1 Propene can be made by the dehydration of propan-2-ol.

What is the percentage yield when 30 g of propene (M_r = 42.0) are formed from 50 g of propan-2-ol (M_r = 60.0)?

A 60% ⬭

B 67% ⬭

C 81% ⬭

D 86% ⬭

(Total 1 mark)

2 Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH{=}CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

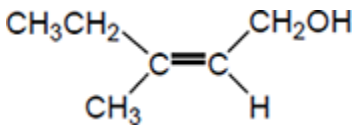
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

.....

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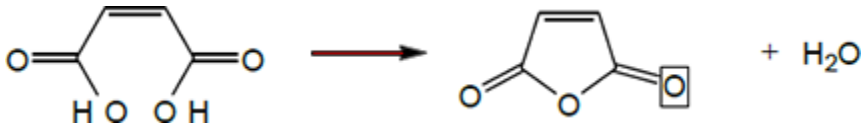
.....

(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment,10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

.....

.....

.....

(2)
(Total 10 marks)

3 Alcohol **A** $(CH_3)_2CHCH(OH)CH_3$ undergoes reactions separately with acidified potassium dichromate(VI) and with concentrated sulfuric acid.

(a) Deduce the IUPAC name for alcohol **A**.

.....

(1)

(b) Draw the structure of the organic product, **B**, formed when **A** is oxidised in the reaction with acidified potassium dichromate(VI).

(1)

(c) Two isomeric alkenes, **C** and **D**, are formed when **A** is dehydrated in the reaction with concentrated sulfuric acid.

Name the mechanism for this dehydration reaction.

.....

(1)

(d) Draw the structure of each isomer.

Isomer **C** Isomer **D**

(2)

(e) Name the type of structural isomerism shown by **C** and **D**.

.....

(1)

(f) List alcohol **A**, product **B** and isomer **C** in order of increasing boiling point.

.....

(1)

(g) Draw the structure of the isomer of **A** that is **not** oxidised by acidified potassium dichromate(VI).

(1)

(h) Draw the structure of the isomer of **A** that **cannot** be dehydrated to form an alkene by reaction with concentrated sulfuric acid.

(1)
(Total 9 marks)

4 The reaction of butane-1,4-diol with butanedioic acid produces the polymer PBS used in biodegradable packaging and disposable cutlery.
Butanedioic acid is produced by two different processes.

Process 1

- Aqueous sodium hydroxide reacts with 1,4-dibromobutane to make butane-1,4-diol.
- Butane-1,4-diol is oxidised to butanedioic acid.

Process 2

- Glucose reacts with carbon dioxide in the presence of microorganisms to produce butanedioic acid directly.
- The carbon dioxide used in this process is obtained from a local factory that produces bioethanol.

(a) Deduce **one** safety reason and one environmental reason why **Process 2** is preferred to **Process 1**.

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

(2)

(b) (i) Name and outline a mechanism for the following reaction that occurs in **Process 1**.

$$BrCH_2CH_2CH_2CH_2Br + NaOH \longrightarrow BrCH_2CH_2CH_2CH_2OH + NaBr$$

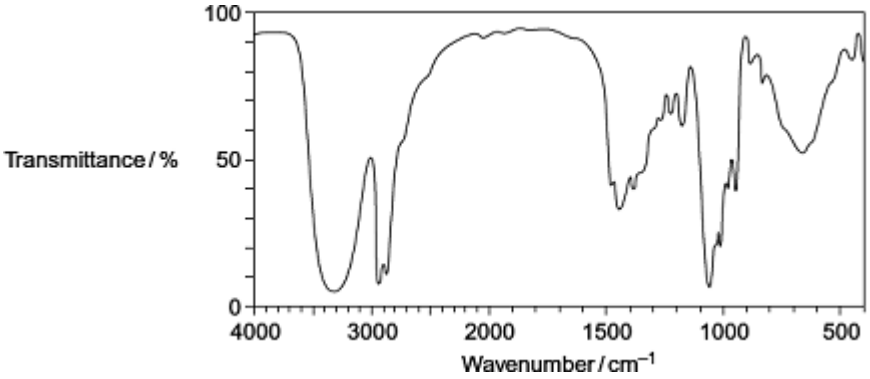
.....

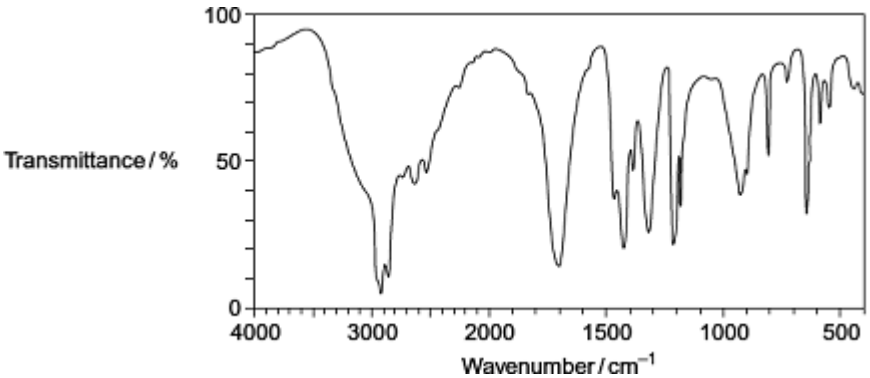
(3)

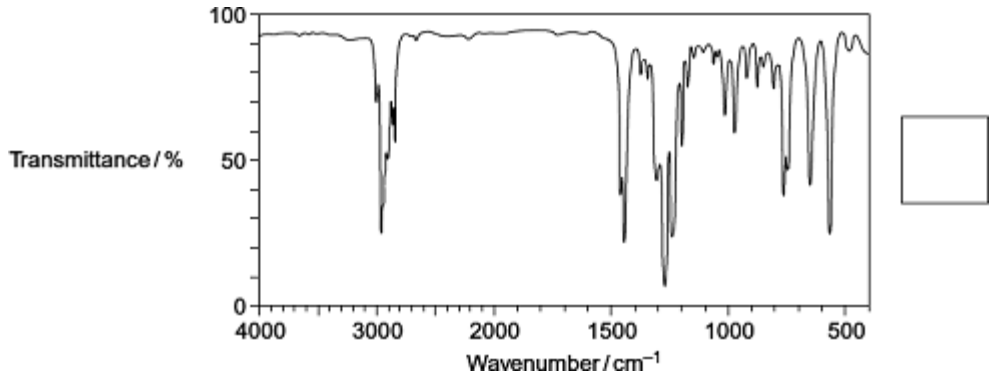
(ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutane
Compound **B** butane-1,4-diol
Compound **C** butanedioic acid

Identify the compound responsible for each spectrum by writing the correct letter, **A**, **B** or **C**, in the box next to each spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.







(3)

(c) In the production of bioethanol, glucose ($C_6H_{12}O_6$) is converted into a dilute aqueous solution of ethanol and carbon dioxide.

Give the name of this process and state **three** essential conditions necessary to produce a good yield of ethanol.

.....

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

.....

(4)

(d) State the class of alcohols to which the diol butane-1,4-diol belongs.

Identify a suitable reagent or combination of reagents for the conversion of butane-1,4-diol into butanedioic acid ($HOOCCH_2CH_2COOH$).

Write an equation for this oxidation reaction using [O] to represent the oxidising agent.

.....

.....

.....

.....

.....

.....

.....

(Extra space) .....

.....

.....

(3)
(Total 15 marks)

5 The following instructions are from an experimental procedure for the preparation of cyclohexene from cyclohexanol and concentrated phosphoric acid.
Read these instructions and answer the questions that follow.

1 Place 25 cm^3 of cyclohexanol into a round-bottomed flask with some porous pot to act as anti-bumping granules. Add 10 cm^3 of concentrated phosphoric acid carefully while shaking the flask. Cool the flask under the tap if it gets too hot.
Make sure the reagents are thoroughly mixed.

2 Set up an apparatus for simple distillation using this flask.

3 Warm the flask, gently at first, for about 15 minutes. Then increase the heating so that cyclohexene begins to distil over. Collect the fraction that distils below 95 °C.

(a) State the purpose of the anti-bumping granules.

.....

.....

(1)

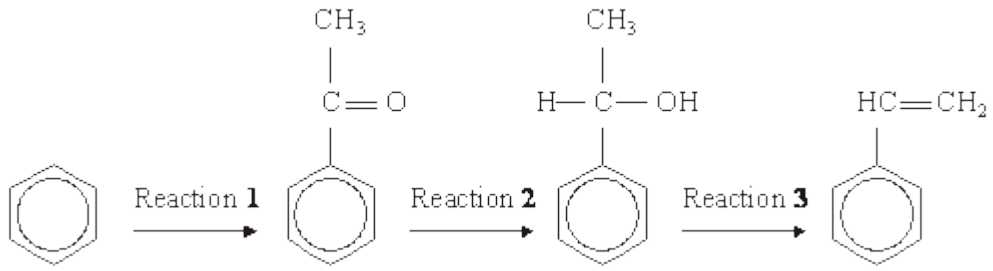
(b) Name the part of the distillation apparatus where cyclohexene vapour is changed back into a liquid.
Draw a simple diagram of this part of the apparatus.

Name .....

Diagram

(2)
(Total 3 marks)

6 A possible synthesis of phenylethene *(styrene)* is outlined below.



(a) In Reaction **1**, ethanoyl chloride and aluminium chloride are used to form a reactive species which then reacts with benzene.
Write an equation to show the formation of the reactive species.
Name and outline the mechanism by which this reactive species reacts with benzene.

(6)

(b) $NaBH_4$ is a possible reagent for Reaction **2**.
Name and outline the mechanism for the reaction with $NaBH_4$ in Reaction **2**.
Name the product of Reaction **2**.

(6)

(c) Name the type of reaction involved in Reaction **3** and give a reagent for the reaction.

(2)
(Total 14 marks)

7 Many naturally-occurring organic compounds can be converted into other useful products.

(a) Glucose, $C_6H_{12}O_6$, can be fermented to make ethanol, which can then be dehydrated to make the unsaturated compound, ethane.

(i) Write an equation for the fermentation of glucose to form ethanol.

.....

(ii) Identify a catalyst for the dehydration of ethanol to form ethene. Write an equation for this reaction.

Catalyst .....

Equation .....

(3)

(b) Vegetable oils, which contain unsaturated compounds, are used to make margarine. Identify a catalyst and a reagent for converting a vegetable oil into margarine.

Catalyst .....

Reagent .....

(2)

(c) Oleic acid can be obtained from vegetable oils. Oleic acid is an example of an unsaturated compound.

$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

oleic acid

(i) Deduce the molecular formula and the empirical formula of oleic acid.

Molecular formula .....

Empirical formula .....

(ii) State what is meant by the term *unsaturated*.

.....

(iii) Identify a reagent for a simple chemical test to show that oleic acid is unsaturated. State what you would observe when oleic acid reacts with this reagent.

Reagent ….....

Observation with oleic acid ……..

.....

(5)
(Total 10 marks)

8 Which one of the following reactions will produce an organic compound that has optical isomers?

A dehydration of butan-2-ol by heating with concentrated sulphuric acid

B reduction of pentan-3-one by warming with $NaBH_4$

C addition of Br_2 to 3-bromopropene

D reduction of 2,3-dimethylpent-2-ene with H_2 in the presence of a nickel catalyst

(Total 1 mark)

9 Glucose can be used as a source of ethanol. Ethanol can be burned as a fuel or can be converted into ethene.

$C_6H_{12}O_6 \rightarrow CH_3CH_2OH \rightarrow H_2C{=}CH_2$

glucose ethanol ethene

(a) Name the types of reaction illustrated by the two reactions above.

Glucose to ethanol .....

Ethanol to ethene .....

(2)

(b) (i) State what must be added to an aqueous solution of glucose so that ethanol is formed.

.....

(ii) Identify a suitable catalyst for the conversion of ethanol into ethene.

.....

(2)

(c) (i) State the class of alcohols to which ethanol belongs.

.....

(ii) Give **one** advantage of using ethanol as a fuel compared with using a petroleum fraction.

.....

(2)

(d) Most of the ethene used by industry is produced when ethane is heated to 900°C in the absence of air. Write an equation for this reaction.

.....

(1)

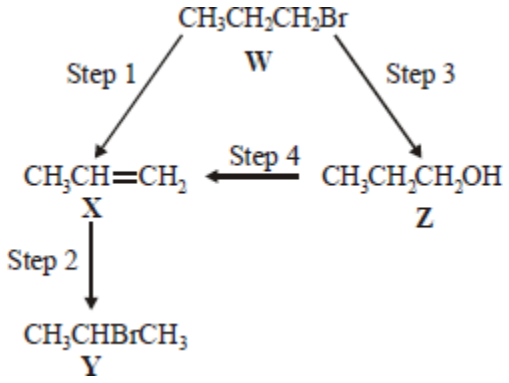
(e) Name the type of polymerisation which occurs when ethene is converted into poly(ethene).

.....

(1)

(Total 8 marks)

10 For this question refer to the reaction scheme below.



Which one of the following reagents would **not** bring about the reaction indicated?

A Step 1 : alcoholic KOH

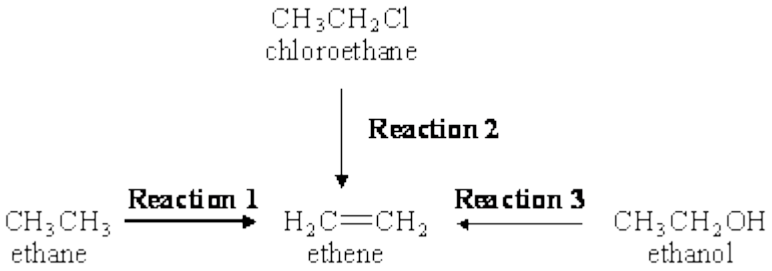
B Step 2 : aqueous Br_2

C Step 3 : aqueous NaOH

C Step 4 : concentrated H_2SO_4

(Total 1 mark)

11 Ethene is an important starting point for the manufacture of plastics and pharmaceutical chemicals. Most of the ethene used by industry is produced by the thermal cracking of ethane obtained from North Sea gas (**Reaction 1**). It is also possible to make ethene either from chloroethane (**Reaction 2**) or from ethanol (**Reaction 3**).



(a) Give essential conditions and reagents for each of **Reactions 2** and **3**.

(4)

(b) Name and outline a mechanism for **Reaction 2**. Suggest a reason why chloroethane is **not** chosen by industry as a starting material to make ethene commercially.

(5)

(c) Name and outline a mechanism for **Reaction 3**. Suggest why this route to ethene may become used more commonly in the future as supplies of North Sea gas begin to run out.

(6)

(Total 15 marks)

12 (a) One of the isomers in part (a) is resistant to oxidation by acidified potassium dichromate(VI).

(i) Identify this isomer.

.....

(ii) This isomer can be dehydrated. Give a suitable dehydrating agent and write an equation for this dehydration reaction.

Dehydrating agent.....

Equation .....

(3)

(b) (i) Identify the isomer in part (a) which can be oxidised to a ketone. Give the structure of the ketone formed.

Isomer .....

Structure of the ketone

(ii) Identify **one** of the isomers in part (a) which can be oxidised to an aldehyde. Give the structure of the aldehyde formed.

Isomer .....

Structure of the aldehyde

(iii) Give a reagent that can be used in a test to distinguish between a ketone and an aldehyde. State what you would observe in the test.

Reagent .....

Observation with ketone .....

.....

Observation with aldehyde .....

.....

(7)

(c) Butan-1-ol can be oxidised to form a carboxylic acid. Using [O] to represent the oxidising agent, write an equation for this reaction and name the product.

Equation .....

Name of product .....

(2)
(Total 12 marks)

13 (a) Ethanol can be manufactured by the direct hydration of ethene and by the fermentation of sugars.

(i) State what is meant by the term *hydration.*

.....

(ii) Give **one** advantage and **one** disadvantage of manufacturing ethanol by fermentation rather than by hydration.

Do **not** include energy consumption or cost.

Advantage .....

.....

Disadvantage .....

.....

(3)

(b) Ethanol can be oxidised to an aldehyde and to a carboxylic acid.

(i) Draw the structure of this aldehyde and of this carboxylic acid.

Structure of aldehyde *Structure of carboxylic acid*

(ii) Give a suitable reagent and reaction conditions for the oxidation of ethanol to form the carboxylic acid as the major product.

Reagent .....

Conditions .....

.....

(5)

(c) (i) Draw the structure of an alcohol containing four carbon atoms which is resistant to oxidation.

(ii) Draw the structure of an alcohol containing four carbon atoms which can be oxidised to a ketone.

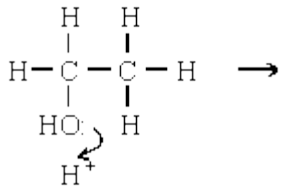
(2)

(d) In the presence of a catalyst, ethanol can be dehydrated to ethene.

(i) Give a suitable catalyst for use in this reaction.

.....

(ii) Complete the mechanism for this dehydration reaction.



(5)
(Total 15 marks)

14 (a) An alcohol containing carbon, hydrogen and oxygen only has 64.9% carbon and 13.5% hydrogen by mass. Using these data, show that the empirical formula of the alcohol is $C_4H_{10}O$

.....

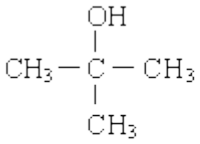
.....

.....

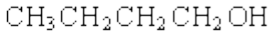
.....

(3)

(b) The structural formulae of two of the four possible alcohols of molecular formula $C_4H_{10}O$ are shown below.



Isomer 1



Isomer 2

(i) What type of alcohol is Isomer 1? Suggest a reason why this type of alcohol is not easily oxidised.

Type of alcohol .....

Reason .....

(ii) Draw the structural formulae of the two remaining alcohols of molecular formula $C_4H_{10}O$

Isomer 3 *Isomer 4*

(4)

(c) Isomer 2 was oxidised by adding it dropwise to acidified potassium dichromate(VI) solution and immediately distilling off the product. When this product was treated with Fehling's solution, a red precipitate was formed.

(i) State the type of product distilled off during the oxidation by acidified potassium dichromate(VI) solution.

.....

(ii) Write an equation for the oxidation by potassium dichromate(VI), showing clearly the structure of the organic product. Use [O] to represent the oxidising agent.

.....

(iii) Name and draw a structure for the organic product formed by the reaction with Fehling's solution.

Name .....

Structure .....

(5)

(d) State **one** advantage and **one** disadvantage of the production of ethanol by the hydration of ethene compared to the fermentation of glucose.

Advantage .....

Disadvantage .....

(2)

(e) Outline a mechanism for the dehydration of ethanol to form ethene in the presence of an acid catalyst.

(4)
(Total 18 marks)

15 (a) In the manufacture of margarine, unsaturated vegetable oils such as sunflower oil are hardened.

(i) State the reagent and conditions used in this process.

Reagent .....

Conditions .....

.....

(ii) Soft and hard margarines are obtained from the same vegetable oil. How does the structure and the melting point of a soft margarine differ from that of a hard one?

Difference in structure .....

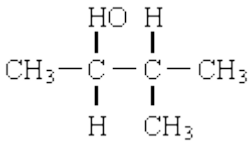
.....

Difference in melting point .....

.....

(5)

(b) In the presence of reagent **X**, the alcohol shown below undergoes a reaction to form two isomeric alkenes.



(i) Name this alcohol.

.....

(ii) Give the name of the type of reaction involved in the formation of the two alkenes.

.....

(iii) Suggest the identity of reagent **X**.

.....

(iv) Give the structural formulae of the two isomeric alkenes.

Alkene 1 *Alkene 2*

(5)
(Total 10 marks)

16 Which one of the following mechanisms is **not** involved in the reaction sequence below?

$CH_3CH_3 \rightarrow CH_3CH_2Cl \rightarrow CH_3CH_2OH \rightarrow CH_2{=}CH_2 \rightarrow CH_3CH_2Br$

A electrophilic addition

B electrophilic substitution

C nucleophilic substitution

D free-radical substitution

(Total 1 mark)

17 Which one of the following alcohols forms a mixture of alkenes when dehydrated?

A propan-1-ol

B propan-2-ol

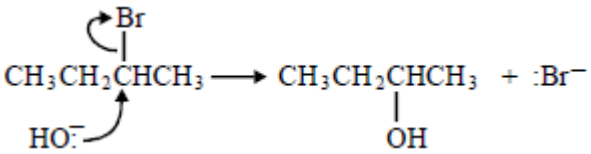
C pentan-1-ol

D pentan-2-ol

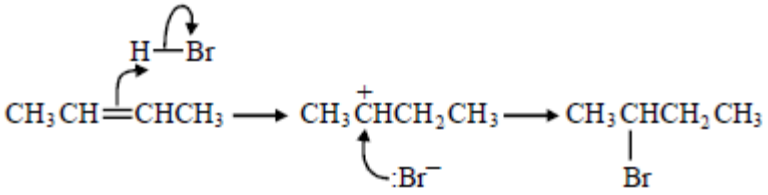
(Total 1 mark)

18 In which of the following is a curly arrow used incorrectly?

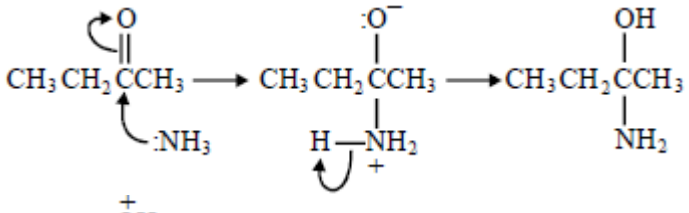
A



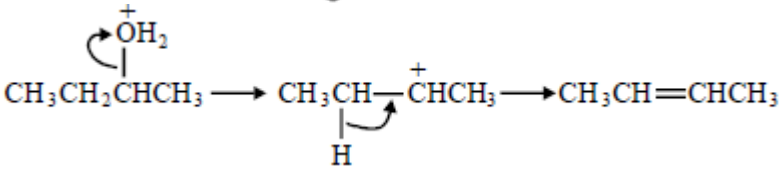
B



C



D

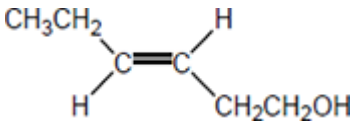


(Total 1 mark)

Mark schemes

1 D

[1]

2 (a) 

1

(b) 

1

(c) **Stage 1**: consider the groups joined to right hand carbon of the C=C bond

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

Consider the atomic number of the atoms attached

M1 can be scored in stage 1 or stage 2

1

C has a higher atomic number than H, so CH_2OH takes priority

1

Stage 2: consider the groups joined to LH carbon of the C=C bond

Both groups contain C atoms, so consider atoms one bond further away

1

C, (H and H) from ethyl group has higher atomic number than H, (H and H) from methyl group, so ethyl takes priority

1

Stage 3: conclusion

The highest priority groups, ethyl and CH_2OH are on same side of the C=C bond so the isomer is Z

Allow M5 for correct ECF conclusion using either or both wrong priorities deduced in stages 1 and 2

1

The rest of the IUPAC name is 3-methylpent-2-en-1-ol

1

(d) Moles of maleic acid = 10.0 / 116.0 = 8.62×10^{-2}

AND mass of organic product expected = $(8.62 \times 10^{-2}) \times 98.0 = 8.45$ g

Or moles of organic product formed = 6.53 / 98.0 = 6.66×10^{-2}

1

% yield = 100 × 6.53 / 8.45

OR = 100 × (6.66 × 10^{-2}) / (8.62 × 10^{-2})

= 77.294 = 77.3%

AND statement that the student was NOT correct

1

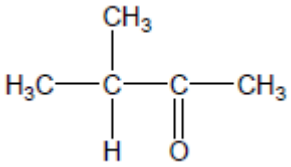
[10]

3

(a) 3-methylbutan-2-ol

1

(b)



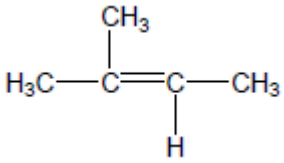
Allow $(CH_3)_2CHCOCH_3$

1

(c) Elimination

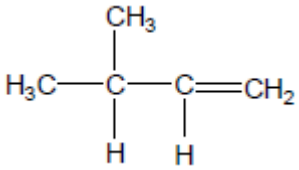
1

(d)



Allow $(CH_3)_2C{=}CHCH_3$

1



Allow $(CH_3)_2CHCH{=}CH_2$

1

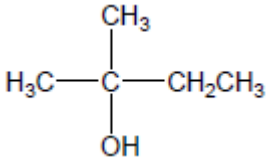
(e) Position

1

(f) C B A

1

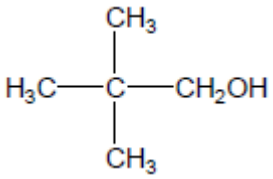
(g)



Allow $(CH_3)_2C(OH)CH_2CH_3$

1

(h)



Allow $(CH_3)_3CCH_2OH$

1

[9]

4 (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)

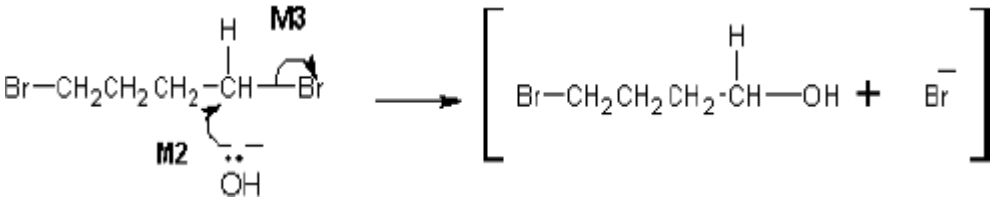
OR

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 acidified potassium or sodium dichromate

*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]

5

(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]

6

(a) $CH_3COCl + AlCl_3 \rightarrow CH_3\overset{+}{C}O + AlCl_4^-$

(1) equation (1)

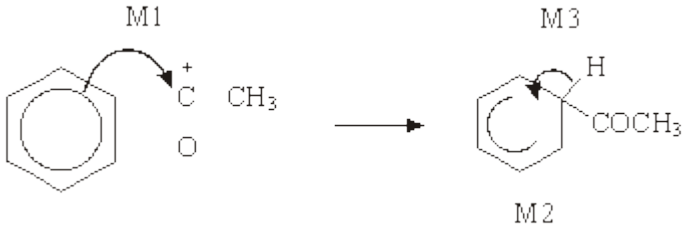
2

penalise wrong alkyl group once at first error
position of + on electrophile can be on O or C or outside [ ]
penalise wrong curly arrow in the equation or lone pair on $AlCl_3$ else ignore

Electrophilic substitution

NOT F/C acylation

1



horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1

M3 arrow into hexagon unless Kekule

allow M3 arrow independent of M2 structure

M1 arrow from within hexagon to C or to + on C

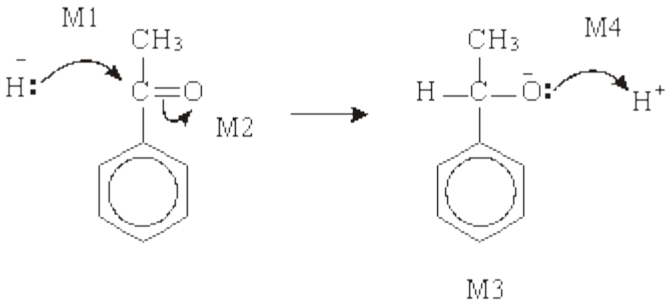
+ must be on C of $\overset{+}{R}CO$

3

(b) Nucleophilic addition

NOT reduction

1



M2 not allowed independent, but can allow M1 for attack of H^- on C+ formed

4

1–phenylethan(–1–)ol or (1–hydroxyethyl)benzene

1

(c) dehydration or elimination

1

(conc) H_2SO_4 or (conc) H_3PO_4

allow dilute and Al_2O_3

Do not allow iron oxides

1

[14]

7

(a) (i) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$;

(penalise C_2H_6O once only in this question)

1

(ii) Concentrated H_2SO_4 OR concentrated H_3PO_4 OR Al_2O_3;

(penalise aqueous or dilute as a contradiction)

1

$C_2H_5OH \rightarrow C_2H_4 + H_2O$ OR $C_2H_5OH \rightarrow H_2C = CH_2 + H_2O$;

(penalise $CH_2{\cdot}CH_2$ and CH_2-CH_2 and $CH_2 : CH_2$ for ethene)

1

(b) Nickel OR Ni OR platinum OR Pt OR palladium OR Pd;

1

Hydrogen OR H_2;

1

(c) (i) $C_{18}H_{34}O_2$ Only;

1

$C_9H_{17}O$ Only;

(empirical formula is not consequential on molecular formula)

1

(ii) (An unsaturated compound) contains (at least) <u>one double bond</u>

OR

Contains C=C;

(must be a positive statement)

1

(iii) M1: Bromine water

OR

Br_2(aq)

OR

Bromine

OR

Br_2;

(penalise "bromide water", but mark on)

1

M1: decolourised or goes colourless

OR

from brown/red/orange/yellow to colourless;

(Must be "colourless" not "clear" for M2)
(chemical error if no reagent or wrong reagent, loses both marks)
(credit $KMnO_4$ for M1, (purple) to colourless for M2 (if acidified) OR (purple) to brown/brown precipitate (if alkaline or unspecified) (No credit for hydrogen or iodine as reagents)

1

[10]

D
8

[1]

9 (a) M1 fermentation

1

M2 dehydration or elimination

1

(b) (i) yeast OR zymase OR an enzyme

1

(ii) <u>concentrated</u> sulphuric or phosphoric acid

(penalise aqueous or dilute as a contradiction)

1

(c) (i) primary or 1°

1

(ii) sugar or glucose or ethanol is renewable
OR ethanol does not contain sulphur-containing impurities
OR ethanol produces <u>less</u> pollution or is <u>less</u> smoky or <u>less</u> CO/C

(the objective is a positive statement about ethanol)
(penalise the idea that ethanol is an infinite source or vague statements that ethanol has less impurities) (penalise the idea that ethanol produces no pollution)

1

(d) $C_2H_6 \rightarrow C_2H_4 + H_2$

1

(e) Addition

(ignore self or chain as a preface to "addition ")
(penalise additional)

1

[8]

10 B

[1]

11 (a) <u>Reaction 2</u>: NaOH OR KOH **(1)** M1 alcohol (ic) OR ethanol (ic)**(1)** M2

ignore heat

Condition mark <u>linked to correct reagent</u> but award M2 if OH^- or base or alkali mentioned

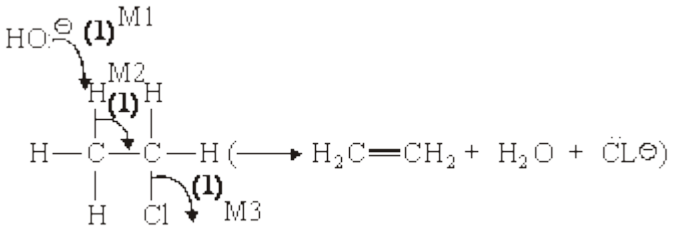
<u>Reaction 3</u>: concentrated H_2SO_4 OR H_3PO_4 M1 **(1)** heat **(1)** M2
OR 150°C - 200°C

Condition mark <u>linked to correct reagent</u> but award M2 if H_2SO_4 or H_3PO_4, but <u>not</u> concentrated

Penalise reagent <u>and</u> condition if dilute H_2SO_4 / H_3PO_4

4

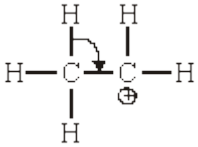
(b) Mechanism:



Award M3  *independently*

M1 and M2 must be to / from correct places

E1 mechanism possible in which M2



Name: of mechanism = elimination **(1)**

NOT dehydrohalogenation

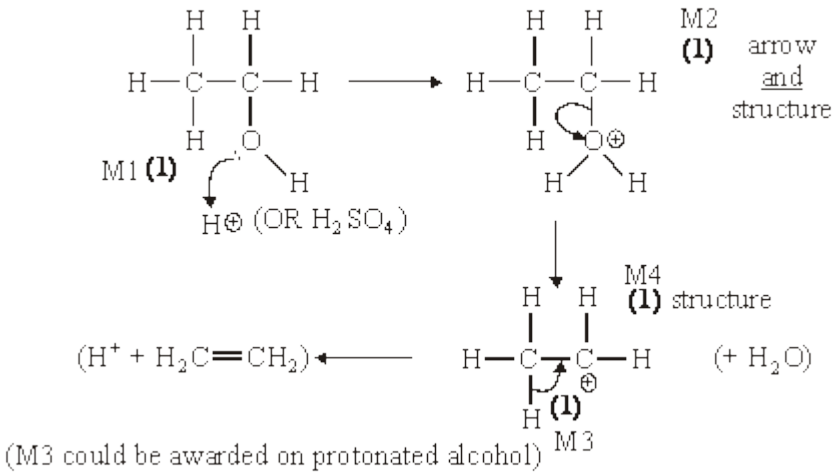
Ignore "base" OR "nucleophilic" before elimination

Reason: Reaction 2 has (very) low yield **(1)**

5

QoL OR chloroethane has to be made (from ethane)
OR chloroethane is expensive
OR chloroethane is not redily available

(c) Mechanism:



Name of mechanism = elimination **(1)**

NOT dehydration alone

Reason: Ethanol could come from (fermentation of) renewable

*QoL sugars / glucose / carbohydrates / sources **(1)***

6

[15]

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

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

ignore additional (aq)

Equation: $CH_3{-}C(CH_3)(OH){-}CH_3 \longrightarrow CH_3{-}C(CH_3){=}CH_2 + H_2O$ **(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:

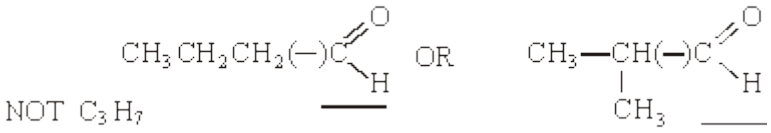
$CH_3\ CH_2(-)C(=O)(-)CH_3$ **(1)**

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

[look at name in table]

Wrong isomer = CE

Structure of the aldehyde:

Either 

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	<u>red solid</u> orange/<u>red</u> brown/ <u>red</u> <u>ppt/solid</u>

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.

(*)		<u>ketone</u>	<u>aldehyde</u>
	$K_2Cr_2O_7$ / 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]

13 (a) (i) addition 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

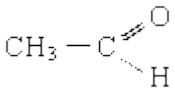
Disadvantage:
slow
low yield
significant land use
has to be distilled
labour intensive

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

3

(b) (i)

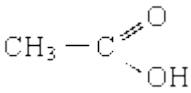
Structure of aldehyde



(1)

NOT CH_3CHO

Structure of carboxylic acid



(1)

NOT CH_3COOH

Penalise incorrect R group once

(ii) *Reagent*: sodium (/ potassium) dichromate <u>(VI)</u>
(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

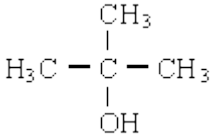
M3 mark independent

Credit $KMnO_4$ for M1

Ignore T and P for M2

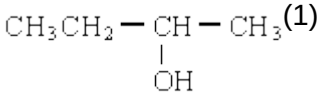
5

(c) (i)



(1)

(ii)



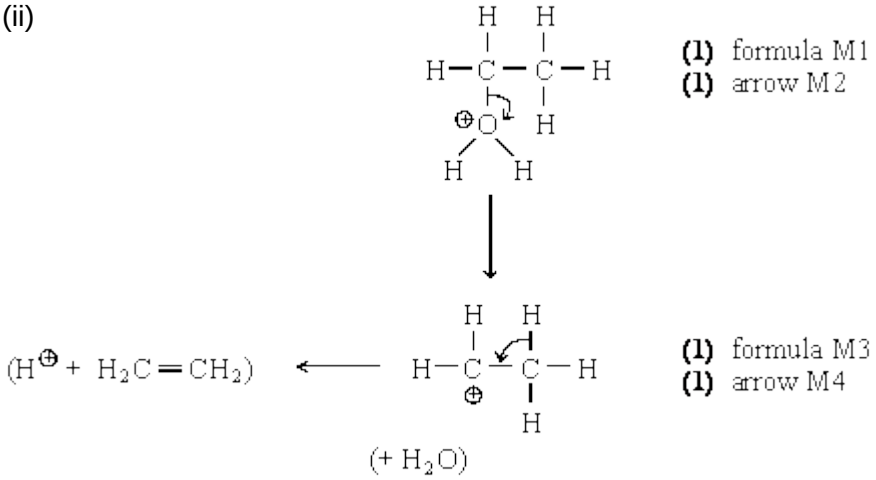
(1)

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]

14

(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

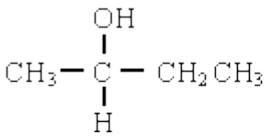
If percentage composition calculation done zero

3

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

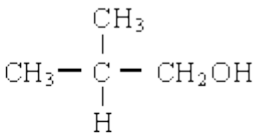
Reason: No hydrogen atom on central carbon **(1)**

(ii)



(1)

Isomer 3



(1)

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

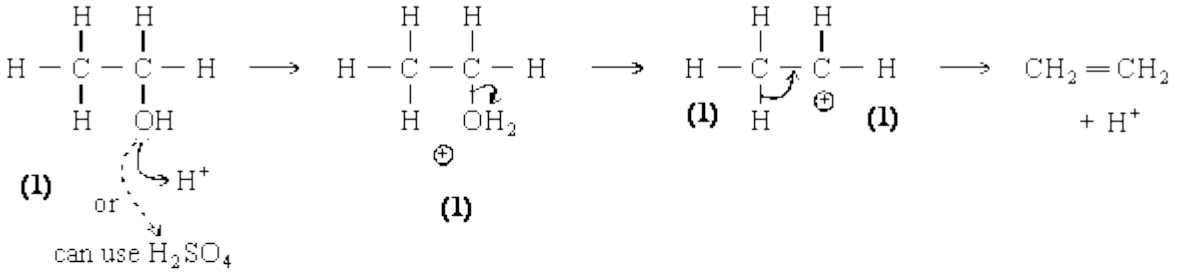
(d) *Advantage*: Fast reaction OR pure product OR continuous process OR cheap on manpower OR high yield, 100% alcohol **(1)**

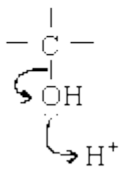
Disadvantage: High technology OR ethene from non renewable source OR expensive equipment not just costly **(1)**

Not answers based on fermentation

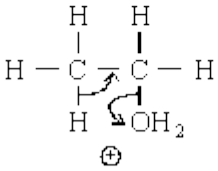
2

(e)





scores M1 only



scores M2 & M4
but not carbocation mark, M3.

4

[18]

15

(a) (i) *Reagent:* Hydrogen of H_2 **(1)**
Conditions: Ni (catalyst) *(Ignore Pt)* **(1)**
100 – 200 °C or heat **(1)**

Not 'high temp' or 'warm'
M1 = 0, M2 = 1 then M3 = 0 max
or M1 = M2 = 0 then M3 = 0
M3 tied to M1. Only award M3 if M1 earned

(ii) *Difference in structure:* soft margarine less hydrogenated or has more C=C bonds or is more unsaturated than hard margarine **(1)**
Difference in melting point: soft has lower melting point **(1)**

Must be comparison

5

(b) (i) 3-methylbutan-2-ol **(1)**

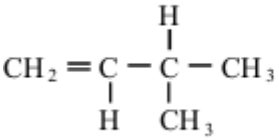
No alternatives

(ii) elimination or dehydration **(1)**

(iii) (c) H_2SO_4 or (c) H_3PO_4 – name or correct formula **(1)**

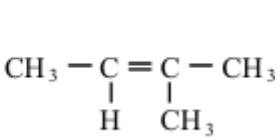
(iv)

Alkene 1



(1)

Alkene 2



(1)

Double bond must be shown
Accept any correct unambiguous structures
if but- 1-ene and but-2-ene offered, allow M2

5

[10]

16 B

[1]

17 D

[1]

18 C

[1]