10.2 Single-Bonded Functional Groups

Section Preview/Outcomes

In this section, you will

- **name** and **draw** members of the alcohol, alkyl halide, ether, and amine families of organic compounds
- **describe** some physical and chemical properties of these families of compounds
- **communicate** your understanding of the following terms: *alcohol, parent alkane, alkyl halide, haloalkane, ether, amine*

You may have read murder mystery novels in which the detective discovers an unconscious victim lying beside a wad of cloth on the floor. The detective sniffs the cloth, notices a distinctive sickly-sweet smell, and announces: "Aha! Chloroform was used to knock out the victim." Chloroform, $CHCl_3$, is an organic compound that was used for many years as an anaesthetic during surgery. Diethyl ether, $CH_3CH_2OCH_2CH_3$, also known as "ether," is another organic compound that was once a common anaesthetic. Because of their toxic and irritating properties, chloroform and ether have been replaced in the operating room by other, less harmful, organic compounds such as methyl propyl ether, $CH_3OCH_2CH_2CH_3$. All three of these compounds have functional groups with single bonds.

In the previous section, you learned how functional groups affect the physical and chemical properties of organic compounds. In this section, you will be introduced to several classes of organic compounds that have single-bonded functional groups.

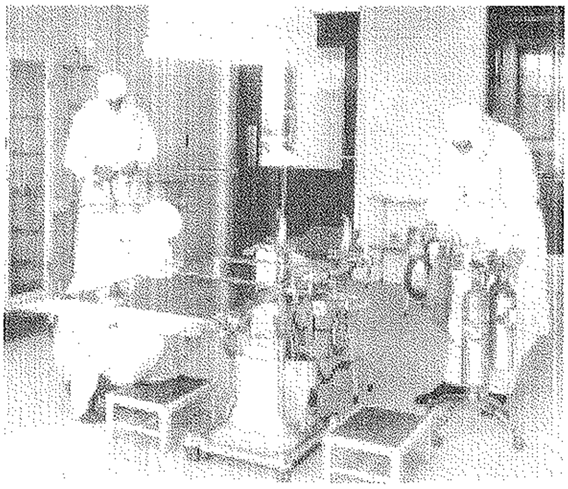


Figure 10.2 Organic compounds with single-bonded functional groups have long been used as anaesthetics.

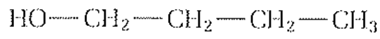
Compounds With Single-Bonded Functional Groups

Alcohols, alkyl halides, ethers, and amines all have functional groups with single bonds. These families of compounds have many interesting uses in daily life. As you learn how to identify and name these types of compounds, think about how intermolecular forces affect their properties and uses.

Alcohols

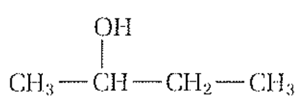
An **alcohol** is an organic compound that contains the —OH, or hydroxyl, functional group. Depending on the position of the hydroxyl group, an alcohol can be *primary*, *secondary*, or *tertiary*. Figure 10.3 gives some examples of alcohols.

primary alcohol



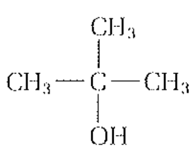
The hydroxyl group is bonded to a carbon that is bonded to only one other carbon atom.

secondary alcohol



The hydroxyl group is bonded to a carbon that is bonded to two other carbon atoms.

tertiary alcohol



The hydroxyl group is bonded to a carbon that is bonded to three other carbon atoms.

Figure 10.3

Table 10.2 lists some common alcohols and their uses. Alcohols are very widely used, and can be found in drug stores, hardware stores, liquor stores, and as a component in many manufactured products.

Table 10.2 Common Alcohols and Their Uses

Name	Common name(s)	Structure	Boiling point	Use(s)
methanol	wood alcohol, methyl alcohol	$CH_3—OH$	64.6°C	• solvent in many chemical processes • component of automobile antifreeze
ethanol	grain alcohol, ethyl alcohol	$CH_3—CH_2—OH$	78.2°C	• solvent in many chemical processes • component of alcoholic beverages • antiseptic liquid
2-propanol	isopropanol, isopropyl alcohol, rubbing alcohol	CH_3 \\ CH—OH CH_3 /	82.4°C	• antiseptic liquid
1,2-ethanediol	ethylene glycol	$HO—CH_2—CH_2—OH$	197.6°C	• main component of automobile antifreeze

Alcohols are named from the **parent alkane:** the alkane with the same basic carbon structure. Follow the steps below to name an alcohol. The Sample Problem that follows gives an example.

How to Name an Alcohol

Step 1 Locate the longest chain that contains an —OH group attached to one of the carbon atoms. Name the parent alkane.

Step 2 Replace the -e at the end of the name of the parent alkane with -ol.

Step 3 Add a position number before the root of the name to indicate the location of the —OH group. (Remember to number the main chain of the hydrocarbon so that the hydroxyl group has the lowest possible position number.) If there is more than one —OH group, leave the -e in the name of the parent alkane, and put the appropriate prefix (di-, tri-, or tetra-) before the suffix -ol.

Step 4 Name and number any other branches on the main chain. Add the name of these branches to the prefix.

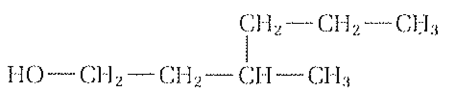
Step 5 Put the name together: prefix + root + suffix.

Sample Problem

Naming an Alcohol

Problem

Name the following alcohol. Identify it as primary, secondary, or tertiary.



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PROBLEM TIP

If an organic compound is complex, with many side branches, the main chain may not be obvious. Sketch the compound in your notebook or on scrap paper. Circle or highlight the main chain

Math LINK

www.mcgrawhill.ca/links/atlchemistry

Methanol and ethanol are produced industrially from natural, renewable resources. Go to the web site above, and click on **Web Links** to find out where to go next. Research the processes that produce these important chemicals. From where do they obtain their raw materials?

Continued

Solution

Step 1 The main chain has six carbon atoms. The name of the parent alkane is hexane.

Step 2 Replacing -e with -ol gives hexanol.

Step 3 Add a position number for the —OH group, to obtain 1-hexanol.

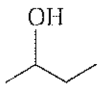
Step 4 A methyl group is present at the third carbon. The prefix is 3-methyl.

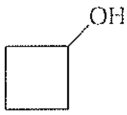
Step 5 The full name is 3-methyl-1-hexanol. This is a primary alcohol.

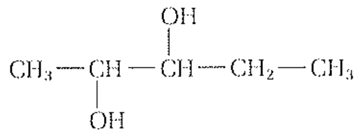
Practice Problems

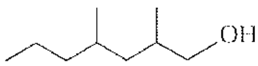
8. Name each alcohol. Identify it as primary, secondary, or tertiary.

(a) $CH_3—CH_2—CH_2—OH$

(b) 

(c) 

(d) 

(e) 

9. Draw each alcohol.

(a) methanol

(b) 2-propanol

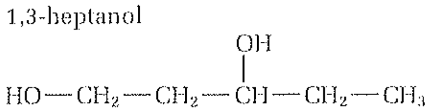
(c) 2,2-butanediol

(d) 3-ethyl-4-methyl-1-octanol

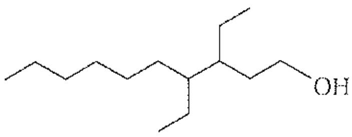
(e) 2,4-dimethyl-1-cyclopentanol

10. Identify any errors in each name. Give the correct name for the alcohol.

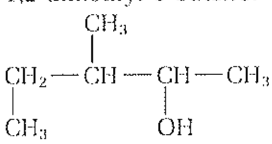
(a) 1,3-heptanol



(b) 3-ethyl-4-ethyl-1-decanol



(c) 1,2-dimethyl-3-butanol



11. Sketch a three-dimensional diagram of methanol. **Hint:** Recall that the shape around an oxygen atom is *bent*.

Table 10.3 lists some common physical properties of alcohols. As you learned earlier in this chapter, alcohols are polar molecules that experience hydrogen bonding. The physical properties of alcohols depend on these characteristics.

Table 10.3 Physical Properties of Alcohols

Polarity of functional group	The O—H bond is very polar. As the number of carbon atoms in an alcohol becomes larger, the alkyl group's non-polar nature becomes more important than the polar O—H bond. Therefore small alcohols are more polar than alcohols with large hydrocarbon portions.
Hydrogen bonding	Alcohols experience hydrogen bonding with other alcohol molecules and with water.
Solubility in water	The capacity of alcohols for hydrogen bonding makes them extremely soluble in water. Methanol and ethanol are *miscible* (infinitely soluble) with water. The solubility of an alcohol decreases as the number of carbon atoms increases.
Melting and boiling points	Due to the strength of the hydrogen bonding, most alcohols have higher melting and boiling points than alkanes with the same number of carbon atoms. Most alcohols are liquids at room temperature.

Additional Characteristics of Alcohols

- Most alcohols are poisonous. Methanol can cause blindness or death when consumed. Ethanol is consumed widely in moderate quantities, but it causes impairment and/or death when consumed in excess.

Reactions of Alcohols

Alcohols can react in several ways, depending on the reactants and on the conditions of the reaction. For example, alcohols can undergo combustion, substitution with halogen acids, and elimination to form alkenes.

Combustion of Alcohols

Alcohols are extremely flammable, and should be handled with caution. Like hydrocarbons, alcohols react with oxygen in combustion reactions to produce carbon dioxide and water.

$$CH_3—CH_2—OH \quad + \quad 3O_2 \quad \rightarrow \quad 2CO_2 \quad + \quad 3H_2O$$

ethanol — oxygen — carbon dioxide — water

Figure 10.4 **The complete combustion of ethanol produces carbon dioxide and water.**

Substitution Reactions of Alcohols

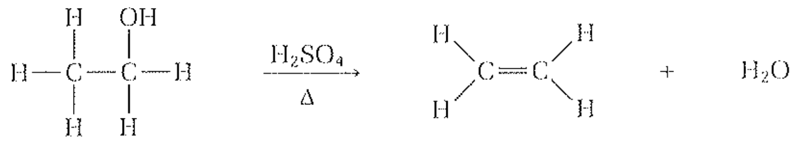
When a halogen acid, such as HCl, HBr, or HI, reacts with an alcohol, the halogen atom is substituted for the OH group of the alcohol. This is shown in Figure 10.5.

$$CH_3—CH_2—OH \ + \ HCl \ \rightarrow \ CH_3—CH_2—C\ell \ + \ H_2O$$

Figure 10.5 **Ethanol reacts with hydrochloric acid to produce chloroethane.**

Elimination Reactions of Alcohols

When an alcohol is heated in the presence of the strong acid and dehydrating agent, H_2SO_4, an elimination reaction takes place. This type of reaction is shown in Figure 10.6, below. The OH group and one H atom leave the molecule, and water is produced. As a result, the molecule forms a double bond. Because water is produced, this type of reaction is also called a *dehydration* (meaning "loss of water") reaction.



ethanol ethene water

Figure 10.6 The Δ symbol is used in chemistry to represent heat added to a reaction.

Alkyl Halides

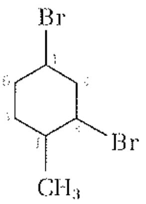
On the previous page, you saw that alcohols can undergo substitution reactions with halogen acids to produce a different kind of organic compound. An **alkyl halide** (also known as a **haloalkane**) is an alkane in which one or more hydrogen atoms have been replaced with halogen atoms, such as F, Cl, Br, or I. The general formula for alkyl halides is R—X, where X represents a halogen atom. Alkyl halides are similar in structure, polarity, and reactivity to alcohols. To name an alkyl halide, first name the parent hydrocarbon. Then use the prefix fluoro-, chloro-, bromo-, or iodo-, with a position number, to indicate the presence of a fluorine atom, chlorine atom, bromine atom, or iodine atom. The following Sample Problem shows how to name an alkyl halide.

Sample Problem

Naming an Alkyl Halide

Problem

Name the following compound.



Solution

The parent hydrocarbon of this compound is cyclohexane. There are two bromine atoms attached at position numbers 1 and 3. Therefore, part of the prefix is 1,3-dibromo-. There is also a methyl group at position number 4. Because the groups are put in alphabetical order, the full prefix is 1,3-dibromo-4-methyl-. (The ring is numbered so that the two bromine atoms have the lowest possible position numbers. See the Problem Tip on page 361.) The full name of the compound is 1,3-dibromo-4-methylcyclohexane.