5.3: Functional Groups

With the huge number of organic compounds in existence, it would be very difficult for you to memorize the properties of each compound separately. Fortunately the compounds fall into **organic families**, which contain certain *combinations of atoms* in each molecule. These combinations are called **functional groups**.

Carbon-Carbon Double or Triple Bonds
One main type of functional group is a double or triple bond between carbon atoms. Double or triple bonds between carbon atoms are more reactive because the second and third bonds that are formed in a multiple bond are not as strong as the first bond. (see addition reactions)

Carbon Bonded to Oxygen or Nitrogen by a single Bond
Another type of functional group is a carbon bonded to a more electronegative atom, such as Oxygen, Nitrogen, or a Halogen. These bonds are *polar* causing the bonds between molecules to increase, resulting in higher melting and boiling points.

Carbon Bonded to Oxygen by a Double Bond
The third type of functional group consists of a carbon atom double-bonded to an oxygen atom. This makes the carbon very positive and the oxygen very negative, creating a *strongly polar* bond, resulting in even higher melting and boiling points than those of single bonded oxygens.

Multiple bonds between C atoms	
−C=C− −C≡C−	Unlike single C−C bonds, double and triple bonds allow atoms to be added to the chain.
C atom bonded to a more electronegative atom (O, N, halogen)	
C−O C−N C−Cl, C−Br, C−F	Unequal sharing of electrons results in polar bonds, increasing intermolecular attraction, and raising boiling and melting points.
C−OH or C−NH−	These groups enable hydrogen bonding, increasing solubility in polar substances.
C atom double-bonded to an O atom	
C=O	The resulting polar bond increases boiling point and melting point.

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Alcohols and Ethers

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.

HOH	ROH	ROR
Water	Alcohol	Ether
	Example: CH_3OH	Example: CH_3-O-CH_3

Naming Alcohols

The functional group that is common to all alcohols is the –OH group, called the *hydroxyl group*. An alcohol consists of a hydrocarbon chain with a hydroxyl group attached somewhere on the chain in place of a hydrogen atom.

Each alcohol name consists of two parts. The first part tells you the number of carbon atoms in the longest carbon chain. The middle part tells you if the chain is saturated or not and the last part *–ol* refers to the hydroxyl group. If there is a number, it represents which carbon the hydroxyl group is attached.

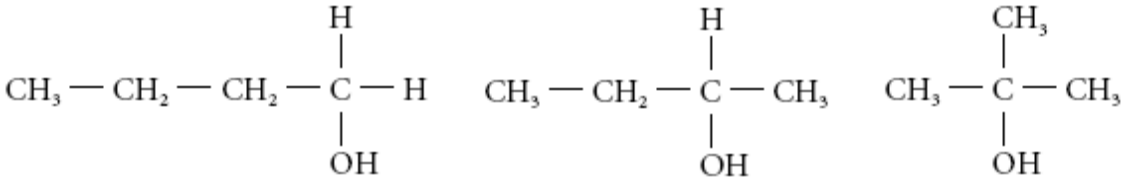
Ex: 1- butanol 2-pentanol $CH_3CH_2CH(OH)CH_3$

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.

1°, 2°, and 3° Alcohols
Alcohols are subclassified according to the type of carbon to which the -OH group is attached. Since C atoms form four bonds, the C atom bearing the -OH group can be attached to a further 1, 2, or 3 alkyl groups, the resulting alcohols classifed as primary, secondary, and tertiary alcohols, respectively (1°, 2°, and 3°). Thus, 1-butanol is a primary alcohol, 2-butanol is a secondary alcohol, and 2-methyl-2-propanol is a tertiary alcohol.



1-butanol, a 1^{o} alcohol

2-butanol, a 2^{o} alcohol

2-methyl-2-propanol, a 3^{o} alcohol

Polyalcohols
Alcohols that contain more than one hydroxyl group are called polyalcohols; the suffixes *-diol* and *-triol* are added to the entire alkane name to indicate two and three -OH groups, respectively.

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: $CH_3OCH_2CH_3$

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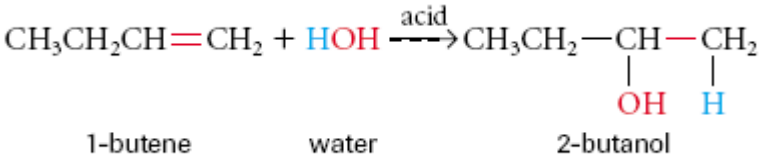
Properties of Ethers

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.

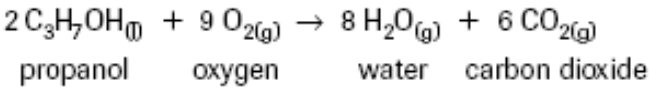
Like alcohols, ethers are good solvents for organic reactions because they mix readily with both polar and nonpolar substances.

Reactions with Alcohols and/or Ethers

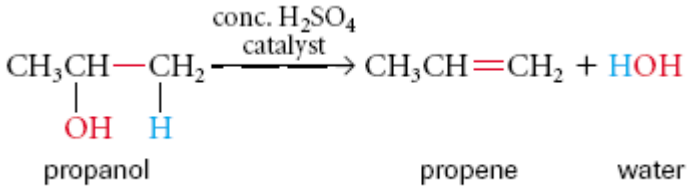
Preparing Alcohols: Hydration Reactions



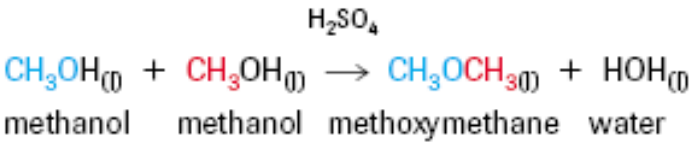
Combustion of Alcohols



From Alcohols to Alkenes: Elimination (Dehydration) Reactions



Preparing Ethers from Alcohols: Condensation Reactions



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Worksheet 5.3: Alcohols and Ethers

1. Draw the structural formula and write the condensed molecular formula for
    a. 1-propanol
    b. 2-propanol
    c. 1-pentanol
    d. 3-octanol
    e. 2,4-pentanol

2. Give the IUPAC or common name for the following ethers and draw their structural formula
    a. methoxypentane
    b. ethoxybutane
    c. propoxypropane
    d. methyl butyl ether
    e. ethyl pentyl ether

3. Arrange the following compounds in order of increasing boiling point: butane, 1-butanol, octane, 1-octanol. Give reasons for your order.

4. Only a few of the simple alcohols are used in combustion reactions. Alcohol-gasoline mixtures, known as gasohol, are the most common examples of simple alcohols. Write a balanced chemical equation, using condensed structural formulas, for the complete combustion of each of the following alcohols:
    a. ethanol (in gasohol)
    b. 2-propanol (isopropyl alcohol or rubbing alcohol)

5. Consider the two compounds $CH_3CH_2CH_2CH_2CH_2OH$ and $CH_3CH_2OCH_2CH_2CH_3$. Name the compound that
    a. will evaporate at a lower temperature
    b. has higher solubility in a nonpolar solvent
    c. Give reasons for your choices.