M1.(a) **M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2
($2C_2H_5OH$)

Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise C_2H_6O once only

M2 fermentation

M3 CH_3CH_2OH + **3**$O_2 \longrightarrow$ **2**CO_2 + **3**H_2O
(C_2H_5OH)

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 CO_2

For M5, "releases / increases carbon emissions" is insufficient as an alternative to releases CO_2

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^-

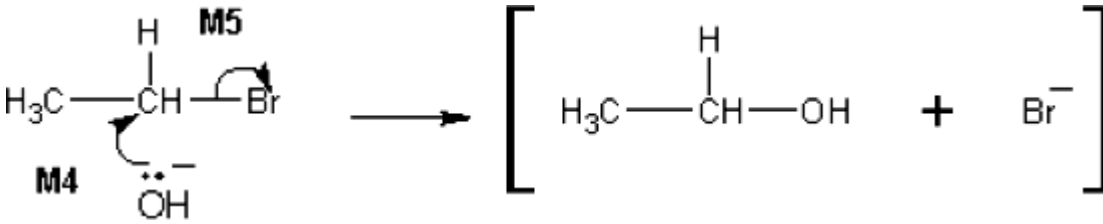
warm / heat / reflux and aqueous or (aq) or water

For M2 ignore "dilute"

For M2 penalise T > 100 °C

M3 nucleophilic substitution

Acidified KOH/NaOH or H_2SO_4 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⁺span>

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 atm ≤ P ≤ 100 atm

OR 5000 kPa ≤ P ≤ 10000 kPa

OR 5 MPa ≤ P ≤ 10 MPa

- High**T**emperature unless they give a value that is not in the ranges given here;

OR 300 °C ≤ T ≤ 600 °C

OR 570 K ≤ T ≤ 870 K

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

4

[15]

M2. (a) to neutralise stomach acidity

OR

as an antacid

OR

eases indigestion/heartburn

Ignore milk of magnesia

Credit suitable reference to indigestion/laxative/relief of constipation

1

(b) (i) an electron acceptor

OR

(readily) gains/accepts/receives electron(s)

NOT an electron pair acceptor

Ignore removes/takes away/attracts electrons

1

(ii) Br_2 ONLY

Ignore "bromine"

Apply the list principle

1

(iii) $H_2SO_4 + \mathbf{2}H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

OR

$SO_4^{2-} + 4H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

Ignore state symbols
Ignore absence of negative charge on electron
Or multiples of equations

1

(c) (i) (acid) catalyst

OR

catalyses (the reaction)

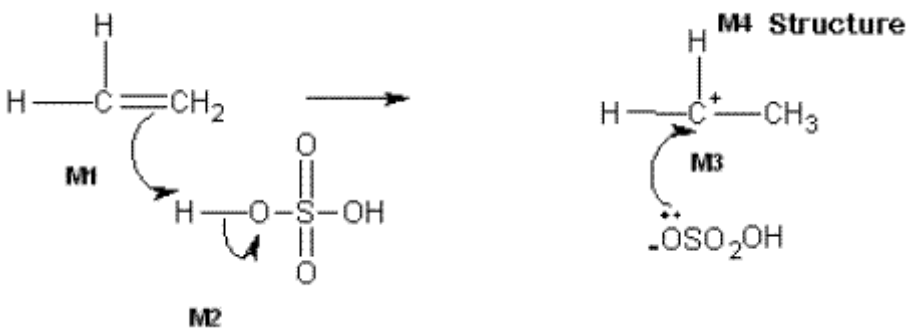
OR

to speed up the reaction/increase the rate (of reaction)

Ignore "provides H^+ ions"
Accept phonetic spelling

1

(ii)



M1 must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H_2SO_4 (or accept H_2SO_3 here)
M1 could be to an H^+ ion and M2 an independent O – H bond break on a compound with molecular formula for H_2SO_4 or H_2SO_3

M2 must show the breaking of the O ─ H bond.

M3 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom.

M4 is for the structure of the carbocation.

NB The arrows here are double-headed

M2 Ignore partial charges unless wrong

M3 NOT HSO_4^-

For M3, credit as shown or $^{-}OSO_3H$ *ONLY with the negative charge anywhere on this ion*

OR correctly drawn out with the negative charge placed correctly on oxygen

Max 3 marks for wrong reactant

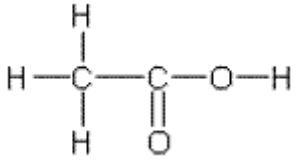
Do not penalise the use of "sticks"

4

(iii) Primary ***OR*** 1° (alcohol)

1

(iv) Displayed formula for ethanoic acid, CH_3COOH



All the bonds must be drawn out and this includes the O — H bond

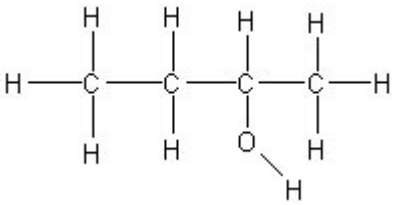
Ignore bond angles.

1

[11]

M3. (a) **M1**

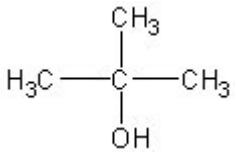
Displayed formula for butan-2-ol



M1 displayed formula <u>must</u> have all bonds drawn out, including the O—H but ignore angles

Penalise "sticks"

M2 Alcohol **X** is



M2 structure must be clearly identifiable as 2-methylpropan-2-ol and may be drawn in a variety of ways.

M3 Alcohol **Y** is named <u>(2)-methylpropan-1-ol</u> ONLY

M3 <u>must be correct name</u>, but ignore structures

3

(b) **M1** The infrared spectrum shows an <u>absorption/peak in the range 3230 to 3550</u> (cm^{-1})(which supports the idea that an alcohol is present)

In M1, allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption.

M2 Reference to the 'fingerprint region' or below 1500 (cm^{-1})

M3 <u>Match with</u> or <u>same as</u> known sample/database spectra

Check the spectrum to see if alcohol OH is labelled and credit.

OR

M2 Run infrared spectra (of the alcohols)

M3 Find which one <u>matches</u> or is the <u>same as</u> this spectrum.

3

(c) **M1** balanced equation

$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2CH_2OH + \mathbf{2}CO_2 + H_2O$

or C_4H_9OH

Or multiples for M1 and M3

In M1 and M3 penalise use of $C_4H_{10}O$ or butan-2-ol once only

M2 Any one from

- <u>excess/adequate/sufficient/correct amount of/enough/plenty/</u>

a good supply of oxygen or air

- good mixing of the fuel and air/oxygen

For M2, do not accept simply "oxygen" or "air" alone
Ignore reference to "temperature"

M3 $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \rightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$
or C_4H_9OH

M4 A biofuel is a fuel produced from (renewable) biological (re)source(s)

OR

(renewable) (re)source(s) from (a specified) plant(s)/fruit(s)/tree(s)

In M4
Ignore references to "carbon neutral"
Ignore "sugar" and "glucose"

4

(d) **M1** butan-1-ol is a primary or 1° (alcohol)

M2 Displayed formula (ONLY) for butanal $CH_3CH_2CH_2CHO$

M3 Displayed formula (ONLY) for butanoic acid $CH_3CH_2CH_2COOH$

M2 and M3 displayed formula must have all bonds drawn out including the O—H but ignore angles.

If butanal and butanoic acid formulae are both correctly given but not displayed, credit one mark out of two.

M4 Oxidation (oxidised) OR Redox

M5 orange to green

Both colours required for M5
Ignore states

5

[15]

M4. (a) **Three conditions in any order for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$
OR
$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

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

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up (to form glucose or in photosynthesis)

1

M3 6 (mol/molecules) CO_2/carbon dioxide given out due to **2** (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

(c) **M1 (could be scored by a correct mathematical expression)**

(Sum of) bonds broken – (Sum of) bonds made/formed = ΔH

OR

$(\Sigma)\ B_{reactants} - (\Sigma)\ B_{products} = \Delta H$

(where B = bond enthalpy/bond energy)

For M1 there must be a correct mathematical expression using ΔH or "enthalpy change"

M2 Reactants = (+) 4719
OR
Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.

Ignore units.

M2 is for either value underlined

M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are <u>not specific</u> for this reaction *OR* they are <u>average</u> values from many <u>different compounds/molecules</u>

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol
therefore ΔH = **<u>– 669</u>** kJ mol^{-1} OR – **<u>670</u>** $kJmol^{-1}$
OR **<u>–668.8</u>** kJ mol^{-1}

Award M1, M2 and M3 for <u>correct answer</u> to the calculation

Penalise M3 ONLY if correct answer but sign is incorrect

In M1, do not penalise incorrect cases in the formula

If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3

If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770

Ignore incorrect units in M2

M4 Incomplete combustion

Do not forget to award this mark. Mark independently

4

[15]