

Alcohols, acids, esters and polymers explained

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Alcohols contain -OH and carboxylic acids contain -COOH . Ethanol forms by fermenting sugar, an alcohol and an acid react to give a sweet-smelling ester, and small monomers join into polymers: addition polymers from alkenes, condensation polymers from two-group monomers with water lost.

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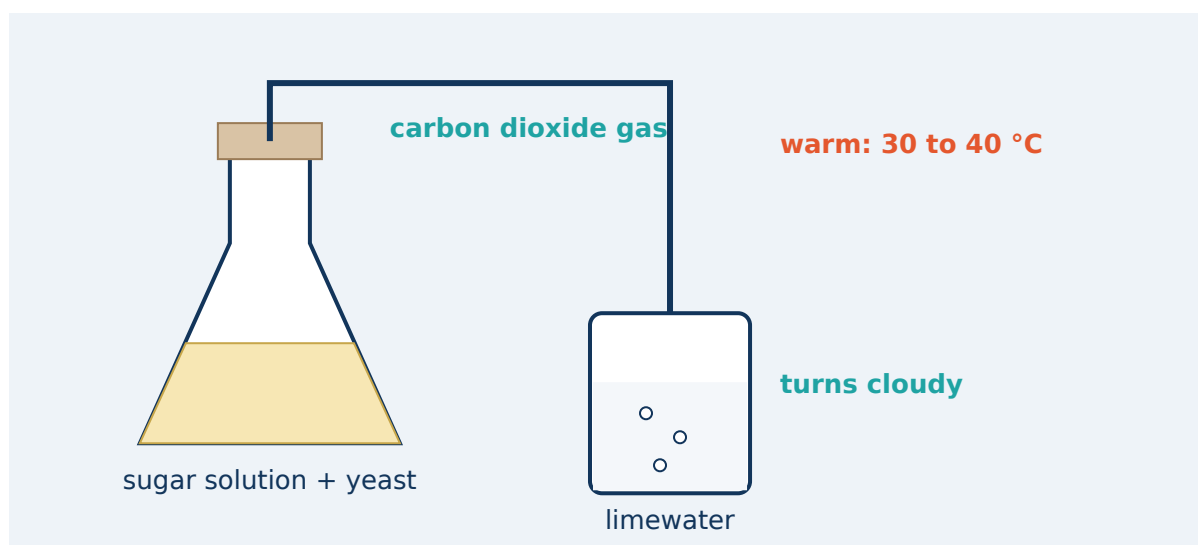
What are alcohols and how are they made?

Definition

An **alcohol** is an organic compound that contains the hydroxyl group -OH . The alcohols form a homologous series with the general formula $\text{C}_n\text{H}_{2n+1}\text{OH}$.

A functional group is the atom or group of atoms that decides how a compound reacts. Every alcohol has -OH , so every alcohol burns, mixes with water (the small ones) and can be oxidised in a similar way. Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is the best known.

Ethanol is made by **fermentation**. Enzymes in yeast turn sugar solution into ethanol and carbon dioxide at 30 to 40 °C with no air: $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$. Below about 20 °C the enzymes work slowly, and above about 60 °C they are destroyed (denatured). Factories can also make ethanol from ethene and steam with a catalyst, $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$, but ethene comes from crude oil, which is not renewable.



Fermentation: yeast produces carbon dioxide, which turns limewater cloudy.

Worked example

Ferment 90 g of glucose ($M = 180 \text{ g/mol}$). Moles of glucose = $90 \div 180 = 0.50 \text{ mol}$. The equation shows 1 glucose gives 2 ethanol, so ethanol = 1.0 mol. Mass = $1.0 \times 46 = 46 \text{ g}$

of ethanol (at 100 % yield).

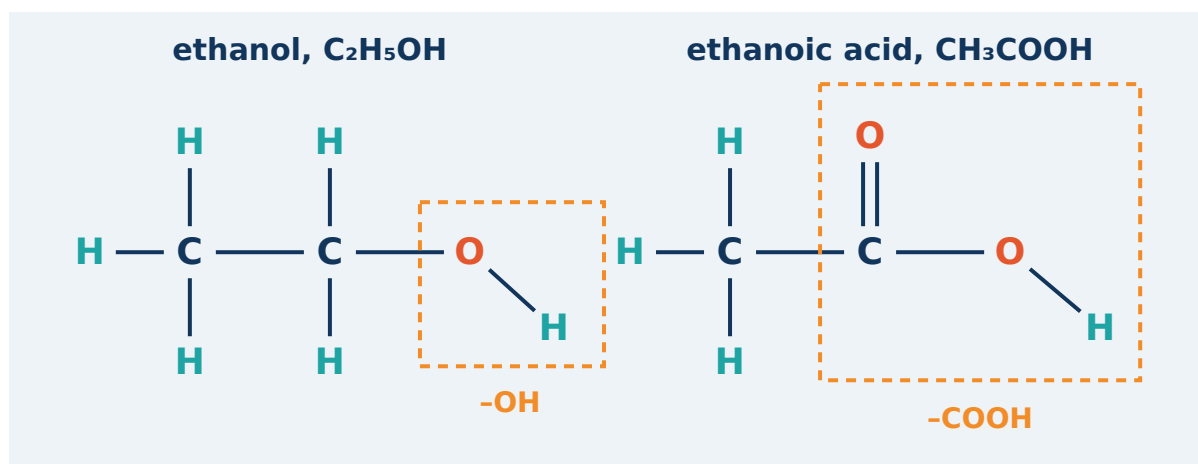
Ethanol is also a fuel: $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$. It is the main alcohol in bioethanol blended with petrol.

What are carboxylic acids?

Definition

A **carboxylic acid** contains the group $-\text{COOH}$. The general formula is $\text{C}_n\text{H}_{2n+1}\text{COOH}$, and the names end in -oic acid.

Carbons	Alcohol	Formula	Carboxylic acid	Formula
1	methanol	CH_3OH	methanoic acid	HCOOH
2	ethanol	$\text{C}_2\text{H}_5\text{OH}$	ethanoic acid	CH_3COOH
3	propanol	$\text{C}_3\text{H}_7\text{OH}$	propanoic acid	$\text{C}_2\text{H}_5\text{COOH}$
4	butanol	$\text{C}_4\text{H}_9\text{OH}$	butanoic acid	$\text{C}_3\text{H}_7\text{COOH}$



The functional groups: $-\text{OH}$ in ethanol and $-\text{COOH}$ in ethanoic acid.

Ethanol turns into ethanoic acid when it is oxidised, by an oxidising agent or by microbes in air. This is why an open bottle of wine turns sour and becomes vinegar. Carboxylic acids are **weak acids**: they ionise only partly in water, so their pH is higher than that of a strong acid of the same concentration. They still react like other acids with carbonates, metals and bases.

Worked example

Balance ethanoic acid with calcium carbonate: $2\text{CH}_3\text{COOH} + \text{CaCO}_3 \rightarrow (\text{CH}_3\text{COO})_2\text{Ca} + \text{H}_2\text{O} + \text{CO}_2$. Carbon: 4 + 1 = 5 on each side. Hydrogen: 8 on the left, 6 + 2 = 8 on the right. Oxygen: 4 + 3 = 7 on the left, 4 + 1 + 2 = 7 on the right. The salt is **calcium ethanoate**, and the gas turns limewater cloudy.

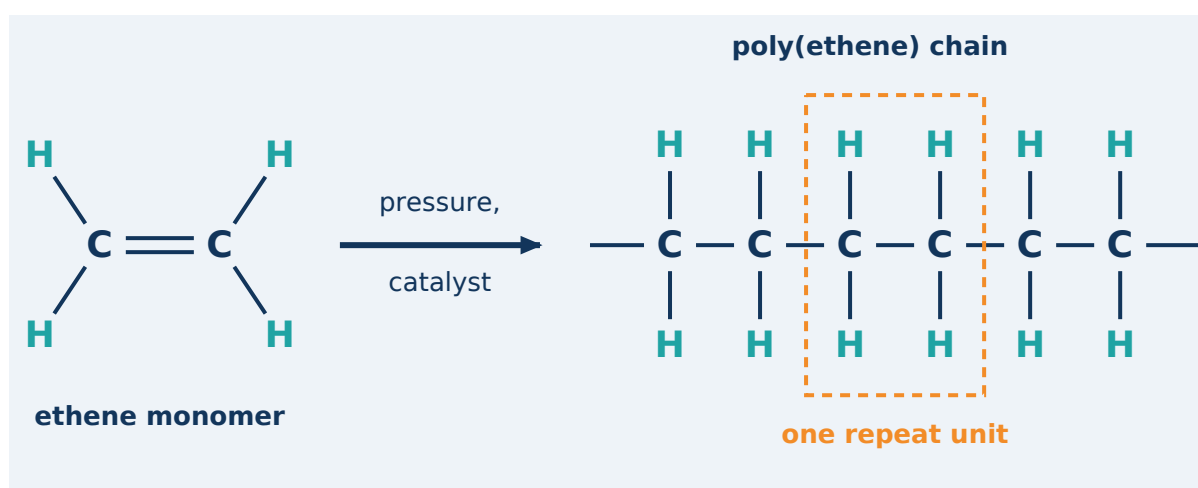
How do esters form?

An alcohol and a carboxylic acid react, with warming and a few drops of concentrated sulfuric acid as catalyst, to form an **ester** and water. The ester linkage is -COO- . Ethanol + ethanoic acid $\rightleftharpoons$ ethyl ethanoate + water. The name has two parts: the alcohol gives the first word (ethyl), the acid gives the second (ethanoate). Esters have sweet, fruity smells and are used in perfumes and food flavourings. Methanol and propanoic acid make methyl propanoate.

What are addition polymers?

Definition

A **polymer** is a very long molecule made of many small repeating units called monomers joined in a chain. In **addition polymerisation** the monomers have a $\text{C}=\text{C}$ bond that opens so the molecules join with no other product.

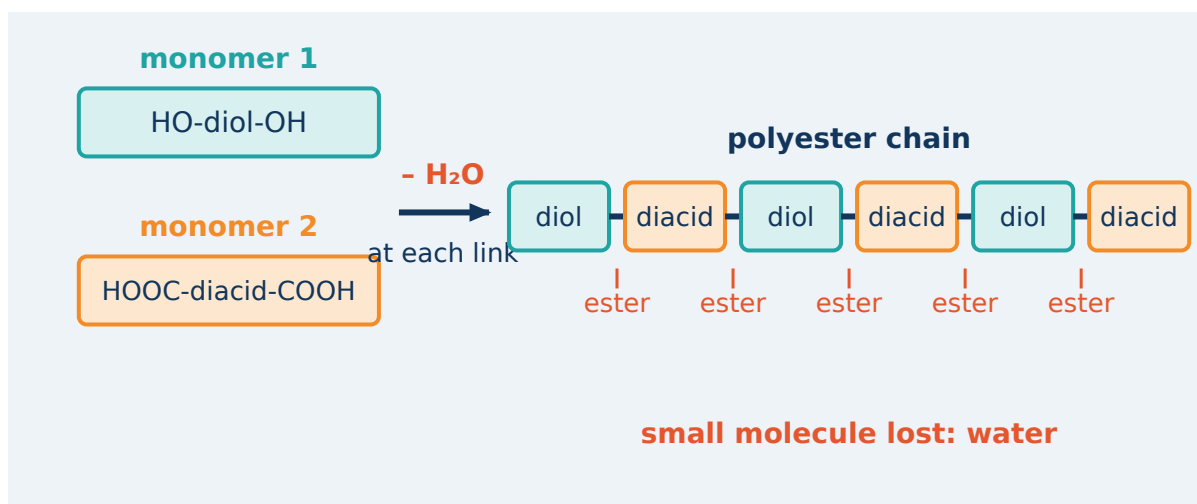


Ethene monomers open their double bonds and join into poly(ethene).

For ethene: $n \text{ C}_2\text{H}_4 \rightarrow (-\text{CH}_2-\text{CH}_2-)_n$. To find the repeat unit, open the double bond and write a single bond with a free bond at each end. Poly(propene) is made from propene, and PVC from chloroethene. Addition polymers are unreactive and do not rot, which makes them useful and also a waste problem.

What are condensation polymers?

In condensation polymerisation two different monomers, each with two functional groups, join and lose a small molecule, usually water, at each link. A diol and a dicarboxylic acid make a polyester with ester links.



Condensation polymerisation: a diol and a diacid join with ester links and release water.

Feature	Addition polymer	Condensation polymer
Monomers	alkene with C=C	two functional groups per molecule
Small molecule lost	none	usually water
Products	polymer only	polymer and water
Example	poly(ethene)	polyester

Common mistake

Do not keep the C=C double bond in the polymer repeat unit: it is used up when the chain forms. Poly(ethene) has only single bonds, so it does not decolourise bromine water.

Lina's tip

To name an ester, say the alcohol first and the acid second: ethanol + propanoic acid gives ethyl propanoate. To draw an addition polymer, open the double bond and extend the bonds on both sides.

Key points to remember

- Alcohol: -OH, C_nH_{2n+1}OH; carboxylic acid: -COOH; ester link: -COO-.
- Fermentation: C₆H₁₂O₆ → 2C₂H₅OH + 2CO₂, yeast, 30 to 40 °C, no oxygen.
- Alcohol + carboxylic acid ⇌ ester + water, with an acid catalyst.
- Addition polymers form from alkenes and lose nothing; condensation polymers lose water at each link.
- Carboxylic acids are weak acids but still react with carbonates to release carbon dioxide.

Alcohols, acids, esters and polymers explained: frequently

asked questions

Which functional group do alcohols contain?

Alcohols contain the hydroxyl group, -OH , attached to a carbon chain. It makes ethanol and the other alcohols burn well and react with carboxylic acids to form esters.

Why must fermentation be kept warm but not hot?

The enzymes in yeast work fastest at about 30 to 40 °C. At low temperature they work slowly, and above about 60 °C they are denatured, so fermentation stops.

Why are carboxylic acids called weak acids?

They ionise only partly in water, so only a small fraction of the molecules release hydrogen ions. Their pH is higher than that of a strong acid of the same concentration.

How is an ester named?

The alcohol gives the first word, ending in -yl , and the acid gives the second word, ending in -oate . Ethanol and ethanoic acid give ethyl ethanoate.

What is the difference between addition and condensation polymerisation?

In addition polymerisation, alkene monomers open their $\text{C}=\text{C}$ bonds and join with no other product. In condensation polymerisation, monomers with two functional groups join and lose a small molecule such as water.