AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.5 ALCOHOLS

SCORE	PERCENTAGE
/198	%

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Q1.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression through the distillation apparatus. The first two points in stage 1 are in the correct order and all other steps are in a logical order for carrying out the practical.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer is mainly coherent and shows a progression through the distillation apparatus.

Some steps in each stage may be out of order and incomplete but the first two points in stage 1 are in the correct order.

3-4 marks

Level 1
Most points are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning. The first two points in stage 1 are present but not necessarily in the correct order.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

Omission of heating of the apparatus.

0 marks

Indicative content:

Stage 1

- *Turn on the water.*
- *Heat the flask, with a Bunsen burner.*
- *This causes water and ethanol vapours to be produced.*

Stage 2

- *Vapours pass up the fractionating column A.*
- *Water and ethanol are separated in column A.*
- *Water condenses back into the flask in column A.*

Stage 3

- *Observe the thermometer at B to keep the temperature at or below the boiling point of ethanol.*

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Only ethanol vapour (with a little water) passes into the condenser.

- *Use the condenser at part C to cool the vapours and condense the ethanol back into a liquid.*

(b) Volume of sample = volume of ethanol + volume of water

Let m = mass of ethanol

$20 = m / 0.79 + (16–m) / 1.00$

$1.266m - m = 20 - 16$ **1**

$0.266m = 4$ so $m = 15$ (g) **1**

[8]

Q2.

(a) Percentage of oxygen by mass = 100 – 40.9 – 4.5 = 54.6 **1**

	C	H	O
%			
Divide by A_r	$\frac{40.9}{12}$	$\frac{4.5}{1}$	$\frac{54.6}{16}$
	= 3.41	= 4.5	= 3.41

1

Divide by smallest =	$\frac{3.41}{3.41} = 1$	$\frac{4.5}{3.41} = 1.32$	$\frac{3.41}{3.41} = 1$
Nearest whole number ratio =	1 × 3	1.32 × 3	1 × 3

= 3 : 3.96 : 3

Nearest integer ratio = 3 : 4 : 3 **1**

Empirical formula $C_3H_4O_3$

Empirical formula mass = 88 = molecular formula mass

Therefore, molecular formula is same as the empirical formula - $C_3H_4O_3$ **1**

(b) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ **1**

(c) Advantage – ethanol is produced at a faster rate **1**

Disadvantage – more energy is used / required in the reaction **1**

(d) Air gets in / oxidation occurs **1**

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(e) Alcohol OH absorption in different place (3230–3550 cm^{-1}) from acid OH absorption (2500–3000 cm^{-1})

1

The C=O in acids has an absorption at 1680–1750 cm^{-1}

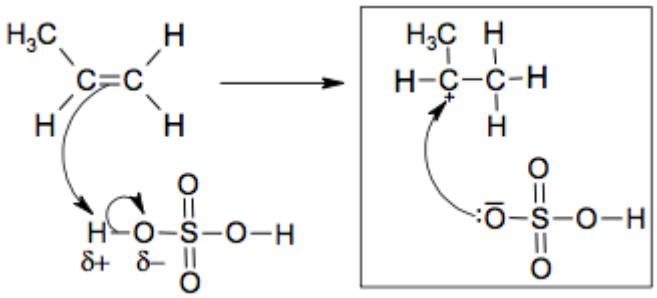
1

[10]

Q3.

(a) Electrophilic addition

1



M2 = curly arrow from C=C towards H of H−O on 'their' sulfuric acid

M3 = curly arrow to break H−O

Penalise incorrect dipole/full charges

M4 = intermediate

M5 = correct anion, lone pair on correct O and curly arrow from that lone pair to C+ on their carbocation

***IGNORE** position of minus sign unless displayed structure*

***IGNORE** product*

1
1
1
1

Major product/propan-2-ol formed via most stable carbocation/carbonium ion
secondary carbocation/carbonium ion more stable (than primary) or reverse argument

M6 for idea of carbocation stability

This statement gets M6 and M7

***NOT** stability of alcohols*

1
1

(b) Hot/High T (and High P)

***ALLOW** 200-450 C/473-723 K (Quoted)*

1

(SiO_2 coated in) phosphoric acid (catalyst)

***NOT** (aq)*

1

advantages of fermentation

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- Low(er) T and P / lower energy use
- Less use of non-renewable fossil fuels/renewable/sustainable (resources)
- Low(er) equipment/plant/capital costs

IGNORE *carbon neutral*

max 2

1
1

Disadvantages of fermentation

- Slow(er) reaction
- Low atom economy
- Impure product/extra purification/distillation required
- Batch process/labour intensive/difficult to automate
- Land used for sugar crops (so not available for food crops)

IGNORE *low yield*

Max 2

1
1

[13]

Q4.

(a)

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

*Penalise C_2H_6O 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

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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 / CO_2 emission to the atmosphere

OR

There is no change in the total amount / level of carbon dioxide / CO_2 present in the atmosphere

*For **M5** – must be about CO_2 and the atmosphere.*

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

5

(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 × 4.18 × 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 ΔH = **− 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 ΔT = 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 (2.40×10^{-3} mol) ethanol is burned / reaction is incomplete

*If c = 4.81 (leads to 1984) penalise **M2** ONLY and mark on for **M3** = − 827*

5

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(c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in <u>breaking / dissociating (a) covalent bond(s)</u>

Ignore bond making.

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

Ignore reference to moles.

2

(ii) **M1**

<u>∑ B(**reactants**) − ∑ B(**products**) = ΔH</u>

OR

<u>Sum</u> of bonds <u>broken</u> − <u>Sum</u> of bonds <u>formed</u> = <u>ΔH</u>

OR

B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O)
– 4B(C=O) – 6B(O–H) = ΔH = −1279

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 $2CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>**.*

M2 (also scores **M1**)
348+360+463+5(412)+ 3B(O=O)

(**3231**) (or **2768** if O–H cancelled)
− 4(805) − 6(463) = ΔH = − 1279

(**5998**) (or **5535** if O–H cancelled)

3B(O=O) = **<u>1488</u>** (kJ mol^{-1})

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

M3

B(O=O) = **<u>496</u>** (kJ mol^{-1})

Award 1 mark for −496

Students may use a cycle and gain full marks

3

[15]

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Q5.

(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"

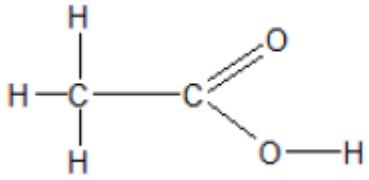
Ignore "anaerobic / absence of oxygen"

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

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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

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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]

Q6.

(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

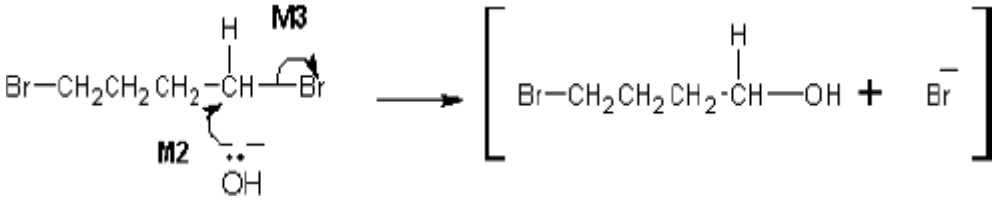
Process 2 uses renewable glucose / renewable resource(s)

2

(b) (i) M1 nucleophilic substitution

*For **M1, both words** required*

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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 <u>original molecule</u>

*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** <u>fermentation</u>

*Mark **M2** to **M4** independently*

Three conditions <u>in any order</u> 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

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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]

Q7.

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

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 $CH_3CH_2OH + \mathbf{3}O_2 \longrightarrow \mathbf{2}CO_2 + \mathbf{3}H_2O$ (C_2H_5OH)

M4 <u>A specified process</u> e.g. planting / harvesting / transport / extracting sugar / distilling ethanol solution / fertiliser production etc.

M5 The specified process <u>uses / burns</u> (fossil) <u>fuel that releases CO_2</u>

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

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 <u>and</u> aqueous or (aq) or water

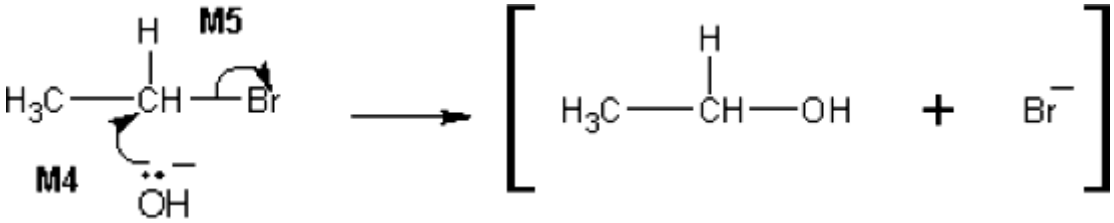
For M2 ignore "dilute"

For M2 penalise T > 100 °C

M3 <u>nucleophilic substitution</u>

Acidified KOH/NaOH or H_2SO_4 with KOH/NaOH loses M1 and M2

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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^+

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

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- 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

- HighTemperature 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]

Q8.

(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

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(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

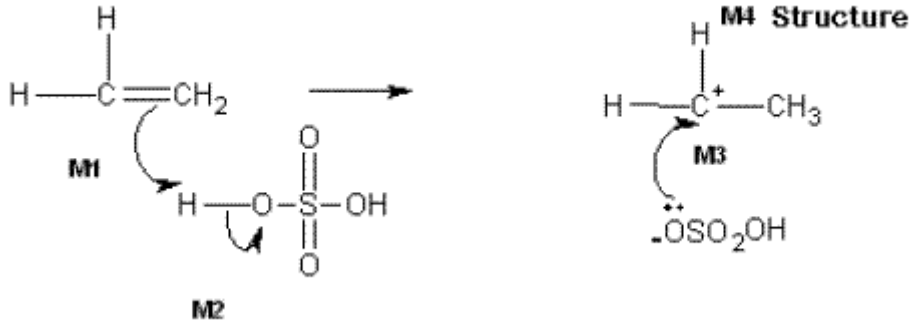
to speed up the reaction/increase the rate (of reaction)

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 <u>as shown</u> or <u>$^{-}$:OSO_3H</u> ONLY with the negative charge anywhere on this ion

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OR <u>correctly</u> drawn out with the negative charge placed correctly on oxygen

Max 3 marks for wrong reactant

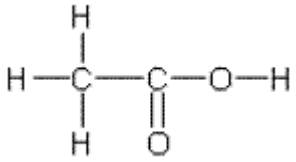
Do not penalise the use of "sticks"

4

(iii) Primary ***OR*** 1° (alcohol)

1

(iv) <u>Displayed formula</u> for ethanoic acid, CH_3COOH



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

Ignore bond angles.

1

[11]

Q9.

(a) **Three conditions <u>in any order</u> 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 <u>6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up</u> (to form glucose or in photosynthesis)

1

M3 <u>6 (mol/molecules) CO_2/carbon dioxide</u> given out <u>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</u>

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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 = Δ*H*

OR

(Σ) $B_{reactants}$ – (Σ) $B_{products}$ = Δ*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 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 = **– 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 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

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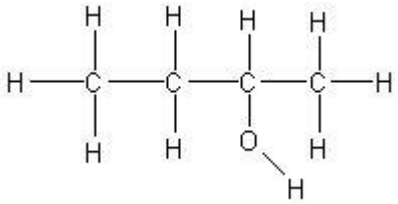
4

[15]

Q10.

(a) **M1**

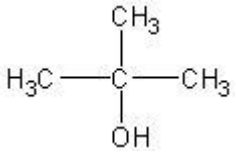
Displayed formula for butan-2-ol



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

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

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

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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 $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \rightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$
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]

Q11.

(a) **M1** Concentrations of reactants and products remain constant

For M1
NOT "equal concentrations"
NOT "amount"

1

M2 Forward rate = Reverse / backward rate

Credit the use of [ ] for concentration
Ignore dynamic, ignore closed system

1

(b) **M1** The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction.

1

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M2 The equilibrium responds by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
Promotes the endothermic reaction by <u>absorbing heat</u> / <u>lowering temperature</u>
OR
<u>Temperature increase is opposed</u> (by shift to the left)
OR
Change is opposed by <u>absorbing heat</u> / <u>lowering temperature</u>.

1

(c) (i) A substance that speeds up / alters the rate but is unchanged at the end / not used up.

<u>Both ideas needed</u>
Ignore references to activation energy and alternative route.

1

(ii) None OR no change OR no effect OR nothing OR Does not affect it / the position (of equilibrium) OR (The position is) the same or unchanged.

1

(d) (i) An activity which has no <u>net / overall</u> (annual) carbon emissions to the atmosphere
OR
An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions to the atmosphere.
OR
There is no change in the <u>total amount</u> of carbon dioxide / carbon /greenhouse gas present in the atmosphere.

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

Ignore carbon monoxide

1

(ii) A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio.

$$2\,(CH_4 + H_2O \rightarrow CO + 3H_2)$$
$$\underline{CH_4 + CO_2 \rightarrow 2CO + 2H_2}$$
$$3CH_4 + 2H_2O + CO_2 \rightarrow 4CO + 8H_2$$

Ratio = 1 : 2

1

[8]

Q12.

(a) (i) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$;

(penalise C_2H_6O once only in this question)

1

(ii) <u>Concentrated</u> H_2SO_4 OR <u>concentrated</u> H_3PO_4 OR Al_2O_3;

(penalise aqueous or dilute as a contradiction)

1

$C_2H_5OH \rightarrow C_2H_4 + H_2O$ OR $C_2H_5OH \rightarrow H_2C = CH_2 + H_2O$;

(penalise CH_2CH_2 and CH_2-CH_2 and CH_2: CH_2 for ethene)

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1

(b) Nickel OR Ni OR platinum OR Pt OR palladium OR Pd;

1

Hydrogen OR H_2;

1

(c) (i) $C_{18}H_{34}O_2$ Only;

1

$C_9H_{17}O$ Only;
(empirical formula is not consequential on molecular formula)

1

(ii) (An unsaturated compound) contains (at least) <u>one double bond</u>

OR

Contains C=C;
(must be a positive statement)

1

(iii) M1: Bromine water

OR

Br_2(aq)

OR

Bromine

OR

Br_2;
(penalise "bromide water", but mark on)

1

M1: decolourised or goes colourless

OR

from brown/red/orange/yellow to colourless;
(Must be "colourless" not "clear" for M2)
(chemical error if no reagent or wrong reagent, loses both marks) (credit $KMnO_4$ for M1, (purple) to colourless for M2 (if acidified) OR (purple) to brown/brown precipitate (if alkaline or unspecified) (No credit for hydrogen or iodine as reagents)

1

[10]

Q13.

(a) M1 fermentation

1

M2 dehydration or elimination

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1

(b) (i) yeast OR zymase OR an enzyme

1

(ii) <u>concentrated</u> sulphuric or phosphoric acid

(penalise aqueous or dilute as a contradiction)

1

(c) (i) primary or 1°

1

(ii) sugar or glucose or ethanol is renewable
OR ethanol does not contain sulphur-containing impurities
OR ethanol produces <u>less</u> pollution or is <u>less</u> smoky or <u>less</u> CO/C

(the objective is a positive statement about ethanol)
(penalise the idea that ethanol is an infinite source or vague statements that ethanol has less impurities) (penalise the idea that ethanol produces no pollution)

1

(d) $C_2H_6 \rightarrow C_2H_4 + H_2$

1

(e) Addition

(ignore self or chain as a preface to "addition ")
(penalise additional)

1

[8]

Q14.

(a) (i) <u>addition</u> of water / steam **(1)**

Ignore "to the reaction"

(ii) *Advantage*: low technology
renewable feedstock / resource
allowed for use in drinks, perfumes
considered to be green **(1)**

any one
NOT "infinite" or "non-finite" resource

Disadvantage:
slow
low yield
significant land use
has to be distilled
labour intensive

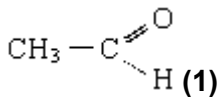
any one
Ignore yeast
NOT (unqualified) batch production
NOT impure product

3

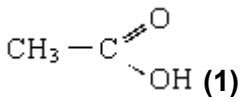
(b) (i)

Structure of aldehyde *Structure of carboxylic acid*

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 **(1)**

NOT CH_3CHO

 **(1)**

NOT CH_3COOH

Penalise incorrect R group once

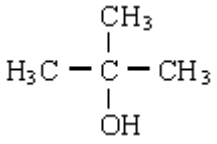
(ii) *Reagent*: sodium (/ potassium) dichromate (VI)
(VI not essential) (1) M1

Conditions: acidified or sulphuric acid **(1) Can be with reagent M2**
(heat under reflux) **(1) M3**

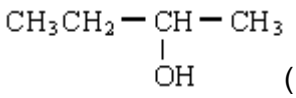
Or correct formula for M1 and M2
M2 depends on M1 (but M2 correct from $Cr_2O_7^{2-}$, $K_2Cr_2O_7^{2-}$ etc
M3 mark independent
Credit $KMnO_4$ for M1
Ignore T and P for M2

5

(c) (i)

 (1)

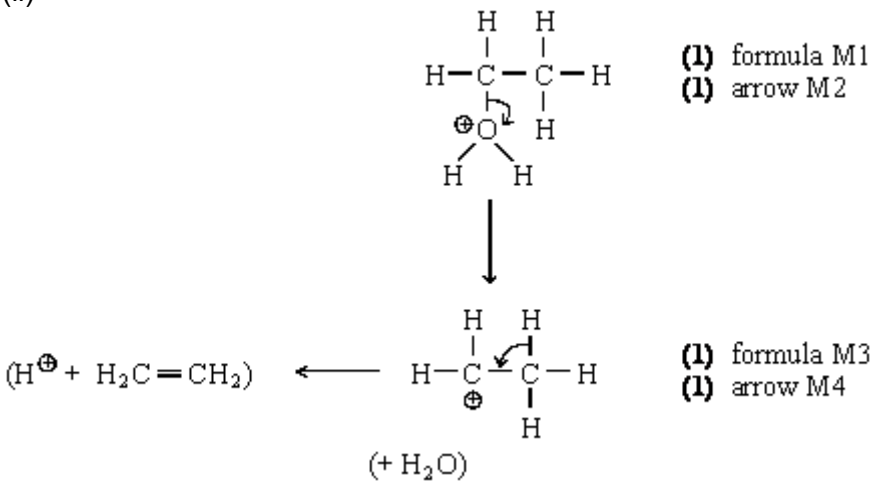
(ii)

 (1)

2

(d) (i) Al_2O_3 or H_2SO_4 or H_3PO_4 **(1)**
Name or formula

(ii)



For M1 the + can be on O or H if $-OH_2$ used
For M2 the arrow must go to the + or to oxygen
Synchronous loss without carbocation loses carbocation structure mark; can still score ¾ i.e. penalise M3

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5

[15]

Q15.

(a) % O = 21.6 % **(1)**

If % O not calculated only M2 available

C $\frac{64.9}{12}$ H $\frac{13.5}{1}$ O $\frac{21.6}{16}$ **(1)**

= 5.41 = 13.5 = 1.35

Ratio: 4 : 10: 1 ($\therefore$ $C_4H_{10}O$) **(1)**

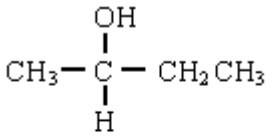
If arithmetic error in any result lose M3

If percentage composition calculation done zero

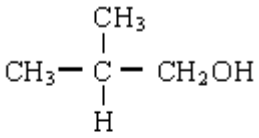
3

(b) (i) *Type of alcohol*: Tertiary **(1)**

Reason: No hydrogen atom on central carbon **(1)**



(1)



(1)

(ii) *Isomer 3* *Isomer 4*

Penalise missing bonds / incorrect bonds once per paper

4

(c) (i) Aldehyde **(1)**

Ignore named aldehydes or their structures,
penalise wrong named compound

(ii) $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$ **(1)**

Balanced **(1)**

$C_4H_{10}O$ is OK as a reactant
[O] can be over arrow
C_3H_7CHO not accepted for product, but $C_2H_5CH_2CHO$ is OK
If use C_3 or C_5 compounds no marks in (ii) C.E of wrong alcohol

(iii) *Name* Butanoic acid **(1)**

Structure: $CH_3CH_2CH_2COOH$ **(1)**

mark conseq. or as stated

5

(d) *Advantage*: Fast reaction OR pure product OR continuous process OR cheap on manpower OR high yield, 100% alcohol **(1)**

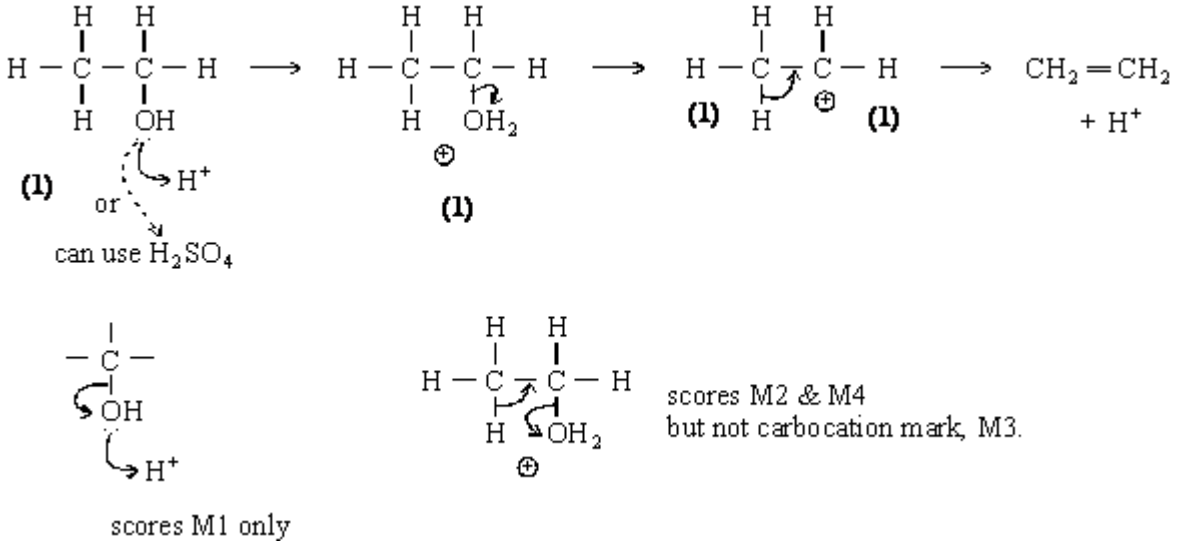
Disadvantage: High technology OR ethene from non renewable source OR expensive equipment not just costly **(1)**

Not answers based on fermentation

2

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(e)



4

[18]

Q16.

A

[1]

Q17.

Condition = two from yeast (*anywhere in question*)
Air excluded **or** sterile / clean **(2)**

Ignore references to pressure / temperature / aqueous / dark / high alcohol conc

Temperature too low inactivates / deactivates enzymes **or** reaction too slow **(1)**
Temperature too high destroys **or denatures** yeast / enzymes **(1)**

Not kills enzymes; not deactivates here

Advantage 1 = sugar / glucose / carbohydrate is renewable resource / source **(1)**
Advantage 2 = production uses low level technology / cheap equipment **(1)**

Ignore references to energy
Do not allow contra-arguments about ethene

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$ balanced **(1)**

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ balanced **(1)**

Allow C_2H_6O but penalise C_2H_5HO once

[8]

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Q3.

The mechanism in part (a) was generally done well although not always named correctly with 'elimination' appearing quite frequently – suggesting confusion with halogenoalkanes. Marks were sometimes lost due to incorrect bonding or structure of H_2SO_4 and HSO_4^-. Some students did not realise that the explanation of stability should be based on the relative stabilities of the intermediate carbocations and not on the stabilities of the two possible final products.

In part (b) the conditions were generally well known although phosphoric acid was sometimes omitted and most students were able to suggest two disadvantages., The advantages were often less well known and some students saw the need to exclude oxygen as a disadvantage.

Q4.

Part (a) discriminated almost as well as the earlier mechanism questions with well over half of the students scoring at least 3 of the 5 marks. Relatively few recognised that (fractional) distillation is a process used to produce a much more concentrated solution of ethanol and many referred to the hydration of ethene, having missed the requirement to start "from a dilute aqueous solution". The concept of carbon-neutral "in the context of this biofuel" required reference both to carbon dioxide **and** the atmosphere. Part (b) was well answered with over half of all students scoring 4 out of 5 marks. By comparison, part (c) proved more demanding. The definition in part (c)(i) most often yielded only 1 of the 2 marks. Too often in part (c)(ii) it proved difficult to decipher the jumble of numbers that some students recorded on the page and only about one-third of students scored all 3 marks.

Q5.

Many very good answers were seen throughout this question. In part (b), only 32% scored full marks because too many students repeated information from the question and missed the opportunity to score marks for conditions. In part (c), the displayed formula for a carboxylic acid requires the O–H bond drawn out and 62% of the students gained this mark. Some very good work was seen for the half-equations in parts (c)(ii) and (c)(iii). Part (d) was answered quite well.

Q6.

Part (a) required a plausible safety reason and many students referred correctly to the corrosive nature of sodium hydroxide. The idea that Process 2 used waste CO_2 from the bioethanol factory was in the stem but this was not always explained appropriately.

The mechanism in part (b)(i) was answered well and although the usual mistakes were seen, students were not put off by the context. The infrared spectra in part (b)(ii) were straightforward to interpret and caused problems only for a minority of students. Fermentation in part (c) was well–known and high scoring. Not surprisingly in part (d), only the best students were able to score the mark for the equation.

Q7.

The idea in part (a) was that Reaction 1 claimed to be carbon-neutral, based solely on the sum of the chemical reactions that occur for photosynthesis, fermentation and combustion

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of ethanol, was poorly understood. Answers rarely referred to the fact that fuels have to be used to plant, harvest and transport crops and then to process them to extract the sugar and to distil the aqueous solution of ethanol. Even when these ideas were given, the idea that this fuel use leads to the release of CO_2 into the atmosphere was given only rarely.

Part (b) discriminated well, although relatively few students referred to the idea that the yield is low or that bromoethane has to be made first.

In part (c), many missed the fact that a concentrated strong acid is required as the catalyst and only a few had recognised the specification requirement to know the typical conditions for the industrial production of ethanol from ethene.

Q8.

In question 5, it was the section on redox in part (b) that was least well answered. It was pleasing to see some very good mechanisms in part (c)(ii) and this part of the question discriminated extremely well producing the full range of marks. In part (c)(iv) too many candidates knew the correct acid but failed to draw a **displayed** formula.

Q9.

Most candidates seem to know something about fermentation and part (a) discriminated extremely well.

In part (b), only the best candidates were able both to state that such a fuel is carbon-neutral and also to demonstrate that the six moles of CO_2 taken in during photosynthesis are later released in the fermentation process followed by the combustion of ethanol. Failure to recognise that two moles of ethanol were burning resulted in only four moles of CO_2 and left candidates confused. A few candidates seemed to think that a balanced equation with six carbon atoms on each side is carbon-neutral.

The calculation in part (c) proved demanding as candidates failed to count up accurately how many of each bond were broken and how many were formed. They were able quite often to get only one of these correct. The idea that mean bond enthalpies are average values obtained from many different compounds was not well known.

In part (d) the equation used to calculate the heat change was well known but conversion to enthalpy change proved difficult for all but the best. The idea of incomplete combustion was often missed.

Q10.

This question was probably the most discriminating. Only the very best 10% were able to score full marks in part (a); the commonest error was the failure to draw <u>all</u> of the bonds in a displayed formula. In part (b) the fingerprint region was well known but only the best 15% stated the need to seek a match between the infrared spectrum of the isomer and a known spectrum. In part (c) poor equations and incorrect or imprecise formulas often marred otherwise good answers. Part (d) proved to be high scoring, but only 6% of the candidates were able to access all of the marks.

Q11.

Part (a) was taken straight from the Specification but only 20% of candidates scored full marks. The explanation in part (b) was generally done well and part (c) was relatively high scoring, even though the demand in (c)(i) required reference both to the change in rate and the idea that a catalyst is not used up in the reaction. Most candidates gave a correct answer to part (d)(i), but only a minority of candidates could work out what to do in part

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(d)(ii).

Q12.

Correct equations were seen in parts (a) and (b), but balancing them was a problem for some. In part (a), some candidates encountered difficulty because they introduced water or oxygen on either side of the equation. The inclusion of H_2SO_4 (or H^+) on both sides of the equation in (a)(ii) was acceptable and gained full credit. Writing the formula of ethanol as C_2H_6O was penalised once only in this question. Many candidates missed the fact that the catalyst has to be *concentrated* sulphuric (or phosphoric) acid, although the alternative answer of aluminium oxide was credited. Many candidates scored full marks in part (b), with the catalyst causing most problems. In part (c)(i), while correct answers were seen, many candidates could not add up correctly the numbers of each type of atom or failed to include oxygen in their answers, losing both marks. In part (c)(ii), large numbers of candidates knew that unsaturated compounds contain a double bond, although some stated categorically that they do not! The test for unsaturation was less well known and caused confusion for some candidates who appeared to be relating an experiment in which the degree of unsaturation has been measured leading to an end point in which the colour of bromine is seen. Candidates need to appreciate that "clear" and "colourless" are not the same.

Q13.

All parts of this question proved to be very accessible to all but the lowest achieving candidates. The most common errors arose from failing to use *concentrated* sulphuric (or phosphoric) acid in part (b)(ii) and from failing to give a clear statement of the advantage which ethanol offers as a fuel.

Q14.

In part (a)(i) the concept of hydration was occasionally confused with hydrolysis, but quite often, incorrect answers involved the addition of H, H_2 or H^+. In part (a)(ii) the idea from some candidates that an advantage of using sugar is that it is an “infinite” resource was not considered to be the same as saying that it is renewable and it was not considered to be sufficient to state as a disadvantage that the ethanol from fermentation is “impure” or that the process is “a batch process”, without some qualification. A few candidates misread the question and commented on the hydration of ethene.

Structures in part (b)(i) were usually well done, but answers to part (b)(ii) were sometimes spoiled by incorrect formulae and the absence either of acid conditions or reflux was not uncommon. Too often the structures in part (c) were drawn carelessly and common errors included a secondary alcohol in (c)(i) and a primary alcohol in (c)(ii) or the formula for butanone in part (c)(ii).

Part (d)(i) was not well known and $NaBH_4$ or Ni were common responses. Drawing the structure of ethanol, including a lone pair on oxygen in part (d)(ii) and starting the mechanism by putting in the first curly arrow allowed all but a small proportion of candidates to gain at least one mark and often as many as two out of four. This mechanism is not well known, despite being on the paper last summer and even some of the better candidates missed out the protonated alcohol and went straight to the carbocation. Some perfect answers were seen and those answers, which used a synchronous (E2) mechanism, were able to score three marks.

Q15.

Part (a) was well answered and the majority of candidates correctly identified the type of

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alcohol in (b)(i). Only a minority of candidates, however, were able to explain the resistance of the tertiary alcohol to oxidation. Most attempts offered little more than a statement that tertiary alcohols are more stable. References to the 'carbonyl carbon' were quite common. Valid arguments, based on the absence of a hydrogen atom on the central carbon, were offered by some candidates. The structures in (b)(ii) were frequently correct but duplicate structures showing a different orientation of a molecule were not uncommon. Many candidates lost marks here due to incorrectly drawn bonds; the most common error being to show a bond between a carbon atom and the hydrogen atom of the alcohol group. In part (c)(i), 'aldehyde' was frequently correctly given as the type of product but it was not unusual for a specific aldehyde, or other compound, to be quoted. Some candidates gave the correct response of 'aldehyde', but then lost the mark by quoting, for example, propanal or pentanal. Many candidates earned one mark for giving the structure of butanal in (c)(ii) but omitted to include [O] or H_2O in their equation and so lost the equation balancing mark. Equations showing a carboxylic acid as the product were seen by some examiners. Part (c)(iii) was not well done. Although correct answers were seen, common errors included quoting copper based products, suggesting 'carboxylic acid' as the name or naming compounds that were not acids, for example, butanal. Some candidates offered no response to this question. In part (d), an acceptable advantage was frequently seen but the disadvantages were less precisely expressed, and the suggestion that ethene, rather than crude oil, was a non-renewable resource was quite common. Part (e) was well done by the better candidates but it was not uncommon to see a mechanism for the hydration of ethene into ethanol. Often, the dehydration step was omitted, as were the charges and the lone pair on the oxygen; also, incorrect positioning of curly arrows was common.

Q17.

The majority of candidates correctly stated that yeast (zymase) was needed for the fermentation. The better candidates mentioned anaerobic conditions but the incorrect contra-statement, that excess oxygen was required, was quite common. A significant minority of candidates offered none or just one essential condition, or quoted a temperature. Many good accounts of the need for a compromise temperature were seen, with relatively few incorrect references to enzymes being 'killed' by too high a temperature. A fair number of candidates discussed the hydration of ethene, and the non-renewable nature of ethene, rather than identifying sugar as a renewable resource. The 'low level technology'/'cheap equipment advantage' enjoyed by fermentation was well known by some, but by no means all, candidates. While correct equations were quite common, a surprisingly large number of equations, particularly the combustion equation, were incorrect.

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