M1.(a) (i) **M1** (Compounds / molecules with) the <u>same structural formula</u>

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

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

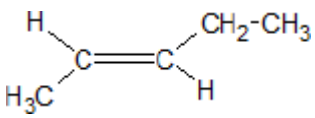
OR <u>atoms / bonds / groups</u> with <u>different spatial arrangements / different orientation</u>

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

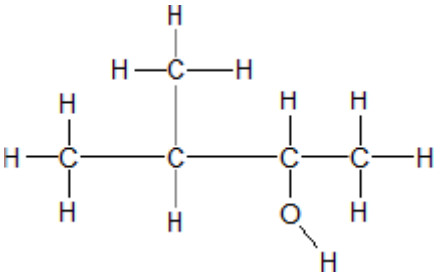
different absorptions / peaks are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



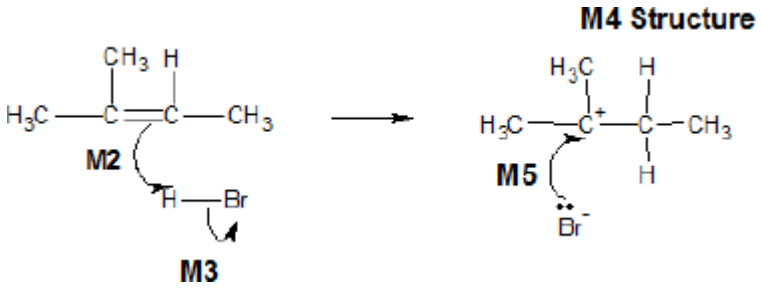
All bonds must be drawn.

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)

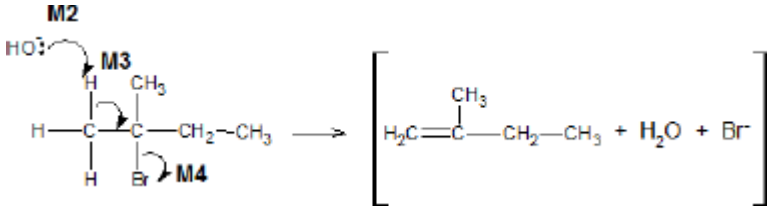
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

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>

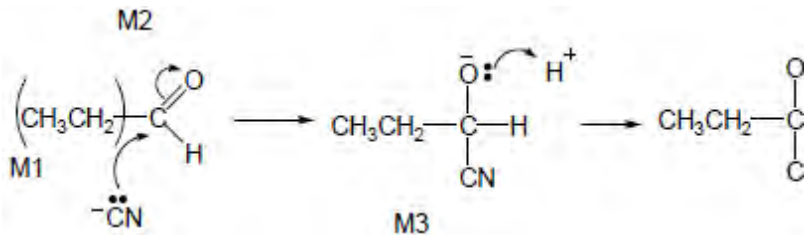
*Penalise **M5** if 'nucleophile'.*

5 **[21]**

M2.(a) Nucleophilic addition

1

M4 for lp, arrow and H+

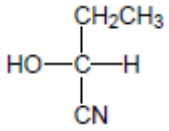


Allow C_2H_{5-} for CH_3CH_{2-}

- *M1 and M4 include lone pair and curly arrow.*
- *Allow: CN^- but arrow must start at lone pair on C.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+.*
- *+ rather than δ+ on C=O loses M2.*
- *Penalise incorrect partial charges.*
- *M3 is for correct structure including minus sign but lone pair is part of M4.*
- *Penalise extra curly arrows in M4.*

4

(b) (i) M1



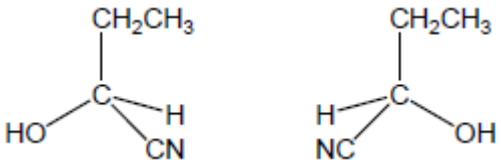
M1 for correct structure of product of part (a).

Allow C_2H_{5-} for CH_3CH_{2-}.

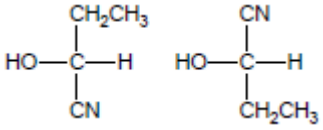
Penalise wrongly bonded, OH or CN or CH_2CH_3 once only in clip.

1

M2

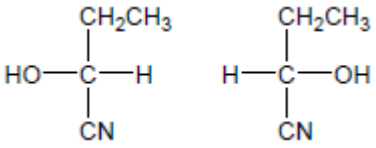


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not <u>show</u> the enantiomers as mirror images.

Students must <u>show</u> an attempt at mirror images, eg allow

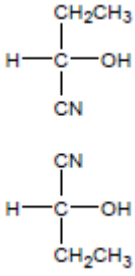


ie vertical groups same and horizontal swapped as if there was a mirror between them

No mirror need be shown

Do not penalize wedge bond when wedge comes into contact with both C & N

However these two could score M2 if placed as below as if with a "mirror" horizontally between them.



1

(ii) M1 (Plane) <u>polarized light</u>

M2 only scores following correct M1

1

M2 <u>Rotated</u> in <u>opposite</u> directions (equally) (only allow if M1 correct close)

or

Not just in different directions but allow one rotates light to the left and one to the right.

Not molecules rotate.

1

(c) 2-hydroxybutane(-1-)nitrile

1

(d) Weak acid / (acid) only slightly / partially dissociated / ionised

Ignore rate of dissociation.

1

$[CN^-]$ very low

Allow (very) few cyanide ions.

Mark independently.

1

(e) (i) $H_2C{=}CH{-}CH_3 + NH_3 + \frac{3}{2}O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O$

OR

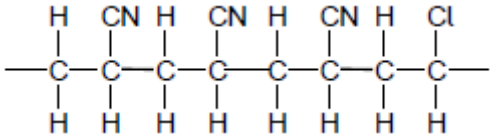
$H_2C{=}CH{-}CH_3 + NH_3 + 3O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O_2$

OR doubled.

Allow C_3H_6 and CH_2CHCN or C_3H_3N on this occasion only.

1

(ii)

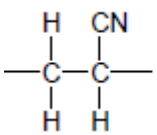
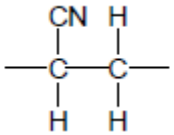
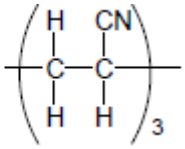


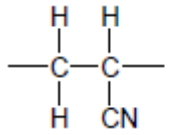
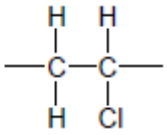
Ignore n.

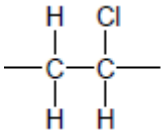
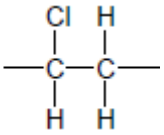
Must show trailing bonds.

Do not penalise C–NC bond here on this occasion.

Must contain, in any order,

3 of  or 3 of  or 

Allow  or 

and one of  or 

Allow $-CH_2CH(CN)CH_2CHCl-$ etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

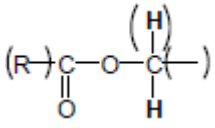
1

[15]

M3.(a) M1 Ester **1**

If Ester 2, can score M3 only.

1

M2 peak at δ = 4.1 due to 

When marking M2 and M3, check any annotation of structures in the stem at the top of the page.

1

M3 (δ = 4.1 peak is) quartet as <u>adjacent / next to / attached to CH_3</u>

1

M4 Other spectrum quartet at δ = 2.1-2.6 (or value in this range)

1

(b) M1 <u>Quaternary</u> (alkyl) <u>ammonium salt / bromide</u>

1

M2 CH_3Br or bromomethane

Penalise contradictory formula and name.

1

M3 Excess (CH_3Br or bromomethane)

Mention of acid eg H_2SO_4 OR alkali eg NaOH loses both M2 and M3.

1

M4 Nucleophilic substitution

Can only score M3 if reagent correct.

Ignore alcohol or ethanol (conditions) or Temp.

1

(c)

	Bromine (penalise Br but mark on)	Acidified $KMnO_4$ (Penalise missing acid but mark on)

Wrong reagent = no marks.

If bromine colour stated it must be red, yellow, orange, brown or any combination, penalise wrong starting colour.

1

Benzene	no reaction / colour remains / no (visible) change	no reaction / colour remains / no (visible) change

Ignore 'clear', 'nothing'.

Allow colour fades slowly.

Allow 'nvc' for no visible change.

1

cyclohexene	(Bromine) decolourised	(Acidified $KMnO_4$) decolourised

1

[11]

M4. M1: uv light/sunlight

OR

T = 450 °C to 1000 °C;

(do not credit "high temperature")
(ignore references to pressure or catalyst)
(penalise M1 if aqueous chlorine OR chlorine water)
(credit M1 if the condition appears over the arrow of the initiation step)

1

M2: $Cl_2 \rightarrow 2Cl\cdot$;

(credit correct half arrows, but penalise (once in the question) the use of double headed arrows)

1

M3: $C_2H_6 + Cl\cdot \rightarrow CH_3CH_2\cdot + HCl$;

(credit CH_3CH_3 for ethane and C_2H_5- for the ethyl radical)

1

M4: $CH_3CH_2\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$;

1

M5: $CH_3CH_2\cdot + CH_3CH_2\cdot \rightarrow C_4H_{10}$;

(penalise the absence of dots once only in this question)
(penalise subsequent ionic reactions as contradictions for each reaction contradicted)

(if <u>neither</u> M3 nor M4 scored, allow $CH_3CH_2\cdot + Cl\cdot \rightarrow C_2H_5Cl$ for one mark)

1

[5]

M5.(a) **Initiation**

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation

$Cl\bullet + CH_3Cl \longrightarrow \bullet CH_2Cl + HCl$

Credit the dot anywhere on the radical.

Second propagation

$Cl_2 + \bullet CH_2Cl \longrightarrow CH_2Cl_2 + Cl\bullet$

Termination (must make 1,2-dichloroethane)

$2 \bullet CH_2Cl \longrightarrow CH_2ClCH_2Cl$

Penalise $C_2H_4Cl_2$

4

(b) (i) (chlorine free) radical

Ignore formula.

1

(ii) M1 $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

M2 $ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$

***M1** and **M2** could be in either order.*

Credit the dot anywhere on the radical.

Penalise absence of dot once only.

Individual multiples acceptable but both need to be doubled if two marks are to be awarded.

2

[7]