M1.(a) (i) M1 (Yield) increases / goes up / gets more

*If **M1** is blank, mark on and seek to **credit the correct information in the explanation.***
*If **M1** is incorrect CE=0 for the clip.*

M2

The (forward) reaction / to the right is <u>exothermic</u> or <u>gives out / releases heat</u>

OR

The reverse reaction / to the left is <u>endothermic</u> or <u>takes in / absorbs heat</u>

M3** depends on a correct statement for **M2

M3 depends on correct M2 and must refer to temperature / heat

The (position of) <u>equilibrium shifts / moves</u> left to right to <u>oppose the decrease in temperature</u>

*For **M3**, the <u>equilibrium shifts / moves</u> to <u>release heat</u> **OR** to <u>raise the temperature</u> **OR** to <u>heat up the reaction</u>.*

3

(ii) M1 *<u>Concentration(s)</u>* (of reactants and products) remain or stay constant / the same

*For **M1** credit [ ] for concentration.*

M2 <u>Forward rate</u> = <u>reverse / backward rate</u>

Not "equal concentrations".
Not "concentrations <u>is / are the same</u>".
Not "amount".

Ignore "dynamic" and ignore "speed".

Ignore "closed system".

It is possible to score both marks under the heading of a single feature.

2

(b) $KBr + H_2SO_4 \longrightarrow KHSO_4 + HBr$

Credit this equation in its ionic form.

Ignore state symbols.

Credit multiples.

1

(c) M1 SO_2 identified

M2 correctly balanced equation (would also gain M1)

*Credit **M2** equation in its ionic form.*

Ignore state symbols.

2HBr + H_2SO_4 ⟶ Br_2 + SO_2 + **2**H_2O

Credit multiples.

Not H_2SO_3 on the right-hand side.

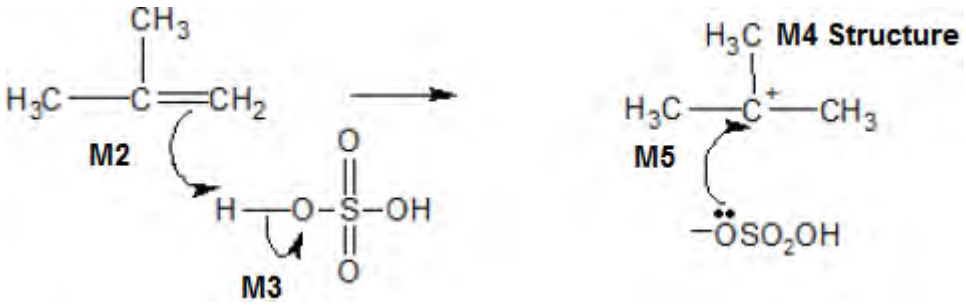
Mark M3 independently

M3 Oxidising agent ***OR*** electron acceptor ***OR*** oxidant ***OR*** to oxidise the bromide (ion) / HBr

***M3** Not "electron pair acceptor".*

3

(d) (i) **M1 Electrophilic addition**



***M1** both words required.*

For the mechanism

***M3** Penalise incorrect partial charges on O − H bond and penalise formal charges*

Ignore partial negative charge on the double bond.

***M5** Not HSO_4^-*

*For **M5**, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion*

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

M2 must show an arrow from the double bond towards the H atom of the H − O bond / HO on a compound with molecular formula for H_2SO_4

M2 could be to an H^+ ion and M3 an independent O − H bond break on a compound with molecular formula for H_2SO_4

*<u>Max any 3 of 4 marks</u> **<u>for a correct mechanism</u>** using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation.*

M3 must show the breaking of the O − H bond on H_2SO_4

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 correct oxygen of the negatively charged ion towards the positively charged carbon atom on their carbocation

Credit the correct use of "sticks".

*For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4***

NB The arrows here are double-headed

5

(ii) Hydrolysis

Credit "(nucleophilic) substitution" but do not accept any other prefix.

Credit phonetic spelling.

1

(iii) Catalyst

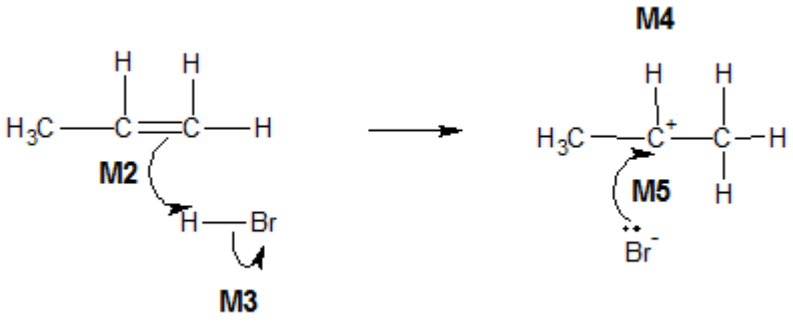
1

[16]

M2.(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

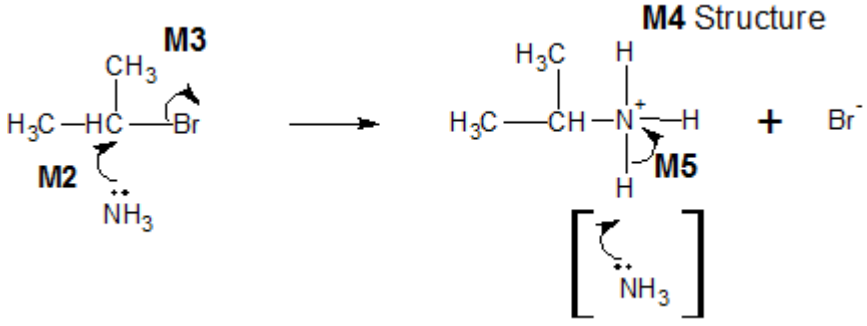
NB These are double-headed arrows

5

(b) **M1 Nucleophilic substitution**

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

Accept phonetic spelling



For the mechanism

Penalise ***M2*** *if NH_3 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_N1 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"

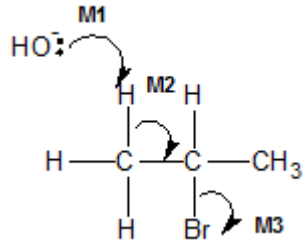
Credit polyprop-1-ene and polypropylene

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]

M3.(a) (i) **M1** (Compounds / molecules with) the same structural formula

*Penalise **M1** if 'same structure' or 'different structural / displayed formula'.*

M2 with atoms / bonds / groups arranged differently in space

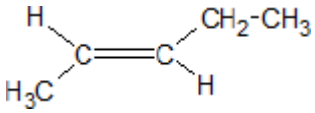
OR atoms / bonds / groups with different spatial arrangements / different orientation

Ignore references to 'same molecular formula' or 'same empirical formula'.

Mark independently.

2

(ii)



Credit C–H_3C

Credit C_2H_5

Penalise C–CH_3CH_2

1

(b) **M1** Br_2 OR bromine (water) OR bromine (in CCl_4 / organic solvent)

*If **M1**, has no reagent or an incorrect reagent, **CE=0**.*

Ignore 'acidified'.

M2 Isomer 1: decolourised / goes colourless / loses its colour

*For **M1** penalise Br (or incorrect formula of other correct reagent), but mark on.*

M3 Isomer 2: remains orange / red / yellow / brown / the same **OR** no reaction / no (observable) change **OR** reference to colour going to the cyclopentane layer

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

*If oxidation state given in name, it must be correct. If 'manganate' OR 'manganate(IV)' or incorrect formula, penalise **M1**, but mark on.*

Alternatives : potassium manganate(VII)

M1 $KMnO_4$ in acid **M2** colourless **M3** purple

M1 $KMnO_4$ in alkali / neutral **M2** brown solid **M3** purple

Credit for the use of **iodine**

M1 iodine (solution / in KI) **M2** colourless **M3** (brown) to purple (credit no change)

Credit for the use of **concentrated** H_2SO_4

M1 concentrated H_2SO_4 **M2** brown **M3** no change / colourless

Ignore 'goes clear'.

Ignore 'nothing (happens)'.

Ignore 'no observation'.

No credit for combustion observations.

3

(c) (i) (Both infrared spectra show an absorption in range) **1620 to 1680** (cm^{-1})

Ignore reference to other ranges (eg for C–H or C–C).

1

(ii) The fingerprint (region) / below 1500 cm^{-1} will be different **or** its fingerprinting will be different

OR

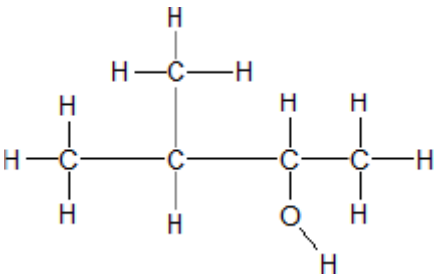
different absorptions / peaks are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



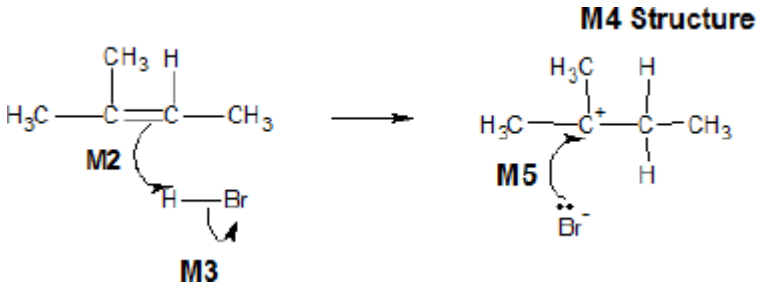
All bonds must be drawn.

Ignore bond angles.

1

(e) (i) **M1 Electrophilic addition**

***M1** both words needed.*



Penalise one mark from <u>their</u> total if half-headed arrows are used.

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

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

M3 must show the breaking of the H–Br bond

***M3** Penalise incorrect partial charges on H–Br bond and penalise formal charges.*

M4 is for the structure of the tertiary carbocation

*Penalise **M4** if there is a bond drawn to the positive charge.*

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 positively charged carbon atom of either a secondary or a tertiary carbocation

*For **M5**, credit attack on a partially positively charged carbocation structure but penalise **M4**.*

***<u>Max 3 of any 4 marks in the mechanism</u>** for wrong organic reactant or wrong organic product (if shown) or secondary carbocation.*

***<u>Max 2 of any 4 marks in the mechanism</u>** for use of bromine.*

Do not penalise the correct use of 'sticks".

NB The arrows here are double-headed

5

(ii) **M1** Reaction goes via intermediate <u>carbocations / carbonium ions</u>

***M1** is a lower demand mark for knowledge that carbocations are involved.*

M2 (scores both marks and depends on M1)

<u>Tertiary</u> <u>carbocation</u> / <u>carbonium ion</u> is <u>more stable</u> (than the secondary carbocation / carbonium ion)

OR

<u>Secondary</u> <u>carbocation</u> / <u>carbonium ion</u> is <u>less stable</u> (than the tertiary

carbocation / carbonium ion)

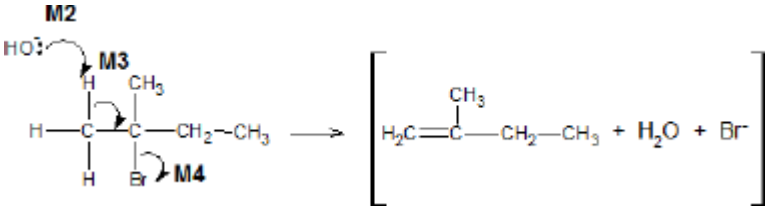
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

2

(f) **M1 Elimination**

***M1** credit 'base elimination' but no other qualifying prefix.*



Penalise one mark from <u>their</u> total if half-headed arrows are used.

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

*Penalise **M2** if covalent KOH*

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**)

M4 is independent provided it is from their <u>original molecule</u> **BUT penalise M2, M3 and M4 if nucleophilic substitution** shown

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

NB The arrows here are double-headed

*Penalise **M4** for formal charge on C or Br of the C–Br bond or incorrect partial charges on C–Br.*

*Penalise **M4** if an additional arrow is drawn from the Br of the C–Br bond to, for example, K^+.*

Ignore other partial charges.

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

***<u>Max 2 of any 3 marks in the mechanism</u>** for wrong reactant <u>or</u> wrong organic product (if shown) <u>or</u> a correct mechanism that leads to the alkene 2-methylbut-2-ene.*

Credit the correct use of "sticks" for the molecule except for the C–H being attacked.

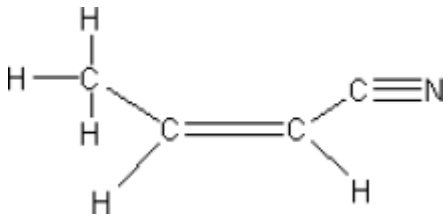
M5 hydroxide ion behaves as a <u>base</u> / <u>proton acceptor</u> / <u>electron pair donor</u> / <u>lone pair donor</u>

*Penalise **M5** if 'nucleophile'.*

5

[21]

M4.(a) (i) Structure of (Z)-but-2-enenitrile with or without either or both of the CH_3 and the CN groups displayed



Penalise C−NC

Do not penalise C−H_3C

Ignore bond angles.

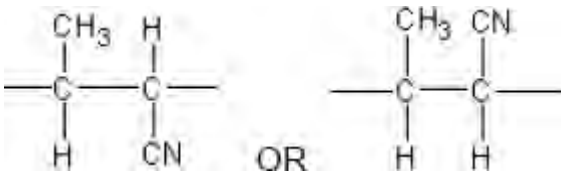
1

(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_3 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^{-1} 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^{-1} to 2220 cm^{-1} **in this case**.*

Feature 2

Absorption / peak in the range **1620 to 1680** cm^{-1} or specified value in this range or marked correctly on spectrum

and

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

Ignore reference to other absorptions eg C-H

Either order.

2

[5]