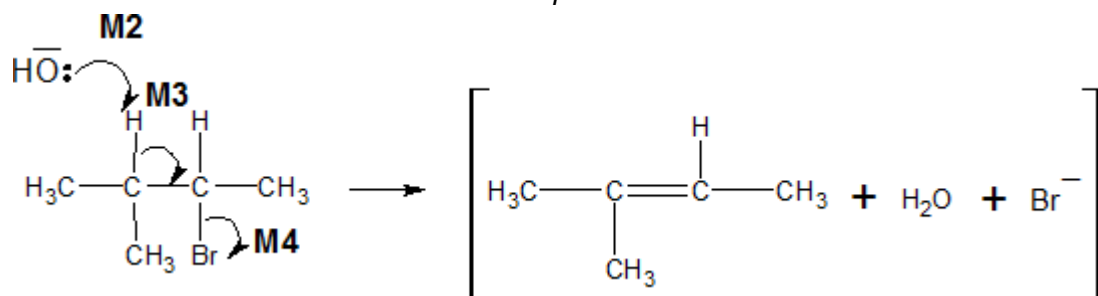


M1.(a) (i) M1 Elimination

M1 Credit "base elimination" but no other prefix.



Penalise **M2** if covalent KOH

Penalise **M4** for formal charge on C or Br of C-Br or incorrect partial charges on C-Br

M2 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

Ignore other partial charges

M3 must show an arrow from a correct C-H bond adjacent to the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M2**

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

M4 is independent provided it is from their original molecule, **BUT CE=0 for the mechanism (penalise M2, M3 and M4 only) if nucleophilic substitution mechanism is shown**

Maximum any 2 of 3 marks for the mechanism for wrong organic reactant or wrong organic product (if shown).

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

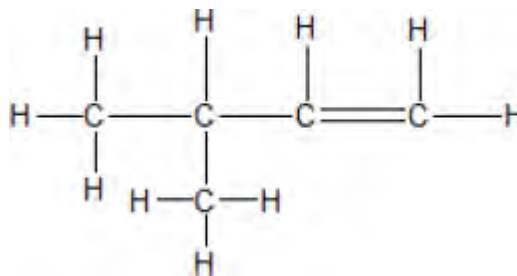
Award full marks for an E1 mechanism in which **M4** is on the correct carbocation

*Penalise **M4**, if an additional arrow is drawn from Br eg to K⁺*

NB These are double-headed arrows

4

(ii) Displayed formula for 3-methylbut-1-ene



All bonds and atoms must be drawn out, but ignore bond angles

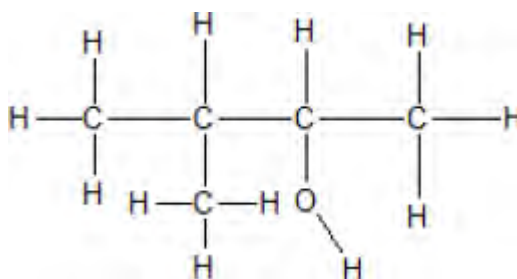
1

(iii) Position(al) (isomerism or isomer)

Penalise any other words that are written in addition to these.

1

(b) (i) Displayed formula for 3-methylbutan-2-ol



All bonds and atoms must be drawn out, but ignore bond angles.

1

(ii) Any **one** from

- Lower / decreased temperature **OR** cold
- Less concentrated (comparative) **OR** dilute KOH
- Water (as a solvent) / (aqueous conditions)
Ignore "pressure".

1

(iii) Nucleophilic substitution

Both words needed - credit phonetic spelling.

1

- (iv) (Strong / broad) absorption / peak in the range **3230 to 3550** cm⁻¹ or specified value in this range or marked correctly on spectrum
Allow the words “dip” OR “spike” OR “trough” OR “low transmittance” as alternatives for absorption.

1
[10]

M2. Compare spectrum of aldehyde with known spectrum of pentanal
Must be a specific reference to a comparison.

1

Exact match

Allow ‘fingerprint regions match exactly’.

1
[2]

M3. (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

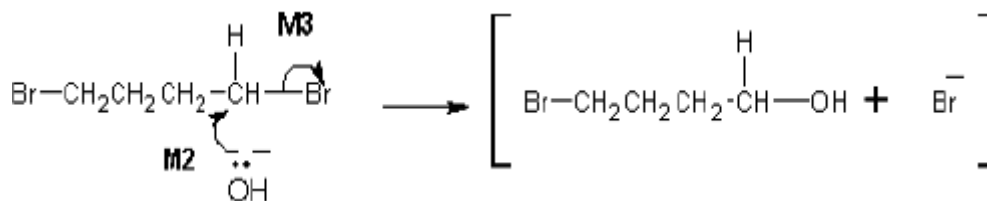
OR

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

OR

Process 2 uses renewable glucose / renewable resource(s)

- (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

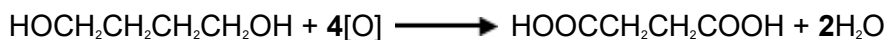
Accept phonetic spelling

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]

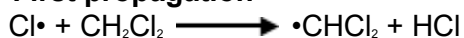
M4. (a) (i) **M1 Initiation**



Penalise absence of dot once only.

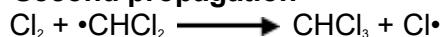
Penalise + or – charges every time

M2 First propagation



Accept dot anywhere on CHCl_2 radical but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only

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

M3 Second propagation

Penalise once only for double headed curly arrows

Mark independently

3

(ii) **M1 Condition**

ultra-violet / uv / sun light

OR high temperature

OR $400^\circ\text{C} \leq T \leq 900^\circ\text{C}$

M2 Type of mechanism

(free-) radical substitution (mechanism)

2



Allow X as alternative to CCl₄ only if X is clearly identified as CCl₄

1

(ii) **M1** Trichloromethane / CHCl₃ has a C–H bond

OR

X / CCl₄ / it has no C–H bond

M1 *must refer to presence or absence of the C–H bond in a compound*

M2 The infrared spectrum shows

(absorption / peak for C–H in range) **2850 to 3300** (cm⁻¹) is missing

M2 *answer must refer to / imply the spectrum*

Allow the words “dip” OR “spike” OR “low transmittance” as alternatives for absorption.

Ignore references to other absorptions.

2

(c) **M1 a statement about bond breakage / formation of Cl•**

C–Cl / carbon-chlorine bond breakage occurs

OR Cl• / chlorine (free) radical forms

OR correct equation $\text{CHClF}_2 \longrightarrow \text{Cl}\cdot + \cdot\text{CHF}_2$

Penalise M1, if Cl• is formed from Cl₂ as the only reaction or an additional reaction

Do not penalise an incorrect equation using CHClF₂ if correct

reference is made to $\text{Cl}\cdot$ formation or $\text{C}-\text{Cl}$ / carbon-chlorine bond breakage



M2 and M3 either order

Penalise absence of dot once only.

Accept dot anywhere on ClO radical

M4 CHClF_2 / chlorine-containing compounds/ CFCs damage/ react with/ decrease the ozone layer

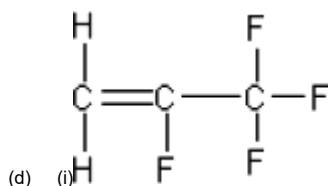
OR this overall decomposition occurs; $2\text{O}_3 \longrightarrow 3\text{O}_2$ **OR** without an ozone layer or with a decreased ozone layer, uv radiation is not being "filtered" / prevented from passing through the atmosphere or there is a concern about an increase in skin cancer etc. **OR** $\text{Cl}\cdot$ catalyses the decomposition of ozone / a single $\text{Cl}\cdot$ causes (chain) reaction / decomposition of many ozone molecules / ozone layer

Award M4 for the general idea behind the EU justification for banning the use of CFCs as refrigerants

Penalise M4 if overall ozone decomposition equation is incorrect

Ignore "greenhouse effect", "global warming" etc.

4



All bonds must be drawn out

1

(ii) 2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / $\text{C}-\text{Cl}$ (bonds)

Ignore "chlorine molecules"

OR it does not produce $\text{Cl}\cdot$ / does not produce chlorine (free) radical(s) **OR** chlorodifluoromethane does contain chlorine / does

produce $\text{Cl}\cdot$ / does produce chlorine (free) radical(s) **OR** $\text{C}-\text{F}$ is too strong and does not break / create radicals **OR** $\text{C}-\text{F}$ is stronger than $\text{C}-\text{Cl}$

1

[14]

M5.(a) (i) CH_2O

Atoms in any order

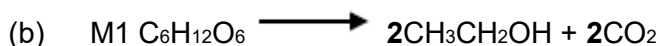
Accept a clear indication that $\text{C}_6\text{H}_{12}\text{O}_6$ yields CH_2O as the answer

- (ii) No peak / no absorption / no C=O in the range 1680 to 1750 (cm^{-1}) (suggesting no evidence of C=O)

Allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption

Ignore references to other wavenumbers

1



Penalise ($\text{C}_2\text{H}_6\text{O}$)

Allow multiples of the equation in M1

Either order

M2 (enzymes from) yeast or zymase

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

For M2 and M3

Ignore "aqueous"

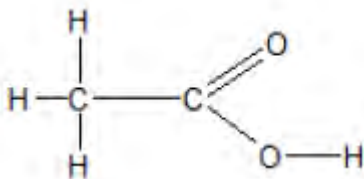
Ignore "anaerobic / absence of oxygen"

Ignore "controlled pH"

Ignore "warm"

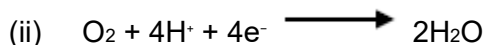
3

- (c) (i) Displayed formula for CH_3COOH



All bonds must be drawn out, but ignore bond angles

1



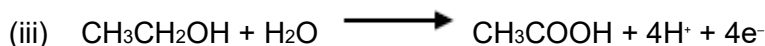
Ignore state symbols

Negative charge on electron not essential

Accept multiples

Accept electrons subtracted from RHS

1



($\text{C}_2\text{H}_6\text{O}$ or $\text{C}_2\text{H}_5\text{OH}$)

Ignore state symbols

Negative charge on electron not essential

Accept multiples

Accept electrons subtracted from LHS

1

(iv) M1 Acidified potassium or sodium dichromate

For M1, it must be a whole reagent and / or correct formulae

OR H_2SO_4 / $\text{K}_2\text{Cr}_2\text{O}_7$ OR H^+ / $\text{K}_2\text{Cr}_2\text{O}_7$ etc.

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

OR correct combination of formula and name

If oxidation state given in name, it must be correct, but mark on from an incorrect attempt at a correct reagent.

M2 (requires an attempt at M1)

orange to green

*Credit **acidified** potassium chromate(VI) / H_2SO_4 + K_2CrO_4*

Possible alternative

M1 (acidified) potassium manganate(VII) **OR** KMnO_4 / H_2SO_4

M2 purple to colourless

Other alternatives will be accepted but M2 is dependent on M1 in every case

M2 requires an attempt at a correct reagent for M1

Ignore reference to states

2

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere / air

The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere / air

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air.

Answer must refer to the atmosphere or air

OR

There is no change in the total amount of carbon dioxide / carbon

/greenhouse gas present in the atmosphere / air

1

(ii) Renewable / sustainable ONLY

Ignore references to global warming or greenhouse gases

1

(iii) **Any one statement about this process from**

Subject to weather / climate

Ignore "batch"

OR

Depletes food supply OR the land use for (specified) food

OR

Requires use of / uses more fossil fuels

OR

Not carbon-neutral OR CO₂ produced during a named process (eg harvest, transport etc.)

OR

Slow process / slow rate of reaction / takes a long time (to grow crops)

OR

This route leads to the production of a mixture of water and ethanol / impure ethanol that requires separation / further processing

1

[13]