

M1. (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

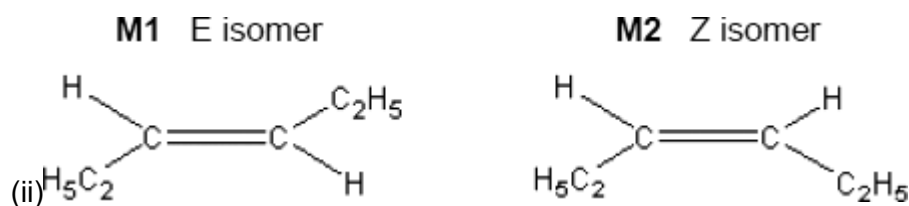
Penalise once only in any part of the mechanism for a line and two dots to show a bond.

**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



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  $\text{CH}_2\text{CH}_3$ ) since the question is about E and Z positions but penalise once only if connection is clearly to the  $\text{CH}_3$  of  $\text{CH}_2\text{CH}_3$

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”*

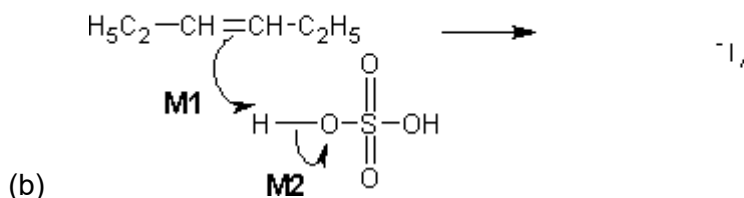
**OR**

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

*Mark independently*

2

Stu e\*\*\*



**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<sub>2</sub>SO<sub>4</sub>

M1 could be to an H<sup>+</sup> ion and M2 an independent O – H bond break on a compound with molecular formula for H<sub>2</sub>SO<sub>4</sub>

*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<sub>2</sub>SO<sub>4</sub>*

**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<sub>4</sub><sup>-</sup>*

*For M4, credit as shown or <sup>-</sup>OSO<sub>3</sub>H 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

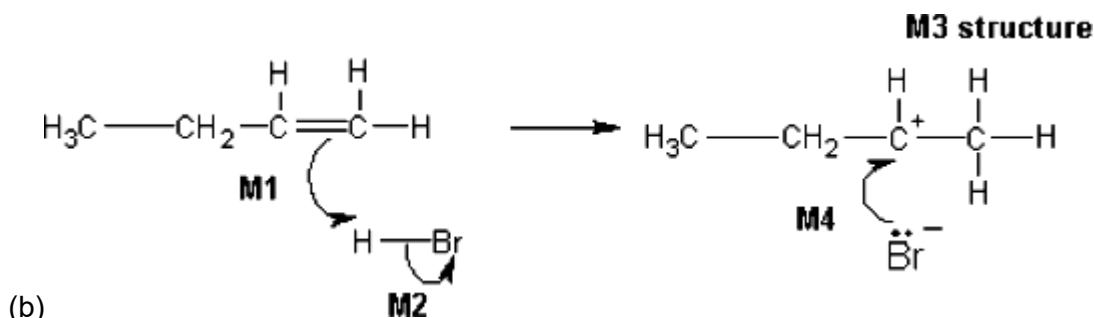
*Max 3 of any 4 marks for wrong organic reactant or wrong organic product (if shown)*

*Accept the correct use of “sticks”*

4

M2.(a) Position(al) (isomerism)

1



*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.*

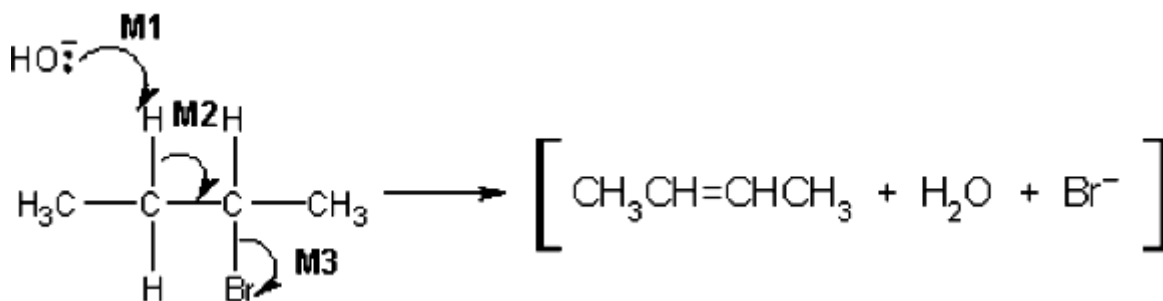
*If Br<sub>2</sub> is used, maximum 2 marks for their mechanism*

*Do not penalise the use of "sticks"*

**NB The arrows here are double-headed**

4

(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<sup>+</sup>

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

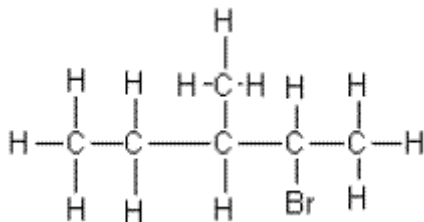
[8]

**M3.** (a) (i) **3-bromo-3-methylpentane ONLY**  
Must be correct spelling but ignore hyphens and commas

1

(ii) Electrophilic addition (reaction)  
Both words needed

(iii) **M1** Displayed formula of 2-bromo-3-methylpentane



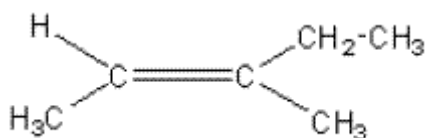
All the bonds must be drawn out but ignore bond angles

**M2** Position(al) (isomerism)

**Do not forget to award this mark**

2

(iv) Structure of (E)-3-methylpent-2-ene



The arrangement of groups around the double bond must be clear with the ethyl group attached in the correct order.  
Ignore bond angles.

Accept  $C_2H_5$  for ethyl

Be lenient on C — C bonds. The main issue here is whether they have drawn an (E) isomer.

Accept "sticks" for C — H bonds and correct skeletal formula

1

(b) (i) **M1** R is represented by **Spectrum 2**

**M2** Spectrum 2 shows an infrared absorption/spike/dip/ trough/peak with any value(s)/range within the range 1620 to 1680 ( $cm^{-1}$ ) OR this range quoted/identified and this is due to C=C  
OR this information could be a correctly labelled absorption on the spectrum

OR Spectrum 1 does not have an infrared absorption in range 1620 to 1680 ( $cm^{-1}$ ) and does not contain C=C.

Award M1 if it is obvious that they are referring to the second spectrum (or the bottom one)

M2 depends on a correct M1  
Ignore other correctly labelled peaks  
Ignore reference to "double bond" or "alkene"

2

(ii) Functional group (isomerism)

1

(iii) Cyclohexane

**OR**

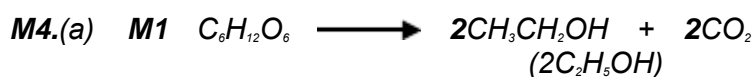
Methylcyclopentane etc.

Named correctly

Ignore structures and ignore numbers on the methyl group of methylcyclopentane

1

[9]

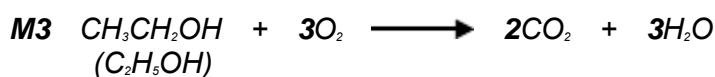


Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise  $C_2H_6O$  once only

M2 fermentation



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

M5 The specified process uses / burns (fossil) fuel that releases  $CO_2$

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

5

(b) M1 sodium or potassium hydroxide / NaOH / KOH

Mark on to M2 from hydroxide ion

**M2 depends on correct M1**

Ignore OH if KOH/ OH

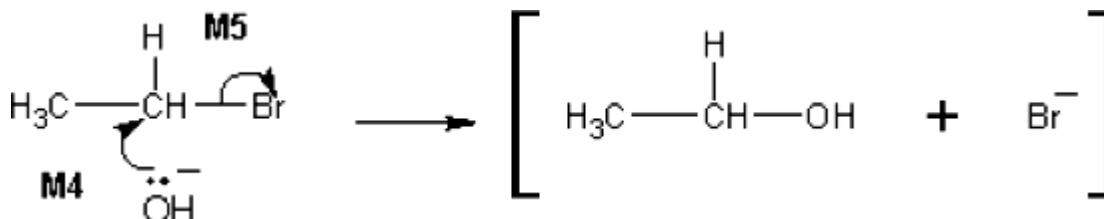
warm / heat / reflux and aqueous or (aq) or water

For M2 ignore "dilute"

For M2 penalise T > 100 °C

**M3 nucleophilic substitution**

Acidified KOH/NaOH or H<sub>2</sub>SO<sub>4</sub> with KOH/NaOH loses M1 and M2



For M3, both words required

**NB The arrows here are double-headed**

**M4** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom.

Penalise M4 if covalent NaOH / KOH is used

Penalise one mark from M4 or M5 if half-headed arrows are used

**M5** must show the movement of a pair of electrons from the

C— Br bond to the Br atom. Mark M5 independently provided it is from their original molecule.

Penalise M5 for formal charge on C of the C—Br or incorrect partial charges on C—Br

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

For M4 and M5, award full marks for an S<sub>N</sub>1 mechanism

For M4 and M5, maximum 1 of 2 marks if wrong reactant is used.

Penalise M5 if an extra arrow is drawn from the Br of the C—Br bond to, for example, K<sup>+</sup>

Do not penalise the use of "sticks"

**M6** One statement from

- The yield is (very) low / not a high yield OR elimination occurs / ethene formed
- The rate of reaction slow
- Bromoethane has to be manufactured / made first
- Bromoethane is expensive

- (c) **M1** concentrated phosphoric acid / conc.  $H_3PO_4$  **OR** concentrated sulfuric acid / conc.  $H_2SO_4$

Answers in any order

Ignore reference to support medium in M1

**M2** hydration or (electrophilic) addition

For M3 and M4 any two from

Do not apply the list principle to these three chosen criteria in M3 and M4

- Excess ethene

**OR** Excess steam / water /  $H_2O$

**OR** remove the ethanol as it forms

**OR** recycle the ethene

- Specified Pressure

$50 \text{ atm} \leq P \leq 100 \text{ atm}$

**OR**  $5000 \text{ kPa} \leq P \leq 10000 \text{ kPa}$

**OR**  $5 \text{ MPa} \leq P \leq 10 \text{ MPa}$

- High Temperature unless they give a value that is not in the ranges given here;

**OR**  $300 \text{ }^\circ\text{C} \leq T \leq 600 \text{ }^\circ\text{C}$

**OR**  $570 \text{ K} \leq T \leq 870 \text{ K}$

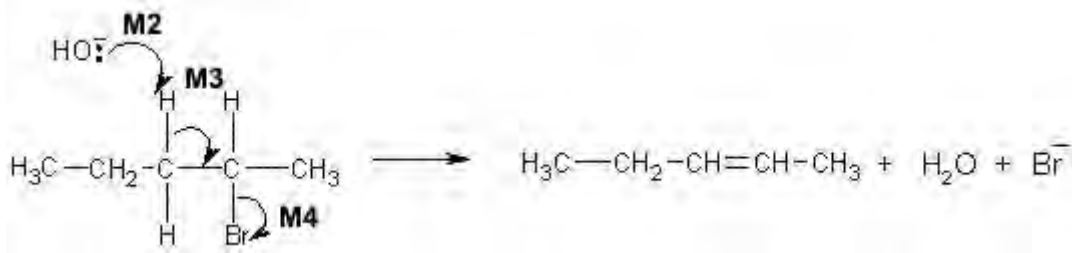
Accept a reference to "low temperature" if they specify a correct temperature range or a correct temperature in the range

4

[15]

**M5.** (a) (i) **M1** Elimination





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

**M3** must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond. Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H

**M4** is independent provided it is from their original molecule

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

**N.B. These are double-headed arrows**

For M1, accept “Base elimination” but no other prefix.

Penalise **M2** if covalent KOH

Penalise **M4** for formal charge on C of C-Br or incorrect partial charges on C-Br

Ignore other partial charges

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

Max any 2 of 3 marks for the mechanism for wrong reactant (or wrong product if shown).

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

4

(ii) **Structure for pent-1-ene**

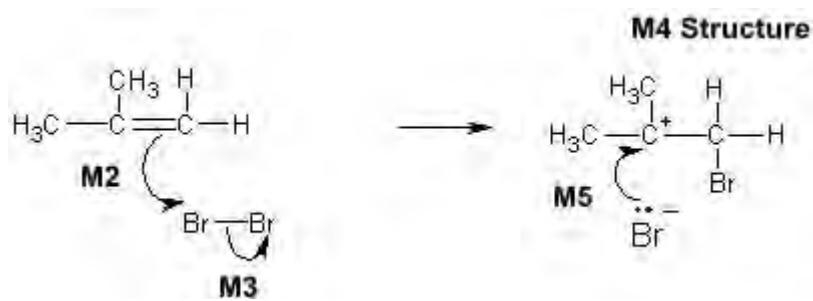


Penalise  $\text{C}_5\text{H}_8$

Accept correct “sticks”

1

(b) **M1 Electrophilic addition**



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

**M3** must show the breaking of the Br-Br bond.

**M4** is for the structure of the tertiary carbocation with Br on the correct carbon atom.

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

**N.B. These are double-headed arrows**

For M1, both words required.

**For the mechanism**

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

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

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

Max any 3 of 4 marks for the mechanism for

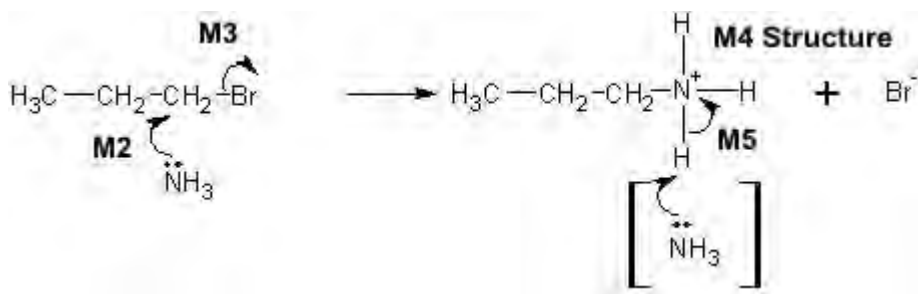
wrong organic reactant or wrong organic product (if shown) or primary carbocation.

If HBr is used, max 2 marks for their mechanism

Accept the correct use of "sticks"

5

(c) **M1 Nucleophilic substitution**



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

**M3** must show the movement of a pair of electrons from the C-Br bond to the Br atom. **M3** is independent 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.

**N.B. These are double-headed arrows**

For **M1**, both words required.

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

Penalise **M3** for formal charge on C or incorrect partial charges

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.

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

Accept the correct use of "sticks"

5

[15]