

Mark schemes

1

(a) **P** 3,3-dimethylbut-1-ene

OR

accept 3,3-dimethylbutene

Ignore absence of commas, hyphens and gaps

Require correct spelling

Q 3-chloro-2,2-dimethylbutane

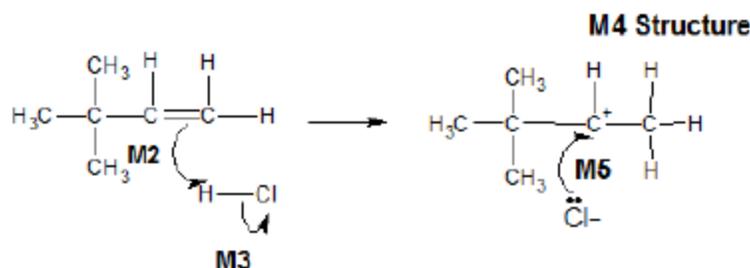
OR

accept 2-chloro-3,3-dimethylbutane

In Q, "chloro" must come before "dimethyl"

2

(b) **M1** Electrophilic addition



M2 must show an arrow from the double bond towards the H atom of HCl

M3 must show the breaking of the H-Cl bond

M4 is for the structure of the carbocation

M5 must show an arrow from the lone pair of electrons on the negatively charged chloride ion towards the positively charged carbon atom on their carbocation.

NB The arrows here are double-headed

M1 both words required

For the mechanism

M3 Penalise incorrect partial charge on H-Cl bond and penalise formal charges

Ignore partial negative charge on the double bond.

Maximum 3 of 4 marks for a correct mechanism using HBr or the wrong organic reactant or wrong organic product (if shown) or a primary carbocation

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

Credit the correct use of "sticks"

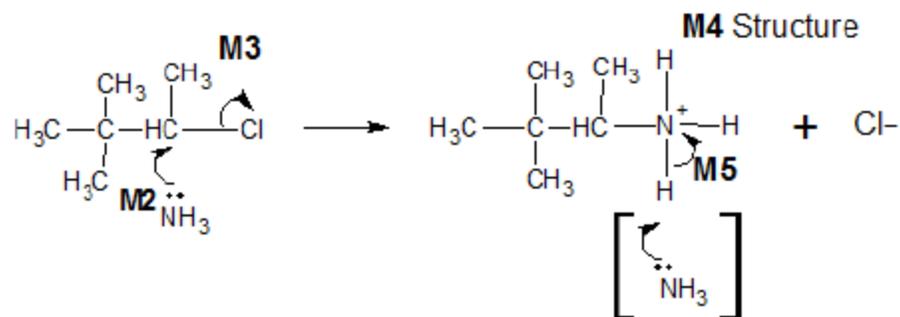
For M5, credit attack on a partially positively charged carbocation structure, but penalise M4

5

(c) **M1 Nucleophilic substitution**

For **M1**, both words required.

Accept phonetic spelling



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

M3 must show the movement of a pair of electrons from the C-Cl bond to the Cl atom. Mark **M3** independently provided it is from their original molecule

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.

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

Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

NB These are double-headed arrows

For the mechanism

Penalise **M2** if NH_3 is negatively charged.

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

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

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

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

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

Accept the correct use of "sticks"

(d) **M1** (base) elimination

***M1** Dehydrohalogenation*

M2 KOH **OR** NaOH

M3 Must be consequential on a correct reagent in **M2**, but if incomplete or inaccurate attempt at reagent (e.g. hydroxide ion), **penalise M2 only and mark on**

Any **one** from

- high temperature **OR** hot **OR** heat / boil under reflux
- concentrated
- alcohol / ethanol (as a solvent) / (ethanolic conditions)

***M3** not “reflux” alone*

***M3** if a temperature is stated it must be in the range 78°C to 200 °C*

Ignore “pressure”

3

(e) **M1**



***M1** Credit correct ionic species in the equation*

M2 and M3

SO₂ **and** Br₂ identified

M4

Concentrated sulfuric acid

- is an oxidising agent
- oxidises the bromide (ion) or Br⁻ or NaBr or HBr
- is an electron acceptor

*In **M2** and **M3** the two gases need to be identified. If equations are used using sulfuric acid and the toxic gases are not identified clearly, allow one mark for the formulas of SO₂ and Br₂*

- *apply the list principle as appropriate but ignore any reference to HBr*
- *the marks are for identifying the two gases either by name or formula*

4

[19]

2

(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

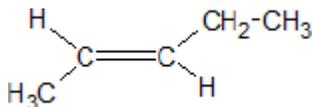
OR atoms / bonds / groups with different spatial arrangements / different orientation

Ignore references to ‘same molecular formula’ or ‘same empirical formula’.

Mark independently.

2

(ii)



Credit C-H₃C

Credit C₂H₅

Penalise C-CH₃CH₂

1

(b) **M1** Br₂ OR bromine (water) OR bromine (in CCl₄ / 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 KMnO₄ in acid **M2** colourless **M3** purple

M1 KMnO₄ 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 H₂SO₄**

M1 concentrated H₂SO₄ **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

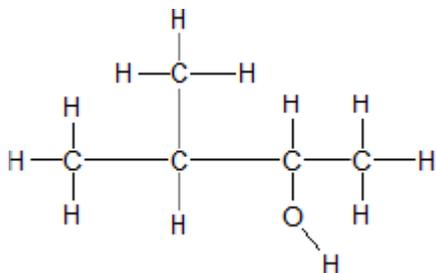
different absorptions / peaks are seen (in the region) below 1500 cm⁻¹ (or a specified region within the fingerprint range)

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

QoL

1

(d)

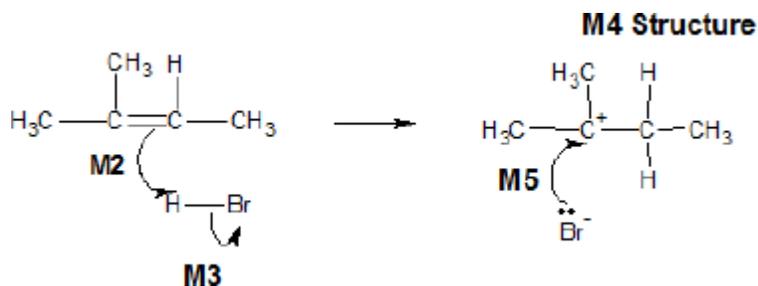


All bonds must be drawn.

Ignore bond angles.

1

- (e) (i) **M1 Electrophilic addition**
M1 both words needed.



Penalise one mark from their 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.

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

Max 2 of any 4 marks in the mechanism for use of bromine.

Do not penalise the correct use of 'sticks'.

NB The arrows here are double-headed

- (ii) **M1** Reaction goes via intermediate carbocations / carbonium ions
M1 is a lower demand mark for knowledge that carbocations are involved.

M2 (scores both marks and depends on M1)

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

OR

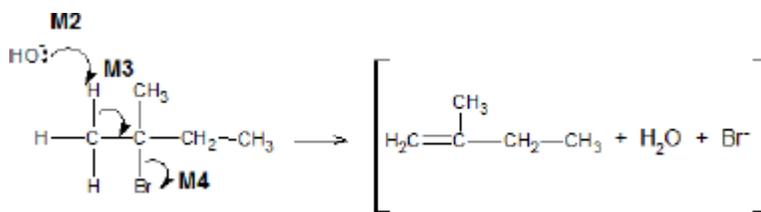
Secondary carbocation / carbonium ion is less stable (than the tertiary carbocation / carbonium ion)

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.

(f) **M1 Elimination**

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



Penalise one mark from their total if half-headed arrows are used.

M2 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to a correct 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 original molecule **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.*

***Max 2 of any 3 marks in the mechanism** for wrong reactant or wrong organic product (if shown) or 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 base / proton acceptor / electron pair donor / lone pair donor

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

3

(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 exothermic or gives out / releases heat

OR

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

M3 depends on a correct statement for M2

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

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

For M3, the equilibrium shifts / moves

*to release heat **OR***

*to raise the temperature **OR***

to heat up the reaction.

3

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

For M1 credit [] for concentration.

M2 Forward rate = reverse / backward rate

Not "equal concentrations".

Not "concentrations is / are the same".

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) $\text{KBr} + \text{H}_2\text{SO}_4 \longrightarrow \text{KHSO}_4 + \text{HBr}$

Credit this equation in its ionic form.

Ignore state symbols.

Credit multiples.

1

(c) M1 SO₂ identified

M2 correctly balanced equation (would also gain M1)

Credit M2 equation in its ionic form.

Ignore state symbols.



Credit multiples.

Not H₂SO₃ on the right-hand side.

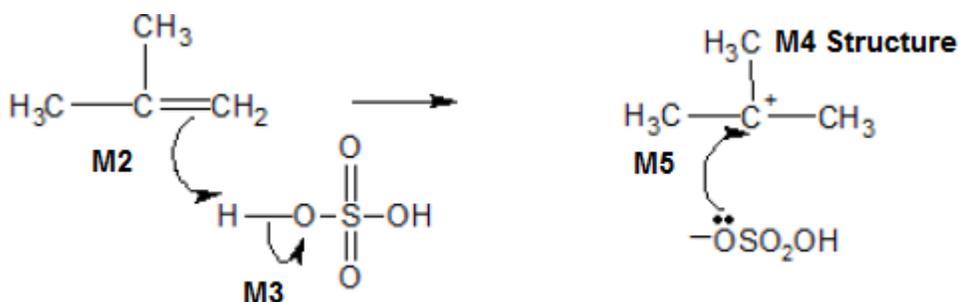
Mark M3 independently

M3 Oxidising agent **OR** electron acceptor **OR** oxidant

OR to oxidise the bromide (ion) / HBr

M3 Not "electron pair acceptor".

(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 as shown or $\text{^-}:\text{OSO}_3\text{H}$ ONLY with the negative charge anywhere on this ion

OR correctly 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

Max any 3 of 4 marks for a correct mechanism 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]

4

(a) Structure for 3-methylbut-1-ene

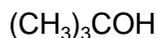


Any correct structural representation.

Credit "sticks" and require the double bond.

1

(b) Structure for 2-methylpropan-2-ol

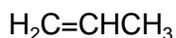


Any correct structural representation.

Credit "sticks".

1

(c) Structure for propene

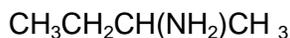


Any correct structural representation.

Credit "sticks" and require the double bond.

1

(d) Structure for 2-aminobutane



Any correct structural representation.

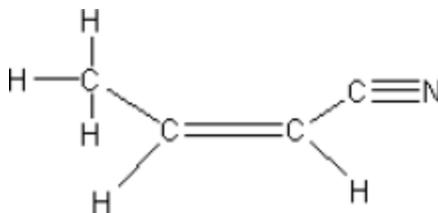
Credit "sticks".

1

[4]

5

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



Penalise C-NC

Do not penalise C-H₃C

Ignore bond angles.

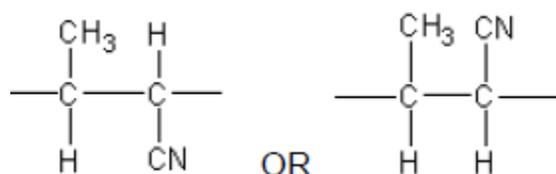
1

(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 CH₃ 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

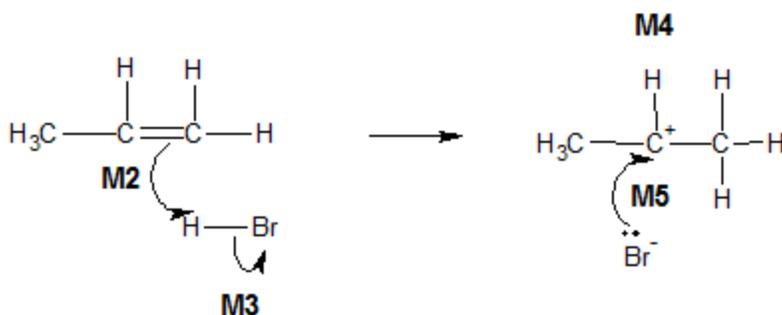
(characteristic absorption / peak for) **C=C** group / **alkene** / **carbon-carbon double bond**

Ignore reference to other absorptions eg C-H

Either order.

2

[5]

6(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

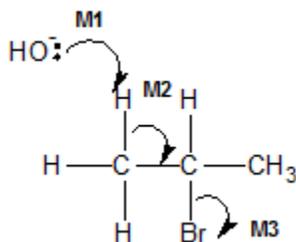
M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom

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

(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

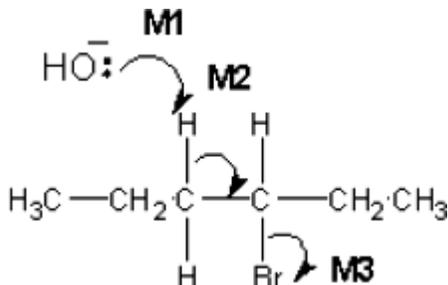
NB These are double-headed arrows

3

[15]

7

(a) (i)



Penalise one mark from their total if half-headed arrows are used

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

Ignore other partial charges

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

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

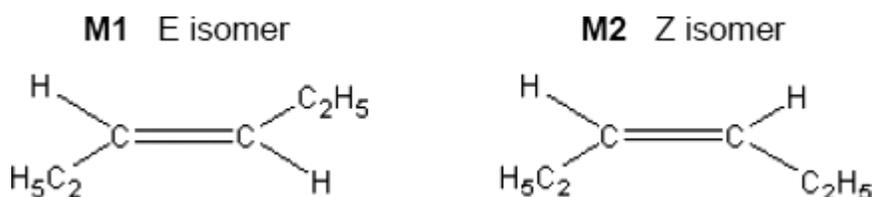
M2 must show an arrow from the correct C–H bond to the correct C–C bond. Only award if an arrow is shown attacking the H atom of the correct C–H bond in **M1**

M3 is independent but **CE=0** if nucleophilic substitution

N.B these are double-headed arrows

3

(ii)



*Award 1 mark if both correct stereoisomers but in the wrong places
Accept no other alkenes.*

Be reasonably lenient on the bonds to ethyl (or to CH₂CH₃) since the question is about E and Z positions but penalise once only if connection is clearly to the CH₃ of CH₂CH₃

Accept linear structures

2

(iii) **M1** (Compounds / molecules with) the same structural formula
*Penalise **M1** if “same structure”*

M2 with atoms/bonds/groups arranged differently in space
Ignore references to “same molecular formula” or “same empirical formula” or any reference to “displayed formula”

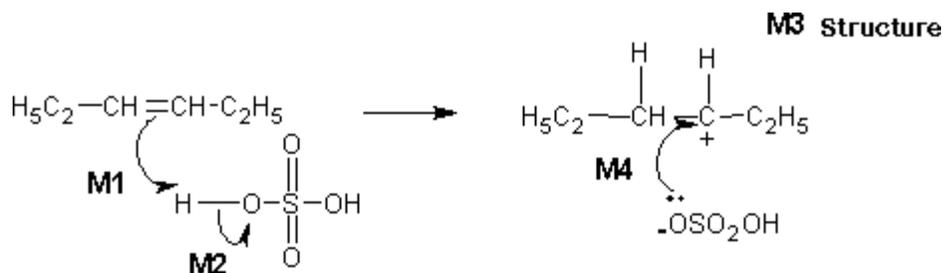
OR

atoms/bonds/groups that have different spatial arrangements / different orientation.

Mark independently

2

(b)



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

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

M1 Ignore partial negative charge on the double bond.

M2 must show the breaking of the O – H bond.

M2 Penalise partial charges on O – H bond if wrong way and penalise formal charges

In M2 do not penalise incorrect structures for H_2SO_4

M3 is for the structure of the carbocation.

M4 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards a correct (positively charged) carbon atom.

M4 NOT HSO_4^-

For **M4**, credit as shown or $\overset{-}{O}SO_3H$ ONLY with the negative charge anywhere on this ion

OR correctly drawn out with the negative charge placed correctly on oxygen

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

NB The arrows here are double-headed

Max 3 of any 4 marks for wrong organic reactant or wrong organic product (if shown)

Accept the correct use of “sticks”

4

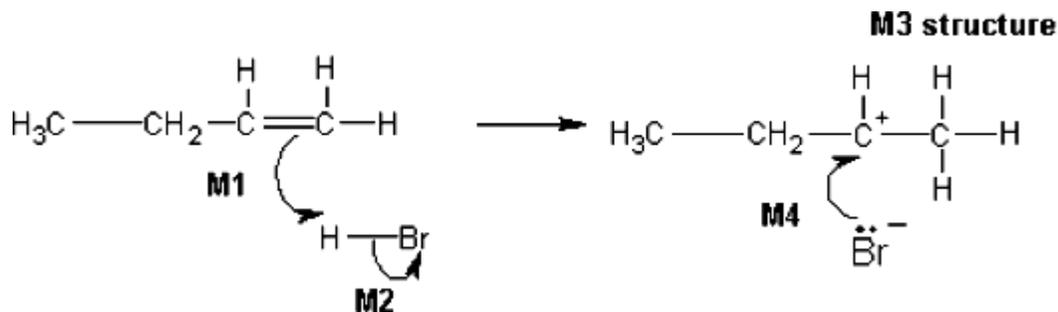
[11]

8

(a) Position(al) (isomerism)

1

(b)



Penalise one mark from their total if half-headed arrows are used

M1 must show an arrow from the double bond towards the H atom of the H-Br molecule

M1 Ignore partial negative charge on the double bond.

M2 must show the breaking of the H-Br bond.

M2 Penalise partial charges on H-Br bond if wrong way and penalise formal charges

M3 is for the structure of the secondary carbocation.

Penalise M3 if there is a bond drawn to the positive charge

M4 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 primary or secondary carbocation.

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

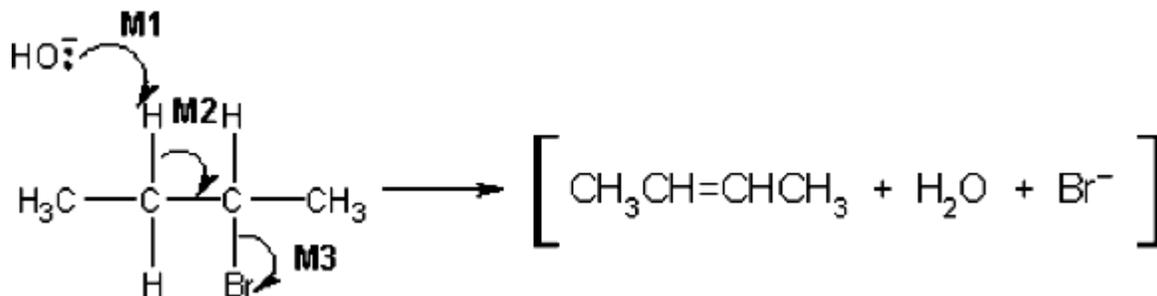
Maximum any 3 of 4 marks for wrong reactant or primary carbocation.

If Br₂ is used, maximum 2 marks for their mechanism

Do not penalise the use of "sticks"

NB The arrows here are double-headed

(c)



Penalise one mark from their total if half-headed arrows are used

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

Penalise M1 if covalent KOH

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

M3 is independent provided it is from their original molecule.

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

Penalise M3 if an extra 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.

Maximum any 2 of 3 marks for wrong reactant or wrong product (if shown) or a mechanism that leads to but-1-ene

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

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

NB The arrows here are double-headed

3

[8]