

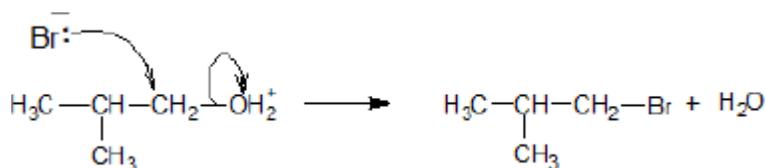
## Mark schemes

- 1** (a) (i) **M1** double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH<sub>2</sub>

*Penalise additional arrows.*

- M2** double-headed arrow from the bond to the O atom

As follows



2

- (ii) **M1** nucleophilic substitution

*M1 both words needed (allow phonetic spelling).*

- M2** 1-bromo(-2-)methylpropane

*M2 Require correct spelling in the name but ignore any hyphens or commas.*

2

- (b) **M1** hydrolysis

*For M1 give credit for 'hydration' on this occasion only.*

- M2** C≡N with absorption range 2220–2260 (cm<sup>-1</sup>)

*Credit 1 mark from M2 and M3 for identifying C≡N and either O–H(acids) or C=O or C–O without reference to wavenumbers or with incorrect wavenumbers.*

- M3** O–H(acids) with absorption range 2500–3000 (cm<sup>-1</sup>)

**OR**

- C=O with absorption range 1680–1750 (cm<sup>-1</sup>)

**OR**

- C–O with absorption range 1000–1300 (cm<sup>-1</sup>)

*Apply the list principle to M3*

3

(c) (i) **M1** Yield / product **OR** ester increases / goes up / gets more

**M2** (By Le Chatelier's principle) the position of equilibrium is driven / shifts / moves to the right / L to R / in the forward direction / to the product(s)

**M3 – requires a correct statement in M2**

(The position of equilibrium moves)

to oppose the increased concentration of ethanol

to oppose the increased moles of ethanol

to lower the concentration of ethanol

to oppose the change and decrease the ethanol

*If no reference to **M1**, marks **M2** and **M3** can still score BUT if **M1** is incorrect CE=0*

*If there is reference to 'pressure' award **M1** ONLY.*

3

(ii) **M1**

Catalysts provide an alternative route / pathway / mechanism

**OR**

surface adsorption / surface reaction occurs

*For **M1**, not simply 'provides a surface' as the only statement.*

***M1** may be scored by reference to a specific example.*

**M2**

that has a lower / reduced activation energy

**OR**

lowers / reduces the activation energy

*Penalise **M2** for reference to an increase in the energy of the molecules.*

*For **M2**, the student may use a definition of activation energy without referring to the term.*

*Reference to an increase in successful collisions in unit time alone is not sufficient for **M2** since it does not explain why this has occurred.*

2

[12]

2

(a) M1 concentrated sulfuric acid OR c(onc)  $\text{H}_2\text{SO}_4$

*If no reagent or incorrect reagent in M1, CE= 0 and no marks for M2 or M3*

M2 (cream solid) turns orange

**OR** orange / red / brown fumes / gas / vapour

*If dilute sulfuric acid OR "aq" (alone) CE=0*

M3 (yellow solid) turns black

**OR** purple fumes / gas / vapour

**OR** correct reference to  $\text{H}_2\text{S}$  observation (eg bad egg smell)

*If  $\text{H}_2\text{SO}_4$  / sulfuric acid given but not stated whether dilute or concentrated, penalise M1 and mark on for M2 and M3*

*If incorrect formula for the acid, penalise M1 but mark M2 and M3*

**OR as an alternative**

M1 concentrated ammonia **OR** c(onc)  $\text{NH}_3$

*If  $\text{NH}_3$  / ammonia / aq ammonia given, but not stated as*

*concentrated **OR** if dilute ammonia given, penalise M1 but mark on for M2 and M3*

*Ignore "partially" and ignore "clear" in M2*

M2 (cream solid) dissolves / solution formed

M3 precipitate remains / does not dissolve / insoluble

**OR** no reaction / no change / (yellow solid) turns to white solid

*If incorrect formula for ammonia, penalise M1 but mark M2 and M3*

*In M3 for ammonia.*

*ignore "nothing (happens)".*

*ignore "no observation".*

- (b) M1  $\text{AgNO}_3$  **OR** silver nitrate **OR** any soluble silver salt  
*If no reagent **OR** incorrect reagent in **M1**, **CE= 0** and no marks for **M2 OR M3***

M2 white precipitate or white solid / white suspension

*An insoluble silver salt **OR** Tollens' **OR** Ag **OR** ammoniacal silver nitrate or HCl /  $\text{AgNO}_3$  **CE= 0** for the clip.*

M3 remains colourless **OR** no reaction **OR** no (observed) change **OR** no precipitate

*For **M1***

*Credit acidified (**OR**  $\text{HNO}_3$ ) silver nitrate for **M1** and mark on.*

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

Credit alternative test for nitrate ions

*For **M2***

*Ignore "cloudy solution" **OR** "suspension".*

*For **M3***

*Ignore "nothing (happens)".*

*Ignore "no observation".*

*Ignore "clear".*

*Ignore "dissolves".*

- (c) M1 Br<sub>2</sub> **OR** bromine (water) **OR** bromine (in CCl<sub>4</sub> / organic solvent)  
*If no reagent or incorrect reagent in M1, CE= 0 and no marks for M2 or M3*

**Either Order**

- M2 (stays) Orange / red / yellow / brown / the same  
**OR** no reaction **OR** no (observed) change  
**OR** reference to colour going to cyclohexane layer

*No credit for combustion observations; CE=0*

*For M2 in every case.*

*Ignore "nothing (happens)".*

*Ignore "no observation".*

*Ignore "clear".*

- M3 decolourised / goes colourless / loses its colour

**With bromine (water)**

*For M1, it must be a whole reagent and / or correct formula.*

*If oxidation state given in name, it must be correct.*

*For M1 penalise incorrect formula, but mark M2 and M3*

**OR as an alternative**

**Use KMnO<sub>4</sub>/H<sub>2</sub>SO<sub>4</sub>**

- M1 acidified potassium manganate(VII) or KMnO<sub>4</sub>/H<sub>2</sub>SO<sub>4</sub>

**OR** KMnO<sub>4</sub>/ H<sup>+</sup> **OR** acidified KMnO<sub>4</sub>

- M2 (stays) purple or no reaction or no (observed) change

**With potassium manganate(VII)**

**For M1**

- M3 purple to colourless solution **OR** goes colourless

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

Credit alternative test using **iodine** (for M1)

- M2 (brown) to purple or accept no change, M3 colourless

Credit alternative test using concentrated H<sub>2</sub> SO<sub>4</sub>

- M2 no change, M3 brown

*Credit alkaline / neutral KMnO<sub>4</sub> for possible full marks but M3 gives brown precipitate or solution goes green.*

- (d) M1 Tollens' (reagent) OR ammoniacal silver nitrate OR a description of making Tollens'  
(Ignore either  $\text{AgNO}_3$  or  $[\text{Ag}(\text{NH}_3)_2]^+$  or "the silver mirror test" on their own, but mark M2 and M3)

M2 silver mirror

**OR** black solid / precipitate (Ignore silver precipitate)

M3 (stays) colourless or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3***

**For M3 in every case**

*Ignore "nothing (happens)".*

*Ignore "no observation".*

Alternative using Fehling's (solution)

M1 Fehling's (solution) or Benedict's solution

(Ignore  $\text{Cu}^{2+}(\text{aq})$  or  $\text{CuSO}_4$  on their own, but mark M2 and M3)

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

M3 (stays) blue or no reaction or no (observed) change

**With potassium dichromate(VI)**

**For M1**

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

Alternative using  $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$

M1 acidified potassium dichromate or  $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$

**OR**  $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$  **OR** acidified  $\text{K}_2\text{Cr}_2\text{O}_7$

M2 (Orange to) green solution OR goes green

M3 (stays) Orange or no reaction or no (observed) change

**For M3**

*Ignore dichromate described as "yellow" or "red".*

**With potassium manganate(VII)**

**For M1**

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

Alternative using  $\text{KMnO}_4/\text{H}_2\text{SO}_4$

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

**OR**  $\text{KMnO}_4/\text{H}^+$  **OR** acidified  $\text{KMnO}_4$

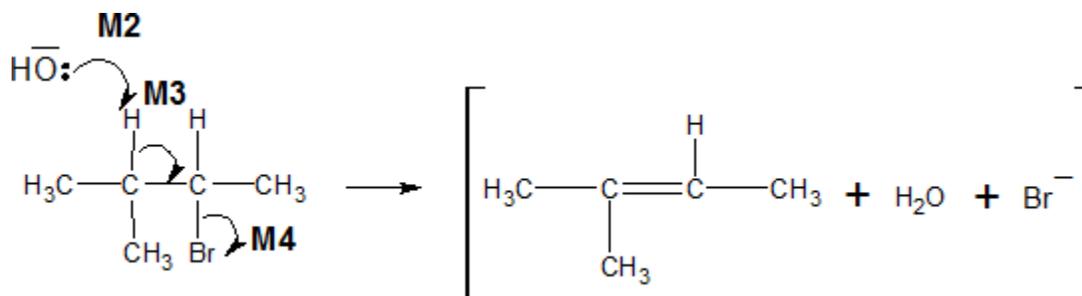
M2 purple to colourless solution OR goes colourless

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

*Credit alkaline / neutral  $\text{KMnO}_4$  for possible full marks but **M2** gives brown precipitate or solution goes green.*

3

(a) (i) M1 Elimination

*M1 Credit "base elimination" but no other prefix.**Penalise M2 if covalent KOH**Penalise M4 for formal charge on C or Br of C-Br or incorrect partial charges on C-Br*

M2 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

*Ignore other partial charges*

M3 must show an arrow from a correct C-H bond adjacent to the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M2**

*Penalise **once only** in any part of the mechanism for a line and two dots to show a bond*

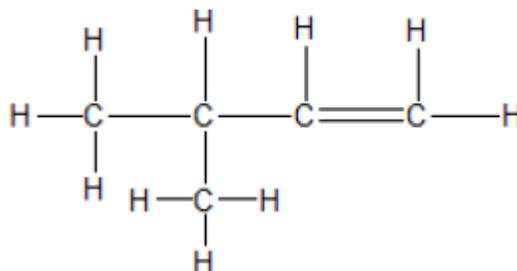
M4 is independent provided it is from their original molecule, **BUT CE=0 for the mechanism (penalise M2, M3 and M4 only) if nucleophilic substitution mechanism is shown**

***Maximum any 2 of 3 marks for the mechanism** for wrong organic reactant or wrong organic product (if shown).**Credit the correct use of "sticks" for the molecule except for the C-H being attacked*

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

*Penalise M4, if an additional arrow is drawn from Br eg to K<sup>+</sup>***NB These are double-headed arrows**

4

(ii) Displayed formula for 3-methylbut-1-ene*All bonds and atoms must be drawn out, but ignore bond angles*

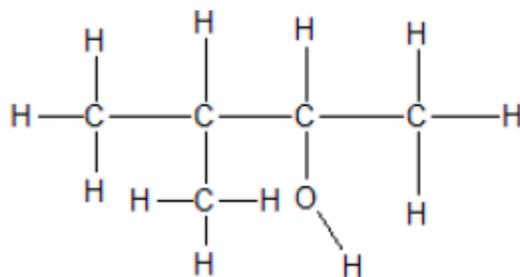
1

(iii) Position(al) (isomerism or isomer)

*Penalise any other words that are written in addition to these.*

1

(b) (i) Displayed formula for 3-methylbutan-2-ol



*All bonds and atoms must be drawn out, but ignore bond angles.*

1

(ii) Any **one** from

- Lower / decreased temperature **OR** cold
- Less concentrated (comparative) **OR** dilute KOH
- Water (as a solvent) / (aqueous conditions)  
*Ignore "pressure".*

1

(iii) Nucleophilic substitution

*Both words needed - credit phonetic spelling.*

1

(iv) (Strong / broad) absorption / peak in the range **3230 to 3550**  $\text{cm}^{-1}$  or specified value in this range or marked correctly on spectrum

*Allow the words "dip" **OR** "spike" **OR** "trough" **OR** "low transmittance" as alternatives for absorption.*

1

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4

Compare spectrum of aldehyde with known spectrum of pentanal

*Must be a specific reference to a comparison.*

1

Exact match

*Allow 'fingerprint regions match exactly'.*

1

[2]

5

(a) (i)  $\text{CH}_2\text{O}$

*Atoms in any order*

*Accept a clear indication that  $\text{C}_6\text{H}_{12}\text{O}_6$  yields  $\text{CH}_2\text{O}$  as the answer*

1

- (ii) No peak / no absorption / no C=O in the **range 1680 to 1750** (cm<sup>-1</sup>) (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



*Penalise (C<sub>2</sub>H<sub>6</sub>O)*

*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”*

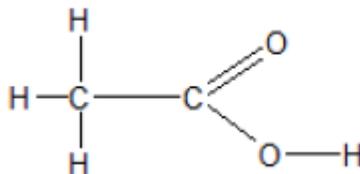
*Ignore “anaerobic / absence of oxygen”*

*Ignore “controlled pH”*

*Ignore “warm”*

3

- (c) (i) Displayed formula for CH<sub>3</sub>COOH



*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



*(C<sub>2</sub>H<sub>6</sub>O or C<sub>2</sub>H<sub>5</sub>OH)*

*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 / CO<sub>2</sub> given out equals the carbon / CO<sub>2</sub> that was taken in from the atmosphere / air*

**OR**

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air.

*Answer must refer to the atmosphere or air*

**OR**

There is no change in the total amount of carbon dioxide / carbon / greenhouse gas present in the atmosphere / air

1

- (ii) Renewable / sustainable ONLY

*Ignore references to global warming or greenhouse gases*

1

(iii) **Any one statement about this process from**

Subject to weather / climate

*Ignore "batch"*

**OR**

Depletes food supply OR the land use for (specified) food

**OR**

Requires use of / uses more fossil fuels

**OR**

Not carbon-neutral OR CO<sub>2</sub> 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  
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6



1

(b) **M1** (P<sub>4</sub> =) **0**

**M2** (H<sub>3</sub>PO<sub>4</sub> =) **(+) 5**

*Accept Roman numeral V for M2*

2

(c) H<sub>2</sub>SO<sub>4</sub>

**Both numbers required**

$$\begin{aligned} M_r &= 2(1.00794) + 32.06550 + 4(15.99491) \\ &= \mathbf{98.06102 \text{ or } 98.0610 \text{ or } 98.061 \text{ or } 98.06 \text{ or } 98.1} \end{aligned}$$

*Calculations not required*

**and**

H<sub>3</sub>PO<sub>4</sub>

$$\begin{aligned} M_r &= 3(1.00794) + 30.97376 + 4(15.99491) \\ &= \mathbf{97.97722 \text{ or } 97.9772 \text{ or } 97.977 \text{ or } 97.98 \text{ or } 98.0} \end{aligned}$$

1

- (d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

**Both ideas needed**

*Ignore reference to activation energy or alternative route.*

1

- (ii) The addition of water (**QoL**) to a molecule / compound

**QoL- for the underlined words**

1

- (iii) **M1**  $\text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O} \longrightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

( $\text{C}_3\text{H}_6$ )

*For M1 insist on correct structure for the alcohol but credit correct equations using either  $\text{C}_3\text{H}_6$  or double bond not given.*

**M2** propan-2-ol

2

**[8]**

7

- (a) (i) **M1** **Initiation**



*Penalise absence of dot once only.*

*Penalise + or - charges every time*

**M2** **First propagation**



*Accept dot anywhere on  $\text{CHCl}_2$  radical but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only*

*Penalise once only for a line and two dots to show a bond.*

**M3** **Second propagation**



*Penalise once only for double headed curly arrows*

*Mark independently*

3

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

ultra-violet / uv / sun light

**OR** high temperature

**OR**  $400^\circ\text{C} \leq T \leq 900^\circ\text{C}$

**M2** **Type of mechanism**

(free-) radical substitution (mechanism)

2



*Allow X as alternative to  $\text{CCl}_4$  only if X is clearly identified as  $\text{CCl}_4$*

1

(ii) **M1** Trichloromethane /  $\text{CHCl}_3$  has a C–H bond

**OR**

X /  $\text{CCl}_4$  / it has no C–H bond

**M1** *must refer to presence or absence of the C–H bond in a compound*

**M2** The infrared spectrum shows

(absorption / peak for C–H in range) **2850 to 3300** ( $\text{cm}^{-1}$ ) is missing

**M2** *answer must refer to / imply the spectrum*

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

*Ignore references to other absorptions.*

2

(c) **M1 a statement about bond breakage / formation of Cl•**

C–Cl / carbon-chlorine bond breakage occurs

**OR** Cl• / chlorine (free) radical forms

**OR** correct equation  $\text{CHClF}_2 \longrightarrow \text{Cl}\cdot + \cdot\text{CHF}_2$

*Penalise M1, if Cl• is formed from Cl<sub>2</sub> as the only reaction or an additional reaction*

*Do not penalise an incorrect equation using CHClF<sub>2</sub> if correct reference is made to Cl• formation or C–Cl / carbon-chlorine bond breakage*



*M2 and M3 either order*

*Penalise absence of dot once only.*

*Accept dot anywhere on ClO radical*

**M4** CHClF<sub>2</sub> / chlorine-containing compounds/ CFCs damage / react with / decrease the ozone layer

**OR**

this overall decomposition occurs;  $2\text{O}_3 \longrightarrow 3\text{O}_2$

**OR**

without an ozone layer or with a decreased ozone layer, uv radiation is not being “filtered” / prevented from passing through the atmosphere or there is a concern about an increase in skin cancer etc.

**OR**

Cl• catalyses the decomposition of ozone / a single Cl• causes (chain) reaction / decomposition of many ozone molecules / ozone layer

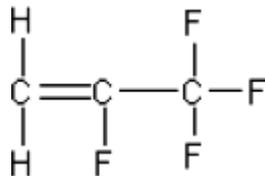
*Award M4 for the general idea behind the EU justification for banning the use of CFCs as refrigerants*

*Penalise M4 if overall ozone decomposition equation is incorrect*

*Ignore “greenhouse effect”, “global warming” etc.*

4

(d) (i)



*All bonds must be drawn out*

1

- (ii) 2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / C–Cl (bonds)  
*Ignore “chlorine molecules”*

**OR**

It does not produce Cl• / does not produce chlorine (free) radical(s)

**OR**

chlorodifluoromethane does contain chlorine / does produce Cl• / does produce chlorine (free) radical(s)

**OR**

C–F is too strong and does not break / create radicals

**OR**

C–F is stronger than C–Cl

1

[14]

8

- (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<sub>2</sub> / CO<sub>2</sub> from the factory / CO<sub>2</sub> from the bioethanol (or biofuel) production

**OR**

reduces or limits the amount of CO<sub>2</sub> released / given out (into the atmosphere)

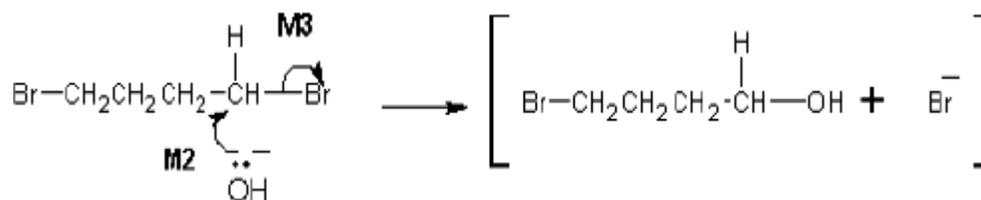
**OR**

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,  $\text{K}^+$

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  $1^{\circ}$  (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]

9

(a) For 2 marks at least one correct reference either to  $M_r$  or value to 5 decimal places required

*QoL (associated with the bold statement here)*

**M1** Compounds 1 and 3 (butanal and butanone) have the same  $M_r$  (to 5dp) because either

*It may be possible to award 2 marks if there is a clear statement about oxygen having a different precise  $A_r$  in the context of the comparison*

- they contain the same number of atoms of the same / each element
- are both  $C_4H_8O$
- have the same molecular formula  
*NB The word "similar" does not mean "the same"*
- contain the same number of C, H and O atoms

**M2** Compound 2 (pentane) has a different  $M_r$  (to 5dp) because either

- it has different numbers of atoms of different elements
- is  $C_5H_{12}$  / only contains C and H
- different molecular formula
- does not contain oxygen (atom) /  $C=O$

2

(b) **With Tollens' (reagent)**

**M1** silver mirror

**OR** black solid/precipitate

(NOT silver (mirror) precipitate)

**M2** (stays) colourless

**OR** no change / no reaction

**OR** no silver mirror

**With Fehling's (solution)**

**M1** Red solid/precipitate

(Credit orange or brown solid)

**M2** (stays) blue

**OR** no change / no reaction

**OR** no red solid

**OR** no (red) precipitate

**N.B No mark is awarded for the reagent**

*If no reagent given allow 1 mark for a consistent statement of M1 and M2*

*For M2, ignore "nothing (happens)"*

*And ignore "no observation"*

2

[4]