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

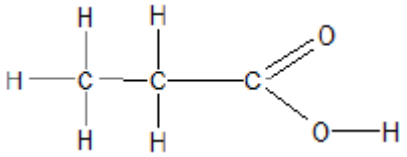
1

(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 **O – H** (in range) **3230 to 3550** (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

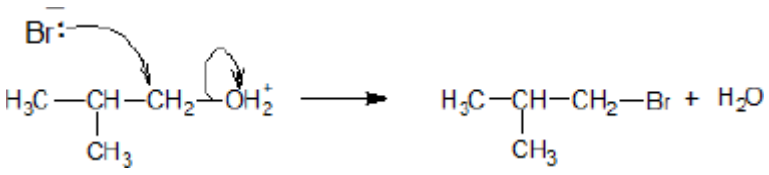
[9]

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** nucleophilic substitution

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 C≡N with absorption range 2220–2260 (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*
%			
Divide by A_r	$\frac{40.9}{12}$	$\frac{4.5}{1}$	$\frac{54.6}{16}$
	= 3.41	*= 4.5*	*= 3.41*

1

Divide by smallest =	$\frac{3.41}{3.41} = 1$	$\frac{4.5}{3.41} = 1.32$	$\frac{3.41}{3.41} = 1$
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) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

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>*

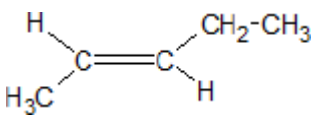
OR *<u>atoms / bonds / groups</u> with <u>different spatial arrangements / different orientation</u>*

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

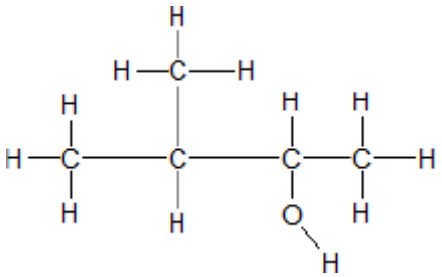
different <u>absorptions / peaks</u> are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



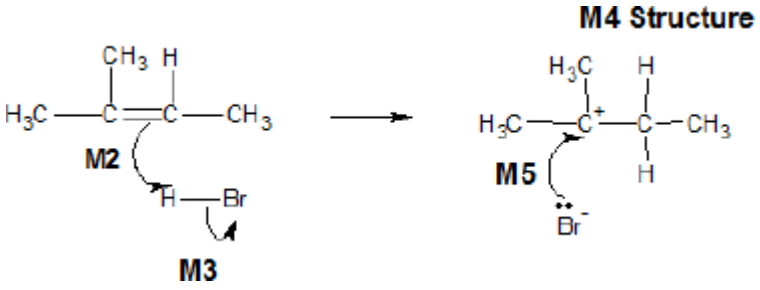
All bonds must be drawn.

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)

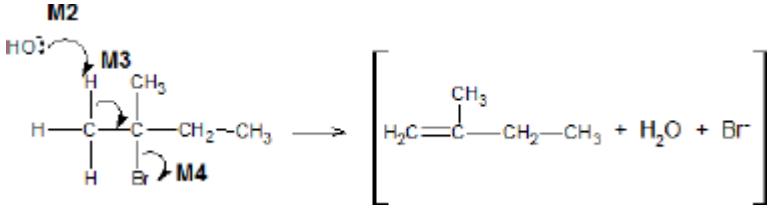
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

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

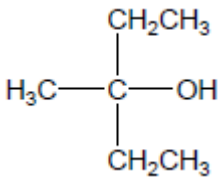
M5 ***1***

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]