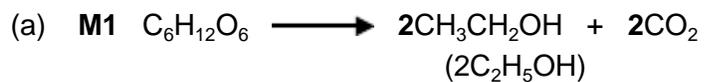


Mark schemes

1

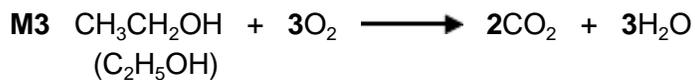


Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise $\text{C}_2\text{H}_6\text{O}$ 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 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⁻

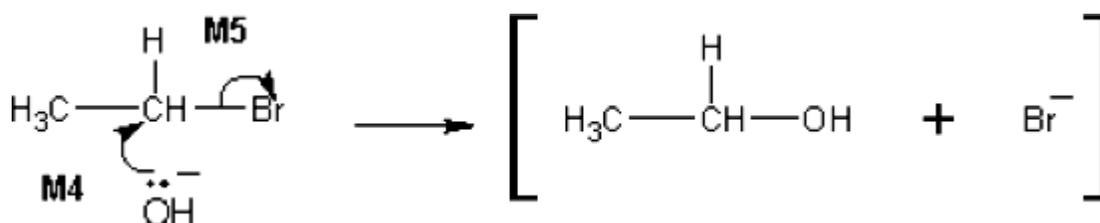
warm / heat / reflux and aqueous or (aq) or water

For M2 ignore "dilute"

For M2 penalise T > 100 °C

M3 nucleophilic substitution

Acidified KOH/NaOH or 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 the 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 atm $\leq P \leq$ 100 atm
 - OR** 5000 kPa $\leq P \leq$ 10000 kPa
 - OR** 5 MPa $\leq P \leq$ 10 MPa
- High Temperature unless they give a value that is not in the ranges given here;
 - OR** 300 °C $\leq T \leq$ 600 °C
 - OR** 570 K $\leq T \leq$ 870 K

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

4

[15]

2

- (a) Pentan-2-one

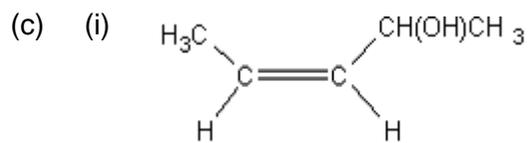
ONLY but ignore absence of hyphens

1

- (b) Functional group (isomerism)

Both words needed

1



Award credit provided it is obvious that the candidate is drawing the Z / cis isomer

The group needs to be CHOHCH₃ but do not penalise poor C–C bonds or absence of brackets around OH

Trigonal planar structure not essential

1

(ii) Restricted rotation (about the C=C)

OR

No (free) rotation (about the C=C)

1

(d)

<p>M1 Tollens' (reagent) (Credit ammoniacal silver nitrate OR a description of making Tollens') (Do not credit Ag^+, AgNO_3 or $[\text{Ag}(\text{NH}_3)_2]^+$ or "the silver mirror test" on their own, but mark M2 and M3)</p>	<p>M1 Fehling's (solution) / Benedict's (Penalise $\text{Cu}^{2+}(\text{aq})$ or CuSO_4 but mark M2 and M3)</p>
<p>M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u></p>	<p>M2 <u>Red solid/precipitate</u> (Credit <u>orange</u> or <u>brown solid</u>)</p>
<p>M3 (stays) colourless OR no (observed) change / no reaction</p>	<p>M3 (stays) blue OR no (observed) change / no reaction</p>

If **M1** is blank CE = 0, for the clip

Check the partial reagents listed and if M1 has a totally incorrect reagent, CE = 0 for the clip

Allow the following alternatives

M1 (acidified) potassium dichromate(VI) (solution); mark on from incomplete formulae or incorrect oxidation state

M2 (turns) green

M3 (stays) orange / no (observed) change / no reaction

OR

M1 (acidified) potassium manganate(VII) (solution); mark on from incomplete formulae or incorrect oxidation state

M2 (turns) colourless

M3 (stays) purple / no (observed) change / no reaction

In all cases for **M3**

Ignore "nothing (happens)"

Ignore "no observation"

3

(e) (i) **Spectrum is for Isomer 1**

or named or correctly identified

The explanation marks in (e)(ii) depend on correctly identifying Isomer 1.

The identification should be unambiguous but candidates should not be penalised for an imperfect or incomplete name. They may say "the alcohol" or the "alkene" or the "E isomer"

1

(ii) **If Isomer 1 is correctly identified, award any two from**

- (Strong / broad) absorption / peak in the range **3230 to 3550** cm^{-1} or specified value in this range or **marked correctly** on spectrum
and
(characteristic absorption / peak for) OH group / **alcohol** group
- No absorption / peak in range **1680 to 1750** cm^{-1} or absence marked correctly on spectrum
and
(No absorption / peak for a) **C=O** group / **carbonyl** group / **carbon-oxygen double bond**
- Absorption / peak in the range **1620 to 1680** cm^{-1} or specified value in this range or marked correctly on spectrum
and
(characteristic absorption / peak for) **C=C** group / **alkene** / **carbon-carbon double bond**

If 6(e)(i) is incorrect or blank, CE=0

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

Ignore reference to other absorptions e.g. C-H, C-O

2

[10]

3

(a) **M1** AgNO₃ OR silver nitrate OR any soluble silver salt

M2 remains colourless or no reaction or no (observed) change or no precipitate

M3 white precipitate or white solid/white suspension

An insoluble silver salt OR Tollens' OR ammoniacal silver nitrate or HCl/AgNO₃ is CE = 0 for the clip

For M1

Credit acidified (or HNO₃) silver nitrate for M1 and mark on

If silver ions or incorrect formula for silver nitrate, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M2

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For M3

Ignore "cloudy solution" OR "suspension"

3

(b) **M1** any soluble sulfate by name or formula e.g. sodium sulfate or sulfuric acid.

M2 white precipitate or white solid/white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate

OR as an alternative

M1 NaOH/KOH

M2 remains colourless or no reaction or no (observed) change

M3 white precipitate or white solid/white suspension

An insoluble sulfate OR conc H_2SO_4 is CE = 0 for the clip

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For the M1 soluble sulfate

If sulfate ions or incorrect formula for the chosen sulfate, penalise M1 but mark M2 and M3

For the M1 NaOH/KOH

If ammonia, then CE = 0

If hydroxide ions or incorrect formula for the chosen hydroxide, penalise M1 but mark M2 and M3

For no (observed) change in both alternatives

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For the white precipitate in both alternatives

Ignore "cloudy solution" OR "suspension"

3

(c) **M1** ammonia (can be dilute or concentrated)

M2 dissolves OR soluble OR (forms a) colourless solution OR goes colourless

M3 does not dissolve OR not soluble OR remains as a solid OR no (observed) change OR no reaction OR yellow solid remains

OR if concentrated ammonia has been used, accept yellow solid turns white.

OR as an alternative using conc sulfuric acid

M1 concentrated sulfuric acid OR c(onc) H_2SO_4

M2 misty/white fumes/gas

OR remains white

OR no change (in colour)

M3 turns black (solid)

OR purple fumes/gas

OR correct reference to H₂S observation (e.g. bad egg smell)

For M1

If incorrect formula or "ammonium", penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M3

Ignore "nothing"

Ignore "no observation"

For the alternative using sulfuric acid

If dilute sulfuric acid or "aq" (alone) or the idea of concentrated not included CE = 0

If incorrect formula, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

3

(d) **M1** acidified potassium dichromate or K₂Cr₂O₇/H₂SO₄

OR K₂Cr₂O₇/H⁺ OR acidified K₂Cr₂O₇

M2 (orange to) green solution OR goes green

M3 (solution) remains orange or no reaction or no (observed) change

Alternative using KMnO₄/H₂SO₄

M1 acidified potassium manganate(VII) or KMnO₄/H₂SO₄

OR KMnO_4/H^+ OR acidified KMnO_4

M2 colourless solution OR goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M1

If "dichromate" or "dichromate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

For M2 ignore dichromate described as "yellow" or "red"

For M3

Ignore "nothing"

Ignore "no observation"

For M1

If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

Credit alkaline KMnO_4 for possible full marks but M2 gives brown precipitate or solution goes green

3

[12]

4

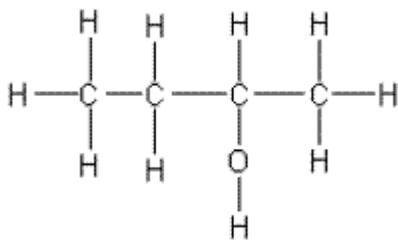
(a) (i) Hexan-1-ol
ONLY

1

(ii) Homologous (series)
ONLY

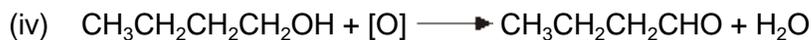
1

(iii) Displayed formula for butan-2-ol



All bonds must be drawn out including the O–H bond
Ignore bond angles

1

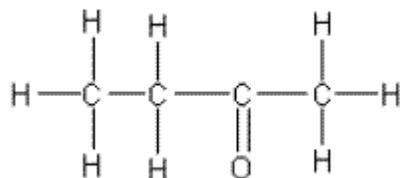


*Require this whole equation as written or formulae drawn out
Penalise "sticks"*

1

(v) Displayed formula for butanone

(credit possible enols, ethers and cyclic structures for $\text{C}_4\text{H}_8\text{O}$)



All bonds must be drawn out

Ignore bond angles

1

(b) **M1** $q = m c \Delta T$ OR calculation $175 \times 4.18 \times 8$

M2 = **5852** (J) OR 5.85 (kJ) OR 5.9 (kJ) (This also scores M1)

M3 0.005 mol, therefore $\Delta H = \underline{-1170}$ (kJ mol⁻¹)

OR $\Delta H = \underline{-1170.4}$ (kJ mol⁻¹)

OR $\Delta H = \underline{-1200}$ (kJ mol⁻¹)

Award full marks for correct answer

In M1, do not penalise incorrect cases in the formula

Ignore incorrect units in M2

Penalise M3 ONLY if correct answer but sign is incorrect OR value is in J mol⁻¹

If $m = 5 \times 10^{-3}$ OR if $\Delta T = 281$, CE and only allow one mark for correct mathematical formula for M1

If $c = 4.81$ (leads to 6734) penalise M2 ONLY and mark on for M3 = -1350 (-1347)

3

(c) (i) **M1** The enthalpy change (or heat change at constant pressure) when 1 mol of a compound/substance/alcohol

M2 is burned completely in oxygen

OR burned in excess oxygen

M3 with all reactants and products/all substances in standard states

OR

all reactants and products/all substances in normal states under standard conditions OR 100 kPa/1 bar and a specified T/298 K

For M3

Ignore reference to 1 atmosphere

3

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

M1 $\Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$

OR a correct cycle of balanced equations

M2 = $4(-394) + 5(-286) - (-327)$

(This also scores M1)

M3 = -2679 (kJ mol⁻¹) OR -2680 (kJ mol⁻¹)

Award 1 mark ONLY for (+) 2679 OR (+) 2680

Correct answer to calculation gains full credit

Credit 1 mark if + 2679 (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 correct method; this requires either a correct cycle with 4CO₂ and 5H₂O OR a clear statement of M1 which could be in words and scores only M1*

3

(d) (i) **M1 This is about the change in formula up the series**

Each alcohol in the series (compared with the previous one)

increases by/has an extra CH₂

OR

has one more C-C and two more C-H

M2 This is about the reaction and bond breaking/making

Combustion of each alcohol in the series breaks one

more C-C and two more C-H compared with the previous one
AND forms one more mol CO₂ and one more mol H₂O

OR

A statement in which there is the idea that the extra OR additional OR difference in number of bonds broken and formed (as the series increases) is the same OR has the same difference in energy

N.B. If the first statement here for M2 is given, both marks score

2

(ii) **For the two marks M1 and M2**

heat loss or heat absorbed by the apparatus

OR

incomplete combustion/not completely burned

OR

The idea that the water may end up in the gaseous state (rather than liquid) OR reactants and/or products may not be in standard states.

2

[18]

5(a) **Three conditions in any order for M1 to M3****M1** yeast or zymase**M2** $30\text{ }^{\circ}\text{C} \geq T \leq 42\text{ }^{\circ}\text{C}$ **M3** anaerobic/no oxygen/no air OR neutral pH**M4** $\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$

OR

 $2\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 4\text{C}_2\text{H}_5\text{OH} + 4\text{CO}_2$ *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) **M1** Carbon-neutral*Ignore "biofuel"*

1

M2 6 (mol/molecules) CO₂/carbon dioxide taken in/used/used up (to form glucose or in photosynthesis)

1

M3 6 (mol/molecules) CO₂/carbon dioxide given out due to 2 (mol/molecules) CO₂/carbon dioxide from fermentation/ Process 2 and 4 (mol/molecules) CO₂/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** $(\Sigma) B_{\text{reactants}} - (\Sigma) B_{\text{products}} = \Delta H$ (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 not specific for this reaction

OR they are average values from many different
compounds/molecules

Do not forget to award this mark

1

(d) **M1** $q = m c \Delta T$ (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 $\Delta H = -669$ kJ mol⁻¹ OR -670 kJmol⁻¹

OR -668.8 kJ mol⁻¹

Award M1, M2 and M3 for correct answer 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 $\Delta T = 281$, 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]

6

Add Tollens / Fehling's / Benedict's reagent / ir spectra

Accept any other chemically correct reagent and observation

1

Silver mirror / blue to red **OR** red precipitate (with ethanal) / peak at 1700 cm⁻¹ (in ethanal)

*Must have correct test to access second mark
Accept 'silver'. Do not accept 'silver solution'
Give one mark for 'silver mirror test' and 'silver mirror'
Accept correct answer based on n.m.r. spectra*

1
[2]

7

Figure 2

1

Further oxidation will occur / ethanoic acid formed

*Do not accept 'poor yield' without qualification
Can gain this mark if logic correct but has chosen wrong Figure*

1
[2]

8

(a) Functional group (isomerism)

1

(b)

M1 Tollens' (reagent)
(Credit ammoniacal silver nitrate **OR**
a description of making Tollens')
(Ignore either AgNO₃ or [Ag(NH₃)₂]⁺)
or "the silver mirror test" on their
own, but mark M2 and M3)

M1 Fehling's (solution) or
Benedict's solution
(Ignore Cu²⁺(aq) or
CuSO₄ on their own, but mark on
to M2 and M3)

M2 silver mirror
OR

M2 Red solid/precipitate
(Credit orange or brown solid)

black solid/precipitate
(NOT silver precipitate)

M3 (stays) colourless
or no change or no reaction

M3 (stays) blue
or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct reagent, penalising M1

No reagent, CE=0

Allow the following alternatives

M1 (acidified) potassium dichromate(VI) (solution)

M2 (turns) green

M3 (stays) orange/no change

OR

M1 (acidified) potassium manganate(VII) (solution)

M2 (turns) colourless

M3 (stays) purple/no change

For M3

Ignore "nothing (happens)"

Ignore "no observation"

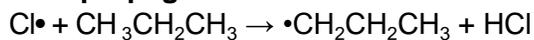
3

(c) (Both have) C=O **OR** a carbonyl (group) 1

(d) (i) (Free-) radical substitution ONLY 1
Penalise "(free) radical mechanism"

(ii) **Initiation**
 $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$
Penalise absence of dot once only.

First propagation

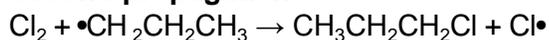


OR C_3H_8

Penalise incorrect position of dot on propyl radical once only.

Penalise $\text{C}_3\text{H}_7\cdot$ once only

Second propagation

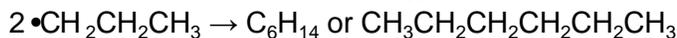


OR

$\text{C}_3\text{H}_7\text{Cl}$

Accept $\text{CH}_3\text{CH}_2\text{CH}_2\cdot$ with the radical dot above/below/to the side of the last carbon.

Termination (must make C_6H_{14})



Use of the secondary free radical might gain 3 of the four marks

4

(e) $M_r = \underline{44.06352}$ (for propane)
 $M_r = \underline{43.98982}$ (for carbon dioxide)
Mark independently

M1 a correct value for both of these M_r values.

M2 a statement or idea that two peaks appear (in the mass spectrum)

OR

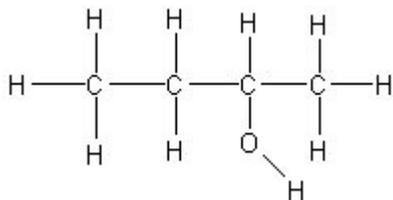
two molecular ions are seen (in the mass spectrum).

2

[12]

9

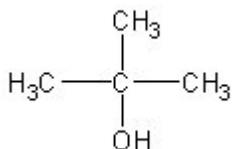
- (a) **M1**
Displayed formula for butan-2-ol



M1 displayed formula must 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 (2)-methylpropan-1-ol ONLY

M3 must be correct name, but ignore structures

3

- (b) **M1** The infrared spectrum shows an absorption/peak in the range 3230 to 3550 (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 Match with or same as 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 matches or is the same as this spectrum.

3

- (c) **M1** balanced equation
 $C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2CH_2OH + 2CO_2 + H_2O$
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

- excess/adequate/sufficient/correct amount of/enough/plenty/
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 $CH_3CH_2CH_2CH_2OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
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]