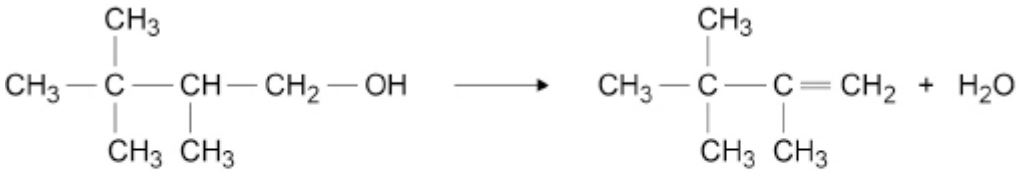
Q1.

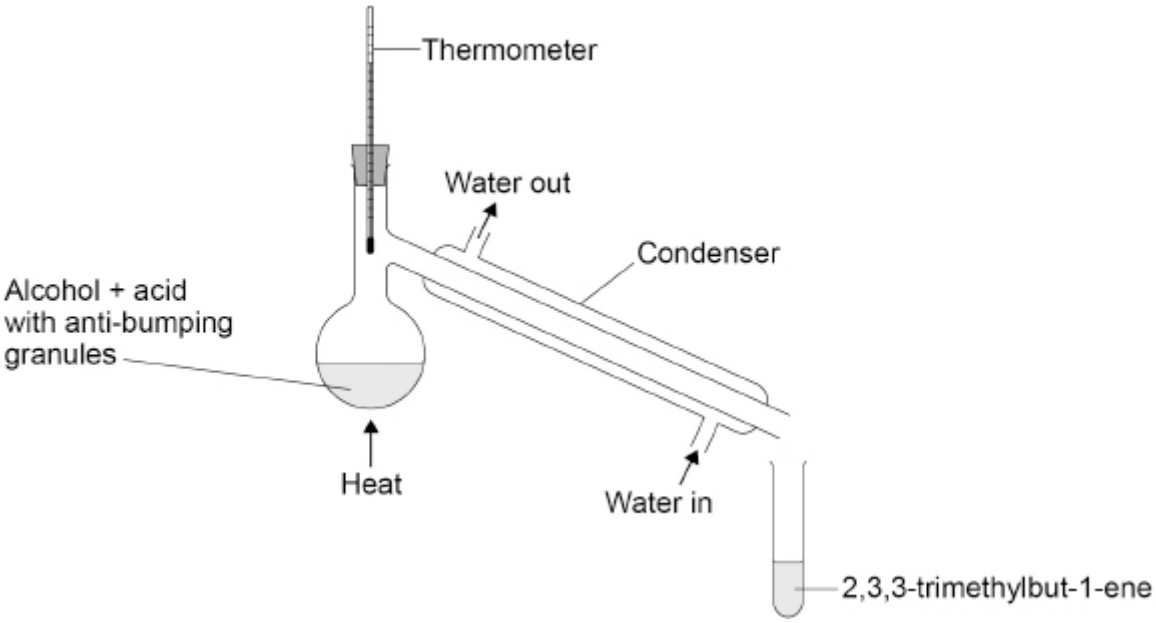
This question is about the preparation of 2,3,3-trimethylbut-1-ene.



2,3,3-trimethylbutan-1-ol 2,3,3-trimethylbut-1-ene

The preparation is done by heating the alcohol with concentrated phosphoric acid, that acts as a catalyst.

The figure below shows the apparatus used.



The distillate is collected in the range 77–82 °C

(a) Explain why the water should enter the condenser at the bottom and not at the top.

_____

_____

_____

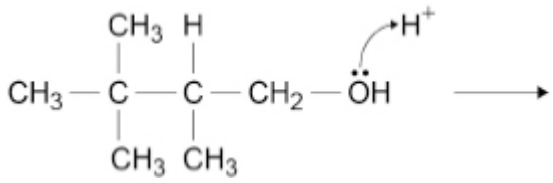
_____

_____

(2)

(b) Name and complete the mechanism for this reaction.

Name of mechanism _____



(4)

(c) In a similar experiment, 12.0 cm^3 of 2,3,3-trimethylbutan-1-ol (M_r = 116.0) produces 6.12 g of 2,3,3-trimethylbut-1-ene.

Calculate the percentage yield.

density of 2,3,3-trimethylbutan-1-ol = 0.818 g cm^{-3}

Percentage yield _____

(5)

(Total 11 marks)

Q2.

This question is about isomerism and the dehydration of alcohols.

Pentan-2-ol has the molecular formula $C_5H_{12}O$

(a) Draw the **displayed** formula of an unbranched position isomer of pentan-2-ol that can be dehydrated to form a single alkene.

(1)

(b) Draw the **skeletal** formula of a chain isomer of pentan-2-ol that can be dehydrated to form a mixture of alkenes.

(1)

(c) Draw the structure of an unbranched functional group isomer of pentan-2-ol.

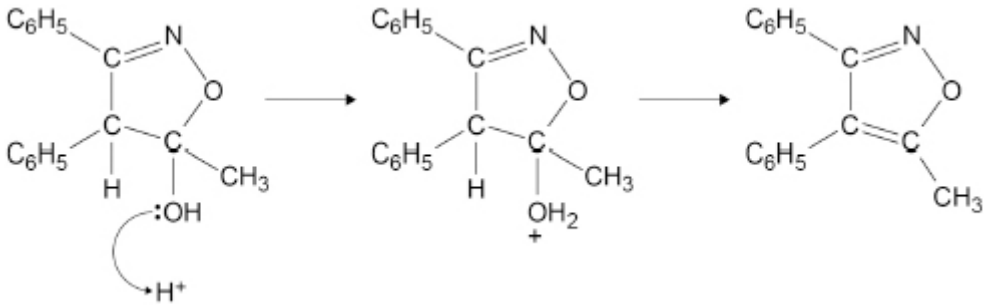
(1)

(d) Another isomer of pentan-2-ol is an alcohol that is **not** dehydrated when heated with concentrated sulfuric acid.

Draw the structure of this isomer.

(1)

(e) An incomplete mechanism for the dehydration of a compound is shown.



Complete the mechanism for this reaction by drawing two curly arrows on the intermediate.

Name the mechanism for this reaction.

_____

(3)

(f) An isomer of the final product can also form in the reaction in part (e).

Draw the structure of this isomer.

(1)

(Total 8 marks)

Q3.

In Europe, some of the glucose from crops is fermented to produce ethanol.

Use of a carbon-neutral fuel leads to no net emissions of carbon dioxide to the atmosphere.

(a) The ethanol produced by fermentation of glucose may be regarded as a carbon-neutral fuel.

Justify this statement. Include the relevant chemical equations in your answer.

(4)

Coffee beans from South America are exported to Europe in an outer layer called silverskin.

The waste silverskin can be fermented to produce a solution containing propanone, ethanol and butan-1-ol.

(b) Suggest why ethanol produced in Europe using silverskin from South America is less likely to be carbon-neutral than ethanol produced from crops grown in Europe.

(1)

(c) **Table 1** shows the enthalpies of combustion of the three fuels from the fermentation of silverskin.

Table 1

Fuel	**Standard enthalpy of combustion / kJ mol^{-1}**	**Energy released per mole of CO_2 produced / kJ**
ethanol, $C_2H_5OH(l)$	–1371	
butan-1-ol, $C_4H_9OH(l)$	–2673	
propanone, $C_3H_6O(l)$	–1786	

One way to measure a fuel's environmental impact is to measure the amount of energy released per mole of CO_2 produced.

Complete **Table 1**.

Use your answers to deduce the fuel with the lowest environmental impact by this measure.

_____

_____

(2)

(d) A student investigated the combustion of propanone (C_3H_6O) using calorimetry.

A copper calorimeter containing water was heated by the complete combustion of some propanone. The student did not record the final temperature of the water.

Table 2 shows the student's results.

Table 2

Mass of propanone burned / g	1.18
Mass of water / g	260
Initial temperature of water / °C	22.3
Final temperature of water / °C	Not recorded

Use the results in **Table 2** to calculate a value for final temperature of the water in the experiment.

Assume that no heat was lost in the experiment and that the heat capacity of the calorimeter is negligible.

For propanone, enthalpy of combustion = –1786 kJ mol^{-1}

For water, specific heat capacity = 4.18 J g^{-1} K^{-1}

Final temperature of water _____ °C

(4)

(e) Butan-1-ol can be added to petrol for cars.

An equation for the complete combustion of gaseous butan-1-ol is shown.

$C_4H_9OH(g) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(g) \quad \Delta H = -2504\ kJ\ mol^{-1}$

Table 3 shows some mean bond enthalpy data.

Table 3

Bond	C=O	C–H	C–O	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	805	412	360	463	496

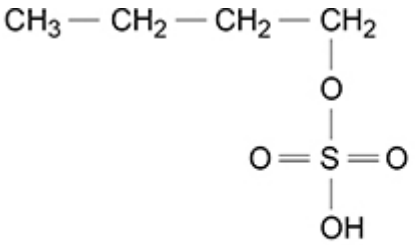
Use these data to calculate a value for the mean C–C bond enthalpy in gaseous butan-1-ol.

C–C bond enthalpy _____ kJ mol^{-1}

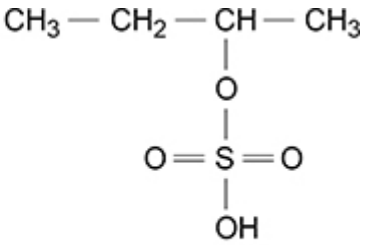
(3)

Butan-1-ol can be manufactured by reacting steam with but-1-ene in the presence of the catalyst, concentrated sulfuric acid.

In the first part of this process, but-1-ene reacts with concentrated sulfuric acid to form compounds **W** and **X**.



Compound **W**



Compound **X**

Butan-1-ol is then made from compound **W**.

(f) Name and outline a mechanism to show the conversion of but-1-ene into compound **W** in the first part of this process.

Name of mechanism _____

Outline of mechanism

(5)

(g) There is a very low yield of butan-1-ol from but-1-ene in this manufacturing process.

Explain why.

_____

_____

_____

_____

(2)

(Total 21 marks)

Q4.

This question is about the preparation of hexan-2-ol.
Hexan-2-ol does not mix with water and has a boiling point of 140 °C

Hexan-2-ol can be prepared from hex-1-ene using this method.

a Measure out 11.0 cm^3 of hex-1-ene into a boiling tube in an ice bath.

b Carefully add 5 cm^3 of concentrated phosphoric acid to the hex-1-ene.

c After 5 minutes add 10 cm^3 of distilled water to the mixture and transfer the boiling tube contents to a separating funnel.

d Shake the mixture and allow it to settle.

e Discard the lower (aqueous) layer.

f Add a fresh 10 cm^3 sample of distilled water and repeat steps **d** and **e**.

g Transfer the remaining liquid to a beaker.

h Add 2 g of anhydrous magnesium sulfate and allow to stand for 5 minutes.

i Filter the mixture under reduced pressure.

j Distil the filtrate and collect the distillate that boils in the range 130–160 °C

(a) It is important to wear eye protection and a lab coat when completing this experiment.

Suggest, with a reason, **one** other appropriate safety precaution for this experiment.

Precaution _____

Reason _____

_____

(2)

(b) Give a reason for adding the distilled water in steps **c** and **f**.

_____

_____

(1)

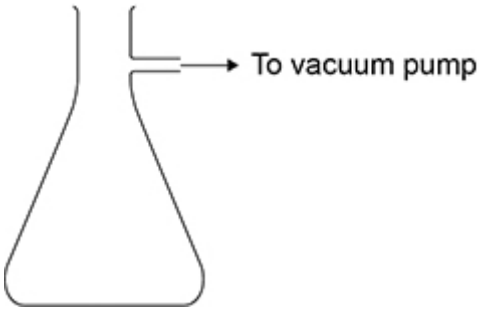
(c) Give a reason for adding anhydrous magnesium sulfate in step **h**.

_____

_____

(1)

(d) Complete and label the diagram of the apparatus used to filter the mixture under reduced pressure in step **i**.



(2)

(e) Identify the most likely organic impurity, other than hex-1-ene, in the distillate collected in step **j**.

Suggest **one** reason why it could be difficult to remove this impurity.

Impurity _____

Reason _____

_____

(2)

(f) Calculate the mass, in g, of hexan-2-ol formed from 11.0 cm^3 of hex-1-ene if the yield is 31.0%

Give your answer to 1 decimal place.

Density of hex-1-ene = 0.678 g cm^{-3}

Mass _____ g

(4)

(Total 12 marks)