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ACTIVE LEARNING IN CHEMISTRY EDUCATION

CHAPTER 26

INTRODUCTION

TO ORGANIC

COMPOUNDS

(Part 2)

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SECTION 26.1 Alcohols

Alcohols are molecules in which an alkyl group is attached to a *hydroxy* group (–OH). The hydroxy group is responsible for the characteristic properties of alcohols so we refer to it as the functional group for alcohols. There are three different methods for naming alcohols, but we will use only the IUPAC system. The rules that you used for naming alkanes and alkenes (in Chapter 25) are similar to those used for the alcohols. The modified rules are listed below.

Additional Rules for the Nomenclature of Alcohols:

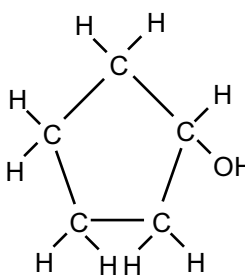
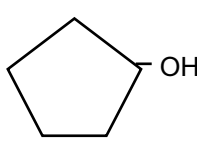
RULE 1: Locate the longest continuous chain of carbon atoms which contains the "hydroxy" (–OH) group. This chain will serve to identify the parent compound.

RULE 2: Number the chain so as to give the carbon atom which is bonded to the –OH group the lowest possible number.

RULE 3: A number is included before the name of the parent compound to indicate the position of the –OH group.

RULE 4: The suffix "ol" is added to the name to indicate that the molecule is an alcohol.

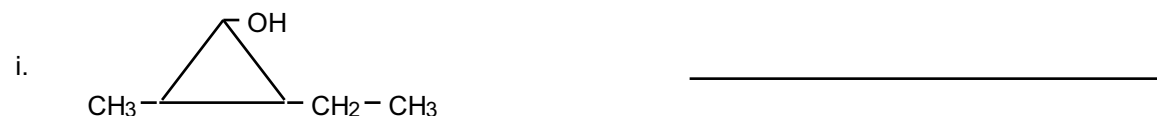
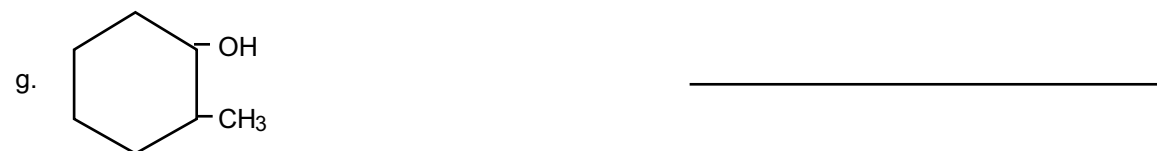
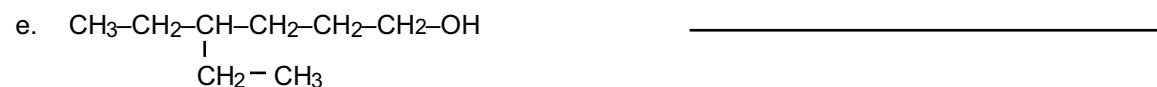
Study the examples below. Note that the number indicating the position of the –OH group is not used if the chain is shorter than 3 carbons. Why? {1} _____

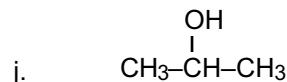
Name	Formula	Condensed Structural Formula
methanol	CH ₃ OH	CH ₃ –OH
ethanol	CH ₃ CH ₂ OH	CH ₃ –CH ₂ –OH
1-propanol	CH ₃ CH ₂ CH ₂ OH	CH ₃ –CH ₂ –CH ₂ –OH
2-propanol	CH ₃ CHOHCH ₃	$\begin{array}{c} \text{OH} \\ \\ \text{CH}_3\text{--CH--CH}_3 \end{array}$
cyclopentanol		

In addition, you see in the example above that the position of the -OH ("hydroxy") group is not included in the names of cyclic alcohols, either. Why not? (Remember that this is also the case for the double bond in cyclic alkenes. {2} _____)

(The *hydroxy* group, -OH , should not be confused with the *hydroxide ion*, OH^{1-} . The hydroxy group has the same formula, but it is not an ion.)

Problem 1. Name the alcohols given below.





This compound is commonly called "rubbing alcohol." Give its IUPAC name.

Problem 2. Draw the condensed structural formulas for the following.

a. 4,4-dimethyl-2-hexanol

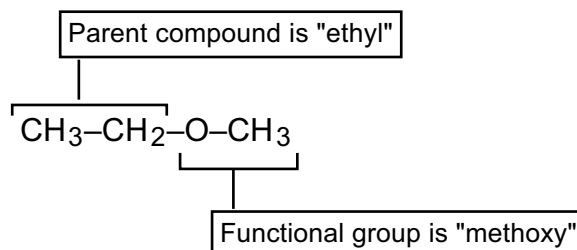
b. cyclopropanol

c. 2,3-diethylcyclohexanol

d. 3,4-diethyl-2-heptanol

Section 26.2 Ethers

Ethers are compounds which contain an oxygen atom bonded to two carbon atoms within the carbon chain. The functional group is the C–O–C arrangement found within the chain. When you look at an ether molecule, you will see an alkyl group on each side of the oxygen. For example, $\text{CH}_3\text{-CH}_2\text{-O-CH}_3$ has an ethyl group on the left of the oxygen atom and a methyl group on the right. The "common name" for this molecule is *methyl ethyl ether*. Although common names are still frequently used for ethers, we will stick to our "game plan" and use the IUPAC system.

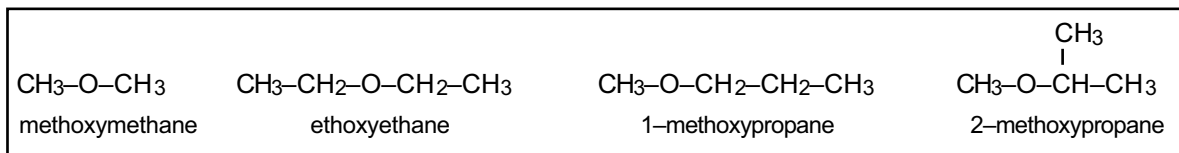


In the IUPAC system, the larger of the two alkyl groups attached to the oxygen is considered to be the parent compound. For the ether mentioned in the last paragraph above, the parent compound would be ethane. The smaller alkyl group and the oxygen atom are considered to be a substituent group on the parent compound. The -O-CH_3 group is the substituent and it is called "methoxy." So the name of that ether is methoxyethane. If the substituent had been $\text{CH}_3\text{-CH}_2\text{-O-}$, it would have been called "ethoxy." Collectively these functional groups of the ethers are known as *alkoxy groups*. Only one modified rule needs to be mentioned here regarding the nomenclature of ethers.

Additional Rule for the Nomenclature of Ethers:

RULE: For ethers with parent chains that contain 3 or more carbon atoms, a number is included to indicate the position of the alkoxy group.

Study the examples below.



Problem 3. Name the following ethers:

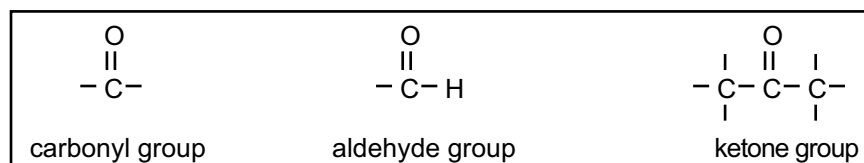
- a. $\text{CH}_3\text{-O-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$ _____
- b. $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-O-CH}_2\text{-CH}_2\text{-CH}_3$ _____
- c. $\begin{array}{c} \text{CH}_3\text{-CH}_2\text{-O-CH-CH}_2\text{-CH}_2\text{-CH}_3 \\ | \\ \text{CH}_3 \end{array}$ _____

Draw condensed structures for the following ethers:

- d. methoxycyclohexane
- e. 3-methoxycyclopentene
- f. 4-ethoxynonane
- g. 2-isopropoxybutane

Section 26.3 Aldehydes and Ketones

The next two organic functional groups we will study are those of the *aldehydes* and *ketones*. Aldehydes and ketones contain a *carbonyl group*, which consists of an oxygen atom which is double-bonded to a carbon atom. There are two kinds of carbonyl groups involved here. In aldehydes, at least one hydrogen is attached to the carbonyl carbon, while in ketones, two carbon atoms are always attached to the carbonyl carbon.



It is helpful to note that in an aldehyde the carbonyl carbon is always a terminal carbon, which means it always occurs at one end of the carbon chain. In ketones, the carbonyl carbon is never a terminal carbon. The nomenclature of aldehydes requires a few rule modifications:

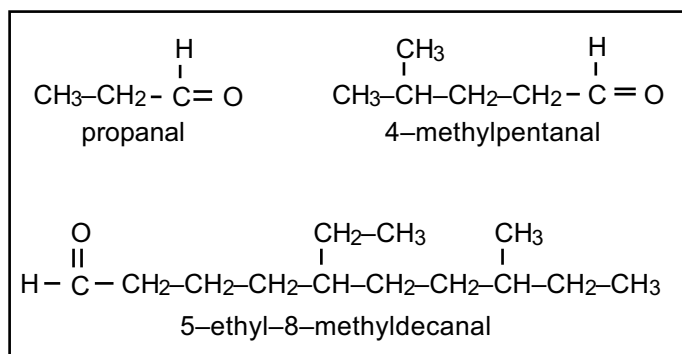
Additional Rules for the Nomenclature of Aldehydes:

RULE 1: The longest continuous chain containing the aldehyde group is considered to be the parent compound.

RULE 2: The carbonyl carbon is part of the parent chain and is always considered to be in the #1 position.

RULE 3: The suffix "al" is added to the name of the parent compound to indicate that the compound is an aldehyde.

Note the examples of *aldehydes* shown below. You see that no number is needed to indicate the position of the functional group since it is always at position #1.



The nomenclature of ketones also requires a few rule modifications.

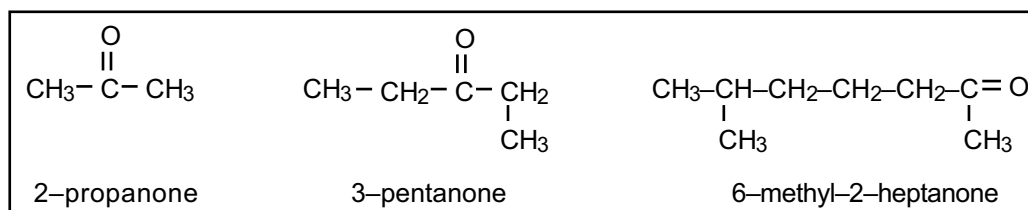
Additional Rules for the Nomenclature of Ketones:

RULE 1: The longest continuous chain containing the ketone group is considered to be the parent compound.

RULE 2: A number is included before the name of the parent compound to indicate the position of the ketone group. The chain is always numbered so that the carbonyl carbon has the lowest possible number.

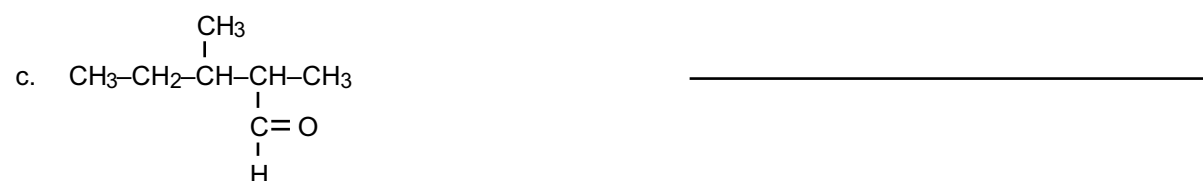
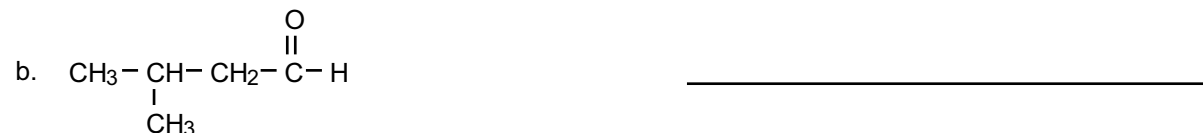
RULE 3: The suffix "one" is added to the name of the parent compound to indicate that the compound is a ketone.

For example:



Why would it be impossible for a ketone to have a name like 3-methyl-1-hexanone? {3} _____

Problem 4. Name the molecules shown below.



Section 26.4 Organic Acids

Organic acids are molecules that contain a *carboxyl* group (sometimes called a carboxylic acid group). This functional group consists of a carbon which is double bonded to an oxygen atom, as was the case with aldehydes and ketones. However, in an acid a hydroxy group (-OH) is also bonded to that same carbon. Be careful not to confuse organic acids with alcohols, aldehydes, or ketones. As was the case with aldehydes, this functional group always occurs on a terminal carbon of the parent chain. Therefore, a number is not used in the name to locate the carboxyl group.

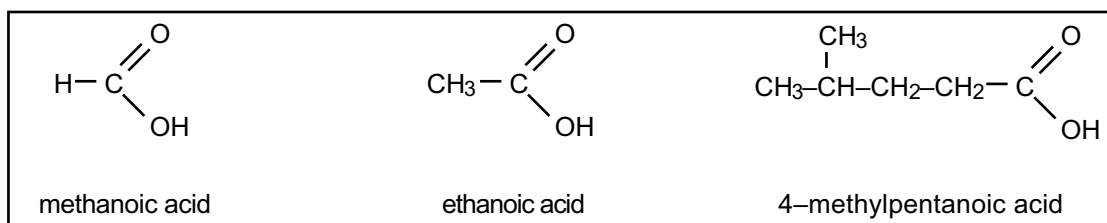
Additional Rules for the Nomenclature of Carboxylic Acids:

RULE 1: The longest continuous chain containing the carboxyl group is considered to be the parent compound.

RULE 2: The carboxyl carbon is part of the parent chain and is always considered to be in the #1 position.

RULE 3: The suffix "oic" is added to the name of the parent compound, and the word "acid" is added to the name.

For example:



Acids also have common names. For example, ethanoic acid is also called *acetic acid* or "vinegar." We will work only with the IUPAC names.

As you attempt to name the carboxylic acids, note that the carboxyl group is written in shorthand as -COOH in the condensed structural formulas.

Problem 5. Name the organic acids below.

- a.
$$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{COOH} \\ | \\ \text{CH}_2-\text{CH}_3 \end{array}$$

- b.
$$\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{COOH}$$

- c.
$$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}_2 \\ | \\ \text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_2-\text{COOH} \end{array}$$

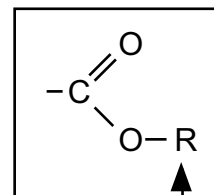
- d.
$$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{COOH} \\ | \qquad \qquad | \\ \text{CH}_3 \qquad \qquad \text{CH}_3 \end{array}$$

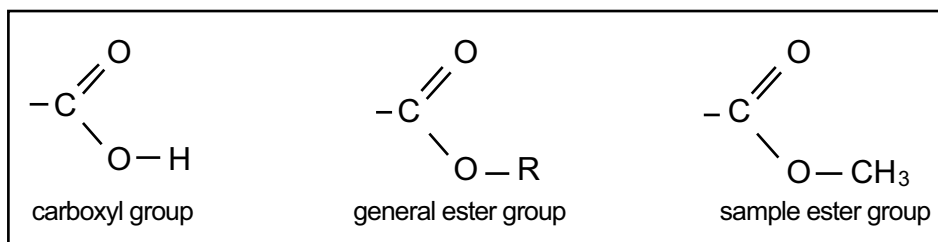
- e.
$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}-\text{CH}_2-\text{COOH} \\ | \\ \text{CH}_3 \end{array}$$

- f.
$$\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3 \\ | \\ \text{CH}_3-\text{C}-\text{CH}_2-\text{CH}_2-\text{COOH} \\ | \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3 \end{array}$$

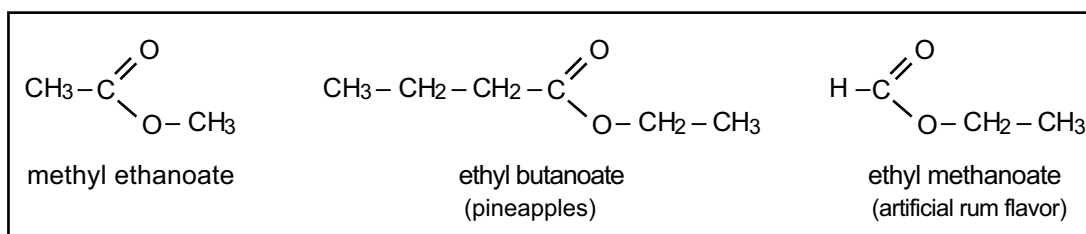
Section 26.5 Esters

Esters are organic compounds which are very common in nature. For example, fats and oils are esters. Esters are also responsible for many of the odors and flavors of fruits. Oil of wintergreen and aspirin are esters. Esters can be considered to be derivatives of carboxylic acids. The functional group of esters looks similar to the carboxyl group of acids, except that the hydrogen atom on the hydroxy group is replaced with an organic group such as an alkyl group. The letter "R" in the structure at right represents some organic group (methyl, ethyl, etc.).





Esters are named by first naming the "R" group followed by the name of the acid portion. The suffix of the acid derivative is then changed from "-ic" to "-ate." For example, in the leftmost structure below, the parent acid is ethanoic acid. The "R" group is methyl, so the name of the ester is *methyl ethanoate*. In the center structure, the parent acid is butanoic, while the "R" group is ethyl, so the ester is named *ethyl butanoate*. Notice that the names of esters consist of two words, while the names of most of the previous types of compounds you have studied consisted of only one word.



Artificial flavors of strawberry, apple, raspberry, cherry, etc., are made from esters.

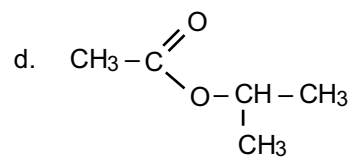
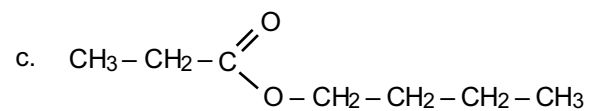
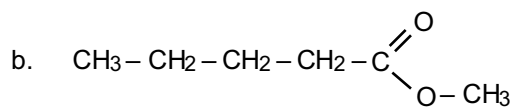
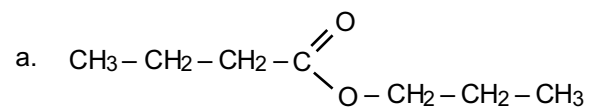
Additional Rules for the Nomenclature of Esters:

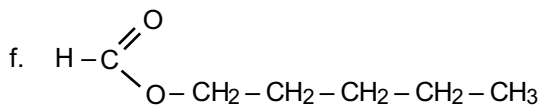
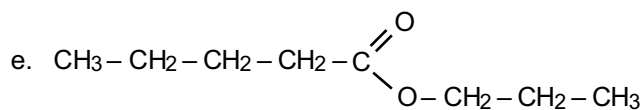
RULE 1: Determine the name of the "R" group.

RULE 2: Place the name of the "R" group in front of the name of the parent acid, forming two words.

RULE 3: Determine the name of the parent acid, and change its suffix from "-ic" to "-ate." Drop the word "acid."

Problem 6. Name the esters below.

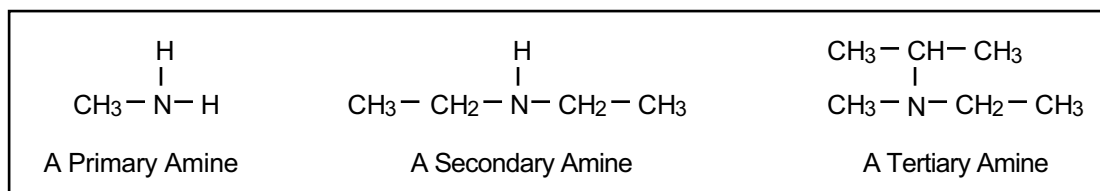




Section 26.6 Amines

Amines are organic compounds which are related to ammonia (NH_3). All amines have the element nitrogen in them. There are three basic kinds of amines:

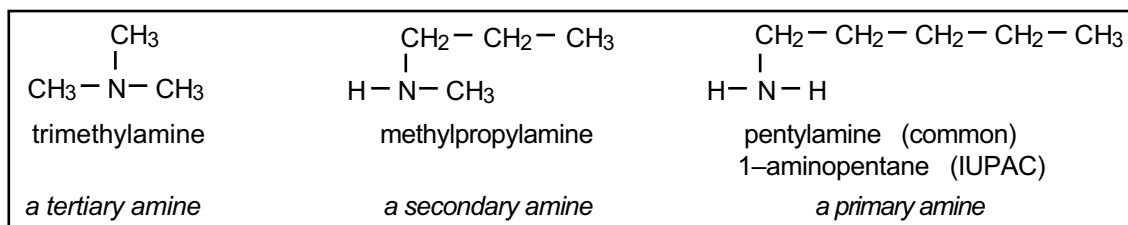
1. In *primary* amines one hydrogen atom in ammonia has been replaced by an alkyl group.
2. In *secondary* amines two hydrogen atoms in ammonia have been replaced by two alkyl groups.
3. In *tertiary* amines all three hydrogen atoms in ammonia have been replaced by three alkyl groups. Examine the examples below:



According to the IUPAC system, primary amines are named by treating the $-\text{NH}_2$ (amino) group in the molecule as a substituent group on the longest (parent) chain of carbon atoms. For example, the primary amine shown above is called *aminomethane*. Two more examples are shown below.



Secondary and tertiary amines are named according to a "common" naming system. Primary amines can have either IUPAC or common names. Amines are the only organic compounds for which we will learn common names. In the common system, amines are named by adding the names of the alkyl group(s) attached to the nitrogen atom to the word "amine." In the past, the alkyl groups were named in order of size (smallest first) instead of in alphabetical order as is normally done in the IUPAC system. However, today we follow the IUPAC rules and name the alkyl groups in alphabetical order. For example, the name of the secondary amine shown above is diethylamine. The name of the tertiary amine above is ethylisopropylmethylamine. Study the examples below. Note that the primary amine can have two names.

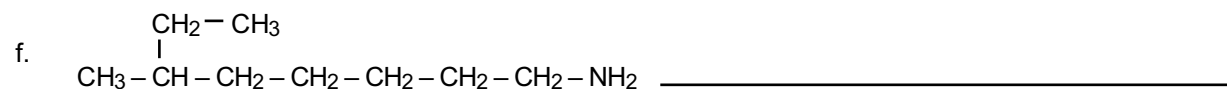


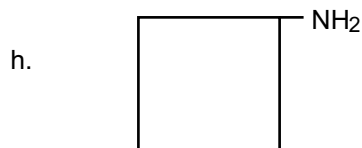
Additional Rules for the Nomenclature of Amines:

RULE 1: In primary amines only, the IUPAC system treats the NH_2 (amino) group as a substituent group on the parent chain.

RULE 2: When using the common naming system, the names of the alkyl groups which are attached to the nitrogen atom are listed in alphabetical order and are attached to the suffix "amine" to form one word. Greek prefixes are used if specific alkyl groups occur more than once in a molecule. Name the amines below. Where two lines are present, give two names.

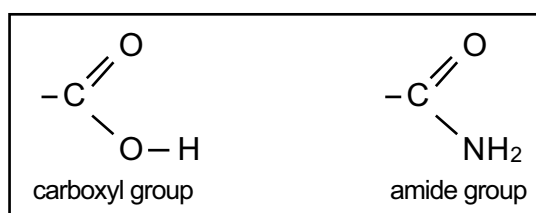
Problem 7. Name the amines below. Where two lines are present, give two names.



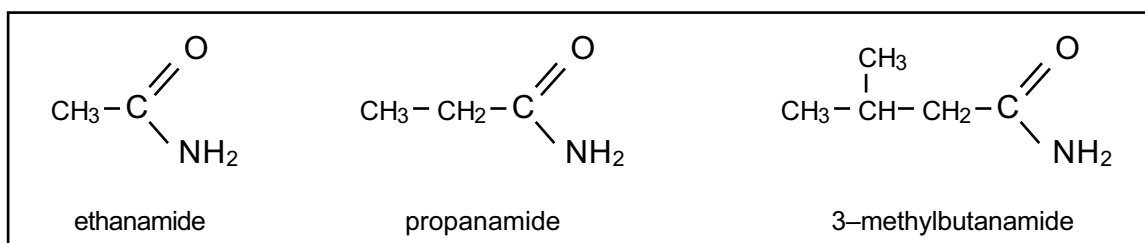


Section 26.7 Amides

You are already familiar with the carboxyl group which is the functional group of a carboxylic acid. If you replace the hydroxy group ($-\text{OH}$) in the carboxyl group with an amino group ($-\text{NH}_2$), you get the functional group of a class of organic compounds known as primary *amides*.



There are three classes of amides just as there were for amines, but we will consider only *primary* amides, and we will name them according to the IUPAC system. Amides are considered to be derivatives of carboxylic acids, which means they are formed from acids. Thus, the amides are named as derivatives of acids. To name an amide, simply identify the name of the organic acid from which the amide was derived, and change the "-oic" suffix in the acid's name to "-amide." The examples of amides shown below were derived from ethanoic, propanoic, and butanoic acids.

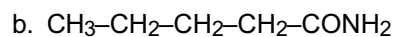


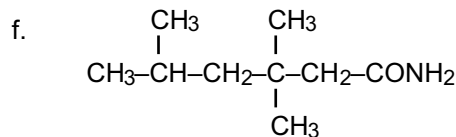
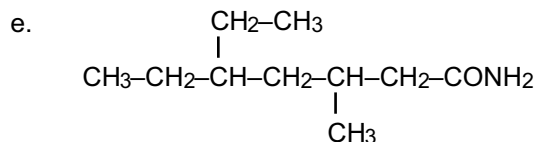
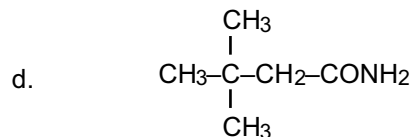
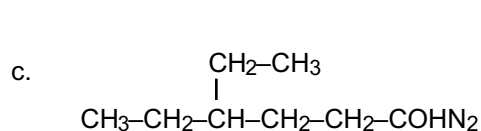
Additional Rules for the Nomenclature of Amides:

RULE 1: Identify the carboxylic acid from which the amide was derived and change the suffix of the acid name from "-oic" to "-amide," and drop the word acid.

RULE 2: Add the names of any alkyl groups to the name of the parent compound, forming one word.

Problem 8. Name the amides shown below. Note that the amide functional group is written in shorthand as CONH_2 .



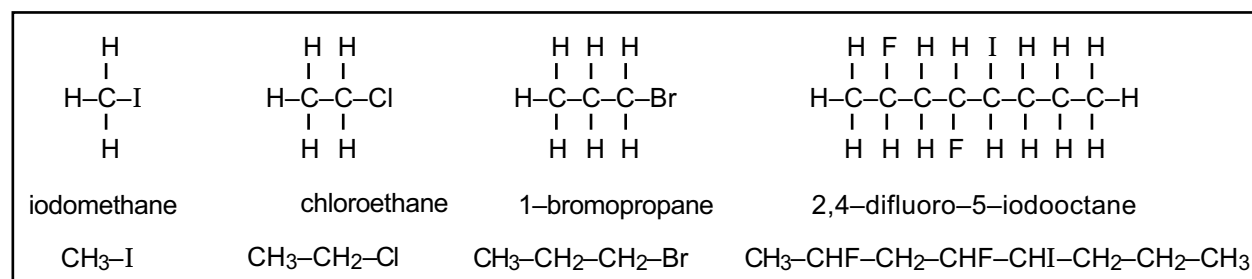


Section 26.8 Halogenated Hydrocarbons

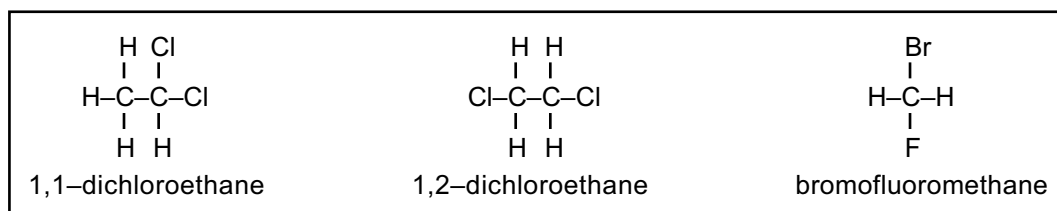
The last group of compounds we are going to discuss includes some that are of great importance and interest today. Included are the chlorofluorocarbons that are used in refrigeration and air conditioning systems and which are thought to be involved in the depletion of ozone in the upper atmosphere.

This class of organic compounds is known as the *halogenated hydrocarbons*. In addition to their use in refrigerants they are used as solvents, aerosol sprays, antiseptics, dry cleaning fluids, insecticides, herbicides, and anesthetics. Most of these compounds are synthetic (human-made).

In these compounds, the functional group is a single atom of a halogen such as fluorine, chlorine, bromine, or iodine. In the IUPAC system, the halogen atoms are considered to be substituents on the parent chain. The "-ine" suffix of the halogen's name is dropped and the letter "o" is added before being added to the name of the parent compound. For example, fluorine becomes "fluoro," chlorine becomes "chloro," bromine becomes "bromo," and iodine becomes "iodo." Note the examples below.



Numbers are not used to indicate the position of a single halogen atom substituent unless the parent carbon chain is longer than 2 atoms; however, if more than one halogen atom substituent is present, then numbers are needed on a two-carbon chain, too! Study the following examples.

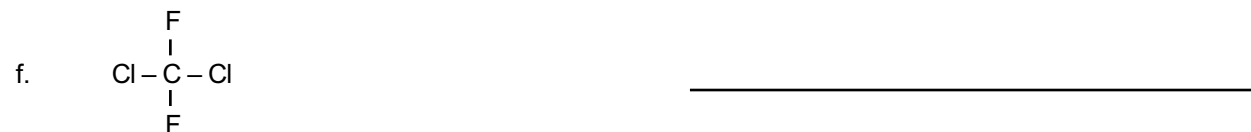
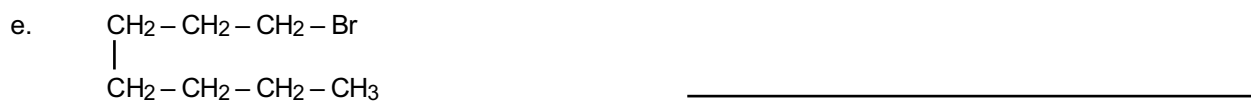


Additional Rules for the Nomenclature of Halogenated Hydrocarbons:

RULE 1: Drop the "-ine" suffix from the name of the halogen atom(s) and add a suffix consisting of the letter "o".

RULE 2: Add the altered name(s) of the halogen atom(s) to that of the parent compound.

Problem 9. Name the halogenated compounds below.



Problem 10. Write condensed structural formulas (such as those shown above) for the following.

a. tetrafluoromethane

b. 1,1,1-trichloroethane

- c. chlorocyclopentane

- d. 1,3-difluoro-2-iodocyclohexane

- e. 3,4-dibromo-6-methyl-1-heptyne

- f. 3-chlorocyclopentene

- g. 2,3-dichlorocyclobutene

Section 26.9 A Review of Organic Nomenclature

The remainder of this chapter consists of a review of nomenclature of the various classes of organic compounds which you have studied.

Problem 11. Some of the names of the six compounds listed below are incorrect. If the name is correct, respond with "O.K." If the name is incorrect, provide the correct name.

- a. 3-chloropentane _____

- b. 1,1-dimethyl-1-propanol _____

- c. 2,2,3-trimethyl-4-bromoheptane _____

- d. 4-methyl-4-hexanol _____

- e. 2,2-dimethyl-3-chloro-3-butanol _____

- f. 1-ethyl-2-ethanol _____

Problem 12. Draw condensed structural formulas for the compounds named below.

a. 1,3,5-tribromocyclohexane

b. 2,3-dichlorobutane

c. 2-ethyl-3-methyl-1-pentanol

d. 1-ethoxypropane

e. 2-iodo-3-isopropylcyclohexanol

f. 3,3-dimethylbutanal

g. 2-methoxy-3-heptanone

h. 3-pentanone

i. 3,4-diethylhexanal

j. 2,4-difluorohexanoic acid

k. 2-hydroxybutanoic acid

l. ethyl ethanoate

m. n-propyl octanoate

n. 4-bromo-3-chloroheptane

o. ethylmethanamine

p. isopropylidimethanamine

q. propanamide

r. 3-methylbutanamide

s. 4-chloro-2-pentanone

t. 2,3,4-triiodopentanoic acid

Problem 13. Give another name for each of the following:

a. ethylamine

b. isopropylamine

Section 26.11 Learning Outcomes

Before leaving this chapter, read through the learning outcomes listed below. Place a check before each outcome when you feel you have mastered it. When you have completed this task, arrange to take any quizzes or exams on this chapter.

- _____ 1. Given their names or condensed structural formulas, distinguish between alcohols, ethers, aldehydes, ketones, organic acids, esters, amines, amides, and halogenated compounds.
- _____ 2. Given their names, draw condensed structural formulas for the classes of compounds given in outcome 1 above.
- _____ 3. Given their condensed structural formulas, give the IUPAC names of molecules belonging to the classes of compounds listed in outcome 1 above.
- _____ 4. Given their condensed structural formulas, give the common names of secondary and tertiary amines.