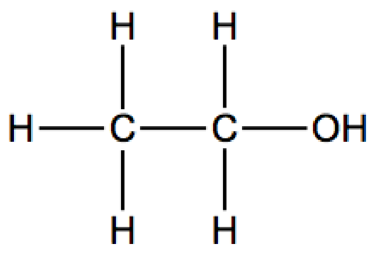
Alcohols

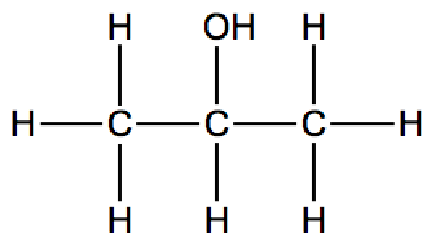
Click here for oxidation of alcohols

Alcohols contain the hydroxyl functional group **OH**.

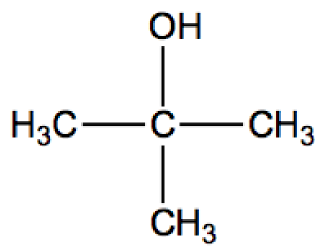
Hydrogen bonding: gives them reasonably high boiling points and the short-chained alcohols will be soluble in water.



primary



secondary



tertiary

To distinguish between primary, secondary and tertiary, look at the carbon directly bonded to the OH. Then ask **how many carbons are attached to this carbon**?

Primary: only **one** carbon attached to the C-OH

Secondary: two carbons attached to the C-OH

Tertiary: no carbons attached to the C-OH

Or alternatively, you can do it by the number of hydrogens attached to the C-OH.

Primary: two or three hydrogens attached to the C-OH

Secondary: one hydrogen attached to the C-OH

Tertiary: no hydrogens attached to the C-OH

Ethanol Production

There are two methods: **fermentation of glucose** (the natural way) and **hydration of ethene** (the chemistry/laboratory way).

1. Fermentation of glucose

Yeast is used as a catalyst at 35-55^oC:

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

This reaction is an example of a **biofuel:**

a fuel produced from a renewable energy source

Pros:

- "green" process as no crude oil is involved or toxic chemicals
- **sugar cane** is the raw material (renewable)
- the process doesn't require much energy

Cons:

- the process is very slow
- the vessel has to be continuously emptied
- equation shows CO_2 given out (not carbon neutral)
- the ethanol obtained isn't anywhere near as pure as from method 2 below

Carbon neutral:

no net CO_2 emissions to the atmosphere

We mentioned above that CO_2 is given out and therefore fermentation is not carbon neutral. But if you look at the **overall process** from the raw material, it can be viewed as carbon neutral.

Initially, the plants (raw material) will absorb CO_2 during photosynthesis:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

CO_2 is produced during fermentation:

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

Even more CO_2 is given out when the ethanol is used as a fuel:

$$2C_2H_5OH \;+\; 6O_2 \rightarrow 4CO_2 \;+\; 6H_2O$$

Overall:

From the above questions, you can see that **$6CO_2$ is taken in** from the atmosphere and **$6CO_2$ is put back out** to the atmosphere, therefore the **net change is zero**. Therefore you could say it is carbon neutral.

But a lot of energy is used in the process and there are likely to be CO_2 emissions involved with those, therefore it *still* isn't truly carbon neutral.

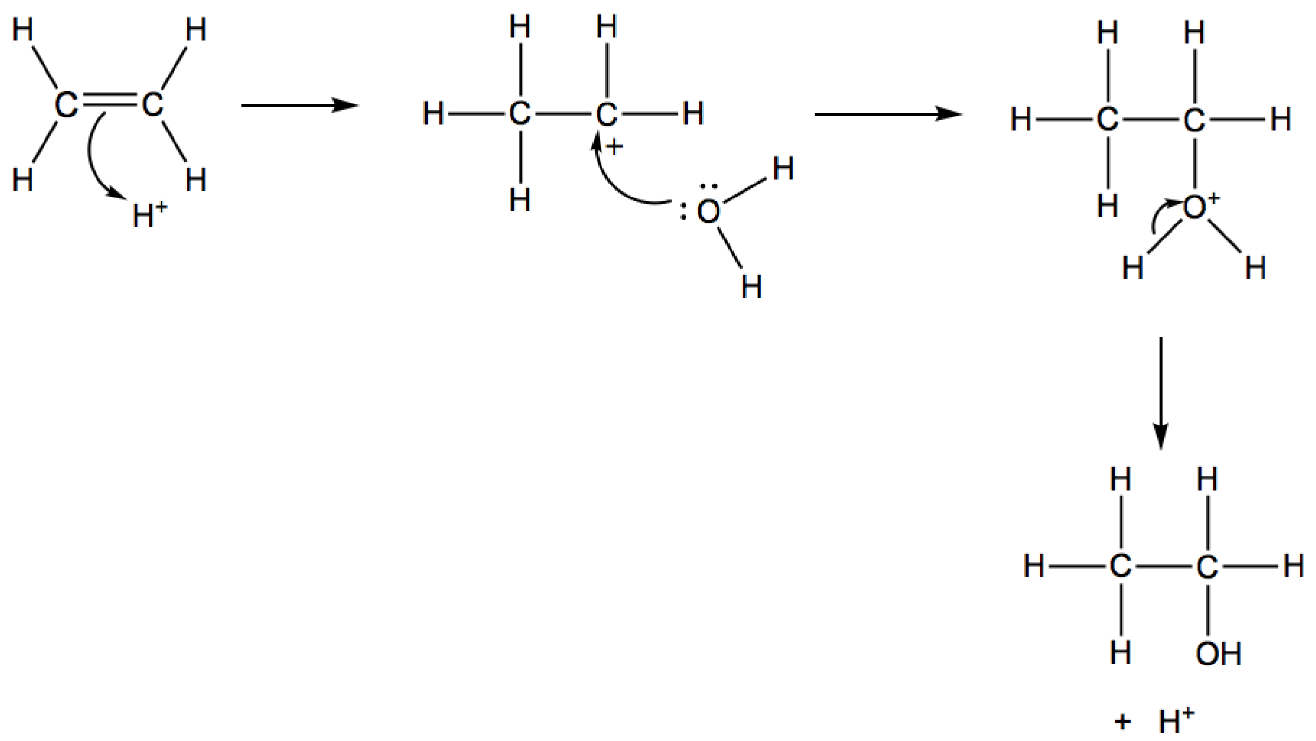
2. Addition of steam to ethene (hydration)

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

Water is added to the C=C bond of ethene in a laboratory. But adding (or removing) water is difficult to do, so quite severe conditions are needed:

- **acid catalyst (H_3PO_4)**
- **300-600°C**
- **50-100 atmospheres**

You need to know the mechanism for this. It is very similar to the electrophilic addition mechanism in the alkene tutorial but from a slightly different perspective:



In the alkenes topic they added sulphuric acid as the catalyst and focussed on the **sulphuric acid**; they weren't that bothered about the alcohol. This is the **same reaction** but in this topic they are more interested in the **final alcohol product** and not the catalyst.

A few points to note:

✓ The H^+ is from the H_3PO_4 which is acting as a **catalyst**.

✓ Water is a **poor electrophile** so it can't add directly to the double bond.

✓ It is necessary to generate a **+ on the carbon** to attract water more readily.

✓ The + on the O has to be neutralised therefore "give it electrons" i.e. draw an arrow **towards** the O. Always draw curly arrows towards a +.

✓ Another little tip: when water is involved in these mechanisms, there are **3 steps involved**, all with one arrow each. So I think of….**one arrow 3 times** as a reminder. It also applies to the dehydration mechanism below.

Pros:

- **high purity** of ethanol obtained
- **fast continuous** process so emptying the vessel is not necessary
- **very high yield** of ethanol by recycling any unreacted ethene

Cons:

- ethene obtained from **crude oil** (non-renewable)
- **high temperatures** and **pressures** required.

Dehydration/Elimination

We can also do the opposite reaction: **remove H_2O** from ethanol → ethene. This is **dehydration**, which is a special case of elimination as is in the haloalkane topic: both remove a small molecule → alkene but are quite different mechanisms.

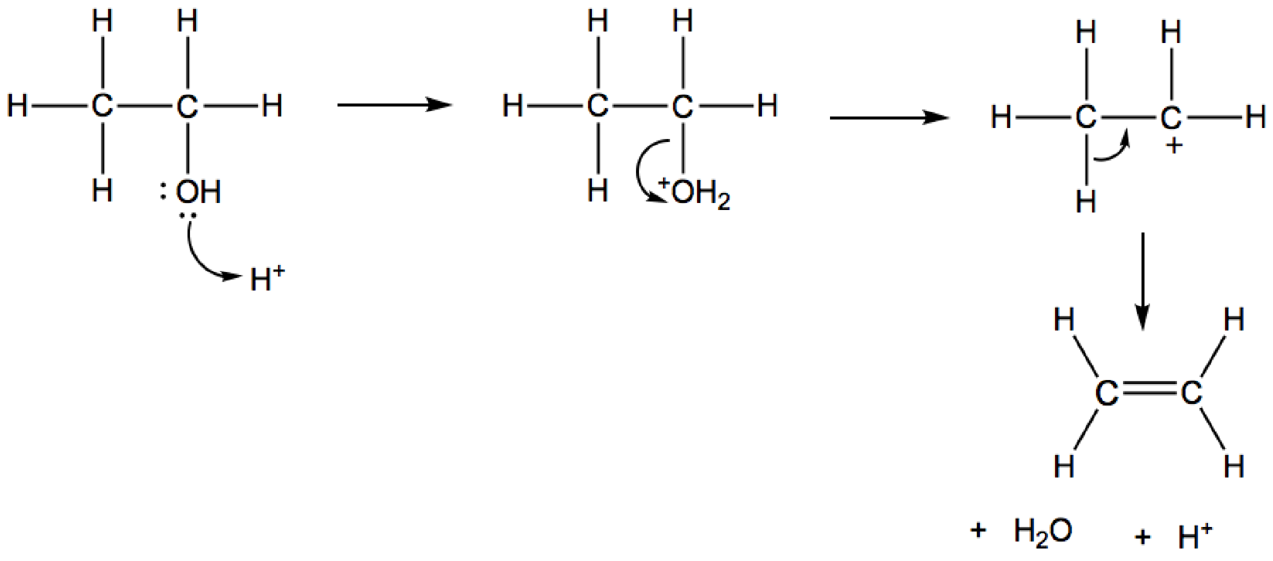
I am mentioning this here as it is very easy to get confused with **similar but slightly different mechanisms**, especially as they are in different topics.

Removing water, like adding it above, is difficult, therefore an **acid catalyst** is again required: either sulphuric or phosphoric acid.

The H^+ is added to the **OH → $^+$OH$_2$** which is much easier to remove than OH.

✓ Anything charged becomes more reactive, which is a similar idea to the hydration mechanism above.

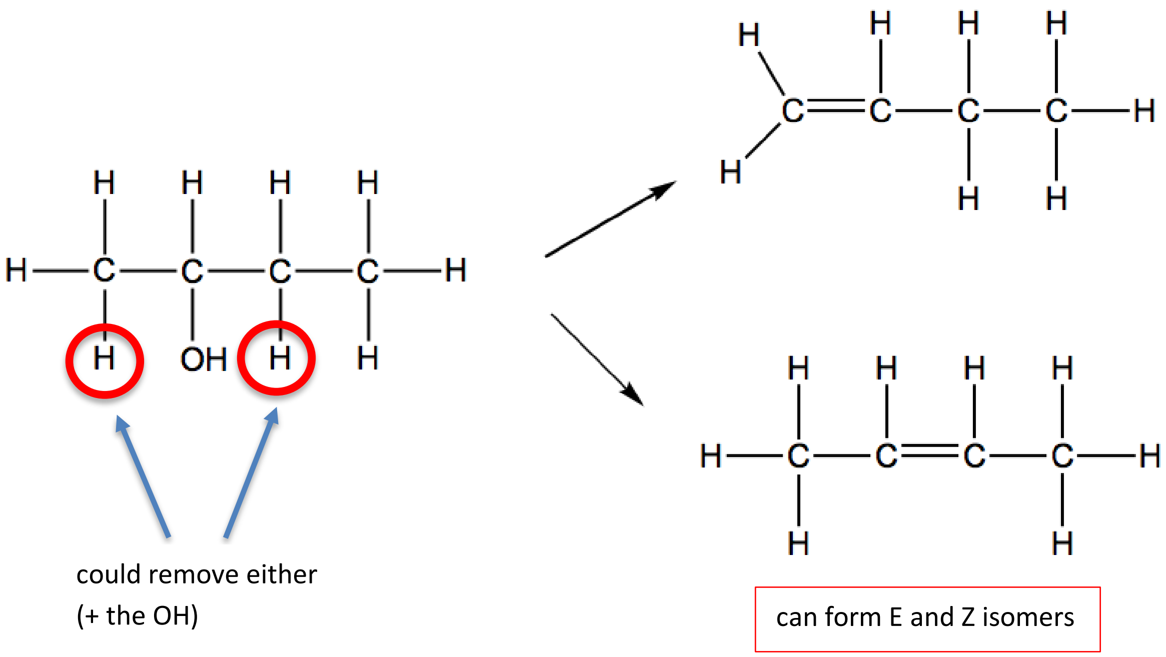
✓ You can also think of this mechanism as "**one arrow 3 times**".



✓ Look out for the final curly arrow. It is going from **bond to bond** which is quite unusual → C=C.

One step further….if we started with an **unsymmetrical secondary alcohol**, we could get two different alkene products.

This is just due to the second part of the mechanism where the 'H' atom could be lost from either side of the OH. Exactly the same mechanism as above, just that there are two options when removing an H. And both will occur → **2 products** shown below.

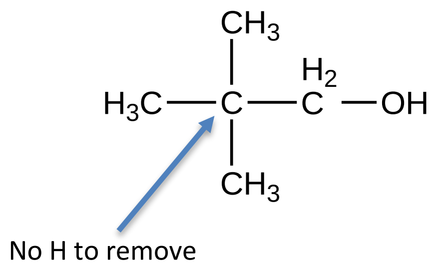


With the primary alcohol such as ethanol, there is no choice, only one H can possibly be removed and therefore only one product formed.

Technically, this is actually **3 products**! The alkene on the bottom could do **E and Z** isomerism which would count as 2 separate products.

✓ look for similarities and differences between this mechanism and the elimination reaction from halogenoalkanes. And also between hydration of ethene and electrophilic addition. Look for ways to understand and spot repeating patterns rather than memorising.

I saw a question where they asked "when would dehydration NOT occur"? The answer: when there is no adjacent hydrogen to remove. For example:



Click here for oxidation of alcohols