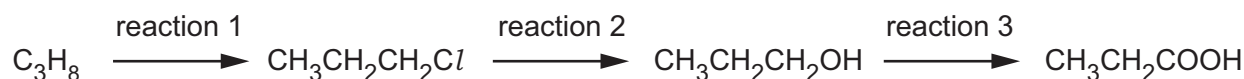
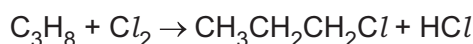


Fig. 4.1

- (a) Reaction 1 in Fig. 4.1 takes place in the presence of sunlight.



The reaction takes place via initiation, propagation and termination steps.

- (i) Name the mechanism shown by reaction 1.

..... [1]

- (ii) Complete the mechanism for reaction 1.

Construct equations to describe the steps of the mechanism.



propagation 1

propagation 2

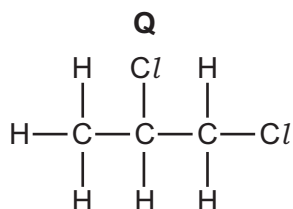
termination $\rightarrow CH_3CH_2CH_2Cl$ [3]

- (iii) Reaction 1 is initiated by the bond fission of Cl_2 .

State the type of bond fission shown in the initiation step.

..... [1]

- (iv) Compound **Q** is a by-product of reaction 1.



Name **Q**.

..... [1]

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(v) The molecular formula of **Q** is $C_3H_6Cl_2$.

Identify the types of structural isomerism and stereoisomerism that a molecule with molecular formula $C_3H_6Cl_2$ can show.

type of structural isomerism

type of stereoisomerism

[2]

(b) State the reagent and solvent required for reaction 2.

..... [1]

(c) Reaction 3 takes place when $CH_3CH_2CH_2OH$ is heated under reflux with acidified potassium dichromate(VI) solution.

(i) State the colour change that takes place in the reaction mixture.

..... [1]

(ii) Construct an equation to represent reaction 3. Use [O] to represent an atom of oxygen from the oxidising agent.

..... [1]

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(d) $\text{CH}_3\text{CH}_2\text{COOH}$ reacts with an unsaturated alcohol **R** to form unsaturated ester **S**.

(i) State the **type** of reaction that forms **S**.

..... [1]

(ii) The infrared spectrum of **S** is shown in Fig. 4.2.

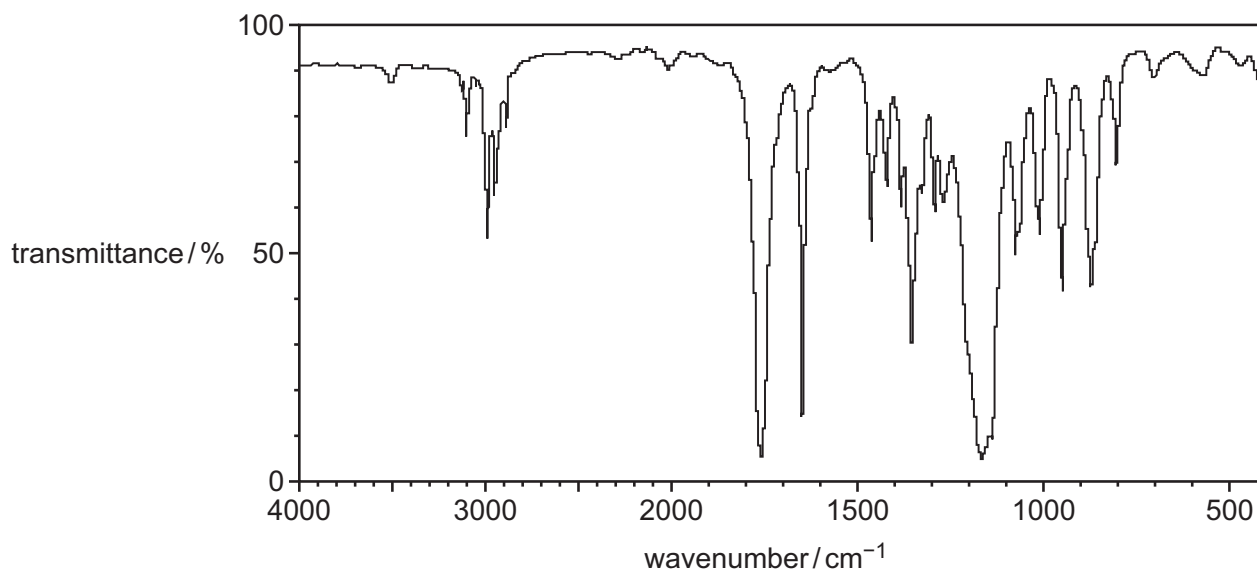


Fig. 4.2

Three absorptions in the infrared spectrum in Fig. 4.2 confirm that **S** is an ester and is unsaturated.

- Write **1**, **2** or **3** on Fig. 4.2 against each of these three absorptions.
- Complete Table 4.1 to show which bond is responsible for each absorption that you have identified in Fig. 4.2.

Table 4.1

absorption	1	2	3
bond responsible			

[3]

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**Table 4.2**

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

(iii) The mass spectrum of **S** shows the following peaks.**Table 4.3**

peak	relative abundance
M ⁺	4.7
[M+1] ⁺	0.31

Use Table 4.3 to calculate the number of carbon atoms in **S**.number of carbon atoms in **S** = ... [1]

[Total: 16]

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Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

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57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.2
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	euporium	152.0
64	Gd	gadolinium	157.3
65	Tb	terbium	158.9
66	Dy	dysprosium	162.5
67	Ho	holmium	164.9
68	Er	erbium	168.9
69	Tm	thulium	168.9
70	Yb	ytterbium	173.1
71	Lu	lutetium	175.0
72	Hf	hafnium	178.5
73	Ta	tantalum	180.9
74	W	tungsten	183.8
75	Re	rhenium	186.2
76	Os	osmium	190.2
77	Ir	iridium	192.2
78	Pt	platinum	195.1
79	Au	gold	197.0
80	Hg	mercury	200.6
81	Tl	thallium	204.4
82	Pb	lead	207.2
83	Bi	bismuth	209.0
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
89	Ac	actinium	—
90	Th	thorium	232.0
91	Pa	protactinium	231.0
92	U	uranium	238.0
93	Np	neptunium	—
94	Pu	plutonium	—
95	Am	americium	—
96	Cm	curium	—
97	Bk	berkelium	—
98	Cf	californium	—
99	Es	einsteinium	—
100	Fm	fermium	—
101	Md	mendelevium	—
102	No	nobelium	—
103	Lr	lawrencium	—

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42. Question part 1/4 | 9701 Oct-Nov 2025 P2 V3 Q3

- 3 Cycloalkanes show similar chemical properties to alkanes but have the same empirical formula as alkenes.

(a) Define empirical formula.

..... [1]

- (b) Cyclopentane, C_5H_{10} , has four cyclic structural isomers. One of these isomers is **C**, shown in Fig. 3.1.

Complete Fig. 3.1 to show two other cyclic structural isomers of C_5H_{10} .

cyclopentane 			C 
--	--	--	---

Fig. 3.1

[2]

- (c) Cyclopentane reacts with Cl_2 in the presence of ultraviolet light to form C_5H_9Cl .

- (i) The reaction is initiated by the bond fission of Cl_2 .

State the type of bond fission shown in the initiation step.

..... [1]

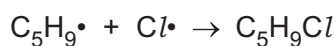
- (ii) Complete the equations to show the two propagation steps that follow the initiation step.

propagation 1 $C_5H_{10} + \dots \rightarrow C_5H_9\cdot + \dots$

propagation 2 $C_5H_9\cdot + \dots \rightarrow \dots$

[2]

- (iii) The final step is shown.



Give the name for this step in the reaction.

..... [1]

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(d) Fig. 3.2 shows a reaction cycle involving cyclopentane, cyclopentene and $\text{C}_5\text{H}_9\text{Cl}$.

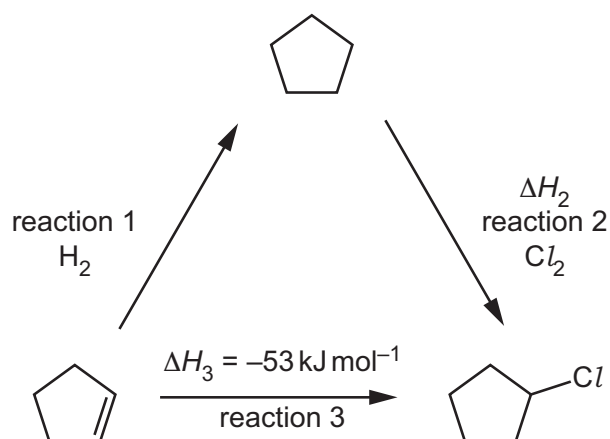


Fig. 3.2

(i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2 .

Table 3.1

compound	enthalpy change of combustion, $\Delta H_c / \text{kJ mol}^{-1}$
	-3292
	-3115
H_2	-286

$\Delta H_2 = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

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(e) Cyclopentene, C_5H_8 , reacts with hot concentrated acidified $KMnO_4$ to form compound **W**, $C_5H_8O_4$.

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

[1]

(ii) The infrared spectrum of **W** is shown in Fig. 3.3.

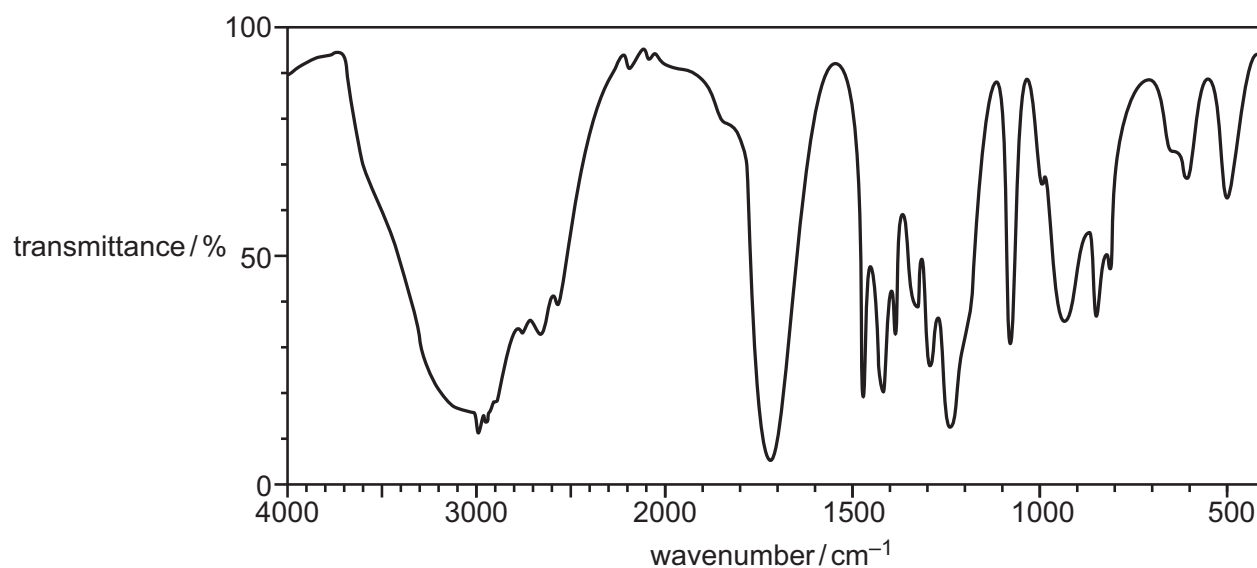


Fig. 3.3

Identify **two** absorptions in the infrared spectrum of **W** that would **not** be present in the infrared spectrum of cyclopentene.

- Write **1** or **2** on Fig. 3.3 against each of these two absorptions.
- Complete Table 3.2 to show which bond is responsible for each absorption that you have identified in Fig. 3.3.

Table 3.2

absorption	1	2
bond responsible		

[2]

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**Table 3.3**

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/cm ⁻¹
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

[Total: 13]

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- 4 Compounds **P** and **Q** are structural isomers.



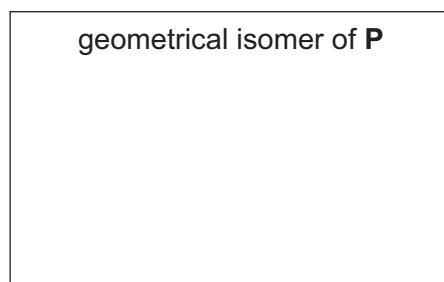
Fig. 4.1

- (a) (i) Define structural isomerism.

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

- (ii) **P** shows geometrical isomerism.

Draw the geometrical isomer of **P**. Explain why the two isomers are **not** identical.



explanation

.....

..... [2]

- (iii) Both **P** and **Q** react with aqueous bromine.

Name the mechanism of this reaction.

..... [1]

- (iv) **Q** is oxidised by hot concentrated acidified $\text{KMnO}_4(\text{aq})$, forming two different organic products.

Construct an equation for this reaction. Use [O] to represent an atom of oxygen from the oxidising agent.

$(\text{CH}_3)_2\text{C}=\text{CHCH}_3$ [2]

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(v) **Q** reacts with HBr(g) to produce two structural isomers, **R** and **S**, as shown in Fig. 4.2.

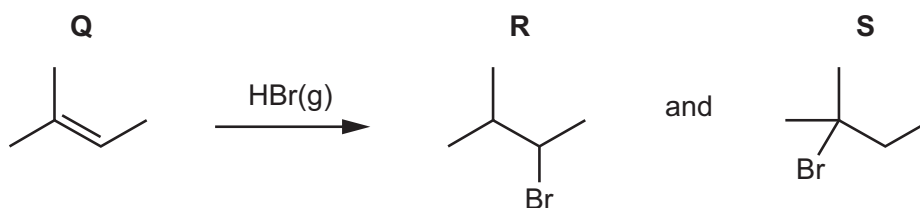


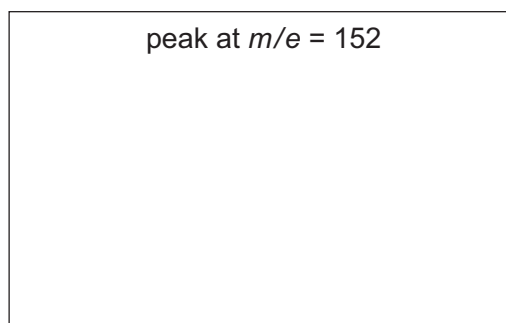
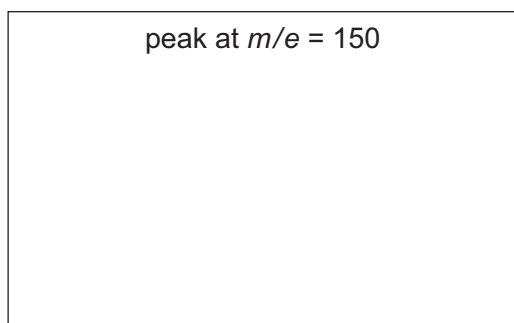
Fig. 4.2

State and explain why isomer **S** is the major product of the reaction.

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

(vi) The mass spectrum of **R** shows peaks at $m/e = 150$ and $m/e = 152$.

Suggest structures for the ions responsible for these peaks.



[2]

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(b) Fig. 4.3 shows a synthesis starting from **T**, a different isomer of **R** and **S**.

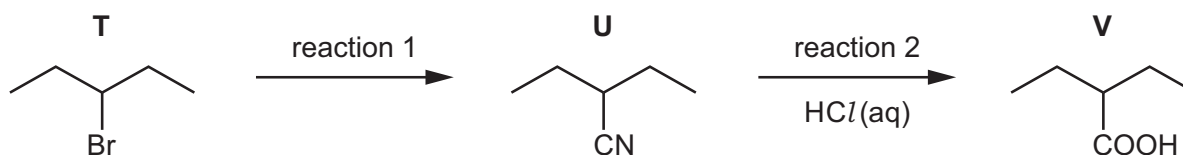


Fig. 4.3

(i) Identify the reagent and conditions for reaction 1.

..... [1]

(ii) Reaction 2 is a hydrolysis reaction.

Construct an equation for reaction 2.

$(\text{C}_2\text{H}_5)_2\text{CHCN}$ [1]

(iii) **V** reacts with propan-2-ol in the presence of a catalytic amount of H_2SO_4 to form organic compound **W**.

Complete Table 4.1 to give details of this reaction.

Table 4.1

	reaction of V with propan-2-ol
type of reaction	
functional group formed	
molecular formula of organic product W	

[3]

[Total: 16]

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Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

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Group																
1	2															
		1 H hydrogen 1.0														
		Key														
		atomic number atomic symbol name relative atomic mass														
3	4															
Li lithium 6.9	Be beryllium 9.0															
11	12															
Na sodium 23.0	Mg magnesium 24.3															
19	20															
K potassium 39.1	Ca calcium 40.1															
37	38															
Rb rubidium 85.5	Sr strontium 87.6															
55	56															
Cs caesium 132.9	Ba barium 137.3															
87	88															
Fr francium —	Ra radium —															

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	europlum	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	ytterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	merendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—

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