# Objectives

- **Explain** how the structure and bonding of carbon lead to the diversity and number of organic compounds.
- **Compare** the use of molecular and structural formulas to represent organic compounds.
- **Compare** structural and geometric isomers of organic compounds.

# Organic Compounds

- All organic compounds contain carbon atoms, but not all carbon-containing compounds are classified as organic.
  - examples: $Na_2CO_3$, CO, and $CO_2$ are considered inorganic.
- **Organic compounds** can be defined as covalently bonded compounds containing carbon, excluding carbonates and oxides.

# Carbon Bonding and the Diversity of Organic Compounds

## Carbon-Carbon Bonding

- The diversity of organic compounds results from the uniqueness of carbon’s structure and bonding.
- Carbon atoms are unique in their ability to form long chains and rings of covalently bonded atoms.
- This type of bonding is known as **catenation,** the covalent bonding of an element to itself to form chains or rings.
  - Carbon atoms in these structures can be linked by single, double, or triple covalent bonds.

# Carbon Bonding and the Diversity of Organic Compounds, *continued*

## Carbon Bonding to Other Elements

- Besides binding to other carbon atoms, carbon atoms bind readily to elements with similar electronegativities.
- **Hydrocarbons** are composed of only carbon and hydrogen; they are the simplest organic compounds.
- Other organic compounds contain hydrocarbon backbones to which other elements, primarily O, N, S, and the halogens, are attached.

# Carbon Bonding and the Diversity of Organic Compounds, *continued*

## Arrangement of Atoms

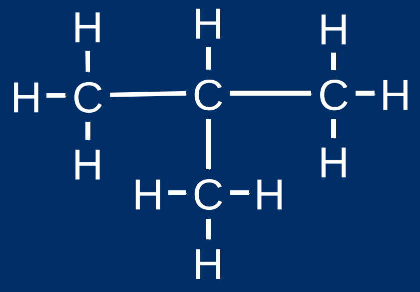
- The bonding capabilities of carbon also allow for many different arrangements of atoms.
- Some compounds may contain the same atoms but have different properties because the atoms are arranged differently.
  - example: the molecular formula $C_2H_4O$ represents both ethanol and dimethyl ether.
- Compounds that have the same molecular formula but different structures are called **isomers.**

# Structural Formulas

- Organic chemists use structural formulas to represent organic compounds.

- A **structural formula** indicates the number and types of atoms present in a molecule and also shows the bonding arrangement of the atoms.

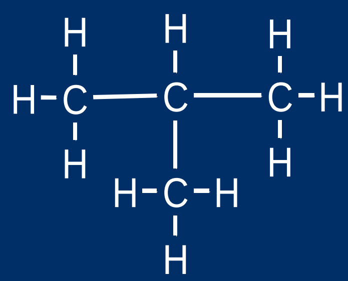
  - example: a structural formula for one isomer of $C_4H_{10}$ is the following:



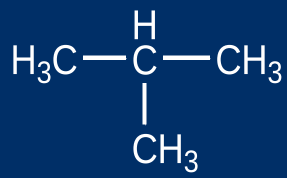

End of Slide

# Structural Formulas, *continued*

- Structural formulas are sometimes condensed to make them easier to read.
- In some condensed structures, bonds to hydrogen are not shown. Hydrogen atoms are understood to bind to the atom they are written beside.
  - example: the following structural and condensed formulas represent the same molecule.

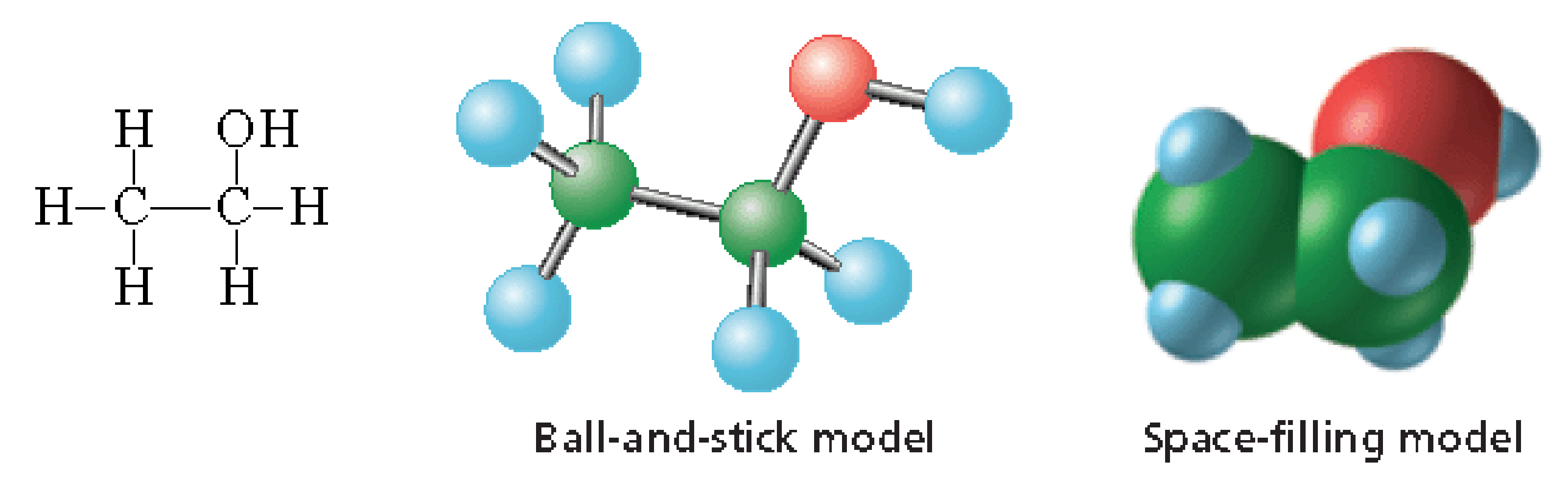


is the same as



# Structural Formulas, *continued*

- Structural formulas do not accurately show the three-dimensional shape of molecules.



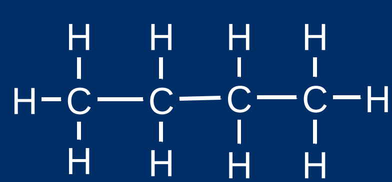

- Three-dimensional shape is depicted with drawings or models, as shown for ethanol above.

# Isomers

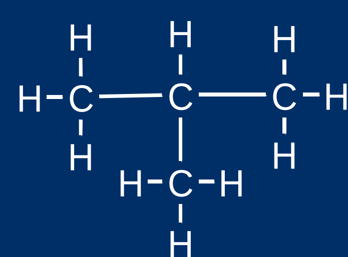
## Structural Isomers

- Isomers are compounds that have the same molecular formula but different structural formulas.

- **Structural isomers,** also called “constitutional isomers,” are isomers in which the atoms are bonded together in different orders.
    - example: the atoms of the molecular formula $C_4H_{10}$ can be arranged in two different ways:



butane

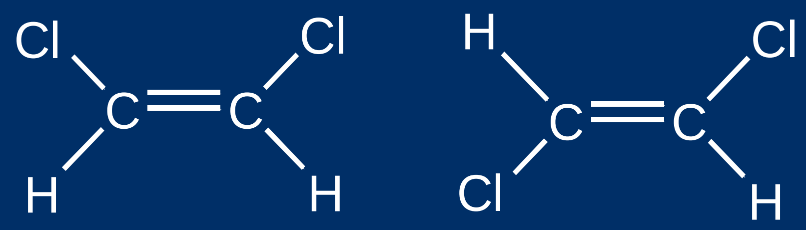


methylpropane

# Isomers, *continued*

## Geometric Isomers

- **Geometric isomers** are isomers in which the order of atom bonding is the same but the arrangement of atoms in space is different.
  - example: the molecule dichloroethene contains a double bond, which prevents free rotation and holds groups to either side of the molecule.
  - There can be two different 1,2-dichloroethene geometric isomers.



# Objectives

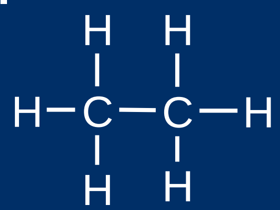
- **Distinguish** among the structures of alkanes, alkenes, alkynes, and aromatic hydrocarbons.
- **Write** structural formulas and names for alkanes, alkenes, and alkynes.
- **Relate** properties of different types of hydrocarbons to their structures.

# Hydrocarbons

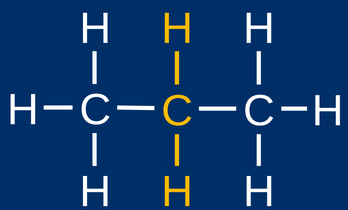
- Hydrocarbons are compounds that contain only carbon and hydrogen. They make up the simplest class of organic compounds.
    - All other organic compounds can be viewed as hydrocarbons in which one or more hydrogen atoms have been replaced by other atoms or other groups of atoms.
- **Saturated hydrocarbons** are hydrocarbons in which each carbon atom in the molecule forms four single covalent bonds with other atoms.

# Alkanes

- Hydrocarbons that contain only single bonds are **alkanes.**
- Straight-chain alkanes differ from one another by one carbon atom and two hydrogen atoms, a $–CH_2–$ group.



ethane



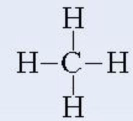
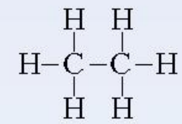
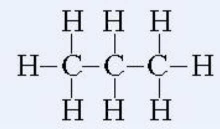
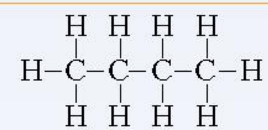
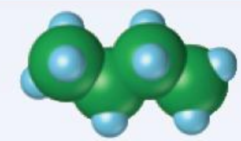
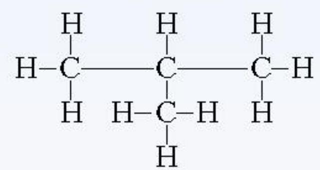
propane

- Compounds that differ in this fashion belong to a *homologous series.*

# Alkanes, *continued*

- A homologous series is one in which adjacent members differ by a constant unit.
- A general molecular formula can be used to determine the formulas of all members of a homologous series.
- In the homologous series of straight-chain alkanes, the formula for each compound is determined by the general formula $C_nH_{2n+2}$.
  - For ethane, $n = 2$, so there are two carbon atoms and $(2 \times 2) + 2 = 6$ hydrogen atoms, and its formula is $C_2H_6$.
  - For propane, $n = 3$, so there are three carbon atoms and $(2 \times 3) + 2 = 8$ hydrogen atoms, and its formula is $C_3H_8$.

# Alkanes

| Molecular formulas | Structural formulas | Space-filling models |
|---|---|---|
| $CH_4$ |  methane |  |
| $C_2H_6$ |  ethane |  |
| $C_3H_8$ |  propane |  |
| $C_4H_{10}$ |  butane |  |
| |  2-methylpropane |  |

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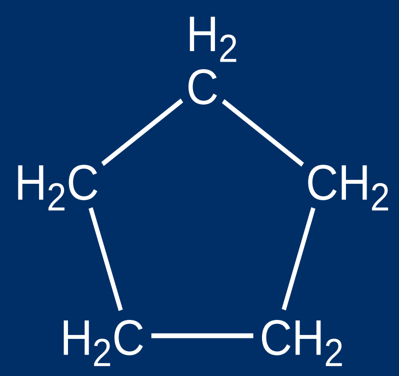
# Cycloalkanes

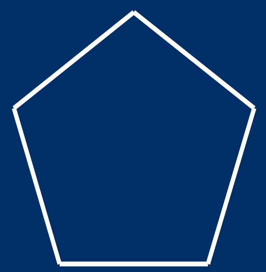
- **Cycloalkanes** are alkanes in which the carbon atoms are arranged in a ring, or cyclic, structure.
- The structural formulas for cycloalkanes are often drawn in a simplified form.
- In skeletal representations it is understood that there is a carbon atom at each corner and enough hydrogen atoms to complete the four bonds to each hydrogen atom.

# Cycloalkanes, *continued*




cyclopentane

*or*

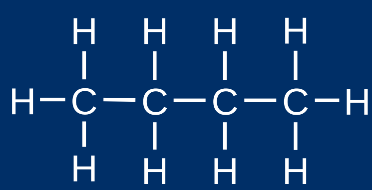


cyclopentane

Skeletal representation

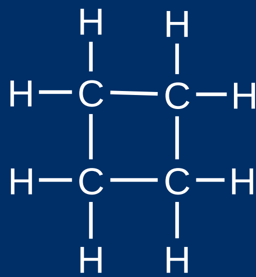
# Cycloalkanes, *continued*

- The general formula for cycloalkanes, $C_nH_{2n}$, shows that they have $2 \times n$ hydrogen atoms, two fewer hydrogen atoms than noncyclic alkanes, $C_nH_{2n+2}$, have.
  - Cycloalkanes have no free ends where a carbon atom is attached to three hydrogen atoms.



butane

$C_4H_{10}$



cyclobutane

$C_4H_8$

## Systematic Names of Alkanes

- Historically, the names of many organic compounds were derived from the sources in which they were found.
- A systematic naming method for organic compounds became necessary because of the many organic compounds that are possible.
- A systematic method has been developed by the International Union of Pure and Applied Chemistry, IUPAC, to name organic compounds.
  - Using this systematic naming, you can tell what the structure of an organic compound is by looking at its name.

# Systematic Names of Alkanes, *continued*

## Unbranched-Chain Alkane Nomenclature

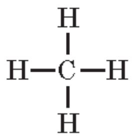
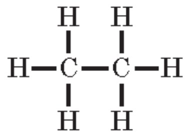
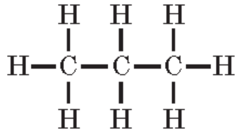
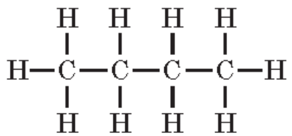
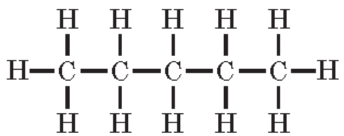
- To name an unbranched alkane, use the prefix that corresponds to the number of carbon atoms in the chain of the hydrocarbon, and add the suffix *-ane.*
  - example:

$$\underset{1}{H_3C}-\underset{2}{\overset{H_2}{C}}-\underset{3}{\overset{H_2}{C}}-\underset{4}{\overset{H_2}{C}}-\underset{5}{\overset{H_2}{C}}-\underset{6}{\overset{H_2}{C}}-\underset{7}{CH_3}$$

heptane

- The rest of the prefixes for alkanes with one to ten carbon atoms are shown in the table on the next slide.

# Names of Alkanes

| Number of carbon atoms | Name of alkane | Molecular formula | Structural formula | Melting point (°C) | Boiling point (°C) |
|---|---|---|---|---|---|
| 1 | methane | $CH_4$ |  | –182 | –164 |
| 2 | ethane | $C_2H_6$ |  | –172 | –88.6 |
| 3 | propane | $C_3H_8$ |  | –187.7 | –42.1 |
| 4 | butane | $C_4H_{10}$ |  | –138.4 | –0.5 |
| 5 | pentane | $C_5H_{12}$ |  | –129.7 | 36.1 |

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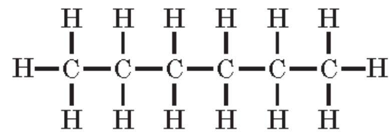
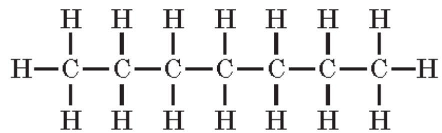
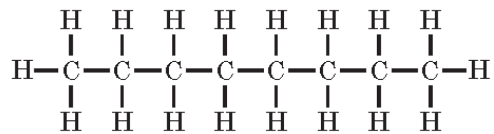
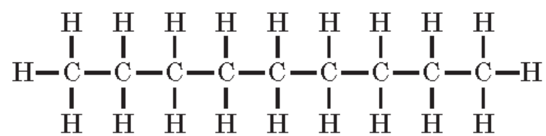
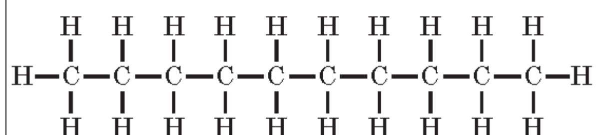
# Names of Alkanes

| Number of carbon atoms | Name of alkane | Molecular formula | Structural formula | Melting point (°C) | Boiling point (°C) |
|---|---|---|---|---|---|
| 6 | hexane | $C_6H_{14}$ |  | –95 | 69 |
| 7 | heptane | $C_7H_{16}$ |  | –90.6 | 98.4 |
| 8 | octane | $C_8H_{18}$ |  | –56.8 | 125.7 |
| 9 | nonane | $C_9H_{20}$ |  | –51 | 150.8 |
| 10 | decane | $C_{10}H_{22}$ |  | –29.7 | 174.1 |

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature

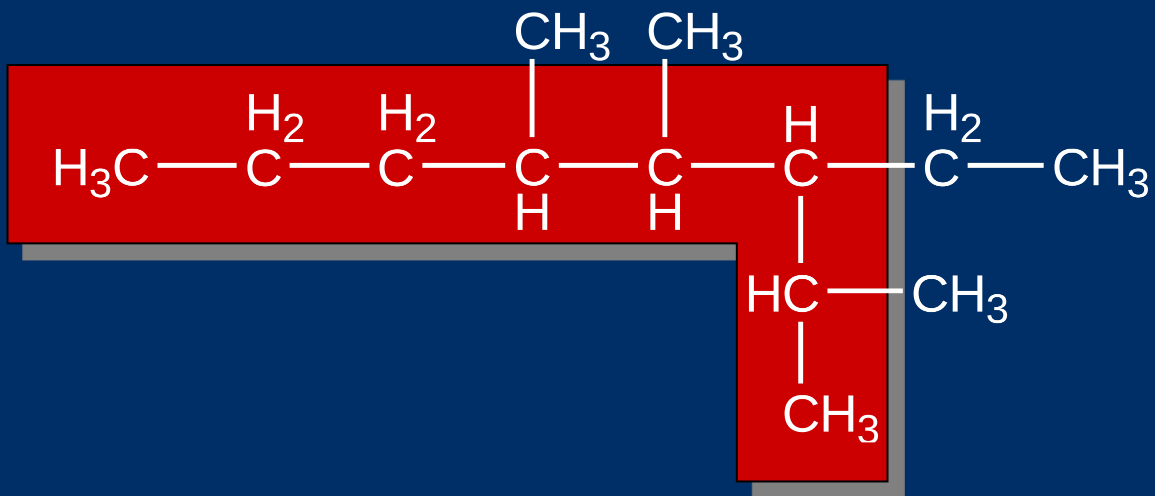
- The naming of branched-chain alkanes also follows a systematic method.
- The hydrocarbon branches of alkanes are alkyl groups.
- **Alkyl groups** are groups of atoms that are formed when one hydrogen atom is removed from an alkane molecule.
- Alkyl groups are named by replacing the suffix -*ane* of the parent alkane with the suffix -*yl.* Alkyl group names are used when naming branched-chain alkanes.

# Straight-Chain Alkyl Groups

| Alkane | Name |
|---|---|
| $CH_4$ | methane |
| $CH_3{-}CH_3$ | ethane |
| $CH_3{-}CH_2{-}CH_3$ | propane |
| $CH_3{-}CH_2{-}CH_2{-}CH_3$ | butane |
| $CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3$ | pentane |
| $-CH_3$ | methyl |
| $-CH_2{-}CH_3$ | ethyl |
| $-CH_2{-}CH_2{-}CH_3$ | propyl |
| $-CH_2{-}CH_2{-}CH_2{-}CH_3$ | butyl |
| $-CH_2{-}CH_2{-}CH_2{-}CH_2{-}CH_3$ | pentyl |

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

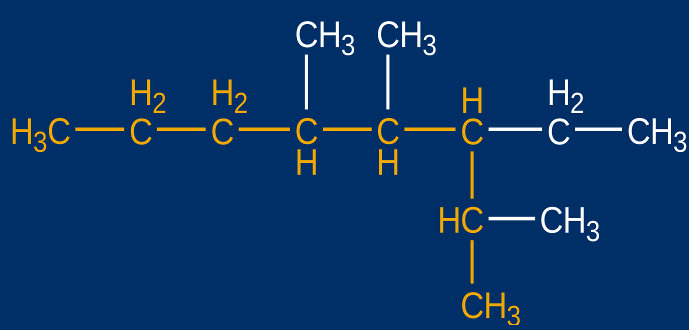



- To name this molecule, first locate the parent hydrocarbon (the longest continuous chain that contains the most straight-chain branches).

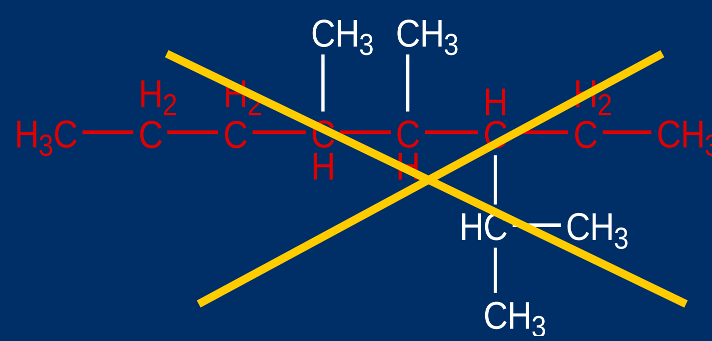
# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

- Do not be tricked by the way the molecule is drawn: the longest chain *with the most straight-chain branches* may be shown bent:



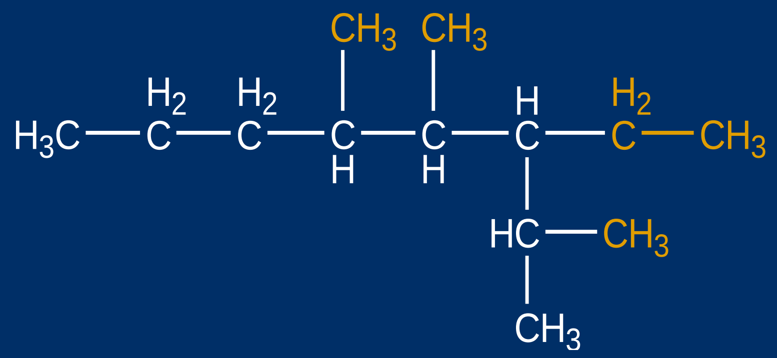
***not:***



# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

- To name the parent hydrocarbon, add the suffix -*ane* to the correct prefix (in this case, *oct-* for an eight-carbon parent chain).
- Now identify and name the alkyl groups.




- The three $-CH_3$ groups are methyl groups.
- The $-CH_2-CH_3$ group is an ethyl group.

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

- Arrange the names in alphabetical order in front of the name of the parent hydrocarbon.

ethyl methyloctane

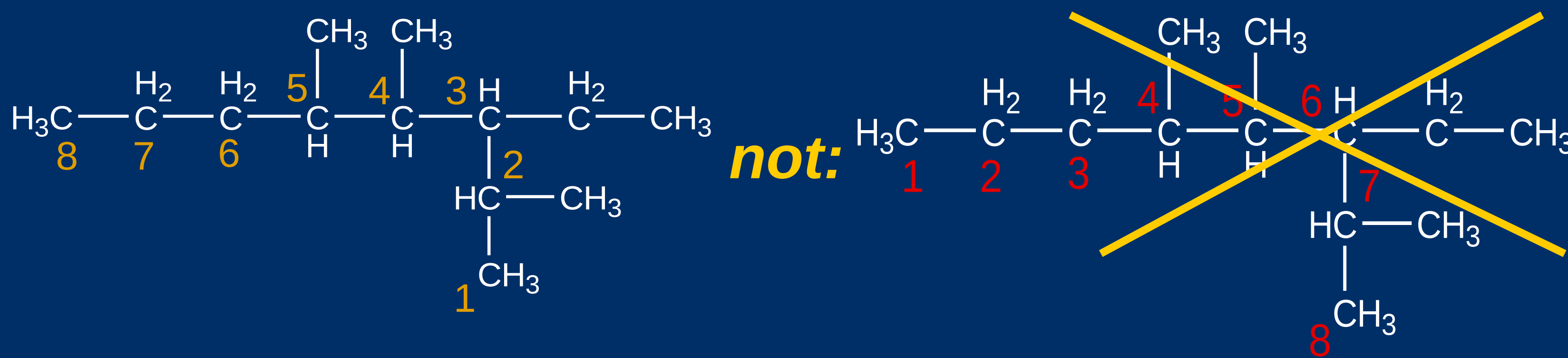
- To show that there are three methyl groups present, attach the prefix *tri-* to the name *methyl* to form *trimethyl.*

ethyl trimethyloctane

# Systematic Names of Alkanes, *continued*

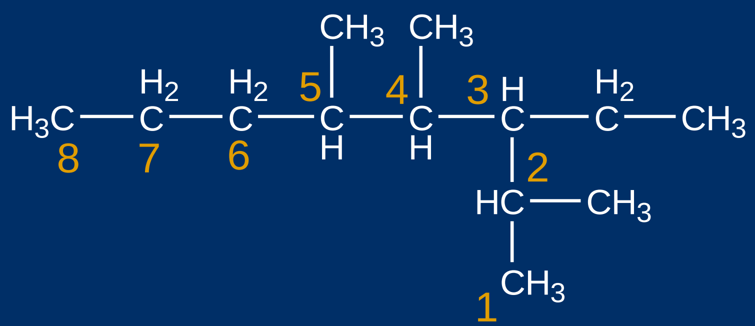
## Branched-Chain Alkane Nomenclature, *continued*

- Now we need to show the locations of the alkyl groups on the parent hydrocarbon. Number the octane chain so that the alkyl groups have the lowest numbers possible.



# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*




- Place the location numbers of *each* of the alkyl groups in front of its name. Separate the numbers from the names of the alkyl groups with hyphens.
  - The ethyl group is on carbon *3.* Because there are three methyl groups, there will be three numbers, separated by commas, in front of *trimethyl.*

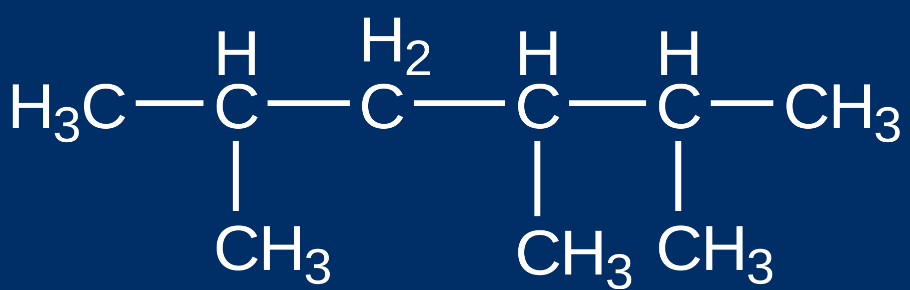
3-ethyl-2,4,5-trimethyloctane

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

### Sample Problem A

Name the following simple branched-chain alkane:

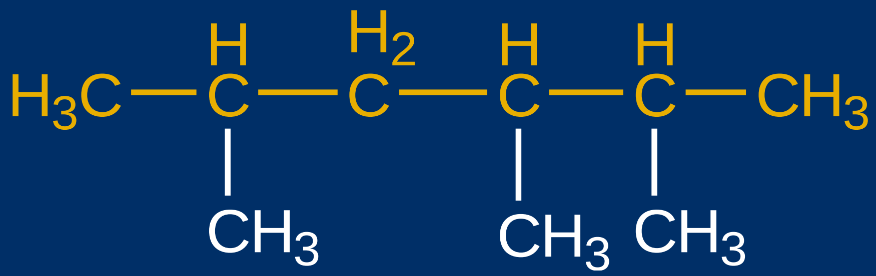


# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

### Sample Problem A Solution

1. Identify and name the parent hydrocarbon.



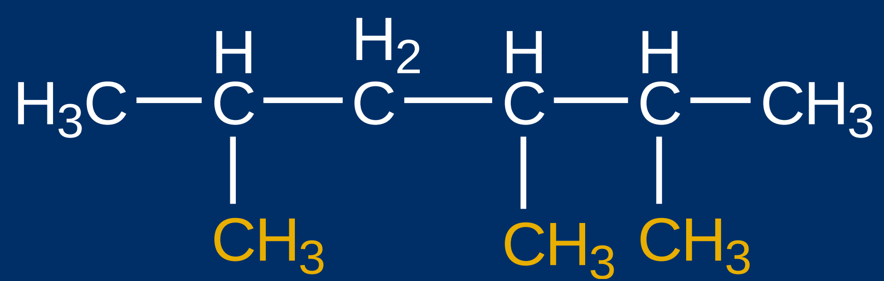

Because the longest continuous chain contains six carbon atoms, the parent hydrocarbon is hexane.

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

### Sample Problem A Solution, *continued*

2. Identify and name the alkyl groups attached to the chain.



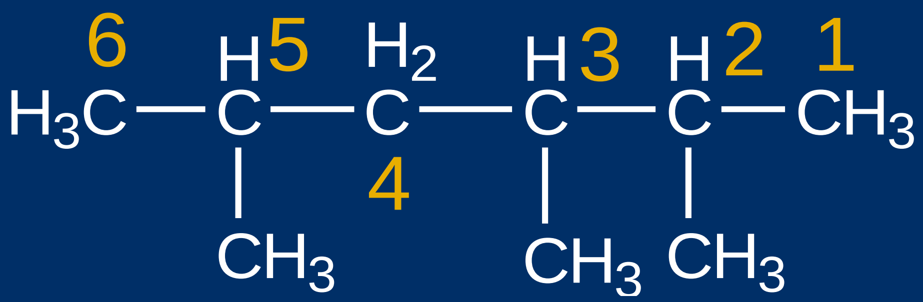

trimethylhexane

# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

### Sample Problem A Solution, *continued*

3. Number the carbon atoms in the continuous chain so that the alkyl groups have the lowest numbers possible.



# Systematic Names of Alkanes, *continued*

## Branched-Chain Alkane Nomenclature, *continued*

### Sample Problem A Solution, *continued*

4. Put the numbers of the positions of the alkyl groups, separated by commas, in front of the name of the alkyl group. Separate the numbers from the name with a hyphen.

2,3,5-trimethylhexane

End Of Slide

# Properties and Uses of Alkanes

- The carbon-hydrogen bonds of alkanes are nonpolar, so alkane molecules are nonpolar.
- The only forces of attraction between nonpolar molecules are weak London dispersion forces.
- London dispersion forces are stronger when the molecules are larger, so physical states of alkanes are a function of their molecular size.

End Of Slide

# Properties and Uses of Alkanes, *continued*

## Physical States

- Alkanes that have the lowest mass—those with one to four carbon atoms—are gases.
  - **Natural gas** is a fossil fuel composed primarily of alkanes containing one to four carbon atoms.
- Larger alkanes, such as gasoline and kerosene, are liquids.
- Alkanes that have a very high molecular mass, such as paraffin wax, are solids.

# Properties and Uses of Alkanes, *continued*

## Boiling Points

- The boiling points of alkanes also increase with molecular mass.
    - As London dispersion forces increase, more energy is required to pull the molecules apart.
- This property is used in the separation of petroleum, a major source of alkanes.
- **Petroleum** is a complex mixture of different hydrocarbons that varies greatly in composition.

# Properties and Uses of Alkanes, *continued*

## Boiling Points, *continued*

- The hydrocarbon molecules in petroleum contain from 1 to more than 50 carbon atoms.
- This range allows the separation of petroleum into different portions that have different boiling point ranges.
- In *fractional distillation,* components of a mixture are separated on the basis of boiling point, by condensation of vapor in a fractionating column.

End of Slide

# Unsaturated Hydrocarbons

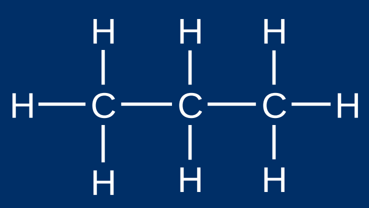
- Hydrocarbons that do not contain the maximum amount of hydrogen are referred to as unsaturated.
- **Unsaturated hydrocarbons** are hydrocarbons in which not all carbon atoms have four single covalent bonds.
- An unsaturated hydrocarbon has one or more double bonds or triple bonds between carbon atoms.
  - Carbon atoms can easily form multiple bonds to other carbon atoms, so multiple bonds in organic compounds are common.

# Unsaturated Hydrocarbons, *continued*

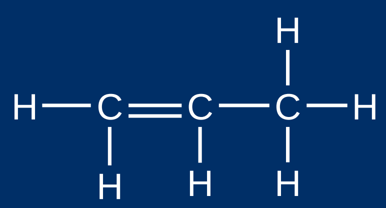
## Alkenes

- **Alkenes** are hydrocarbons that contain double covalent bonds.

- An alkene with one double bond has two fewer hydrogen atoms than the corresponding alkane.



$C_3H_8$



$C_3H_6$

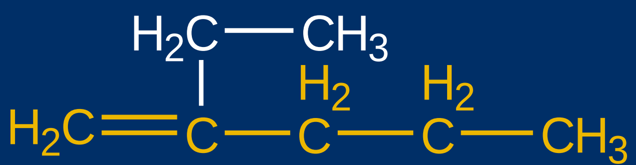
- The general formula for noncyclic alkenes with one double bond is $C_nH_{2n}$, instead of $C_nH_{2n+2}$ as it is for alkanes.

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes

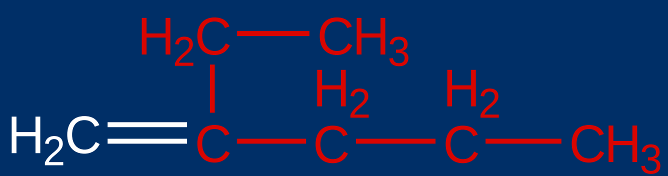
- The rules for naming a simple alkene are similar to those for naming an alkane.

- For the purposes of naming an alkene, the parent hydrocarbon is the longest continuous chain of carbon atoms *that contains the double bond.*



**pentene**

***not:***

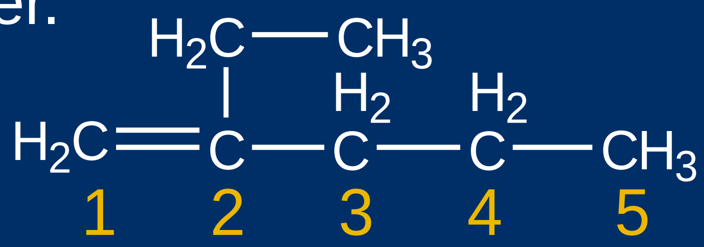


hexane

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

- The carbon atoms in the chain are numbered so that the first carbon atom in the double bond has the lowest number.




1-pentene

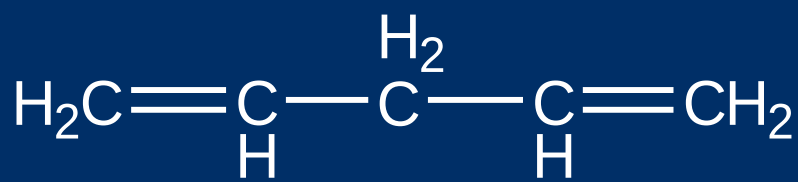
- The position number and name of the alkyl group are placed in front of the double-bond position number.

2-ethyl-1-pentene

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

- If there is more than one double bond in an alkene, the suffix of the name is modified to indicate the number of bonds: 2 = *-adiene*, 3 = *-atriene*, and so on.



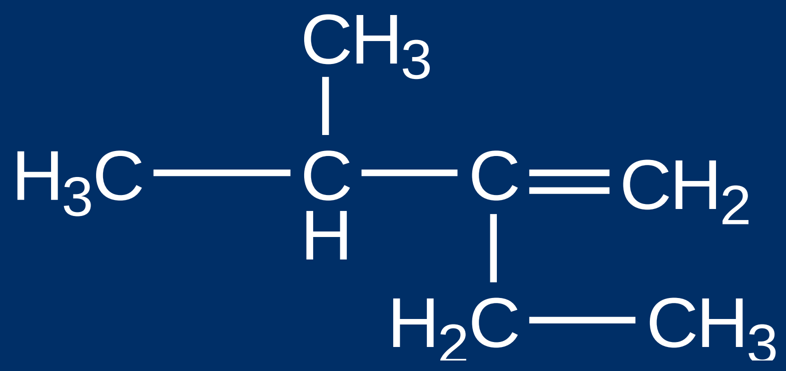

1,4-pentadiene

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

### Sample Problem B

Name the following alkene:

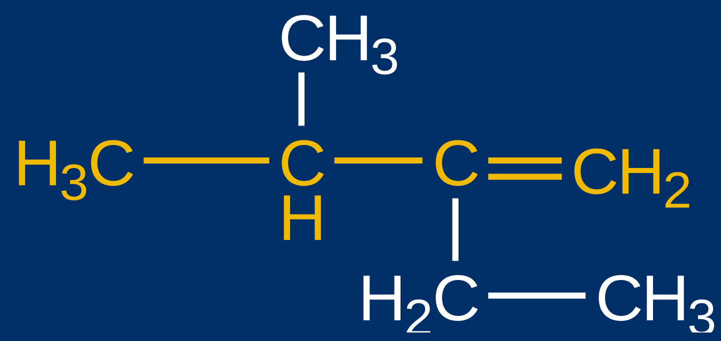


# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

## Sample Problem B Solution

1. Identify and name the parent hydrocarbon.




The parent hydrocarbon has four carbon atoms and one double bond, so it is named butene.

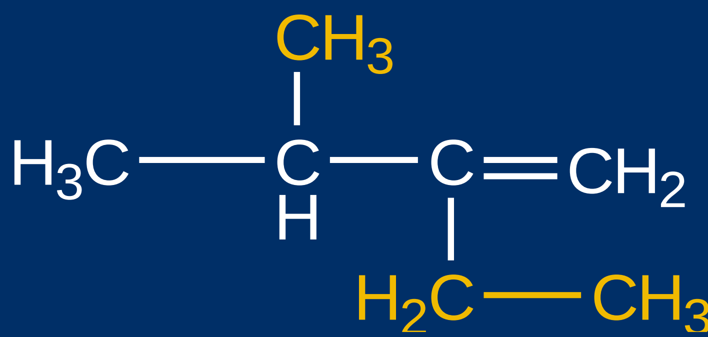
End Of Slide

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

## Sample Problem B Solution

2. Identify and name the alkyl groups.



The alkyl groups are *ethyl* and *methyl*. Place their names in front of the name of the parent hydrocarbon in alphabetical order.

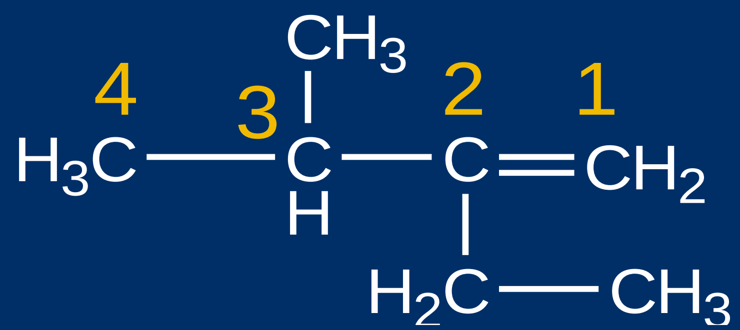
ethyl methyl butene

# Unsaturated Hydrocarbons, *continued*

## Systematic Names of Alkenes, *continued*

## Sample Problem B Solution, *continued*

3. Number the carbon chain to give the double bond the lowest position.



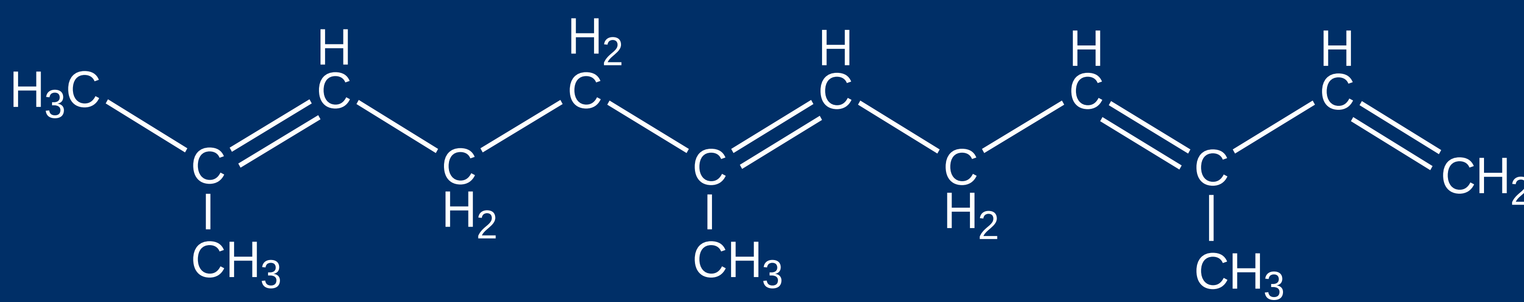

Place the position number of the double bond in front of butene. Place the position numbers of the alkyl groups in front of each alkyl group.

2-ethyl-3-methyl-1-butene

# Unsaturated Hydrocarbons, *continued*

## Properties and Uses of Alkenes

- Alkenes are nonpolar and show trends in properties similar to those of alkanes in boiling points and physical states.
    - example:



- α-farnesene, a solid at room temperature, is found in the natural wax covering of apples.

# Unsaturated Hydrocarbons, *continued*

## Alkynes

- Hydrocarbons with triple covalent bonds are **alkynes.**

- The simplest alkyne is ethyne, more commonly known as *acetylene*, $C_2H_2$:

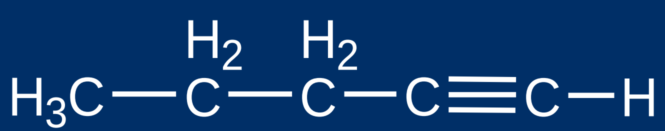
$$H-C\equiv C-H$$

- The general formula for an alkyne with one triple bond is $C_nH_{2n-2}$.

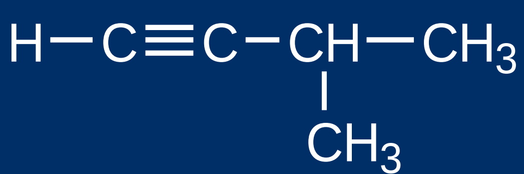
# Unsaturated Hydrocarbons, *continued*

## Systematic Naming of Alkynes

- Alkyne nomenclature is almost the same as alkene nomenclature. The only difference is that the *-ene* suffix of the corresponding alkene is replaced with *-yne.*
  - examples:




1-pentyne



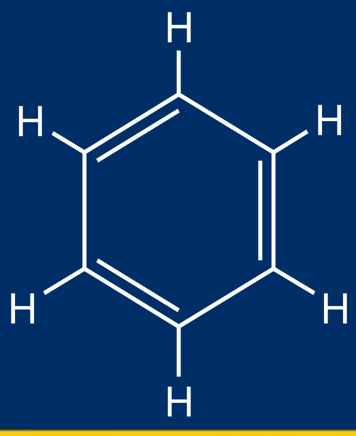

3-methyl-1-butyne

# Unsaturated Hydrocarbons, *continued*

## Aromatic Hydrocarbons

- **Aromatic hydrocarbons** are hydrocarbons that have six-membered carbon rings and delocalized electrons.

- **Benzene** is the primary aromatic hydrocarbon. The molecular formula of benzene is $C_6H_6$.



## Unsaturated Hydrocarbons, *continued*

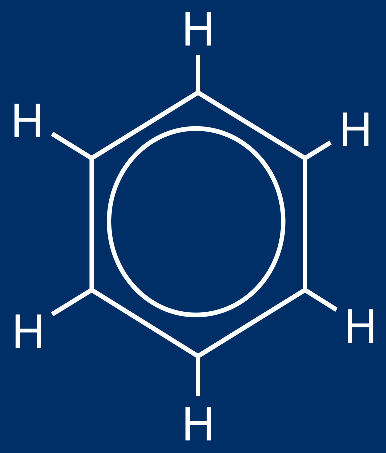
### Aromatic Hydrocarbons, *continued*

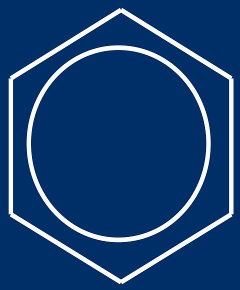
- Benzene does not behave chemically like an alkene.
- The structure of the benzene ring allows electrons to be spread through delocalized *p*-orbitals over the whole ring.
- The structural and skeletal formulas show benzene as a resonance hybrid, representing the delocalization of electrons.

# Unsaturated Hydrocarbons, *continued*

## Aromatic Hydrocarbons, *continued*

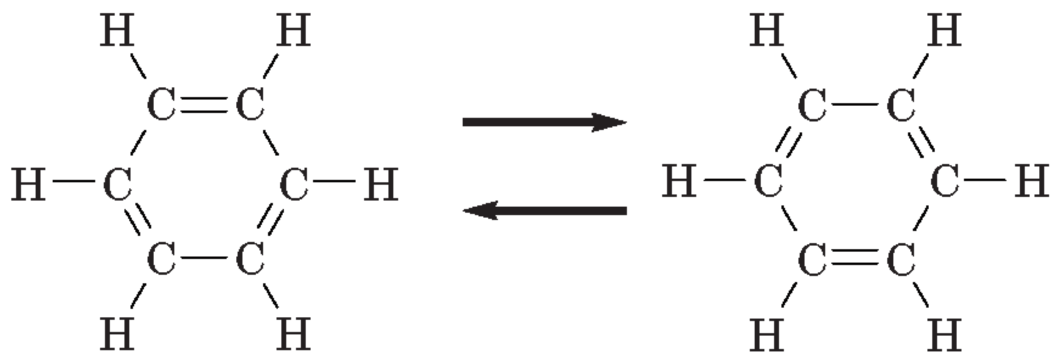
- The structural and skeletal formulas of benzene



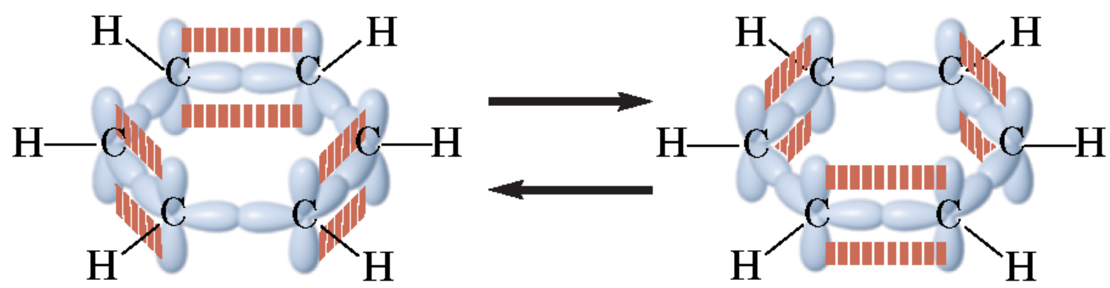



# Resonance Structures of Benzene

Benzene has two possible resonance structures.



Because the electrons involved in the double bonds are contained in orbitals that all touch each other, each resonance structure is equally likely.



# Objectives

- **Define** “functional group” and explain why functional groups are important.
- **Identify** alcohols, alkyl halides, ethers, aldehydes, ketones, carboxylic acids, esters, and amines based on the functional group present in each.
- **Explain** the relationships between the properties and structures of compounds with various functional groups.

# Functional Groups

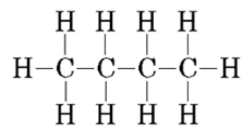
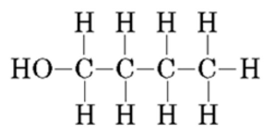
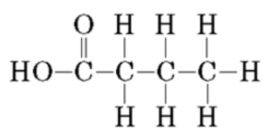
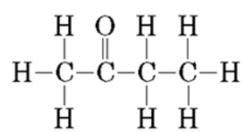
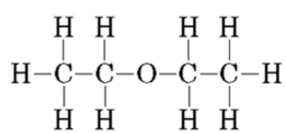
- A **functional group** is an atom or group of atoms that is responsible for the specific properties of an organic compound.
- A given functional group undergoes the same types of chemical reactions in every molecule in which it is found.
- Compounds that contain the same functional group can be classed together.

# Classes of Organic Compounds

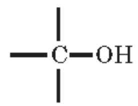
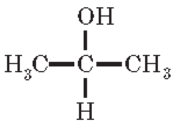
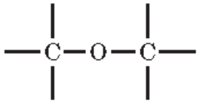
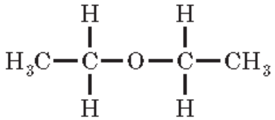
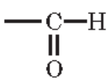
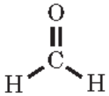
- A functional group gives an organic compound properties that are very different from those of the corresponding hydrocarbon.

- The compounds in the table on the next slide all have four carbon atoms, but they have very different physical properties due to their different functional groups.

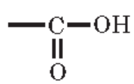
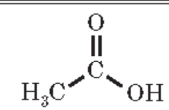
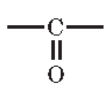
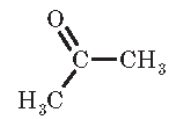
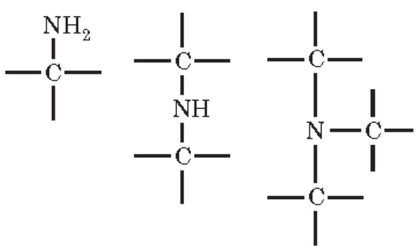
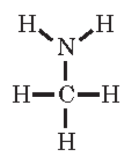
# Comparing Classes of Organic Compounds

| Name | Structural formula | Melting point (°C) | Boiling point (°C) | Density (g/mL) |
|---|---|---|---|---|
| Butane |  | −138.4 | −0.5 | 0.5788 |
| 1-butanol |  | −89.5 | 117.2 | 0.8098 |
| Butanoic acid |  | −4.5 | 163.5 | 0.9577 |
| 2-butanone |  | −86.3 | 79.6 | 0.8054 |
| Diethyl ether |  | −116.2 | 34.5 | 0.7138 |

# Common Organic Functional Groups

| Name | Chemical symbol | Naming suffix or prefix | Example | Properties and uses |
|---|---|---|---|---|
| **Alcohol** |   | *-ol* |   isopropanol | some properties similar to water, able to form hydrogen bonds, useful precursor for many compounds |
| **Ether** |   | *ether* |   diethyl ether | volatile solvents, used in anesthetics, no hydrogen bonding |
| **Aldehyde** |   | *-al* |   methanal or formaldehyde | reactive compounds formed by oxidizing alcohols, used to preserve tissues and in poly-mers, no hydrogen bonding |

# Common Organic Functional Groups

| Name | Chemical symbol | Naming suffix or prefix | Example | Properties and uses |
|---|---|---|---|---|
| **Organic acid** |  | *-oic acid* or *-ate* for ionized form |  ethanoic acid or acetic acid | usually weakly acidic compounds, formed by oxidizing aldehydes, combined with glycerol in fats, strong hydrogen bonding |
| **Ketone** |  | *-one* |  acetone | polar solvents used in paints and textile processing, no hydrogen bonding |
| **Amine** |  | *-amine*, *amino-*, *-ine*, or *azo-* |  methylamine | slightly basic compounds with some similarities to ammonia, often have unpleasant, fishy smell, weak hydrogen bonding |

# Classes of Organic Compounds, *continued*

## Alcohols

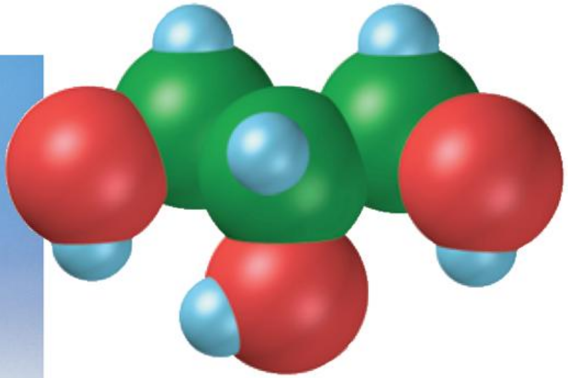
- **Alcohols** are organic compounds that contain one or more hydroxyl groups.
- The general formula for a class of organic compounds consists of the functional group and the letter *R*, which stands for the rest of the molecule.
- The general formula for alcohols is *R*–OH.

# Classes of Organic Compounds, *continued*

## Alcohols, *continued*

- The hydroxyl group, –OH, of alcohols makes them able to hydrogen-bond, and also makes them soluble in water.
- Lotions, creams, and cosmetics, usually contain an alcohol called glycerol to keep them moist.
- Alcohols are sometimes used today as alternative fuels.
  - example: gasohol, a one-to-nine ratio of ethanol and gasoline.

# Alcohol: Glycerol



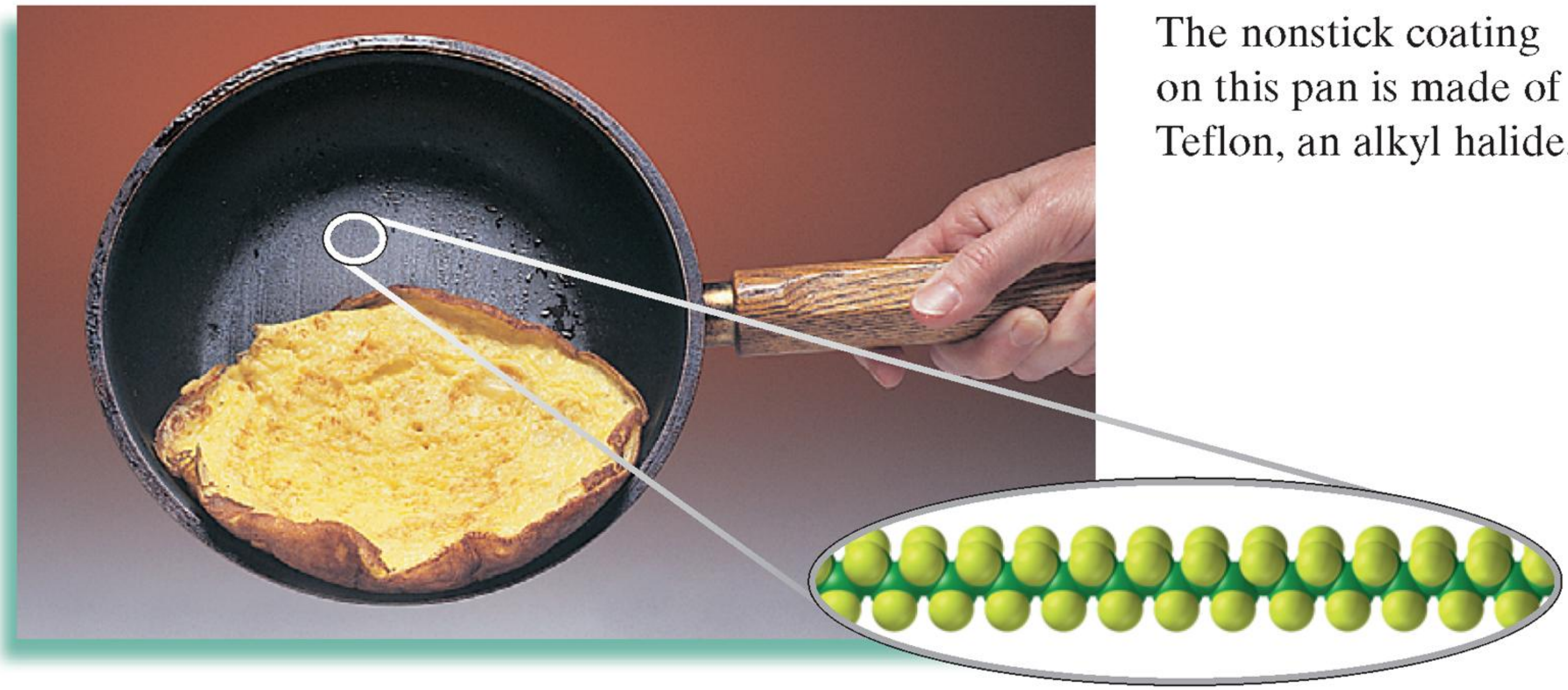
Glycerol contains three hydroxyl groups. This structure allows it to form multiple hydrogen bonds with water. Glycerol is added as a moisturizer to skin products.

# Classes of Organic Compounds, *continued*

## Alkyl Halides

- **Alkyl halides** are organic compounds in which one or more halogen atoms—fluorine, chlorine, bromine, or iodine—are substituted for one or more hydrogen atoms in a hydrocarbon.
- The general formula of an alkyl halideis *R*–*X* (where *X* represents any halogen).
  - examples:
    - Chlorofluorocarbons, or CFCs (implicated in ozone-layer depletion)
    - Teflon®, a polymer made from tetrafluoroethene, $C_2F_4$.

# Alkyl Halide: Teflon



The nonstick coating on this pan is made of Teflon, an alkyl halide.

# Classes of Organic Compounds, *continued*

## Ethers

- **Ethers** are organic compounds in which two hydrocarbon groups are bonded to the same atom of oxygen.
- General formula of an ether: *R–O–R’* (where *R’* represents a hydrocarbon group, either the same one as *R* or a different one).
- Ethers are not very reactive compounds, and are relatively nonpolar.
- Ethers are commonly used as solvents.

# Classes of Organic Compounds, *continued*

## Aldehydes and Ketones

- Aldehydes and ketones contain the *carbonyl group.*


- **Aldehydes** are organic compounds in which the carbonyl group is attached to a carbon atom at the end of a carbon-carbon chain.

- **Ketones** are organic compounds in which the carbonyl group is attached to carbon atoms within the chain.

# Classes of Organic Compounds, *continued*

## Aldehydes and Ketones, *continued*

- The general formula for an aldehyde is:

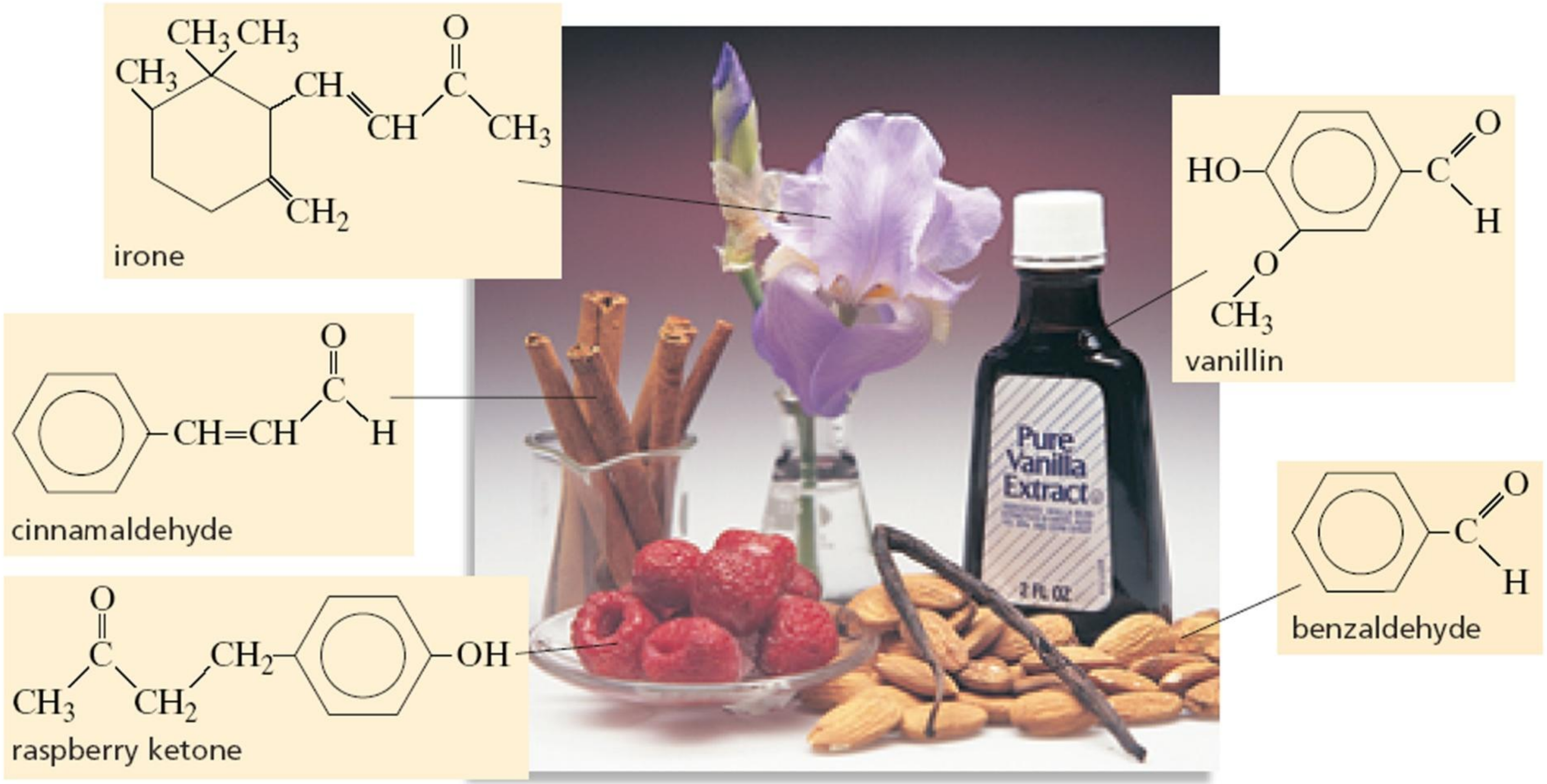
$$\begin{array}{c} \mathrm{O} \\ \| \\ R-\mathrm{C}-\mathrm{H} \end{array}$$

- The general formula for a ketone is:

$$\begin{array}{c} \mathrm{O} \\ \| \\ R-\mathrm{C}-R' \end{array}$$

- Aldehydes and ketones are often responsible for certain odors and flavors.

# Aldehydes and Ketones

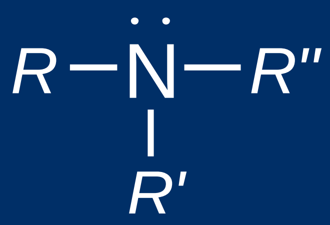


# Classes of Organic Compounds, *continued*

## Amines

- **Amines** are organic compounds that can be considered to be derivatives of ammonia, $NH_3$.

- General formula of an amine:



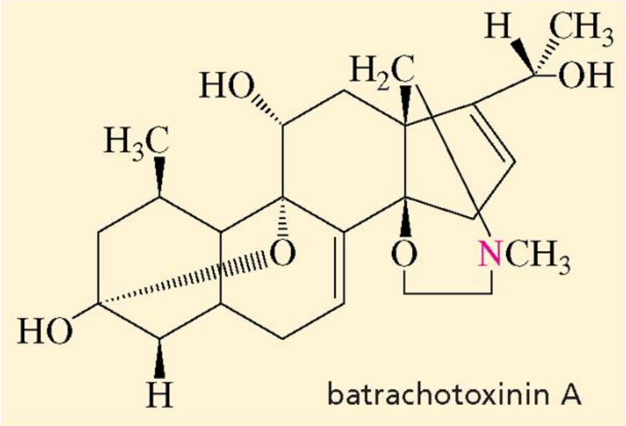

- Amines are common in nature. They often from during the breakdown of proteins in animal cells.

# Classes of Organic Compounds, *continued*

## Amines, *continued*

- The unshared electron pair on the nitrogen makes amines act as weak bases in aqueous solutions:

# Amine

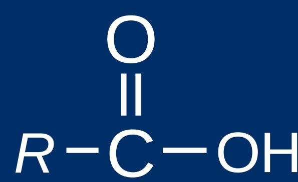



The poison dart frog produces toxic amines, one of which is batrachotoxinin A, that kills nerve cells. The nitrogen atom of the amine is shown in red.

# Classes of Organic Compounds, *continued*

## Carboxylic Acids

- **Carboxylic acids** are organic compounds that contain the carboxyl functional group.

- General formula: 


- Like inorganic acids, carboxylic acids react to lose a hydrogen ion and become a negatively charged ion in water.

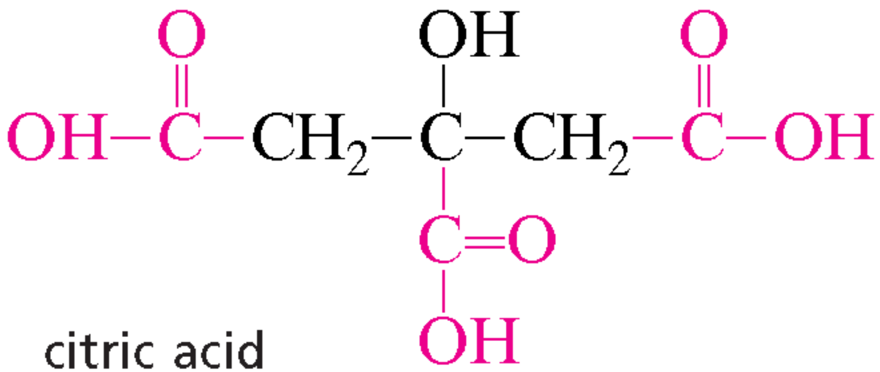
# Classes of Organic Compounds, *continued*

## Carboxylic Acids, *continued*

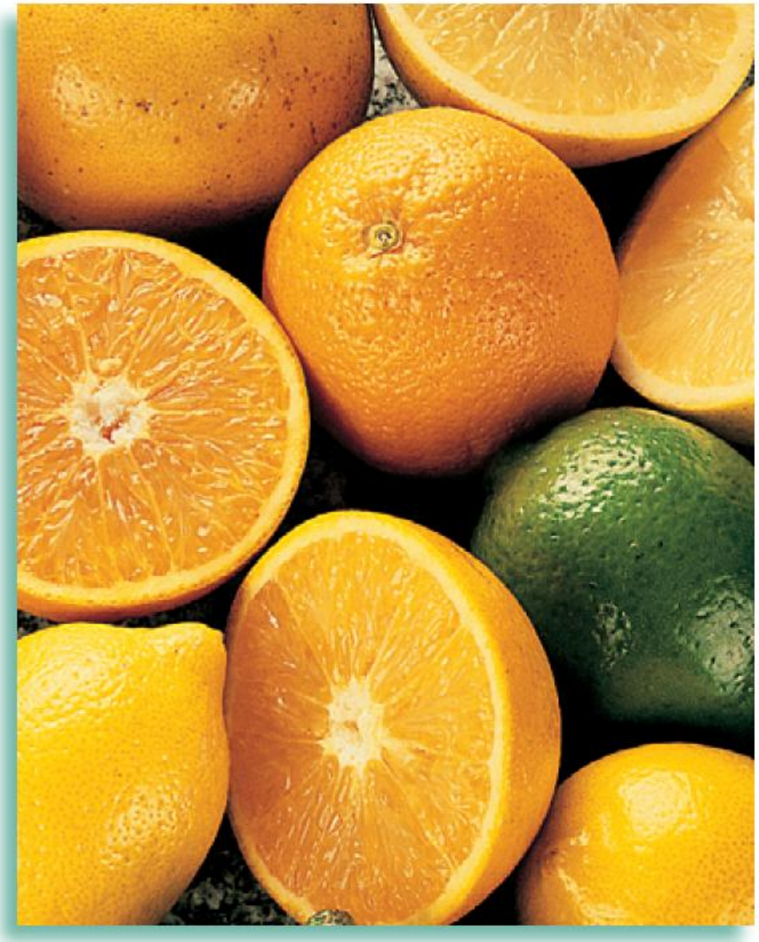
- examples of carboxylic acids:
  - acetic acid (the weak acid in vinegar)
  - citric acid
  - benzoic, propanoic, and sorbic acids (used as preservatives)

- Carboxylic acids are much weaker than many inorganic acids such as hydrochloric, sulfuric, and nitric acids.

# Carboxylic Acid: Citric Acid




citric acid



# Carboxylic Acids Found in Plants and Animals

| Carboxylic acid | Structural formula | Source |
|---|---|---|
| methanoic acid | $\mathrm{H-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | ants |
| butanoic acid | $\mathrm{CH_3-CH_2-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | rancid butter |
| hexanoic acid | $\mathrm{CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | milk fats, coconut oil, palm oil |
| lactic acid | $\mathrm{CH_3-\overset{\overset{\displaystyle OH}{\vert}}{C}H-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | sour milk, blood, and muscle fluid |
| malic acid | $\mathrm{OH-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-\overset{\overset{\displaystyle OH}{\vert}}{C}H-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | apples |
| oxalic acid | $\mathrm{OH-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-OH}$ | rhubarb |

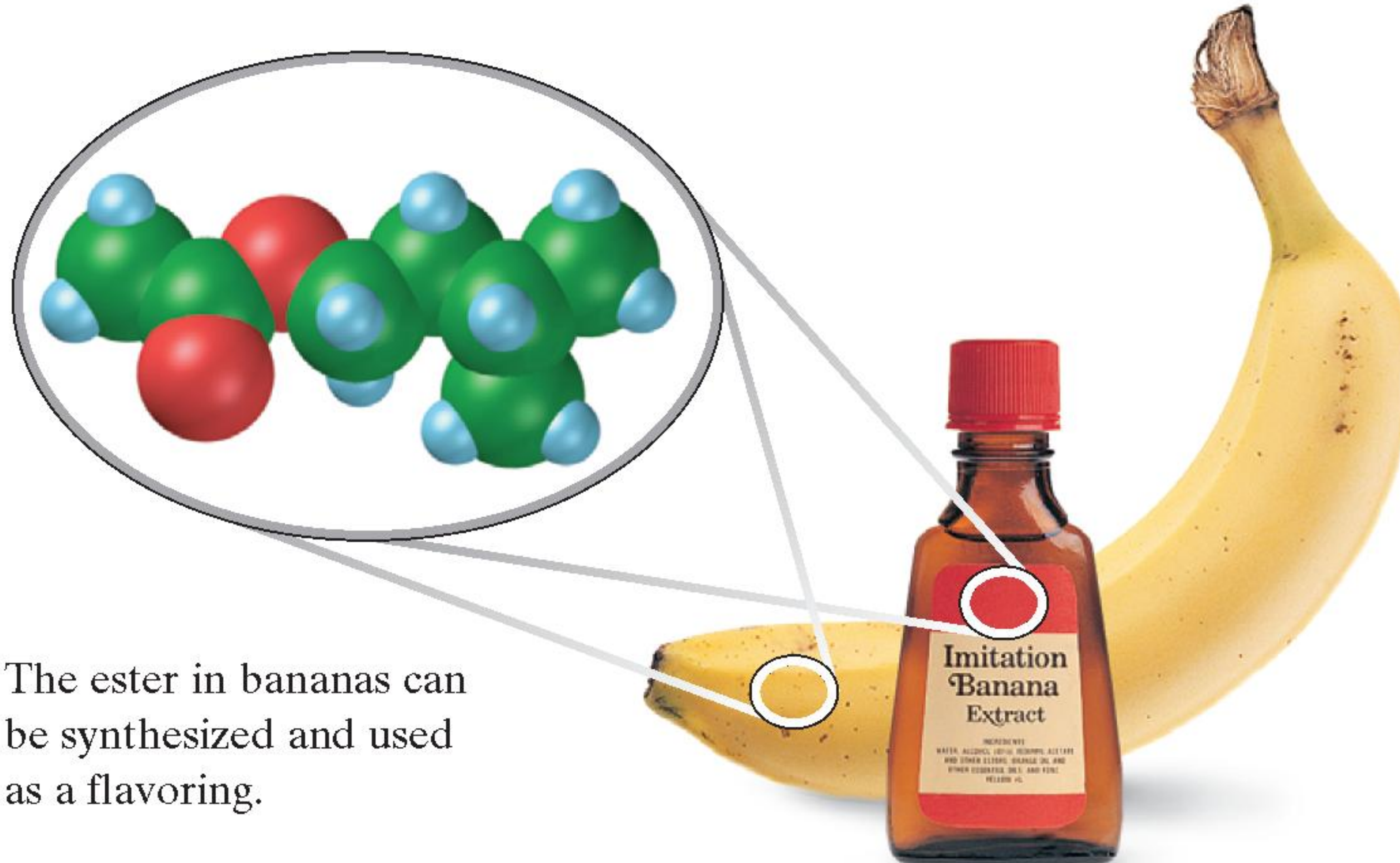
Chapter menu Resources

# Classes of Organic Compounds, *continued*

## Esters

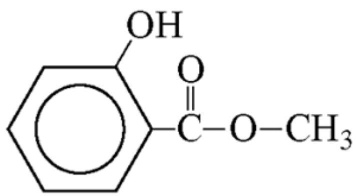
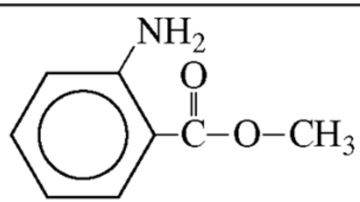
- **Esters** are organic compounds that have carboxylic acid groups in which the hydrogen of the hydroxyl group has been replaced by an alkyl group.
- General formula: $R-\overset{\overset{\displaystyle O}{\|}}{C}-O-R'$
- Esters are considered *derivatives* of carboxylic acids because of their structural similarity to carboxylic acids.
- Like aldehydes and ketones, esters are responsible for many common odors and flavors.

# Ester




The ester in bananas can be synthesized and used as a flavoring.

# Common Odors and Flavors of Esters

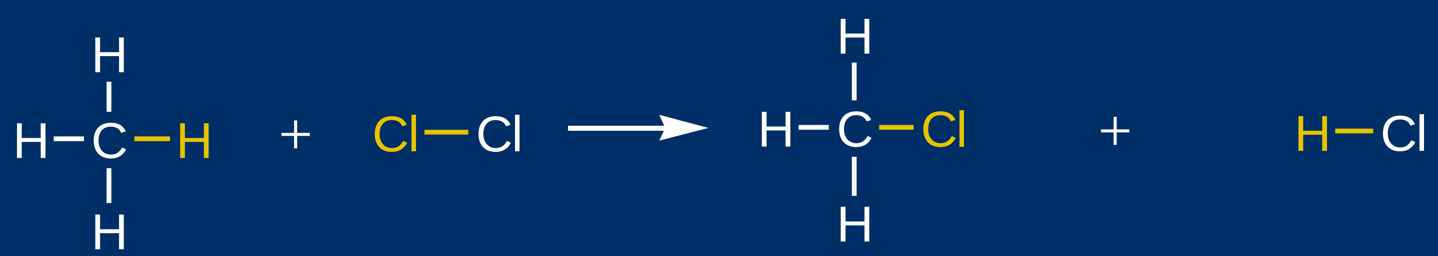
| Ester | Structural formula | Flavor or odor |
|---|---|---|
| ethyl butanoate | $CH_3-CH_2-CH_2-C(=O)-O-CH_2-CH_3$ | pineapple |
| methyl salicylate |  | wintergreen oil |
| geraniol formate | $H-C(=O)-O-CH_2-CH=C(CH_3)-CH_2-CH_2-CH=C(CH_3)-CH_3$ | rose |
| methyl anthranilate |  | grape juice and jasmine |
| linalyl acetate | $CH_3-C(=O)-O-C(CH_3)(CH=CH_2)-CH_2-CH_2-CH=C(CH_3)-CH_3$ | lavender |

# Objectives

- **Describe** and **distinguish** between the organic reactions: substitution, addition, condensation, and elimination.
- **Relate** some functional groups to some characteristic reactions.
- **Identify** the two main types of polymers and the basic reaction mechanisms by which they are made.

## Substitution Reactions

- A **substitution reaction** is one in which one or more atoms replace another atom or group of atoms in a molecule.
  - example: reaction between a methane (an alkane) and chlorine (a halogen) to form an alkyl halide.

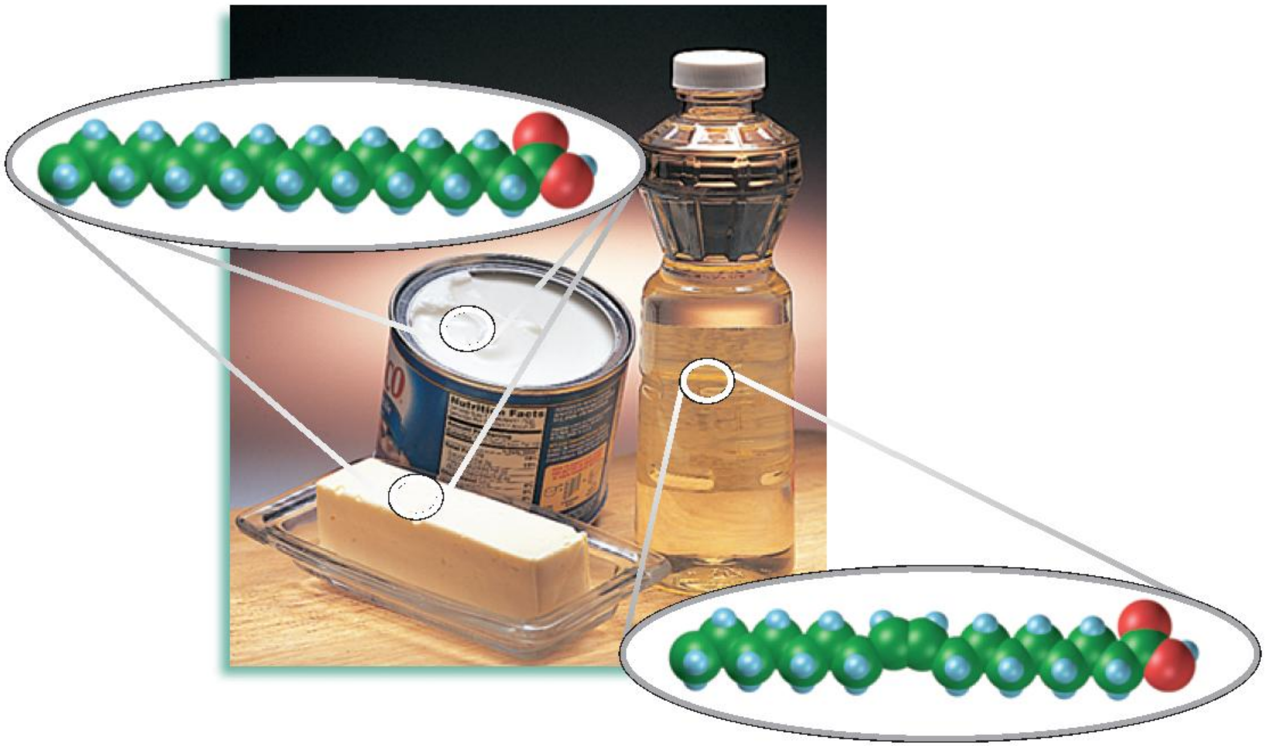


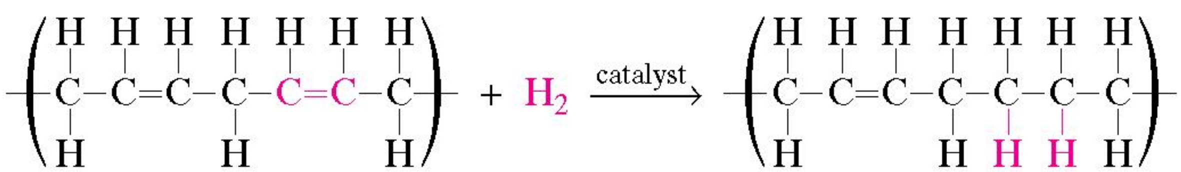
methane chlorine chloromethane hydrogen chloride

# Addition Reactions

- An **addition reaction** is one in which two parts of a molecule are added to an unsaturated molecule, increasing the saturation of the molecule.
  - example: *hydrogenation,* the addition of hydrogen atoms to an unsaturated molecule.
    - Vegetable oils contain long chains of carbon atoms with many double bonds.

# Hydrogenation of Fatty Acid





# Condensation Reaction

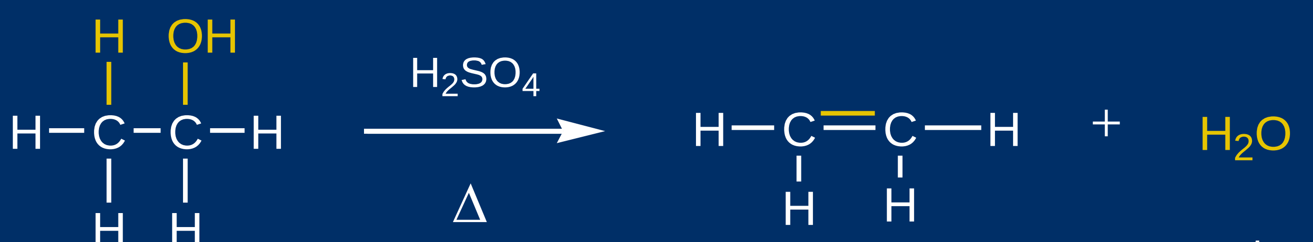
- A **condensation reaction** is one in which two molecules or parts of the same molecule combine.
- A small molecule, such as water, is usually removed during the reaction.
  - example: a reaction between two amino acids (which contain both amine and carboxyl groups).

amino acid + amino acid → dipeptide + water

  - When repeated many times, this reaction forms a protein molecule: a chain of amino acids.

# Elimination Reaction

- An **elimination reaction** is one in which a simple molecule, such as water or ammonia, is formed from adjacent carbon atoms of a larger molecule.
  - example: the heating of ethanol in the presence of concentrated sulfuric acid.




ethanol

water

# Elimination Reaction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# Polymers

- **Polymers** are large molecules made of many small units joined to each other through organic reactions.
- The small units are **monomers.** A polymer can be made from identical or different monomers.
- A polymer made from two or more different monomers is a **copolymer.**
- Polymers are all around us.
  - Natural polymers: starch, cellulose, proteins
  - Synthetic polymers: plastics, synthetic polymers (*e.g.* polypropylene)

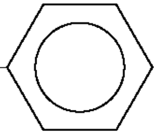
# Addition Polymers

- An *addition polymer* is a polymer formed by addition reactions between monomers that contain a double bond.
  - example: molecules of ethene can polymerize with each other to form polyethene, commonly known as polyethylene.

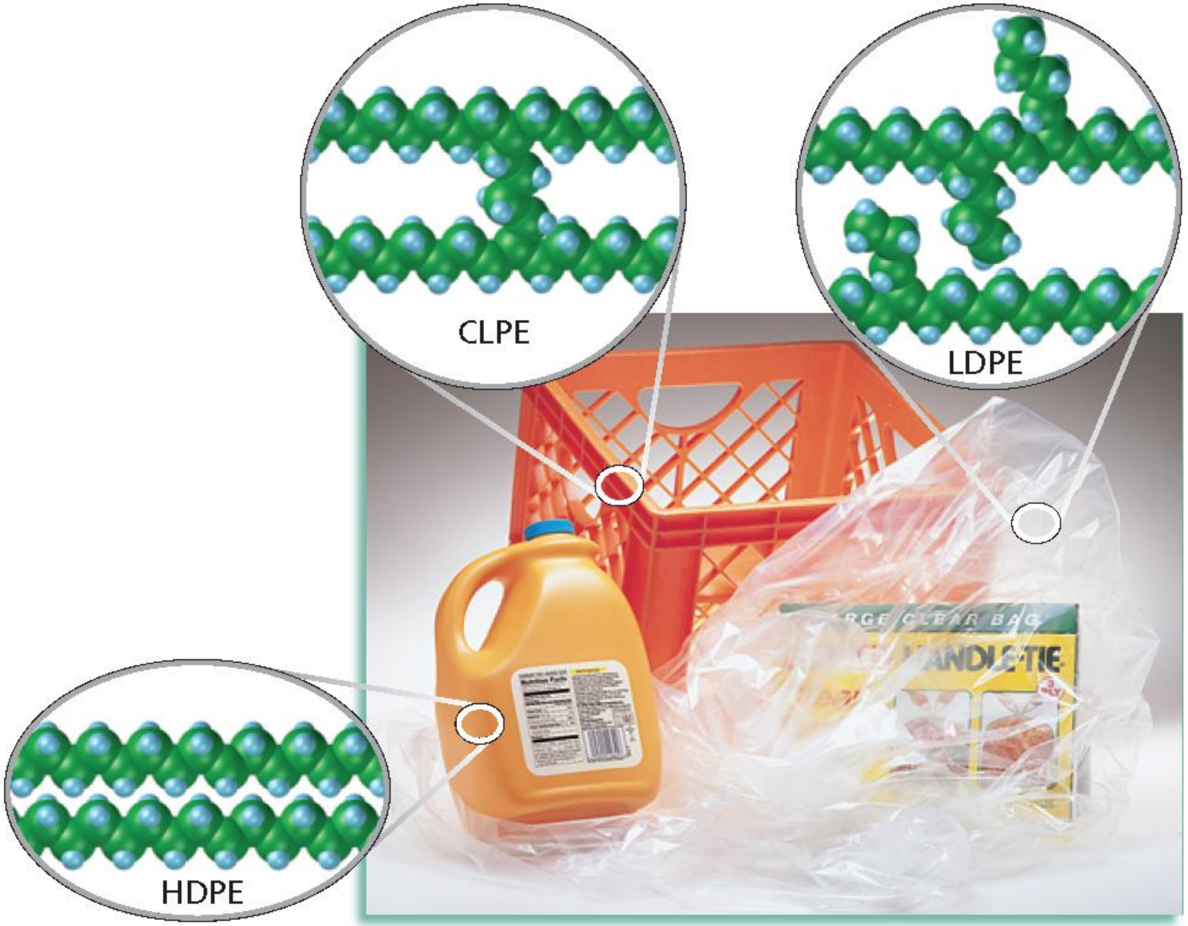
$$n\mathrm{CH_2{=}CH_2} \xrightarrow{\text{catalyst}} \left(\mathrm{CH_2{-}CH_2}\right)_n$$

  - The letter *n* shows that the addition reaction can be repeated multiple times to form a polymer *n* monomers long.
  - This reaction can be repeated hundreds or thousands of times.

# Addition Polymers

| Monomer structure | Monomer name | Polymer name | Typical use |
|---|---|---|---|
| $CH_2{=}CH{-}CH_3$ | propylene | polypropylene | plastic bottles |
| $CH_2{=}CH{-}Cl$ | vinyl chloride | polyvinyl chloride (PVC) | piping |
| $CH_2{=}CH{-}CN$ | acrylonitrile | polyacrylonitrile | fabrics |
| $CH_2{=}CH{-}$  | styrene | polystyrene | insulation |
| $CH_2{=}CH{-}O{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}CH_3$ | vinyl acetate | polyvinyl acetate (PVA) | latex paints |

# Forms of Polyethylene



# Condensation Polymers

- A *condensation polymer* is a polymer formed by condensation reactions.
- Monomers of condensation polymers must contain two functional groups: this allows each monomer to link with two other monomers by condensation reactions.
- Condensation polymers are usually copolymers with two monomers in an alternating order.

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