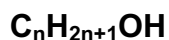
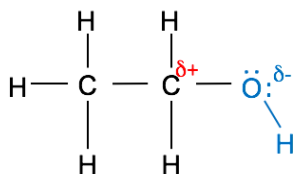

3.5 The Alcohols

Introduction:

General formula



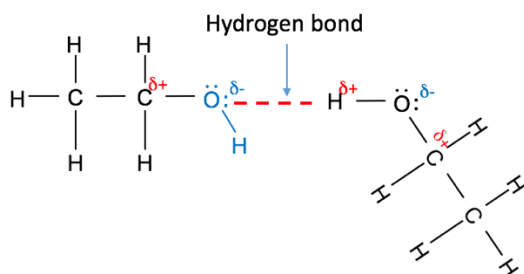
Reactivity



The more electronegative oxygen produces a polar bond

This makes the alcohols more reactive

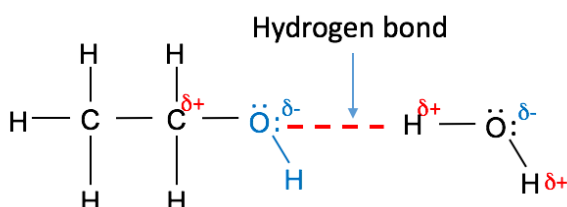
Boiling points



They can form hydrogen bonds with each other

This gives the alcohols a higher boiling point than their corresponding alkanes

Solubility

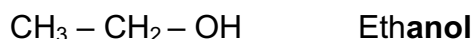


They can form hydrogen bonds with water

This makes the first 3 alcohols soluble in water. After that, the long alkyl chain interferes with the H bonds

Naming the alcohols

- The suffix '**ol**' is used, as it starts with a vowel, we insert '**an**' between the stem and the suffix:-



- For the above examples numbers are not required. However, after these the OH can be in different positions, **position isomers**:



Naming alcohols

Give the IUPAC name of the following alcohols:

Alcohol	IUPAC name
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	
$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$	
$\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$	

Draw the structure of the following alcohols:

Alcohol	Structural formula	Skeletal formula
Propan – 2 – ol		
Pentan – 2 – ol		
Hexan – 1,3 – diol		

Complete the table below for pentan – 1 – ol

Structural formula	Position Isomer	Chain Isomer

Classification of alcohols:

- Alcohols can be classified as primary, secondary or tertiary based upon their structures.
- The reactions of the alcohols can depend upon its structure and therefore classification so it is important you can classify them

Primary (1°)	<p>Methanol</p> <p>Butan-1-ol</p>	Primary (1°) alcohol. The OH carbon (*) is attached to 1 other carbon atom.
Secondary (2°)	<p>2-propanol</p>	Secondary (2°) alcohol. The OH carbon (*) is attached to 2 other carbon atoms.
Tertiary (3°)	<p>2-methyl-2-propanol</p>	Tertiary (3°) alcohol. When the OH carbon (*) is attached to 3 other carbon atoms.

Draw the following molecules as structural formula and classify them as 1°, 2° or 3°

a. Propan-2-ol

b. 2-methylpropan-2-ol

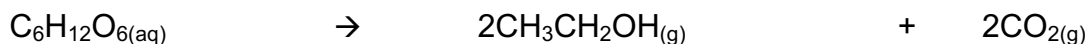
c. Propan-1-ol

d. 3-methyl hexan-3-ol

Making ethanol

- Ethanol is made in 1 of 2 ways:

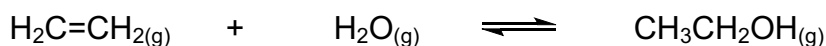
1) Fermentation:



Conditions: Yeast / anaerobic conditions (without oxygen) / 30 – 40°C

- Fermentation is exothermic.
- At low temperatures the reaction is slow.
- At high temperatures the enzymes in yeast are denatured.
- When the ethanol concentration reaches 15%, the alcohol kills the yeast.
- Fractional distillation is required to purify ethanol.

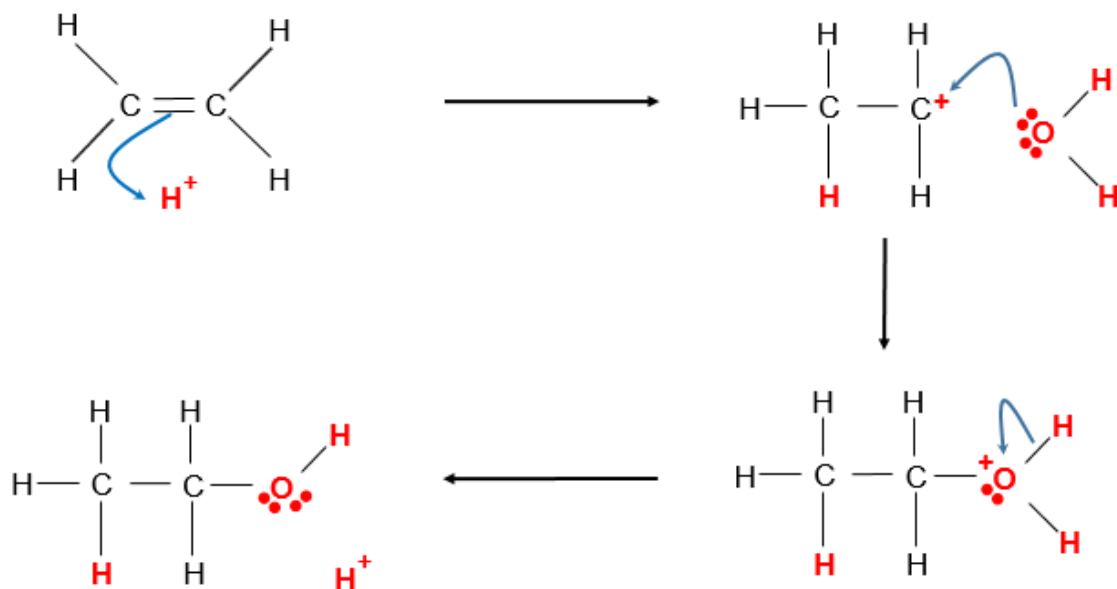
2) Hydration of ethene:



Conditions: Steam / 300°C / 60 atm / solid H_3PO_4 catalyst

- This is a reversible reaction and only about 5% of ethene is converted to ethanol.
- Unreacted gases are recycled - this gives a 95% conversion.

The mechanism:



- This mechanism was covered in the alkenes.

Comparing the processes:

Process	Hydration of Ethene	Fermentation
Raw material	Ethene from crude oil – finite – non renewable	Sugar – renewable resource
Quality of product	Pure	Impure – requires fractional distillation
Rate of reaction	Fast	Slow
Type of process	Continuous	Batch
Costs	High set up cost / low labour costs – Low cost	Low set up costs / high labour costs – High cost

Use of alcohols:

Ethanol as a fuel:

- Ethanol can make up 10% of petrol, it gives it a higher octane rating so burns more efficiently.
- As the ethanol is made from a biological material, it can be described as a **biofuel** or **bioethanol** and can be added to petrol

Advantages	Disadvantages
Sugar – renewable resource, not finite like oil	Food vs Fuel
Carbon neutral – only release the same amount of CO ₂ that was absorbed in photosynthesis	Deforestation to grow crop – removes trees that absorb CO ₂
	Trees from deforestation are often burnt – CO ₂ released
	Loss of habitats
	Fertilisers used – can pollute water systems / produce NO (greenhouse gas)
	Modern car engines need to be modified

Carbon neutral

1. Photosynthesis



2. Fermentation



3. Combustion

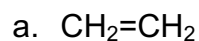


Overall: The amount of CO_2 taken in through photosynthesis is equal to the amount of CO_2 released through fermentation and combustion

However: This process will require machinery which will inevitably be run from the use of fossil fuels which will produce CO_2

Questions:

1) Write balanced chemical reactions for the hydration of:



c. Explain why you would get 2 possible alcohols when $\text{CH}_3\text{CH}=\text{CH}_2$ undergoes hydration. Use balanced chemical reactions in your answer.

d. Outline the mechanism for the hydration of $\text{CH}_3\text{CH}=\text{CH}_2$

2) State and explain the trend in solubilities of the alcohols. Draw a labelled diagram to illustrate your answer.

3) For each of the 2 processes, give one advantage and one disadvantage for the production of alcohols.

Process	Advantage	Disadvantage
Fermentation		
Hydration		

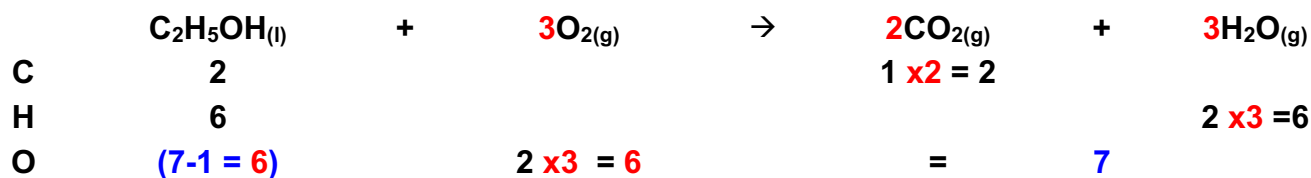
Reactions of the alcohols

There are 3 types of reactions of the alcohols:

- 1) Combustion
- 2) Dehydration (elimination)
- 3) Oxidation

1. Combustion

- In a plentiful supply of oxygen, alcohols will burn to form carbon dioxide and water.
- Balancing is more tricky due to the oxygen in the alcohol.



- You have to **take one oxygen away** before you multiply the O_2 's up

Have a go at the following:

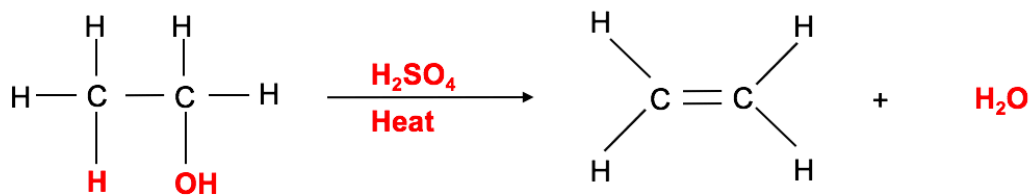
- Complete combustion of methanol

- Complete combustion of pentan – 1 – ol

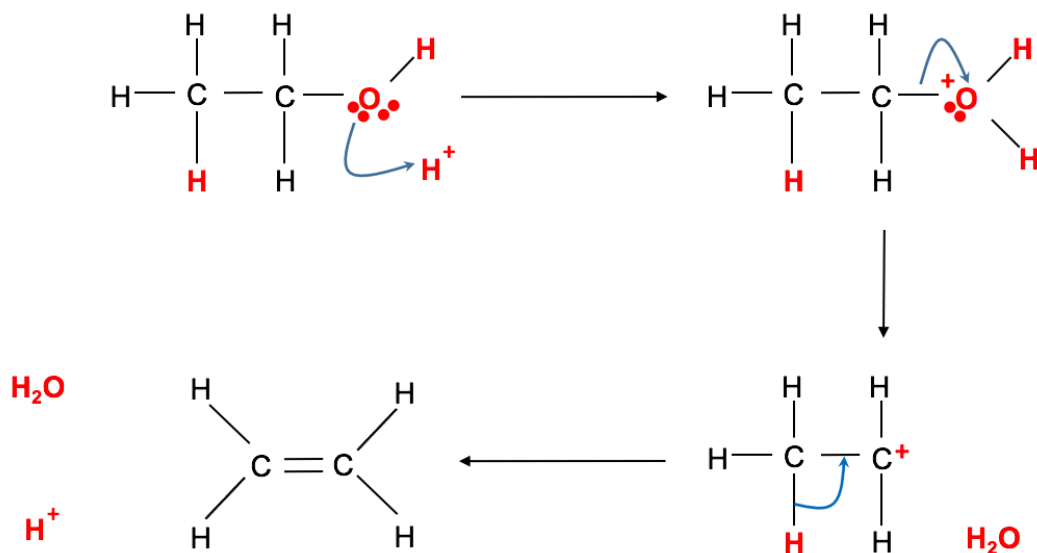
- Incomplete combustion of ethanol

- Incomplete combustion of propan – 2 – ol

2. Dehydration of an alcohol – Elimination reaction



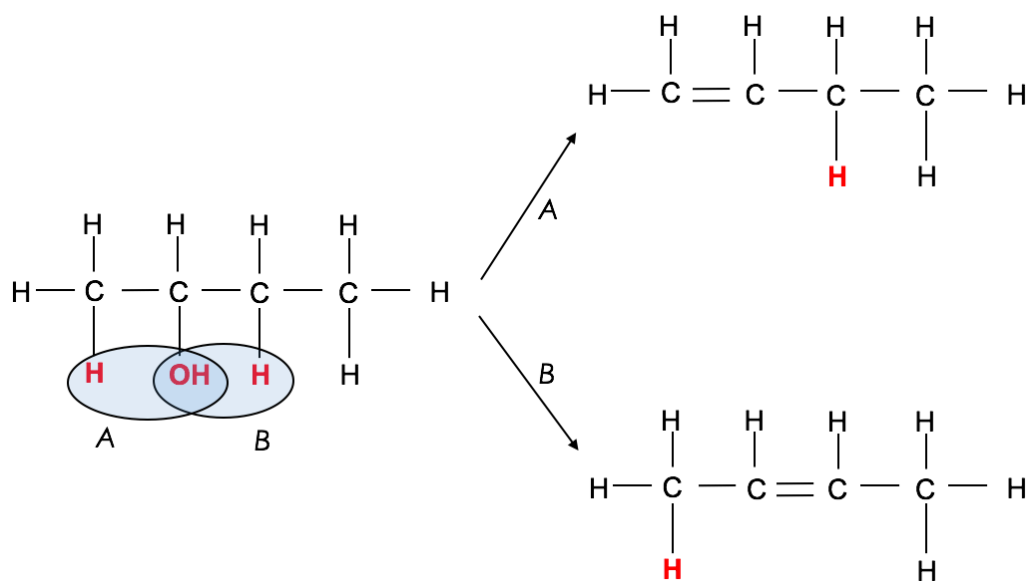
The mechanism:



- The catalyst is concentrated sulphuric acid, H_2SO_4
- The reaction requires heat

Unsymmetrical alcohols

- Dehydration of unsymmetrical alcohols gives rise to 2 alkenes, **position isomers**

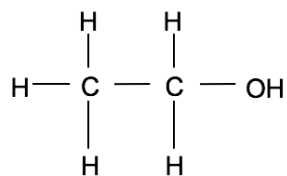


- The dehydration using 'B' would also give **E/Z isomerism**

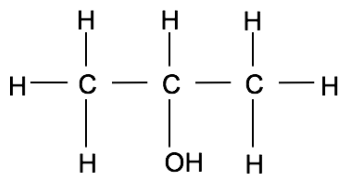
Questions:

1) Draw and name the organic products formed from the dehydration of the following alcohols

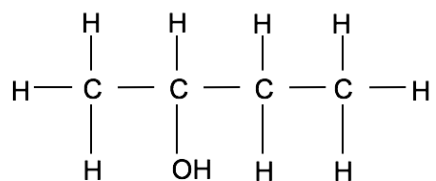
a.



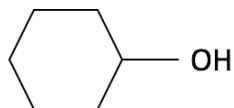
b.



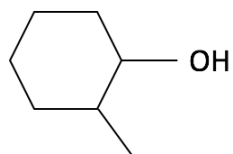
c.



d.



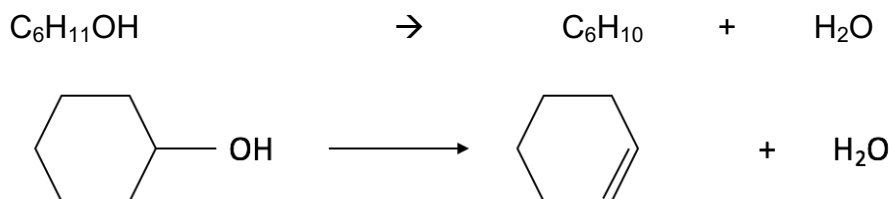
e.



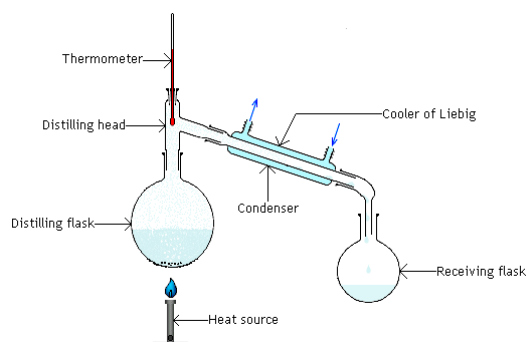
2) Draw the mechanism for the reaction in 1b

Required Practical 5 – Purification of a product

Dehydration of an alcohol



1) Heat and 1st distillation



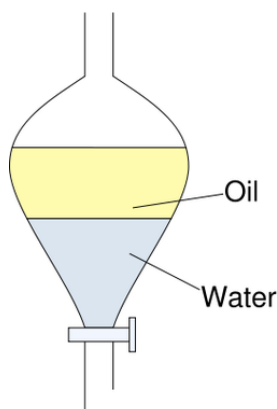
- The heat for the reaction is provided from a distillation process.
- The reason that distillation is used as the source of heat is that the product can be distilled off as it forms.
- The product is usually in a water / acid / reactant mixture.

Intermolecular forces of the reaction mixture

Cyclohexanol	Water	Sulphuric acid	Cyclohexene
H - Bonding	H - Bonding	H - Bonding	Van Der Waals
Strong – High boiling point	Strong – High boiling point	Strong – High boiling point	Weak – Low boiling point

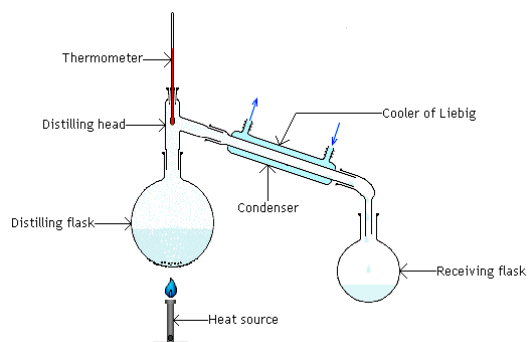
- The alkene only has the weakest VDW forces of attraction it will evaporate 1st
- This allows the crude alkene to be collected as it is formed at its boiling point – 83°C

2) Separation



- The crude cyclohexene will contain water soluble impurities that need separating from the alkene.
- The cyclohexene is transferred to a separating funnel.
- Water is added to the separating funnel and shaken to remove water soluble impurities from the cyclohexene and transfer them to the water.
- Allow to settle. The cyclohexene (hydrocarbon) is less dense than water and does not mix due to their different intermolecular forces.
- Run off the aqueous layer (waste)

3) Purification – 2nd distillation



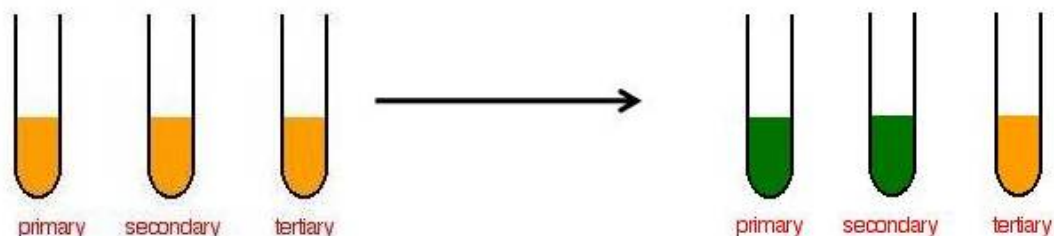
- Pour the cyclohexene into a round bottom flask.
- Add CaCl_2 – a drying agent. This removes any droplets of water trapped in the cyclohexene, allow 20 minutes for this.
- Any other (hydrocarbon based) impurities are removed from a 2nd distillation.
- Only the liquid around cyclohexene's boiling point is collected.
- This is the pure cyclohexene.

3. Oxidation of alcohols:

The oxidising agent – Potassium dichromate (VI) / sulphuric acid



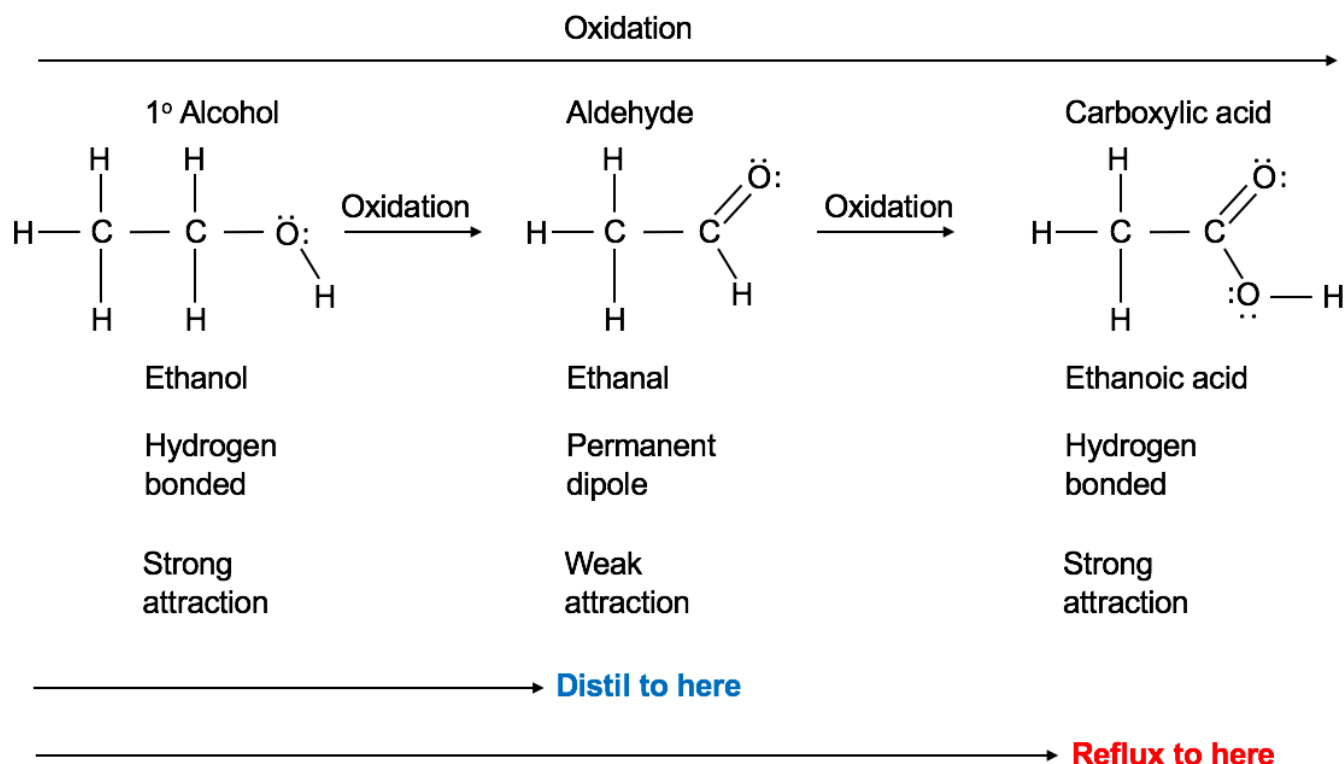
- This is orange in colour and is a mixture of Sulphuric acid, H_2SO_4 (H^+) and $\text{K}_2\text{Cr}_2\text{O}_7$.
- When added to primary, secondary and tertiary alcohols we get different results:



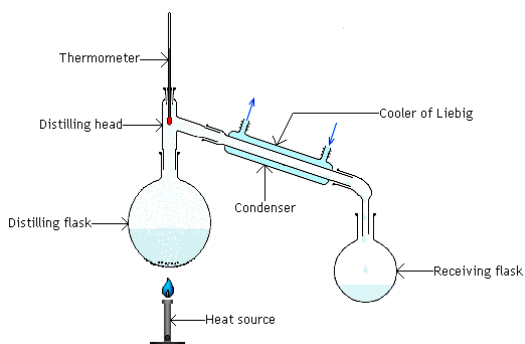
- The results show that only **primary** and **secondary alcohols** can be **oxidised** / tertiary alcohols cannot be oxidised.

a) Primary alcohols

- Primary alcohols when oxidised form an **Aldehyde** first
- Then oxidise further to a **Carboxylic acid**:



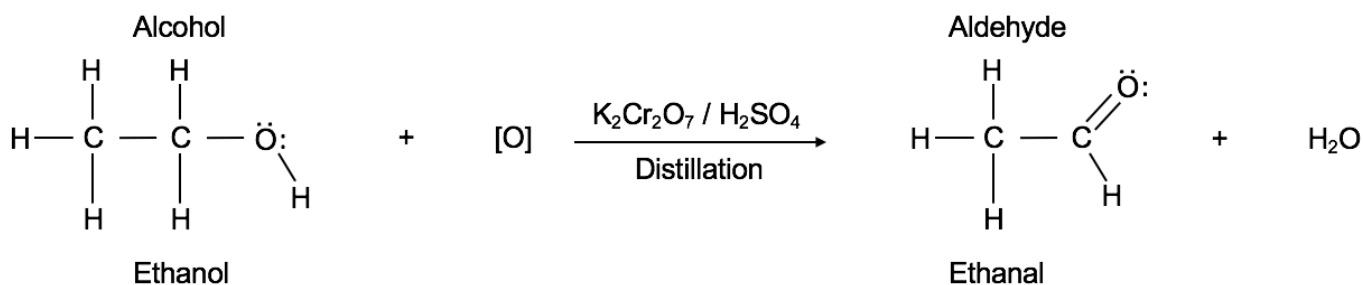
i) Primary alcohol → Aldehyde:



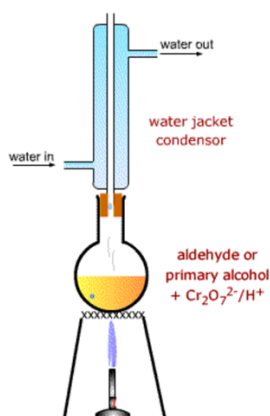
- The aldehyde has to be distilled off as it forms to prevent further oxidation.
- As it has the weakest intermolecular force it evaporates first.

Balanced chemical reaction:

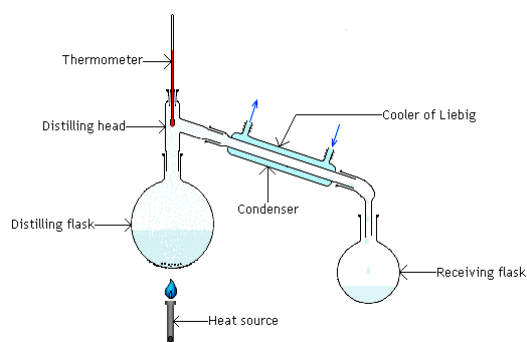
- [O] is used as the oxidising agent and used to balance the chemical equation
- Balance H first with H₂O
- Then O with [O]



ii) Primary alcohol → Carboxylic acid:



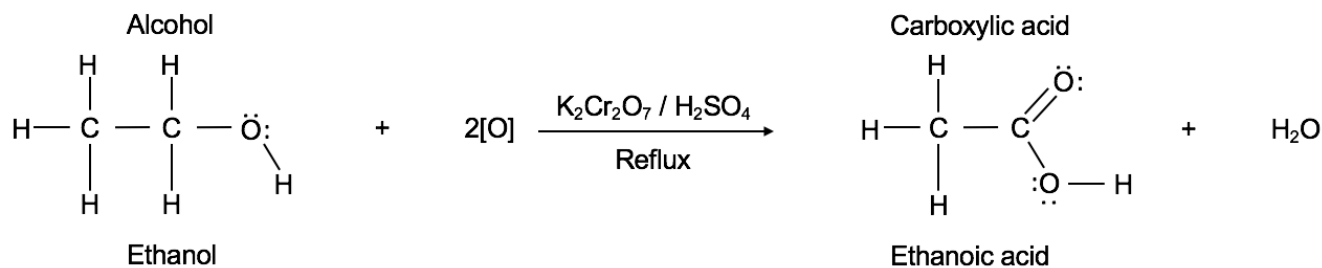
- The mixture is refluxed. Anything that evaporates is condensed back into the reaction mixture.
- We don't worry about further oxidation of the aldehyde as we want this to oxidise further to form the carboxylic acid.



- The carboxylic acid is then distilled off from the mixture

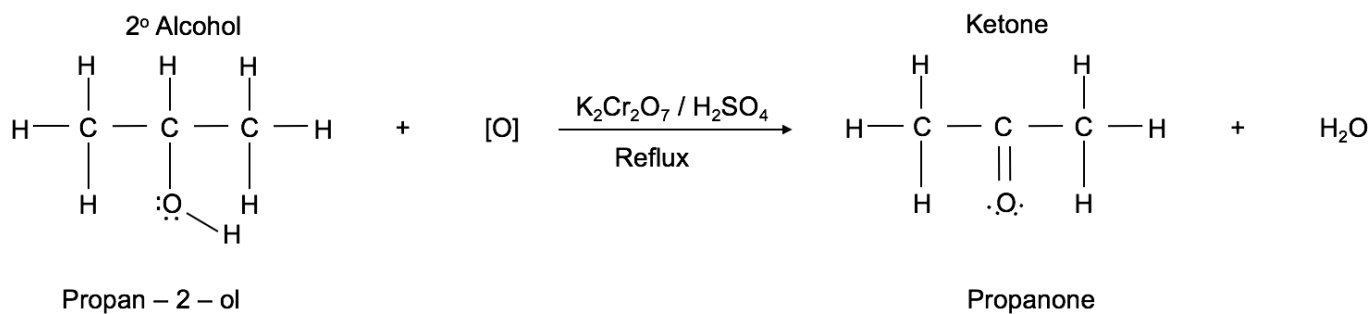
Balanced chemical reaction:

- Balance H first with H₂O
- Then O with [O]



b) Secondary alcohols:

- secondary alcohols only oxidised to form a **Ketone**
- Balance H first with H₂O
- Then O with [O]



c) Tertiary alcohols:

- These cannot be oxidised with sodium dichromate (VI) / sulphuric acid.
- They are only oxidised by combustion.

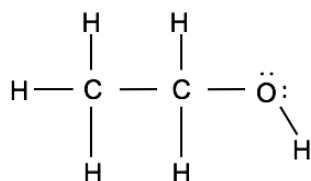
Summary of alcohol oxidation

1° alcohol → Aldehyde → Carboxylic acid

2° alcohol → Ketone

3° alcohol

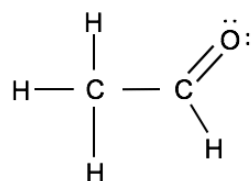
1° Alcohol



Ethanol

Oxidation

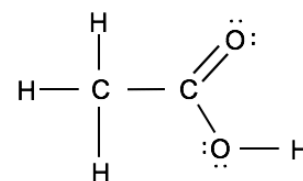
Aldehyde



Ethanal

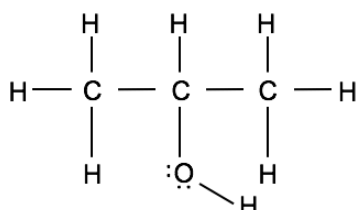
Oxidation

Carboxylic acid



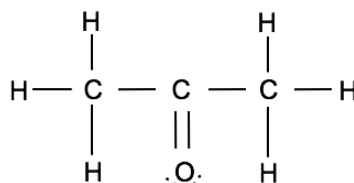
Ethanoic acid

2° Alcohol



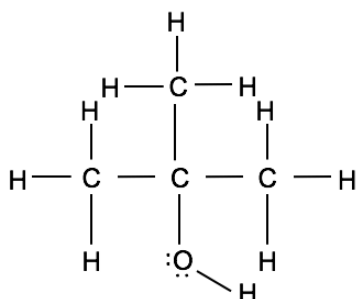
Propan-2-ol

Oxidation



Propanone

3° Alcohol



2-methyl Propan-2-ol

Questions:

1) Classify the following alcohols as primary, secondary or tertiary:

- a. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- b. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$
- c. $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2$
- d. Pentan – 2 – ol
- e. Butan – 1 – ol
- f. 2 – Methyl propan – 2 – ol

2) Draw the oxidation products of the alcohols in question 1:

a.

b.

c.

d.

e.

f.

3) Write balanced chemical reactions for:

a. Oxidation of $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

b. Oxidation of $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$

c. Oxidation of $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2$

d. Oxidation of Pentan – 2 – ol

e. Partial oxidation of Butan – 1 – ol

4) State and explain the process to oxidise the alcohol in question 3e

- 5) An unknown alcohol with molecular formula C_3H_8O was oxidised using $K_2Cr_2O_7 / H_2SO_4$. The oxidation product collected and tested:

The oxidation product was added to $AgNO_3$ dissolved in ammonia and heated. The inside of the tube gave a silver precipitate.

- What functional group must the oxidation product have?
- Suggest a structure and name the oxidation product.
- Suggest a structure and name the unknown alcohol.
- Write a balanced chemical equation for the oxidation of the unknown alcohol. Use $[O]$ as the oxidising agent to balance the reaction.
- What colour change would be observed during the oxidation reaction, explain your answer.
- Write an ionic equation to show what happened to the silver ions in the test.
- Draw the organic product formed after the reaction with $AgNO_3$.