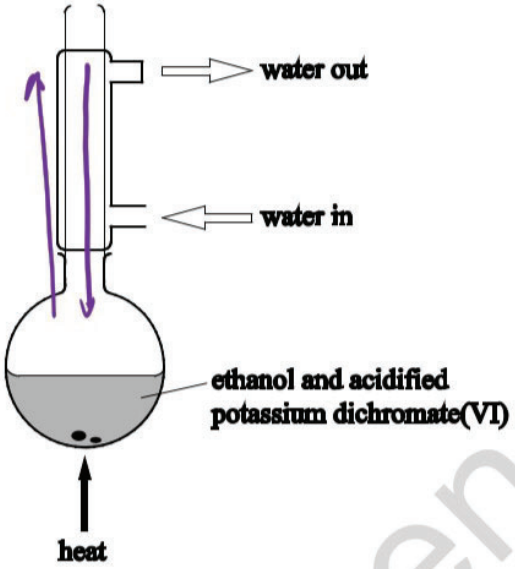
1. Ethanol is oxidised to ethanoic acid using acidified potassium dichromate(IV) solution. The reaction is heated under reflux using the equipment shown in the diagram below.

[O] → aldehyde [O] → ethanoic acid




What is the reason for heating under reflux?

**A** to ensure even heating

**B** to prevent any substances escaping → allows full oxidation

**C** to boil the mixture at a higher temperature

**D** to allow efficient mixing

Your answer **B**

2. $CN^-$ ions react with haloalkanes and with carbonyl compounds.

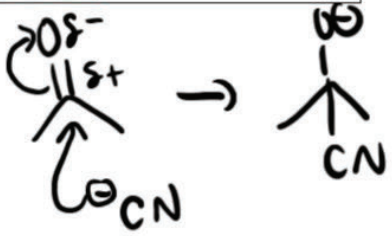
E = e⁻ pair acceptor = ⊕
Nu = e⁻ pair donor = ⊖

Which row gives the correct mechanisms for the reactions?

⊖C≡N
↳Nu

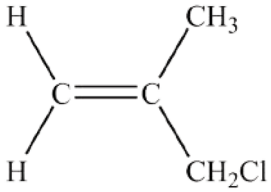
| | Reaction of $CN^-$ with haloalkanes | Reaction of $CN^-$ with carbonyl compounds |
|---|---|---|
| A | Electrophilic substitution | Electrophilic addition |
| B | Electrophilic substitution | Nucleophilic addition |
| C | Nucleophilic substitution | Electrophilic addition |
| D | Nucleophilic substitution | Nucleophilic addition |

Your answer D


[1]

3. Methyl allyl chloride, MAC, is a chemical used in the production of insecticides. The structure of MAC is shown below.

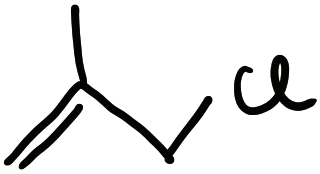


**MAC**

Give the **molecular** formula of MAC.

$C_4H_7Cl$ ..... **[1]**

Draw the **skeletal** formula of MAC.



example of skeletal formula showing the C-C backbone. **[1]**

MAC has several structural isomers.

State what is meant by *structural isomers*.

compounds with the same molecular formulae but different structural formulae. **[1]**

MAC is highly flammable. When MAC burns, one of the products formed is a toxic gas.

1.321 g of this gas occupies 1.053 $dm^3$ at 100 kPa (100000 Pa) and 350 K ($1.053 \times 10^{-3}$ $m^3$).

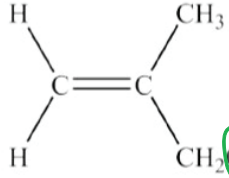
$PV = nRT$ $\quad Mr = \frac{m}{n}$

$n = \frac{PV}{RT}$ ($R = 8.314\ JK^{-1}mol^{-1}$ (data sheet))

$n = \frac{100000 \times 1.053 \times 10^{-3}}{8.314 \times 350}$

$n = 0.0362$ mol

Use the information provided to suggest the identity of the gas.



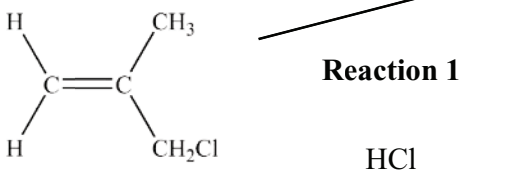
MAC

$Mr = \frac{1.321}{0.0362} = 36.5$

HCl = 1 + 35.5 = 36.5

gas = HCl ..... **[4]**

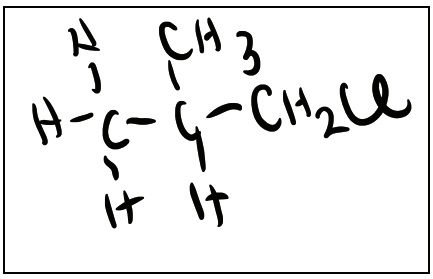
The flowchart below shows some reactions of MAC.




**MAC**

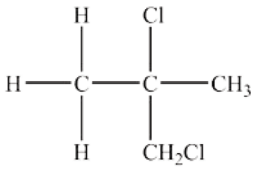
$H_2$ / Ni

**Reaction 1**

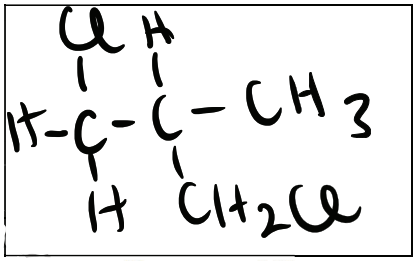


HCl

**Reaction 2**




+



**Compound A**
(major product)

**Compound B**
(minor product)

Complete the flowchart above.

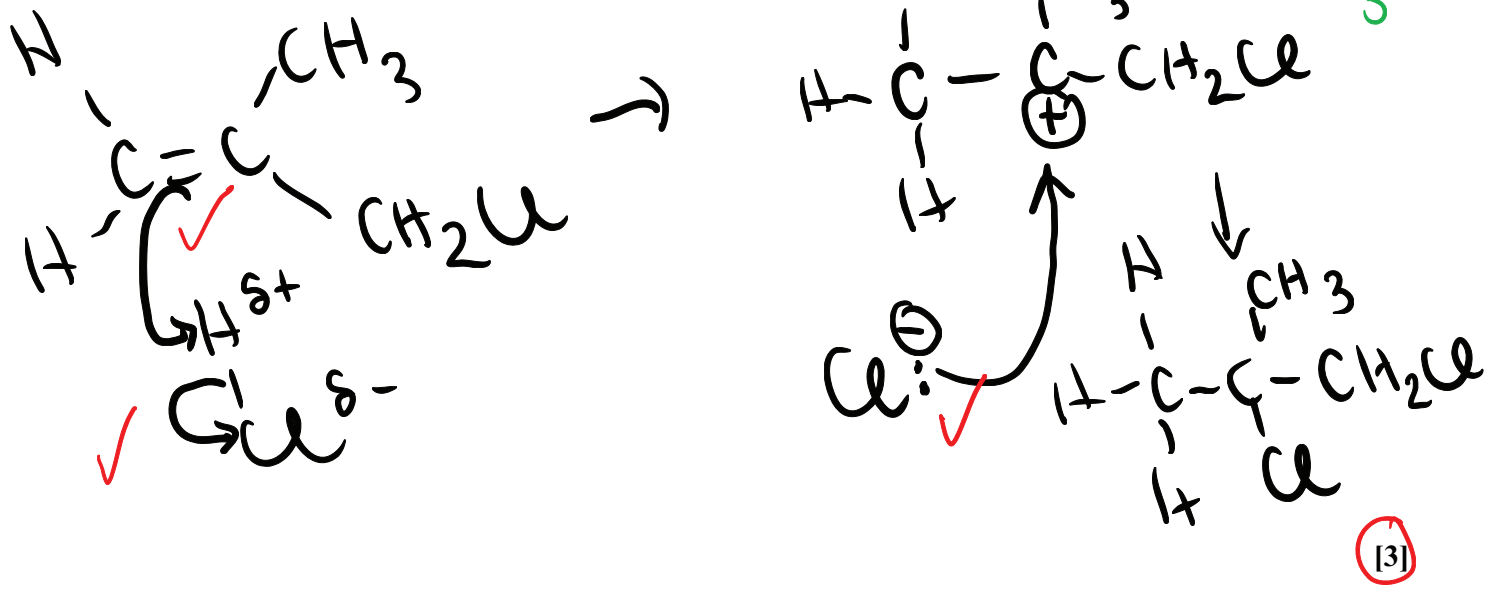
- Draw the structure of the product of **Reaction 1**.
- Draw the structure of the minor organic product of **Reaction 2** (Compound **B**).

**[2]**

**Reaction 2** creates a mixture of compounds. Compound **A** is the major product.

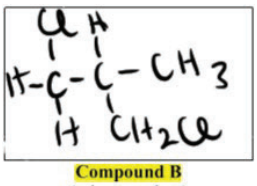
Draw the mechanism for the formation of compound **A**.

Use curly arrows and show relevant dipoles.



**[3]**

Explain why compound **B** is the minor product of **Reaction 2**.



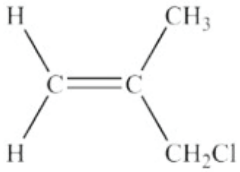
Compound B
(minor product)

Because it had the least stable carbocation intermediate. [1]

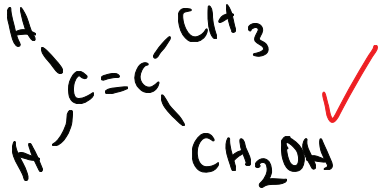
**MAC** reacts with water in the presence of $AgNO_3(aq)$ and ethanol.

Draw the structure of the organic product of this reaction.

State what you would **observe** in this reaction and identify the compound responsible for the observation.



**MAC**

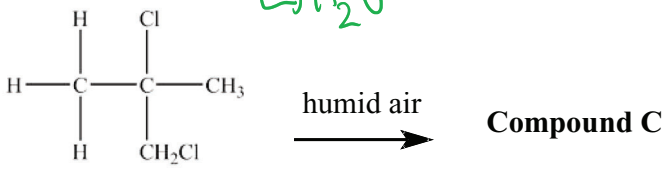


$Cl^{\ominus}$

white precipitate → AgCl (s) ✓

[2]

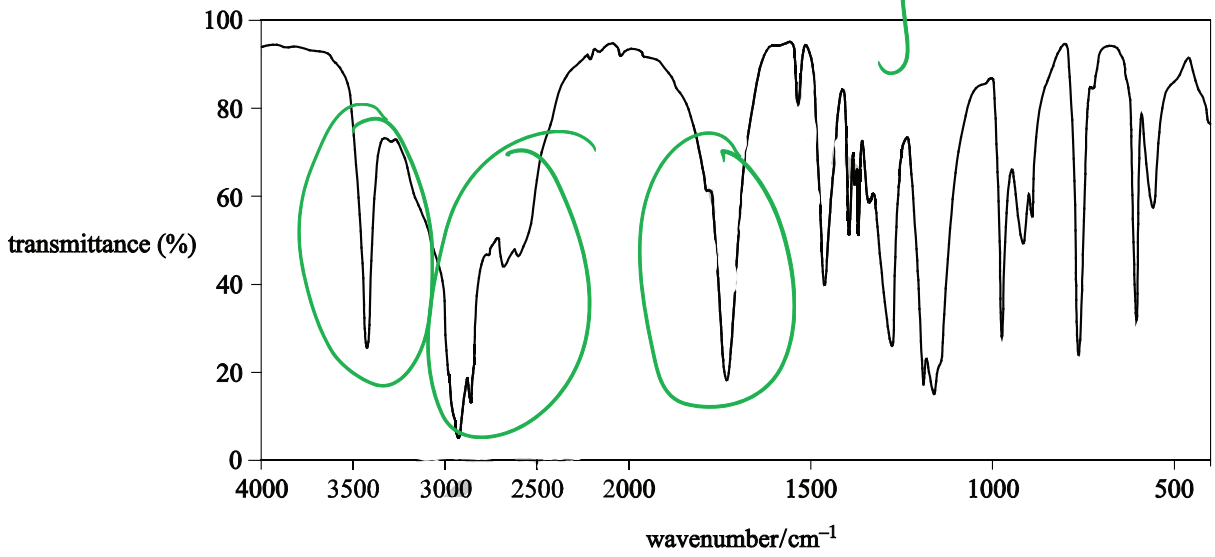
Compound **A** reacts slowly in humid conditions to form compound **C**.




**Compound A**

Compound **C** contained the following percentage composition by mass:
C, 46.1%; H, 7.7%; O, 46.2%

The infrared spectrum of compound **C** is shown below.



Using the information on the previous page, deduce the structure of compound **C**.

$n = \frac{m}{A_r}$

Give your reasoning.

| | C | H | O |
|---|---|---|---|
| % | 46.1 | 7.7 | 46.2 |
| n | $\frac{46.1}{12} = 3.84$ | $\frac{7.7}{1} = 7.7$ | $\frac{46.2}{16} = 2.89$ |
| ratio | 1.33 : | 2.66 : | 1 ✓ |
| → x3 | 4 : | 8 : | 3 |

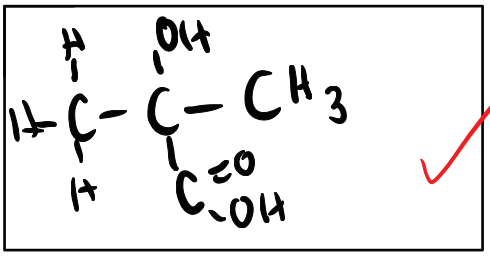
$C_4H_8O_3$ ✓

3450 $cm^{-1}$ = OH alcohol ✓

2500 - 3300 $cm^{-1}$ broad absorption OH → –C(=O)(OH)

1640 - 1750 $cm^{-1}$ = C=O → C(=O)OH

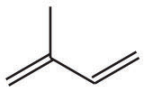
structure =



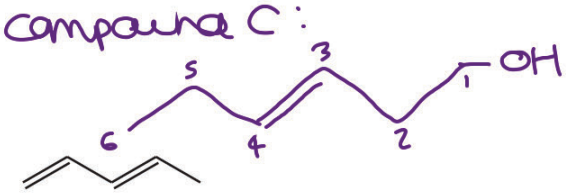
[5]

4. This question is about unsaturated hydrocarbons.

**(a)** Compound **A** and compound **B** are isomers.



**compound A**




**compound B**

Compound **A** has a lower melting point than compound **B**.

Suggest why.

Compound A is branched meaning it has fewer points of contact and weaker london forces which require less energy to break.

**[2]**

**(b)** Compound **C**, $CH_3CH_2CH{=}CHCH_2CH_2OH$, exists as *cis* and *trans* stereoisomers.

**(i)** Name compound **C**.

Hex-3-en-1-ol

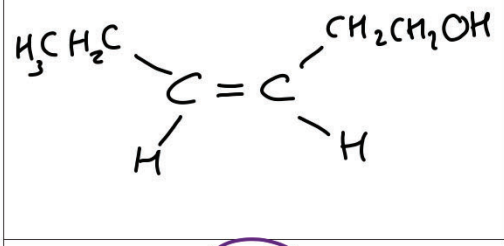
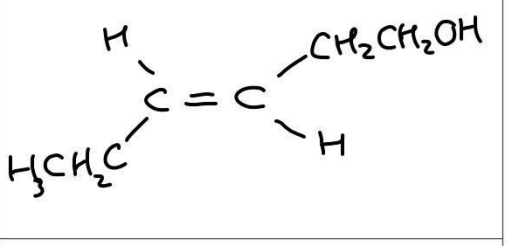
**[1]**

**(ii)** Define the term *stereoisomers*.

same structural formula but a different spatial arrangement of atoms.

**[1]**

**(iii)** Draw the structures of the *cis* and *trans* stereoisomers of compound **C**.

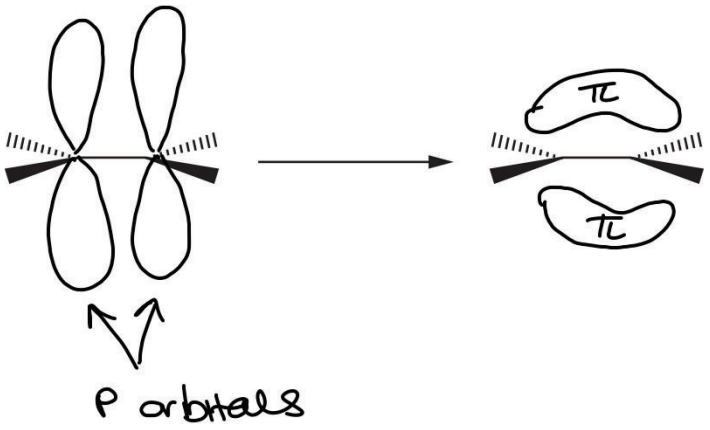
| | |
|---|---|
|  |  |
| *cis* | *trans* |

H on same side of C=C

**[2]**

**(c)** The C=C group in an alkene contains a π-bond.

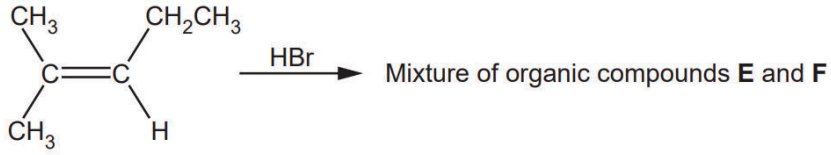
Complete the diagram below to show how p-orbitals are involved in the formation of a π-bond.




**[1]**

a π bond is the sideways overlap of p orbitals.

**(d)** Compound **D**, shown below, reacts with hydrogen bromide by electrophilic addition. A mixture of two organic compounds, **E** and **F**, is formed.




**compound D**

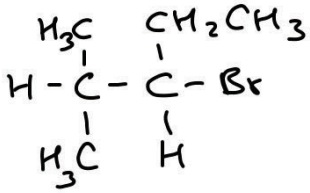
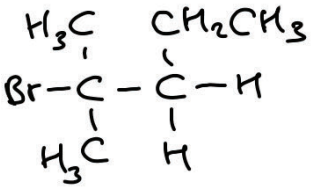
**(i)** Suggest how an HBr molecule can act as an electrophile.

electron pair acceptor

HBr accepts a pair of electrons

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

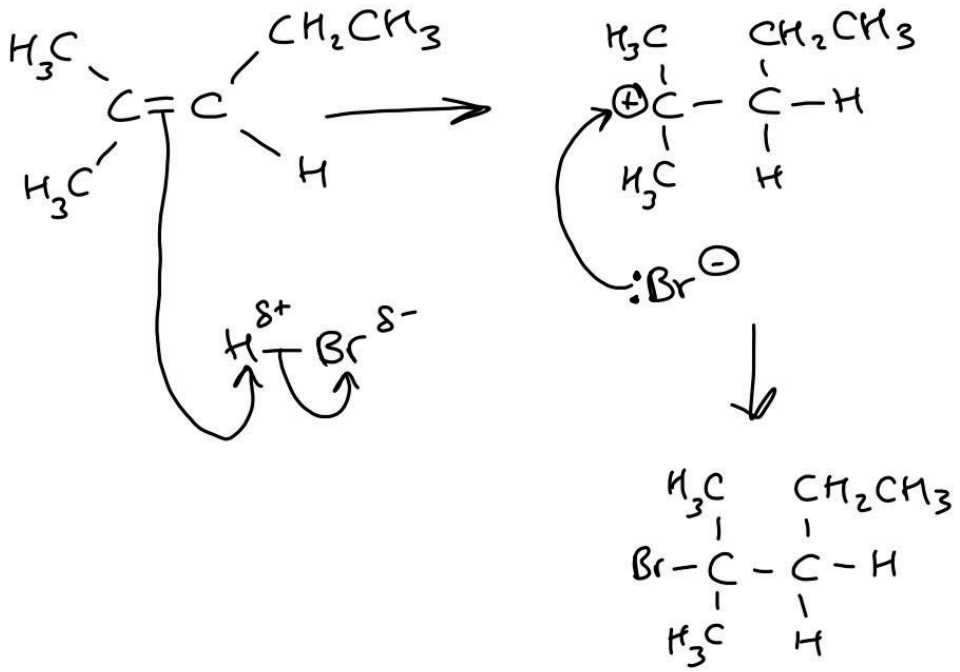
**(ii)** Draw the structures of the two organic compounds **E** and **F**.

| | |
|---|---|
|  |  |
| **E** | **F** |

**[2]**

**(iii)** Outline the mechanism of the reaction between compound **D** and hydrogen bromide to form **either** compound **E or** compound **F**.

Include curly arrows and relevant dipoles.



**[3]**

**(iv)** Which of **E** or **F** is the major organic product?

Explain your answer.

Major organic product ....F.....

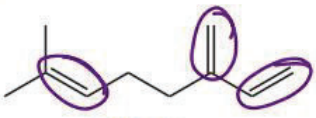
Explanation ....reaction goes via the most stable carbocation intermidiate.....

.....

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

**(e)** Myrcene, $C_{10}H_{16}$, is a naturally occurring hydrocarbon containing more than one carbon-carbon double bond.

$mol = \frac{vol\ (cm^3)}{24000\ cm^3}$



myrcene

3 double bonds so 1:3 molar ratio needed

**(i)** Reaction of 204 mg of myrcene with hydrogen gas produces a saturated alkane.

Calculate the volume of hydrogen gas, in $cm^3$ and measured at RTP, needed for this reaction.

Show your working.

$$\text{moles of myrcene} = \frac{204 \times 10^{-3}}{((12 \times 10) + 16)} = 1.5 \times 10^{-3}\ mol$$

$$1.5 \times 10^{-3} \times 3 = 4.5 \times 10^{-3}\ mol$$

$$4.5 \times 10^{-3} \times 24000 = 108\ cm^3$$

volume = 108 $cm^3$ **[2]**

**(ii)** β-Carotene is a naturally occurring unsaturated hydrocarbon found in carrots.
A β-carotene molecule contains 40 carbon atoms, has two rings, and a branched chain.

0.0200 mol of β-carotene reacts with 5.28 $dm^3$ of hydrogen gas to form a saturated hydrocarbon.

Using molecular formulae, construct a balanced equation for this reaction.

Include relevant calculations and reasoning.

$$\frac{5.28}{24} = 0.22\ mol\ \text{of}\ H_2$$

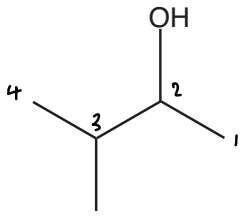
$$\frac{0.22}{0.02} = 11 \rightarrow 11\ \text{double bonds}$$

$C_{40}H_{78}$

Equation $C_{40}H_{56} + 11H_2 \rightarrow C_{40}H_{78}$ **[4]**

5. This question is about reactions of organic compounds containing carbon, hydrogen and oxygen.

**(a)** A chemist investigates two reactions of alcohol **A**, shown below.




**alcohol A**

**(i)** What is the systematic name of alcohol **A**?

3-methylbutan-2-ol ..... **[1]**

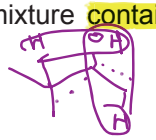
**(ii)** What is the structural formula of alcohol **A**?

$(CH_3)_2CHCHOHCH_3$ ..... **[1]**

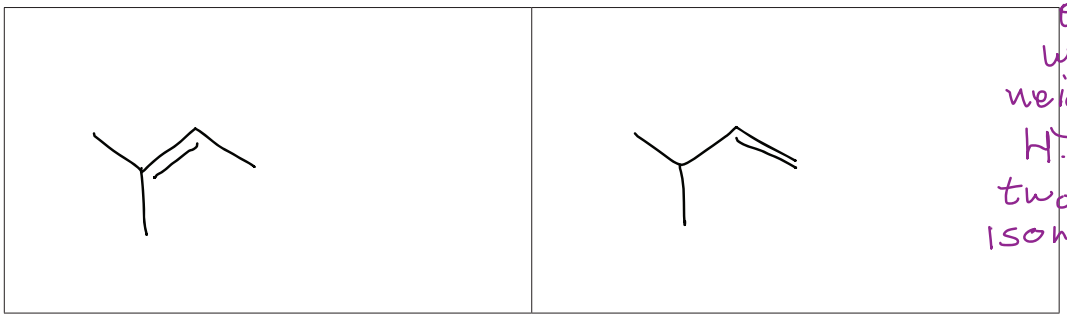
**(iii)** The chemist heats alcohol **A** with an acid catalyst to form a mixture containing **two** alkenes.

elimination reaction

Draw the structures of the **two** alkenes formed in this reaction.



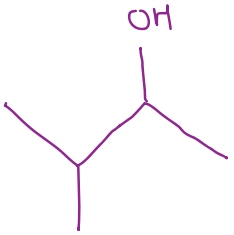
OH is eliminated with either neighbouring H. Forming two structural isomers.

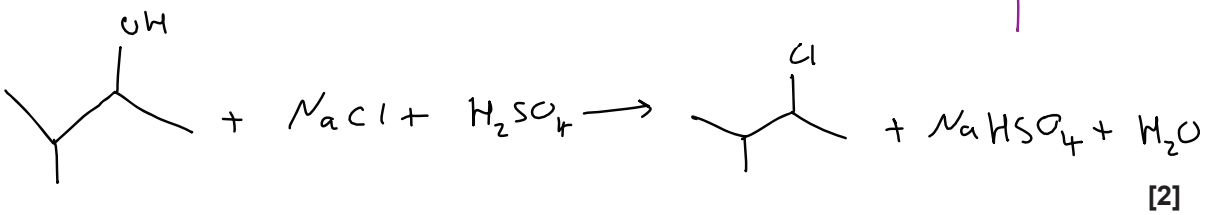


**[2]**

**(iv)** The chemist heats alcohol **A** with sodium chloride and sulfuric acid.

Construct a balanced equation for this reaction.
Show structures for the organic compounds in your equation.



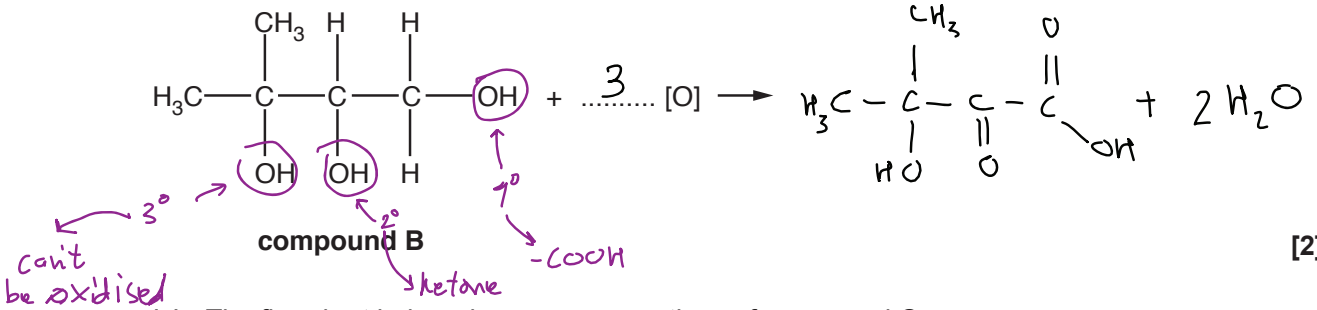



**[2]**

oxidising agent

**(b)** Compound **B**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product.

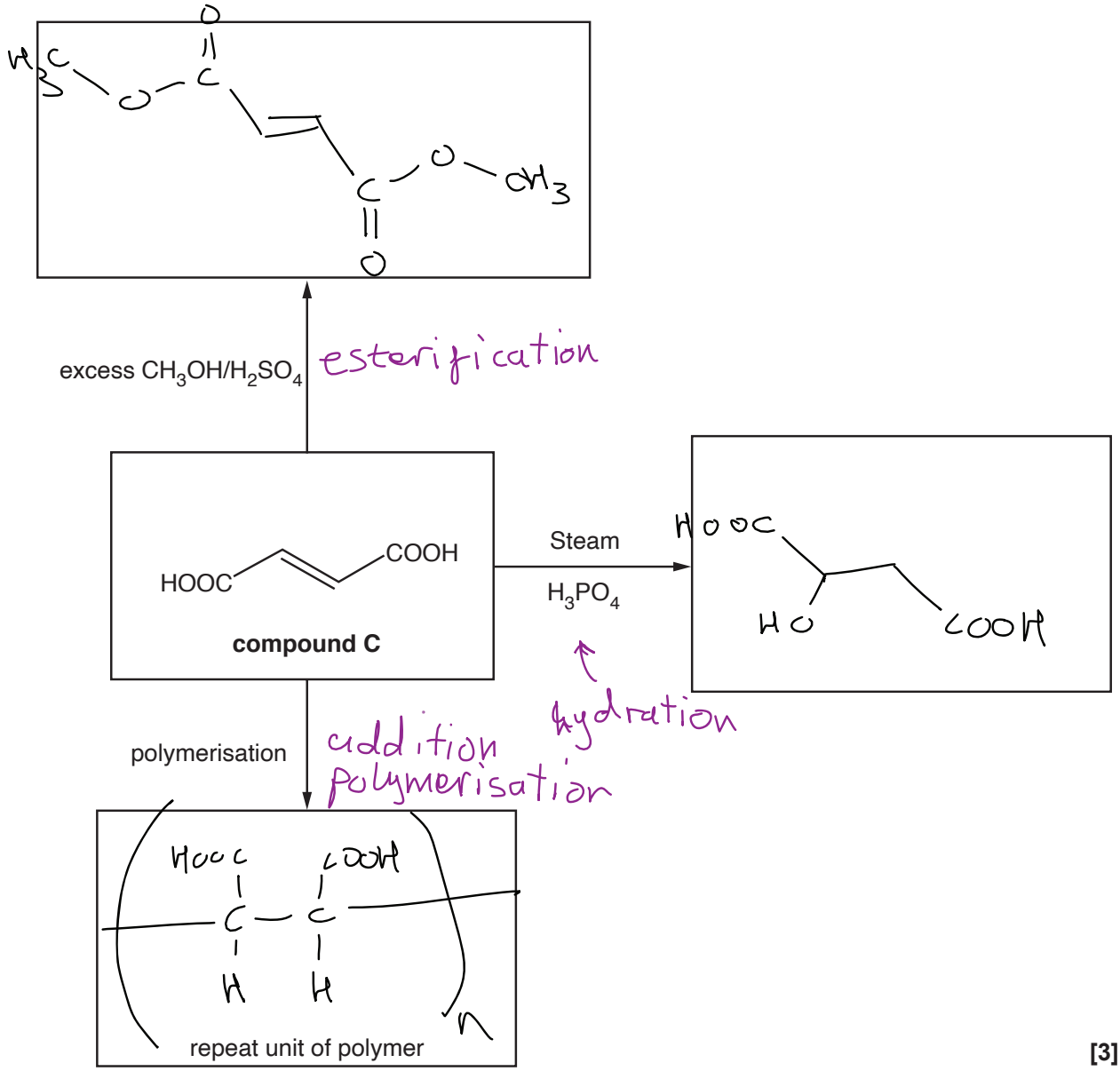
Complete the equation for this reaction.




**[2]**

**(c)** The flowchart below shows some reactions of compound **C**.

In the boxes, draw the organic products of these reactions.




**[3]**