This page discusses the dehydration of alcohols in the lab to make alkenes—for example, dehydrating ethanol to produce ethene.

The dehydration of ethanol to give ethene

This is a simple method of making gaseous alkenes such as ethene. If ethanol vapor is passed over heated aluminum oxide powder, the ethanol is essentially cracked to yield ethene and water vapor.

\[ \text{CH}_3\text{-CH}_2\text{-OH} \xrightarrow{\text{Al}_{2}\text{O}_3} \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \]

To produce a few test tubes of ethene, the following apparatus can be used:

This system can be scaled up by boiling ethanol in a flask and passing the vapor over aluminum oxide that is heated in a long tube.

Dehydration of alcohols using an acid catalyst

The acid catalysts normally used in alcohol dehydration are either concentrated sulfuric acid or concentrated phosphoric(V) acid, \( \text{H}_3\text{PO}_4 \). Concentrated sulfuric acid produces messy results. Because sulfuric acid is also a strong oxidizing agent, it oxidizes some of the alcohol to carbon dioxide and is simultaneously reduced itself to sulfur dioxide. Both of these gases must be removed from the alkene. Sulfuric acid also reacts with the alcohol to produce a mass of carbon. There are other side reactions as well (not discussed here).

The dehydration of ethanol to yield ethene

In this process, ethanol is heated with an excess of concentrated sulfuric acid at a temperature of 170°C. The gases produced are passed through a sodium hydroxide solution to remove the carbon dioxide and sulfur dioxide produced from side reactions. The ethene is collected over water.

\[ \text{CH}_3\text{-CH}_2\text{-OH} \xrightarrow{\text{conc. H}_2\text{SO}_4} \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \]

The concentrated sulfuric acid is a catalyst. Therefore, it is written over the reaction arrow rather than in the equation.
The dehydration of cyclohexanol to yield cyclohexene

This is a preparation commonly used to illustrate the formation and purification of a liquid product. The fact that the carbon atoms are joined in a ring has no bearing on the chemistry of the reaction. Cyclohexanol is heated with concentrated phosphoric(V) acid, and the liquid cyclohexene distils off and can be collected and purified. Phosphoric(V) acid tends to be used instead of sulfuric acid because it is safer and facilitates a less complex reaction.

\[ \text{cyclohexanol} \xrightarrow{\text{conc. } \text{H}_3\text{PO}_4} \text{cyclohexene} + \text{H}_2\text{O} \]

The dehydration of more complicated alcohols

With more complicated alcohols, the formation of more than one alkene is possible. Butan-2-ol is a good example of this, with three different alkenes formed when it is dehydrated.

Example 1: Dehydration of Butan-2-ol

When an alcohol is dehydrated, the -OH group and a hydrogen atom from the next carbon atom in the chain are removed. With molecules like butan-2-ol, there are two possibilities for this.

\[
\begin{align*}
\text{OH} & \quad \text{you remove the -OH group} \\
\text{CH}_3\text{CHCH}_2\text{CH}_3 & \\
\text{and this hydrogen} & \quad \text{or this one}
\end{align*}
\]

The following products are formed:

\[
\begin{align*}
\text{OH} & \\
\text{CH}_3\text{CHCH}_2\text{CH}_3 & \\
\text{CH}_2=\text{CHCH}_2\text{CH}_3 & \quad \text{CH}_3\text{CH}=\text{CHCH}_3
\end{align*}
\]

The products are but-1-ene, \(\text{CH}_2=\text{CHCH}_2\text{CH}_3\), and but-2-ene, \(\text{CH}_3\text{CH}=\text{CHCH}_3\).

This situation is further complicated by the fact that but-2-ene exhibits geometric isomerism; thus, a mixture of two isomers is formed: \textit{cis}-but-2-ene and \textit{trans}-but-2-ene.
The compound cis-but-2-ene is also known as (Z)-but-2-ene; trans-but-2-ene is also known as (E)-but-2-ene. Which isomer is formed is a matter of chance.

Hence, the dehydration of butan-2-ol leads to a mixture containing the following compounds:

- but-1-ene
- cis-but-2-ene (also known as (Z)-but-2-ene)
- trans-but-2-ene (also known as (E)-but-2-ene)

Contributors

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