The manufacture of epoxyethane from ethene

Epoxyethane is manufactured by reacting ethene with a limited amount of oxygen in the presence of a silver catalyst at a temperature of about 250 - 300°C and a pressure of less than 15 atmospheres. Because the solid silver is catalysing a gas reaction, this is an example of heterogeneous catalysis.

\[
\text{CH}_2\equiv\text{CH}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{CH}_2=\text{CH}_2 \quad \text{O}
\]

The reaction is exothermic and the temperature has to be carefully controlled to prevent further oxidation of the ethene to carbon dioxide and water.

The halogenation of benzene

Benzene reacts with chlorine or bromine in the presence of a catalyst. The catalyst is either aluminium chloride (or aluminium bromide if you are reacting benzene with bromine) or iron.

Strictly speaking iron isn't a catalyst, because it gets permanently changed during the reaction. It reacts with some of the chlorine or bromine to form iron(III) chloride, FeCl₃, or iron(III) bromide, FeBr₃.

\[
2\text{Fe} + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3
\]

\[
2\text{Fe} + 3\text{Br}_2 \rightarrow 2\text{FeBr}_3
\]

These compounds act as the catalyst and behave exactly like aluminium chloride in these reactions.

The reaction with chlorine

The reaction between benzene and chlorine in the presence of either aluminium chloride or iron gives chlorobenzene.

\[
\text{C}_6\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_6\text{H}_5\text{Cl} + \text{HCl}
\]

or:
The reaction with bromine

The reaction between benzene and bromine in the presence of either aluminium bromide or iron gives bromobenzene. Iron is usually used because it is cheaper and more readily available.

\[ \text{C}_6\text{H}_6 + \text{Br}_2 \rightarrow \text{C}_6\text{H}_5\text{Br} + \text{HBr} \]

or:

\[ \text{C}_6\text{H}_6 + \text{C}_2 \rightarrow \text{C}_6\text{H}_5\text{Cl} + \text{HCl} \]

The Friedel-Crafts alkylation of benzene

Alkylation involves replacing a hydrogen atom on a benzene ring by an alkyl group like methyl or ethyl. This is another example of the use of aluminium chloride as a catalyst. Benzene is treated with a chloroalkane (for example, chloromethane or chloroethane) in the presence of aluminium chloride as a catalyst. The equation shows the reaction using a methyl group, but any other alkyl group could be used in the same way.

Substituting a methyl group gives methylbenzene - once known as toluene.

\[ \text{C}_6\text{H}_6 + \text{CH}_3\text{Cl} \rightarrow \text{C}_6\text{H}_5\text{CH}_3 + \text{HCl} \]

or:

\[ \text{C}_6\text{H}_6 + \text{CH}_3\text{Cl} \rightarrow \text{C}_6\text{H}_5\text{CH}_3 + \text{HCl} \]

The Friedel-Crafts acylation of benzene

An acyl group is an alkyl group attached to a carbon-oxygen double bond. Acylation means substituting an acyl group into something - in this case, into a benzene ring. The most commonly used acyl group is CH\(_3\)CO-. This is called the ethanoyl group. In the example which follows we are substituting a CH\(_3\)CO- group into the ring, but you could equally well use any
other alkyl group instead of the CH₃.

\[
\text{CH}_3\overset{\text{O}}{\text{C}}
\]

**the ethanoyl group**

The most reactive substance containing an acyl group is an acyl chloride (also known as an acid chloride). Benzene is treated with a mixture of ethanoyl chloride, CH₃COCl, and aluminium chloride as the catalyst. A ketone called phenylethanone is formed.

\[
\text{C}_6\text{H}_6 \ + \ \text{CH}_3\text{COCl} \quad \rightarrow \quad \text{C}_6\text{H}_5\text{COCH}_3 \ + \ \text{HCl}
\]

or:

\[
\text{\includegraphics[width=2cm]{benzene.png}} \ + \ \text{CH}_3\overset{\text{O}}{\text{Cl}} \quad \rightarrow \quad \text{\includegraphics[width=2cm]{phenylethanone.png}} \ + \ \text{HCl}
\]