



## 3.2.9 Alkenes

*Polymerisation*

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152 minutes



149 marks

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**M1.** Oxygen or air **(1)** Can score from the equation  
Silver catalyst **(1)**

Linked to process: e.g. Consequence of leaks etc. **(1)**

Hazard 1 = flammable **or** explosive **(1)**

Hazard 2: = toxic **or** causes respiratory failure or neurological effects **(1)**

$(\text{CH}_2\text{CH}_2)_n\text{O} + \text{H}_2\text{O} \rightarrow \text{HOCH}_2\text{CH}_2\text{OH}$  **(1)** Not  $(\text{CH}_2\text{CH}_2)_2\text{O}$ ,  $\text{CH}_2\text{CH}_2\text{O}$ ,  
 $\text{C}_2\text{H}_4\text{O}$ , but only penalise once

Uses include antifreeze or polyester formation / terylene **(1)**, Not plastics, polymers, surfactants

$n(\text{CH}_2\text{CH}_2)_n\text{O} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{O}(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$  **(1)**

Uses include brake fluids or plasticisers **(1)** **OR surfactant or detergent**

$\text{CH}_3\text{CH}_2(\text{OCH}_2\text{CH}_2)_n\text{OH}$  and  $\text{H}(\text{CH}_2\text{CH}_2\text{O})_{n+1}\text{OH}$  are OK in last equation

[8]

**M2.** (a) ethan(e)-1,2-diol OR 1,2-ethan(e)diol **(1)**  
antifreeze **(1)** OR production of Terylene / polyester  
feedstock for polyester / PET

*NOT surfactant NOT plasticizer NOT solvent NOT de-icer*

2

(b) Reaction 1  $\text{H}_2\text{O}$  or steam **(1)**

Reaction 2  $\text{O}_2$  **(1)** NOT air

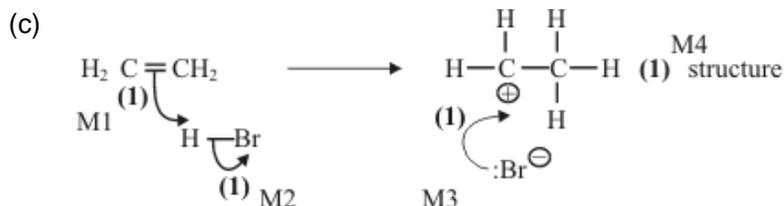
*Ignore reaction 3*

Reaction 4  $\text{H}_2\text{O}$  **(1)**

Reaction 5  $\text{NH}_3$  **(1)**

*For Reaction 4; credit dil  $\text{H}_2\text{SO}_4$  OR  $\text{H}_2\text{SO}_4(\text{aq})$  OR  $\text{HCl}(\text{aq})$  but NOT steam and NOT  $\text{NaOH}(\text{aq})$*

4



*Penalise M2 incorrect  $\delta+$  /  $\delta-$*

*Penalise  $\delta-$  on alkene (M1)*

*Penalise dots on bonds once*

*Penalise M4 (structure) for use of wrong alkene*

*Penalise M1 for use of  $\text{Br}_2$*

4

(d) Water OR aqueous solution OR (aq) in equation (1)

M1

Yeast OR enzyme/zymase OR  $T \leq 45^\circ\text{C}$

*but T not below 20°C and allow warm*

*N.B. yeast and  $T=60^\circ$  ✗ con*

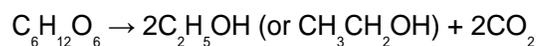
*Ignore pH*

*Ignore anaerobic / oxygen*

*Ignore time*

*Ignore pressure*

M2



*Allow  $\text{C}_6\text{H}_{12}\text{O}_{11}$  if balanced equation*

*M4 OR M5 needs the use of good English and correct chemistry to gain credit*

M3

M4: The rate of fermentation is slower (1)

OR The rate of hydration is faster

QoL OR (The rate of) fermentation is slow and

(the rate of) hydration is fast

*reference correctly to time rather than rate gains credit*

M5: The product of fermentation is less pure or lower purity

OR The product of hydration is more pure or higher purity

OR The product of fermentation is impure and that of hydration is pure

OR Specific reference to 10–15% versus 90–100%

OR correct reference to higher or lower yield

5

[15]



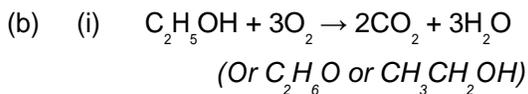
*(Or  $\text{CH}_3\text{CH}_2\text{OH}$ )*

*(Ignore state symbols in the equation)*

1

(ii) Fermentation

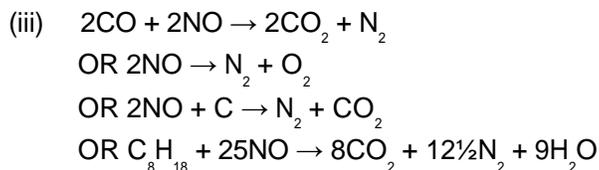
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1

(ii) CO or carbon monoxide or C or carbon ONLY

1



(In equation 2, allow additional  $O_2$  on both sides of the equation)

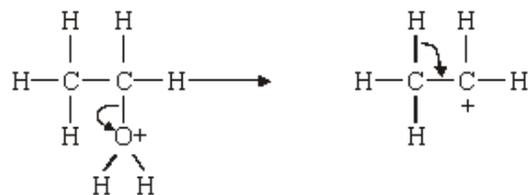
1

(c) Elimination

(Penalise additional words such as "electrophilic")

1

M1 structure of protonated alcohol (allow  $CH_3CH_2^+OH_2$ )



1

M2 arrow to show breakage of C – O bond on protonated alcohol

1

M3 structure of carbocation (allow  $CH_3^+CH_2$ )

1

M4 arrow from correct C – H bond on carbocation

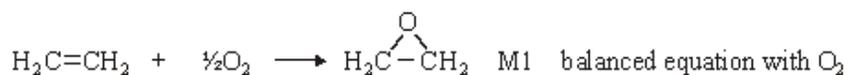
(penalise 'sticks' once only for structures M1 and M3)

(synchronous mechanism using correct structure required for M1, loses M3)

1

- (d) Silver OR silver-based  
(NOT silver oxide)

1



1

M2 correct structure for epoxyethane

(Allow  $\text{CH}_2=\text{CH}_2$  or  $\text{C}_2\text{H}_4$  in the equation)

(Credit the structure of epoxyethane independently)

(Credit M1 provided  $\text{O}_2$  has been used and the atoms balance, but the structure is poor e.g.  $\text{C}_2\text{H}_4\text{O}$  or  $\text{CH}_2\text{OCH}_2$  but NOT  $\text{CH}_3\text{CHO}$ )

1

[13]

- M4.** (a) M1 X is 1,2-dibromoethane only

1

M2 electrophilic addition

(both words needed)

1

M3 the double bond is a centre of electron density

OR electron-rich

OR nucleophilic

OR a source of an electron pair

OR a pi cloud/bond of electrons

1

M4 a dipole or polarity is induced/created/formed in the  
Br-Br bond/molecule -

award this mark only if the quality of language justifies the award.

1

- (b) nucleophilic substitution  
(both words needed) 1
- Mechanism M1 curly arrow from lone pair on oxygen of hydroxide ion to C atom of C-Br 1
- Mechanism M2 curly arrow from C-Br bond to side of Br atom  
(a possible repeat error here from Question 4a)  
(award a maximum of one mark for the wrong haloalkane)  
(credit an S<sub>N</sub>1 mechanism in which M1 will be a curly arrow from the lone pair on oxygen of the hydroxide ion to the correct positive carbon atom) 1
- Y is susceptible to attack by hydroxide ions for one of the following reasons
- o the C-Br bond is polar
  - o the carbon atom is partially positive (or shown as such)
  - o the carbon atom is electron deficient 1
- (c) M1 oxygen  
(ignore "air") 1
- M2 silver or silver-based  
(penalise silver nitrate) 1
- M3 Z is epoxyethane 1
- M4 epoxyethane
- o has a strained ring structure
  - o has a bond angle of 60°
  - o has a bond angle significantly less than tetrahedral  
(ignore "unstable", "has strained bonds", "is stressed") 1

- (d) Ethane-1,2-diol is used in antifreeze  
OR in the manufacture of PET/Terylene/polyester  
(penalise "solvent" or "plasticiser")

1

Hazard in Route *via* X/Y

- o bromine is toxic or corrosive
- o sodium hydroxide is corrosive or caustic

1

Hazard in Route *via* epoxyethane

- o risk of explosion in reaction 4
- o epoxyethane is toxic
- o epoxyethane is a respiratory irritant
- o epoxyethane causes neurological damage

1

[15]

- M5.** (a) (i) Electron pair/ lone pair acceptor OR seeking/bonds  
with an electron pair  
(insist on reference to a pair of electrons)

1

- (ii) M1 curly arrow from middle of C=C bond of the alkene towards/  
alongside the H atom of the H-Br;  
(penalise arrows which go towards one of the carbon atoms)  
(ignore a partial negative charge on the C=C)

1

M2 curly arrow from H-Br bond to side of Br atom;  
(penalise M2 if there are formal charges on HBr or if there are  
partial charges which are the wrong)  
(penalise M2 if the single bond has two dots in addition to the line)

1

M3 correct structure for carbocation;  
(penalise M3 if the positive charge is placed on the end of a bond)  
(penalise M3 if any alkene other than ethene is used - all other  
marks can score)

1

M4 curly arrow from lone pair on bromide ion to the positive carbon  
of carbocation, ensuring that bromide ion has a negative charge;

- (b) (i) M1 Oxygen OR  $O_2$ ;  
*(do not credit "air" alone, but otherwise ignore)*
- M2 silver OR Ag OR silver-based  
*(penalise silver nitrate)* 1
- (ii) correct structure for epoxyethane;  
*(penalise poorly presented C-O bonds)* 1
- (iii) water  
 OR  
 $H_2O$ ;  
*(credit steam OR  $H_2SO_4$  (aqueous OR dilute) OR  $NaOH(aq)$  OR  $HCl(aq)$ ,  
 OR  $H_3PO_4(aq)$ , but insist that (aq) is included)  
 (do not credit  $HCl$  or  $H_2SO_4$  (concentrated or without water present))* 1
- (c) (i) M1: potassium cyanide OR KCN OR sodium Cyanide OR NaCN;  
*(ignore conditions - dissolved in (aq) or (alc) or  $KOH(aq)$  all work)  
 (penalise HCN)* 1
- M2: propanenitrile;  
*(credit propan-1-nitrile OR propan nitrile, but not propanitrile)* 1
- (ii) M1: ammonia OR  $NH_3$ ;  
*(If formula is written, insist that it is correct)  
 (ignore conditions, but penalise acidic)* 1
- M2: ethylamine;  
*(credit aminoethane)* 1
- (iii) M1: curly arrow from lone pair on nitrogen of (correct formula for) ammonia towards/alongside C atom of C-Br;  
*(penalise M1 if formula of ammonia is wrong or has a negative charge or has no lone pair or arrow is from negative charge)* 1
- M2: curly arrow from C-Br bond towards/alongside side Br atom;  
*(credit M2 independently)  
 (penalise M2 if formal positive charge on C atom of C-Br)* 1

M3: correct structure of the ethylammonium ion;  
(credit the structure drawn out with all four bonds around the nitrogen atom OR written as  $C_2H_5NH_3^+$  OR  $CH_3CH_2NH_3^+$ )

1

M4: curly arrow from the middle of one of the H-N bonds towards the positive N atom;

(possible to credit M4 on an incorrect ethylammonium ion with no positive charge)  
(ignore use of ammonia or bromide ion etc. to remove proton from ethylammonium ion)  
(If the wrong haloalkane is used, award MAX. 3 marks for the mechanism) (If  $S_N1$  mechanism is used, give full credit in which M1 is for a curly arrow from the lone pair of the N atom of (correct formula for) ammonia towards/alongside the positive carbon atom of  $CH_3CH_2^+$ )

[17]

M6. (a) Ag or silver or silver-based or silver on an alumina base  
(penalise specific silver compounds)

1

epoxyethane

1

(b) electrophilic addition 1

**M1:** curly arrow from C=C bond towards/alongside the side of H atom on H.OSO<sub>2</sub>OH

*(penalise M1 if arrow to H<sub>2</sub>SO<sub>4</sub> OR to formal charge on H of H.O bond)*

*(ignore partial charges on H and O of H<sub>2</sub>SO<sub>4</sub>, but penalise if these are incorrect on the H atom being attacked)*

*(credit M1 and M2 if correct curly arrow to H+ provided the anion is present)*

1

**M2:** curly arrow from H-O bond towards/alongside the side of the O atom on H-OSO<sub>2</sub>OH

*(credit the arrow even if there are partial or formal charges on H and O but the structure of H<sub>2</sub>SO<sub>4</sub> is correct)*

1

**M3:** correct structure of the carbocation

*(penalise use of 'sticks' in this structure)*

1

**M4:** curly arrow from lone pair on an individual oxygen atom of (correct formula for) hydrogensulphate ion towards/alongside C atom bearing the positive charge

*(insist that the anion has the correct formula with a lone pair of electrons and a negative charge)*

1

(c) (i) ethanal 1

correct structure for ethanal

*(aldehyde functional group must be drawn out)*

1

(ii) oxidation or redox 1

[10]

**M7.** (a) (i) M1 curly arrow from lone pair of electrons on oxygen of hydroxide ion  
*(insist on a lone pair of electrons on the oxygen atom and a negative charge, but only credit this mark if the attack is to a correct H atom)*

1

M2 curly arrow from the middle of the C-H bond to the middle of the C-C bond.

*(only credit this mark if the arrow originates from the correct C-H bond and if an attempt has been made at M1)*

1

M3 curly arrow from the middle of the C–Br bond towards/alongside the Br atom.

*(credit M3 independently unless the bond breaking is contradicted by an additional arrow)*

*(penalise M3 curly arrow if the C–Br has a formal positive charge)*

*(ignore partial charges on the C–Br bond, but penalise if incorrect)*

*(credit full marks for an E1 mechanism, with M2 awarded for a correct curly arrow on the correct carbocation)*

*(award a maximum of two marks for an incorrect haloalkane)*

*(ignore products)*

1

(ii) Haloalkane/C<sub>2</sub>H<sub>5</sub>Br is made from ethane

OR haloalkane is not (readily) available

OR haloalkane is expensive

OR it is (too) expensive/costly

OR (reaction) yield is too low/poor

OR it is too slow

OR a valid reference to nucleophilic substitution/alcohol formation occurring as an alternative reaction.

*(ignore references to temperature or to energy consumption)*

*(do not credit statements which refer to the idea that this route is not chosen, because industry chooses another route e.g. cracking)*

1

(b) (i) Strained ring/ bonds/ structure/molecule

OR three-membered ring

OR 60° bond angle

OR bond angle much less than tetrahedral

*(penalise “stressed ring”)*

*(ignore “weak bonds”, ignore “unstable”)*

1

(ii) ethane-1,2-diol OR correct structure

*(penalise ethylene glycol OR 1,2-dihydroxyethane if these appear alone)*

*(credit ethan-1,2-diol)*

*(If both a structure and a formula are given, credit either correct one of these provided the other is a good, if imperfect, attempt)*

1

(used in) antifreeze

OR

for OR in the manufacture/making/formation of terylene, polyester, PET only

*(ignore reference to terylene etc. if they accompany “antifreeze”)*

*(penalise “de-icer”, “solvent”, “surfactant”, “plasticizer”)*

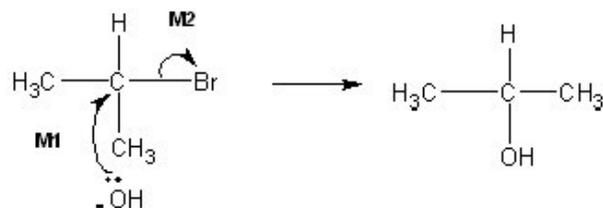
*(If the candidate indicates that the product is antifreeze, then this can gain credit, but not if contradicted in its use e.g. as de-icer)*

1

[7]

M8. (a) (i) Nucleophilic substitution

1



2

**M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

**M2** must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

*Penalise M1 if covalent KOH is used*

*Penalise M2 for formal charge on C or incorrect partial charges*

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

*Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks"*

*Ignore product*

Award full marks for an S<sub>N</sub>1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

(iii) Polar C-Br **OR** polar carbon-bromine bond **OR** dipole on C-Br  
**OR** δ+ (δ-)

C atom of carbon-bromine bond is δ+/electron deficient **OR** C—Br

(Credit carbon-halogen bond as an alternative to carbon-bromine bond)

*It must be clear that the discussion is about the carbon atom of the C-Br bond. NOT just reference to a polar molecule.*

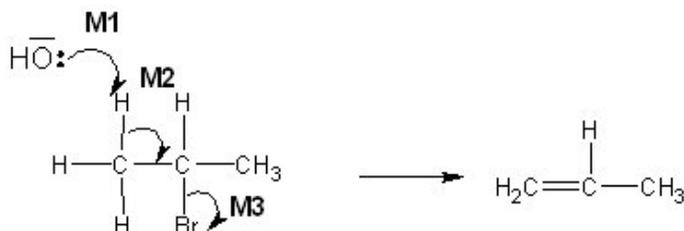
*Ignore X for halogen*

1

(b) Elimination

Credit "base elimination" but NOT "nucleophilic elimination"  
No other prefix.

1



3

**M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

**M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

**M3** is independent.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

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

Max 2 marks **for the mechanism** for wrong reactant and/or "sticks"

Ignore product

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

(c) Any one condition from this list to favour elimination;

Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide **OR** concentrated KOH/hydroxide  
Ignore "aqueous"
- high temperature or hot or heat under reflux or  $T = 78$  to  $100^\circ\text{C}$   
Ignore "excess"

1

(d) (i) Addition (polymerisation) ONLY

Penalise "additional"

1

(ii) But-2-ene ONLY (hyphens not essential)

Ignore references to *cis* and *trans* or *E/Z*

Ignore butane

1

[12]

**M9.** (a) (i) **M1** (yellow precipitate is) silver iodide OR AgI (which may be awarded from the equation)

**M2**  $\text{Ag}^+ + \text{I}^- \rightarrow \text{AgI}$  (Also scores M1 unless contradicted)

**M3** sodium chloride OR NaCl

*For M2*

*Accept multiples*

*Ignore state symbols*

*Allow crossed out nitrate ions, but penalise if not crossed out*

3

(ii) The silver nitrate is acidified to

- react with / remove ions that would interfere with the test
- prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test
- remove (other) ions that react with the silver nitrate
- react with / remove carbonate / hydroxide / sulfite (ions)  
*Ignore reference to “false positive”*

1

(iii) **M1 and M2 in either order**

**M1** Fluoride (ion) OR F<sup>-</sup>

**M2** • Silver fluoride / AgF is soluble / dissolves (in water)

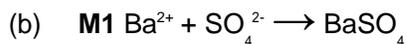
- no precipitate would form / no visible / observable change

*Do not penalise the spelling “fluoride”,*

*Penalise “fluride” once only*

*Mark M1 and M2 independently*

2



(or the ions together)

**M2** white precipitate / white solid / white suspension

**M3** Barium meal or ( internal ) X-ray or to block X-rays

**M4**  $\text{BaSO}_4$  / barium sulfate is insoluble (and therefore not toxic)

*For M1, ignore state symbols*

*Allow crossed out sodium ions, but penalise if not crossed out*

*For M2, ignore "milky"*

*If  $\text{BaSO}_3$  OR  $\text{BaS}$  used in M1 and M4, penalise once only*

*For M3 Ignore radio-tracing*

*For M4 NOT barium ions*

*NOT barium*

*NOT barium meal*

*NOT "It" unless clearly  $\text{BaSO}_4$*

4

(c) **M1**  $2(12.00000) + 4(1.00794) = 28.03176$

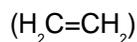
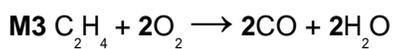
**M2** Ethene and CO or "they" have an imprecise  $M_r$  of 28.0 / 28

OR

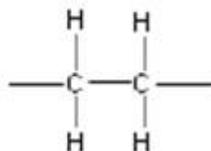
Ethene and CO or "they" have the same  $M_r$  to one d.p.

OR

These may be shown by two clear, simple sums identifying both compounds



**M4** Displayed formula



**M5** Type of polymer = Addition (polymer)

*M1 must show working using 5 d.p. for hydrogen*

*Penalise “similar” or “close to”, if this refers to the imprecise value in M2, since this does not mean “the same”*

*For M3, accept  $\text{CH}_2=\text{CH}_2$  OR  $\text{CH}_2\text{CH}_2$*

*For M4, all bonds must be drawn out including those on either side of the unit.*

*Penalise “sticks”*

*Ignore brackets around **correct** repeating unit but penalise “n”*

*Penalise “additional”*

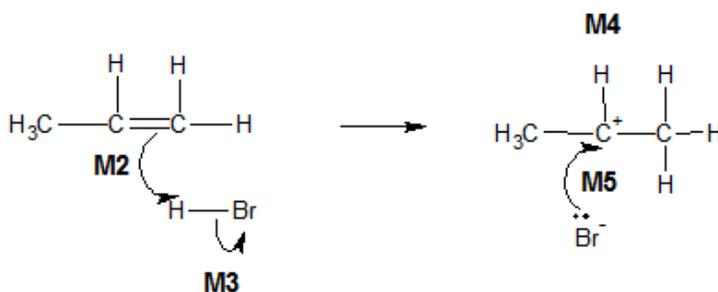
5

[15]

**M10.** (a) **M1 electrophilic addition**

*For M1, both words required*

*Accept phonetic spelling*



**For the mechanism**

**M2** Ignore partial negative charge on the double bond

M2 must show an arrow from the double bond towards the H atom of the H-Br molecule

**M3** Penalise partial charges on H-Br bond if wrong way and penalise formal charges

M3 must show the breaking of the H-Br bond

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

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom

**Maximum any 3 of 4 marks for the mechanism** for wrong (organic) reactant **OR** wrong organic product (if shown) **OR** primary carbocation

*Accept the correct use of sticks*

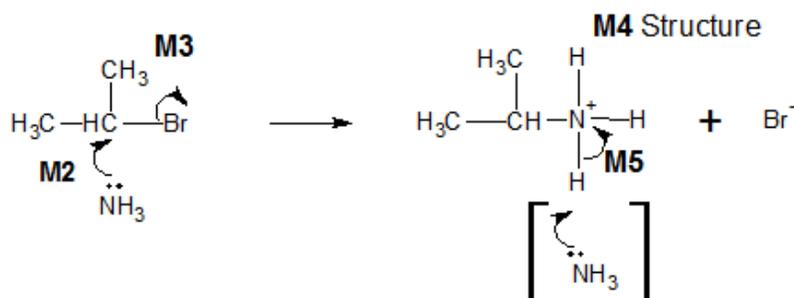
**NB** These are double-headed arrows

5

(b) **M1 Nucleophilic substitution**

For **M1**, both words required

Accept phonetic spelling



**For the mechanism**

Penalise **M2** if NH<sub>3</sub> is negatively charged

M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom

Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br

Penalise **M3** for an additional arrow from the Br to something else

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 their original molecule

The second mole of ammonia is not essential for **M5**; therefore ignore any species here

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on / or close to, the N atom

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

M5 is for an arrow from the N-H bond to the N atom

**Maximum any 3 of 4 marks for the mechanism** for wrong organic reactant **OR** wrong organic product if shown

Award full marks for an S<sub>N</sub>1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

Accept the correct use of "sticks"

**NB These are double-headed arrows**

5

(c) M1 (addition) polymerisation OR poly-addition

Ignore "additional"

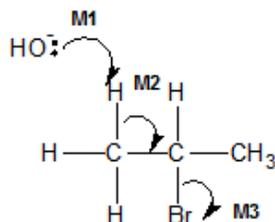
Credit polyprop-1-ene and polypropylene

M2 poly(propene) / polypropene

Penalise "condensation polymerisation"

2

(d)



Penalise **M1** if covalent KOH

M1 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

Penalise **M3** for formal charge on C of C-Br or incorrect partial charges on C-Br.

M2 must show an arrow from a correct C-H bond adjacent to the C-Br bond to the appropriate C-C bond. Only award if an arrow is shown attacking the H atom of a correct C-H bond in **M1**

Ignore other partial charges

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

M3 is independent provided it is from their original molecule, but **CE=0** if **nucleophilic substitution**

**Maximum any 2 of 3 marks** for wrong organic reactant

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

**NB These are double-headed arrows**

3

[15]

**M11.** (a) (i) M1 c(oncentrated) phosphoric acid / c(onc.) H<sub>3</sub>PO<sub>4</sub>

**OR** c(oncentrated) sulfuric acid / c(onc.) H<sub>2</sub>SO<sub>4</sub>

In **M1**, the acid must be concentrated.

Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants

**OR** pass the gases over the catalyst several / many times

In **M2**, ignore "remove the ethanol".

Credit "re-use".

2

- (ii) M1  
(By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction

**M2 depends on a correct statement of M1**

The equilibrium moves / shifts to

- oppose the addition of / increased concentration of / increased moles / increased amount of water / steam
- to decrease the amount of steam / water

**Mark M3 independently**

M3 Yield of product / conversion increase **OR** ethanol increases / goes up / gets more

3

- (iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

**M2 At higher pressures**

More / higher cost of electrical energy to pump / pumping cost

**OR**

Cost of higher pressure equipment / valves / gaskets / piping etc.

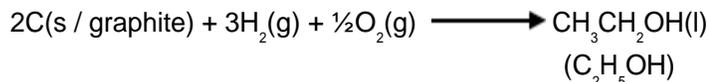
**OR** expensive equipment

*Credit all converse arguments for M2*

2

- (b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation



*Not multiples but credit correct state symbols in a correctly balanced equation.*

*Penalise C<sub>2</sub>H<sub>6</sub>O but credit correct state symbols in a correctly balanced equation.*

2

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

*If standard enthalpy of formation **CE=0***

M2 is burned / combusts / reacts completely in oxygen

**OR** burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states

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

*For M3*

*Ignore reference to 1 atmosphere*

3

(ii) M1

Correct answer gains full marks

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

Credit 1 mark for (+) 1279 (kJ mol<sup>-1</sup>)

OR

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

OR

$$B(\text{C-C}) + B(\text{C-O}) + B(\text{O-H}) + 5B(\text{C-H}) + 3B(\text{O=O}) \text{ (LHS)} \\ - 4B(\text{C=O}) - 6B(\text{O-H}) \text{ (RHS)} = \Delta H$$

M2 (also scores **M1**)

$$348+360+463+5(412)+3(496) \text{ [LHS} = \mathbf{4719}]$$

$$(2060) \quad (1488)$$

$$- 4(805) - 6(463) \text{ [RHS} = - \mathbf{5998}] = \Delta H$$

$$(3220) \quad (2778)$$

OR using only bonds broken and formed (**4256 – 5535**)

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 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1**

M3

$$\Delta H = - \mathbf{1279} \text{ (kJ mol}^{-1}\text{)}$$

Allow a maximum of one mark if the only scoring point is LHS = 4719 OR RHS = 5998

Award 1 mark for +1279

**Candidates may use a cycle and gain full marks**

3

(d) (i) Reducing agent OR reductant OR electron donor  
OR to reduce the copper oxide

Not "reduction".

Not "oxidation".

Not "electron pair donor".

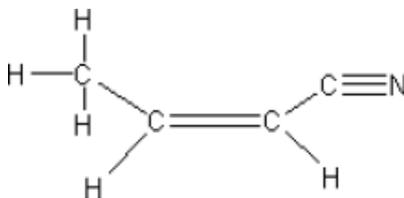
1

(ii) CH<sub>3</sub>COOH

1

[17]

- M12.** (a) (i) Structure of (Z)-but-2-enitrile with or without either or both of the CH<sub>3</sub> and the CN groups displayed



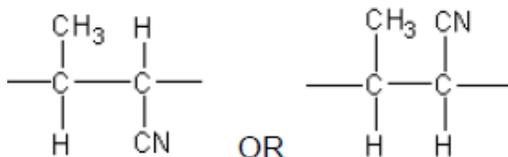
Penalise C–NC  
Do not penalise C–H<sub>3</sub>C  
Ignore bond angles.

1

- (ii) Restricted rotation / no (free) rotation about the double bond / about the C=C  
**OR** does not rotate (about the double bond)  
Must use the word rotate / rotation.

1

- (b) Repeating unit of polyalkene



All the bonds relevant to the unit must be drawn out including those on either side of the unit. There is no need to expand either the CH<sub>3</sub> or the CN  
Penalise C–NC  
Penalise “sticks”.  
Ignore brackets.  
Penalise “n”

1

- (c) **Feature 1**

Absorption / peak in the range **2220 to 2260** cm<sup>-1</sup> or specified value in this range or marked correctly on spectrum

**and**

(characteristic absorption / peak for) **C≡N** / **CN** group / **nitrile** / **cyanide** group

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

Allow a peak at 2200 cm<sup>-1</sup> to 2220 cm<sup>-1</sup> **in this case**.

**Feature 2**

Absorption / peak in the range **1620 to 1680** cm<sup>-1</sup> or specified value in this range or marked correctly on spectrum

**and**

(characteristic absorption / peak for) **C=C** group / **alkene** / **carbon-carbon double bond**

Ignore reference to other absorptions eg C-H  
Either order.

2

[5]

