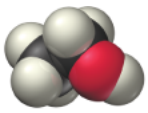
Pearson

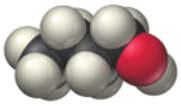
21.9: Alcohols

As we discussed in Section 21.8, **alcohols** are organic compounds containing the —OH functional group, or **hydroxyl group**, and they have the general formula R—OH. In addition to methanol and isopropyl alcohol, ethanol and 1-butanol are also common alcohols:



CH_3-CH_2-OH

ethanol



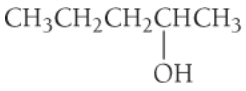
$CH_3-CH_2-CH_2-CH_2-OH$

1-butanol

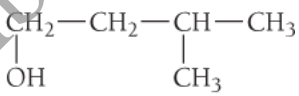
Naming Alcohols

The names of alcohols are like the names of alkanes with the following differences:

- The base chain is the longest continuous carbon chain that contains the —OH functional group.
- The base name has the ending *-ol*.
- We number the base chain to assign the —OH group the lowest possible number.
- We insert a number indicating the position of the —OH group just before the base name. For example:



2-pentanol



3-methyl-1-butanol

About Alcohols

The familiar alcohol in alcoholic beverages, ethanol, is most commonly formed by the yeast fermentation of sugars, such as glucose, from fruits and grains:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{yeast}} 2\ \underset{\text{ethanol}}{CH_3CH_2OH} + 2\ CO_2$$

Alcoholic beverages contain ethanol, water, and a few other components that impart flavor and color. Beer usually contains 3–6% ethanol. Wine contains about 12–14% ethanol, and spirits—beverages such as whiskey, rum, or tequila—range from 40% to 80% ethanol, depending on their *proof*. The proof of an alcoholic beverage is twice the percentage of its ethanol content, so an 80-proof whiskey contains 40% ethanol. Ethanol is used as a gasoline additive because it increases the octane rating of gasoline and fosters its complete combustion, reducing the levels of certain pollutants such as carbon monoxide and the precursors of ozone.

Isopropyl alcohol (or 2-propanol) is available at any drugstore under the name of rubbing alcohol. It is commonly used as a disinfectant for wounds and to sterilize medical instruments. Isopropyl alcohol should never be consumed internally, as it is highly toxic. Four ounces of isopropyl alcohol can cause death. A third common alcohol is methanol, also called wood alcohol. Methanol is commonly used as a laboratory solvent and as a fuel additive. Like isopropyl alcohol, methanol is toxic and should never be consumed.

Alcohol Reactions

Alcohols undergo a number of reactions including substitution, elimination (or dehydration), and oxidation. Alcohols also react with active metals to form strong bases.

Substitution

Alcohols react with acids such as HBr to form halogenated hydrocarbons.

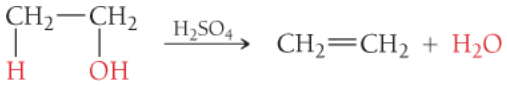
$$ROH + HBr \rightarrow R\text{–}Br + H_2O$$

In these reactions, the halogen replaces the hydroxyl group on the alcohol. For example, ethanol reacts with hydrobromic acid to form bromoethane and water:

$$CH_3CH_2OH + HBr \rightarrow CH_3CH_2Br + H_2O$$

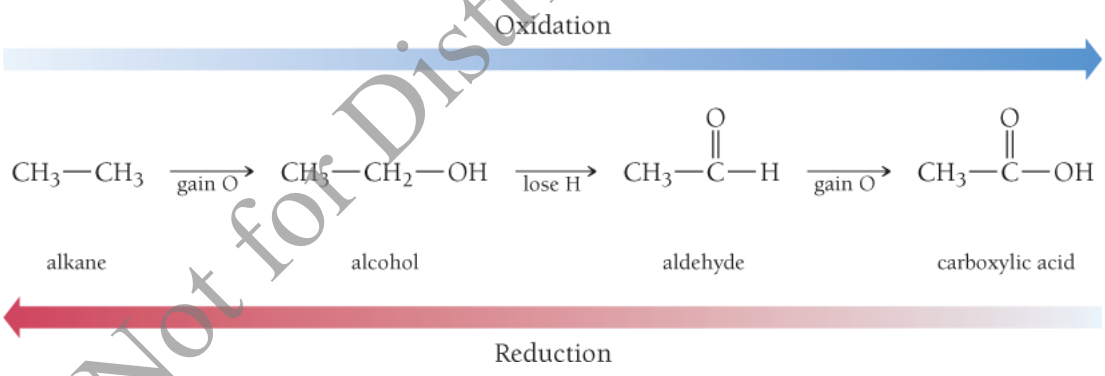
Elimination (or Dehydration)

In the presence of concentrated acids such as H_2SO_4, alcohols react and eliminate water, forming alkenes. These kinds of reactions are known as **elimination reactions**. For example, ethanol eliminates water to form ethene according to the reaction:



Oxidation

In organic chemistry, we think of oxidation and reduction in terms of the changes to the carbon atoms in the molecule. Thus, oxidation is the gaining of oxygen or the losing of hydrogen by a carbon atom. Reduction is the loss of oxygen or the gaining of hydrogen by a carbon atom. We can draw a series showing relative states of oxidation:



In this view, an alcohol is a partially oxidized hydrocarbon; it can be further oxidized to form an aldehyde or carboxylic acid, or it can be reduced to form a hydrocarbon (but this is rare). For example, ethanol can be oxidized to acetic acid according to the reaction:

$$CH_3CH_2OH \xrightarrow[H_2SO_4]{Na_2Cr_2O_7} CH_3COOH$$

Reaction with Active Metals

Alcohols react with active metals, such as sodium, much as water does. For example, methanol reacts with sodium to form *sodium methoxide* and hydrogen gas:

$$\underset{\text{sodium methoxide}}{CH_3ONa} + \frac{1}{2}H_2$$

The reaction of *water* with sodium produces *sodium hydroxide* and hydrogen gas:

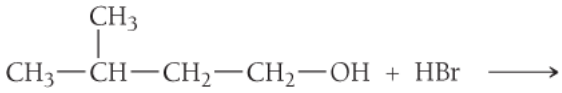
$$H_2O + Na \rightarrow NaOH + \frac{1}{2}H_2$$

In both cases, a strong base forms (OH^- in the case of water and CH_3O^- in the case of methanol).

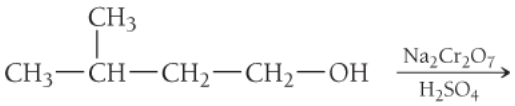
Example 21.7 Alcohol Reactions

Determine the type of reaction (substitution, dehydration, oxidation, or reaction with an active metal) that occurs in each case, and write formulas for the products.

a.

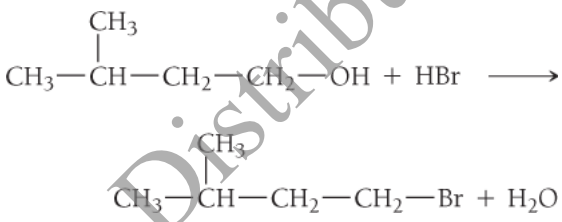


b.

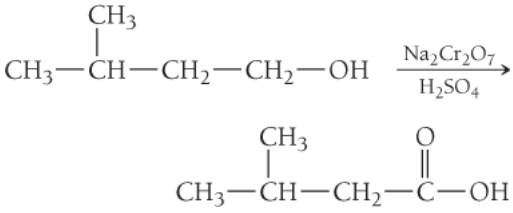


SOLUTION

a. An alcohol reacting with an acid is an example of a *substitution reaction*. The product of the substitution reaction is a halogenated hydrocarbon and water.



b. An alcohol in solution with sodium dichromate and acid undergoes an *oxidation reaction*. The product of the oxidation reaction is a carboxylic acid functional group. (We discuss carboxylic acid functional groups in detail in Section 21.11.)



FOR PRACTICE 21.7 Determine the type of reaction (substitution, dehydration, oxidation, or reaction with an active metal) that occurs in each case, and write formulas for the products.

a. $CH_3CH_2OH + Na \rightarrow$

b.