1

(a) 2,2,4-trimethylpentane

This answer only but ignore punctuation

1

(b) M1 (fractional or simple) distillation

Incorrect process in M1 CE=0

If M1 blank, mark on for M2 and M3 (ignore boiling, condensing)

1

M2 idea that isooctane / the one with the lower boiling point boils (first) (or reaches top of column first)

Ignore reference to octane boiling and being collected at higher temperature

If temperature referred to, should be between 99 and 124°C

"it" refers to isooctane

M2 – allow vaporises/evaporates first

1

M3 idea that isooctane condenses / liquefies and collected

Penalise M2 and M3 if octane boils first

In M2 and M3 – if no specific reference to individual alkanes, could score one mark for M2 + M3 combined if M2 and M3 both otherwise correct

M2 and M3 must refer to a laboratory apparatus (not to an industrial process)

1

(c) $C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$

Accept multiples; ignore state symbols

Accept any correct structural representation of isooctane

1

(d) M1 Alternative route/mechanism/pathway

1

M2 With lower activation energy

Accept E_a for activation energy

1

(e) $2CO + 2NO \longrightarrow 2CO_2 + N_2$

Accept multiples; ignore state symbols

1

(f) M1 to reduce amount of metals needed / small amount of metal needed

Relates to low amount of metal

1

M2 Increase / maximise / produce large surface area or to give catalyst a larger surface area: volume ratio or so that high(er) proportion of atoms/metal is on surface

Is related to large surface area

1

(g) M1 bromine (water or in organic solvent or CCl_4) / Br_2 (aq) / Br_2

No reagent or an incorrect reagent (e.g. bromide), CE=0;

Penalise Br (or incorrect formula of other correct reagent) but mark on for M2

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

Ignore 'acidified'

1

M2 (orange/yellow to) colourless / decolourised / loses its colour

Ignore goes clear

Ignore brown/red, but penalise other incorrect colours

1

Alternatives:

M1 = potassium manganate(VII), M2 = colourless

M1 = <u>conc</u> sulfuric acid, M2 = brown

M1 = iodine, M2 = colourless

[12]

2

(a) M1 have the same molecular formula
or are C_3H_6O
or both have the same number/amount of each type of atom or same amount of each element
or are isomers

Not just the same atoms;

1

M2 <u>identical / exactly the same / same precise</u> (relative) molecular mass / formula mass / M_r

Same (relative) molecular mass / formula mass / M_r is NOT enough got score M2

Allow <u>same accurate</u> (relative) molecular mass / formula mass / M_r

Ignore reference to number of decimal places

1

(b) M1 prop-2-en-1-ol

Must refer to this compound clearly by name or structure (not to alcohol alone); ignore minor slips in name/structure

1

M2 O(-)H (alcohol) and 3230–3550 (cm^{-1}), or
C=C and 1620–1680 (cm^{-1})

Marked independently from M1

Could score from bond labelled on correct signal on spectrum

Allow any value within these ranges

If additional incorrect signals given penalise M2

Ignore signals below 1500 cm^{-1} and C-H signals

1

(c) (i) Determine the level by looking at the chemical content. (**NB** - If there is clear breakage of covalent bonds then max level 2 (max 3 marks).

(ii) The mark within that level is then determined by looking at how coherent and logical the answer is and by use of terminology; start at the higher mark and penalise poor terminology/explanation; examples of terminology that would reduce the mark to the lower one:

- reference to van der Waals 'bonds' or dipole-dipole 'bonds in relevant compounds that are being credited
- uncertainty about whether hydrogen bonds are the O-H bonds within or are forces/bonds between molecules (if the alcohol is being credited)
- use of 'vdw' or 'dip-dip' unless these terms 'van der Waals' for 'dipole-dipole' have been used elsewhere in answer (note that IMF and H-bond would not be penalised)

(iii) If the answer does not achieve level 1, then 1 mark maximum could be scored for any correct point from the list of indicative content

Level 3

- **Relative order** of boiling points of **all three** compounds
- Strongest intermolecular force of **all three** compounds identified
- Answer explains this coherently and logically and uses correct terminology for all **three** compounds

5-6 marks

Level 2

- **Relative** boiling points of **two** compounds correctly compared
- Strongest intermolecular force for these **two** compounds correctly identified
- Answer explains this coherently and logically and uses correct terminology for **these two** compounds

3-4 marks

Level 1

- **One** compound with the **highest** or **lowest** boiling point is correctly identified
- Strongest intermolecular force for that **one** compound identified
- Answer explains this coherently and logically and uses correct terminology for **this one** compound
- Allow 1 mark for individual correct point from indicative content on the right if no other mark scored

1-2 marks

Level 0

None of the indicative chemistry content given.

0 marks

Indicative chemistry content:

• Correct order (highest to lowest) = prop-2-en-1-ol > propanal > butane

• Prop-2-en-1-ol has hydrogen bonds

• Propanal has (permanent) dipole-dipole forces

• Butane has van der Waals' forces

• Strength of intermolecular forces:
hydrogen bonds > dipole-dipole > van der Waals

(Note - actual values for reference are prop-2-en-1-ol 97°C, propanal 46°C and butane −1°C)

[10]

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

1

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

1

M1 and M2 could be in either order

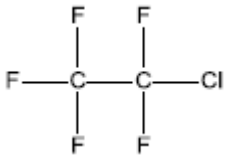
Credit the dot anywhere on the radical

Penalise absence of dot once only

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

Ignore state symbols

(b)



Must be displayed formula

1

(c) Does not contain Cl or does not release Cl (atoms/radicals)
or no C-Cl bonds
or C-F bond(s) strong / does not break / no F (atom/radicals) released

1

(d) M1 $CHF_2CH_3 + \bullet F \longrightarrow \bullet CF_2CH_3 + HF$

1

M2 $\bullet CF_2CH_3 + F_2 \longrightarrow CF_3CH_3 + \bullet F$

1

M1 and M2 could be in either order

Credit the dot anywhere on the radical

Penalise absence of dot once only

(e) M1 moles CF_3CH_3 = 1410/84(.0) (=16.8, 16.79 mol)

1

M2 molecules = M1 × 6.022 × 10^{23} = 1.01 × 10^{25} (3sf only)

1

Correct answer scores both marks

Allow M2 for M1 × Avogadro with answer to 3 sf (but must have attempted to calculate moles for M1)

Ignore incorrect units

(f) (bonds) vibrate/stretch/bend OR (as bonds) are polar

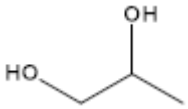
NOT polar molecules; 'they' = bonds

1

[9]

4

(a)



Any correct skeletal formula (both OH groups must be shown)

1

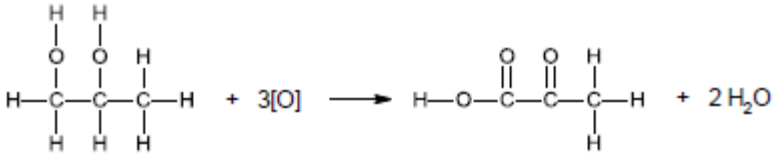
(b) M1 Displayed formula of correct product

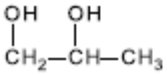
Incorrect organic product CE=0

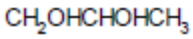
Must be displayed formula but can be shown separately or in the equation

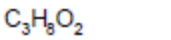
1

M2 Balanced equation









Allow any correct structural formula (or molecular formula $C_3H_4O_3$) for product in balanced equation

Allow any correct formula of propane-1,2-diol (including its molecular formula $C_3H_8O_2$)

1

(c) M1 flask with condenser vertically above it (without gaps between flask and condenser)

Distillation diagram CE = 0

Condenser must have outer tube for water that is sealed at top and bottom; condenser must have two openings for water in/out (that are open, although these openings do not need to be labelled)

Penalise M1 if apparatus is sealed (a continuous line across the top and/or bottom of the condenser is penalised)

1

M2 flask and condenser labelled

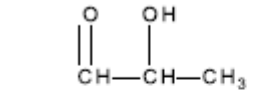
Allow condensing tube for condenser label

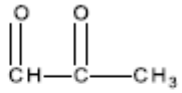
1

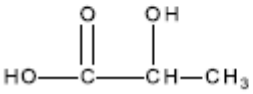
(d) Form small(er) bubbles or prevent large bubbles

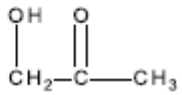
1

(e) Any one of these four structures:









Allow any correct structural / displayed / skeletal formula

For reference:

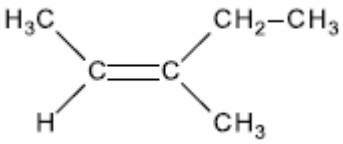
Carbon 1	Carbon 2
aldehyde	alcohol
carboxylic acid	alcohol
aldehyde	ketone
alcohol	ketone

1

[7]

5

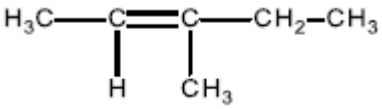
(a)



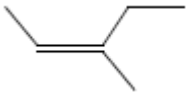
Must show all 4 groups bonded to C=C

Allow CH_3- for methyl group; allow C_2H_5 for ethyl group

Allow correct structure of the style

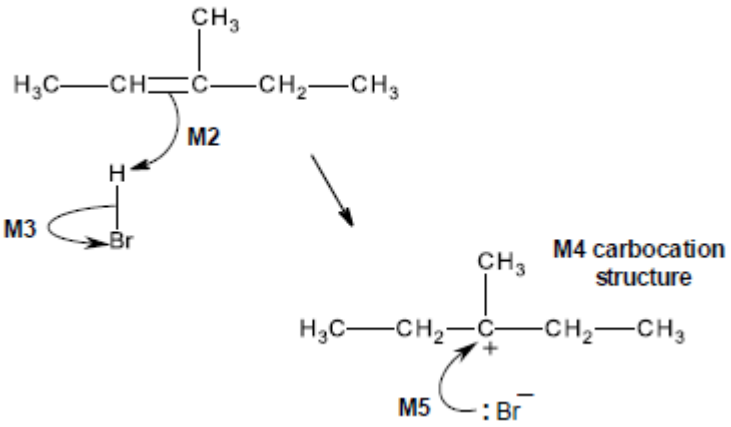


Allow correct skeletal structure



1

(b) M1 electrophilic addition



NB the arrows here are double-headed

1

M2 must show an arrow from the double bond towards the H atom of the H-Br molecule

1

M3 must show the breaking of the H-Br bond

1

M4 is for the structure of the tertiary carbocation

1

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged atom (of either a secondary or) of a tertiary carbocation

1

M6 3-bromo-3-methylpentane is formed from 3^{y} carbocation
OR
2-bromo-3-methylpentane is formed from 2^{y} carbocation

1

M7 3^{y} carbocation more stable than 2^{y}

1

M2-M5 *Penalise one mark from their total if half-headed arrows are used*

M2 *Ignore partial negative charge on the double bond*

M3 *Penalise incorrect partial charges on H-Br bond and penalise formal charges*

*Penalise **M4** if there is a bond drawn to the positive charge*

Penalise only once in any part of the mechanism for a line and two dots to show a bond

Max 3 of any 4 marks (M2-5) *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"

*For **M5**, credit attack on a partially positively charged carbocation structure but penalise **M4***

M6 is high demand and must refer to product being formed from/via correct class of carbocation

M7 is high demand and must be clear answer refers to stability of carbocations (intermediates) not products

Candidate that states that products are carbocations would lose M6 and M7

***M6,7** allow carbonium ion in place of carbocation; or a description of carbocation in terms of alkyl groups/ number of carbon atoms joined to a positive C*

*When asked to outline a mechanism, candidates are **expected** to draw a mechanism with curly arrows (specification 3.3.1.2). On this occasion only we would allow a detailed description as shown.*

***M2** must describe the movement of a pair of electrons / curly arrow from the C=C towards the H atom of the H-Br molecule*

***M3** must describe the breaking of the H-Br bond with the bonding pair of electrons moving to the Br / curly arrow from H-Br bond to Br*

***M4** is for the structure of the tertiary carbocation (i.e. positive C bonded to one methyl and two ethyl groups)*

***M5** must describe the movement of a pair of electrons from the Br^- ion to the positive C atom of the carbocation / curly arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged C atom (of either a secondary or) of a tertiary carbocation*

[8]

6 C **[1]**

7 D **[1]**

8 D **[1]**

9 A **[1]**

10 B **[1]**

11 B **[1]**

12 D **[1]**

13 A **[1]**

14 B

[1]

15 (a) (i) Alk**a**ne(s)

Ignore C_nH_{2n+2}

1

(ii) $C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O$

Allow multiples

1

(iii) 2, 2, 4-trimethylpentane

1

(b) (i) But-1-ene

Ignore (E or Z)

1

(ii) $C_{14}H_{30}$

1

(iii) Thermal

If catalytic CE = 0

1

High pressure / 7000kPa / 70 atms
and
High temperature/temperature in range 400-1000°C (673–1273K)

(Allow ≥1000 kPa or ≥10 atms – no upper value)

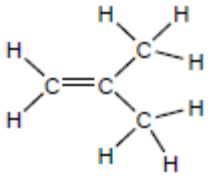
Allow high temperature and pressure or high pressure and temperature

If no units for temperature allow 673-1000

Must show unambiguous structure

Penalise lack of displayed formula once only

1

(iv) 

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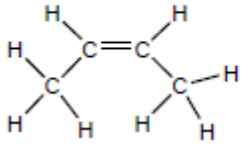

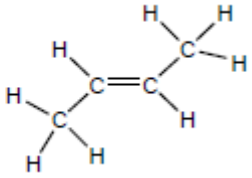

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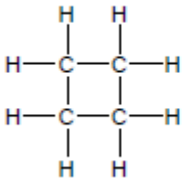
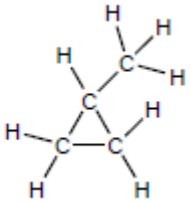




1

[10]

16 (a) (i) $CH_3Cl + 2Cl_2 \longrightarrow CHCl_3 + 2HCl$

IGNORE *state symbols*

ALLOW *multiples*

1

(ii) (Free-)radical substitution

This answer only

1

(iii) Initiation:

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only

1

1st Propagation step

$Cl\bullet + CH_2Cl_2 \longrightarrow \bullet CHCl_2 + HCl$

Penalise + and/or – charges every time

1

2nd Propagation step

$\bullet CHCl_2 + Cl_2 \longrightarrow CHCl_3 + Cl\bullet$

ALLOW *• anywhere on* $\bullet CHCl_2$ *but, if drawn out as a structure, then • must be on C*

1

Termination

$2 \bullet CHCl_2 \longrightarrow C_2H_2Cl_4$

Mark independently

ALLOW $\bullet CH_2Cl + \bullet CCl_3 \longrightarrow C_2H_2Cl_4$

IGNORE *state symbols throughout*

1

(b) (i) $CClF_3 \longrightarrow \bullet CF_3 + Cl\bullet$

ALLOW *• anywhere on* $\bullet CF_3$ *unless displayed*

1

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

Equations can be in either order

Penalise absence of • once only

1

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

ALLOW *• anywhere on •ClO*

NOT $\bullet O_3$

1

[9]

17 (a) <u>OH</u> AND <u>alcohol</u>

IGNORE *hydroxy(l)*

1

(b) **A** = butan-2-ol / $CH_3CH(OH)CH_2CH_3$

If formulae given then must be unambiguous

If both formula and name given then formula must match name for mark to be awarded

1

B = butan-1-ol / $CH_3CH_2CH_2CH_2OH$

1

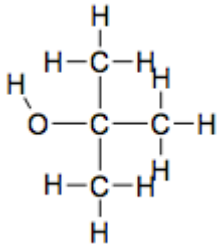
Product from **A / P** is a <u>ketone</u>
AND
Product from **B / Q** is an <u>aldehyde</u>

Penalise reference to incorrect class of alcohol

1

(c) Type of Bond: C=C

1



*Must show all bonds in Isomer **C** including O–H bond*

1

Reagent: conc. H_2SO_4 / conc. H_3PO_4

If incorrect attempt at correct reagent, mark on

Apply list principle for reagents and conditions marks

Conc required - may appear on conditions line

NOT (aq) For M3 even if seen on conditions line

ALLOW

Reagent = Al_2O_3

Condition = 'passing vapour over hot solid' owtte

1

Conditions: 180 °C / High temp / Hot / Reflux /

ALLOW stated temp in range 100-300 °C/373-573 K

IGNORE 'heat'

M4 dependent on correct reagent in M3

1

(d) (i) S = aldehyde/CHO **AND** T = carboxylic/COOH/CO_2H

1

T forms hydrogen bonds

1

(Which are) stronger than / need more energy to break than forces <u>between molecules/IMFs</u> in S ora (or reverse argument)

If implication of breaking covalent bonds max M1 only

1

(ii) (No oxidation has occurred as..)

(Still) contains peak at 3230−3550 cm-1 due to O−H/alcohol

Does not contain peak at 2500−3000 cm-1 due to O−H/carboxylic acid

Does not contain peak at 1680−1750 cm-1 due to C=O

Must have wavenumber range (or value within range) and bond or functional group to score each mark.

Any 2

[13]

18 (a) NaOH/KOH

IGNORE *OH-*

NOT *M1 if any mention of acidified/H+ in reagents or conditions*

1

Reaction 1 = ethanolic/alcoholic **AND** *reaction 2* = aqueous

IGNORE *temp*

NOT *ethanoic*

1

rxn 1 = base/proton acceptor

1

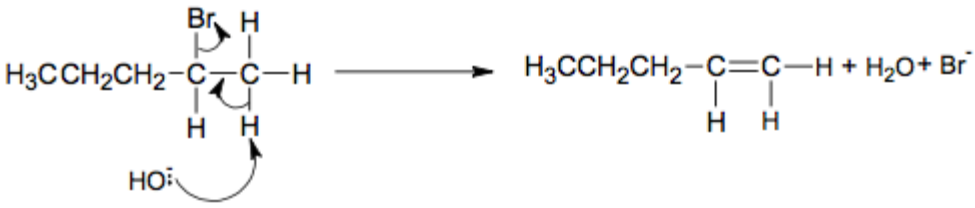
rxn 2 = nucleophile/lone pair donor/electron pair donor

1

(Base) Elimination

NOT *nucleophilic*

1



M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

M7 must show an arrow from a correct C–H bond on C adjacent to the C of 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 **M6**

M8 is independent provided it is from their original molecule and shows curly arrow from C-Br to Br

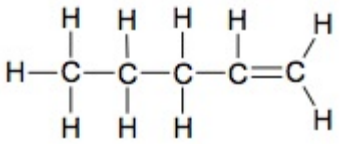
ALLOW *correct E1 mechanism*

IGNORE *incorrect inorganic products*

If forming pent-2-ene can award M8 only even if arrows in mechanism correct

If C chain length or halogen wrong in reactant or product max 2/3

1
1
1

(b) 

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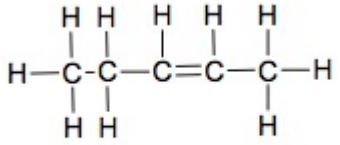
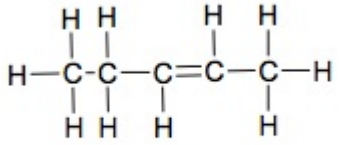


Z-pent-2-ene

1



E-pent-2-ene

1

If no M2 and M3 ***ALLOW*** *1 mark if both structures* ***OR*** *both names correct*

NOT *cis and trans*

No free rotation around C=C

ALLOW *no rotation of C=C*

1

2 different atoms/groups on each of the C=C Cs owtte

IGNORE *'functional'*

1

(c) Same volume/amount of $AgNO_3$(aq) added to same volume/amount/no. of drops of haloalkane (in beaker/flask) in each experiment

Both volume references needed

IGNORE *inappropriate volumes*

1

Same temp **OR** same [$AgNO_3$] each time

1

record time to measure sensible observation about the amount of AgCl ppt

e.g. first appearance of ppt / ppt obscures mark / reading on a colorimeter

IGNORE *colour of ppt*

ALLOW *silver mirror*

NOT *reference to same time if describing method based on timing how long (for ppt to form)*

ALLOW *gravimetric method based on same time for each experiment*

1

Rate = amount/time **OR** proportional to 1/time **OR** reference to shorter time = higher rate/longer time = lower rate

ALLOW *greater mass = higher rate if gravimetric method*

1

[17]