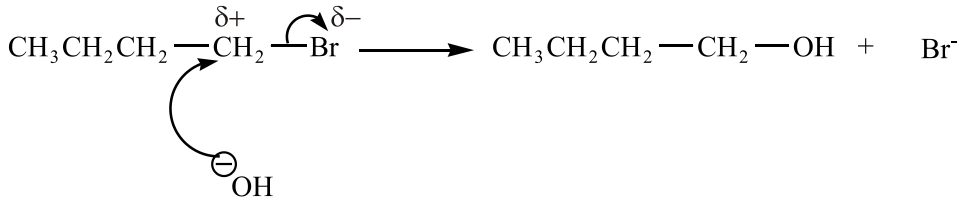
1. (i) substitution/hydrolysis **(1)** 1

(ii) electron pair donor **(1)** 1

(iii)



correct dipole **(1)**
curly arrow from the O in the OH- to C in the CH_2 **(1)**
curly arrow to show movement of bonded pair in the C–Br bond **(1)**
Br^- as a product **(1)** 4

[6]

2. (i) Any two realistic fragments,
e.g. CH_3^+: 15; $C_2H_5^+$: 29; $C_3H_7^+$: 43; $C_4H_9^+$: 57; OH^+: 17, *etc*. **(1) (1)**
Do not penalise missing charge. 2

(ii) breathalysers/monitoring of air pollution, MOT emission testing, *etc*. **(1)** 1

[3]

3. **Availability of starting materials:**

availability

sugar is renewable because it can be grown **(1)**
ethane is finite because it is obtained by processing of crude oil **(1)**

energy:

fermentation: energy is required for distillation/
hydration: energy is required to generate steam **(1)**

atom economy and waste products:

atom economy for fermentation < atom economy hydration **(1)**
In fermentation, CO_2 is produced in addition to ethanol/ethanol is not the only product **(1)**
In hydration, ethanol is the only product/hydration is an addition reaction (1)
Atom economy of fermentation could be increased by finding a use CO_2 (1)

Atom economy linked to a chemical equation to show that hydration has 100% atom economy/fermentation has 51% atom economy **(1)** 7max

[7]

4. (a) (i) (volatile components) can escape/distil out **(1)**
ethanal is most volatile/bpt less than 60 °C/partial oxidation **(1)** 2

(ii) (volatile components) cannot escape/ refluxed **(1)**
complete oxidation will be achieved/oxidised to the acid **(1)** 2

(b) $C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$
C_2H_5OH, 2[O] and CH_3COOH **(1)**
rest of equation **(1)** 2

[6]

5. (i) $C_6H_{12}O_6$ (aq) $\rightarrow 2C_2H_5OH(l)$ or (aq) $+ 2CO_2(g)$ balanced equation 1
state symbols can be awarded only if equation shows $C_6H_{12}O_6$,
C_2H_5OH and CO_2 1

(ii) anaerobic, aqueous, temp range 25 – 40°C/warm to just above room temp 2

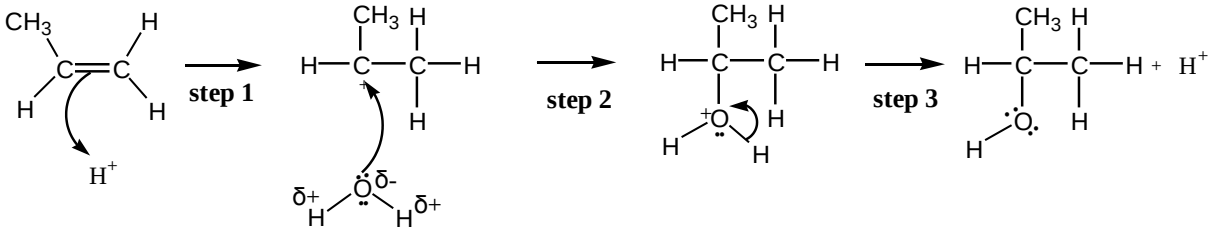
(iii) no more bubbles/gas/CO_2 1

[5]

6. (a) (i) phosphoric acid/H^+/sulphuric acid 1

(ii) lone/electron pair of electrons acceptor 1

(b) (i)



Step 1	curly arrow from π-bond to H^+	1
Step 2	curly arrow from lone pair on the $O^{\delta-}$ to C+	1
Step 3	curly arrow from O—H bond to O+	1

(ii) catalyst … no marks because it is **not** consumed/used up in the reaction/owtte 1

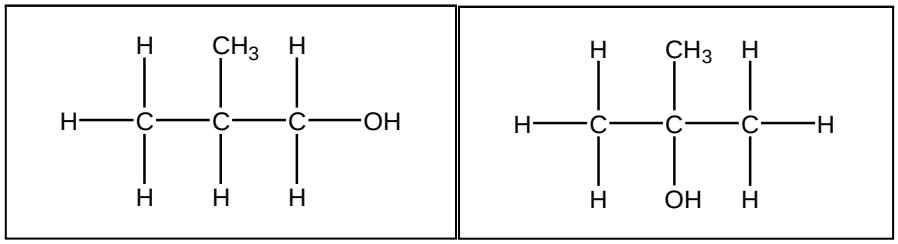
[6]

7. $CH_3CH(OH)CH_3 + 4½O_2 \rightarrow 3CO_2 + 4H_2O$ /C_3H_8O

(1 mark if correct formula for all four chemicals and 1 mark for correct balancing)

[2]

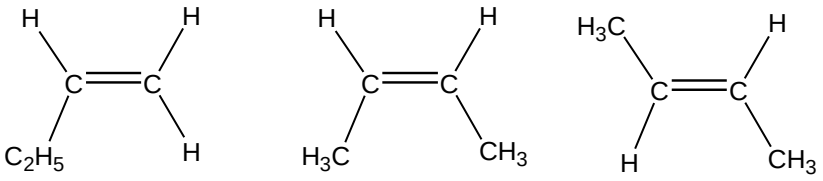
8. (i) 2



(ii) either (2-)methylpropan-1-ol or (2-)methylpropan-2-ol 1

[3]

9.



Minimum – must display/show C=C

[3]

10. (a) (i) H^+ 1

$Cr_2O_7^{2-}$ 1

(ii) Orange to green/black/blue 1

(b) (i) contains a C=O/aldehyde, ketone, carboxylic acid and ester/ carbonyl/carbonyl in an aldehyde 1

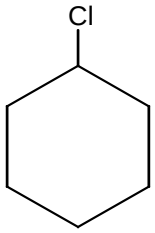
(ii) does **not** contain a O–H/ (hydrogen bonded in a) carboxylic acid 1

(iii) distillation (no mark) **because** distillation allows loss of volatile components /removes butanal from oxidising mixture 1

prevents formation of RCOOH/ partial oxidation would be achieved or reverse argument for reflux not being used in that reflux prevents loss of volatile components hence complete oxidation would be achieved/RCOOH would be formed ✓ 1

[7]

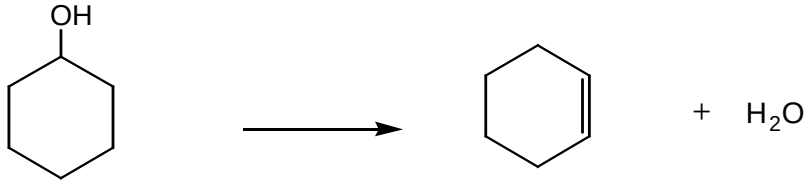
11. (a) (i) 1



(ii) H_2SO_4/Al_2O_3/(hot) pumice/H_3PO_4 1

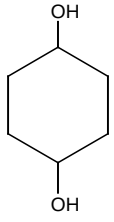
(H_2SO_4(aq) or dil H_2SO_4 loses the mark)

(iii) 1



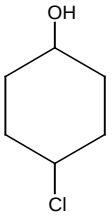
$C_6H_{11}OH$ / $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$

(b) (i) 1



diol

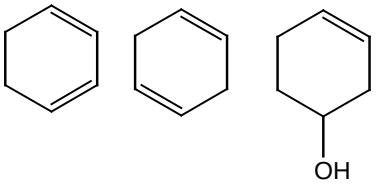
also allow



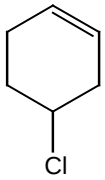
Cl-alcohol

(ii) 2

from the diol allow



from the Cl-alcohol allow



[6]

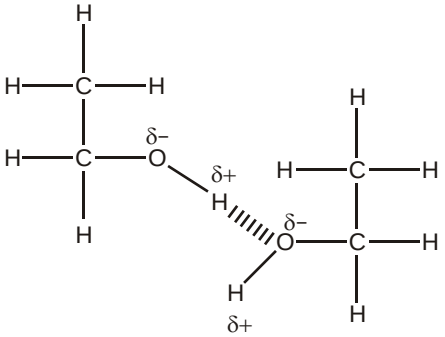
12. (i) *low volatility*, = **high** boiling point/ not easy to vapourise/owtte 1

intermolecular bonds. = bonds/forces/attractions **between** molecules 1

(ii) type of intermolecular bond = hydrogen bond 1

dipoles on both O-H bonds 1

H-bond shown as a 'dashed bond' 1



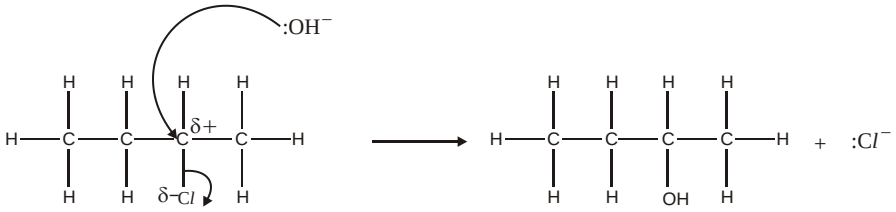
(iii) (The boiling point of glycerol will be higher than ethanol because there are)

more OH groups ∴ <u>more H-bonds</u> 1

[6]

13. (a) (i) butan-2-ol by name or by formula ✓ 1

(ii)



curly arrow from the O of the OH- to $C^{(\delta+)}$ ✓

curly arrow from C-C*l* bond to C*l* **and** correct dipoles ✓

correct products/ allow NaC*l* ✓

curly arrow from lone pair on :OH^- ✓

S_N1 route can still score all 4 marks:

curly arrow from C-C*l* bond to C*l* **and** correct dipoles ✓

curly arrow from the O of the OH^- to C+ ion ✓

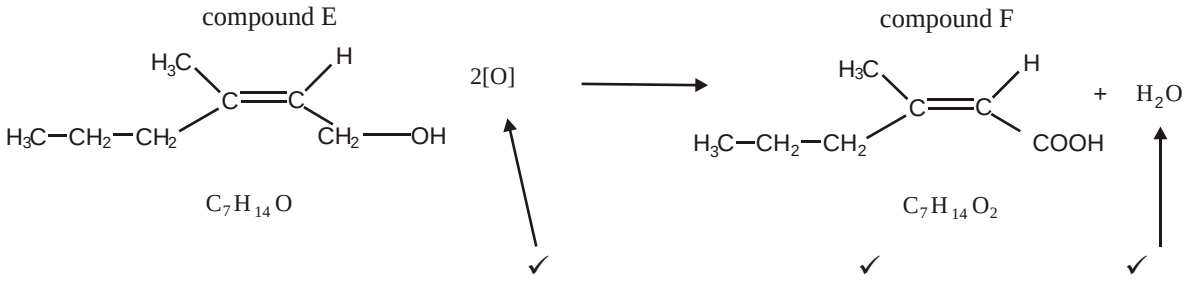
correct products/ allow NaC*l* ✓

curly arrow from lone pair on :OH^- ✓ 4

[5]

14. (i) H^+ ✓ $Cr_2O_7^{2-}$ 2

(ii)



✓ ✓ ✓ ✓

3

(iii) carboxylic acid would have an absorption between 1680 – 1750 cm^{-1} /1700 cm^{-1} or 2500 – 3300 cm^{-1}. 1

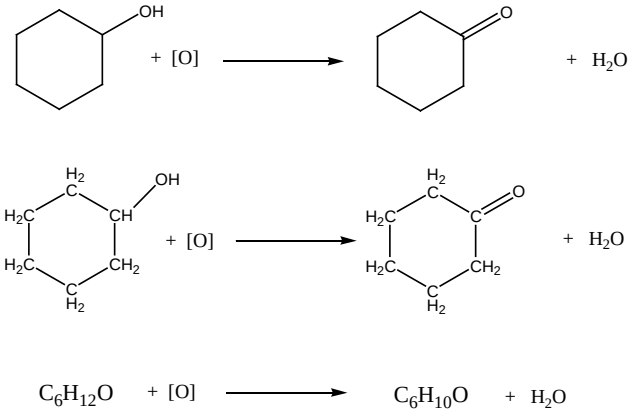
[6]

15. (a) (i) H_2SO_4 – any mention of (aq) loses the mark 1

(ii) any correct formula/structure or name for benzoic acid 1

(b) (i) dichromate/$Cr_2O_7^{2-}$/permanganate 1

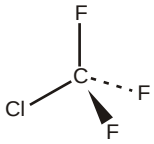
(ii) 1



$C_6H_{12}O$ + [O] ⟶ $C_6H_{10}O$ + H_2O

[4]

16. (i) 1



require an attempt at a 3D structure and bond angles must clearly not be 90°.

require at least one 'wedge' bond or one 'dotted' bond

(ii) 108 – 111° 1

(iii) volatile/low boiling/gas/non-toxic/non-flammable/unreactive/liquefied under pressure/inert 1

(iv) homolytic = bonded pair split <u>equally</u>/ each retains 1 electron 1

fission = <u>bond</u> breaking 1

(v) C-C*l* (no mark) because it is the <u>weaker bond</u> 1

(vi) C*l*• 1

•CF_3 (allow CF_3•) 1

(lack of 'dots' penalise once)

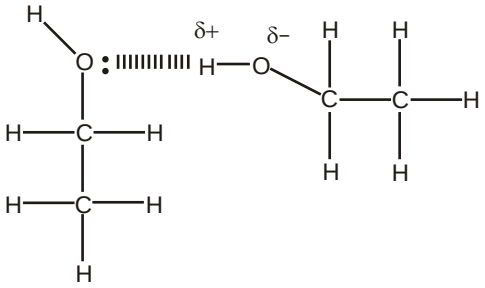
[8]

17. $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

(C_2H_5OH & CO_2 ✓)

[2]

18.



dipoles 1

hydrogen bond between O in one O-H and H in the other O-H 1

lone pair from O involved in the H-bond 1

[3]

19. (a) (i) (volatile components) can escape/distil out 1

ethanal is most volatile/b pt less than 60°C/partial oxidation 1

(ii) (volatile components) cannot escape/ refluxed 1

complete oxidation will be achieved/oxidised to the acid 1

(b) $C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$

($CH_3COOH + H_2O$ ✓) 2

(c) spectrum C 1

spectrum C only shows absorption at 1700 cm^{-1} for the C=O 1

the other two spectra contain the OH group absorption at approx 3000 cm^{-1} 1

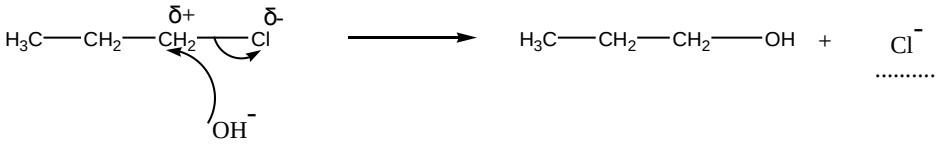
[9]

20. (a) (i) reaction 1 1

(ii) reaction 4 1

(iii) reaction 3 1

(b) (i) lone pair/electron pair donor 1



Correct dipole 1

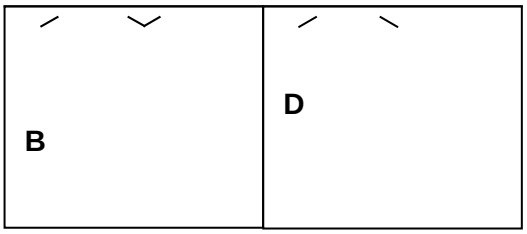
Curly arrow from the O in the OH^- to C in the CH_2 1

Curly arrow to show movement of bonded pair in the C-C*l* bond 1

C*l*$^-$ as a product 1

(c) (i) same molecular formula , different structure/arrangement of atoms. 2
(same formula, different structure.)

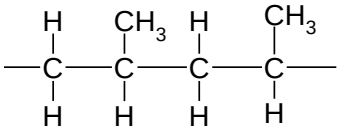
(ii) 2



(d) (i) addition, (not additional) 1

(ii) poly(propene)/ polypropene/ polypro-1-ene, polypropylene 1

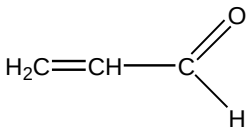
(iii) 1



[15]

21. (a) (i) prop-2-en-1-ol CH_2=$CHCH_2OH$ must show the C=C double bond 1

acrolein



***mus**t clearly show the aldehyde group and the C=C*

1

(ii) alkene/C=C double bond 1

(b) (i) acidified /H^+ 1

dichromate/$Cr_2O_7^{2-}$ 1

(ii) CH_2CHCH_2OH/ C_3H_6O/ $C_3H_5OH + [O] \longrightarrow CH_2CHCHO$/ C_3H_4O/ $C_2H_3CHO + H_2O$

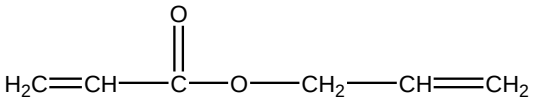
not CH_2CHCOH 1

[6]

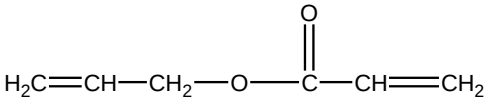
22. (i) $CH_2CHCH_2OOCCHCH_2$ /($C_6H_8O_2$) 1

H_2O 1

(ii) 2



or



1 mark if the ester group, 1 mark for the rest of the molecule.

COO/CO_2 without displaying the ester, they can still get 1 mark.

[4]

23. Essential marks:

Order	RI>RBr>RC*l* /owtte	1
reason for the order	C-I bond weakest/length/C-C*l* bond strongest and mention/intermolc forces loses the mark	1
an equation	$Ag^+ + X^- \longrightarrow AgX$ (solid or ppt) or an equation for hydrolysis/using OH- or H_2O	1

max = 3

Two possible methods of monitoring the reaction

Method 1	**Method 2**	
$AgNO_3$	$AgNO_3$	1
Ethanol & Waterbath/ /hydroxide temp 40 – 80°C not heat/not bunsen	$NaOH/OH^-$ & neutralise with HNO_3	1
relative rate of precipitation	relative amount of precipitation	1

[6]

24. Properties:

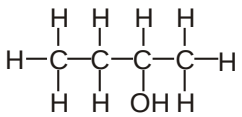
Non-toxic/harmless		1
non-flammable		1
any two from:		2
(propellant in) aerosols	because it is volatile/ unreactive/ non-toxic/ easily compressed	
blowing polystyrene	because it is unreactive	
dry cleaning	because it is a good solvent for organic material	
degreasing agent	because it is a good solvent for organic material	
fire extinguishers	because it is non-flammable	

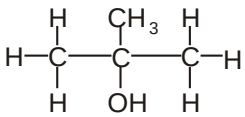
QWC

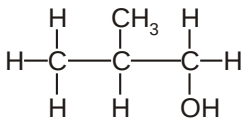
- reasonable spelling, punctuation and grammar throughout

[4]

25. (a) ✓✓✓







3

(b) (i) orange to green/dark green/brown/black ✓ 1

(ii) C_4H_9OH/ $C_4H_{10}O + 2[O] \rightarrow C_3H_7COOH + H_2O$ ✓✓ 2

1 mark available for correct formula of the carboxylic acid

(iii) Identify isomer 2-methylpropan-1-ol by appropriate number/name/formula ✓ 1

(c) (i) CH_2 has mass = 14, $14 \times 4 = 56$ ✓ 1

$\therefore C_4H_8$ ✓ 1

(ii) $C_4H_9OH \rightarrow C_4H_8 + H_2O$ ✓ 1

(iii) Identify butan-2-ol by appropriate number/name/formula 1

(d) (i) H_2SO_4 ✓ 1

(ii) 0.06 ✓ 1

(iii) 60% ✓ 1

[14]

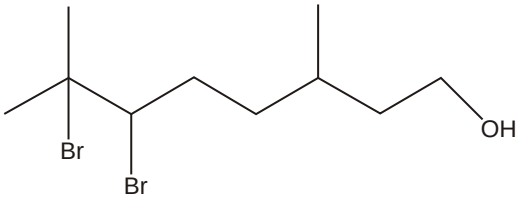
26. (a) (i) alkene ✓ 1

alcohol/hydroxy/hydroxyl ✓ 1

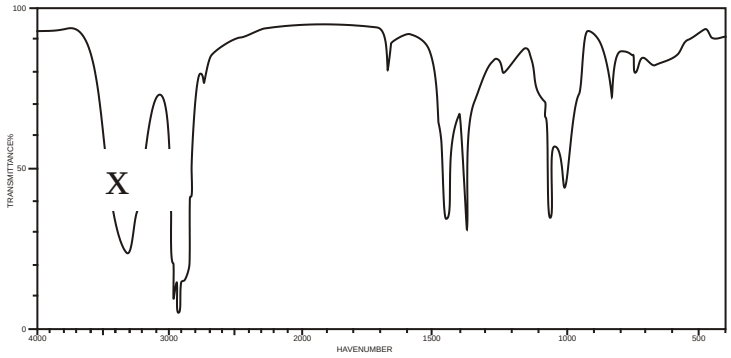
(b) (i) I = alkene & II = alcohol… both are needed ✓ 1

(ii) decolourised / colourless ✓ 1

(iii) ✓ 1



(iv) **X** as shown below ✓ 1



(c) (i) Ni/Pt/Rh/Pd ✓ 1

(ii) compound **B** is $C_{10}H_{22}O$ ✓ 1

(iii) $C_{10}H_{20}O + H_2 \rightarrow C_{10}H_{22}O$ ✓ 1

[9]

27. (a) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ ✓✓ 2
$2CO_2 + 3H_2O$ gets 1 mark

(b) **Fermentation** 1

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ 1

Yeast /enzyme / temperature about 30 °C/ batch process ✓ 1

Hydration of ethene. ✓ 1

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓ 1

Temp > 100 °C/Press 370 – 100 atm / 6 –20 MPa/phosphoric acid catalyst/ continuous process ✓ 1

Glucose is obtained from plants ✓ 1

Ethene is obtained from crude oil/cracking/fossil fuel ✓ 1

glucose is renewable/ethene isn't ✓ 1

1 mark available for *Quality of written communication*….. base the award of the mark on the ability to communicate the essential chemistry by correct use of at least two from:

fermentation/hydration/catalyst/renewable/sustainable/biofuel/ enzymes/finite/cracking ✓ 1

[12]

28. (a) (i) C_4H_{10} ✓ 1

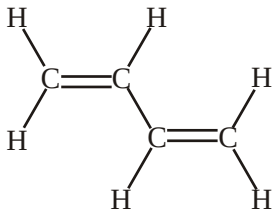
(ii) C_2H_5O ✓ 1

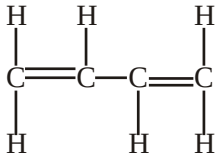
(iii) B and E ✓ 1

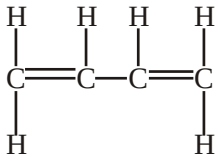
(iv) A and F ✓ 1

(b) ($C_4H_9OH \rightarrow$) $C_4H_8 + H_2O$ ✓ 1

(c) any unambiguous formula: ✓ 1







$CH_2CHCHCH_2$

$CH_2CHCHCH_2$

buta-1,3-diene ✓ 1

name ecf to the structure only if structure above has formula C_4H_6

[7]

29. (a) C*l* $^-$ must be shown as a product ✓ 1

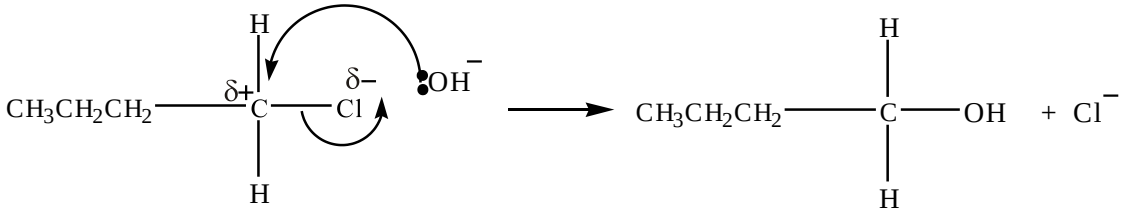
(at least 1) lone pair of electrons on the O in the OH^- with curly arrow

from the lone pair on the OH^- to the C($^{\delta+}$)✓ 1

dipoles on the C-C*l* bond ✓ 1

curly arrow from C-C*l* bond to the C*l*$^{\delta-}$ ✓ 1

The mechanism below would get all 4 marks.



(b) (i) mark for method/dividing by A_r / C, 3.15; H, 6.3; C*l*, 1.58. ✓ 1

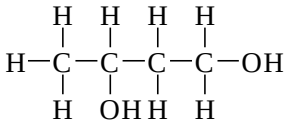
divide by smallest to get C_2H_4Cl ✓ 1

alternative method:

% of each element x 127 ÷ A_r of that element = molecular formula, hence deduce empirical formula

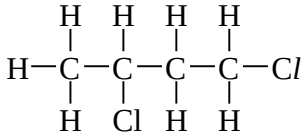
(ii) $C_4H_8Cl_2$ ✓ 1

(iii) any unambiguous form of: ✓



1

(iv) any unambiguous form of: ✓



1

ecf to (iii) provided that there are two OHs in (iii)

[9]

30. (a) (i) Alkene/C=C ✓ 1

Alcohol/ROH/hydroxy/hydroxyl/OH (not OH^- or hydroxide) ✓ 1

(ii) One of the C in both C=C is joined to two atoms or groups that are the same ✓ 1

(b) Observation decolourisation (of Br_2) ✓ 1

Molecular formula $C_{10}H_{18}OBr_4$ ✓✓ 2

$C_{10}H_{18}OBr_2$ gets 1 mark

(c) reagent CH_3COOH ✓ 1

catalyst $H_2SO_4/H^+/HCl$ (aq) *or dilute loses the mark* ✓ 1

(d) (i) $C_{10}H_{18}O + 2[O] \rightarrow C_{10}H_{16}O_2 + H_2O$ ✓✓ 2

1 mark for H_2O and 1 mark for 2[O]

(ii) The infra-red spectrum was of compound **Y**

because absorption between 1680 – 1750 cm^{-1} indicates a C=O ✓ 1

and the absence of a peak between 2500 – 3300 cm^{-1} shows the absence of the OH hydrogen bonded in a carboxylic acid ✓ 1

[12]