Mark schemes

1

(a) **M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2
($2C_2H_5OH$)

Mark independently

For M1 and M3 ignore state symbols and credit multiples

For M1 and M3 penalise C_2H_6O once only

M2 fermentation

M3 CH_3CH_2OH + **3**O_2 $\longrightarrow$ **2**CO_2 + **3**H_2O
(C_2H_5OH)

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^-

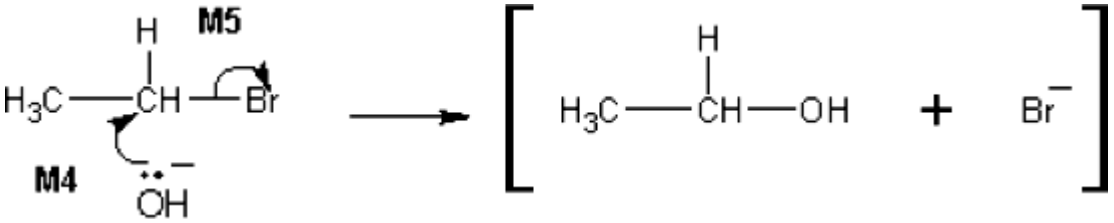
warm / heat / reflux <u>and</u> aqueous or (aq) or water

For M2 ignore "dilute"

For M2 penalise T > 100 °C

M3 <u>nucleophilic substitution</u>

Acidified KOH/NaOH or H_2SO_4 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 <u>original molecule.</u>

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_N1 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^+span>

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
- <u>Bromoethane</u> has to be manufactured / made first
- <u>Bromoethane</u> is expensive

For M6 ignore references to other costs and expenses

6

(c) **M1** <u>concentrated</u> phosphoric acid / <u>conc</u>. H_3PO_4 ***OR*** <u>concentrated</u> 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 <u>any two</u> from

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

- <u>Excess</u> ethene

  OR <u>Excess</u> steam / water / H_2O

  OR remove the ethanol as it forms

  OR recycle the ethene

- <u>Specified</u> Pressure

  50 atm ≤ P ≤ 100 atm

  OR 5000 kPa ≤ P ≤ 10000 kPa

  OR 5 MPa ≤ P ≤ 10 MPa

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

  OR 300 °C ≤ T ≤ 600 °C

  OR 570 K ≤ T ≤ 870 K

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

4

[15]

2

(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 $C_2H_5B_r$

Structure of bromoethane.

Ignore name and structure of nitrile

Credit "sticks" for C-H bonds

1

[10]

3

(a) Pentan-2-one

ONLY but ignore absence of hyphens

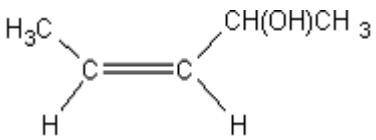
1

(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 <u>rotation</u> (about the C=C)

OR

No (free) <u>rotation</u> (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

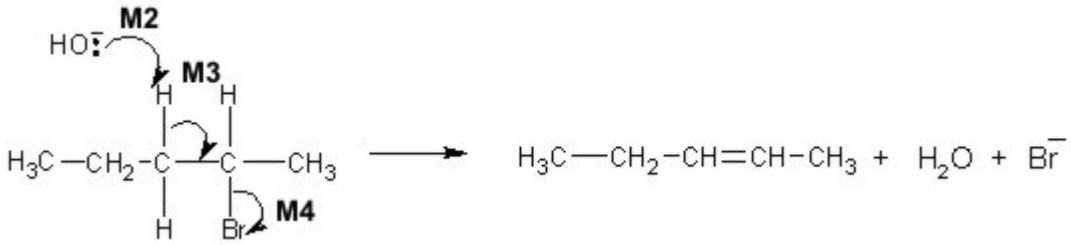
  Allow the words "dip" OR "spike" OR "trough" OR "low transmittance" as alternatives for absorption.

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

2

[10]

4 (a) (i) **M1** <u>Elimination</u>



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

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 <u>no other prefix</u>.

*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.

*<u>Max any 2 of 3 marks **for the mechanism**</u> 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**

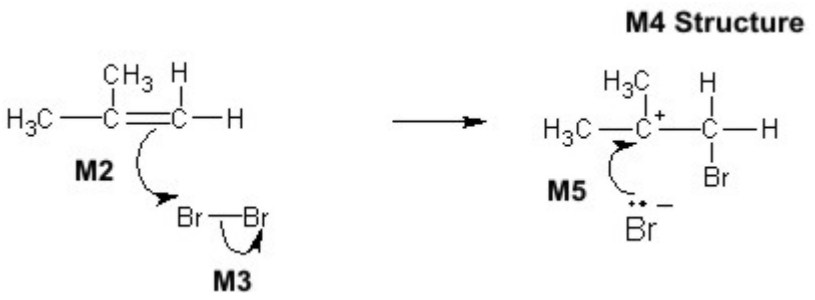
$CH_3CH_2CH_2CH=CH_2$

Penalise C_3H_7

Accept correct "sticks"

1

(b) **M1 <u>Electrophilic addition</u>**



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*

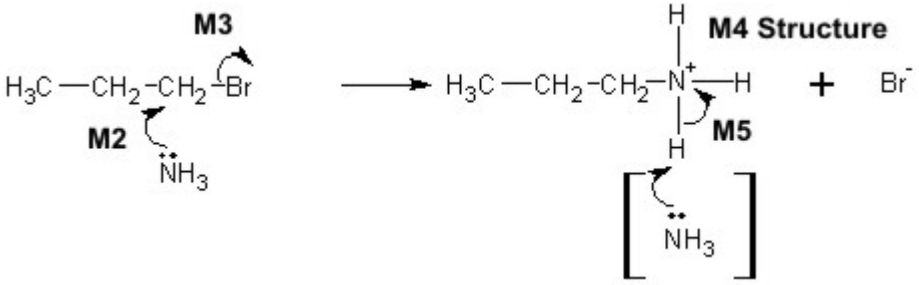
wrong organic reactant or wrong organic product (if shown) or primary carbocation.

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]

5 (a) (i) (Free-) radical substitution

Both words needed

1

(ii) UV light/Ultra-violet light/sunlight
OR high temperature/150 °C ≤ T ≤ 500 °C

1

(iii) Propagation (Step)

Ignore "first" or "second"

Accept phonetic spelling

1

(iv) **M1** Termination (Step)

M2 $\mathbf{2}CH_3CH_2CH_2\bullet \longrightarrow C_6H_{14}$

In M2

C_6H_{14} may be drawn out as $CH_3CH_2CH_2CH_2CH_2CH_3$

The dot may be anywhere around the terminal CH_2 on the radical

Accept $C_3H_7\bullet$ with dot anywhere

Penalise the absence of any radical dot

2

(v) $C_3H_8 + \mathbf{8}Br_2 \longrightarrow C_3Br_8 + \mathbf{8}HBr$

Or multiples

1

(b) (i) **M1** Double bonds are

electron-rich

OR <u>electron pair donors</u>

OR centres of <u>electron density</u>.

M2 Bromine <u>becomes polarised/becomes polar</u>

OR forms an <u>induced dipole</u>

OR <u>becomes δ+/δ–</u>

M1 QoL – require <u>one</u> of these terms

Ignore "(very) negative" and "nucleophile" as applied to the double bond.

Penalise M2 for ion formation from bromine

For M2, do not credit dipole formation <u>solely</u> as a consequence of electronegativity

2

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

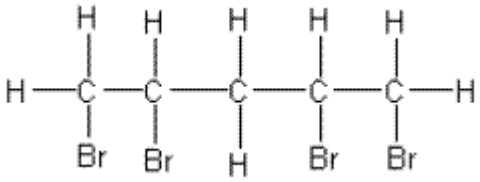
Both words needed

Accept phonetic spelling

1

(iii) Structure for 1,2,4,5-tetrabromopentane, for example $BrCH_2CHBrCH_2CHBrCH_2Br$

OR



Must be clear that they have drawn 1,2,4,5-tetrabromopentane and does NOT need to be displayed

Credit use of "sticks" for each C-H bond

1

(c) +

M1 Structure of CH_3CHCH_3

M2 (Secondary) Carbocation OR (secondary) carbonium ions

Mark independently

For M1 the positive charge must be on the central carbon atom

Penalise bond to positive charge

Penalise answers which show more than the correct carbocation e.g. the mechanism, unless the intermediate is clearly identified

Credit use of "sticks" for each C-H bond

For M2, penalise "primary" or "tertiary"

2

[12]

6

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

Must be correct spelling but ignore hyphens and commas

1

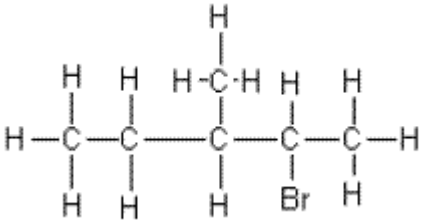
(ii) <u>Electrophilic addition</u> (reaction)

Both words needed

Accept phonetic spelling

1

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



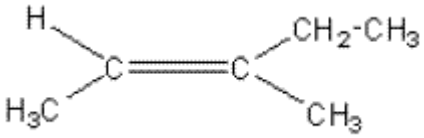
All the bonds must be drawn out but ignore bond angles

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 <u>and</u> this is due to <u>C=C</u>
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}) <u>and</u> does not contain <u>C=C</u>.

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) <u>Functional group</u> (isomerism)

1

(iii) Cyclohexane

OR

Methylcyclopentane etc.

Named correctly

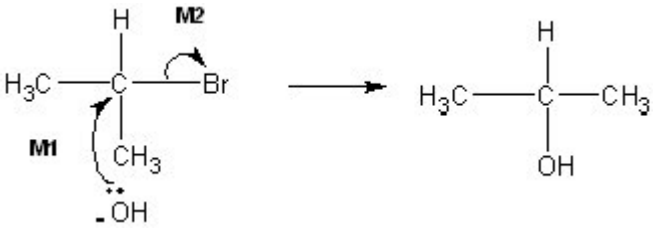
Ignore structures and ignore numbers on the methyl group of methylcyclopentane

1

[9]

7 (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_N1 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)

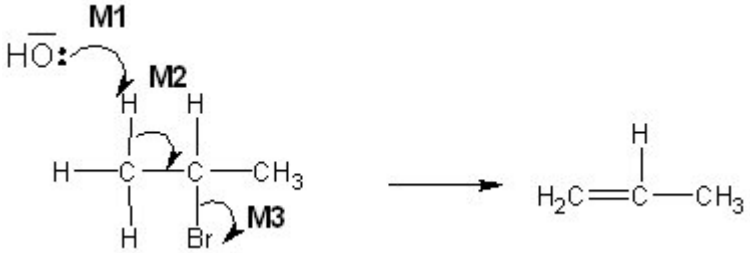
It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule.
Ignore X for halogen

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°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]