M1.(a) **M1** acidified potassium dichromate or $K_2Cr_2O_7$ / H_2SO_4

OR $K_2Cr_2O_7$ / H^+ ***OR*** acidified $K_2Cr_2O_7$

M2 (orange to) green solution ***OR*** goes green

M3 (solution) remains orange or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*For **M2** ignore dichromate described as "yellow" or "red"*

*For **M3** ignore "nothing (happens)" or "no observation"*

Alternative using $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate or $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 colourless solution ***OR*** goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

*For **M1***

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green*

3

(b) **M1** (Shake with) Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent)

M2 (stays) orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

M3 decolourised / goes colourless / loses its colour / orange to colourless

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on***

*No credit for combustion observations; **CE = 0***

*For **M2 in every case***

Ignore "nothing (happens)"
Ignore "no observation"
Ignore "clear"

***OR* as alternatives**

Use $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 (stays) purple or no reaction or no (observed) change

M3 decolourised / goes colourless / loses its colour

Use iodine

M1 iodine or I_2 / KI or iodine solution

M2 no change

M3 decolourised / goes colourless / loses its colour

Use concentrated sulfuric acid

M1 concentrated H_2SO_4

M2 no change

M3 brown

***For M1**, it must be a whole reagent and / or correct formula*
For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3
With potassium manganate(VII)
*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***
*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives brown precipitate or solution goes green*
Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent as those used for other reagents.

3

(c) **M1** Any soluble chloride including hydrochloric acid (ignore concentration)

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble iodide including HI

M2 yellow precipitate or yellow solid / yellow suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble bromide including HBr

M2 cream precipitate or cream solid / cream suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 NaOH or KOH or any soluble carbonate

M2 brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate / solid / suspension with carbonate)

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If no reagent or incorrect reagent or insoluble chloride in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Allow chlorine water

*If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on***

*For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives)*

*For **M3***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

3

(d) **M1** Any soluble sulfate including (dilute or aqueous) sulfuric acid

M2 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

M3 white precipitate or white solid / white suspension

*If no reagent or incorrect reagent or insoluble sulfate in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates

If concentrated sulfuric acid or incomplete reagent (e.g. sulfate ions) or inaccurate attempt at formula of chosen sulfate, ***penalise M1 only and mark on***

For ***M3 (or M2 in the alternative)*** *require the word "white" and some reference to a solid.*

Ignore "cloudy solution" OR "suspension"

For ***M2 (or M3 in the alternative)***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

***OR* as an alternative**

M1 NaOH or KOH

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, ***penalise M1 only and mark on***

If ***M1*** *uses NH_3 (dilute or concentrated)* ***penalise M1 only and mark on***

3

[12]

M2.(a) Reagent

Acidified
$K_2Cr_2O_7$

Acidified
$KMnO_4$

I_2 / NaOH

Named
RCOOH with HCl or H_2SO_4

Named
RCOCl

Allow names including potassium permanganate

Wrong or no reagent CE = 0

1

P (ketone)
no reaction
no reaction
Yellow ppt
no reaction
no reaction

Penalise incorrect formulae or incomplete reagent, such as $K_2Cr_2O_7$ or acidified dichromate, but mark on.

1

S (2° alcohol)
(orange to) green
(purple to) colourless
no reaction
fruity or sweet smell
Misty fumes

Allow no change or nvc but penalise nothing or no observation

If 2 reagents added sequentially or 2 different reagents used for P and S then CE = 0

1

(b) Tollens'
silver mirror / solid

1

Fehling's / Benedicts
red ppt

1

(c) **G**
P

If not P then no marks for clip

1

5 OR five

1

(d) $C_4H_{12}Si$

Must be molecular formula

Wrong substance CE = 0 for clip

1

Any **two** from
- One or single peak OR all (four) carbon atoms are equivalent or one

environment

1

- upfield from others or far away from others or far to right
- non toxic OR inert
- low boiling point or volatile or easy removed from sample

Ignore and don't credit single peak linked to 12 equivalent H or has a peak at δ = 0

but use list principle for wrong statements

1
1

(e) Figure 1 is **R**

*If not **R** cannot score M2*

M1

1

90−150 (ppm) or value in range is (two peaks for) C = C / alkene

M2

1

Figure 2 is **T**

*If not **T** cannot score M4 or M5*

M3

1

50-90 (ppm) or value in range is C—O or alcohol or ether

M4

1

two peaks (so not S which would have only one)

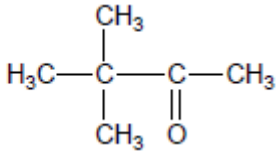
M5

1

(f)

U

$C_6H_{12}O_6$

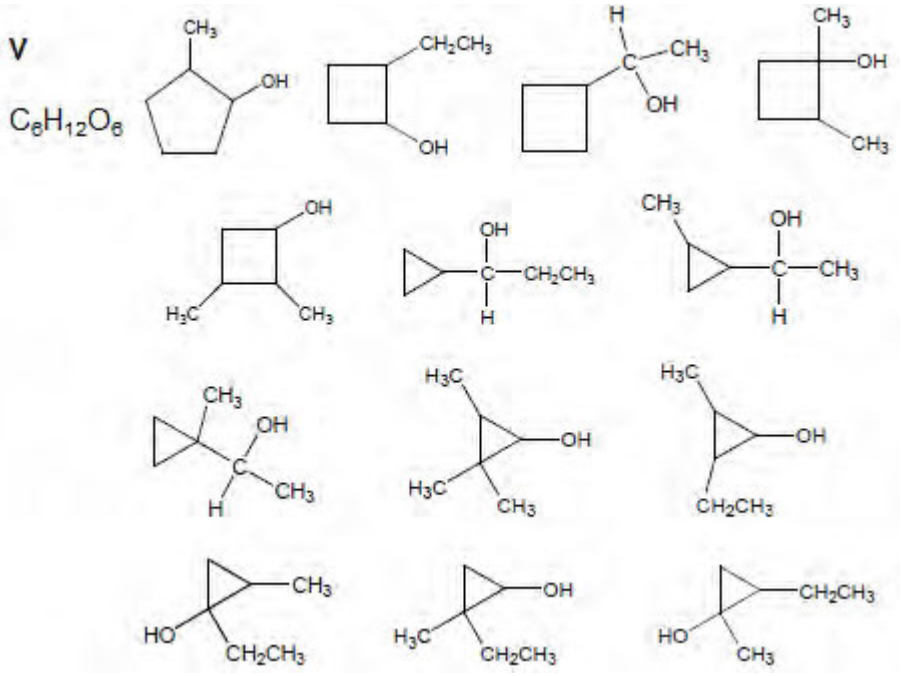


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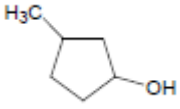
Answers include

V

$C_6H_{12}O_6$



*Not allow **S***



*because **V** must be an isomer of **S***

[17]

M3.(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

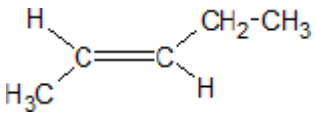
OR atoms / bonds / groups with different spatial arrangements / different orientation

Ignore references to 'same molecular formula' or 'same empirical formula'.

Mark independently.

2

(ii)



Credit C–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 **<u>concentrated</u> H_2SO_4**

M1 <u>concentrated</u> 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) **<u>1620 to 1680</u>** (cm^{-1})

Ignore reference to other ranges (eg for C–H or C–C).

1

(ii) The <u>fingerprint</u> (region) / below 1500 cm^{-1} will be different **or** its <u>fingerprinting</u> will be different

OR

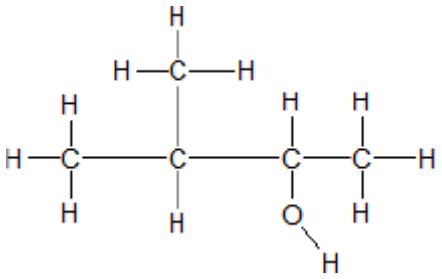
different <u>absorptions / peaks</u> are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



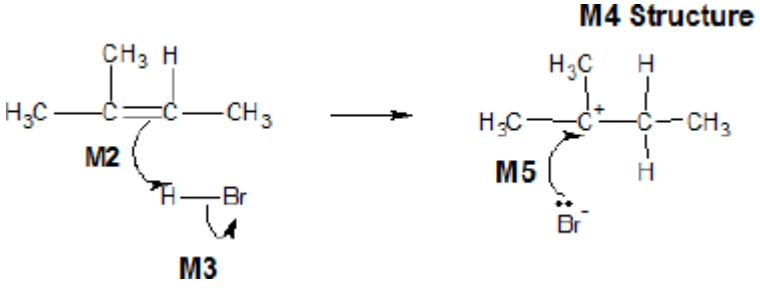
All bonds must be drawn.

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**.*

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

5

(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)

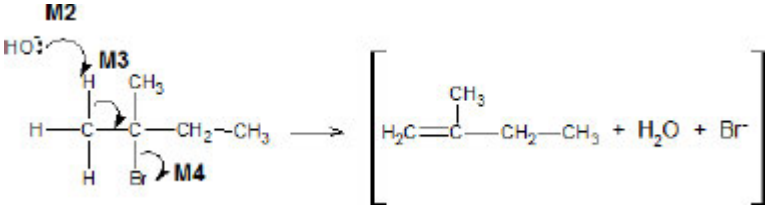
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

2

(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'.*

5

[21]

M1.(a) (i) C_4H_{10}

M_r = 4(12.00000) + 10(1.00794)

= <u>58.07940</u> or <u>58.0794</u> or <u>58.079</u> or <u>58.08</u>

<u>and</u> **<u>58.1</u>**

Working is essential, leading to the final value of 58.1 which must be stated in addition to one of the four numbers underlined

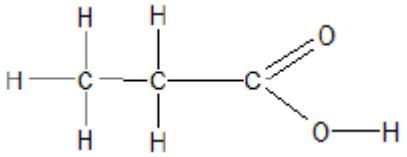
1

(ii) <u>By definition</u>
OR
The <u>standard</u> / <u>reference</u> (value / isotope)

Reference to ^{12}C alone is not enough

1

(b)



All bonds and atoms must be drawn
Give credit for the displayed formula for the anion

1

(c) (i) $H_2C = CHCH_2OH$

Any correct representation including correct use of "sticks".
Require the double bond to be shown

1

(ii) <u>Addition</u> (polymerisation)

ONLY this answer

1

(iii) **M1** **<u>C = C</u>** (in range) **<u>1620 to 1680</u>** (cm^{-1})

M2 **<u>O – H</u>** (in range) **<u>3230 to 3550</u>** (cm^{-1})

Award one mark for two correct ranges but a failure to draw out the C = C or O–H bonds

2

(d) (i) CH_3COCH_3

Any correct representation including correct use of "sticks"

1

(ii) C

1

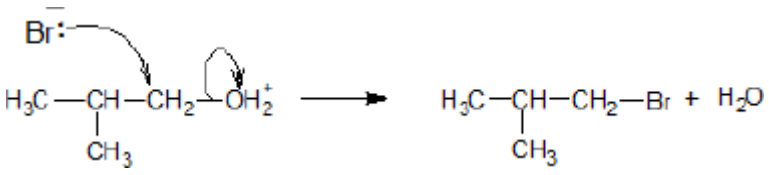
[9]

M2.(a) (i) **M1** double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH_2

Penalise additional arrows.

M2 double-headed arrow from the bond to the O atom

As follows



2

(ii) **M1** <u>nucleophilic substitution</u>

M1 *both words needed (allow phonetic spelling).*

M2 1-bromo(-2-)methylpropane

M2 *Require correct spelling in the name but ignore any hyphens or commas.*

2

(b) **M1** hydrolysis

*For **M1** give credit for 'hydration' on this occasion only.*

M2 <u>C≡N</u> with absorption range <u>2220–2260</u> (cm^{-1})

*Credit 1 mark from **M2** and **M3** for identifying C≡N **and** either O–H(acids) **or** C=O **or** C–O without reference to wavenumbers or with incorrect wavenumbers.*

M3 O–H(acids) with absorption range 2500–3000 (cm^{-1})

OR

C=O with absorption range 1680–1750 (cm^{-1})

OR

C–O with absorption range 1000–1300 (cm^{-1})

*Apply the list principle to **M3***

3

(c) (i) **M1** Yield / product **OR** ester increases / goes up / gets more

***M2** (By Le Chateliers principle) the position of equilibrium is driven / shifts / moves to the right / L to R / in the forward direction / to the product(s)*

M3 – requires a correct statement in M2

(The position of equilibrium moves)

to oppose the increased concentration of ethanol

to oppose the increased moles of ethanol

to lower the concentration of ethanol

to oppose the change and decrease the ethanol

*If no reference to **M1**, marks **M2** and **M3** can still score BUT if **M1** is incorrect CE=0*

*If there is reference to 'pressure' award **M1** ONLY.*

3

(ii) ***M1***

Catalysts provide an alternative route / pathway / mechanism

OR

surface adsorption / surface reaction occurs

*For **M1**, not simply 'provides a surface' as the only statement.*

***M1** may be scored by reference to a specific example.*

M2

that has a lower / reduced activation energy

OR

lowers / reduces the activation energy

*Penalise **M2** for reference to an increase in the energy of the molecules.*

*For **M2**, the student may use a definition of activation energy without referring to the term.*

*Reference to an increase in successful collisions in unit time alone is not sufficient for **M2** since it does not explain why this has occurred.*

2

[12]

***M3.**(a) Percentage of oxygen by mass = 100 – 40.9 – 4.5 = 54.6*

1

	C	*H*	*O*
%	*40.9*	*4.5*	*54.6*
Divide by A_r	*12*	*1*	*16*
	= 3.41	*= 4.5*	*= 3.41*

1

Divide by smallest =	*3.41 / 3.41 = 1*	*4.5 / 3.41 = 1.32*	*3.41 / 3.41 = 1*
Nearest whole number ratio =	*1 × 3*	*1.32 × 3*	*1 × 3*

= 3 : 3.96 : 3

Nearest integer ratio = 3 : 4 : 3

1

Empirical formula $C_3H_4O_3$

Empirical formula mass = 88 = molecular formula mass

Therefore, molecular formula is same as the empirical formula - $C_3H_4O_3$

1

(b) 

1

(c) *Advantage – ethanol is produced at a faster rate*

1

Disadvantage – more energy is used / required in the reaction

1

(d) *Air gets in / oxidation occurs*

1

(e) *Alcohol OH absorption in different place (3230–3550 cm^{-1}) from acid OH absorption (2500–3000 cm^{-1})*

1

The C=O in acids has an absorption at 1680–1750 cm^{-1}

1

[10]

M4.(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>*

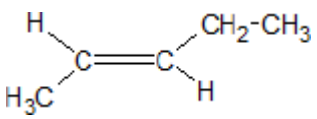
OR *<u>atoms / bonds / groups</u> with <u>different spatial arrangements / different orientation</u>*

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 **<u>concentrated</u> H_2SO_4***

M1 *<u>concentrated</u> 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) **<u>1620 to 1680</u>** (cm^{-1})*

Ignore reference to other ranges (eg for C–H or C–C).

1

(ii) *The <u>fingerprint</u> (region) / below 1500 cm^{-1} will be different **or** its <u>fingerprinting</u> will be different*

OR

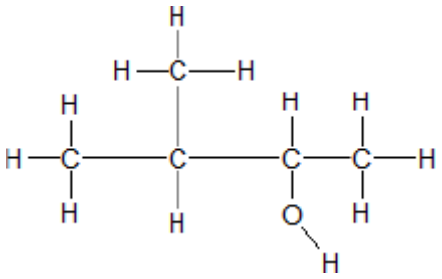
different <u>absorptions / peaks</u> are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



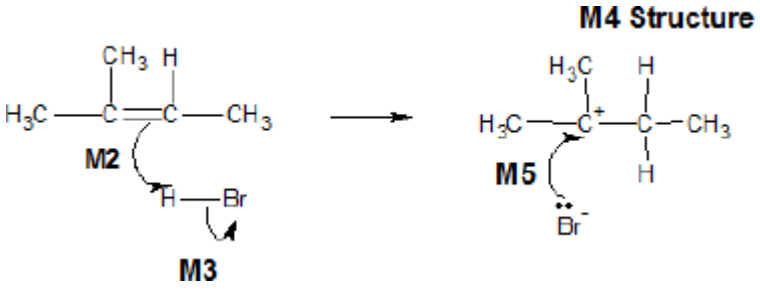
All bonds must be drawn.

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**.*

***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

5

(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)

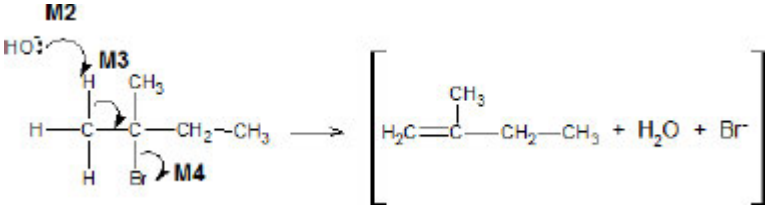
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

2

(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 <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]

M5.IR

Extended response

Absorption at 3360 cm^{-1} shows OH alcohol present

Deduction of correct structure without explanation scores maximum of 4 marks as this does not show a clear, coherent line of reasoning.

M1

1

NMR

There are 4 peaks which indicates 4 different environments of hydrogen

Maximum of 6 marks if no structure given OR if coherent logic not displayed in the explanations of how two of OH, CH_3 and CH_2CH_3 are identified.

M2

1

The integration ratio = 1.6 : 0.4 : 1.2 : 2.4

The simplest whole number ratio is 4 : 1 : 3 : 6

M3 ***1***

The singlet (integ 1) must be caused by H in OH alcohol

M4 ***1***

The singlet (integ 3) must be due to a CH_3 group with no adjacent H

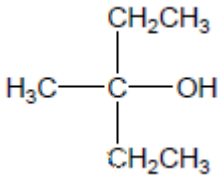
M5 ***1***

Quartet + triplet suggest CH_2CH_3 group

M6 ***1***

Integration 4 and integration 6 indicates two equivalent CH_2CH_3 groups

M7 ***1***



M8 ***1***

[8]

M1.(a) (i) C_4H_{10}

M_r = 4(12.00000) + 10(1.00794)

= <u>58.07940</u> or <u>58.0794</u> or <u>58.079</u> or <u>58.08</u>

<u>and</u> **<u>58.1</u>**

Working is essential, leading to the final value of 58.1 which must be stated in addition to one of the four numbers underlined

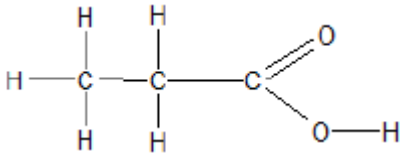
1

(ii) <u>By definition</u>
OR
The <u>standard</u> / <u>reference</u> (value / isotope)

Reference to ^{12}C alone is not enough

1

(b)



All bonds and atoms must be drawn
Give credit for the displayed formula for the anion

1

(c) (i) $H_2C = CHCH_2OH$

Any correct representation including correct use of "sticks".
Require the double bond to be shown

1

(ii) <u>Addition</u> (polymerisation)

ONLY this answer

1

(iii) **M1** **<u>C = C</u>** (in range) **<u>1620 to 1680</u>** (cm^{-1})

M2 **<u>O – H</u>** (in range) **<u>3230 to 3550</u>** (cm^{-1})

Award one mark for two correct ranges but a failure to draw out the C = C or O–H bonds

2

(d) (i) CH_3COCH_3

Any correct representation including correct use of "sticks"

1

(ii) C

1

[9]

M2. (a) **2**$Ca_5F(PO_4)_3$ + $9SiO_2$ + **15**C ⟶ $9CaSiO_3$ + CaF_2 + **15**CO + **6**P

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

<u>and</u>

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that <u>speeds up</u> a reaction OR <u>alters / increases the rate</u> of a reaction **AND** is <u>chemically unchanged at the end / not used up</u>.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH=CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

M3.(a) H ***OR*** hydrogen ***OR*** $H^{\bullet}$

Ignore brackets ignore dot

penalise + or – charge

1

(b) CH_3 ***OR*** methyl ***OR*** $CH_3^{\bullet}$ ***OR*** $^{\bullet}CH_3$

Ignore brackets ignore dot

penalise + or – charge

1

(c) Either order

C_2H_5 ***OR*** ethyl ***OR*** $CH_3CH_2^{\bullet}$ ***OR*** $C_2H_5^{\bullet}$

Ignore brackets ignore dot

penalise + or – charge

1

CHO ***OR*** HCO ***OR*** COH ***OR*** H—C=O

1

(d) I A

1

II C

1

III D

1

IV B

1

[8]

M4. (a) The molecular ion is

- The molecule with one/an electron knocked off/lost
  Ignore the highest or biggest m/z peak

OR

- The molecule with a (single) positive charge

OR

- the ion with/it has the largest/highest/biggest m/z (value/ratio)
  Ignore "the peak to the right"

OR

- the ion with/it has an m/z equal to the M_r
  Ignore "compound"

1

(b) (i) 2(14.00307) + 15.99491 = 44.00105
A sum is needed to show this

1

(ii) Propane/C_3H_8 and carbon dioxide/CO_2 (and N_2O) or
they or both the gases/molecules or all three gases/molecules
have an (imprecise) M_r of 44.0 (OR 44)

OR

they have the same M_r or molecular mass (to one d.p)

This could be shown in a calculation of relative masses for propane and carbon dioxide

1

(iii) By definition

OR

The standard/reference (value/isotope)

Ignore "element"

Ignore "atom"

1

(c) (i) **M1 (could be scored by a correct mathematical expression)**

$\Delta H = \Sigma\Delta H_{products} - \Sigma\Delta H_{reactants}$

OR a correct cycle of balanced equations

M1 and M2 can be scored with correct moles as follows
$\Delta H + 2(-46) = +82 + 3(-286)$

$\Delta H - 92 = -776$

$\Delta H = 92 - 776$ OR $92 + 82 - 858$

M3
$\Delta H = -684$ (kJ mol^{-1}) (This is worth 3 marks)

Award 1 mark ONLY for + 684

Full marks for correct answer.

Ignore units.

Deduct one mark for an arithmetic error.

3

(ii) The value is quoted at a pressure of 100 kPa OR 1 bar or 10^5 Pa

OR

All reactants and products are in their standard states/their normal states at 100 kPa or 1 bar

Ignore 1 atmosphere/101 kPa

Ignore "constant pressure"

1

[8]