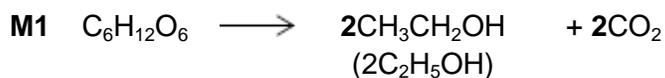


Mark schemes

- 1** (a) H_2SO_4
Allow H_3PO_4 or HCl 1
- (b) Dichromate / Cr(VI) reduced or Cr(III) formed.
Allow Cr^{6+} and Cr^{3+} 1
- (c) The alcohol is flammable
Allow enables temperature to be controlled 1
- (d) Tollens' 1
- Silver mirror
OR Fehling's
Red precipitate
OR Benedict's
Red precipitate 1
- [5]**

2

(a)



Penalise C₂H₆O for ethanol in M1.

M2 and M3

Mark M2 and M3 independently.

Any **two** conditions in any order for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.

Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.

M4 (fractional) distillation or GLC

Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).

M5 Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO₂ emission to the atmosphere

OR

There is no change in the total amount / level of carbon dioxide / CO₂ present in the atmosphere

For M5 – must be about CO₂ and the atmosphere.

The idea that the carbon dioxide / CO₂ given out equals the carbon dioxide / CO₂ that was taken in from the atmosphere.

- (b) **M1** $q = m c \Delta T$ (this mark for correct mathematical formula)
*Full marks for **M1**, **M2** and **M3** for the correct answer.*
*In **M1**, do not penalise incorrect cases in the formula.*

M2 = $(75 \times 4.18 \times 5.5)$

1724 (J) **OR** 1.724 (kJ) **OR** 1.72 (kJ) **OR** 1.7 (kJ)

(also scores **M1**)

*Ignore incorrect units in **M2**.*

M3 Using 0.0024 mol

therefore $\Delta H = \underline{-718}$ (kJ mol⁻¹)

(Accept a range from -708 to -719 but do not penalise more than 3 significant figures)

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect.*
*Therefore **+718** gains two marks.*

*If units are quoted in **M3** they must be correct.*

*If $\Delta T = 278.5$, CE for the calculation and penalise **M2** and **M3**.*

M4 and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the $(2.40 \times 10^{-3} \text{ mol})$ ethanol is burned / reaction is incomplete
*If $c = 4.81$ (leads to 1984) penalise **M2** ONLY and mark on for **M3** = - 827*

5

- (c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in breaking / dissociating (a) covalent bond(s)
Ignore bond making.

M2 averaged for that type of bond over different / a range of molecules / compounds

Ignore reference to moles.

2

(ii) **M1**

$$\underline{\sum B(\text{reactants})} - \underline{\sum B(\text{products})} = \underline{\Delta H}$$

OR

$$\underline{\text{Sum of bonds broken}} - \underline{\text{Sum of bonds formed}} = \underline{\Delta H}$$

OR

$$\begin{aligned} & B(\text{C-C}) + B(\text{C-O}) + B(\text{O-H}) + 5B(\text{C-H}) + 3B(\text{O=O}) \\ & - 4B(\text{C=O}) - 6B(\text{O-H}) = \Delta H = -1279 \end{aligned}$$

Correct answer gains full marks.

*Credit **1 mark for - 496** (kJ mol⁻¹)*

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**).*

*If no AE, check for a correct method; this requires either a correct cycle with 2CO₂ and 3H₂O OR a clear statement of **M1** which could be in words and scores only M1.*

M2 (also scores **M1**)

$$348+360+463+5(412)+ 3B(\text{O=O})$$

$$(3231) \quad (\text{or } 2768 \text{ if O-H cancelled})$$

$$- 4(805) - 6(463) = \Delta H = - 1279$$

$$(5998) \quad (\text{or } 5535 \text{ if O-H cancelled})$$

$$3B(\text{O=O}) = \underline{1488} \text{ (kJ mol}^{-1}\text{)}$$

*Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998** (or **5535**) OR bonds broken includes the calculated value of **3231** (or **2768**).*

M3

$$B(\text{O=O}) = \underline{496} \text{ (kJ mol}^{-1}\text{)}$$

Award 1 mark for -496

Students may use a cycle and gain full marks

3

[15]

3Acidified potassium dichromate*Accept words or formulae.**Accept acidified potassium permanganate.**Accept Lucas reagent (conc HCl, ZnCl₂) (cloudy in 5 mins for 2°, instantly for 3°).**Mark on for incomplete reagent.**Incorrect reagent CE = 0 / 3**Inclusion of Tollen's etc with acidified potassium dichromate is incorrect reagent.**Not no reaction.*

Either

Obs with 2-methylpropan-2-ol

No visible change

1

Obs with butan-2-ol

Orange to green (both colours needed)

1

or

Obs with 2-methylpropan-2-ol orange

Obs with butan-2-ol green

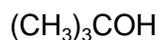
[3]**4**

(a) Structure for 3-methylbut-1-ene

*Any correct structural representation.**Credit "sticks" and require the double bond.*

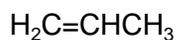
1

(b) Structure for 2-methylpropan-2-ol

*Any correct structural representation.**Credit "sticks".*

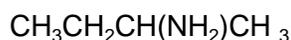
1

(c) Structure for propene

*Any correct structural representation.**Credit "sticks" and require the double bond.*

1

(d) Structure for 2-aminobutane



Any correct structural representation.

Credit "sticks".

1

[4]

5

(a) $\text{HOOC}-\text{CHOH}-\text{CHOH}-\text{COO}$

Any suitable structural formula.

Displayed formula not required but bond sequences must be correct if shown.

1

(b) $\text{C}_4\text{H}_6\text{O}_6 + \text{NaHCO}_3 \rightarrow \text{C}_4\text{H}_5\text{O}_6\text{Na} + \text{CO}_2 + \text{H}_2\text{O}$

OR



Allow equations based on the structural formula.

Allow multiples including fractions.

Allow any structure for $\text{C}_4\text{H}_6\text{O}$ or $\text{C}_4\text{H}_5\text{O}_6\text{Na}$

1

(c) Suitable named indicator (eg litmus, methyl orange, Universal Indicator) / identified reactive metal (Mg, Zn or Fe)

Do not allow phenolphthalein without explanation of how a colour change would be seen.

Incorrect reagent, chemical error = 0 / 2

1

Appropriate colour in acid (eg red) / gas evolved

1

(d) (i) Reagent: Acidified potassium dichromate (solution)

If incomplete (correct) reagent, lose M1 but mark on.

Incorrect reagent, chemical error = 0 / 3

Allow acidified potassium manganate(VII)

1

Obs: orange to green

Purple to colourless (solution).

1

Obs: no (visible) change

Allow 'no visible reaction', but do not allow 'no reaction' without qualification.

1

- (ii) Both would give the same result / both oxidised by reagent / both react with the reagent or similar

Allow consequential answer from (i).

Chemical error if reagent in (i) is incorrect, 0 / 1

1

- (e) The water would allow the tartaric acid and sodium hydrogencarbonate to react (before use)

Ignore any reference to water reacting with the ingredients.

Ignore references to prevention of 'caking' or 'clumping'.

Ignore references to shelf life without qualification.

1

- (f) Acid reacts (with NaHCO_3 / Na_2CO_3) to form CO_2

Allow 'neutralises (NaHCO_3 / Na_2CO_3) to form CO_2 '

1

- (g) It is only used in very small quantities

Allow 'decomposes in the reaction'.

Do not allow 'reacts' without qualification.

Ignore reference to formation of salts.

1

[11]

6

- (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

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 $\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 2\text{CH}_3\text{CH}_2\text{OH} + 2\text{CO}_2$

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"

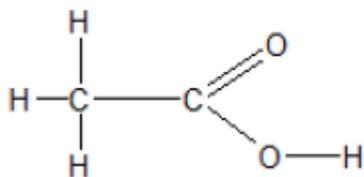
Ignore "anaerobic / absence of oxygen"

Ignore "controlled pH"

Ignore "warm"

3

(c) (i) Displayed formula for CH₃COOH



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



(C₂H₆O or C₂H₅OH)

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

Possible alternative

M1 (acidified) potassium manganate(VII) **OR** $\text{KMnO}_4 / \text{H}_2\text{SO}_4$

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 / CO₂ given out equals the carbon / CO₂ 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]

7

(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)

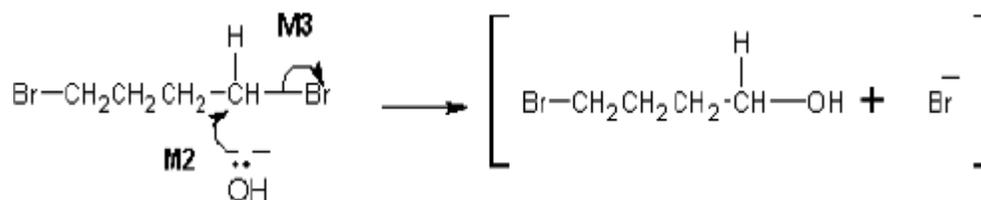
OR

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 $\text{S}_{\text{N}}1$ 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]

8

(a) To prevent vigorous boiling / uneven boiling / bubbling vigorously

Reference to an effect on 'reaction' here loses this mark.

1

(b) Condenser

Accept 'condensation chamber' or 'condensation tube'.

1

Should show effective water jacket and central tube

If a flask is also drawn then the condenser must be at an appropriate angle.

Apparatus must clearly work.

Ignore direction of water flow.

Diagram must have a clear flow of vapour and water eg unblocked central tube or flow indicated by arrows.

1

[3]

9

(Mix the alcohol with warm) $K_2Cr_2O_7 / H^+$ allows 3° identification by lack of reaction

Scheme must allow the alcohol to be distinguished to get all marks.

1

Distillation of initial product needed for 1° / 2°

If distillation stage not clear then max. 2 (M1 and M3).

Awareness of correct reactions / lack of reaction relating to each class of alcohol is worth 1 mark.

1

Effect of Tollens' / Fehling's on oxidation product to identify 1° or 2° (by default)

Reacting Tollens' / Fehling's with alcohols directly is incorrect and gains no M2 or M3.

Detailed observations relating to the reactions are not needed but should be penalised where incorrect.

1

[3]