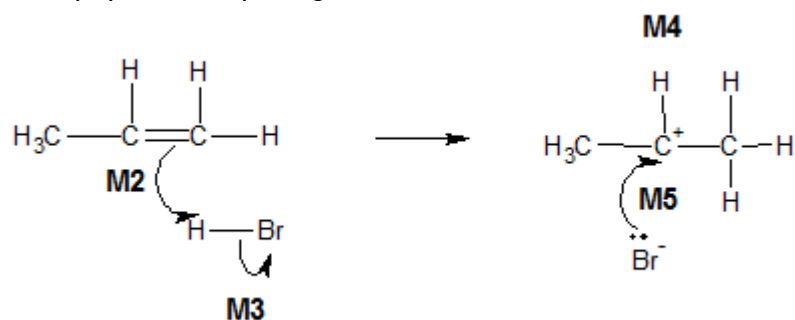


M1.(a) M1 electrophilic addition

For M1, both words required

Accept phonetic spelling



For the mechanism

M2 Ignore partial negative charge on the double bond

M2 must show an arrow from the double bond towards the H atom of the H-Br molecule

M3 Penalise partial charges on H-Br bond if wrong way and penalise formal charges

M3 must show the breaking of the H-Br bond

Penalise once only in any part of the mechanism for a line and two dots to show a bond

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom

Maximum any 3 of 4 marks for the mechanism for wrong (organic) reactant OR wrong organic product (if shown) OR primary carbocation

Accept the correct use of sticks

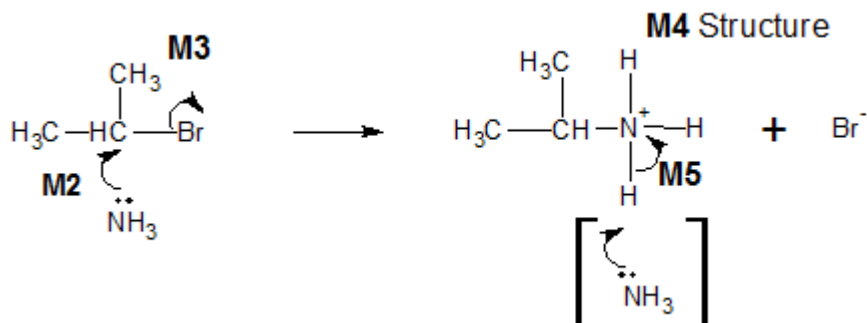
NB These are double-headed arrows

5

(b) M1 Nucleophilic substitution

For M1, both words required

Accept phonetic spelling



For the mechanism

Penalise **M2** if NH_3 is negatively charged

M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom

Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br

Penalise **M3** for an additional arrow from the Br to something else

M3 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark **M3** independently provided it is from their original molecule

The second mole of ammonia is not essential for **M5**; therefore ignore any species here

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on / or close to, the N atom

Penalise once only for a line and two dots to show a bond

M5 is for an arrow from the N-H bond to the N atom

Maximum any 3 of 4 marks for the mechanism for wrong organic reactant **OR** wrong organic product if shown

Award full marks for an $\text{S}_{\text{N}}1$ mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

Accept the correct use of "sticks"

NB These are double-headed arrows

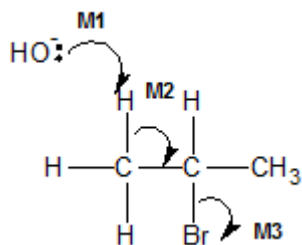
5

- (c) M1 (addition) polymerisation OR poly-addition
Ignore "additional"
Credit polyprop-1-ene and polypropylene

M2 poly(propene) / polypropene
Penalise "condensation polymerisation"

2

(d)



Penalise M1 if covalent KOH

M1 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

Penalise M3 for formal charge on C of C-Br or incorrect partial charges on C-Br.

M2 must show an arrow from a correct C-H bond adjacent to the C-Br bond to the appropriate C-C bond. Only award if an arrow is shown attacking the H atom of a correct C-H bond in **M1**

Ignore other partial charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond

M3 is independent provided it is from their original molecule, but **CE=0** if **nucleophilic substitution**

Maximum any 2 of 3 marks for wrong organic reactant

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

NB These are double-headed arrows

3

[15]

M2. (a) **M1 Safety (in Process 1)**

Sodium hydroxide / alkali is corrosive / harmful / caustic or sodium hydroxide is alkali(ne)

Ignore references to chromium compounds

OR

Bromine compounds are toxic / poisonous

"Carbon-neutral" alone is insufficient for M2

M2 Environmental

Ignore references to greenhouse gases

Process 2 could be used as a carbon sink / for carbon capture

OR

uses waste / recycled CO₂ / CO₂ from the factory / CO₂ from the bioethanol (or biofuel) production

OR

reduces or limits the amount of CO₂ released / given out (into the atmosphere)

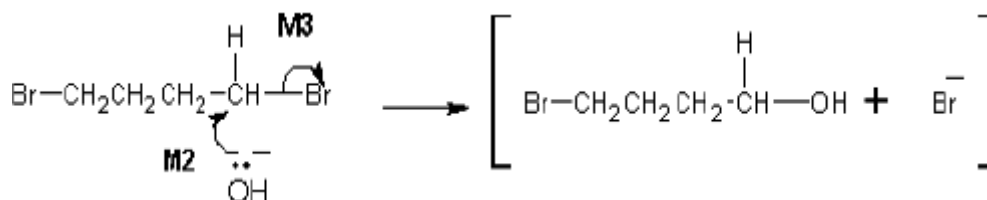
OR

Process 2 uses renewable glucose / renewable resource(s)

2

(b) (i) M1 nucleophilic substitution

For M1, both words required



M2 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom.

Penalise M2 if covalent NaOH / KOH is used

Penalise one mark from M2 or M3 if half-headed arrows are used

M3 must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from the original molecule

Penalise M3 for formal charge on C of the C–Br or incorrect partial charges on C–Br

Penalise once only for a line and two dots to show a bond.

For **M2** and **M3** award full marks for an S_N1 mechanism

For M2 and M3, maximum 1 of 2 marks for the mechanism if wrong reactant is used.

Penalise M3 if an extra arrow is drawn from the Br of the C–Br bond to, for example, K⁺

Accept the correct use of “sticks

NB The arrows here are double-headed

3

- (ii) **M1** B
M2 C
M3 A

3

- (c) **M1** fermentation

*Mark **M2** to **M4** independently*

Three conditions in any order for M2 to M4

Penalise "bacteria" and "phosphoric acid" using the list principle

M2 (enzymes from) yeast or zymase

M3 $25^{\circ}\text{C} \leq T \leq 42^{\circ}\text{C}$ OR $298\text{ K} \leq T \leq 315\text{ K}$

Ignore reference to "aqueous" or "water", "closed container", "pressure, "lack of oxygen", "concentration of ethanol" and "batch process" (i.e. not part of the list principle)

M4 anaerobic / no oxygen / no air OR neutral pH

4

- (d) **M1** primary OR 1° (alcohol)

Mark independently

M2 acidified potassium or sodium dichromate

*For **M2**, it must be a whole reagent and/or correct formulae*

OR $\text{H}_2\text{SO}_4 / \text{K}_2\text{Cr}_2\text{O}_7$ OR $\text{H}^+ / \text{K}_2\text{Cr}_2\text{O}_7$

Do not penalise incorrect attempt at formula if name is correct or vice versa

Accept phonetic spelling

If oxidation state given in name, it must be correct.

*For **M2** accept acidified potassium manganate(VII)*

OR correct combination of formula and name

M3



*For **M3** structures must be correct and not molecular formula*

3

[15]

M3. (a) (i) Electron pair donor

OR

Species which uses a pair of electrons to form a co-ordinate/covalent bond.

Credit "lone pair" as alternative wording

Credit "electron pair donator"

1

(ii) Replacement of the halogen (atom) (by the nucleophile)

OR

The carbon-halogen bond/C-X breaks and a bond forms with the nucleophile or between the carbon and the nucleophile

They must describe the idea of substitution in a haloalkane.

Accept the idea that a nucleophile replaces the halogen which becomes a halide ion

Penalise reference to "halogen molecule" and penalise the idea that the haloalkane contains a halide

1

(iii) Splitting molecules using/by water

OR

breaking/splitting/dissociating (C_iVX) bond(s)/using/by water

NOT simply the reaction with water or simply the addition of water.

Ignore "compound"

1

(iv) (Heat) energy/enthalpy required/needed/absorbed (at constant pressure) to break/split it/the (carbon-halogen) bond

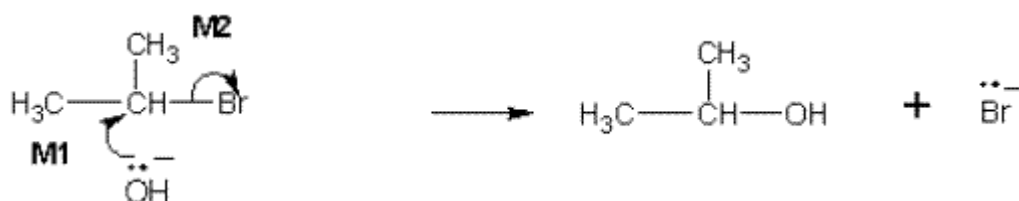
OR

(Heat) energy/enthalpy required/needed/absorbed (at constant pressure) for homolysis of the (C-X/the carbon-halogen) bond

Ignore bond formation

Ignore "average"

(b)



M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

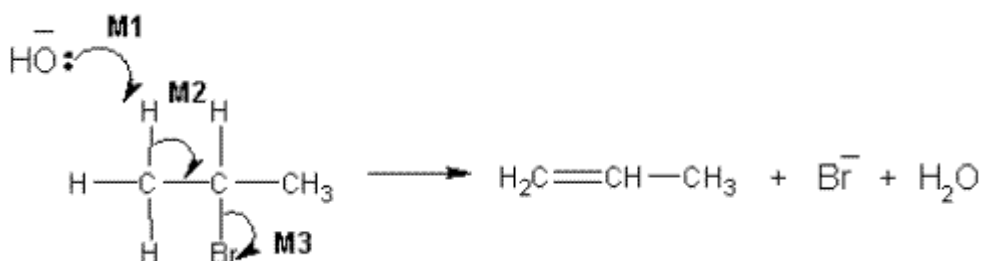
Penalise once only for a line and two dots to show a bond.

Max 1 mark for the wrong reactant

Accept the correct use of "sticks"

2

(c) (i)



M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 is independent provided it is from the original molecule

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks for wrong reactant

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

3

(ii) **M1** Stated that the spectrum has an absorption/absorbance/peak in the range 1620 cm⁻¹ to 1680 (cm⁻¹) or specified correctly in this range from the spectrum

M2 depends on correct range or wavenumber being specified

M2 (Infrared absorption) due to C=C OR carbon-carbon double bond
QoL for correct M1 statement which includes both the word absorption (or alternative) and the correct range or wavenumber

Allow "peak" OR "dip" OR "spike" OR "trough"

OR "low transmittance" as alternatives for absorption.

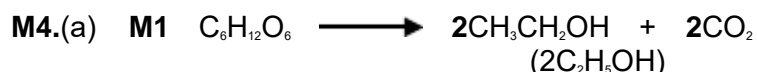
For M2 it is not sufficient simply to state that an alkene has C=C

M2 could be on the spectrum

Ignore reference to other absorptions

2

[11]

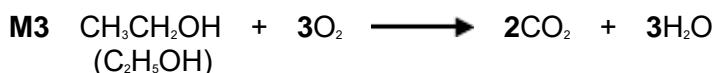


Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise C_2H_5O once only

M2 fermentation



M4 A specified process e.g. planting / harvesting / transport / extracting sugar / distilling ethanol solution / fertiliser production etc.

M5 The specified process uses / burns (fossil) fuel that releases CO₂
For M5, "releases / increases carbon emissions" is insufficient as an alternative to releases CO₂

5

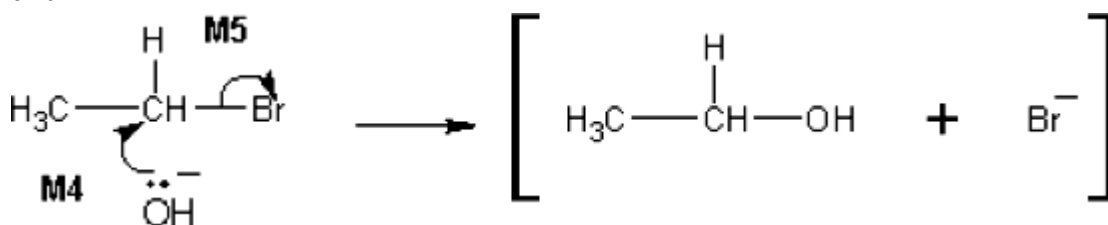
(b) **M1** sodium or potassium hydroxide / NaOH / KOH
Mark on to M2 from hydroxide ion

M2 **depends on correct M1**
Ignore OH if KOH/ OH

warm / heat / reflux and aqueous or (aq) or water
For M2 ignore "dilute"
For M2 penalise T > 100 °C

M3 nucleophilic substitution

Acidified KOH/NaOH or H₂SO₄ with KOH/NaOH loses M1 and M2



For M3, both words required

NB The arrows here are double-headed

M4 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom.

Penalise M4 if covalent NaOH / KOH is used

Penalise one mark from M4 or M5 if half-headed arrows are used

M5 must show the movement of a pair of electrons from the

C— Br bond to the Br atom. Mark M5 independently provided it is from their original molecule.

Penalise M5 for formal charge on C of the C—Br or incorrect partial charges on C—Br

Penalise once only for a line and two dots to show a bond.

For M4 and M5, award full marks for an S_N1 mechanism

For M4 and M5, maximum 1 of 2 marks if wrong reactant is used.

Penalise M5 if an extra arrow is drawn from the Br of the C—Br bond to, for example, K⁺

Do not penalise the use of "sticks"

M6 One statement from

- The yield is (very) low / not a high yield OR elimination occurs / ethene formed
- The rate of reaction slow
- Bromoethane has to be manufactured / made first
- Bromoethane is expensive

For M6 ignore references to other costs and expenses

6

- (c) **M1** concentrated phosphoric acid / conc. H_3PO_4 **OR** concentrated sulfuric acid / conc. H_2SO_4

Answers in any order

Ignore reference to support medium in M1

M2 hydration or (electrophilic) addition

For M3 and M4 any two from

Do not apply the list principle to these three chosen criteria in M3 and M4

- Excess ethene
OR Excess steam / water / H_2O
OR remove the ethanol as it forms
OR recycle the ethene
- Specified Pressure
 $50 \text{ atm} \leq P \leq 100 \text{ atm}$
OR $5000 \text{ kPa} \leq P \leq 10000 \text{ kPa}$
OR $5 \text{ MPa} \leq P \leq 10 \text{ MPa}$
- High Temperature unless they give a value that is not in the ranges given here;
OR $300 \text{ }^\circ\text{C} \leq T \leq 600 \text{ }^\circ\text{C}$
OR $570 \text{ K} \leq T \leq 870 \text{ K}$

Accept a reference to "low temperature" if they specify a correct temperature range or a correct temperature in the range

4

[15]

