

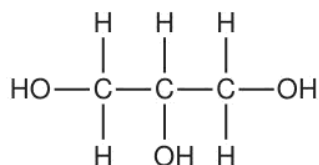
- (a) (i) Explain the meaning of the term *structural isomers*.

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

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

sp^2 hybridisation
.....
 sp^3 hybridisation
..... [2]

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



propane-1,2,3-triol

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

[1]

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

..... [1]

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

..... [1]

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

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

.....

.....

.....

..... [2]

- (ii) Ethanal, CH_3CHO , also reacts with hydrogen cyanide. The product of this reaction is $\text{CH}_3\text{CH}(\text{OH})\text{CN}$.

Draw the mechanism of this reaction.

Include all necessary charges, dipoles, lone pairs and curly arrows.

[3]

[Total: 19]

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- 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]

- (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]

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

..... [1]

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

F

G

[2]

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

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

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(ii) Name **H** and **I**.

H
I [2]

[Total: 23]

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May/June 2017 9701/22 · Q4 (a)(i), (a)(iii), (a)(iv), (a)(v), (a)(vi), (b)(ii), (c)(ii), (c)(iii), (d)(ii) (cont.)

- (a) Define the term *structural isomers*.

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

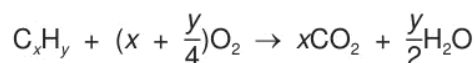
- (b) **P** is a hydrocarbon, C_xH_y . A gaseous sample of **P** occupied a volume of 25 cm^3 at 37°C and 100 kPa .

The sample was completely burned in 200 cm^3 of oxygen (an excess).

The final volume, measured under the same conditions as the gaseous sample (so that the water produced is liquid and its volume can be ignored), was 150 cm^3 .

Treating the remaining gaseous mixture with concentrated alkali, to absorb carbon dioxide, decreased the volume to 50 cm^3 .

The equation for the complete combustion of **P** can be represented as shown.



- (i) Use the data given to calculate the value of x .

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

- (ii) Use the data given to calculate the value of $(x + \frac{y}{4})$.

$(x + \frac{y}{4}) = \dots\dots\dots$ [1]

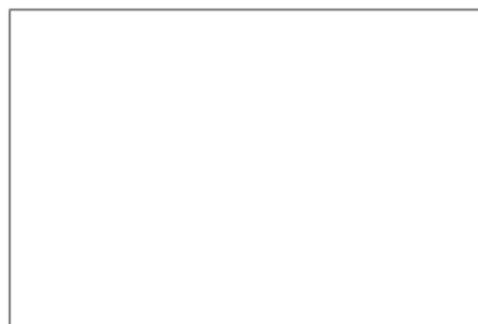
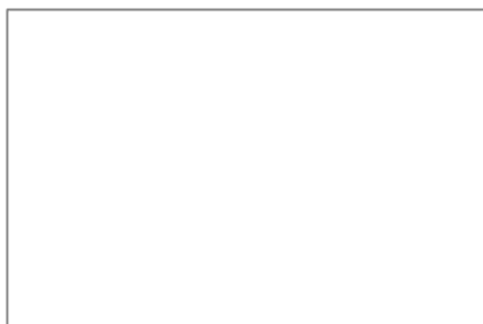
3

If you were unable to calculate values in **(b)(i)** and **(b)(ii)** then use the data in this box for the remaining parts of this question. These are **not** the correct values.

$$x = 6 \qquad \left(x + \frac{y}{4}\right) = 9$$

(iv) **P** is unbranched.

Give the skeletal formulae for two possible structures of **P** that are positional isomers of each other.



[2]

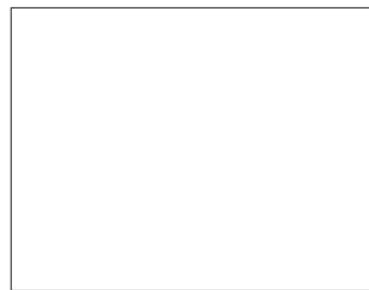
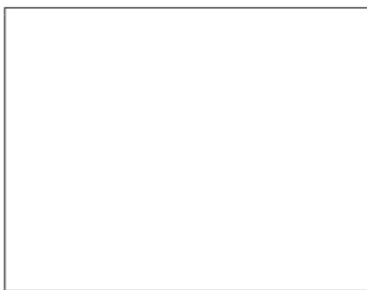
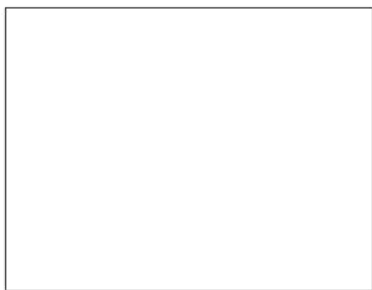
(v) Use the general gas equation to calculate the mass of **P** present in the original 25 cm³ gaseous sample, which was measured at 37 °C and 100 kPa.

Give your answer to **three** significant figures.

mass = g [3]

[Total: 11]

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



[1]

(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]

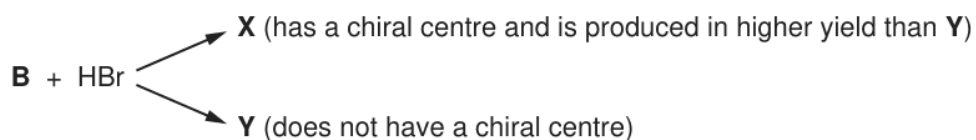
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(d) **B** does **not** show geometrical isomerism.

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]

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

Draw these isomers using the conventional three-dimensional representation.

.....

[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]

May/June 2017 9701/23 · Q4 (b), (c)(ii), (d)(i), (d)(iii), (e)(i) (cont.)

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

[2]

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[Turn over

- (v) Lactic acid has a chiral centre.

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

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

[Total: 18]

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10

[Turn over

March 2018 9701/22 · Q3 (b)(ii), (d)(v)

- (b) There are three structural isomers of **X** that are alcohols.

Draw the structures of these three isomers of **X**.

[2]

May/June 2018 9701/21 · Q4 (b)

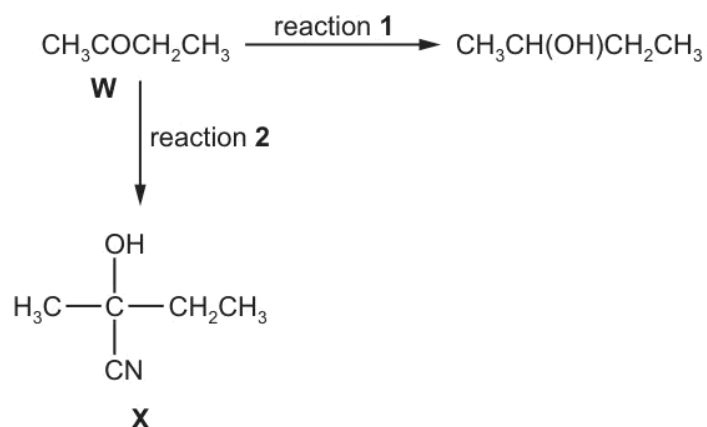
(b) There are two structural isomers of **W** that are also carbonyl compounds.

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

--	--

[2]

Two reactions of **W** are shown.



May/June 2018 9701/22 · Q4 (b)

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

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

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

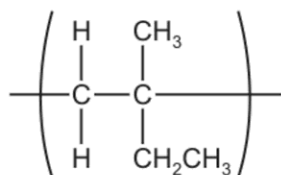
.....
.....
..... [2]

- (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.

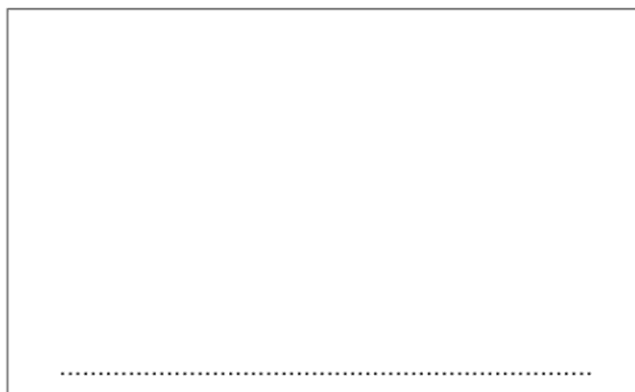
reason 1
.....
reason 2
..... [2]

- (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.

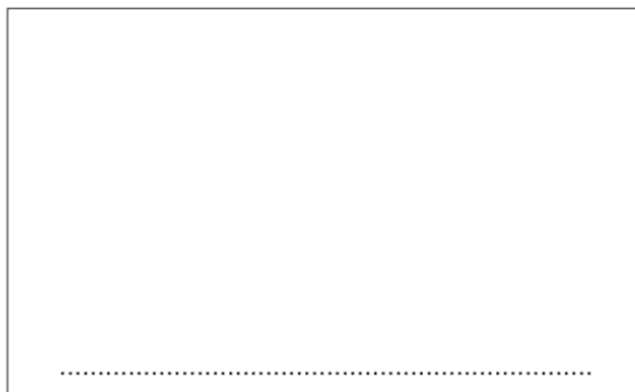


[2]

- (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]

May/June 2018 9701/23 · Q2 (a)(i), (a)(ii), (b)(i), (b)(ii), (b)(iii) (cont.)

(b) There are three structural isomers of **A**.

Draw the structures of these three isomers of **A**.

--	--	--

[2]

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May/June 2018 9701/23 · Q4 (b)

(iii) State the name of the mechanism that occurs in reaction 3.

..... [1]

March 2019 9701/22 · Q4 (c)(iii)

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

.....
.....

species acting as nucleophile [2]

- (b) $\text{CH}_3\text{CH}(\text{OH})\text{CN}$ exists as a pair of stereoisomers.

- (i) Name the type of stereoisomerism shown by $\text{CH}_3\text{CH}(\text{OH})\text{CN}$.

..... [1]

- (ii) Draw three-dimensional diagrams of this pair of stereoisomers.

Indicate with an asterisk (*) the chiral centre on one of the structures drawn.

[3]

- (c) Give the structure of the organic product of the reaction of $\text{CH}_3\text{CH}(\text{OH})\text{CN}$ with dilute sulfuric acid.

..... [1]

[Total: 7]

11

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May/June 2019 9701/21 · Q5 (a), (b)(i), (b)(ii), (c) (cont.)

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

..... [1]

May/June 2019 9701/22 · Q4 (d)(iii)

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

..... [1]

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

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

.....

..... [1]

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



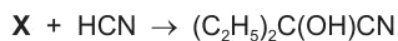
[2]

Z, $\text{C}_5\text{H}_{10}\text{O}$, has a branched carbon chain. It shows geometrical isomerism.

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

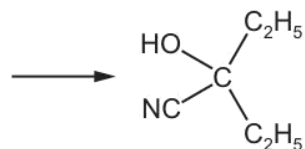
[3]

(vii) **X** contains a carbonyl group. **X** reacts with HCN, in the presence of a small amount of NaCN, to form $(\text{C}_2\text{H}_5)_2\text{C}(\text{OH})\text{CN}$ as shown.



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

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



[3]

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

..... [1]

[Total: 22]

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Oct/Nov 2019 9701/21 · Q4 (c)(ii), (c)(iii), (c)(iv), (c)(vi) (cont.)

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

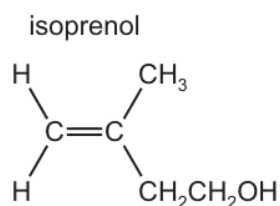
..... [1]

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

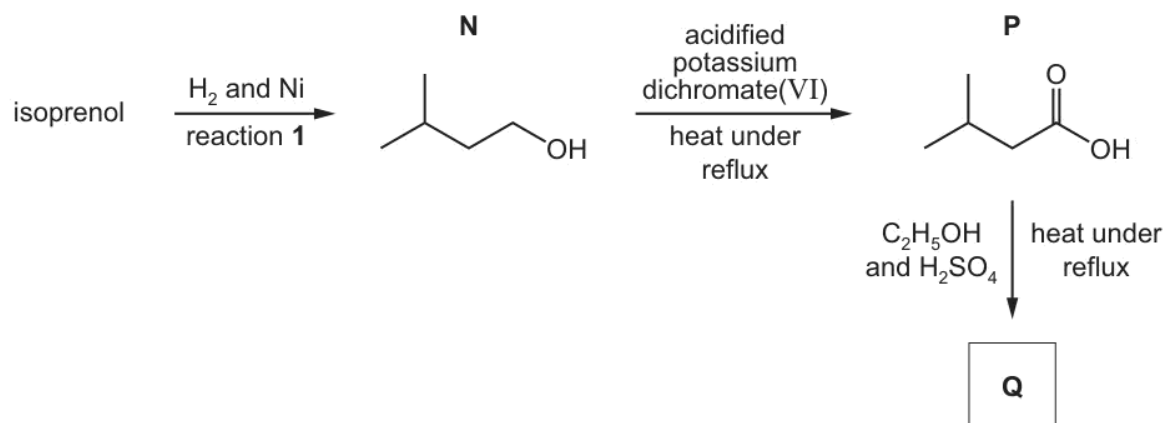
Describe a chemical test to confirm the presence of an alkene functional group. Give the result of the test.

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

(d) Isoprenol is a structural isomer of prenol.



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

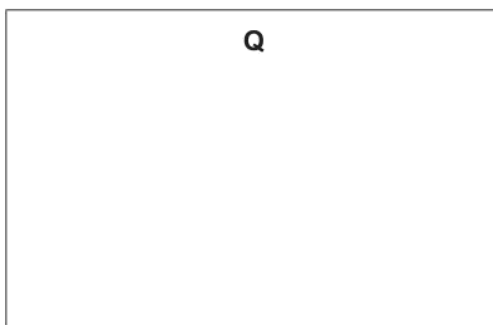


(i) Give the name of **N**.

..... [1]

Oct/Nov 2019 9701/22 · Q4 (b)(iii), (c)(i), (d)(i), (d)(iii) (continued ·)

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



commercial use [2]

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Oct/Nov 2019 9701/22 · Q4 (b)(iii), (c)(i), (d)(i), (d)(iii) (cont.)

- (ii) Name the reaction mechanism for reaction 2.

..... [1]

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

Explain why.

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

March 2020 9701/22 · Q3 (a)(ii), (a)(iv)

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

..... [1]

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

..... [1]

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May/June 2020 9701/21 · Q5 (c)(i), (c)(ii)

(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]

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

..... [1]

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[Turn over

- (b) Explain in detail, why glucose and fructose are a pair of structural isomers. Your answer should refer specifically to these two molecules.

.....

.....

..... [2]

May/June 2020 9701/22 · Q3 (b)

(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		

[6]

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

..... [2]

May/June 2020 9701/22 · Q5 (a), (b)(ii), (c) (continued ·)

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

[1]

[Total: 12]

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May/June 2020 9701/22 · Q5 (a), (b)(ii), (c) (cont.)

(b) Both fructose and glucose contain chiral centres.

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

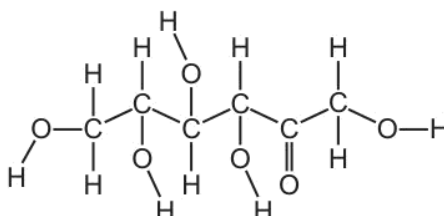
..... [1]

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(ii) On the diagram of the fructose molecule, label all the chiral centres with an asterisk (*).



[1]

May/June 2020 9701/23 · Q3 (b)(i), (b)(ii)

(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]

(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]

May/June 2020 9701/23 · Q4 (b)(i), (c)(i)

(ii) Draw the displayed formula of the alcohol used in this reaction.

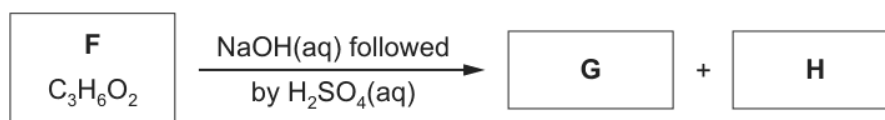
[2]

(iii) Name the isomers **C**, **D** and **E**.

isomer	name
C	
D	
E	

[2]

- (b) **F** is an organic molecule which has the molecular formula $C_3H_6O_2$.
When **F** is heated with $NaOH(aq)$ followed by $H_2SO_4(aq)$ the products **G** and **H** are made.



Separate samples of **G** and **H** are added to

- $Na_2CO_3(aq)$
- sodium metal
- alkaline aqueous iodine.

The observations are described in the table.

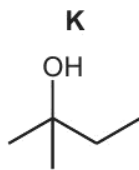
reagent(s)	G	H
$Na_2CO_3(aq)$	colourless bubbles of gas produced	no visible reaction
$Na(s)$	colourless bubbles of gas produced	colourless bubbles of gas produced
alkaline aqueous iodine	no visible reaction	yellow precipitate forms

- (i) Complete the table to identify the functional groups present in **F**, **G** and **H**.

	functional group
F	
G	
H	

[3]

- (ii) **J** reacts with NaOH(aq) to form **K**.



Fully name the mechanism of the reaction of **J** with NaOH(aq) to form **K**.

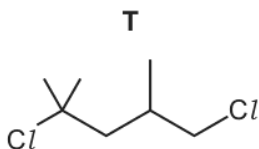
..... [1]

- (iv) Explain why **L** does **not** show geometrical (cis-trans) isomerism.

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

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

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

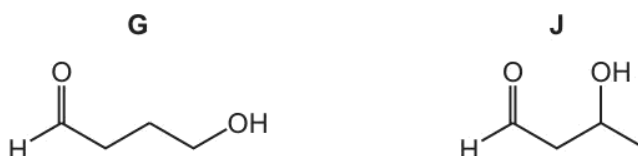


.....
.....
.....

[2]

Oct/Nov 2020 9701/22 · Q3 (c)(ii)

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



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

..... [1]

Oct/Nov 2020 9701/22 · Q4 (b)(i)

- (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 $\text{Na}_2\text{CO}_3(\text{aq})$ is added to **X**.

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

..... [1]

May/June 2021 9701/21 · Q5 (c)(i)

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

.....
..... [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]

May/June 2021 9701/22 · Q4 (a)(ii), (b)(ii)

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

[1]

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

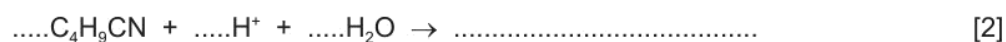
[1]

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

[2]

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

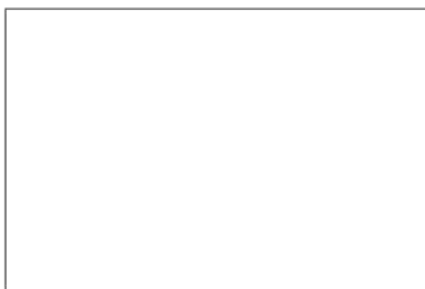
Complete the equation for this reaction.



(ii) Name the functional group present in **M** that changes during this reaction.

[1]

- (b) (i) Use the information in the table to deduce the skeletal formula of **X**, $\text{C}_3\text{H}_6\text{O}_3$. Draw the skeletal formula of **X** in the box. Label the chiral centre of compound **X** with an asterisk (*).



[2]

- (c) Compound **X** is one of a pair of stereoisomers.

Stereoisomerism occurs when a molecule has at least one of two key features.

State the two key features that give rise to stereoisomerism.

- 1
-
- 2
-

[2]

May/June 2021 9701/23 · Q5 (b)(i), (c), (d) (continued ·)

(d) A structural isomer of compound **X** does not fizz when added to sodium.

Explain what is meant by *structural isomer*.

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

[Total: 10]

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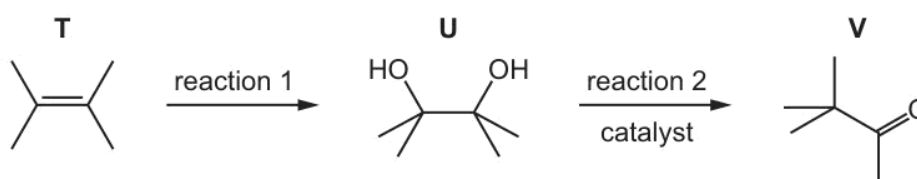
9701/23/M/J/21

May/June 2021 9701/23 · Q5 (b)(i), (c), (d) (cont.)

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

[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]

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- (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]

Oct/Nov 2021 9701/22 · Q3 (b), (d)(i), (e)(iv), (e)(v)

(ii) **J** has **two** optical isomers.

Draw the three-dimensional structures of the **two** optical isomers of **J**.

.....

[2]

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March 2022 9701/22 · Q4 (a)(ii)

- (a) Molecules of **T** exist as a pair of stereoisomers.

Name the type of stereoisomerism shown by molecules of **T**. Explain your answer.

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

- (c) Fig. 3.2 shows two reactions of **T**.

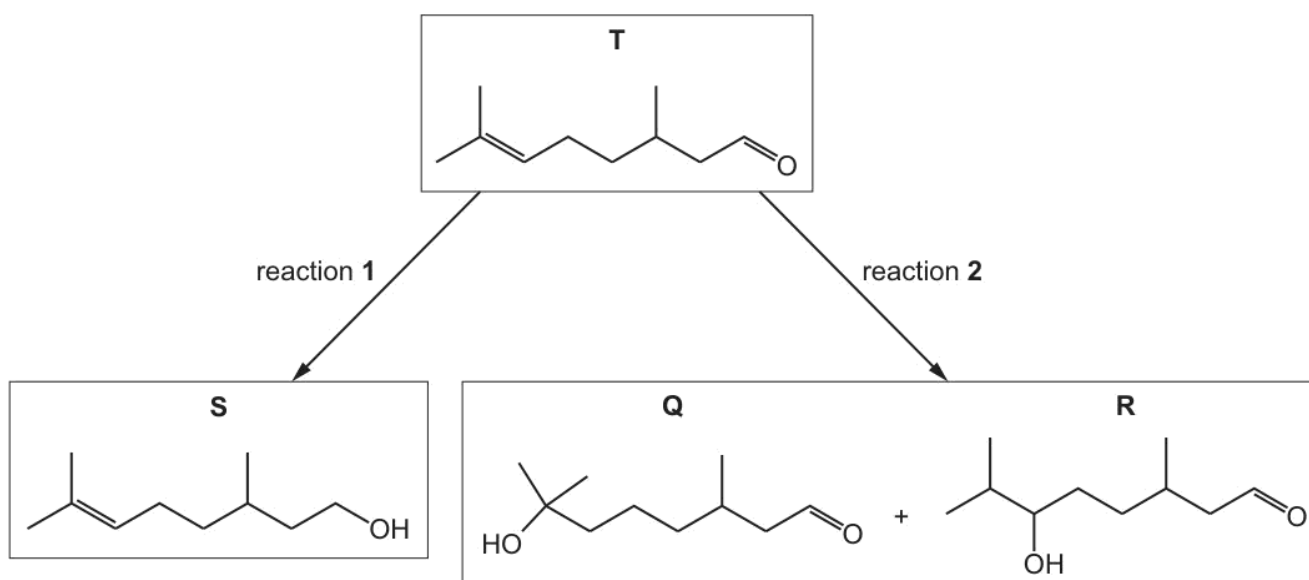


Fig. 3.2

- (i) Identify a suitable reagent for reaction 1.

..... [1]

- (ii) Identify the reagent and conditions needed for reaction 2.

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

- [3]

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- Q** 
- R** 

Fig. 3.3

- [3]

- (ii) When $\text{PCl}_5(\text{s})$ is added to separate samples of **Q** and **R** at room temperature, both react vigorously.

Complete the equation shown in Fig. 3.4 to describe the reaction that occurs when **R** reacts with $\text{PCl}_5(\text{s})$.

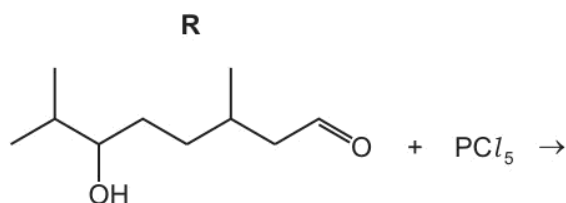


Fig. 3.4

[2]

- (iii) Suggest why samples of **Q** and **R** must be dried before PCl_5 is added. Include a relevant equation to support your answer.

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

[Total: 17]

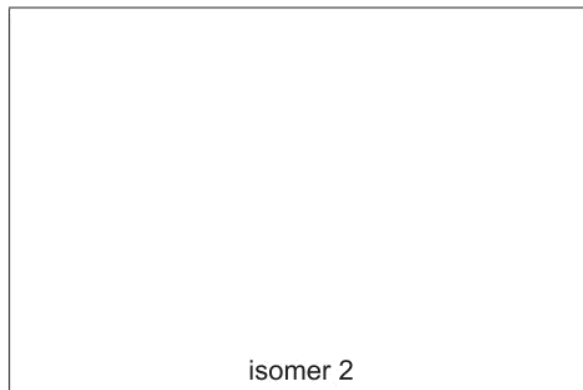
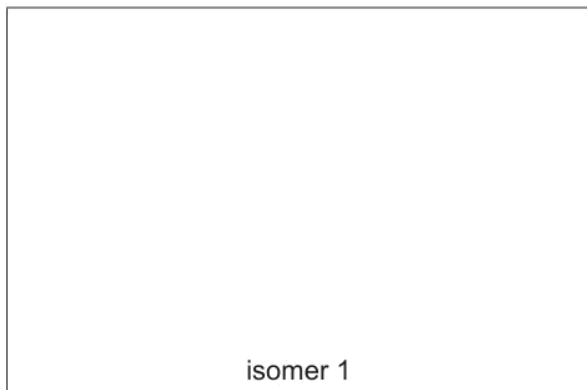
- (ii) A 3.196 g sample of Br_2 reacts completely with 2.800 g of **V**.

Calculate how many alkene functional groups are present in one molecule of **V**. Show your working.

number of alkene functional groups in **V** = [1]

(iii) **W** could be one of four structural isomers.

- Draw the skeletal formulae for two possible structural isomers of **W**.
- Describe the type of structural isomerism shown.



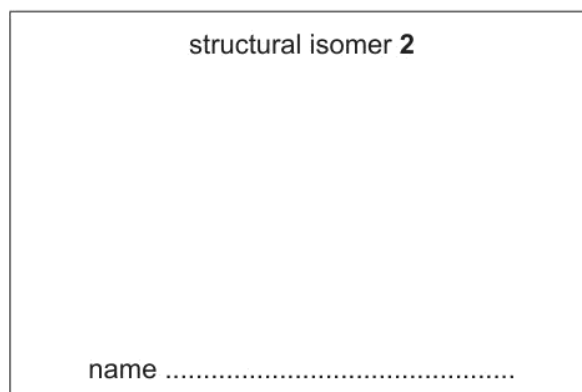
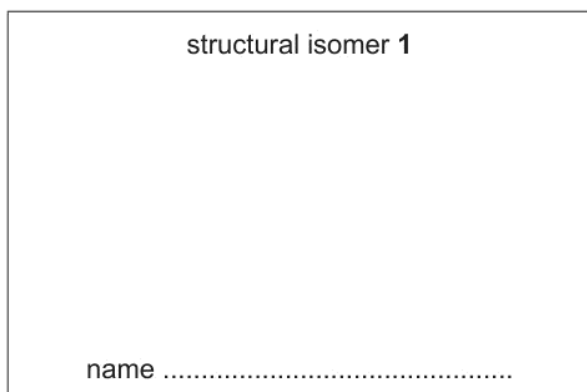
type of structural isomerism

.....
[3]

- 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.

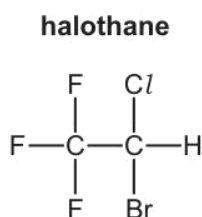


Fig. 4.1

- (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]

9

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

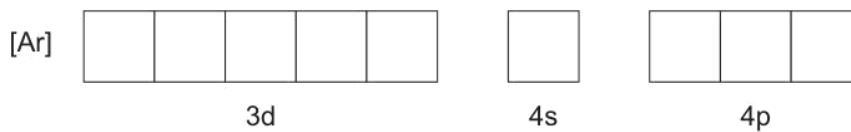


Fig. 4.2

[1]

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

..... [1]

[Total: 8]

- (b) The functional group in **G** is an oxygen atom bonded to two carbon atoms.

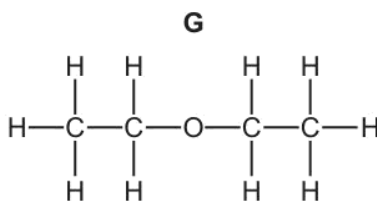


Fig. 3.3

G, **H** and **J** are structural isomers with molecular formula $C_4H_{10}O$.
H and **J** are straight chain molecules.

Table 3.3 shows the boiling points and reactions of **G**, **H** and **J** when heated under reflux with excess acidified $K_2Cr_2O_7$.

Table 3.3

	G	H	J
boiling point/ $^{\circ}C$	35	117	98
heat under reflux with excess acidified $K_2Cr_2O_7$	remains orange	orange to green	orange to green

- (i) Identify the type of structural isomerism shown between **G** and **H** using the information in Table 3.3.

..... [1]

May/June 2022 9701/23 · Q3 (b)(i)

- (ii) **A1** and **A2** are structural isomers.

Define structural isomers.

.....
 [1]

- (iii) State the effect of a decrease in pressure on the position of equilibrium in reaction 2. Explain your answer.

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

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8

[Turn over]

Fig. 3.1 shows the two structural isomers of S_2Cl_2 .

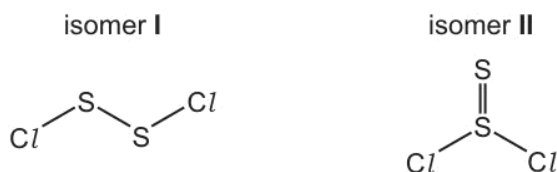


Fig. 3.1

- (iv) Define the term structural isomer.

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

Oct/Nov 2022 9701/23 · Q3 (d)(iii), (d)(iv)

- (ii) One of the products of the reaction is CH_2Cl_2 which reacts further to produce CHCl_3 .

Complete Table 3.2 to show details of the mechanism that forms CHCl_3 from CH_2Cl_2 .

Table 3.2

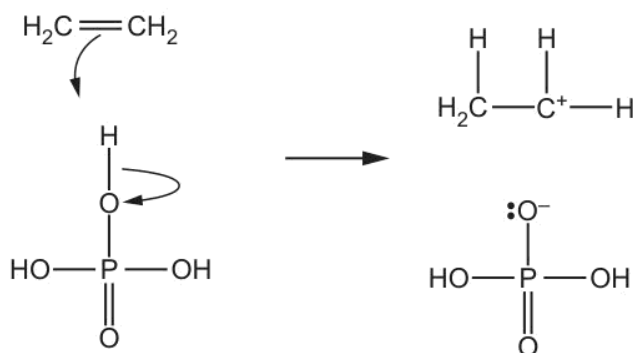
name of step	equation
initiation	
propagation	$\text{CH}_2\text{Cl}_2 + \text{Cl}\cdot \rightarrow$
termination	 $\rightarrow \text{CHCl}_3$

[3]

May/June 2023 9701/21 · Q3 (d)(ii)

- (c) The mechanism for reaction 1 can be described in three steps. Steps 1 and 2 for reaction 1 are shown in Fig. 4.1.

step 1



step 2

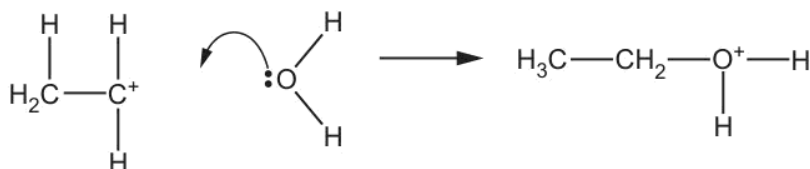


Fig. 4.1

- (i) Describe the behaviour of H_3PO_4 in step 1 in Fig. 4.1. Explain your answer.

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

- (ii) Identify the species that behaves as an electrophile in step 2 in Fig. 4.1. Explain your answer.

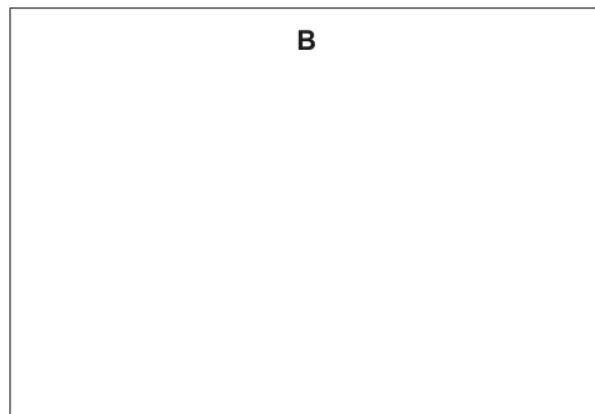
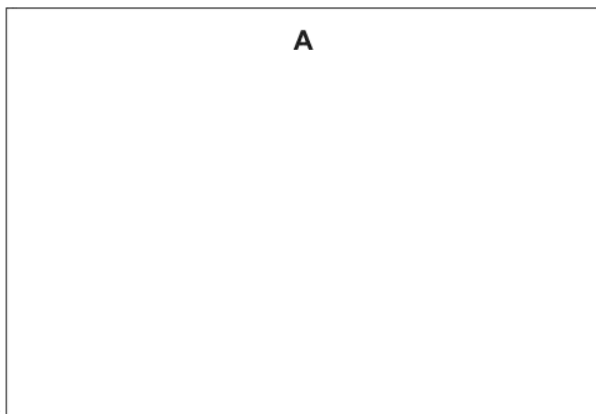
.....
..... [1]

May/June 2023 9701/22 · Q4 (c)(i), (c)(ii)

5 (a) Describe structural isomerism.

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

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



[2]

(c) **C** is a structural isomer of **A** and **B**.

C is straight chained and has two functional groups.

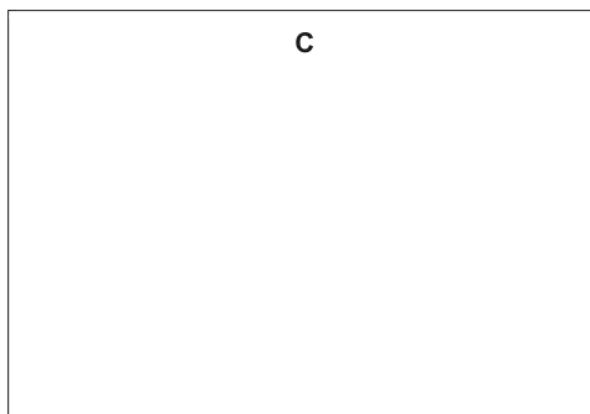
C shows only one type of stereoisomerism.

Table 5.2 describes observations when separate samples of **C** are added to different reagents.

Table 5.2

reagent	C
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	no reaction
Br ₂ (aq)	orange to colourless
alkaline I ₂ (aq)	yellow precipitate appears

(i) Draw the structure of **C** in the box.



[2]

(ii) Name the type of stereoisomerism shown by molecules of **C**.

..... [1]

- (d) **D** reacts in the presence of a sulfuric acid catalyst to form **E** and water.

The structure of **E** is shown in Fig. 5.1.

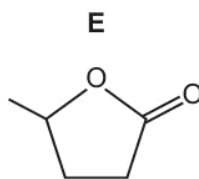


Fig. 5.1

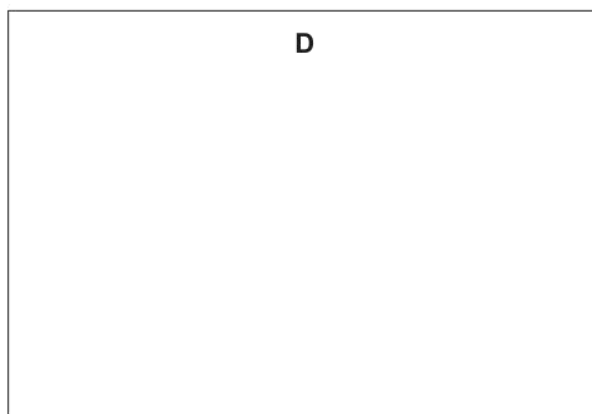
- (i) Name the functional group present in **E**.

..... [1]

- (ii) Identify the type of reaction that occurs when **D** reacts to form **E**.

..... [1]

- (iii) Draw the structure of **D** in the box.



[1]

13

May/June 2023 9701/22 · Q5 (a), (b)(ii), (c)(i), (c)(ii), (d)(i), (d)(ii), (d)(iii) (cont.)

(a) **P**, **Q**, **R** and **S** show stereoisomerism.

Complete Table 4.1 by identifying with a tick (✓) the type of stereoisomerism that each molecule shows.

The type of stereoisomerism shown by **Q** is given.

Table 4.1

	P	Q	R	S
geometrical isomerism				
optical isomerism		✓		

[2]

(b) (i) Give the structural formula of **Q**.

..... [1]

(ii) Name the mechanism in reaction 2.

..... [1]

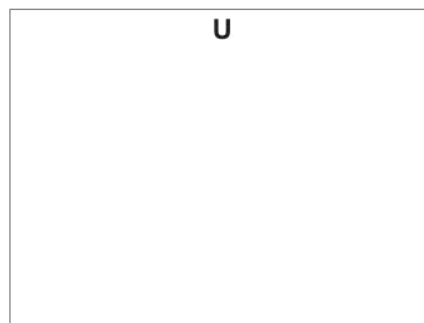
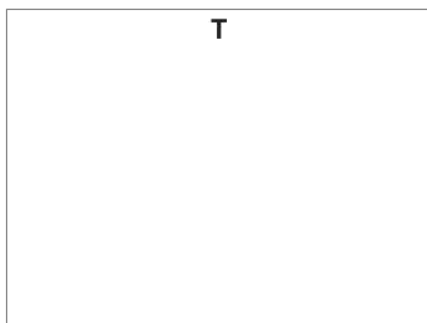
(iii) Complete the equation for reaction 3. **R** is represented as C_4H_9CN .

$C_4H_9CN +$ [1]

(iii) **T** also has a single functional group.

Use the information in **(c)(i)** and your answer to **(c)(ii)** to identify **T** and **U**.

Draw the structures of **T** and **U** in the boxes.



[2]

[Total: 11]

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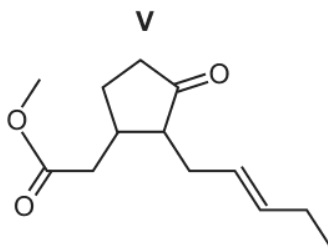
15

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	Key												13	14	15	16	17	18
		atomic number atomic symbol name relative atomic mass																	
3 Li lithium 6.9	4 Be beryllium 9.0													5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
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		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 209.0	83 Bi bismuth 208.98	84 Po polonium —	85 At astatine —		
87 Fr francium —	88 Ra radium —	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 —		
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			
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 —			

- 6 (a) **V** shows stereoisomerism.



- (i) Explain what is meant by stereoisomerism.

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

- (ii) Deduce the number of stereoisomers of **V**. Explain your reasoning.

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

- (iv) Name **all** the functional groups present in **V**.

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

(b) Fig. 6.2 shows two reactions involving **V**.

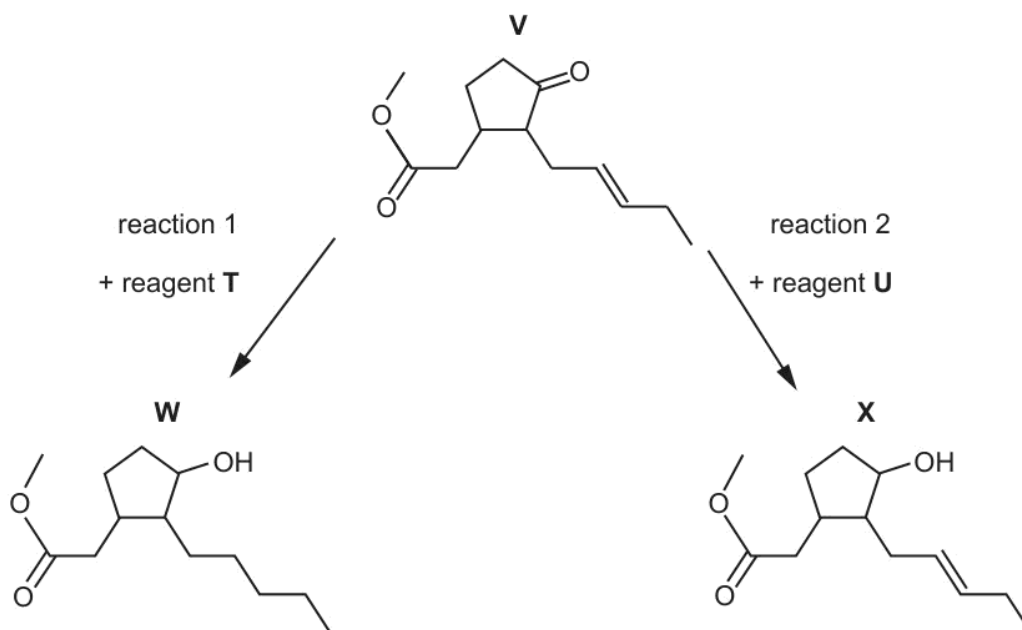


Fig. 6.2

(i) Identify the role of reagent **T** for each functional group that reacts in reaction 1.

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

(ii) Suggest the identity of reagent **U** in reaction 2.

..... [1]

May/June 2024 9701/21 · Q6 (a)(i), (a)(ii), (a)(iv), (b)(i), (b)(ii) (cont.)

- (a) Draw the three-dimensional structures of the **two** stereoisomers of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$. R can be used to represent $\text{CH}_3(\text{CH}_2)_5$.

.....

[2]

- (d) $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ is heated with **D** to produce three different molecules, **E**, **F** and **G**.

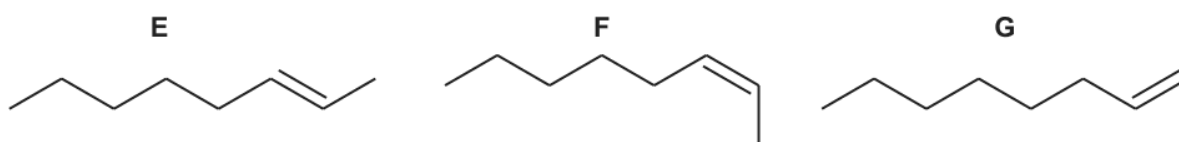


Fig. 4.2

- (i) Name the type of reaction.

..... [1]

- (ii) Identify **D** and the conditions used.

..... [1]

May/June 2024 9701/22 · Q4 (a), (d)(i), (d)(ii)

- (c) **Y** is a structural isomer of **W**.

Both **W** and **Y** produce colourless bubbles when sodium is added to them.

Y does **not** react when heated with acidified $\text{K}_2\text{Cr}_2\text{O}_7$.

Y does **not** react when warmed with alkaline $\text{I}_2(\text{aq})$.

- (i) Name the functional group present in **Y**.

..... [1]

May/June 2024 9701/22 · Q5 (c)(i)

(ii) Name the mechanism for step 1 in Fig. 5.2.

..... [1]

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May/June 2024 9701/23 · Q5 (b)(ii)

- (d) Hydrated rhodium(III) chloride, $\text{RhCl}_3 \cdot x\text{H}_2\text{O}$, catalyses the conversion of ethene to but-2-ene.

Both stereoisomers of but-2-ene are formed in the reaction.

- (i) Hydrated rhodium(III) chloride contains 20.5% by mass of water of crystallisation.

Deduce the integer value of x in $\text{RhCl}_3 \cdot x\text{H}_2\text{O}$.

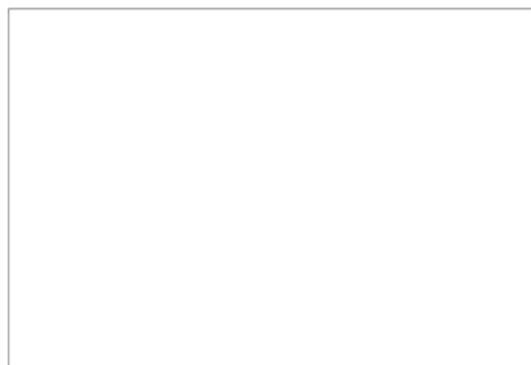
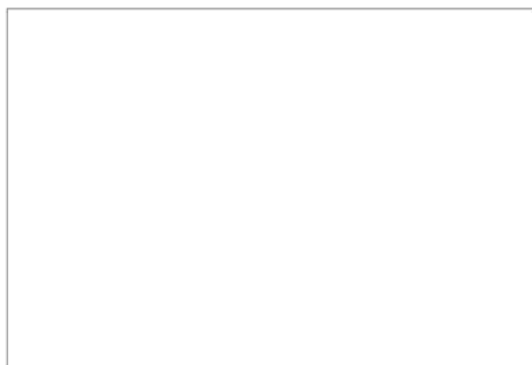
Show your working.

$x = \dots\dots\dots$
[2]

- (ii) Define stereoisomers.

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

- (iv) Draw the two stereoisomers of but-2-ene.



[2]

[Total: 16]





5

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Oct/Nov 2024 9701/21 · Q1 (d)(i), (d)(ii), (d)(iv) (cont.)

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

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

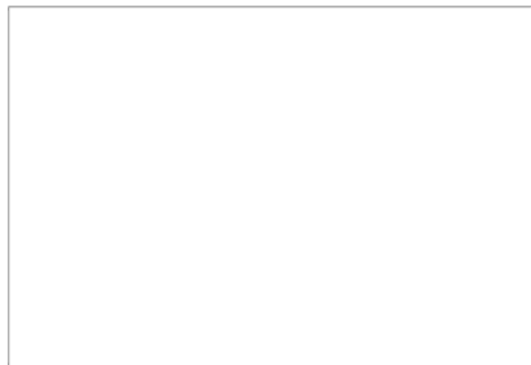
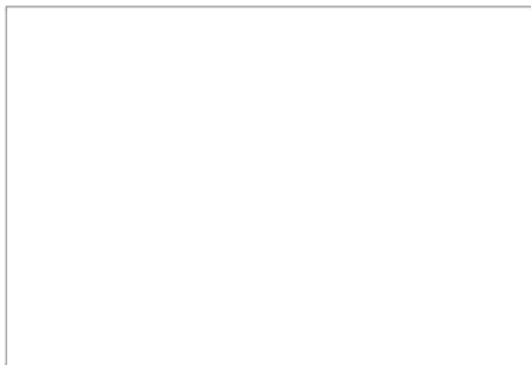
Oct/Nov 2024 9701/21 · Q4 (a)(ii)

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

..... [1]

Oct/Nov 2024 9701/22 · Q4 (d)(ii)

(iv) Draw the two stereoisomers of but-2-ene.



[2]

[Total: 16]

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9701/23/O/N/24

Oct/Nov 2024 9701/23 · Q1 (d)(iv) (continued ·)



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6

Oct/Nov 2024 9701/23 · Q1 (d)(iv) (cont.)

- (ii) Name the mechanism involved in the reaction of IBr with propene.

..... [1]

- (iii) The reaction of IBr with propene forms two structural isomers.

Draw the **two** structural isomers shown by these molecules.



[2]

- (iv) Identify the type of structural isomerism shown by the molecules in (d)(iii).

..... [1]

- (v) Explain why the two structural isomers do **not** form in equal amounts.

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

[Total: 15]

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[Turn over]

March 2025 9701/22 · Q3 (d)(ii), (d)(iii), (d)(iv), (d)(v)

(c) Compounds **A**, **B** and **C** belong to the alcohol homologous series. Each molecule of **A**, **B** and **C** contains four saturated carbon atoms.

(i) Identify the type of hybridisation shown in the saturated carbon atoms of all alcohols.

..... [1]

May/June 2025 9701/22 · Q4 (c)(i)

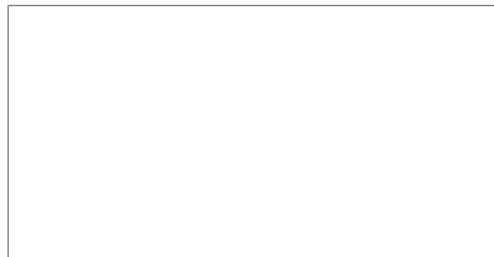
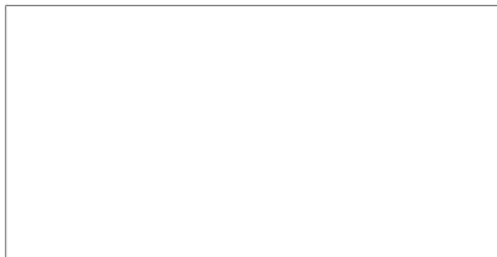
(ii) Draw the displayed formula of **G**.

[2]

May/June 2025 9701/24 · Q4 (d)(ii)

- (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]



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

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

[Total: 7]

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[Turn over]

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- (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} .

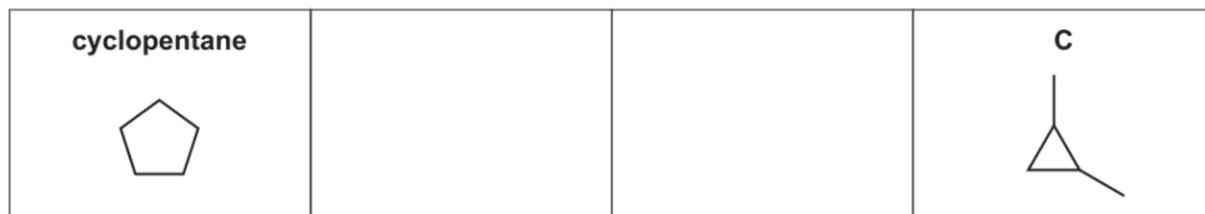


Fig. 3.1

[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]

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- (ii) Define stereoisomerism.

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

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(a) Define homologous series.

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

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

1
2 [2]

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

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

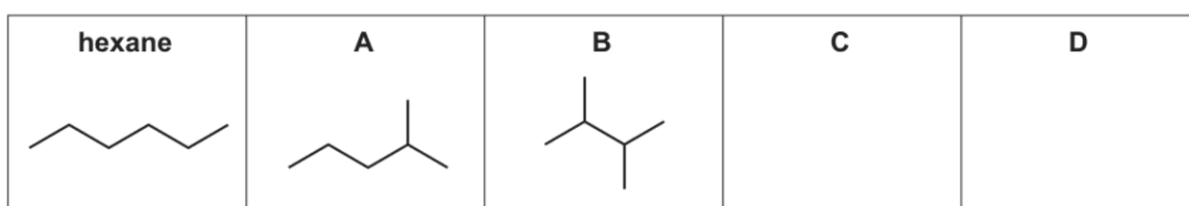


Fig. 3.1

(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]



- (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**.

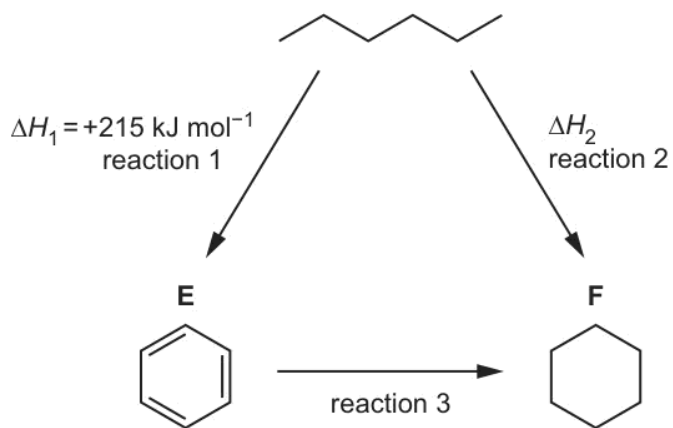
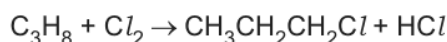


Fig. 3.2

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

..... [1]

- (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

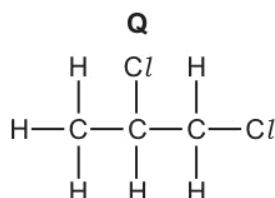
termination $\rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$
[3]

- (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]



(v) The molecular formula of **Q** is $\text{C}_3\text{H}_6\text{Cl}_2$.

Identify the types of structural isomerism and stereoisomerism that a molecule with molecular formula $\text{C}_3\text{H}_6\text{Cl}_2$ can show.

type of structural isomerism

type of stereoisomerism

[2]

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

..... [1]

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(ii) Define stereoisomerism.

.....

..... [2]

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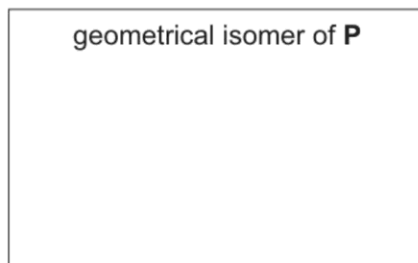
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- (a) (i) Define structural isomerism.

.....
..... [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]

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

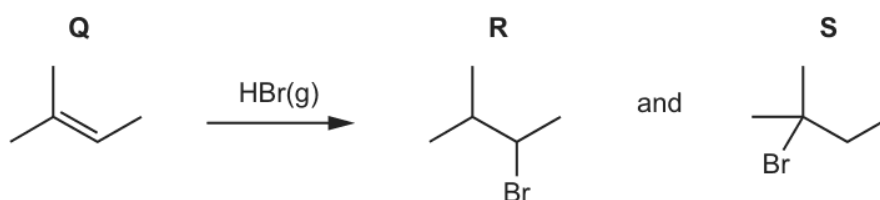


Fig. 4.2

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

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

- (ii) Reaction 2 is a hydrolysis reaction.

Construct an equation for reaction 2.

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