3.2.10 Alcohols

Classification of reactions

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244 minutes

240 marks

M1. (a) % O = 21.6 % **(1)**

If % O not calculated only M2 available

C $\frac{64.9}{12}$ H $\frac{13.5}{1}$ O $\frac{21.6}{16}$ **(1)**

= 5.41 = 13.5 = 1.35

Ratio: 4 : 10: 1 (∴ $C_4H_{10}O$) **(1)**

If arithmetic error in any result lose M3

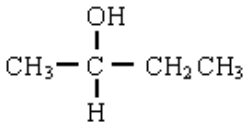
If percentage composition calculation done zero

3

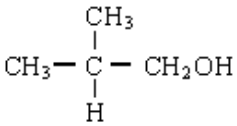
(b) (i) *Type of alcohol*: Tertiary **(1)**

Reason: No hydrogen atom on central carbon **(1)**

(ii)



(1)



(1)

Isomer 3 *Isomer 4*

Penalise missing bonds / incorrect bonds once per paper

4

(c) (i) Aldehyde **(1)**

Ignore named aldehydes or their structures,
penalise wrong named compound

(ii) $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$ **(1)**

Balanced **(1)**

$C_4H_{10}O$ is OK as a reactant

[O] can be over arrow

C_3H_7CHO not accepted for product, but $C_2H_5CH_2CHO$ is OK

If use C_3 or C_5 compounds no marks in (ii) C.E of wrong alcohol

(iii) *Name* Butanoic acid **(1)**

Structure: $CH_3CH_2CH_2COOH$ **(1)**

mark conseq. or as stated

5

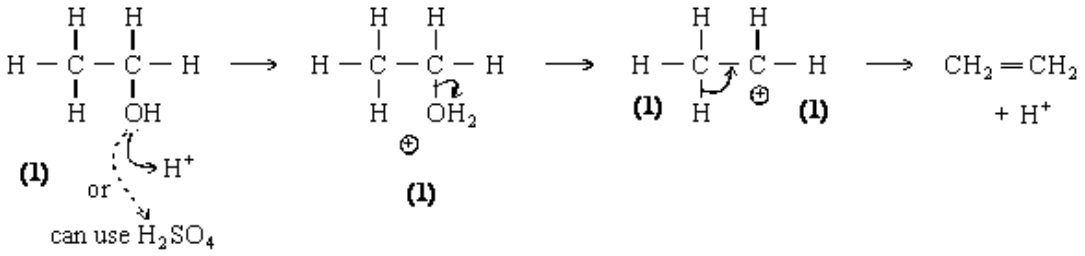
(d) *Advantage*: Fast reaction OR pure product OR continuous process OR cheap on manpower OR high yield, 100% alcohol **(1)**

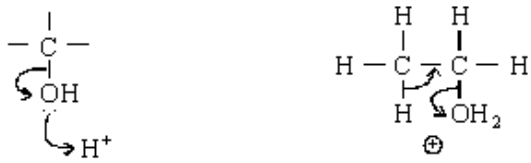
Disadvantage: High technology OR ethene from non renewable source OR expensive equipment not just costly **(1)**

Not answers based on fermentation

2

(e)





scores M1 only

scores M2 & M4
but not carbocation mark, M3.

4

[18]

M2. (a) (i) <u>addition</u> of water / steam **(1)**

Ignore "to the reaction"

(ii) *Advantage*: low technology
renewable feedstock / resource
allowed for use in drinks, perfumes
considered to be green **(1)**

any one
NOT "infinite" or "non-finite" resource

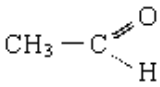
Disadvantage:
slow
low yield
significant land use
has to be distilled
labour intensive

any one
Ignore yeast
NOT (unqualified) batch production
NOT impure product

3

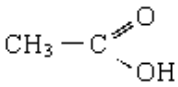
(b) (i)

Structure of aldehyde


(1)

NOT CH_3CHO

Structure of carboxylic acid


(1)

NOT CH_3COOH

Penalise incorrect R group once

(ii) *Reagent*: sodium (/ potassium) dichromate (VI)
(VI not essential) (1) M1

Conditions: acidified or sulphuric acid **(1) Can be with reagent M2**
(heat under reflux) **(1) M3**

Or correct formula for M1 and M2

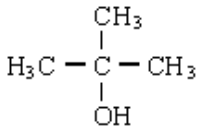
M2 depends on M1 (but M2 correct from $Cr_2O_7^{2-}$, $K_2Cr_2O_7^{2-}$ etc

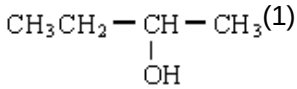
M3 mark independent
Credit $KMnO_4$ for M1

Ignore T and P for M2

5

(c) (i) (1)



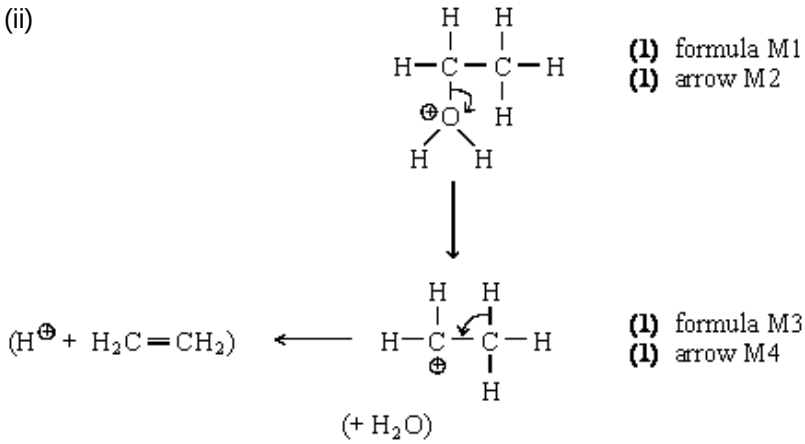
(ii)  (1)

2

(d) (i) Al_2O_3 or H_2SO_4 or H_3PO_4 **(1)**

Name or formula

(ii)



For M1 the + can be on O or H if $-OH_2$ used

For M2 the arrow must go to the + or to oxygen
Synchronous loss without carbocation loses carbocation structure mark; can still score ¾ i.e. penalise M3

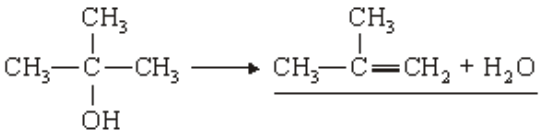
5

[15]

M3. (a) (i) 2-methylpropan-2-ol **(1)** OR the second one

ignore additional (aq) **(1)**

(ii) *Dehydrating agent*: conc H_2SO_4 OR conc H_3PO_4 OR Al_2O_3 **(1)**

Equation:  **(1)**

Allow C_4H_9OH in equation provided RHS is correct

if b(i) is blank, b(ii) equation must be full for credit
i.e. NOT C_4H_9OH

Mark consequential on b(i)

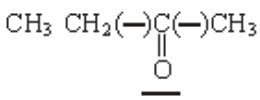
3

(b) (i) *Isomer*: butan-2-ol OR the fourth one

[look at name in table]

wrong isomer = CE

Structure of the ketone:

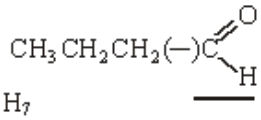
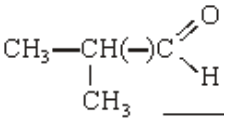
 **(1)**

(ii) *Isomer*: butan-1-ol OR the first one
OR 2-methylpropan-1-ol OR the third one

[look at name in table]

Wrong isomer = CE

Structure of the aldehyde:

Either  OR 

NOT C_3H_7

(iii)

Reagent	M1	Tollen's ($AgNO_3/NH_3$)	Fehling's
Observation with ketone	M2	Stays colourless no change	stays blue no change
Observation with aldehyde	M3	Silver mirror black ppt	red solid orange/red brown/ red ppt/solid

Other include(*)
$K_2Cr_2O_7$ / H_2SO_4
$KMnO_4/H_2SO_4$
Schiff's
Benedict's
Wrong reagent R
No reagent = CE
Penalise $AgNO_3$ $[Ag(NH_3)_2]$ but allow M2 and M3 sequentially.

(*)		ketone	aldehyde
	$K_2Cr_2O_7$ / H_2SO_4 acidified	orange no change	green
	$KMnO_4/H_2SO_4$ acidified	purple no change	colourless (v. Pale pink)

Benedict's ≡ Fehling's ; Schiff's colouless → pink with CHO violet

7

(c) *Equation*: $CH_3CH_2CH_2CH_2OH$ (or C_4H_9OH) + 2[O] → $CH_3CH_2CH_2COOH$ (or C_3H_7COOH) + H_2O **(1)**

Name of product: butanoic acid **(1)**
Accept butaneoic acid

2

[12]

M4. (a) (i) Potassium (OR sodium) dichromate(VI) OR correct formula OR potassium manganate(VII)

(Oxidation state not needed, but must be correct if included)

(Penalise errors in the formula or oxidation state, but mark conditions)

1

Acidified OR H_2SO_4 / HCl (*NOT with* $KMnO_4$) / H_3PO_4 / HNO_3

(Ignore heat or reflux)

(Credit "acidified" as part of reagent)

1

Oxidation or redox

1

(ii) $NaBH_4$ OR $LiAlH_4$ OR H_2/Ni

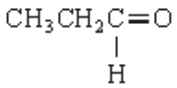
1

$CH_3COCH_3 + 2[H] \rightarrow CH_3CH(OH)CH_3$

(Credit H_2 *in the equation if* H_2 *has been chosen as reagent)*

1

(b) (i)



(Structure must show aldehyde structure)

(Credit C_2H_5 *as alternative to* CH_3CH_2*)*

(ii)

M1 Tollens' reagent OR ammoniacal silver nitrate OR $AgNO_3 + NH_3$	OR Fehling's solution	OR acidified potassium dichromate	1
M2 stays colourless	stays blue	stays orange	1

(Provided reagent is correct, credit "no reaction", "no change", "nothing", "no observation" for M2)

M3 silver mirror / deposit OR black / grey precipitate	red / brown / orange precipitate / solid	goes green	1

(Credit other correct reagents and observation)

(For M1, penalise $AgNO_3$ alone, penalise $Ag(NH_3)_2^+$, penalise "potassium dichromate", etc., but, in each case, mark on and credit correct M2 and M3)

(If totally wrong reagent or no reagent, CE = no marks for M1,M2 or M3)

1

[9]

M5. (a) Compounds with the same molecular formula

1

but different structures due to different positions of the same functional group on the same carbon skeleton/chain

1

(b) Compound A is butan-1-ol only

1

Compound C is butanone or butan-2-one

(penalise but-1-ol, but allow repeat error for but-2-one)
(credit butane-1-ol)

1

(c) (i) oxidation or redox

1

(ii) $K_2Cr_2O_7$ or potassium dichromate(VI)

(penalise the dichromate ion or incorrect oxidation state, but mark on)

1

acidified or H_2SO_4 (or other identified strong acid)

(penalise H^+)

(do not credit the acid unless M1 has been correctly attempted)

1

(iii) (heat under) reflux

OR use excess <u>oxidising</u> agent

1

(iv) correctly drawn structure of 2-methylpropan-2-ol

(insist on clearly drawn C-C and C-0 bonds)

1

(v) correctly drawn structure of methanoic acid

(insist on C-0 and C=O displayed in the formula)

1

(d) (i) Tollens' reagent or this whole reagent specified
(ammoniacal silver nitrate)
OR Fehling's solution
OR <u>acidified</u> potassium dichromate(VI)

1

(ii) correctly drawn structure of methylpropanal

(insist on C-H and C=O of aldehyde displayed in the formula)

1

[12]

M6. (a) M1: $CH_3CH_2CH_2CH_2OH$;

1

M2: $CH_3CH(OH)CH_2CH_3$;

(penalise incorrect alcohols in part (a), but mark consequentially in part (b) and in part (c), if relevant)
(if three alcohols drawn, award MAX. 1 mark)

1

(b) M1, M2 and M3: Correct structures for butanal, butanone and butanoic acid;

(award these structure marks wherever the structures appear, but insist that the C=O is shown in each structure and additionally, the C-O in the carboxylic acid

3

M4: balanced equation for the reaction of butan-1-ol with [O] to produce butanal and water;

1

M5: balanced equation for the reaction of butan-1-ol with [O] to produce butanoic acid and water

OR

balanced equation for the reaction of butanal with [O] to produce butanoic acid;

1

M6: balanced equation for the reaction of butan-2-ol with [O] to produce butanone and water;

(Credit condensed structures or molecular formulas in each equation, provided it is obvious to which reaction the equation refers) (Insist that whatever formula is used in each equation that it is a conventional representation of the compound; for example penalise $CH_3CH_2CH_2COH$ for butanal)

1

(c) M1: Correct structure for 2-methylpropan-2-ol;
M2: 2-methylpropan-2-ol

1

OR

methylpropan-2-ol;

(penalise on every occasion in parts (a) and (c), structures for the alcohols that are presented with the alcohol functional group as C-H-O)

1

[10]

M7. (a) **M1**: aqueous or solution in water or (aq) in the equation

1

M2: yeast or zymase

(do not credit 'an enzyme' unless qualified)

1

M3: anaerobic/absence of oxygen/absence of air or neutral pH/pH value 6 – 8

1

M4: T in the range 30 – 40 °C only

(ignore references to pressure)

(ignore uv light)

1

M5: fermentation

1

M6: $C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$

(ignore state symbols but penalise M1 if the state symbol in the equation contradicts)

1

M7: $CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

(credit use of C_2H_5OH)

(penalise use of C_2H_6O once only in M6 or M7)

1

(b) **M1**: dehydration is the <u>elimination</u> of water or removal of <u>combined</u> water or <u>qualified</u> loss of/removal of water e.g. <u>from</u> a compound/molecule/alcohol or removal of H and O in the ratio 2:1 <u>from</u> a compound/ molecule/alcohol

(do not credit 'from a 'substance')

(do not credit 'removal of water molecules' unless qualified from a compound/molecule etc.)

1

M2: Catalyst = concentrated H_2SO_4 or concentrated/oily/syrupy phosphoric acid or aluminium oxide/ pumice/porous pot

1

M3: $CH_3CH_2OH \rightarrow H_2C{=}CH_2 + H_2O$

(credit use of C_2H_5OH)

(penalise use of C_2H_6O here unless already penalised in part(a).

Possible credit as repeat error)

(credit C_2H_4 and $CH_2{=}CH_2$ for ethene, but penalise CH_2CH_2, CH_2. CH_2, CH_2:CH_2)

(ignore H_2SO_4 if it appears on <u>both sides</u> of equation)

1

(c) **M1**: large(r) to small(er) molecules/hydrocarbons/compounds or high(er) M_r alkanes to low(er) M_r alkanes (+ alkenes) (+ H_2)

1

M2: breakage/homolysis/splitting of C–C/carbon chain/carbon skeleton

(do not credit breaking C–H bonds alone, but ignore if accompanied by C–C)

1

M3: reactive intermediate is (free/alkyl) radical or radical mechanism

(do not credit 'free radical substitution' and penalise M3 as a contradiction if mentioned with free radical intermediates)

1

M4: any T (or range) in the range 400 to 900°C or high temperature

(ignore 'pressure')

1

M5: $CH_3CH_2CH_2CH_3$ (OR C_4H_{10}) → $H_2C{=}CH_2$ + CH_3CH_3 (OR C_2H_6) or $CH_3CH_2CH_2CH_3$ (OR C_4H_{10}) → $2H_2C{=}CH_2$ + H_2

(credit C_2H_4 and $CH_2{=}CH_2$ for ethene, but penalise CH_2CH_2, $CH_2{:}CH_2$, $CH_2{:}CH_2$ and note possible RE from part(b))

1

[15]

M8. (a) Ag or silver or silver-based or silver on an alumina base

(penalise specific silver compounds)

1

epoxyethane

1

(b) electrophilic addition

1

M1: curly arrow <u>from C=C</u> bond towards/alongside the side of H atom on H-OSO_2OH

(penalise M1 if arrow to H_2SO_4 OR to formal charge on H of H-O bond)

(ignore partial charges on H and O of H_2SO_4, but penalise if these are incorrect on the H atom being attacked)

(credit M1 and M2 if correct curly arrow to H+ provided the anion is present)

1

M2: curly arrow from <u>H–O bond</u> towards/alongside the side of the O atom on H–OSO_2OH

(credit the arrow even if there are partial or formal charges on H and O but the structure of H_2SO_4 is correct)

1

M3: correct structure of the carbocation

(penalise use of 'sticks' in this structure)

1

M4: curly arrow from lone pair on an individual oxygen atom of (correct formula for) hydrogensulphate ion towards/alongside C atom bearing the positive charge

(insist that the an ion has the correct formula with a lone pair of electrons and a negative charge)

1

(c) (i) ethanal

1

correct structure for ethanal

(aldehyde functional group must be drawn out)

1

(ii) oxidation or redox

1

[10]

M9. (a) (i) M1 pentan-3-one only

1

M2 $CH_3CH_2CH_2COCH_3$

(insist on C=O being drawn out)

(penalise use of C_3H_7)

1

(ii) *aldehyde* $(CH_3)_2CHCH_2\underline{CHO}$

1

ketone $(CH_3)_2CH\underline{CO}CH_3$

1

(insist on a clear structure for the C=O of the functional groups, but do not be too harsh on the vertical bonds between carbon atom son this occasion)

(If both structures correct, but wrong way around, award one mark)

(ignore names)

(b) (i) $CH_3CH_2CH_2CH_2\underline{CHO} + [O] \rightarrow CH_3CH_2CH_2CH_2\underline{COOH}$

(accept C_4H_9CHO going to C_4H_9COOH)

(insist on a balanced equation – for example do not credit [O] over the arrow alone)

1

(ii) pentanoic acid

(credit pentan–1–oic acid)

1

(c) (i) $CH_3CH_2CH_2CH_2CH_2OH$ OR pentan–1–ol

(If both a structure and a formula are given, credit either correct one of these provided the other is a good, if imperfect, attempt)

1

(ii) Primary

(credit 1° or 1)

1

[8]

M10. (a) hydration OR (electrophilic) addition

(penalise incorrect words in front of the word "addition" e.g. "nucleophilic")

(penalise "indirect hydration" but credit "direct hydration" or "steam hydration")

1

$H_2C{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$

(ignore state symbols)
(credit use of C_2H_5OH for ethanol)
(penalise use of C_2H_6O for ethanol on the first occasion)
(credit C_2H_4 and $CH_2{=}CH_2$ for ethene)
(penalise CH_2CH_2, $CH_2.CH_2$, $CH_2{:}CH_2$ for ethene on the first occasion)
(ignore H_2SO_4 OR extra H_2O OR H^+ if it appears on both sides)

1

<u>conc.</u> H_2SO_4 OR <u>conc.</u> H_3PO_4

1

(b) (i) Carbon OR C

(credit "soot" or "sooty")
(penalise "coke" or "coal")
(credit "carbon + carbon monoxide" provided it is clear that carbon is solid; penalise "carbon + carbon dioxide")

1

(ii) $CH_3CH_2OH + O_2 \rightarrow 2C + 3H_2O$
OR
$CH_3CH_2OH + 1½O_2 \rightarrow C + CO + 3H_2O$

(credit multiples of these equations)
(credit use of C_2H_5OH for ethanol)
(penalise use of C_2H_6O for ethanol, but note a possible repeat error from part (a) above)

1

[5]

M11. (a) Allow 1 mark each for any correctly drawn primary, secondary and tertiary alcohol of molecular formula C_4H_8O

3

Tertiary alcohol cannot be oxidised

1

(b) Region 1500–400 cm^{-1}

1

exact match to spectrum of known compound

1

(c) **A**

$CH_3CH_2CH_2OH$

or $CH_3CH(OH)CH_3$ **(1)**

B

$CH_3CH_2–O–CH_3$ **(1)**

C

one alkene e.g.

$CH_2=CHCH_2CH_2CH_3$

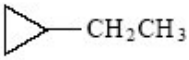
$CH_3–CH=CH–CH_2CH_3$

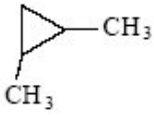
$(CH_3)_2C=CHCH_3$

$H_2C=C(CH_3)CH_2CH_3$

D

one cycloalkane e.g.

(1) 



(1)

etc

E

CH_3CH_2CHO **(1)**

F

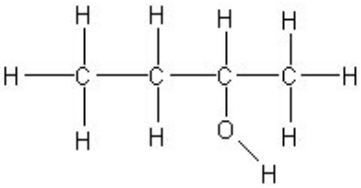
CH_3COCH_3 **(1)**

6

[12]

M12. (a) **M1**

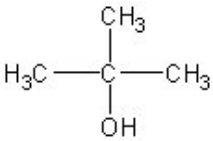
Displayed formula for butan-2-ol



M1 displayed formula must have all bonds drawn out, including the O—H but ignore angles

Penalise "sticks"

M2 Alcohol **X** is



M2 structure must be clearly identifiable as 2-methylpropan-2-ol and may be drawn in a variety of ways.

M3 Alcohol **Y** is named (2)-methylpropan-1-ol ONLY

M3 must be correct name, but ignore structures

3

(b) **M1** The infrared spectrum shows an absorption/peak in the range 3230 to 3550 (cm^{-1})(which supports the idea that an alcohol is present)

In M1, allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption.

M2 Reference to the 'fingerprint region' or below 1500 (cm^{-1})

M3 Match with or same as known sample/database spectra

Check the spectrum to see if alcohol OH is labelled and credit.

OR

M2 Run infrared spectra (of the alcohols)

M3 Find which one matches or is the same as this spectrum.

3

(c) **M1** balanced equation

$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2CH_2OH + \mathbf{2}CO_2 + H_2O$

or C_4H_9OH

Or multiples for M1 and M3

In M1 and M3 penalise use of $C_4H_{10}O$ or butan-2-ol once only

M2 Any one from

- excess/adequate/sufficient/correct amount of/enough/plenty/ a good supply of oxygen or air
- good mixing of the fuel and air/oxygen

For M2, do not accept simply "oxygen" or "air" alone

Ignore reference to "temperature"

M3 $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \rightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$

or C_4H_9OH

M4 A biofuel is a fuel produced from (renewable) biological (re)source(s)

OR

(renewable) (re)source(s) from (a specified) plant(s)/fruit(s)/tree(s)

In M4

Ignore references to "carbon neutral"

Ignore "sugar" and "glucose"

4

(d) **M1** butan-1-ol is a primary or 1° (alcohol)

M2 Displayed formula (ONLY) for butanal $CH_3CH_2CH_2CHO$

M3 Displayed formula (ONLY) for butanoic acid $CH_3CH_2CH_2COOH$

M2 and M3 displayed formula must have all bonds drawn out including the O—H but ignore angles.

If butanal and butanoic acid formulae are both correctly given but not displayed, credit one mark out of two.

M4 Oxidation (oxidised) OR Redox

M5 orange to green

Both colours required for M5
Ignore states

5

[15]

M13. (a) Functional group (isomerism)

1

(b)

M1 Tollens' (reagent)
(*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens'*)
(*Ignore either* $AgNO_3$ *or* $[Ag(NH_3)_2^+]$ *or "the silver mirror test" on their own, but mark M2 and M3*)

M2 silver mirror

OR

black solid/precipitate
(NOT silver precipitate)

M3 (stays) colourless
or no change or no reaction

M1 Fehling's (solution) or Benedict's solution
(*Ignore* $Cu^{2+}(aq)$ *or* $CuSO_4$ *on their own, but mark on to M2 and M3*)

M2 Red solid/precipitate
(*Credit orange or brown solid*)

M3 (stays) blue
or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct reagent, penalising M1

No reagent, CE=0

Allow the following alternatives
M1 *(acidified) potassium dichromate(VI) (solution)*
M2 *(turns) green*
M3 *(stays) orange/no change*
OR
M1 *(acidified) potassium manganate(VII) (solution)*
M2 *(turns) colourless*
M3 *(stays) purple/no change*

For M3
Ignore "nothing (happens)"
Ignore "no observation"

3

(c) (Both have) C=O ***OR*** a carbonyl (group)

1

(d) (i) (Free-) radical substitution ONLY

Penalise "(free) radical mechanism"

1

(ii) **Initiation**

$Cl_2 \rightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation

$Cl\bullet + CH_3CH_2CH_3 \rightarrow \bullet CH_2CH_2CH_3 + HCl$

OR C_3H_8

Penalise incorrect position of dot on propyl radical once only.

Penalise $C_3H_7\bullet$ once only

Second propagation

$Cl_2 + \bullet CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2Cl + Cl\bullet$

OR

C_3H_7Cl

Accept $CH_3CH_2CH_2\bullet$ with the radical dot above/below/to the side of the last carbon.

Termination (must make C_6H_{14})

$2\ \bullet CH_2CH_2CH_3 \rightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$

Use of the secondary free radical might gain 3 of the four marks

4

(e) M_r = 44.06352 (for propane)

M_r = 43.98982 (for carbon dioxide)

Mark independently

M1 a correct value for both of these M_r values.

M2 a statement or idea that two peaks appear (in the mass spectrum)

OR

two molecular ions are seen (in the mass spectrum).

2

[12]

M14. (a) to neutralise stomach acidity

OR

as an antacid

OR

eases indigestion/heartburn

Ignore milk of magnesia
Credit suitable reference to indigestion/laxative/relief of constipation

1

(b) (i) an electron acceptor

OR

(readily) gains/accepts/receives electron(s)

NOT an electron pair acceptor
Ignore removes/takes away/attracts electrons

1

(ii) Br_2 ONLY

Ignore "bromine"
Apply the list principle

1

(iii) $H_2SO_4 + \mathbf{2}H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

OR

$SO_4^{2-} + 4H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

Ignore state symbols
Ignore absence of negative charge on electron
Or multiples of equations

1

(c) (i) (acid) catalyst

OR

catalyses (the reaction)

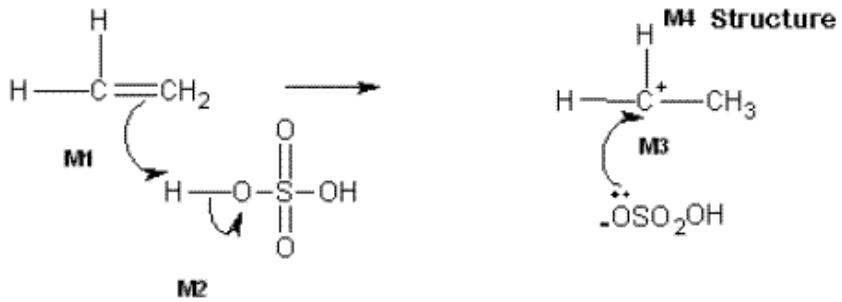
OR

to speed up the reaction/increase the rate (of reaction)

Ignore "provides H^+ ions"
Accept phonetic spelling

1

(ii)



M1 must 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 (or accept H_2SO_3 here)

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 or H_2SO_3

M2 must show the breaking of the O — H bond.

M3 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom.

M4 is for the structure of the carbocation.

NB The arrows here are double-headed

M2 Ignore partial charges unless wrong

M3 NOT HSO_4^-

For M3, 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

Max 3 marks for wrong reactant

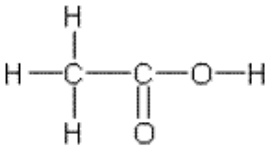
Do not penalise the use of "sticks"

4

(iii) Primary ***OR*** 1° (alcohol)

1

(iv) Displayed formula for ethanoic acid, CH_3COOH



All the bonds must be drawn out and this includes the O — H bond

Ignore bond angles.

1

[11]

M15. (a) (i) Hexan-1-ol1

ONLY

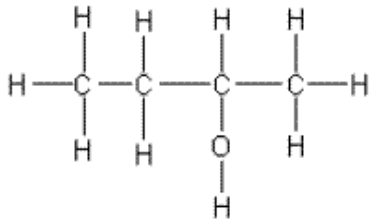
1

(ii) Homologous (series)

ONLY

1

(iii) <u>Displayed formula</u> for butan-2-ol



<u>All bonds</u> must be drawn out including the O–H bond

Ignore bond angles

1

(iv) $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$

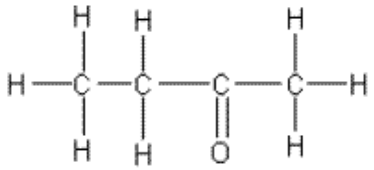
Require this whole equation <u>as written or formulae drawn out</u>

Penalise "sticks"

1

(v) <u>Displayed formula</u> for butanone

(credit possible enols, ethers and cyclic structures for C_4H_8O)



<u>All bonds</u> must be drawn out

Ignore bond angles

1

(b) **M1** q = m c ΔT OR calculation 175 × 4.18 × 8

M2 = **5852** (J) OR 5.85 (kJ) OR 5.9 (kJ) (This also scores M1)

M3 0.005 mol, therefore ΔH = **–1170** (kJ mol^{-1})

OR ΔH = **–1170.4** (kJ mol^{-1})

OR ΔH = **–1200** (kJ mol^{-1})

Award full marks for correct answer

In M1, do not penalise incorrect cases in the formula

Ignore incorrect units in M2

Penalise M3 ONLY if correct answer but sign is incorrect OR value is in J mol^{-1}

If m = 5 × 10^{-3} OR if ΔT = 281, CE and only allow one mark for correct mathematical formula for M1

If c = 4.81 (leads to 6734) penalise M2 ONLY and mark on for M3 = –1350 (–1347)

3

(c) (i) **M1** The enthalpy change (or heat change at constant pressure) when 1 mol of a compound/substance/alcohol

M2 is burned completely in oxygen

OR burned in excess oxygen

M3 with all reactants and products/all substances in standard states

OR

all reactants and products/all substances in normal states under standard conditions OR 100 kPa/1 bar and a specified T/298 K

For M3

Ignore reference to 1 atmosphere

3

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

M1 $\Delta H = \Sigma\Delta H_f$ (**products**) – .$\Sigma\Delta H_f$ (**reactants**)

OR a correct cycle of balanced equations

M2 = 4(–394) + 5(–286) – (–327)

(This also scores M1)

M3 = **– 2679** (kJ mol^{-1}) OR **–2680** (kJ mol^{-1})

Award 1 mark ONLY for (+) 2679 OR (+) 2680

Correct answer to calculation gains full credit

Credit 1 mark if + 2679 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2)*
- *If no AE, check for correct method; this requires either a correct cycle with 4CO_2 and 5H_2O OR a clear statement of M1 which could be in words and scores only M1*

3

(d) (i) **M1 This is about the change in formula up the series**

Each alcohol in the series (compared with the previous one)

increases by/has an extra CH_2

OR

has one more C-C and two more C-H

M2 This is about the reaction and bond breaking/making

Combustion of each alcohol in the series breaks one

more C-C and two more C-H compared with the previous one AND forms one more mol CO_2 and one more mol H_2O

OR

A statement in which there is the idea that the extra OR additional OR difference in number of bonds broken and formed (as the series increases) is the same OR has the same difference in energy

N.B. If the first statement here for M2 is given, both marks score

2

(ii) **For the two marks M1 and M2**

heat loss or heat absorbed by the apparatus

OR

incomplete combustion/not completely burned

OR

The idea that the water may end up in the gaseous state (rather than liquid) OR reactants and/or products may not be in standard states.

2

[18]

M16. (a) **M1** $AgNO_3$ OR silver nitrate OR any soluble silver salt

M2 remains colourless or no reaction or no (observed) change or no precipitate

M3 white precipitate or white solid/white suspension

An insoluble silver salt OR Tollens' OR ammoniacal silver nitrate or HCl/$AgNO_3$ is CE = 0 for the clip

For M1

Credit acidified (or HNO_3) silver nitrate for M1 and mark on

If silver ions or incorrect formula for silver nitrate, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M2

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For M3

Ignore "cloudy solution" OR "suspension"

3

(b) **M1** any soluble sulfate by name or formula e.g. sodium sulfate or sulfuric acid.

M2 white precipitate or white solid/white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate

OR as an alternative

M1 NaOH/KOH

M2 remains colourless or no reaction or no (observed) change

M3 white precipitate or white solid/white suspension

An insoluble sulfate OR conc H_2SO_4 is CE = 0 for the clip

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For the M1 soluble sulfate

If sulfate ions or incorrect formula for the chosen sulfate, penalise M1 but mark M2 and M3

For the M1 NaOH/KOH

If ammonia, then CE = 0

If hydroxide ions or incorrect formula for the chosen hydroxide, penalise M1 but mark M2 and M3

For no (observed) change in both alternatives

Ignore "nothing"

Ignore "no observation"

Ignore "clear"

Ignore "dissolves"

For the white precipitate in both alternatives

Ignore "cloudy solution" OR "suspension"

3

(c) **M1** ammonia (can be dilute or concentrated)

M2 dissolves OR soluble OR (forms a) colourless solution OR goes colourless

M3 does not dissolve OR not soluble OR remains as a solid OR no (observed) change OR no reaction OR yellow solid remains

OR if concentrated ammonia has been used, accept yellow solid turns white.

OR as an alternative using conc sulfuric acid

M1 concentrated sulfuric acid OR c(onc) H_2SO_4

M2 misty/white fumes/gas

OR remains white

OR no change (in colour)

M3 turns black (solid)

OR purple fumes/gas

OR correct reference to H_2S observation (e.g. bad egg smell)

For M1

If incorrect formula or "ammonium", penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M3

Ignore "nothing"

Ignore "no observation"

For the alternative using sulfuric acid

If dilute sulfuric acid or "aq" (alone) or the idea of concentrated not included CE = 0

If incorrect formula, penalise M1 but mark M2 and M3

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

3

(d) **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) <u>green</u> solution OR goes <u>green</u>

M3 (solution) remains <u>orange</u> or no reaction or no (observed) change

Alternative using $KMnO_4/H_2SO_4$

M1 acidified potassium manganate(VII) 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

If no reagent or incorrect reagent in M1, then no marks for M2 or M3

For M1

If "dichromate" or "dichromate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

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

For M3

Ignore "nothing"

Ignore "no observation"

For M1

If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

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

3

[12]

M17. (a) Pentan-2-one

ONLY but ignore absence of hyphens

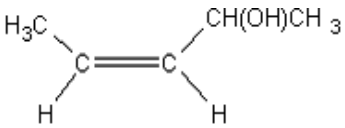
1

(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]

M18. (a) **For 2 marks at least <u>one correct reference either to M_r</u> or <u>value to 5 decimal places required</u>**

QoL *(associated with the bold statement here)*

M1 Compounds <u>1 and 3</u> (butanal and butanone) have the same M_r (to 5dp) <u>because</u> **either**

It may be possible to award 2 marks if there is a clear statement about oxygen having a different precise A_r in the context of the comparison

- they contain the <u>same</u> number of atoms of the same / each element
- are <u>both</u> C_4H_8O
- have the <u>same molecular formula</u>
  NB The word "similar" does not mean "the same"
- contain the same number of C, H and O atoms

M2 Compound <u>2</u> (pentane) has a different M_r (to 5dp) <u>because</u> **either**

- it has <u>different</u> numbers of atoms of different elements
- is C_5H_{12} / <u>only contains</u> C and H
- <u>different molecular formula</u>
- does not contain oxygen (atom) / C=O

2

(b) **WithTollens' (reagent)**

M1 silver mirror

OR black solid/precipitate

(NOT silver (mirror) precipitate)

M2 (stays) colourless

OR no change / no reaction

OR no silver mirror

With Fehling's (solution)

M1 Red solid/precipitate

(Credit orange or brown solid)

M2 (stays) blue

OR no change / no reaction

OR no red solid

OR no (red) precipitate

N.B No mark is awarded for the reagent

If no reagent given allow 1 mark for a consistent statement of M1 and M2

For M2, ignore "nothing (happens)"

And ignore "no observation"

2

[4]

M19. (a) **M1 Safety (in Process 1)**

Sodium hydroxide / alkali is corrosive / harmful / caustic or sodium hydroxide is alkali(ne)

Ignore references to chromium compounds

OR

Bromine compounds are toxic / poisonous

*"Carbon-neutral" alone is insufficient for **M2***

M2 Environmental

Ignore references to greenhouse gases

Process 2 could be used as a carbon sink / for carbon capture

OR

uses waste / recycled CO_2 / CO_2 from the factory / CO_2 from the bioethanol (or biofuel) production

OR

reduces or limits the amount of CO_2 released / given out (into the atmosphere)

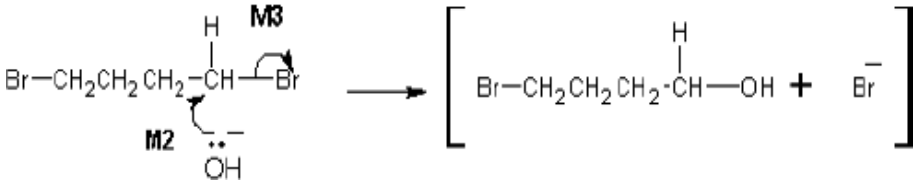
OR

Process 2 uses renewable glucose / renewable resource(s)

2

(b) (i) M1 nucleophilic substitution

*For **M1, both words** required*



M2 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 **M2** if covalent NaOH / KOH is used*

*Penalise one mark from **M2** or **M3** if half-headed arrows are used*

M3 must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from the original molecule

*Penalise **M3** 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 **M2** and **M3** award full marks for an S_N1 mechanism

*For **M2** and **M3**, maximum 1 of 2 marks for the mechanism if wrong reactant is used.*

*Penalise **M3** if an extra arrow is drawn from the Br of the C–Br bond to, for example, K^+*

Accept the correct use of "sticks

NB The arrows here are double-headed

3

(ii) **M1** B

M2 C

M3 A

3

(c) **M1** fermentation

*Mark **M2** to **M4** independently*

Three conditions in any order for M2 to M4

Penalise "bacteria" and "phosphoric acid" using the list principle

M2 (enzymes from) yeast or zymase

M3 25°C ≤ T ≤ 42°C OR 298 K ≤ T ≤ 315 K

Ignore reference to "aqueous" or "water", "closed container", "pressure, "lack of oxygen",

"concentration of ethanol" and "batch process" (i.e. not part of the list principle)

M4 anaerobic / no oxygen / no air OR neutral pH

4

(d) **M1** primary OR 1° (alcohol)

Mark independently

M2 <u>acidified potassium or sodium dichromate</u>

*For **M2**, it must be a whole reagent and/or correct formulae*

OR H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$

Do not penalise incorrect attempt at formula if name is correct or vice versa

Accept phonetic spelling

If oxidation state given in name, it must be correct.

*For **M2** accept acidified potassium manganate(VII)*

OR correct combination of formula and name

M3

$HOCH_2CH_2CH_2CH_2OH + \mathbf{4}[O] \longrightarrow HOOCCH_2CH_2COOH + \mathbf{2}H_2O$

*For **M3** structures must be correct and not molecular formula*

3

[15]

M20. (a) (i) CH_2O

Atoms in any order

Accept a clear indication that $C_6H_{12}O_6$ yields CH_2O as the answer

1

(ii) No peak / no absorption / no C=O in the **<u>range 1680 to 1750</u>** (cm^{-1}) (suggesting no evidence of C=O)

Allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption

Ignore references to other wavenumbers

1

(b) M1 $C_6H_{12}O_6 \longrightarrow \mathbf{2}CH_3CH_2OH + \mathbf{2}CO_2$

Penalise (C_2H_6O)

*Allow multiples of the equation in **M1***

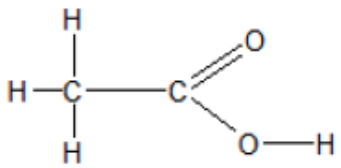
Either order
M2 (enzymes from) yeast or zymase

M3 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K

*For **M2** and **M3***
Ignore "aqueous"
Ignore "anaerobic / absence of oxygen"
Ignore "controlled pH"
Ignore "warm"

3

(c) (i) Displayed formula for CH_3COOH



All bonds must be drawn out, but ignore bond angles

1

(ii) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

Ignore state symbols
Negative charge on electron not essential
Accept multiples
Accept electrons subtracted from RHS

1

(iii) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

(C_2H_6O or C_2H_5OH)

Ignore state symbols
Negative charge on electron not essential
Accept multiples
Accept electrons subtracted from LHS

1

(iv) M1 Acidified potassium or sodium dichromate

*For **M1**, it must be a whole reagent and / or correct formulae*

OR H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$ etc.

Do not penalise incorrect attempt at formula if name is correct or vice versa

OR correct combination of formula and name

If oxidation state given in name, it must be correct, but mark on from an incorrect attempt at a correct reagent.

M2 (requires an attempt at M1)
orange to green

*Credit **acidified** potassium chromate(VI) / H_2SO_4 + K_2CrO_4*

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

M2 purple to colourless

*Other alternatives will be accepted but **M2** is dependent on **M1** in every case*
M2** requires an attempt at a correct reagent for **M1
Ignore reference to states

2

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere / air

The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere / air

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air.

Answer must refer to the atmosphere or air

OR

There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere / air

1

(ii) Renewable / sustainable ONLY

Ignore references to global warming or greenhouse gases

1

(iii) **Any one statement about this process from**

Subject to weather / climate

Ignore "batch"

OR

Depletes food supply OR the land use for (specified) food

OR

Requires use of / uses more fossil fuels

OR

Not carbon-neutral OR CO_2 produced during a named process (eg harvest, transport etc.)

OR

Slow process / slow rate of reaction / takes a long time (to grow crops)

OR

This route leads to the production of a mixture of water and ethanol / impure ethanol that requires separation / further processing

1

[13]

M21. (a) Structure for 3-methylbut-1-ene

$H_2C{=}CHCH(CH_3)_2$

Any correct structural representation.

Credit "sticks" and require the double bond.

1

(b) Structure for 2-methylpropan-2-ol

$(CH_3)_3COH$

Any correct structural representation.
Credit "sticks".

1

(c) Structure for propene

$H_2C{=}CHCH_3$

Any correct structural representation.
Credit "sticks" and require the double bond.

1

(d) Structure for 2-aminobutane

$CH_3CH_2CH(NH_2)CH_3$

Any correct structural representation.
Credit "sticks".

1

[4]