3.2.9 Alkenes

Structure Bonding & Reactivity

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79 minutes

79 marks

M1. (a) Contains a C=C ***OR*** a double bond

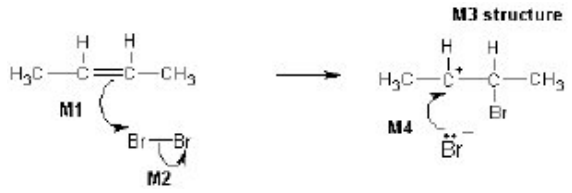
1

(b) **Electrophilic addition**

Both words needed

1

Mechanism:



Ignore partial negative charge on the double bond.

M2 Penalise partial charges on bromine 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.

M1 Must show an arrow from the double bond towards one of the Br atoms on a Br-Br molecule.

Deduct 1 mark for sticks.

M2 Must show the breaking of the Br-Br bond.

M3 Is for the structure of the secondary carbocation with Br substituent.

M4 Must show an arrow from the lone pair of electrons on a negatively charged bromide ion towards the positively charged carbon atom.

Deduct 1 mark for wrong reactant, but mark consequentially.
If HBr, mark the mechanism consequentially and deduct one mark
If but-1-ene, mark the mechanism consequentially and deduct one mark.
If both HBr and but-1-ene, mark the mechanism consequentially and deduct ONLY one mark.

4

(c) (i) **M1** Compounds with the same structural formula

Penalise M1 if "same structure"
Ignore references to "same molecular formula" or "same empirical formula"

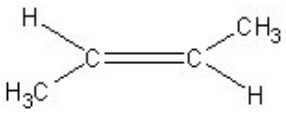
1

M2 With atoms/bonds/groups arranged differently in space
OR
atoms/bonds/groups have different spatial arrangements/ different orientation.

Mark independently.

1

(ii)



Award credit provided it is obvious that the candidate is drawing the <u>trans isomer</u>.

Do not penalise poor C–C bonds

Trigonal planar structure not essential

1

[9]

M2. (a) (i) **3**-bromo-**3**-methylpentane ONLY

Must be correct spelling but ignore hyphens and commas

1

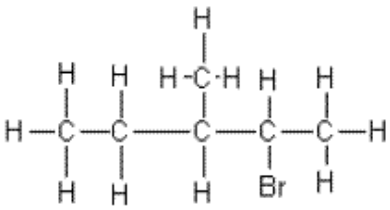
(ii) <u>Electrophilic addition</u> (reaction)

Both words needed

Accept phonetic spelling

1

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



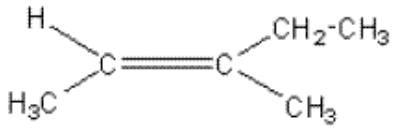
All the bonds must be drawn out but ignore bond angles

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

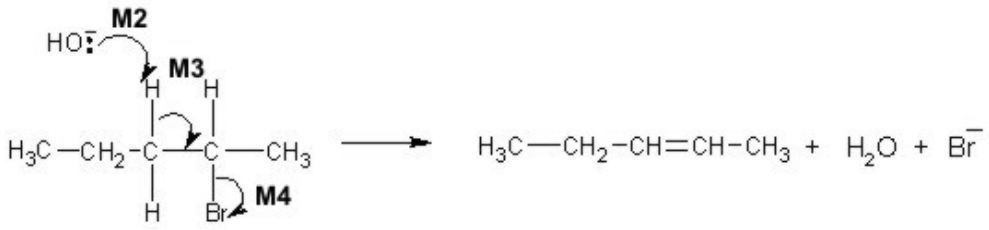
OR

Methylcyclopentane etc.
Named correctly
Ignore structures and ignore numbers on the methyl group of methylcyclopentane

1

[9]

M3. (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**

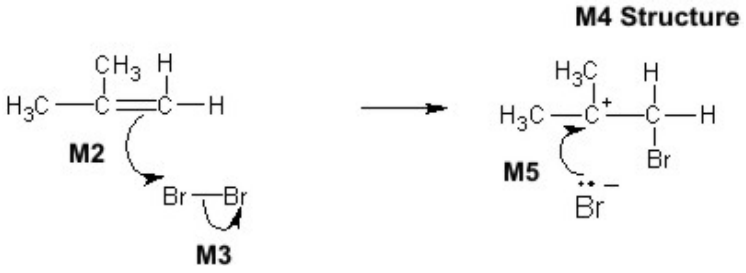
$CH_3CH_2CH_2CH{=}CH_2$

Penalise C_3H_7

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*

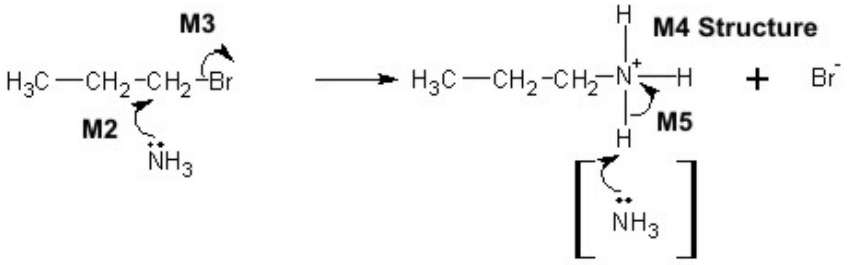
wrong organic reactant or wrong organic product (if shown) or primary carbocation.

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]

M4. (a) Pentan-2-one

ONLY but ignore absence of hyphens

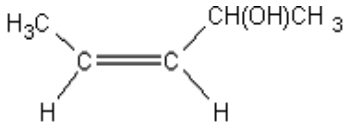
1

(b) Functional group (isomerism)

Both words needed

1

(c) (i)



Award credit provided it is obvious that the candidate is drawing the Z / cis isomer

The group needs to be $CHOHCH_3$ but do not penalise poor C–C bonds or absence of brackets around OH

Trigonal planar structure not essential

1

(ii) Restricted rotation (about the C=C)

OR

No (free) rotation (about the C=C)

1

(d)

M1 Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Do not credit Ag^+, $AgNO_3$ or $[Ag(NH_3)_2]^+$] or "the silver mirror test" on their own, but mark M2 and M3)*	**M1** Fehling's (solution) / Benedict's *(Penalise $Cu^{2+}(aq)$ or $CuSO_4$ but mark M2 and M3)*
M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u>	**M2** <u>Red solid/precipitate</u> *(Credit <u>orange</u> or <u>brown solid</u>)*
M3 (stays) colourless OR no (observed) change / no reaction	**M3** (stays) blue OR no (observed) change / no reaction

*If **M1** is blank CE = 0, for the clip*

Check the partial reagents listed and if M1 has a <u>totally</u> <u>incorrect</u> reagent, CE = 0 for the clip

Allow the following alternatives

***M1** (acidified) potassium dichromate(VI) (solution); mark on from incomplete formulae or incorrect oxidation state*

***M2** (turns) green*

M3 (stays) orange / no (observed) change / no reaction

OR

***M1** (acidified) potassium manganate(VII) (solution);*

mark on from incomplete formulae or incorrect oxidation state

***M2** (turns) colourless*

***M3** (stays) purple / no (observed) change / no reaction*

*In all cases for **M3***

Ignore "nothing (happens)"

Ignore "no observation"

3

(e) (i) **Spectrum is for Isomer 1**

or named or correctly identified

The explanation marks in (e)(ii) depend on correctly identifying Isomer 1.

The identification should be unambiguous but candidates should not be penalised for an imperfect or incomplete name. They may say "the alcohol" or the "alkene" or the "E isomer"

1

(ii) **If Isomer 1 is correctly identified, award <u>any two</u> from**

- (Strong / broad) absorption / peak in the range **<u>3230 to 3550</u>** cm^{-1} or specified value <u>in this range</u> or **<u>marked correctly</u>** on spectrum
  <u>and</u>
  (characteristic absorption / peak for) <u>OH</u> group /**<u>alcohol</u>** group

- No absorption / peak in range **<u>1680 to 1750</u>** cm^{-1} or absence <u>marked correctly</u> on spectrum
  <u>and</u>
  (No absorption / peak for a) **<u>C=O</u>** group / **<u>carbonyl</u>** group / **<u>carbon-oxygen double bond</u>**

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

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

  If 6(e)(i) is incorrect or blank, CE=0

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

  Ignore reference to other absorptions e.g. C-H, C-O

2

[10]

M5. (a) $Ca(OH)_2$ OR $Mg(OH)_2$

Ignore name

Could be ionic

1

(b) NaF or sodium fluoride

OR

NaCl or sodium chloride

Either formula or name can score

Do not penalise the spelling "fluoride"

When both formula and name are written,

- *penalise contradictions*
- *if the attempt at the correct **formula** is incorrect, ignore it and credit **correct name** for the mark unless contradictory*
- *if the attempt at the correct name is incorrect, ignore it and credit **correct formula** for the mark unless contradictory*

1

(c) NaClO OR NaOCl

Ignore name (even when incorrect)

The correct formula must be clearly identified if an equation is written

1

(d) **Br_2** (ONLY)

Only the correct formula scores;

penalise lower case "b", penalise upper case "R", penalise superscript

Ignore name

The correct formula must be clearly identified if an equation is written

1

(e) **M1** S OR S_8 OR S_2

M2 I_2 (ONLY)

Ignore names

penalise lower case "i" for iodine,

penalise superscripted numbers

Mark independently

The correct formula must be clearly identified in each case if an equation is written

2

(f) (i) $CH_3CH_2CH=CH_2$

Structure of but-1-ene. Ignore name

Credit "sticks" for C-H bonds

1

(ii) $CH_3CH_2CH_2CH_2OH$

Structure of butan-1-ol. Ignore name

Credit "sticks" for C-H bonds

1

(iii) $CH_3CH_2CH_3$

Structure of propane. Ignore name

Ignore calculations and molecular formula

Credit "sticks" for C-H bonds

Ignore the molecular ion

1

(iv) CH_3CH_2Br OR C_2H_5Br

Structure of bromoethane.

Ignore name and structure of nitrile

Credit "sticks" for C-H bonds

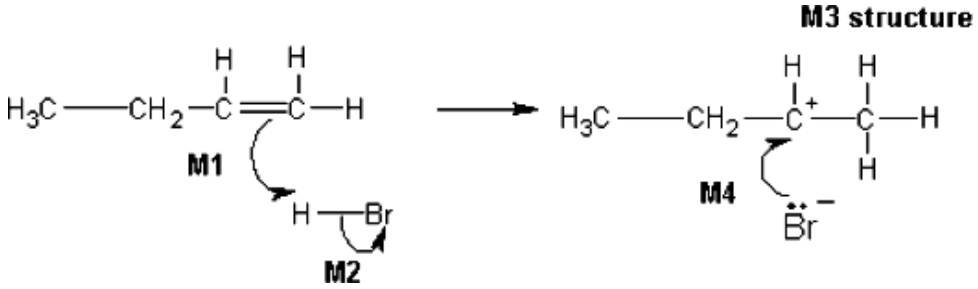
1

[10]

M6. (a) Position(al) (isomerism)

1

(b)



Penalise one mark from <u>their</u> 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

<u>Maximum any 3 of 4 marks</u> for wrong reactant or primary carbocation.

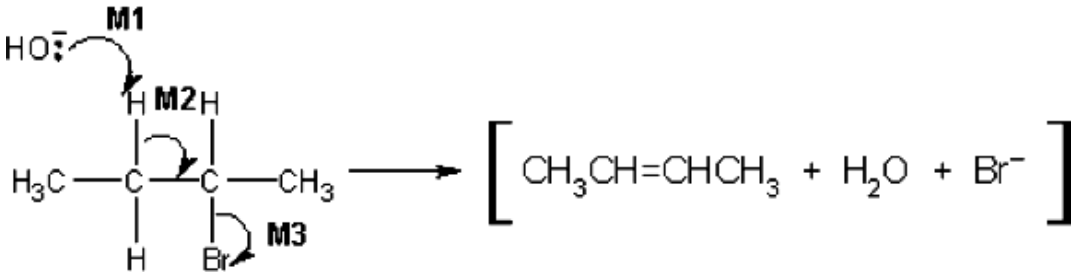
If Br_2 is used, <u>maximum 2 marks</u> for their mechanism

Do not penalise the use of "sticks"

NB The arrows here are double-headed

4

(c)



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

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to a correct</u> 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 <u>original molecule.</u>

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.

<u>Maximum any 2 of 3 marks</u> 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

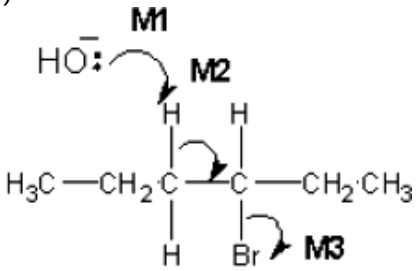
Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

NB The arrows here are double-headed

3

[8]

M7. (a) (i)



Penalise one mark from <u>their</u> 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 <u>to the correct</u> 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 <u>attacking</u> the H atom of the correct C–H bond in **M1**

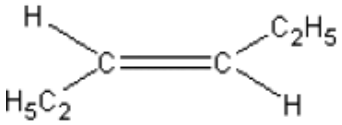
M3 is independent but **CE=0 if nucleophilic substitution**

N.B these are double-headed arrows

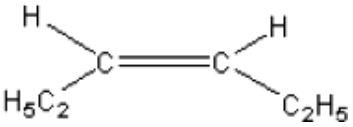
3

(ii)

M1 E isomer



M2 Z isomer



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 CH_2CH_3) since the question is about E and Z positions but penalise once only if connection is clearly to the CH_3 of CH_2CH_3

Accept linear structures

2

(iii) **M1** (Compounds / molecules with) the <u>same structural formula</u>

*Penalise **M1** if "same structure"*

M2 with <u>atoms/bonds/groups</u> arranged <u>differently in space</u>

Ignore references to "same molecular formula" or "same empirical formula" or any reference to "displayed formula"

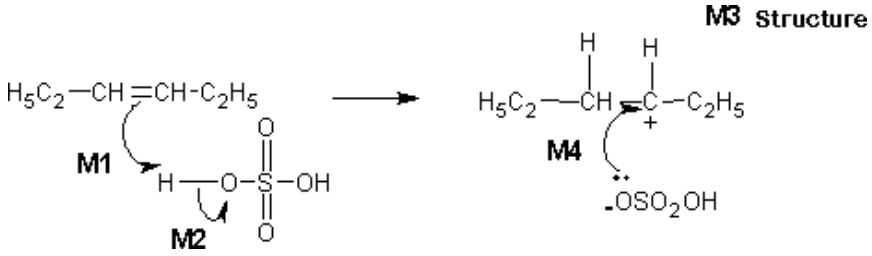
OR

<u>atoms/bonds/groups</u> that have <u>different spatial arrangements / different orientation</u>.

Mark independently

2

(b)



M1must 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* $^-OSO_3H$ *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

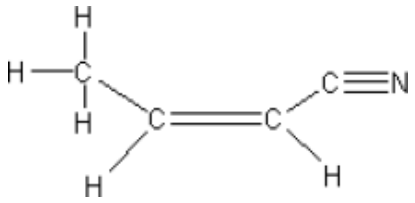
Max 3 of any 4 marks for wrong organic reactant or wrong organic product (if shown)

Accept the correct use of "sticks"

4

[11]

M8. (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.

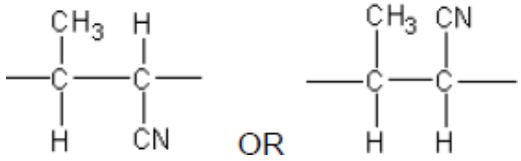
1

(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]