

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

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

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

[1]

May/June 2017 9701/21 · Q4 (b)(ii), (b)(iii)

- (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*.

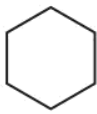
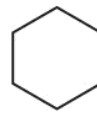
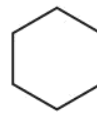
.....
..... [1]

(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	 + $\text{Cl}\cdot \longrightarrow$  +
.....	 + $\text{Cl}_2 \longrightarrow$  + $\text{Cl}\cdot$
termination	 + $\text{Cl}\cdot \longrightarrow$

[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]

March 2018 9701/22 · Q4 (a)(i), (a)(ii), (b), (c)(i) (cont.)

- (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]

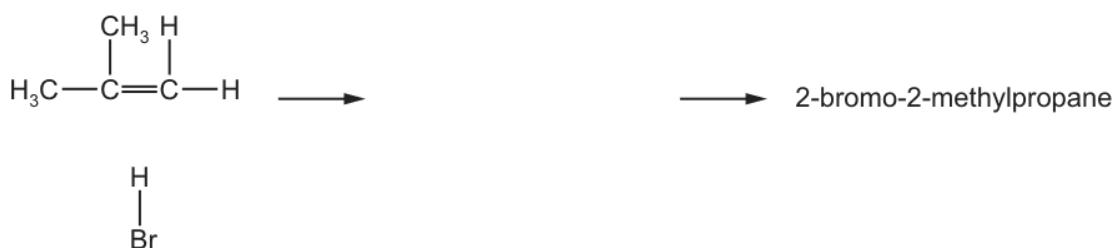
May/June 2018 9701/21 · Q2 (b)

- (d) The reaction of methylpropene, $(\text{CH}_3)_2\text{CCH}_2$, with hydrogen bromide, HBr , produces a mixture of two halogenoalkanes.

One of the halogenoalkanes, 2-bromo-2-methylpropane, is formed as the major product while 1-bromo-2-methylpropane is formed in small quantities.

- (i) Complete the mechanism to show the reaction of methylpropene with HBr to form the **major** product.

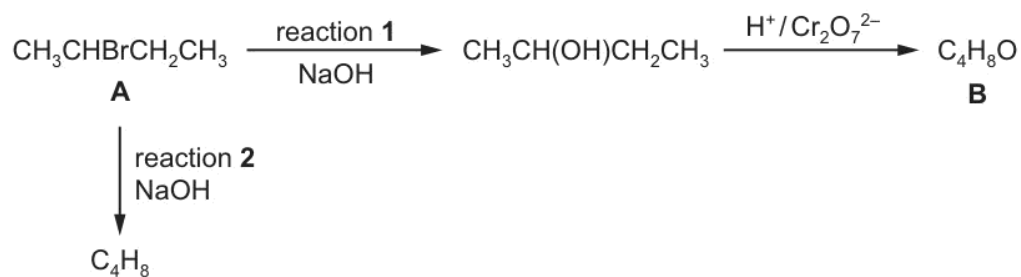
Include the structure of the intermediate and all necessary charges, dipoles, lone pairs and curly arrows. The structure of 2-bromo-2-methylpropane is not required.



[4]

May/June 2018 9701/21 · Q4 (d)(i)

(a) Some reactions of **A** are shown.



(i) Name **A**.

..... [1]

(ii) Name the class of compound to which **B** belongs.

..... [1]

(e) Reaction **2** uses the same reagent as reaction **1**, but under different conditions.

State **two** differences in the conditions needed to ensure that reaction **2** is more likely to take place than reaction **1** when this reagent is added.

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

[Total: 13]

12

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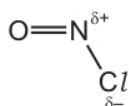
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9701/23/M/J/18

May/June 2018 9701/23 · Q4 (a)(i), (a)(ii), (e) (cont.)

(e) Nitrosyl chloride, NOCl , is a reactive gas that is sometimes formed when NO reacts with Cl_2 .

nitrosyl chloride



NOCl is a strong electrophile and readily undergoes an addition reaction with alkenes.

Complete the diagram to show the mechanism of the electrophilic addition reaction of NOCl with ethene.

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

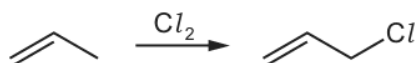


[2]

[Total: 13]

March 2019 9701/22 · Q1 (e)

- (b) Allyl chloride can be produced by many different methods. The most common method is chlorination of propene which proceeds via a free-radical substitution mechanism.



- (i) The initiation step in this reaction is the formation of chlorine radicals ($Cl^\bullet$) from Cl_2 molecules.

State the conditions required to initiate this reaction.

..... [1]

- (iii) Explain why the free-radical substitution reaction gives a low yield of allyl chloride.

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

March 2019 9701/22 · Q4 (b)(i), (b)(iii)

- (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]

- (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]

- (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]

(e) Under certain conditions, chlorine undergoes a free-radical substitution reaction with ethane.

(i) State the conditions required to initiate this reaction.

..... [1]

(ii) Write the overall equation for this free-radical substitution reaction.

..... [1]

[Total: 12]

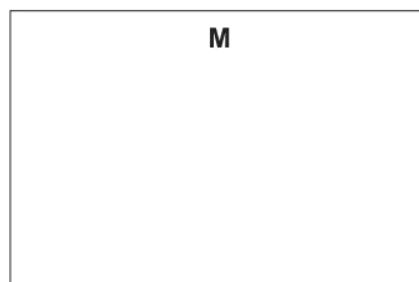
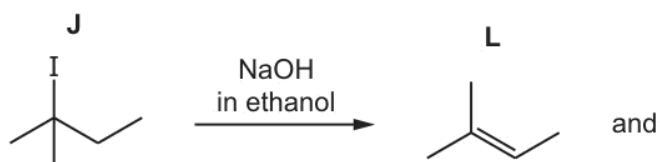
(e) Gallium oxide, Ga_2O_3 , and aluminium oxide react in the same way with $\text{HCl}(\text{aq})$ and with $\text{NaOH}(\text{aq})$.

(i) Suggest the equation for the reaction between Ga_2O_3 and $\text{HCl}(\text{aq})$.

..... [1]

May/June 2020 9701/22 · Q1 (e)(i)

(iii) **J** reacts with NaOH dissolved in ethanol to form a mixture of two alkenes, **L** and **M**. Alkene **L** is shown.

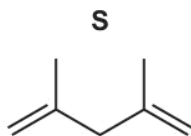


In the box provided, draw the structure of **M**.

[1]

Oct/Nov 2020 9701/21 · Q4 (c)(iii)

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



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

[1]

- (c) Complete the table to show the numbers of sigma (σ) bonds and pi (π) bonds present in propene, C_3H_6 , and C_3H_8O .

	σ	π
C_3H_6		
C_3H_8O		

[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]

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9701/21/M/J/21

11

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

..... [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]

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9701/22/M/J/21

9

(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]

May/June 2021 9701/22 · Q4 (b)(i), (c)

- (ii) On Fig. 3.2, sketch the pH titration curves produced when:
- $0.1 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ is added to 25 cm^3 of $0.1 \text{ mol dm}^{-3} \text{ HBr(aq)}$, to excess
 - $0.1 \text{ mol dm}^{-3} \text{ NH}_3(\text{aq})$ is added to 25 cm^3 of $0.1 \text{ mol dm}^{-3} \text{ HBr(aq)}$, to excess.

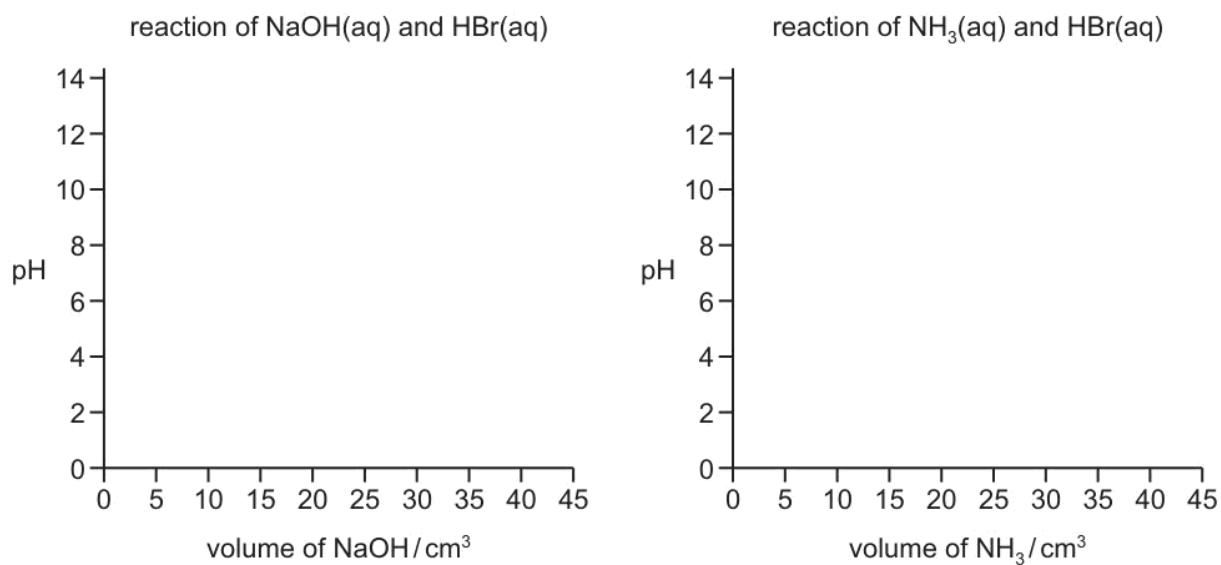
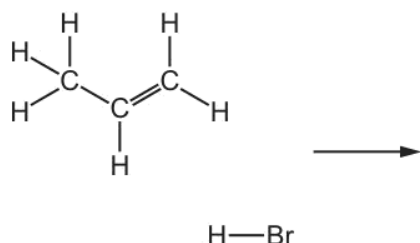


Fig. 3.2

[3]

(e) HBr reacts with propene to form two bromoalkanes, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ and $(\text{CH}_3)_2\text{CHBr}$.

- (i) Complete the diagram to show the mechanism of the reaction of HBr and propene to form the major organic product.
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.
Draw the structures of the intermediate and the major organic product.



[4]

March 2022 9701/22 · Q3 (d)(ii), (e)(i) (cont.)

(b) Fig. 2.1 shows some reactions of magnesium and its compounds.

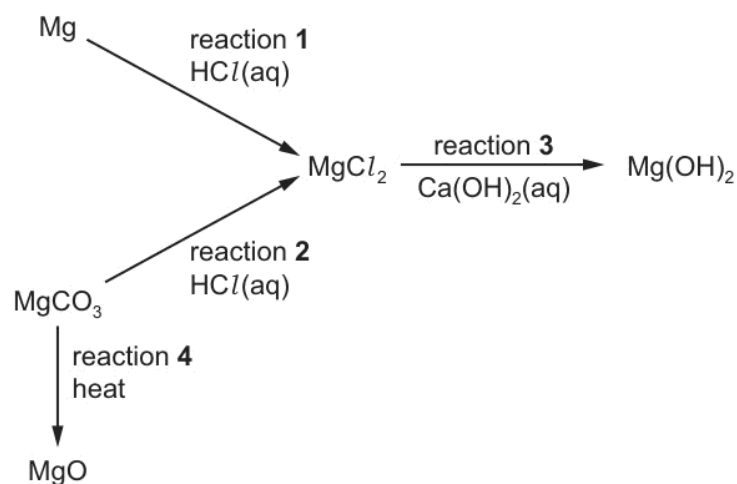


Fig. 2.1

- (i) Identify the other products of reactions 1 and 2.

reaction 1

reaction 2

[2]

Oct/Nov 2022 9701/23 · Q2 (b)(i)

(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]

[Turn over

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9701/21/M/J/24

10

May/June 2024 9701/21 · Q5 (c)(i), (c)(ii)

- (b) The halogenoalkane $\text{CH}_3\text{CH}_2\text{Cl}$ forms when chlorine reacts with C_2H_6 via a free-radical substitution mechanism.

- (i) Define free radical.

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

Oct/Nov 2024 9701/21 · Q2 (b)(i)

- 3 (a) Hexene reacts with hydrogen gas to produce hexane.

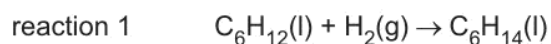


Fig. 3.1 shows the distribution of energies of $\text{H}_2(\text{g})$ molecules at temperature T .

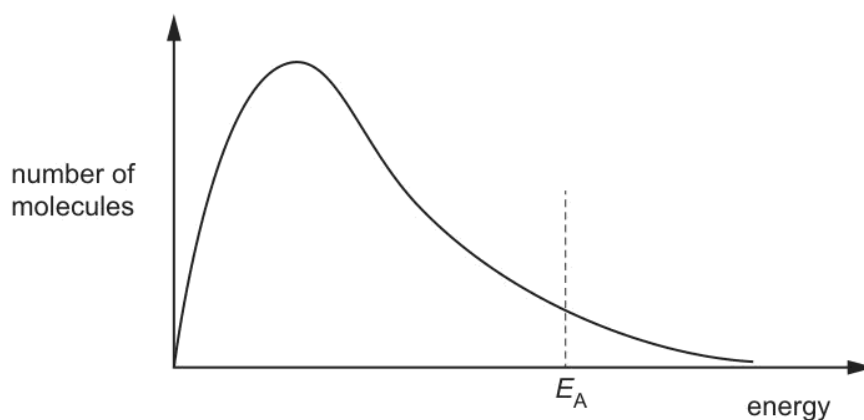


Fig. 3.1

- (i) Sketch on Fig. 3.1 the shape of the curve for the same sample of $\text{H}_2(\text{g})$ molecules when the temperature is increased. [2]
- (iii) State the role of nickel when it is added to reaction 1. [1]
-
- (iv) Annotate Fig. 3.2 to show the effect of adding nickel to reaction 1 at temperature T .

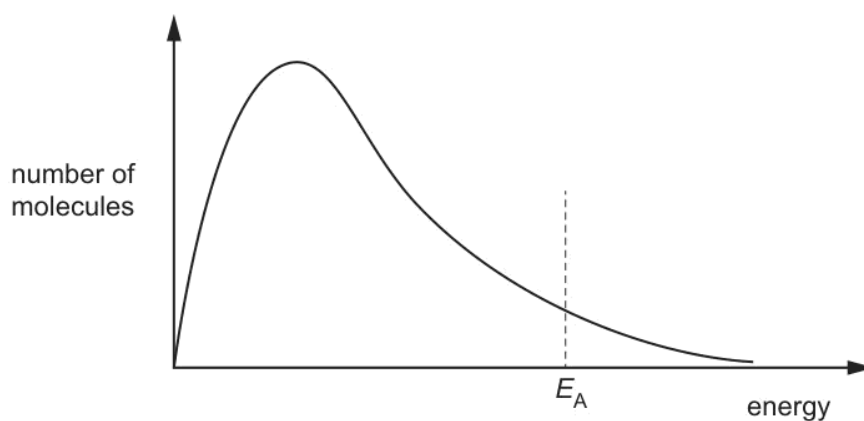


Fig. 3.2

[1]

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9701/21/M/J/25

7

- 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.

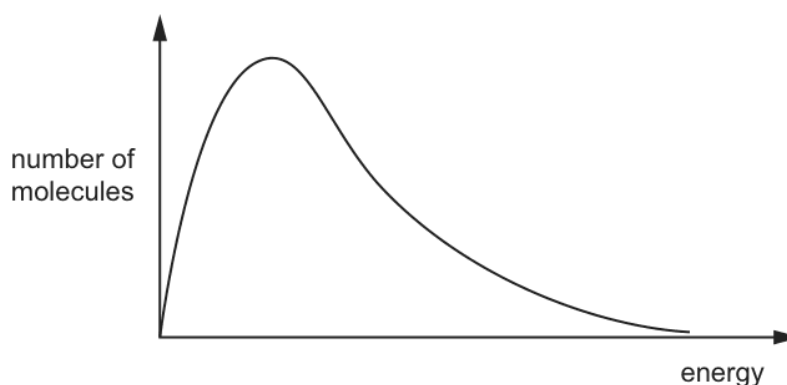


Fig. 3.1

.....

 [2]





May/June 2025 9701/23 · Q3 (a)(i), (a)(ii), (b)(i), (b)(ii), (b)(iii) (cont.)

(iv) The reaction between $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and $\text{HCl}(\text{aq})$ is repeated in a second experiment.

In this second experiment, 25.0 cm^3 of 0.050 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ reacts with 0.0020 mol of $\text{HCl}(\text{aq})$. Calculate the number of sulfur atoms produced.

number of sulfur atoms produced = [2]

May/June 2025 9701/23 · Q4 (a)(iv)

- 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.

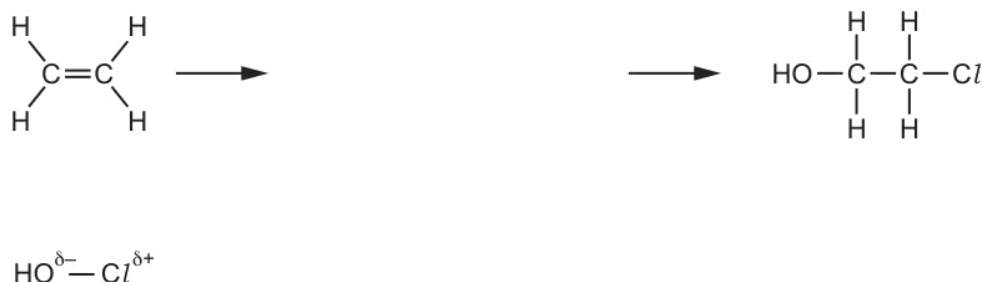


Fig. 6.1

[4]





13

- (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.

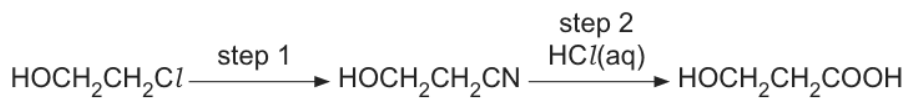


Fig. 6.2

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

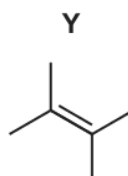
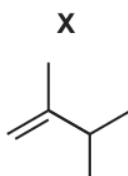
..... [1]

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

..... [1]

May/June 2025 9701/23 · Q6 (a)(i), (a)(ii), (a)(iii), (b), (c)(i), (c)(ii) (cont.)

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



- (i) Name **X**.

..... [1]

Oct/Nov 2025 9701/21 · Q4 (c)(i)

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

..... [1]

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9701/22/O/N/25



10

[Total: 14]
[Turn over]

Oct/Nov 2025 9701/22 · Q3 (e)(iii)

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

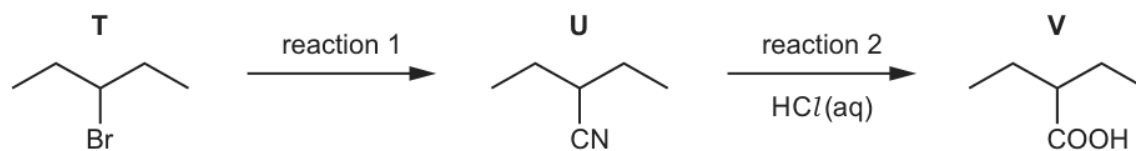


Fig. 4.3

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

..... [1]

Oct/Nov 2025 9701/24 · Q4 (b)(i)