

(d) An aqueous solution, **Z**, contains a mixture of sodium chloride and sodium iodide.

(i) Excess aqueous silver nitrate is added to **Z** in a test-tube. A yellow precipitate forms.

Explain the colour of this precipitate.

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

May/June 2017 9701/23 · Q2 (d)(i)

(ii) The chlorate(I) ion is formed when cold aqueous sodium hydroxide reacts with chlorine.

Write an **ionic** equation for this reaction. State symbols are **not** required.

..... [1]

March 2018 9701/22 · Q3 (c)(ii)

- (c) Reaction 1 occurs by two different mechanisms at the same time.

These mechanisms are referred to as S_N1 and S_N2 .

- (i) State what the letters 'S' and 'N' represent in the abbreviation S_N1 .

S

N

[1]

- (ii) Complete the S_N1 mechanism for reaction 1.

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



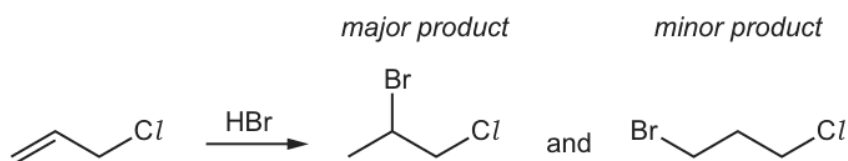
[3]

- (d) The S_N1 mechanism for reaction 1 is repeated using $\text{CH}_3\text{CHClCH}_2\text{CH}_3$ or $\text{CH}_3\text{CHICH}_2\text{CH}_3$ in place of the $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$.

State and explain how the rates of these two reactions will compare with the rate of the original reaction using $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$.

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

- (d) 2-bromo-1-chloropropane, $\text{CH}_3\text{CHBrCH}_2\text{Cl}$, is the major product of the reaction of allyl chloride with HBr .



Explain why 2-bromo-1-chloropropane is the major product of this reaction.

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.....

.....

..... [2]

[Total: 13]

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March 2019 9701/22 · Q4 (d) (cont.)

- (a) A sample of potassium cyanide dissolved in ethanol is added to a sample of 1-bromobutane, $\text{CH}_3(\text{CH}_2)_3\text{Br}$, and heated under reflux. A nucleophilic substitution reaction occurs and compound **A** is formed.

(i) Name compound **A**.

..... [1]

(ii) What is meant by the term *nucleophile*?

.....

..... [1]

(iii) Identify the nucleophile in this reaction.

..... [1]

(iv) Explain why this reaction is described as a substitution reaction.

.....

..... [1]

- (b) State the reagent(s) and conditions needed for $\text{CH}_3(\text{CH}_2)_3\text{Br}$ to react to form $\text{CH}_3(\text{CH}_2)_3\text{NH}_2$.

reagent(s)

conditions

[2]

- (c) Equal amounts of three different halogenoalkanes are added to three separate test-tubes. An equal amount of aqueous silver nitrate and ethanol is added to each test-tube. The time taken for a precipitate to form is recorded for each halogenoalkane.

halogenoalkane	time taken for precipitate to form/s
$(\text{CH}_3)_3\text{CCl}$	460
$(\text{CH}_3)_3\text{CBr}$	190
$(\text{CH}_3)_3\text{CI}$	40

- (i) Describe and explain the trend in reactivity of the different halogenoalkanes shown in this experiment.

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

- (ii) All three halogenoalkanes tend to react via the $\text{S}_{\text{N}}1$ mechanism.

Explain why the $\text{S}_{\text{N}}1$ mechanism is favoured.

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

- (iii) Identify a halogenoalkane which tends to react with an aqueous solution of silver nitrate and ethanol via the $\text{S}_{\text{N}}2$ mechanism.

..... [1]

[Total: 12]

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May/June 2019 9701/23 · Q5 (a)(i), (a)(ii), (a)(iii), (a)(iv), (b), (c)(i), (c)(ii), (c)(iii) (cont.)

(c) PCl_5 can be used to convert alcohols to halogenoalkanes.

(i) Write an equation for the reaction of $\text{C}_2\text{H}_5\text{OH}$ with PCl_5 to form $\text{C}_2\text{H}_5\text{Cl}$.

..... [1]

(iii) Halogenoalkanes can also be prepared by reacting alcohols with hydrogen halides, such as HCl and HI .

- HCl is prepared using NaCl and concentrated H_2SO_4 .
- HI is prepared by reacting NaI with concentrated H_3PO_4 .

Suggest why HI is **not** prepared by the reaction of NaI with concentrated H_2SO_4 .

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

(iv) The rate of the hydrolysis reaction of halogenoalkanes with NaOH(aq) is dependent on the halogen that is bonded to carbon.

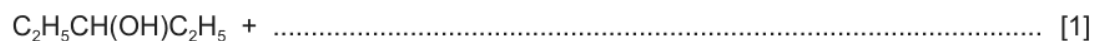
State and explain the order of reactivity when NaOH(aq) reacts separately with $\text{C}_2\text{H}_5\text{Cl}$, $\text{C}_2\text{H}_5\text{Br}$ and $\text{C}_2\text{H}_5\text{I}$.

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

[Total: 13]

- (ii) Pentan-3-ol, $\text{C}_2\text{H}_5\text{CH}(\text{OH})\text{C}_2\text{H}_5$, reacts slowly with HCl to form a secondary halogenoalkane.

Complete the equation for this reaction using structural formulae.



March 2020 9701/22 · Q2 (e)(ii)

- (ii) The table gives the formula of each gallium-containing product formed when gallium oxide reacts separately with hot aqueous hydrochloric acid and hot aqueous sodium hydroxide.

	formula of gallium-containing product
hot aqueous hydrochloric acid	GaCl_3
hot aqueous sodium hydroxide	$\text{NaGa}(\text{OH})_4$

Give the name of the type of behaviour shown by gallium oxide in these reactions.

..... [1]

[Total: 8]

- 4 (a) An unlabelled bottle contains a straight-chain halogenoalkane, **Q**. The molecular formula of **Q** is $C_5H_{11}X$, where **X** is a halogen; bromine, chlorine or iodine.

A test is carried out to identify the halogen present in **Q**.

A sample of **Q** is added to $NaOH(aq)$ and warmed. Dilute nitric acid is then added followed by a few drops of aqueous silver nitrate. A cream precipitate is observed.

- (i) Suggest the identity of **X**.

..... [1]

- (ii) Write an ionic equation to describe the formation of the cream precipitate. Include state symbols.

..... [1]

- (iii) Describe a further test which would confirm the identity of **X**.

test

expected result

[2]

- (b) The reaction of **Q** with $NaOH(aq)$ tends to proceed via an S_N2 mechanism.

- (i) Suggest the structural formula of the straight-chain halogenoalkane **Q**.

[1]

- (ii) Explain why the reaction tends to proceed via an S_N2 mechanism rather than an S_N1 mechanism.

.....

.....

..... [2]

9

- (c) Two different halogenoalkanes, **P** and **R**, both with the molecular formula C_4H_9Cl , are separately dissolved in ethanol and heated under reflux with sodium hydroxide.

The major organic product of each of these reactions is methylpropene.

- (i) Name the type of reaction occurring.

..... [1]

- (ii) Write an equation, using molecular formulae, to represent the reaction occurring.

..... [1]

- (iii) Draw the skeletal formula of methylpropene.

[1]

(iv) Give the names of **P** and **R**.

..... [2]

[Total: 12]

- (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]

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May/June 2020 9701/23 · Q4 (b)(iii), (b)(iv)

- (e) Element **E** is a Period 5 element.

E reacts with oxygen to form an insoluble white oxide that has a melting point of 1910 °C. The oxide of **E** conducts electricity only when liquid.

E also reacts readily with $Cl_2(g)$ to form a white solid that reacts exothermically with water. The resulting solution reacts with aqueous silver nitrate to form a white precipitate that dissolves in dilute ammonia.

- (i) Suggest the type of bonding shown by the **oxide** of **E**. Explain your answer.

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

Oct/Nov 2020 9701/21 · Q2 (e)(i)

- (iv) Iodine reacts with hot concentrated aqueous sodium hydroxide in the same way as chlorine.

Write an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

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- (ii) 1,2-diiodoethane, $\text{CH}_2\text{ICH}_2\text{I}$, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

..... [1]

Oct/Nov 2020 9701/21 · Q4 (a)(iv), (b)(ii)

- (ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

..... [1]

Oct/Nov 2020 9701/22 · Q2 (e)(ii)

- (ii) Write an equation for the reaction of Cl_2 with cold aqueous sodium hydroxide.

..... [1]

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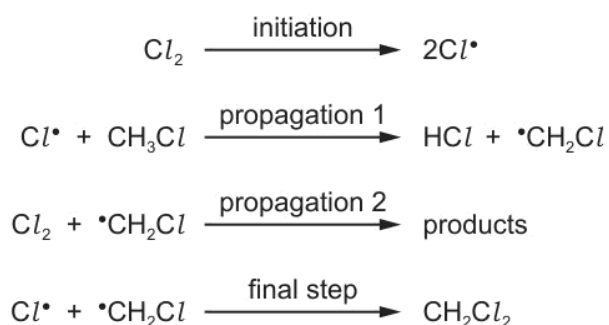
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[Turn over]

- (g) Dichloromethane, CH_2Cl_2 , is widely used as an organic solvent.

CH_2Cl_2 can be prepared by reacting CH_3Cl and Cl_2 at room temperature.

The reaction proceeds via several steps, as shown.



- (i) Give the name of the mechanism of this reaction.

..... [1]

March 2021 9701/22 · Q2 (d)(ii), (g)(i)

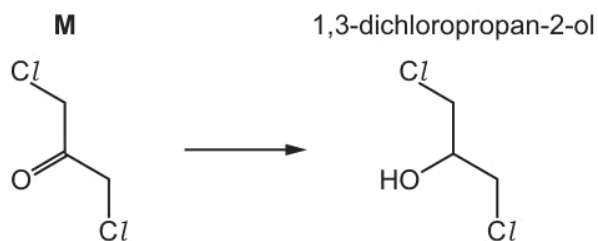
- (e) 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

- (i) Name this type of reaction.

..... [1]

May/June 2021 9701/21 · Q6 (e)(i)

- 4 (a) 1,3-dichloropropan-2-ol can be made by reacting **M**.



- (i) Give the systematic name of **M**.

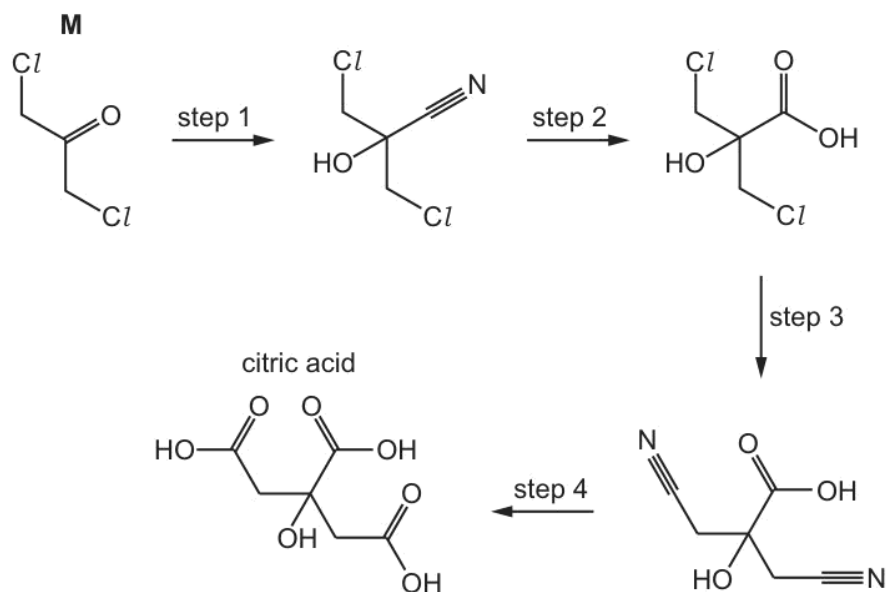
..... [1]

- (iii) State a suitable reagent for this reaction.

..... [1]

May/June 2021 9701/23 · Q4 (a)(i), (a)(iii), (c) (continued ·)

(c) Citric acid can be made from **M** in a four-step reaction.



Complete the table for each step of the reaction sequence to identify:

- the reagents and conditions required
- the type of reaction.

step	reagent and conditions	type of reaction
1		
2	dilute sulfuric acid	
3		
4	dilute sulfuric acid	

[5]

[Total: 12]

May/June 2021 9701/23 · Q4 (a)(i), (a)(iii), (c) (cont.)

- (b) A sample of 2-iodopropane, $\text{CH}_3\text{CH}(\text{I})\text{CH}_3$, reacts under the same conditions as reaction 1 to produce $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$.

Explain why 2-iodopropane reacts at a faster rate than 2-bromopropane.

.....

 [2]

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- (c) Fig. 5.2 shows how butan-1-ol can be made from 1-bromopropane in three steps.



Fig. 5.2

- (i) In step 1, 1-bromopropane reacts with CN^- to form butanenitrile.

Complete Fig. 5.3 to show the mechanism for step 1. Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.

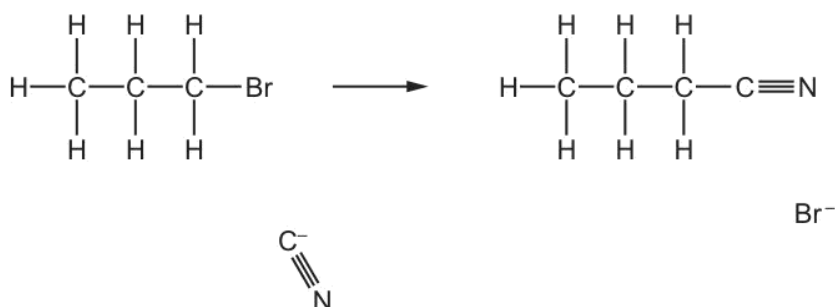


Fig. 5.3

[2]

May/June 2022 9701/22 · Q5 (b), (c)(i)

- (b) Two bottles labelled **Q** and **M** each contain a straight-chain halogenoalkane with molecular formula C_4H_9X , where **X** represents Cl, Br or I.
A sample from each bottle is added to separate samples of equal amounts of aqueous silver nitrate in ethanol. In each reaction, the same organic product, **T**, and a precipitate are made, as shown in Fig. 4.2.



Fig. 4.2

Table 4.1 describes the colour of each of the precipitates made.

Table 4.1

halogenoalkane added to $\text{AgNO}_3(\text{aq})$ in ethanol	colour of precipitate
Q	white
M	yellow

- (i) Identify the functional group present in **T** and name the type of reaction that occurs using the information in Fig. 4.2 and Table 4.1.

functional group in **T**

type of reaction

[2]

- (v) Deduce the structure of the straight-chain halogenoalkane **M**.

[2]

[Total: 12]

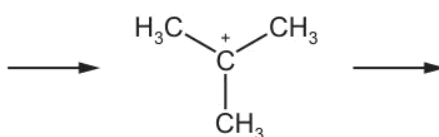
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[Turn over

May/June 2022 9701/23 · Q4 (b)(i), (b)(v) (cont.)

- (e) OH^- (aq) reacts with 2-bromo-2-methylpropane in an $\text{S}_{\text{N}}1$ reaction.
The molecular ion $(\text{CH}_3)_3\text{C}^+$ forms as the intermediate in this reaction.
- (i) Draw the mechanism for the $\text{S}_{\text{N}}1$ reaction of OH^- with 2-bromo-2-methylpropane.
Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.
Draw the structures of the organic reactant and organic product.



[3]

Oct/Nov 2022 9701/22 · Q1 (e)(i)

- (b) NaCl is one product of the reaction of chlorine gas and cold aqueous sodium hydroxide.

Identify the other products.

..... [1]

Oct/Nov 2022 9701/23 · Q3 (b)

- (d) Cl_2 reacts readily with propene to form **K**, 1,2-dichloropropane.

K can be used to form **L**.

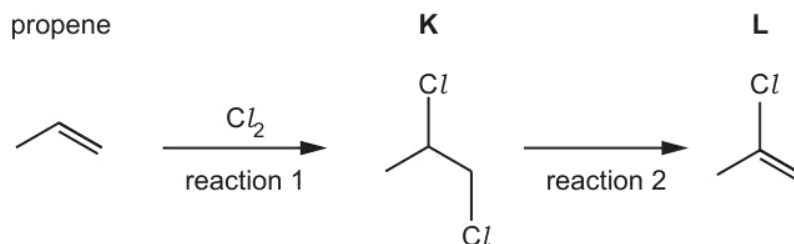


Fig. 2.1

- (i) Complete Fig. 2.2 to show the mechanism for the reaction of Cl_2 with propene in reaction 1.

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

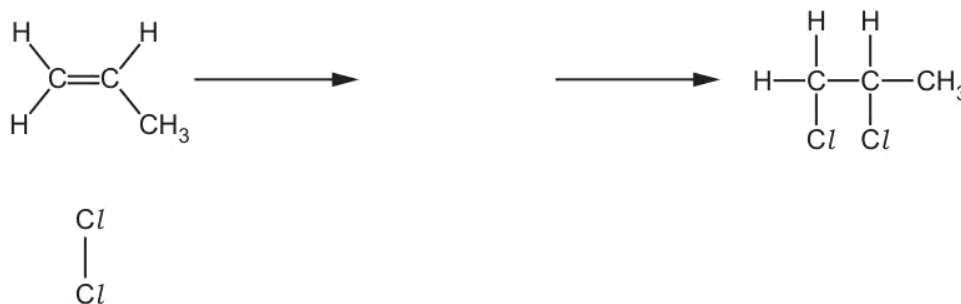


Fig. 2.2

[4]

March 2024 9701/22 · Q2 (d)(i)

- (b) A sample of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ reacts with NaOH to make $\text{CH}_3(\text{CH}_2)_5\text{CH}(\text{OH})\text{CH}_3$ in an $\text{S}_{\text{N}}1$ mechanism.

Complete Fig. 4.1 to show the mechanism for the reaction of $\text{CH}_3(\text{CH}_2)_5\text{CHBrCH}_3$ and NaOH .

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



Fig. 4.1

[3]

- (c) Substitution reactions of NH_3 and OH^- with halogenoalkanes both involve a lone pair of electrons.

(i) Name the role of NH_3 and OH^- in these reactions.

..... [1]

- (d) When 2-bromo-2-methylpropane reacts with OH^- , two mechanisms, $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$, both occur. The $\text{S}_{\text{N}}2$ mechanism has a slower rate.

Fig. 4.1 shows the reaction pathway diagram for the $\text{S}_{\text{N}}1$ mechanism.

Sketch a graph on Fig. 4.1 to show the reaction pathway for the $\text{S}_{\text{N}}2$ mechanism.

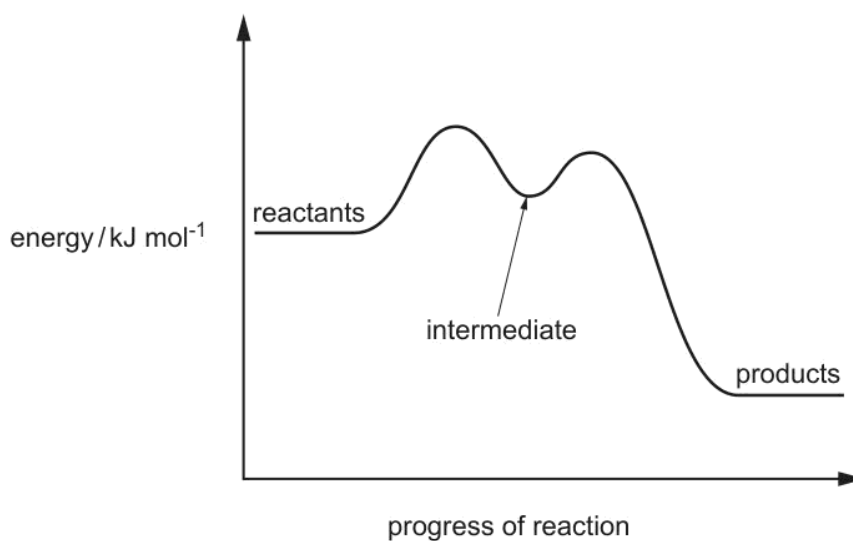


Fig. 4.1

[2]

May/June 2024 9701/23 · Q4 (c)(i), (d), (e)(ii), (f)(i), (f)(ii) (continued ·)

- (e) (i) Complete Fig. 4.2 to show the mechanism for the S_N1 reaction that occurs when $\text{CH}_3\text{CHBrC}_2\text{H}_5$ reacts with NH_3 to produce $\text{CH}_3\text{CH}(\text{NH}_2)\text{C}_2\text{H}_5$. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

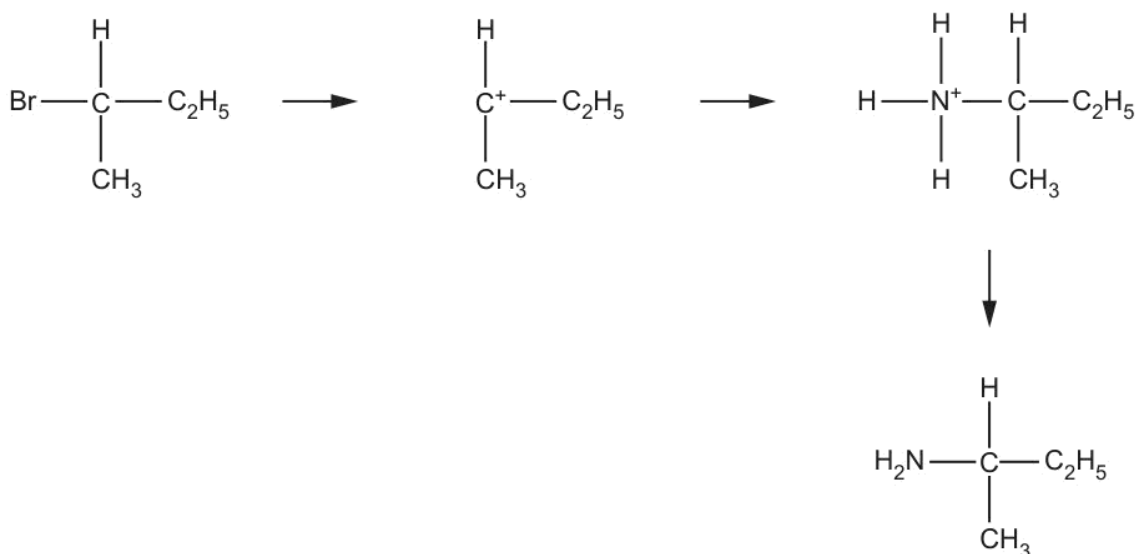


Fig. 4.2

[3]

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- (ii) Identify the inorganic product that forms in the reaction in Fig. 4.2.

..... [1]

- (f) (i) Complete Table 4.1 by drawing the structural formula of the intermediate that is formed when 2-bromo-2-methylpropane reacts in an S_N1 reaction.

Table 4.1

	2-bromobutane	2-bromo-2-methylpropane
structural formula of intermediate in S_N1 reaction	$\begin{array}{c} \text{H} \\ \\ \text{C}^+ - \text{C}_2\text{H}_5 \\ \\ \text{CH}_3 \end{array}$	

[1]

- (ii) Identify the halogenoalkane in Table 4.1 that has the greater tendency to react using the S_N1 mechanism. Explain your answer.

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

[Total: 16]

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[Turn over

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May/June 2024 9701/23 · Q4 (c)(i), (d), (e)(ii), (f)(i), (f)(ii) (cont.)

(c) CHCl_3 is another halogenoalkane. CHCl_3 forms when propanone reacts with NaClO .

NaClO is made from chlorine in a disproportionation reaction.

- (i) Identify a reagent and conditions that can be used to convert chlorine to NaClO .

..... [1]

Oct/Nov 2024 9701/21 · Q2 (c)(i)

- (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

[3]

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- (iii) In reaction 5, compound **B** reacts with an excess of NaOH dissolved in ethanol. The products are HBr, H₂O and an unsaturated hydrocarbon **D**.

Suggest the identity of **D**.

..... [1]

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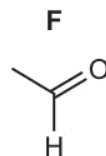
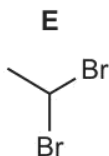
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[Turn over]

- (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]

Oct/Nov 2024 9701/22 · Q4 (a), (c)(iii), (d)(i) (cont.)

- (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]

- (ii) Write an equation for the reaction of aluminium oxide with an excess of aqueous sodium hydroxide.

..... [1]

[Total: 14]

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9701/24/M/J/25

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May/June 2025 9701/24 · Q1 (d)(ii)

- (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]

Oct/Nov 2025 9701/21 · Q4 (a)(iii)

- (b) Propan-2-ol reacts with sodium to produce $(\text{CH}_3)_2\text{CH-O}^-$ anions.

These anions react with 2-bromopropane to form compound **N**, as shown in Fig. 3.3.

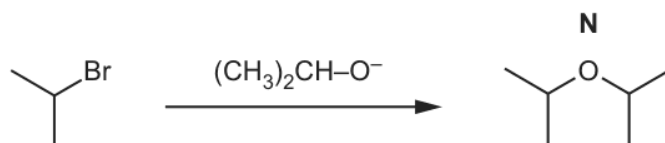


Fig. 3.3

- (i) Write an equation for the reaction of propan-2-ol with sodium.

..... [1]

- (ii) The reaction of 2-bromopropane with $(\text{CH}_3)_2\text{CH-O}^-$ anions follows an $\text{S}_{\text{N}}1$ mechanism.

Complete Fig. 3.4 to show this mechanism. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

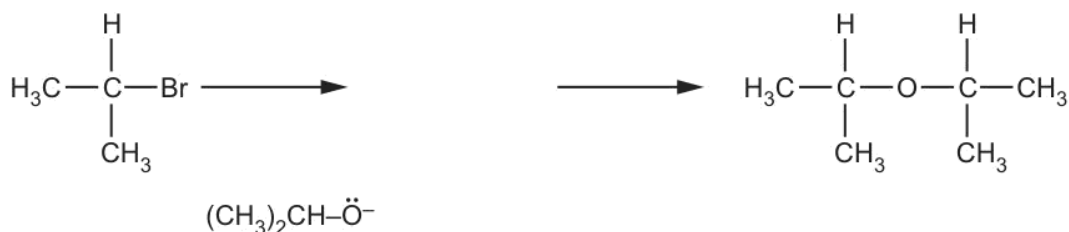


Fig. 3.4

[3]

- (iii) Suggest how the rate of the $\text{S}_{\text{N}}1$ reaction would change, if at all, if 2-chloropropane were used instead of 2-bromopropane.

Explain your answer.

.....

 [2]