F322: Alcohols

1. 2-Methylpropan-2-ol ✓

ALLOW *methylpropan-2-ol*

[1]

2. Has O–H (bonds)
OR has hydroxyl (groups) **OR** has hydroxy (groups) ✓

ALLOW *marks from a diagram of hydrogen bonding*
IGNORE *reference to alcohol functional group*

Forms hydrogen bonds with water (molecules) ✓

DO NOT ALLOW *'forms hydrogen bonds'*

[2]

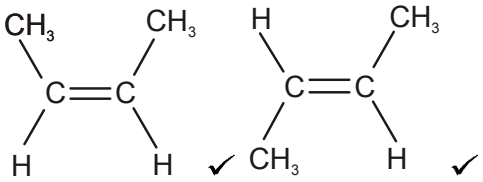
3. $CH_3COOCH_2CH_2OOCCH_3$

1 mark for each ester end of molecule ✓✓

ALLOW *displayed formula* ***OR*** *skeletal formula*
ALLOW *sticks*
$CH_3COOCH_2CH_2OH$ shows one of the two ester groups and scores one mark

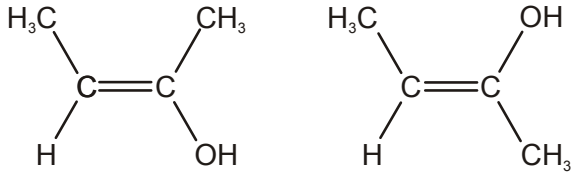
[2]

4. (i)



✓ ✓

DO NOT ALLOW



i.e. no ECF

2

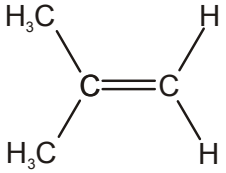
(ii) *E/Z* ✓

ALLOW *cis-trans*
IGNORE *geometric*

1

(iii) $CH_3CH_2CH=CH_2$ **OR** but-1-ene ✓

*If but-1-ene given in part **(i)**,*
***ALLOW** but-2-ene **OR** $CH_3CH=CHCH_3$*
*i.e. ECF from **(i)***
***DO NOT ALLOW** methylpropene:*



1

[4]

5. From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid

If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6

The mark scheme for **F** = propanone and propanal is shown below.

mass spec of E– Remember to check the spectrum
Quality of Written Communication – mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**ALLOW** *m*/*e*) value is 60 ✓

m/*z* = 45 indicates loss of CH_3
OR *m*/*z* = 45 indicates presence of CH_3CHOH
OR CH_2CH_2OH **OR** C_2H_5O ✓

IR of F – Remember to check the spectrum
IR shows no broad absorption between 2500 to 3300 cm^{-1} so no O—H bond
OR no broad absorption between 2500 to 3300 cm^{-1} so not a carboxylic acid ✓

IR shows absorption at 1700 cm^{-1} due to a C=O bond
OR absorption at 1700 cm^{-1} indicates a ketone **OR** aldehyde present

Identification and equation
F is CH_3COCH_3 **OR** propanone ✓

E is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓

$CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ ✓

If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2
ALLOW E is $CH_3CH_2CH_2OH$ ✓

ALLOW: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓

The mark scheme for **F** = propanoic acid is shown below.

mass spec of E– Remember to check the spectrum
QWC – mass spec gives M^+ or molecular ion of 60
OR mass spec gives parent ion of 60
OR highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓

m/*z* = 45 indicates loss of CH_3
OR *m*/*z* = 45 indicates presence of CH_3CHOH
OR CH_2CH_2OH **OR** C_2H_5O ✓

IR of F– Remember to check the spectrum
IR shows (broad) absorption somewhere between 3500 and 2500 cm^{-1} suggests carboxylic acid
OR O–H bond ✓

IR shows absorption at 1700 cm^{-1} due to C=O
OR absorption at 1700 cm^{-1} indicates a carboxylic acid ✓

Identification and equation
F is CH_3CH_2COOH **OR** propanoic acid ✓

E is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓

$CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓

Extra guidance for marking of question

If **E** has **not** been identified **OR** if **F** has been identified as a **keton**e **or aldehyde**, use the **first** mark scheme

If **F** has been identified as a **carboxylic acid**, use the **second** mark scheme

Mass spec

These two marking points stand as **independent** marks whichever compounds have been identified.

The positive sign for fragment ions is not required. **IGNORE** negative charge.
The mass spec may well be on the actual spectrum.

IR mark

These stand as **independent** marks whichever compounds have been identified.
The IR analysis may well be on the actual spectrum.

Identification marks

If both structure and name are given they must **both** be correct but allow 'propanol' drawn with the correct structure because the position number of the –OH has been clearly identified

ALLOW ECF for identification of **F** e.g. if **E** is pentan-2-ol ✗ then an answer of pentan-2-one for **F** will be given a mark ✓ as ECF

ALLOW identification marks for **E** and **F** from equation

Equation mark

ALLOW ECF for any correct equation showing the oxidation of **any** alcohol to the appropriate product.
ALLOW molecular formulae in equations,

i.e. $C_3H_7OH + [O] \longrightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \longrightarrow C_3H_6O + H_2O$ ✓ ;

$C_3H_7OH + [O] \longrightarrow C_2H_5COH + H_2O$ ✓

[7]

6. (a) **method 1:**
fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓

method 2:
hydration of ethene **OR** reaction of ethene with water **OR** reaction of steam with ethene ✓

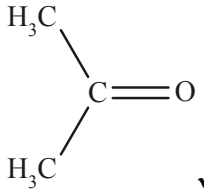
$C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓

ALLOW *sugar from equation*
ALLOW *C_2H_6O in equation*
ALLOW *correct multiples*
IGNORE *state symbols*

ALLOW *ethene from the equation*
IGNORE *mention of any catalyst*
ALLOW *C_2H_6O in equation* ***OR*** *H_2O over the arrow*
ALLOW *correct multiples*
IGNORE *state symbols*

4

(b) (i) $(CH_3)_2CO$ **OR**



✓

$(CH_3)_2CHOH + [O] \rightarrow (CH_3)_2CO + H_2O$ ✓

If name and formula given both need to be correct
ALLOW *propanone* ***OR*** *acetone*
IGNORE *propone*
NOT *incorrect named compound*
ALLOW $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$
ALLOW *O instead of [O]*
ALLOW *correct multiples*
IGNORE *state symbols*

2

(ii) CH_3CH_2COOH **OR** propanoic acid ✓

Any number or range of numbers between 1750–1640 (cm^{-1}) for C=O ✓

Any number or range of numbers between 2500–3300 (cm^{-1}) for O–H ✓

ALLOW *C=O and O—H marks independent of compound identified* ***i.e. stand alone marks***
ALLOW *correct bonds shown by the appropriate absorption on the IR spectrum*
IGNORE *reference to C—O bond*

3

(c) (i) 2-methylpropan-2-ol ✓

ALLOW *methylpropan-2-ol* ***OR*** *tertiarybutanol*

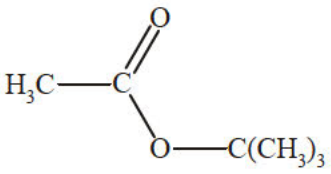
1

(ii) ester ✓

1

(iii) $CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$

OR



ester group shown ✓

rest of molecule ✓

ALLOW *skeletal formula* ***OR*** *displayed formula*

ALLOW *ester linkage even if rest of structure is wrong*

2

[13]

7. 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]

8. (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]

9. (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

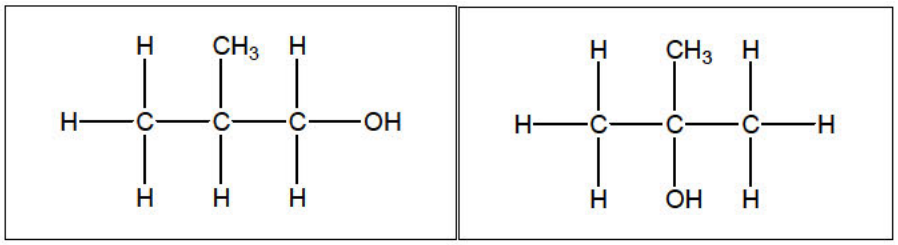
(iii) no more bubbles/gas/CO_2 1

[5]

10. $CH_3CH(OH)CH_3 + 4½O_2 \rightarrow 3CO_2 + 4H_2O$ /C_3H_8O
(1 mark if correct formula for all four chemicals and 1 mark for correct balancing)

[2]

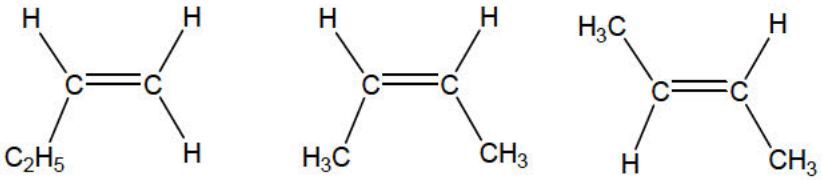
11. (i) 2



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

[3]

12.



Minimum – must display/show C=C

[3]

13. (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

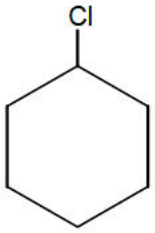
(ii) does **not** contain a O–H/ (hydrogen bonded in a) carboxylic acid 1

(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]

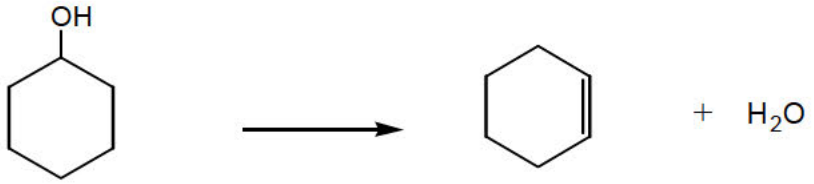
14. (a) (i) 1



(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

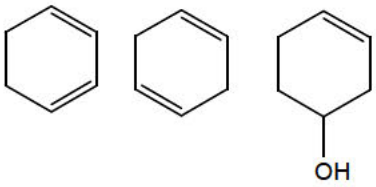
diol

also allow

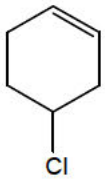
Cl-alcohol

(ii) 2

from the diol allow



from the Cl-alcohol allow



[6]

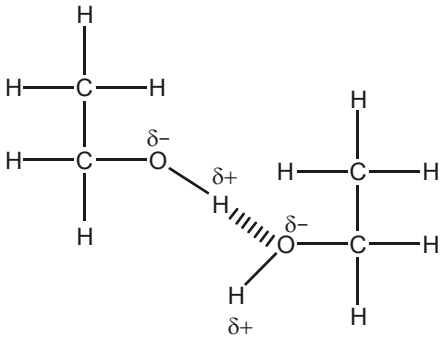
15. (i) *low volatility*, = **high** boiling point/ not easy to vapourise/owtte 1

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



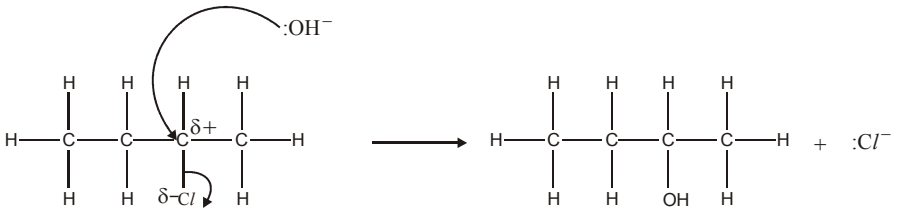
(iii) (The boiling point of glycerol will be higher than ethanol because there are)

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

[6]

16. (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* **<u>and</u>** 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* **<u>and</u>** correct dipoles ✓

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

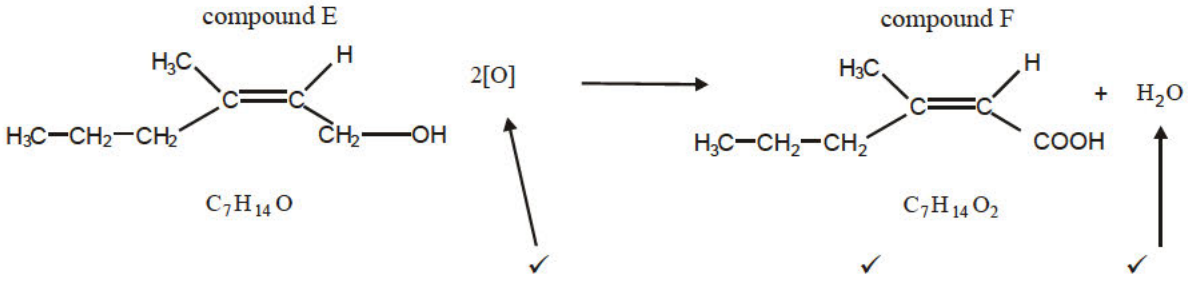
correct products/ allow NaC*l* ✓

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

[5]

17. (i) H^+ ✓ $Cr_2O_7^{2-}$ 2

(ii)



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

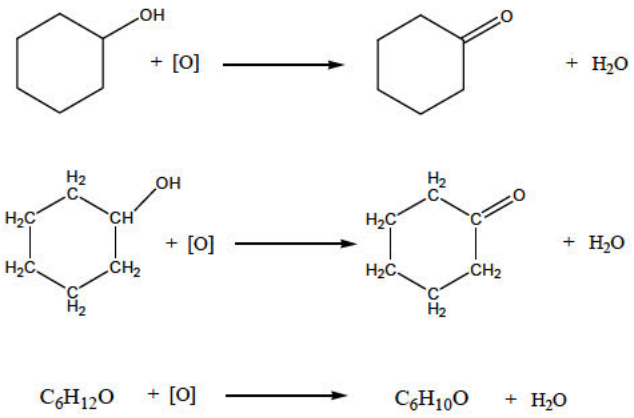
[6]

18. (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



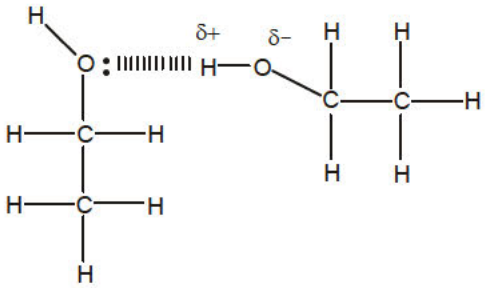
[4]

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

(C_2H_5OH & CO_2 ✓)

[2]

20.



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]

21. (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

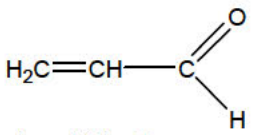
spectrum C only shows absorption at 1700 cm^{-1} for the C=O 1

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

[9]

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

acrolein



***must** 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/ $C_2H_3CHO + H_2O$

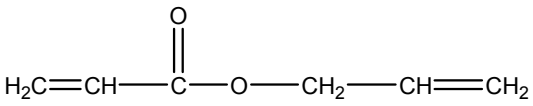
not CH_2CHCOH 1

[6]

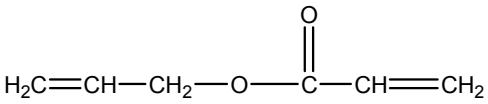
23. (i) $CH_2CHCH_2OOCCHCH_2$ /($C_6H_8O_2$) 1

H_2O 1

(ii) 2



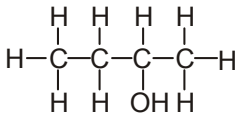
or

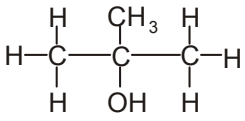


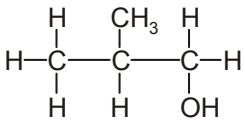
1 mark if the ester group, 1 mark for the rest of the molecule. COO/CO_2 without displaying the ester, they can still get 1 mark.

[4]

24. (a) ✓✓✓







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(b) (i) <u>orange</u> 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]

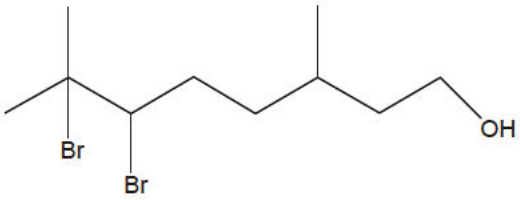
25. (a) (i) alkene ✓ 1

alcohol/hydroxy/hydroxyl ✓ 1

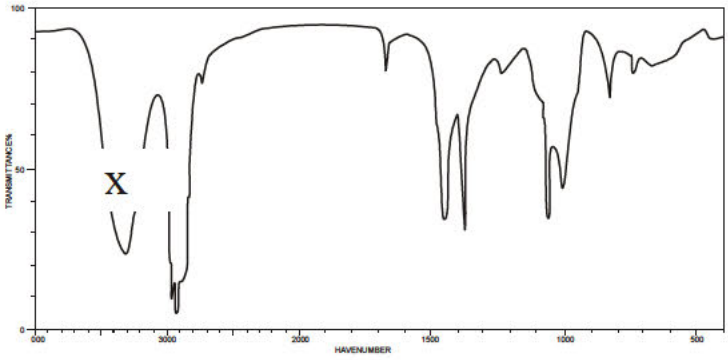
(b) (i) I = alkene & II = alcohol… both are needed ✓ 1

(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]

26. (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]

27. (a) (i) C_4H_{10} ✓ 1

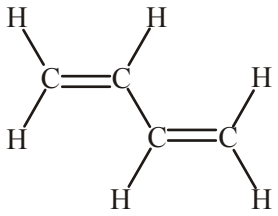
(ii) C_2H_5O ✓ 1

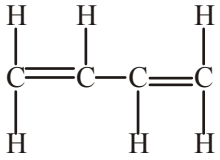
(iii) B and E ✓ 1

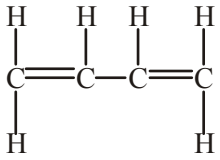
(iv) A and F ✓ 1

(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]

28. (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]