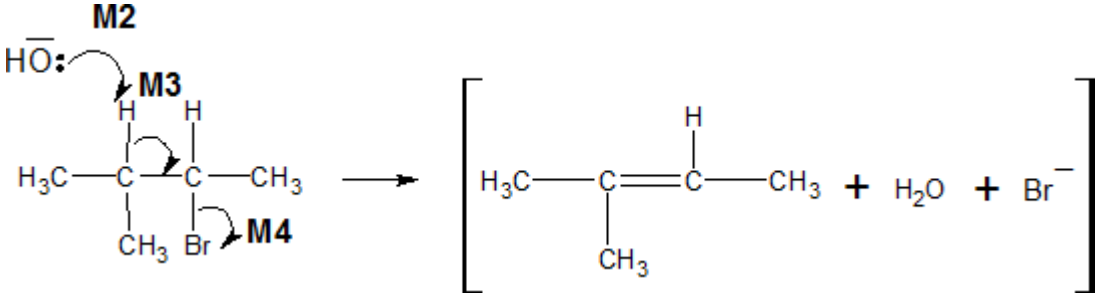
M1.(a) (i) M1 **Elimination**

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

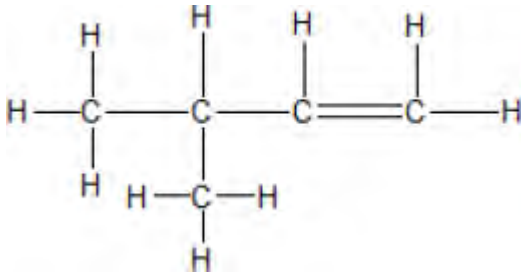
Award full marks for an E1 mechanism in which **M4** is on the correct carbocation

*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

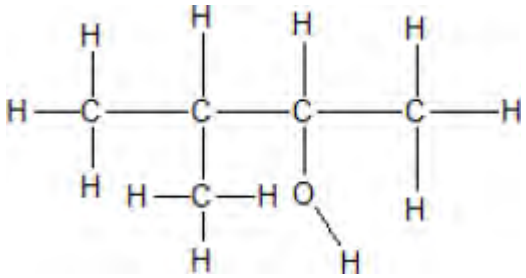
1

(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 CO_2 / CO_2 from the factory / CO_2 from the bioethanol (or biofuel) production

OR

reduces or limits the amount of CO_2 released / given out (into the atmosphere)

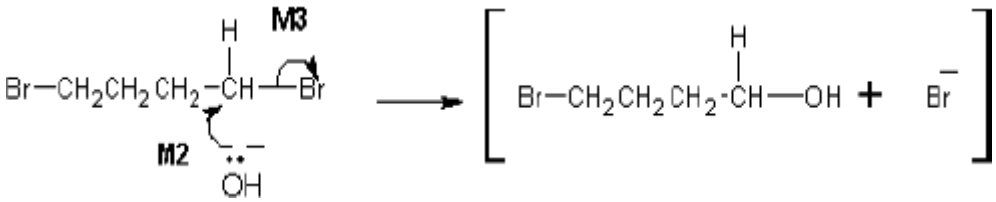
OR

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°C ≤ T ≤ 42°C OR 298 K ≤ T ≤ 315 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 <u>acidified potassium or sodium dichromate</u>

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

OR H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$

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

$HOCH_2CH_2CH_2CH_2OH + \mathbf{4}[O] \longrightarrow HOOCCH_2CH_2COOH + \mathbf{2}H_2O$

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

3

[15]

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

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only.

Penalise + or – charges every time

M2 First propagation

$Cl\bullet + CH_2Cl_2 \longrightarrow \bullet CHCl_2 + HCl$

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**

$Cl_2 + \bullet CHCl_2 \longrightarrow CHCl_3 + Cl\bullet$

Penalise once only for double headed curly arrows

Mark independently

3

(ii) **M1** **Condition**

ultra-violet / uv / sun light

OR high temperature

OR 400°C ≤ T ≤ 900°C

M2 **Type of mechanism**

(free-) radical substitution (mechanism)

2

(b) (i) $CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$

Allow X as alternative to CCl_4 only if X is clearly identified as CCl_4

1

(ii) **M1** Trichloromethane / $CHCl_3$ has a C–H bond

OR

X / CCl_4 / 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 $CHClF_2 \longrightarrow Cl\bullet + \bullet CHF_2$

*Penalise **M1**, if Cl• is formed from Cl_2 as the only reaction or an additional reaction*

Do not penalise an incorrect equation using $CHClF_2$ if correct

reference is made to Cl• formation or C–Cl / carbon-chlorine bond breakage

M2 $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

M3 $ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$

***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 decomposi ion occurs; $2O_3 \longrightarrow 3O_2$**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**Cl• catalyses the decomposi ion of ozone / a single Cl• causes (chain) reaction / decomposi ion of many ozone molecules / ozone layer

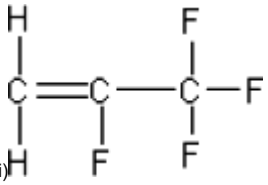
*Award **M4** for the general idea behind the EU justification for banning the use of CFCs as refrigerants*

*Penalise **M4** if overall ozone decomposition equation is incorrect*

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

4

(d) (i)



All bonds must be drawn out

1

(ii) 2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / C–Cl (bonds)

Ignore "chlorine molecules"

***OR**It does not produce Cl• / does not produce chlorine (free) radical(s)**OR**chlorodifluoromethane does contain chlorine / does*

*produce Cl• / does produce chlorine (free) radical(s)**OR**C–F is too strong and does not break / create radicals**OR**C–F is stronger than C–Cl*

1

[14]

M5.(a) (i) CH_2O

Atoms in any order

Accept a clear indication that $C_6H_{12}O_6$ yields CH_2O as the answer

1

(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

(b) M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2

Penalise (C_2H_6O)

*Allow multiples of the equation in **M1***

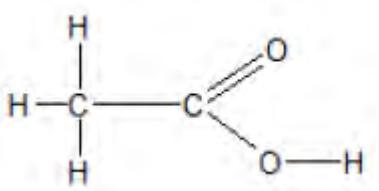
Either order
M2 (enzymes from) yeast or zymase

M3 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 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

(ii) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

Ignore state symbols

Negative charge on electron not essential

Accept multiples

Accept electrons subtracted from RHS

1

(iii) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

(C_2H_6O or C_2H_5OH)

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 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$ 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 CO_2 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]