This page looks at the use of acid catalysts in some organic reactions. It covers the nitration of benzene, the hydration of ethene to manufacture ethanol, and the reactions both to produce esters and to hydrolyse them under acidic conditions. You will find links to the full mechanisms for each of these reactions if you want them.

The nitration of benzene

Benzene is treated with a mixture of concentrated nitric acid and concentrated sulphuric acid at a temperature not exceeding 50°C. As the temperature increases there is a greater chance of getting more than one nitro group, -NO₂, substituted onto the ring.

Nitrobenzene is formed.

\[ C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O \]

or:

\[ \text{Cyclic ring } + HNO_3 \rightarrow \text{Cyclic ring with NO}_2 + H_2O \]

The concentrated sulfuric acid is acting as a catalyst. Because everything is present in the same liquid phase, this is a good example of homogeneous catalysis.

The hydration of ethene to make ethanol

Ethene is mixed with steam and passed over a catalyst consisting of solid silicon dioxide coated with phosphoric(V) acid. The temperature used is 300°C and the pressure is about 60 to 70 atmospheres. Because the catalyst is in a different phase from the reactants, this is an example of heterogeneous catalysis.

\[ \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \xrightarrow{\text{H}_3\text{PO}_4} \text{CH}_3\text{CH}_2\text{OH} \]

This is a reversible reaction and only about 5% of the ethene reacts on each pass over the catalyst. When the reaction mixture is cooled, the ethanol and any excess steam condense, and the gaseous ethene can be recycled through the process. A conversion rate of about 95% is achieved by continual recycling in this way.

Making esters - the esterification reaction

Esters are what is formed when an organic acid reacts with an alcohol in the presence of concentrated sulfuric acid as the catalyst. Everything is present in a single liquid phase, and so this is an example of homogeneous catalysis.

For example, ethanoic acid reacts with ethanol to produce ethyl ethanoate.
The ethyl ethanoate has the lowest boiling point of anything in the mixture, and so is distilled off as soon as it is formed. This helps to reduce the reverse reaction.

The acid catalyzed hydrolysis of esters

In principle, this is the reverse of the esterification reaction but, in practice, it has to be done slightly differently. The ester is heated under reflux with a dilute acid such as dilute hydrochloric acid or dilute sulfuric acid.

The equation for the reaction is simply the esterification equation written backwards.

\[
\text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O} \xrightarrow{\text{dilute acid}} \text{CH}_3\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}
\]

The dilute acid used as the catalyst also provides the water for the reaction. You need a large excess of water in order to increase the chances of the forward reaction happening and the ester hydrolyzing. You would normally hydrolyse esters quite differently by heating them with sodium hydroxide solution (alkaline hydrolysis). This is not an example of a catalytic reaction because the hydroxide ions are used up during the reaction.

\[
\text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}
\]

The main advantage of doing it like this is that it is a one-way reaction. The ester can be completely hydrolysed rather than only partially if the reaction is reversible.

Contributors

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