1.4 Alcohols, Ethers, and Thiols

Alcohols

Alcohols and ethers both contain a carbon atom bonded to an oxygen atom with a single bond. Their structures are similar to the structure of water. If you think of water as being HOH, then an alcohol is simply water with one of the H atoms replaced by an alkyl group, R. An alkyl group is a hydrocarbon group derived from an alkane. The general formula for an alcohol can be written ROH. Similarly, an ether is water with both H atoms replaced by alkyl groups. The general formula for an ether is ROR.

\[
\begin{align*}
\text{HOH} & \quad \text{ROH} & \quad \text{ROR} \\
\text{Water} & \quad \text{Alcohol} & \quad \text{Ether}
\end{align*}
\]

Example: CH\textsubscript{3}OH

An alcohol is an organic compound that contains the hydroxyl group (–OH).

- **primary alcohol**: an alcohol in which the hydroxyl group is bonded to a terminal carbon atom
- **secondary alcohol**: an alcohol in which the hydroxyl group is bonded to a carbon atom with two alkyl groups bonded to it
- **tertiary alcohol**: an alcohol in which the hydroxyl group is bonded to a carbon atom with three alkyl groups bonded to it

\[
\begin{align*}
\text{(a) butan-1-ol} & \quad \text{(b) butan-2-ol} & \quad \text{(c) 2-methyl-propan-2-ol} \\
& \quad \text{a primary alcohol (1°)} & \quad \text{a secondary alcohol (2°)} & \quad \text{a tertiary alcohol (3°)}
\end{align*}
\]

Because the bonds between the C-O and O-H are polar covalent, alcohols are polar molecules.

**Naming and Drawing Alcohols**

We name an alcohol by replacing the final -e of the parent hydrocarbon with -ol.

The name includes the number of the carbon atom to which the hydroxyl group is attached.
If the chain also has hydrocarbon or halide constituents, we assign the lowest number to the carbon atom with the hydroxyl group.

\[
\begin{align*}
\text{propan-1-ol} & \quad \text{propan-2-ol} \\
\end{align*}
\]

Alcohols containing more than one \(-\text{OH}\) group are referred to as polyalcohols. The suffix \(-\text{diol}\) (for two \(-\text{OH}\) groups) or \(-\text{triol}\) (for three \(-\text{OH}\) groups) is added to the alkane name instead of \(-\text{ol}\).

\[
\begin{align*}
\text{ethane-1,2-diol} & \quad \text{propane-1,2,3-triol} \\
\text{ethylene glycol} & \quad \text{glycerine} \\
\end{align*}
\]

The naming conventions for cyclic alcohols are the same as for straight-chain alcohols.

\[
\text{cyclooctanol}
\]

The simplest aromatic alcohol is a benzene ring with one hydroxyl group bonded to it. If the benzene ring has two \(-\text{OH}\) groups, the name is based on benzene and includes the numbers for the \(-\text{OH}\) groups.

\[
\begin{align*}
\text{phenol} & \quad \text{benzene-1,2-diol} \\
\end{align*}
\]
Steps to Name an Alcohol

1. Identify the longest carbon chain or ring.
2. If there is only one –OH group, the compound has the suffix -ol. If more than one group, use the suffixes -diol or -triol.
3. Number the parent chain from the end so that the –OH group is attached to the carbon atom with the lowest possible number.
4. Identify any other substituents and their locations.
5. If you are required to identify the type of alcohol, count the number of carbon atoms bonded to the atom to which the –OH group is attached.

Properties of Alcohols
Because of the polar hydroxyl groups, alcohols have higher boiling points of comparable alkanes. Alcohols are much more soluble in water than alkanes are. The long hydrocarbon portion of larger alcohol molecules allows them to mix with nonpolar substances as well, making these alcohols useful solvents for both water-based and oil-based substances.
Like hydrocarbons, alcohols are also combustible.

**Ethers**

The functional group in ethers is an oxygen atom bonded to two carbon atoms. The general formula is ROR.

**Naming Ethers**

Ethers are named by adding *oxy* to the prefix of the *smaller* hydrocarbon group and joining the new prefix to the alkane name of the *larger* hydrocarbon group.

Ethers are often given common names derived from the two alkyl groups, followed by the term *ether*.

Example: CH\(_3\)OCH\(_2\)CH\(_3\)

\[
\begin{align*}
H_3C & - CH_2 - CH_2 - O - CH_3 \\
\end{align*}
\]

**Drawing Ethers**

1-ethoxybutane           2-methoxypropane           3-ethoxypentane
**Properties of Ethers**  
The C-O bonds make ethers slightly more polar than regular hydrocarbons and therefore have slightly higher boiling points, but lower than those of alcohols.

Like alcohols, ethers are good solvents for organic reactions because they mix readily with both polar and nonpolar substances.

**Thiols**  
A thiol is an organic compound that includes the sulfhydryl functional group, $\text{–SH}$.

The sulfhydryl group is similar to the hydroxy group, $\text{–OH}$. Thiols generally have strong odours.

  e.g. garlic, skunk

\[
\begin{align*}
\text{H}_3\text{C} & \quad \text{C} & \quad \text{SH} \\
\text{H}_3\text{C} & \quad \text{C} & \quad \text{CH}_2 \\
\text{H}_3\text{C} & \quad \text{C} & \quad \text{CH}_2
\end{align*}
\]

(E) 2-butene-1-thiol  
3-methyl-1-butanethiol  
2-quinolinemethanthiol

To name thiols, the suffix $\text{-thiol}$ is added to the end of the alkane name.

For example, HSCH$_3$ is methanethiol.

**Reactions with Alcohols and/or Ethers**

Preparing Alcohols: **Hydration** Reactions

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH} & \quad \text{C} \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{OH} \quad \text{H} \\
\text{but-1-ene} & \quad \text{water} & \quad \text{butan-2-ol}
\end{align*}
\]

**Combustion** of Alcohols

\[
2 \text{C}_3\text{H}_7\text{OH}_{(l)} + 9 \text{O}_2(g) \rightarrow 8 \text{H}_2\text{O}_{(g)} + 6 \text{CO}_2(g)
\]

propanol  

oxygen  

water  

carbon dioxide
From Alcohols to Alkenes: \textbf{Dehydration} (Elimination) Reactions

\[
\text{propanol} \xrightarrow{\text{sulfuric acid}} \text{propene} + \text{water}
\]

\[
\text{butan-2-ol} \xrightarrow{\text{sulfuric acid}} \text{but-2-ene} + \text{H}_2\text{O} \quad \text{(major product)}
\]

\[
\text{butan-2-ol} \xrightarrow{\text{sulfuric acid}} \text{but-1-ene} + \text{H}_2\text{O} \quad \text{(minor product)}
\]

Preparing Ethers from Alcohols: \textbf{Condensation} Reactions

\[
\text{ethanol} + \text{methanol} \xrightarrow{\text{H}_2\text{SO}_4} \text{methoxyethane} + \text{H}_2\text{O}
\]

Write the chemical equation for the addition reaction of pent-1-ene and water.

Write the chemical equation for the dehydration of ethanol.
Draw the chemical equation, showing structural formulas, for the addition reaction that forms butan-2-ol.

Write the chemical equation for the dehydration of pentanol.

Worksheet 1.4: Alcohols, Ethers, and Thiols

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