1. M1: uv light/sunlight

OR

T = 450 °C to 1000 °C;

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

1

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

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

1

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

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

1

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

1

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

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

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

1

[5]

2. (a) (i) $CH_4 + \mathbf{3}F_2 \longrightarrow CHF_3 + \mathbf{3}HF$

1

(ii) **M1 Initiation**

$F_2 \longrightarrow 2F\bullet$

M2 First propagation

$F\bullet + CHF_3 \longrightarrow \bullet CF_3 + HF$

M3 Second propagation

$F_2 + \bullet CF_3 \longrightarrow CF_4 + F\bullet$

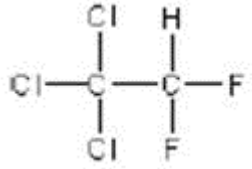
M4 Termination (must make C_2F_6)

$\mathbf{2}\bullet CF_3 \longrightarrow C_2F_6$ or CF_3CF_3

Penalise absence of dot once only.
Radical dot on $\bullet CF_3$ can be anywhere but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only.
Penalise once only for a line and two dots to show a bond.
Penalise each of "Fl" and lower case F, once only in this clip

4

(b) (i) Displayed formula
e.g.



All bonds must be drawn out.
Ignore bond angles. Penalise "sticks"

1

(ii) **M1** C–Cl bond OR carbon-chlorine bond
M2 chlorine atom OR chlorine (free) radical

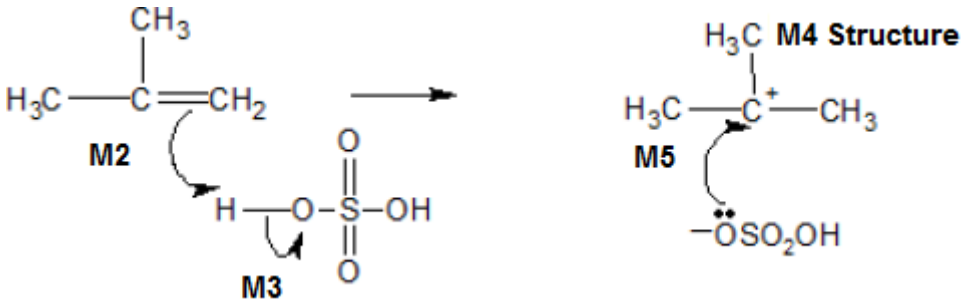
M3 **2**$O_3 \longrightarrow$ **3**O_2

M1 NOT carbon-halogen
Penalise incorrect spelling of chlorine once only in this clip
M2 ignore formulae
Ignore Cl_2 or $Cl\bullet$ or $ClO\bullet$ balanced on both sides of the equation
Ignore other equations leading to the overall equation

3

[9]

3. (i) **M1 Electrophilic addition**



M1 *both words required.*

For the mechanism

M3 *Penalise incorrect partial charges on O − H bond and penalise formal charges*
Ignore partial negative charge on the double bond.

M5 *Not* HSO_4^-

*For **M5**, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion*
OR *<u>correctly</u> drawn out with the negative charge placed correctly on oxygen.*

M2 must show an arrow from the double bond towards the H atom of the H − O bond / HO on a compound with molecular formula for H_2SO_4
M2 could be to an H^+ ion and M3 an independent O − H bond break on a compound with molecular formula for H_2SO_4

*<u>Max any 3 of 4 marks</u> **<u>for a correct mechanism</u>** using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation.*

M3 must show the breaking of the O − H bond on H_2SO_4

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 correct oxygen of the negatively charged ion towards the positively charged carbon atom on <u>their</u> carbocation

Credit the correct use of "sticks".

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

NB The arrows here are double-headed

5

(ii) Hydrolysis

Credit "(nucleophilic) substitution" but do not accept any other prefix.

Credit phonetic spelling.

1

(iii) Catalyst

1

[7]

5. (a) **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'.

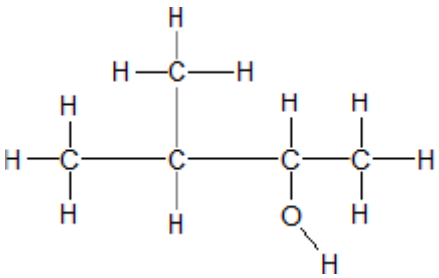
Ignore 'nothing (happens)'.

Ignore 'no observation'.

No credit for combustion observations.

3

(b)



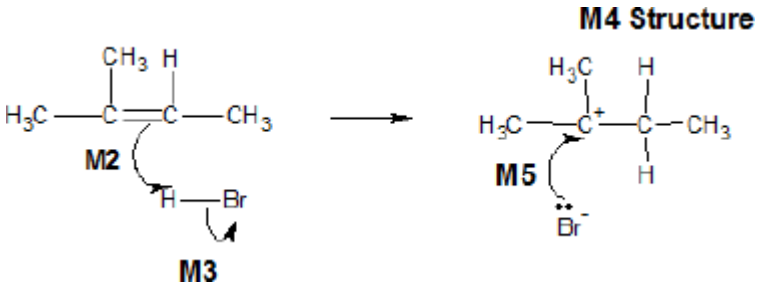
All bonds must be drawn.

Ignore bond angles.

1

(c) (i) **M1 Electrophilic addition**

M1 *both words needed.*



Penalise one mark from <u>their</u> total if half-headed arrows are used.

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

M2 *Ignore partial negative charge on the double bond.*

M3 must show the breaking of the H–Br bond

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

M4 is for the structure of the tertiary carbocation

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

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

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

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

<u>Max 3 of any 4 marks in the mechanism</u> *for wrong organic reactant or wrong organic product (if shown) or secondary carbocation.*

<u>Max 2 of any 4 marks in the mechanism</u> *for use of bromine.*

Do not penalise the correct use of 'sticks".

NB The arrows here are double-headed

5

(ii) **M1** Reaction goes via intermediate 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

[11]

5. (a) (i) Splitting/breaking C– X/bond(s) using/by (adding)/with water

OR

Splitting/breaking the molecule/substance/compound using/by (adding)/with water

NOT simply the reaction of/with water

NOT simply the addition or adding of water.

NOT the "splitting of water"

Accept any halogen bond, but penalise other specified bonds

1

(ii) **M1** yellow ONLY

M2 $Ag^+ + I^- \rightarrow AgI$ ($Ag^+ I^-$)

For M1, penalise cream(y) OR white

Ignore pale or light or dark (yellow)

For M2, ignore state symbols

2

(iii) **M1** AgF OR silver fluoride is soluble/dissolves (in water)

M2 No result
OR no precipitate
OR no (visible) change would occur
OR colourless solution

Accept "silver flouride"

Mark independently

Ignore reference to C – F bond breakage in M1

Ignore "no reaction" and "nothing"

2

(b) The bond that takes <u>less</u> energy to break/the low<u>er</u> bond enthalpy (energy)/weak<u>er</u> bond means the precipitate/reaction/hydrolysis occurs fast<u>er</u>/quicker/takes <u>less time</u>

OR

The bond that takes <u>more</u> energy/the high<u>er</u> bond enthalpy (energy)/strong<u>er</u> bond means the precipitate/reaction/hydrolysis occurs slow<u>er</u>/takes long<u>er</u>/takes <u>more time</u>

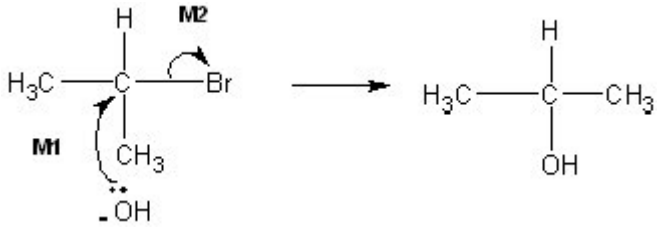
Insist on comparative on <u>both</u> bond strength and rate of reaction

1

[6]

6. (a) (i) <u>Nucleophilic substitution</u>

1



2

M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.
M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 1 mark **<u>for the mechanism</u>** for the wrong reactant and/or "sticks"*

Ignore product

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

(iii) <u>Polar C–Br</u> ***OR*** <u>polar carbon–bromine bond</u> ***OR*** <u>dipole on C–Br</u> ***OR*** δ+ (δ–)
C atom of <u>carbon–bromine bond</u> is δ+/electron deficient ***OR*** <u>C—Br</u>

(Credit carbon–halogen bond as an alternative to carbon–bromine bond)

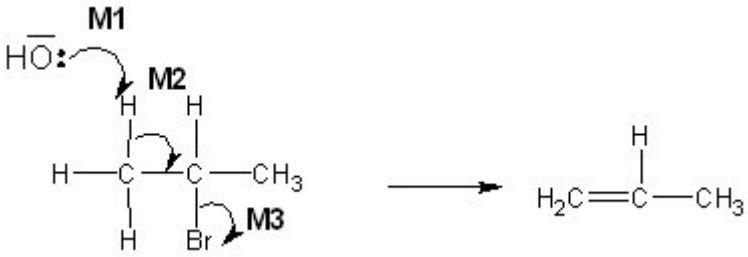
It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule. Ignore X for halogen

1

(b) Elimination

Credit "base elimination" but NOT "nucleophilic elimination"
No other prefix.

1



3

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom
M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1
M3 is independent.

Mechanism
Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 2 marks **for the mechanism** for wrong reactant and/or "sticks"*

Ignore product

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

(c) *Any one condition from this list to favour elimination*;

Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide ***OR*** concentrated KOH/hydroxide

  Ignore "aqueous"
- high temperature or hot or heat under reflux or T = 78 to 100°C

  Ignore "excess"

1

(d) (i) Addition (polymerisation) ONLY

Penalise "additional"

1

(ii) But-2-ene ONLY (hyphens not essential)

Ignore references to cis and trans or E/Z
Ignore butane

1

[12]

7. (a)

M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH ($2C_2H_5OH$) + **2**CO_2

*Penalise C_2H_6O for ethanol in **M1**.*

M2 and **M3**

*Mark **M2** and **M3** independently.*

Any **two** conditions **in any order** for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

  A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.

  Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.

M4 (fractional) distillation or GLC

Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).

M5 Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO_2 emission to the atmosphere

OR

There is no change in the total amount / level of carbon dioxide / CO_2 present in the atmosphere

*For **M5** – must be about CO_2 and the atmosphere.*

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

5

[5]

8. (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)

[4]

9. (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]

10. (a) To prevent vigorous boiling / uneven boiling / bubbling vigorously

Reference to an effect on 'reaction' here loses this mark.

1

(b) Condenser

Accept 'condensation chamber' or 'condensation tube'.

1

Should show effective water jacket and central tube

If a flask is also drawn then the condenser must be at an appropriate angle.

Apparatus must clearly work.

Ignore direction of water flow.

Diagram must have a clear flow of vapour and water eg unblocked central tube or flow indicated by arrows.

1

[3]

11. Figure 2

1

Further oxidation will occur / ethanoic acid formed

Do not accept 'poor yield' without qualification

Can gain this mark if logic correct but has chosen wrong Figure

1

[2]

12. B

[1]

13. B

[1]

14. A

[1]

15. A

[1]

16. A

[1]

17. C

[1]