Chapter 22: Hydrocarbon Compounds

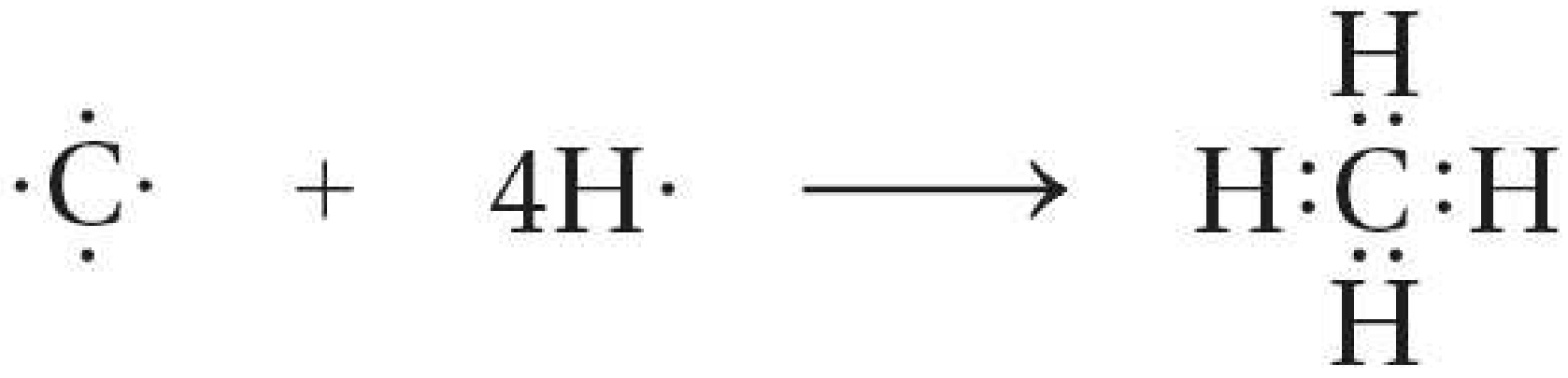
22.1 Hydrocarbons

Organic Chemistry and Hydrocarbons

- Because carbon has four valence electrons, a carbon atom always forms four covalent bonds.
  - The simplest organic compounds contain only carbon and hydrogen and are called **hydrocarbons.**

Organic Chemistry and Hydrocarbons

One carbon atom can form a single covalent bond with four hydrogen atoms.



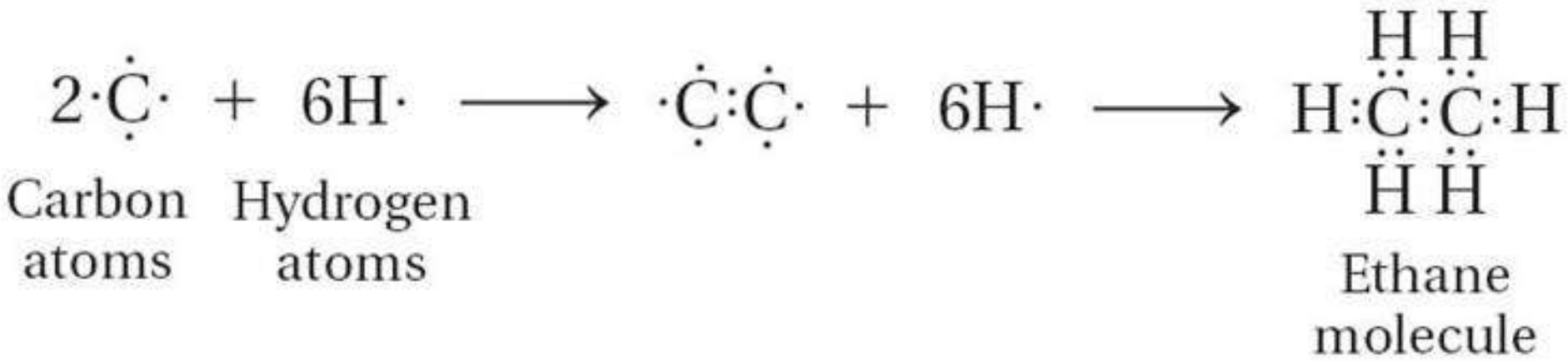
Alkanes

- An **alkane** is a hydrocarbon in which there are only single covalent bonds.
  - The carbon atoms in an alkane can be arranged in a straight chain or in a chain that has branches.

Alkanes

Straight-Chain Alkanes

Ethane is the simplest of the **straight-chain alkanes**, which contain any number of carbon atoms, one after the other, in a chain.



Alkanes

A group of compounds forms a **homologous series** if there is a constant increment of change in molecular structure from one compound in the series to the next.

Carbon Prefixes

# C	Prefix	# C	Prefix
1	Meth	6	Hex
2	Eth	7	Hept
3	Prop	8	Oct
4	But	9	Non
5	Pent	10	Dec

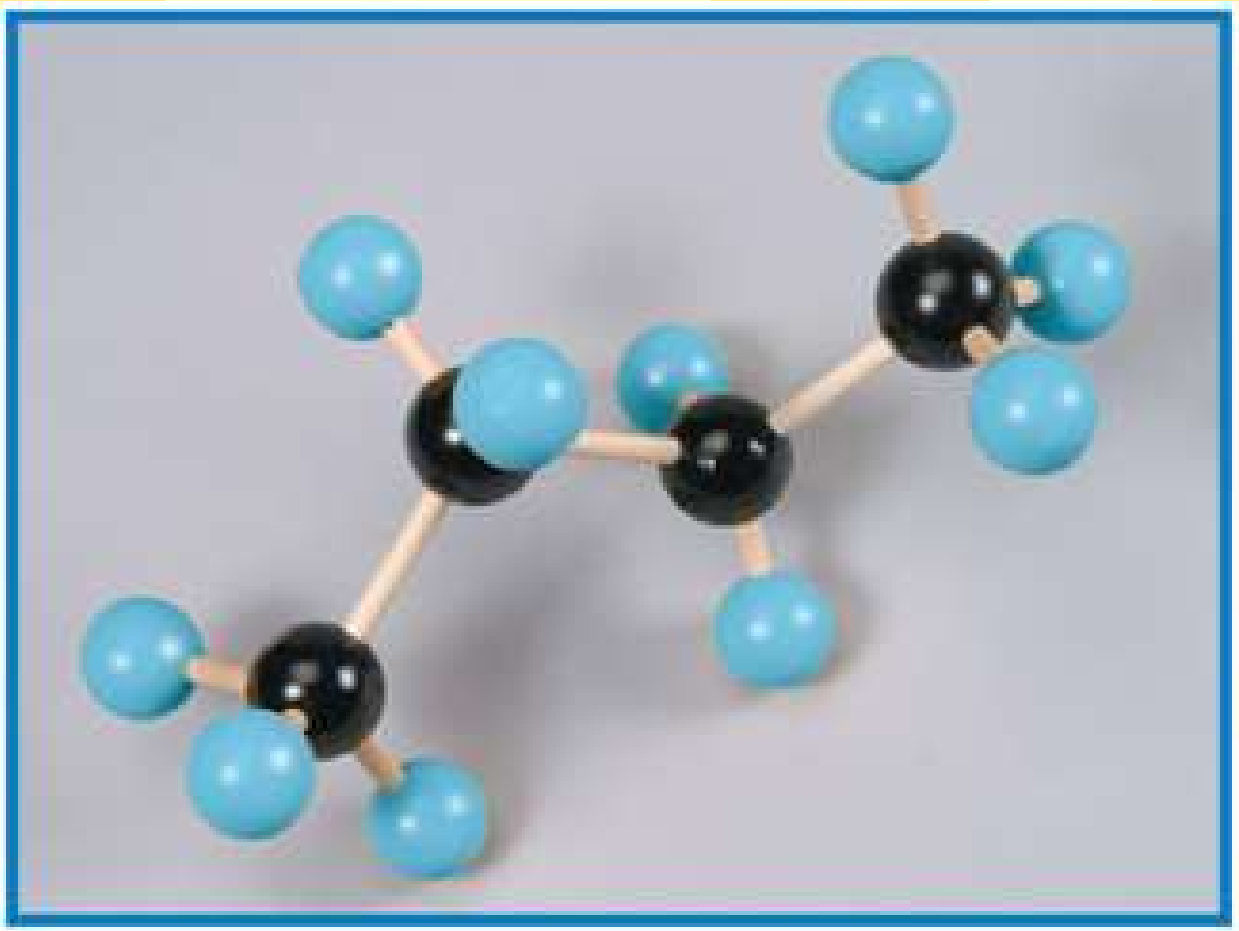
Alkanes

- In a **condensed structural formula**, some bonds and/or atoms are left out of the structural formula. Although the bonds and atoms do not appear, they are there.

CONCEPTUAL PROBLEM 22.1

Drawing Structural Formulas for Alkanes

Draw complete structural formulas for the straight-chain alkanes that have three and four carbons.

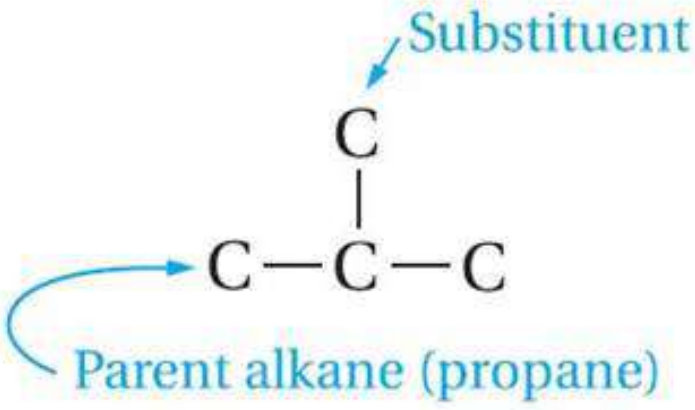


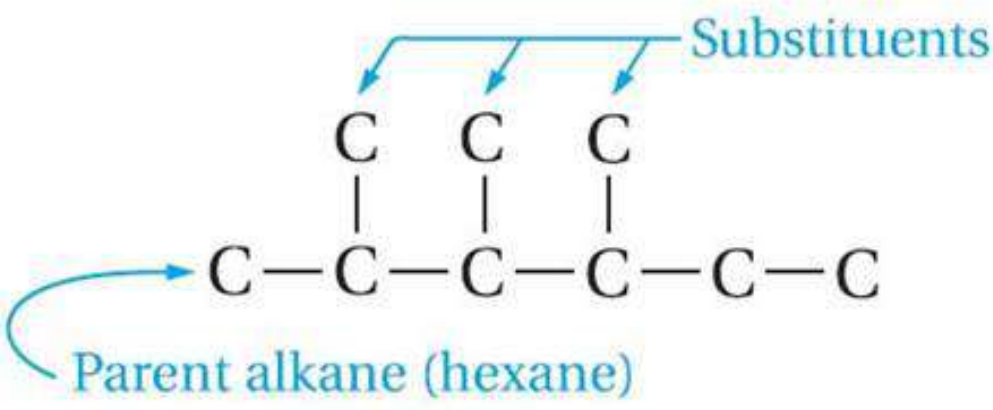
for Conceptual Problem 22.1

1. Draw complete structural formulas for the straight-chain alkanes with five and six carbons.

Alkanes

- Branched-Chain Alkanes
  - An atom or group of atoms that can take the place of a hydrogen atom on a parent hydrocarbon molecule is called a **substituent**.

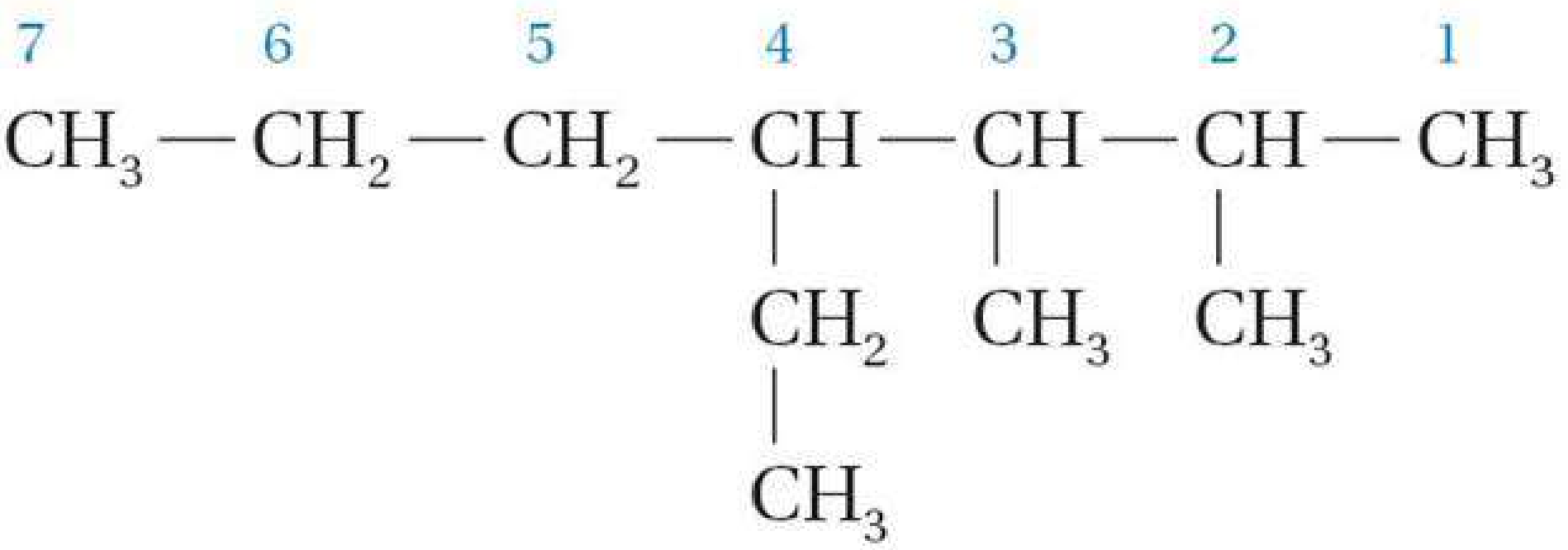




Alkanes

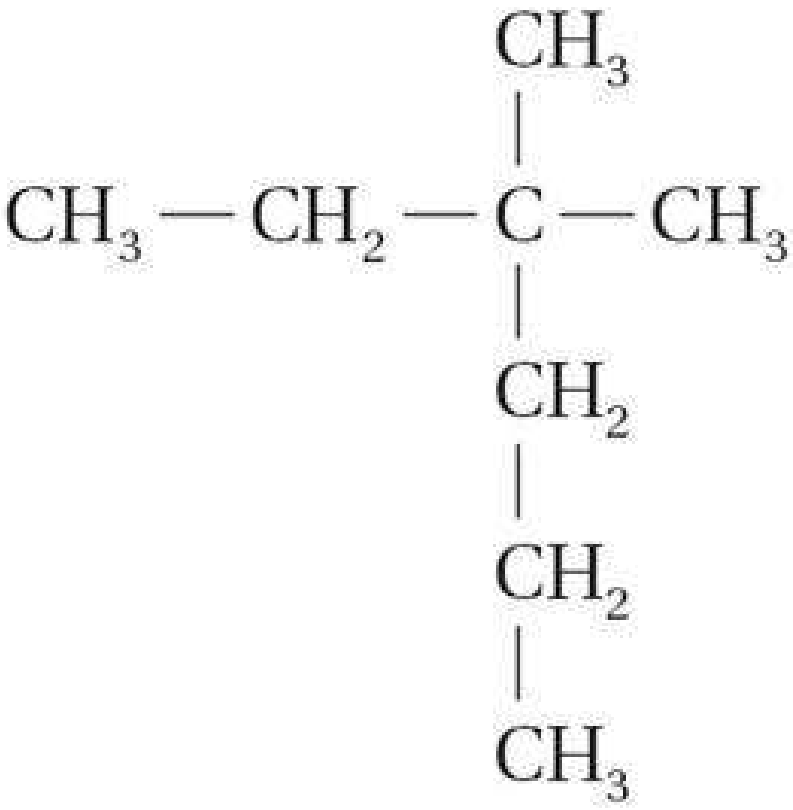
A hydrocarbon substituent is called an **alkyl group**.

An alkane with one or more alkyl groups is called a **branched-chain alkane**.



Naming Branched-Chain Alkanes

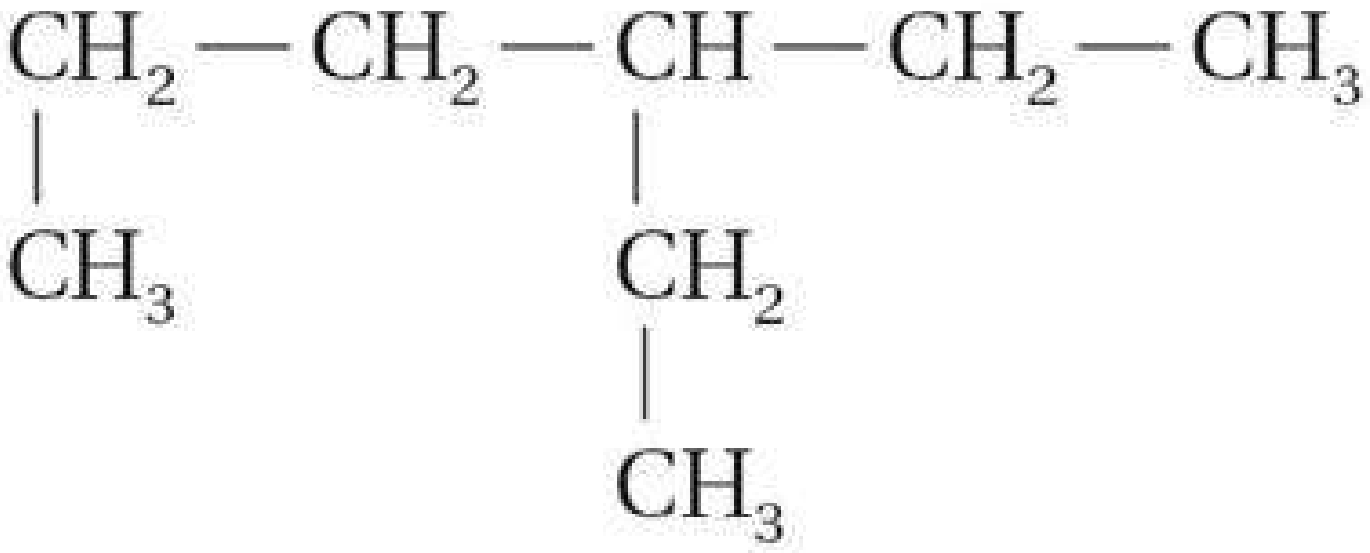
Name this compound using the IUPAC system. Notice that the longest chain is not written in a straight line.



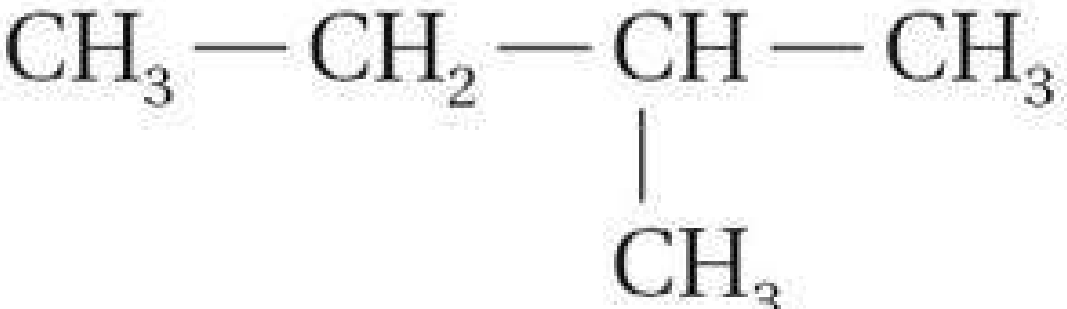
for Conceptual Problem 22.2

3. Name these compounds according to the IUPAC system.

a.



b.



CONCEPTUAL PROBLEM 22.3

Drawing Structural Formulas for Branched-Chain Alkanes

The compound 2,2,4-trimethylpentane (isooctane) is found in gasoline. Draw a complete structural formula for isooctane.

for Conceptual Problem 22.3

5. Draw a structural formula for 2,3-dimethylhexane.

Properties of Alkanes

- Molecules of hydrocarbons, such as alkanes, are nonpolar molecules.

- **The nonpolar molecules in the oil spill are not attracted to the polar water molecules in the ocean.**

22.1 Section Quiz.

1. Choose the correct words for the spaces. Because carbon has _____ valence electrons, it can form _____ bonds.

- four, four covalent
- four, four ionic
- six, six covalent
- six, four or fewer covalent

22.1 Section Quiz.

2. Alkanes are hydrocarbons that contain only _____ bonds.

- carbon-carbon
- single covalent
- carbon-hydrogen
- ionic

22.1 Section Quiz

3. Choose the correct words for the spaces. Hydrocarbons are highly soluble in _____ solvents because they are _____ molecules.

- nonpolar, nonpolar
- nonpolar, polar
- polar, nonpolar
- polar, polar

22.2 Unsaturated Hydrocarbons

Alkenes

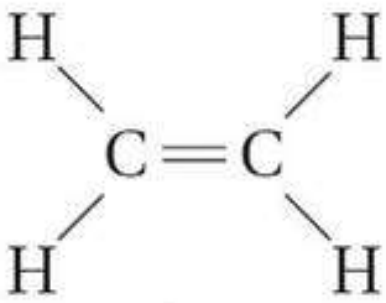
At least one carbon-carbon bond in an alkene is a double covalent bond. Other bonds may be single carbon-carbon bonds and carbon-hydrogen bonds.

Alkenes

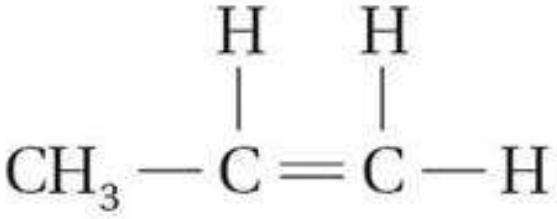
- Organic compounds that contain the maximum number of hydrogen atoms per carbon atom are called **saturated compounds.**
  - Compounds that contain double or triple carbon-carbon bonds are called **unsaturated compounds.**

Alkenes

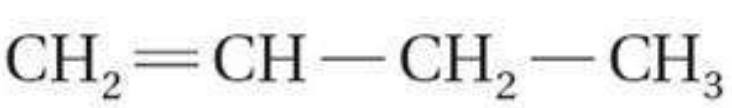
Alkenes are hydrocarbons that contain one or more carbon-carbon double covalent bonds.



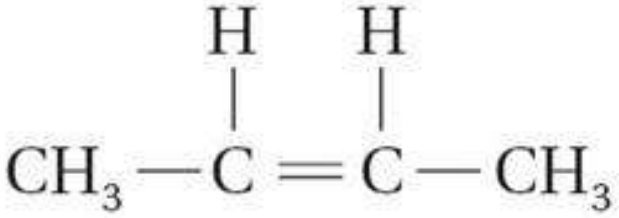
Ethene
(ethylene)



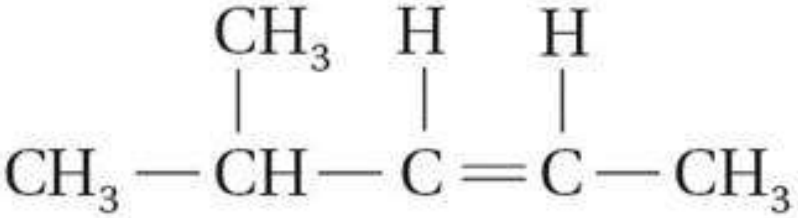
Propene
(propylene)



1-butene



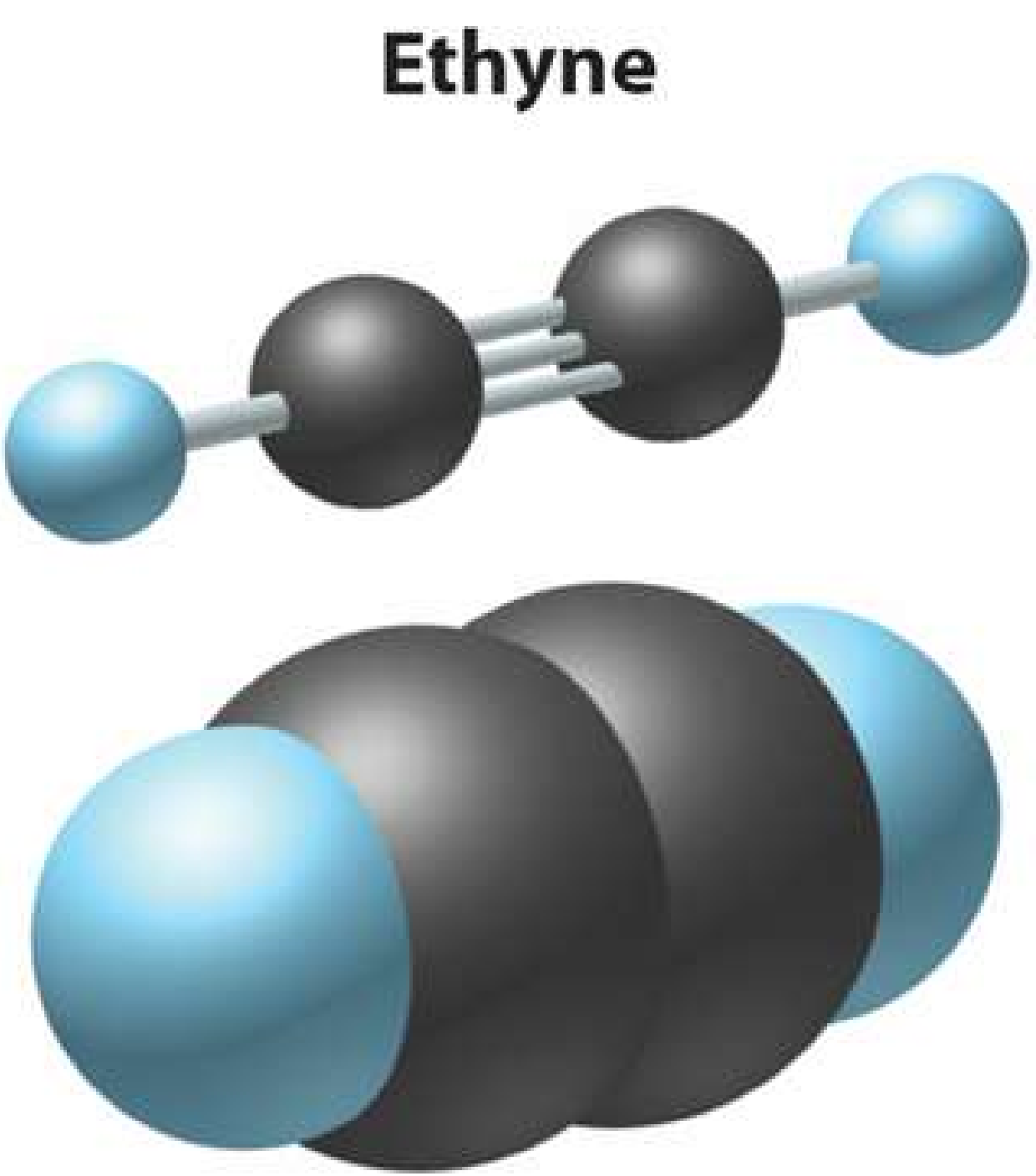
2-butene



4-methyl-2-pentene

Alkynes

The triple bond restricts rotation in an ethyne molecule, which has a linear shape.



22.2 Section Quiz.

1. Alkenes and alkynes are called unsaturated compounds because they contain

- single bonds only.
- double or triple bonds.
- oxygen atoms.
- hydrogen atoms.

22.2 Section Quiz.

2. What is the correct name for a compound with a C-C-C=C-C carbon skeleton?

- 3-pentyne
- 2-pentene
- 3-pentene
- 4-pentene

22.2 Section Quiz.

3. Which of the following substances is an alkyne?

- C_6H_{12}
- C_2H_4
- C_2H_2
- C_4H_8

22.3 Isomerism

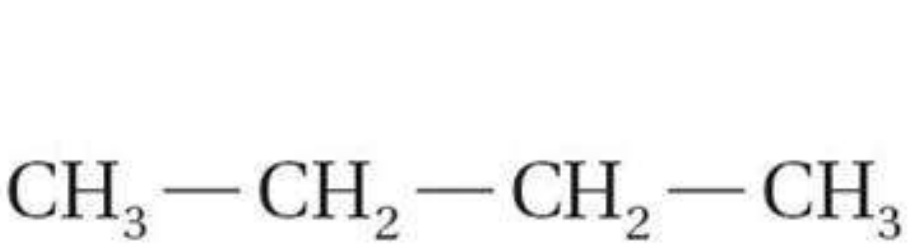
Structural Isomers

Compounds that have the same molecular formula but different molecular structures are called **isomers.**

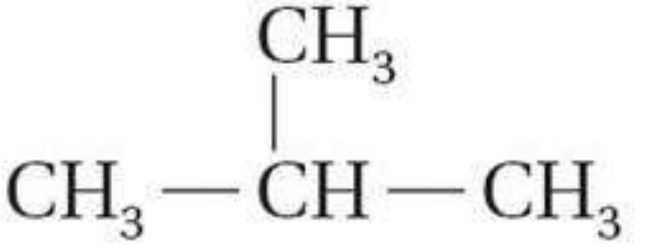
- Structural isomers differ in physical properties such as boiling point and melting point. They also have different chemical reactivities.

Structural Isomers

Structural isomers are compounds that have the same molecular formula, but the atoms are joined together in a different



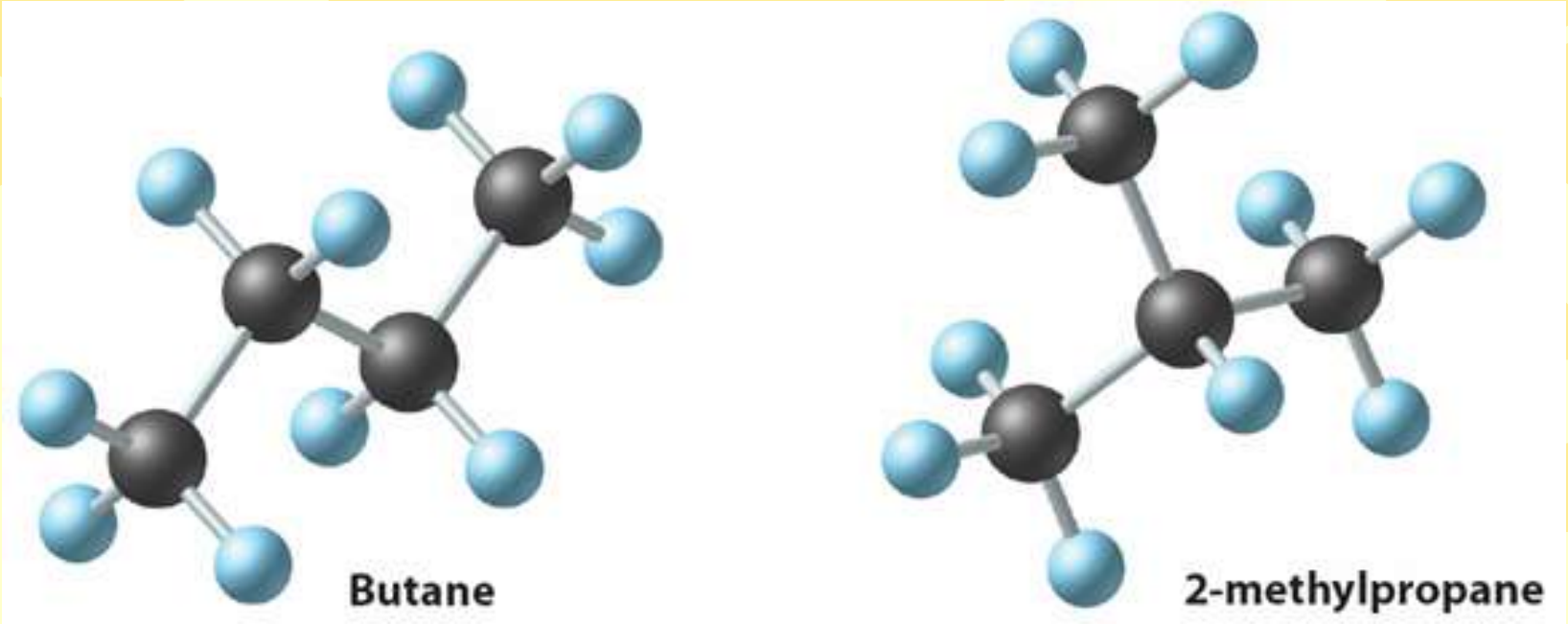
Butane (C_4H_{10})
(bp −0.5°C)



2-methylpropane (C_4H_{10})
(bp −10.2°C)

Structural Isomers

Both butane and 2-methylpropane have the molecular formula C_4H_{10}. The atoms in their molecules are arranged in a different order, so they are structural isomers.



22.3 Section Quiz

1.Structural isomers have different properties because they have

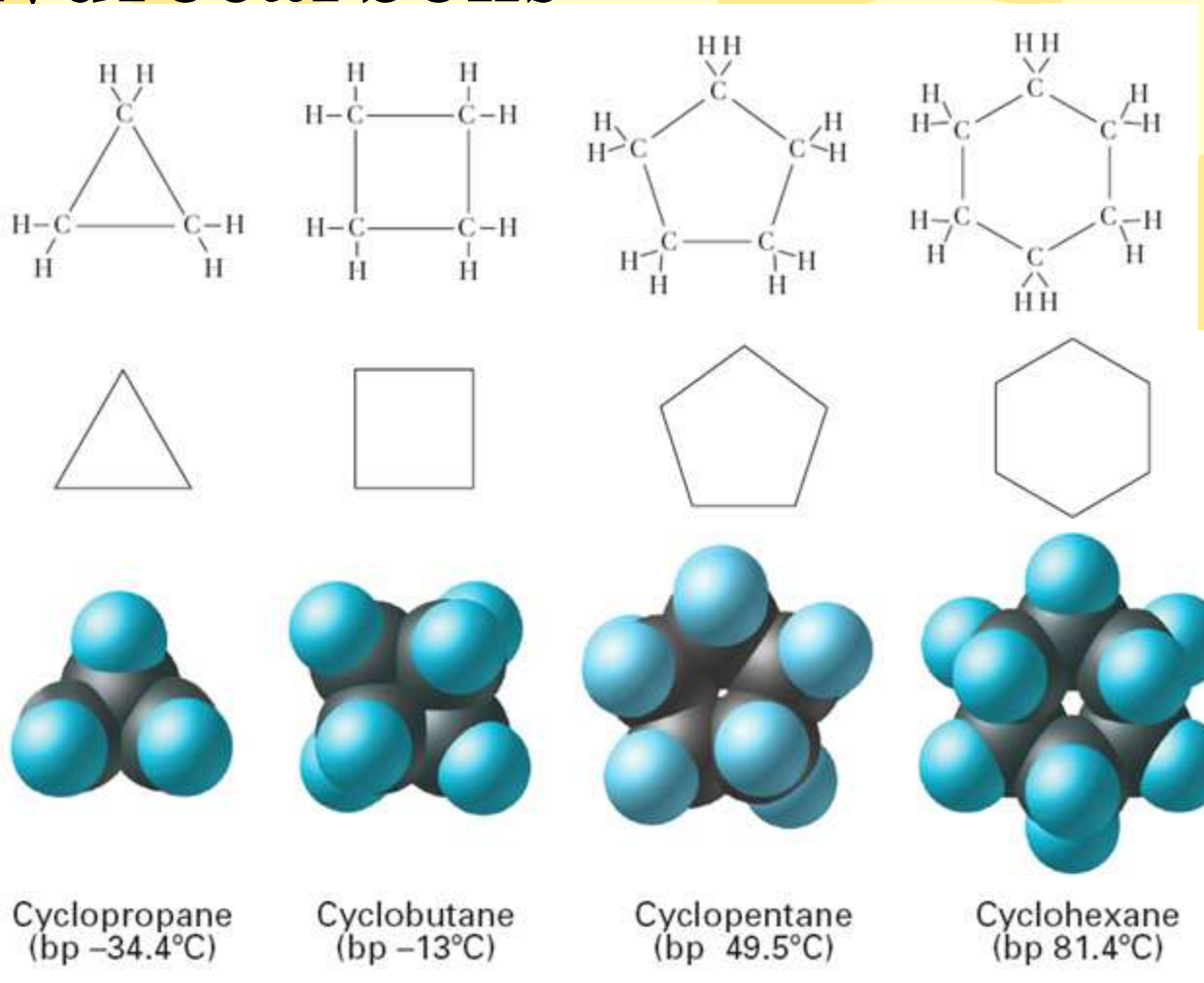
- a different number of bonds.
- different types of bonds.
- different substituents.
- a different order of atoms.

22.4 Hydrocarbon Rings

Cyclic Hydrocarbons

- In some hydrocarbon compounds, the carbon chain is in the form of a ring.
- Compounds that contain a hydrocarbon ring are called **cyclic hydrocarbons.**

Three Ways to Represent Cyclic Hydrocarbons



Aromatic Hydrocarbons

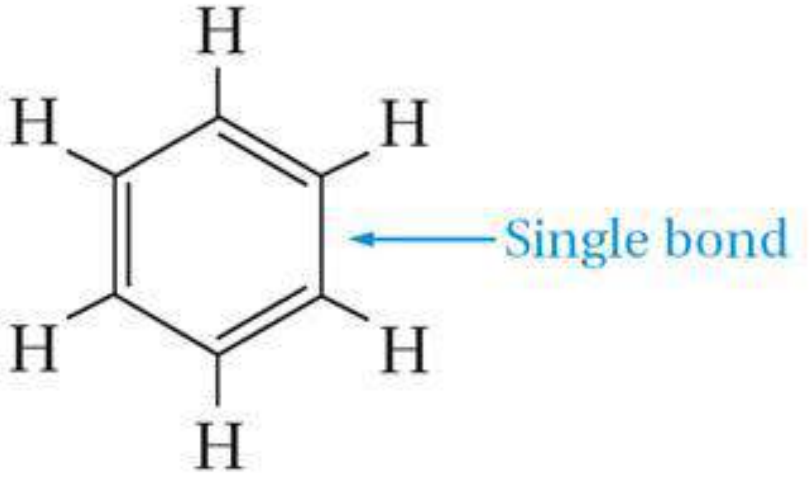
- In a benzene molecule, the bonding electrons between carbon atoms are shared evenly around the ring.

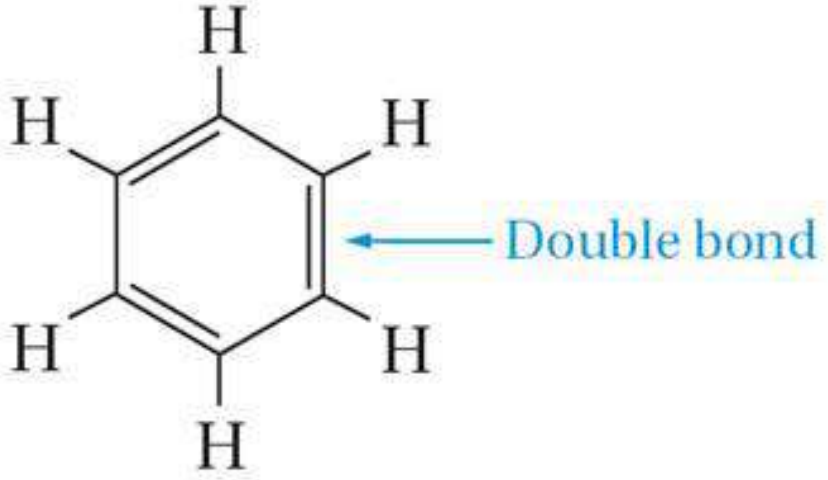
  - An **aromatic compound** is an organic compound that contains a benzene ring or other ring in which the bonding is like that of benzene.

Aromatic Hydrocarbons

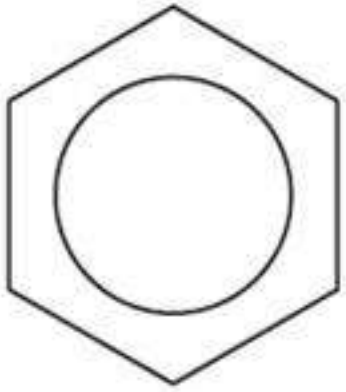
The Structure of Benzene

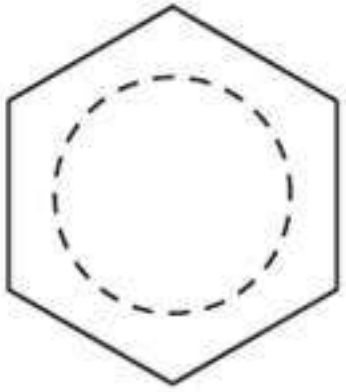
Benzene can be shown as switching, or resonating, between two arrangements of alternating double and single bonds.





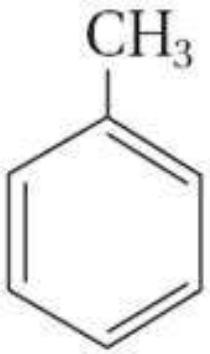
The three symbols below can be used to represent the benzene ring. If the bonds are shown as alternating single and double bonds (on right), it is important to remember that bonds don't actually alternate and that all bonds are identical.



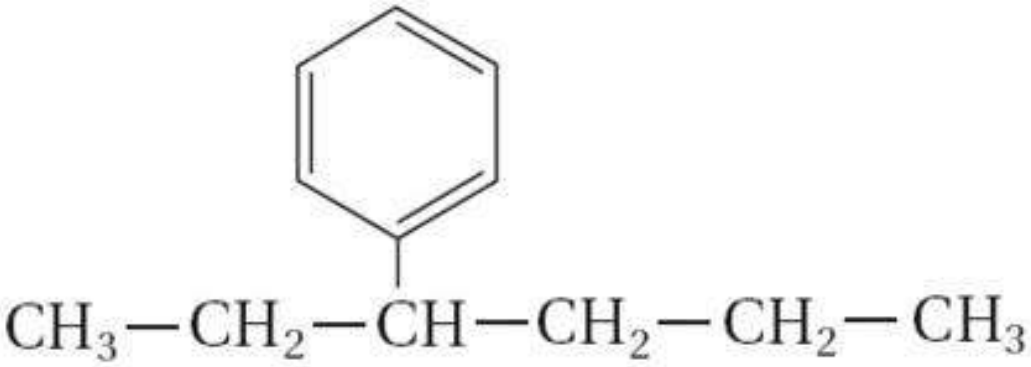


Substituted Aromatic Compounds

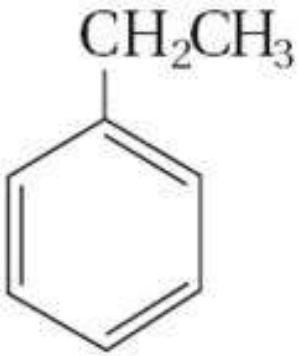
Compounds with a substituent on a benzene ring are named as a derivative of benzene. When benzene is a substituent, it is called a phenyl group.



Methylbenzene
(toluene)



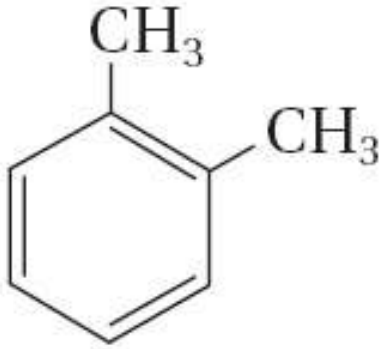
3-phenylhexane



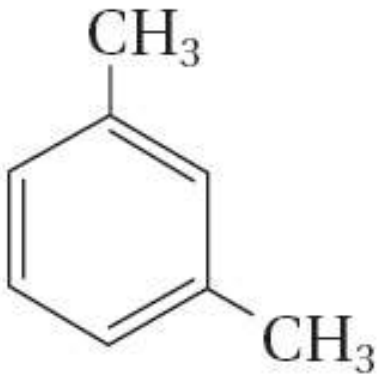
Ethylbenzene

Aromatic Hydrocarbons

- A benzene ring can have two or more substituents.



1,2-dimethylbenzene
(*o*-xylene)
(bp 144°C)



1,3-dimethylbenzene
(*m*-xylene)
(bp 139°C)

1,4-dimethylbenzene
(*p*-xylene)
(bp 139°C)

22.4 Section Quiz.

1. Choose the correct words for the spaces. Alkanes that do not contain a ring structure are _____ hydrocarbons. Alkanes that do contain ring structures are called _____ hydrocarbons.

- aliphatic, aromatic
- aromatic, aliphatic
- aliphatic, cyclic
- aromatic, cyclic

22.4 Section Quiz.

2. The carbon-carbon bonds in a benzene molecule are

- alternating double and single bonds.
- identical hybrid bonds.
- all double bonds.
- all single bonds.

22.4 Section Quiz.

3. When an alkane has a benzene ring as a substituent, the ring is called _____ group.

- a benzene
- a toluene
- a phenyl
- an arene

Chapter 23

23.1 Introduction to Functional Groups

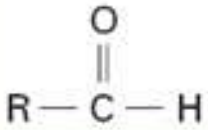
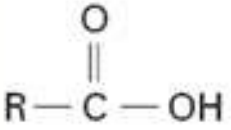
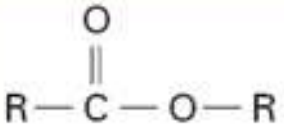
Functional Groups

- **Organic compounds can be classified according to their functional groups.**
  - A **functional group** is a specific arrangement of atoms in an organic compound that is capable of characteristic chemical reactions.

Functional Groups

Table 23.1

Organic Compounds Classified by Functional Group

Compound type	Compound structure	Functional group
Halocarbon	R — X (X = F, Cl, Br, or I)	Halogen
Alcohol	R — OH	Hydroxyl
Ether	R — O — R	Ether
Aldehyde		Carbonyl
Ketone		Carbonyl
Carboxylic acid		Carboxyl
Ester		Ester
Amine	R — NH_2	Amino
Amide		Amide

Halogen Substituents

- **A halocarbon is a carbon-containing compound with a halogen substituent.**
- **Halocarbons** are a class of organic compounds containing covalently bonded fluorine, chlorine, bromine, or iodine.

Halogen Substituents

- On the basis of their common names, halocarbons in which a halogen is attached to a carbon of an aliphatic chain are called **alkyl halides.**
- Halocarbons in which a halogen is attached to a carbon of an arene ring are called **aryl halides**.

23.1 Section Quiz.

1. Organic molecules are classified according to their
   - functional groups.
   - longest chain.
   - derivatives.
   - number of rings.

23.1 Section Quiz

2. What is the correct IUPAC name for the compound $CH_2BrCH_2CH_2Br$?

- methylbromoethylbromide
- dibromopropane
- 1,3-dibromopropane
- propyl-1,3-dibromide

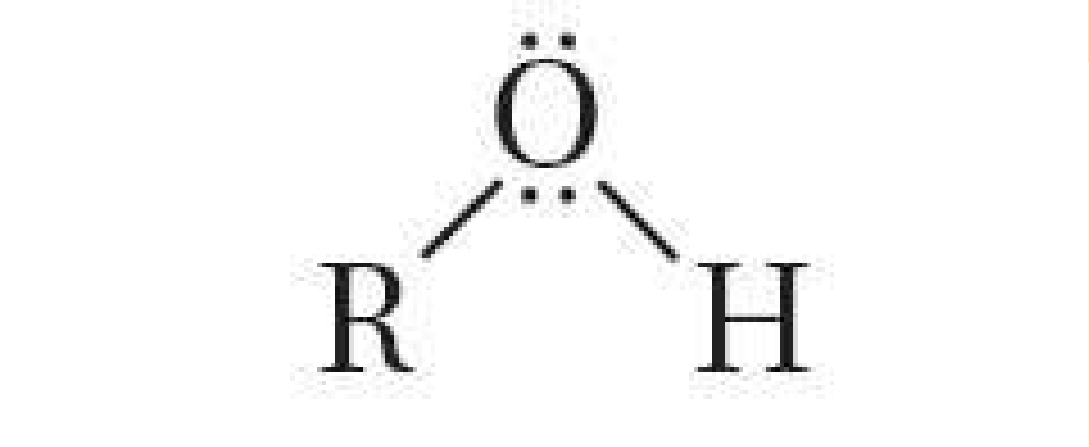
Chapter 23

23.2 Alcohols and Ethers

Alcohols

An **alcohol** is an organic compound with an — OH group.

The —OH functional group in alcohols is called a **hydroxyl group** or hydroxy function.



Alcohol molecule

Alcohols

When using the IUPAC system to name continuous-chain and substituted alcohols, drop the -*e* ending of the parent alkane name and add the ending -*ol*.

Alcohols

Primary alcohol

$$R-CH_2-OH$$

Only one R group is attached to C — OH of a primary (abbreviated 1°) alcohol.

$$CH_3-OH$$

Methanol
(methyl alcohol)

$$CH_3-CH_2-OH$$

Ethanol
(ethyl alcohol)

$$CH_3-CH_2-CH_2-OH$$

1-propanol
(propyl alcohol)

Properties of Alcohols

Fermentation is the production of ethanol from sugars by the action of yeast or bacteria. A second reaction product, carbon dioxide, causes bread to rise.

$$C_6H_{12}O_6(aq) \longrightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$$

Glucose — Ethanol — Carbon dioxide

Properties of Alcohols

Ethanol is the intoxicating substance in alcoholic beverages. It is a depressant that can be fatal if taken in large doses at once.

Denatured alcohol is ethanol with an added substance to make it toxic (poisonous).

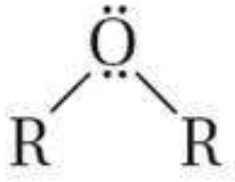
- Denatured alcohol is used as a reactant or as a solvent in industrial processes.

Ethers

The general structure of an ether is R—O—R. The alkyl groups attached to the ether linkage are named in alphabetical order and are followed by the word *ether*.

Ethers

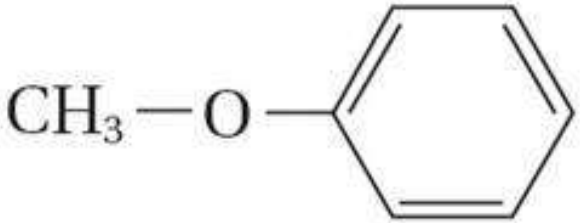
An **ether** is a compound in which oxygen is bonded to two carbon groups.



Ether molecule

$CH_3CH_2-O-CH_3$

Ethylmethyl ether



Methylphenyl ether
(anisole)

23.2 Section Quiz.

4. Which structure is ethylmethyl ether?

- $CH_3—CH_2—OH—CH_2$
- $CH_3—CH_2—CHO$
- $CH_3CH_2—O—\ CH_3$
- $CH_2CH—CH_3—OH$

Chapter 23

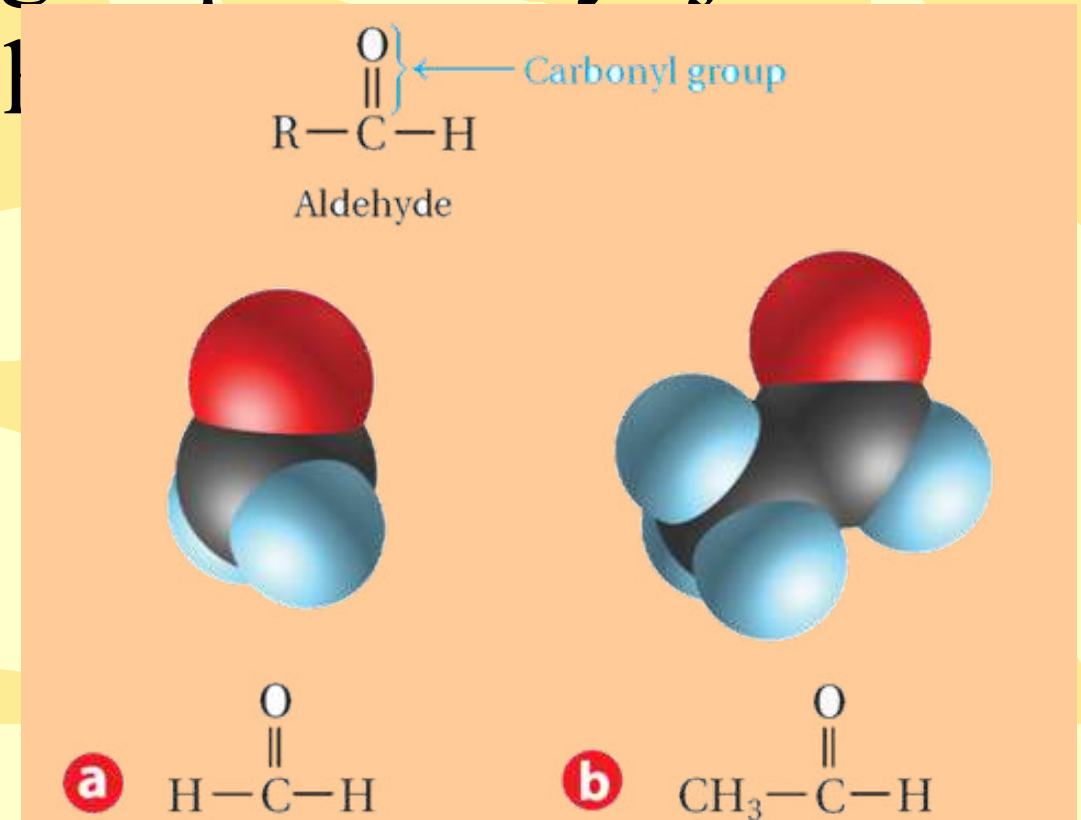
23.3 Carbonyl Compounds

Aldehydes and Ketones

- A **carbonyl group** is a functional group with the general structure C═O.
  - The C═O functional group is present in aldehydes and ketones.

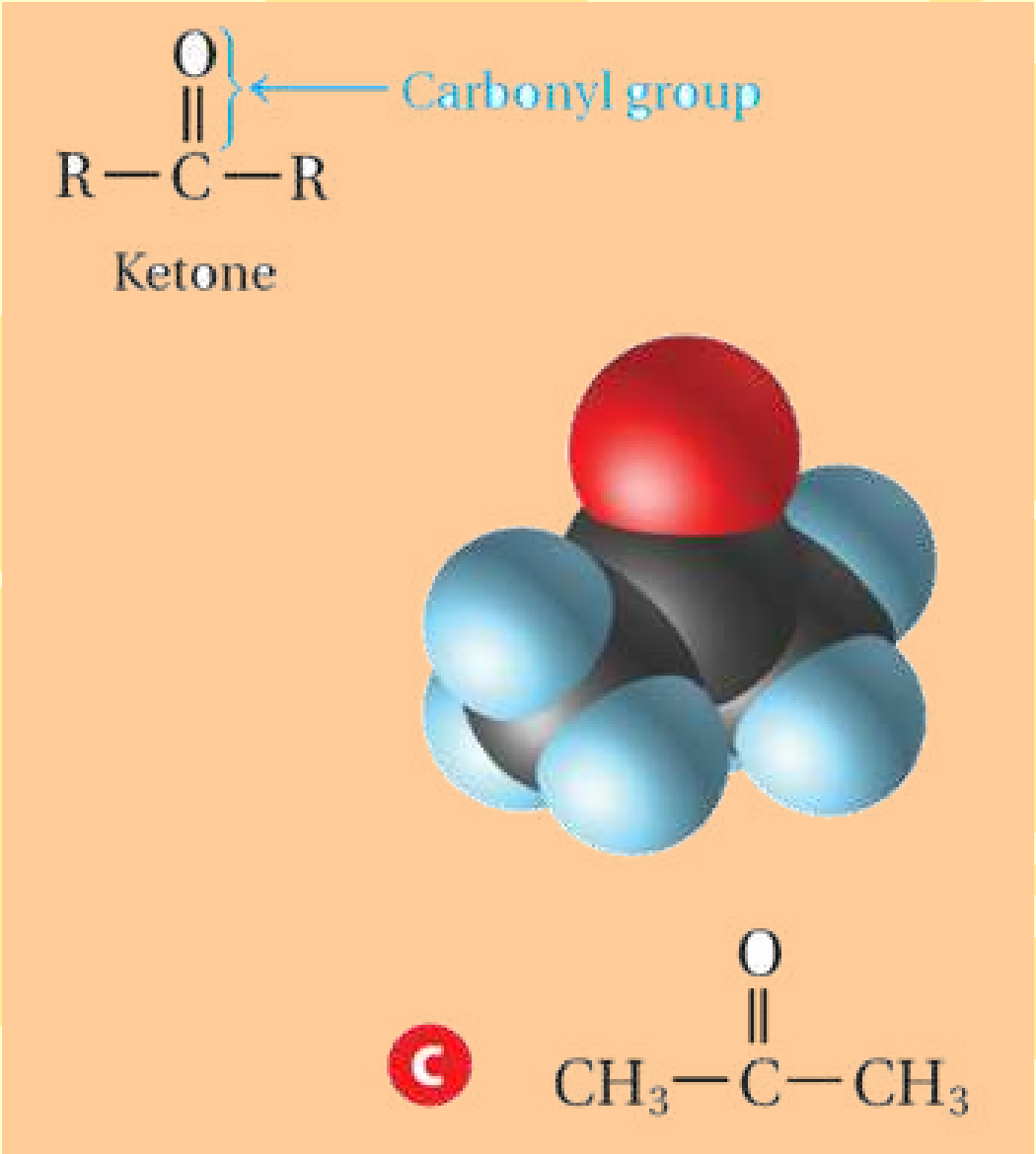
Aldehydes and Ketones

An **aldehyde** is an organic compound in which the carbon of the carbonyl group is always joined to at least one l



Aldehydes and Ketones

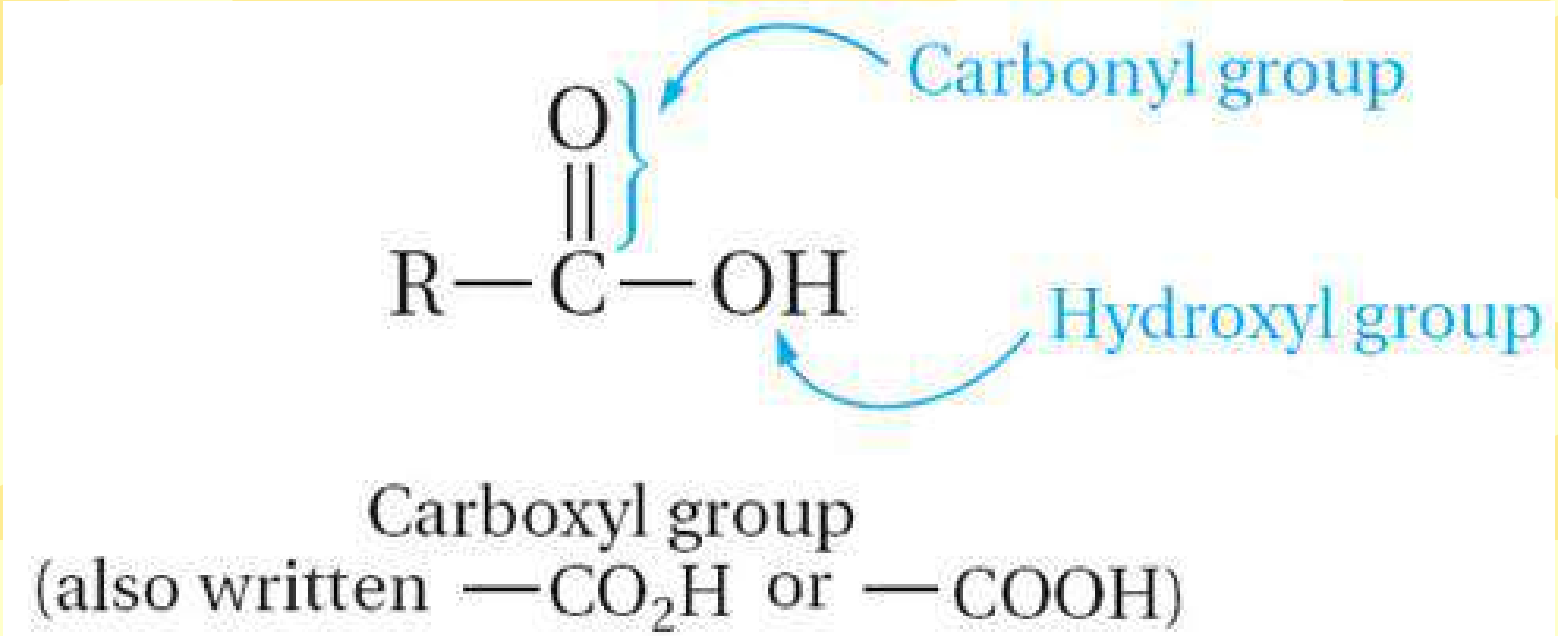
A **ketone** is an organic compound in which the carbon of the carbonyl group is joined to two other carbons.



Carboxylic Acids

A **carboxyl group** consists of a carbonyl group attached to a hydroxyl group.

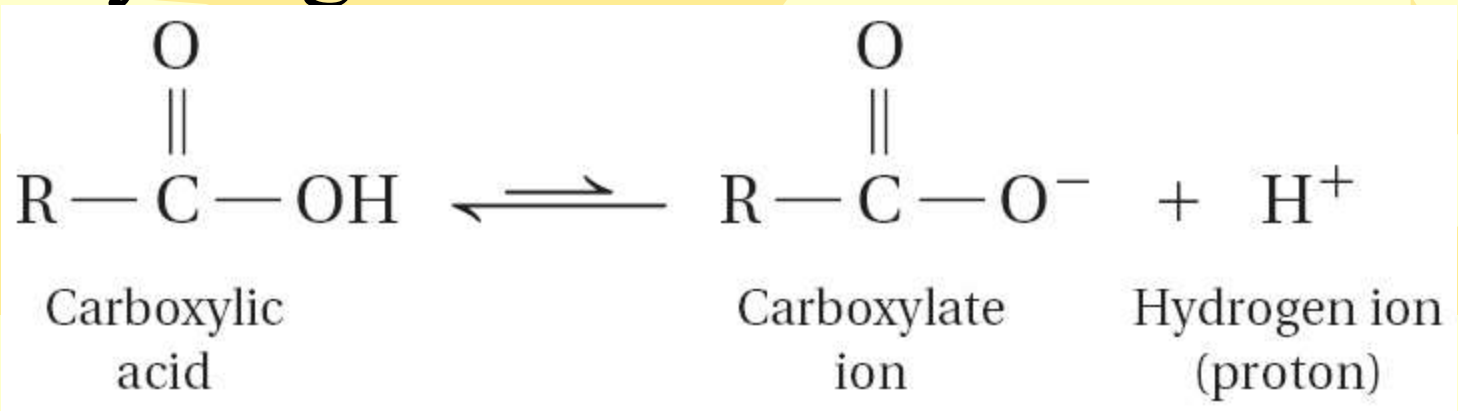
A **carboxylic acid** is a compound with a carboxyl group.



Carboxylic Acids

The general formula for a carboxylic acid is RCOOH.

- Carboxylic acids are weak because they ionize slightly in solution to give a carboxylate ion and a hydrogen ion.



Carboxylic Acids

Many continuous-chain carboxylic acids were first isolated from fats and are called **fatty acids.**

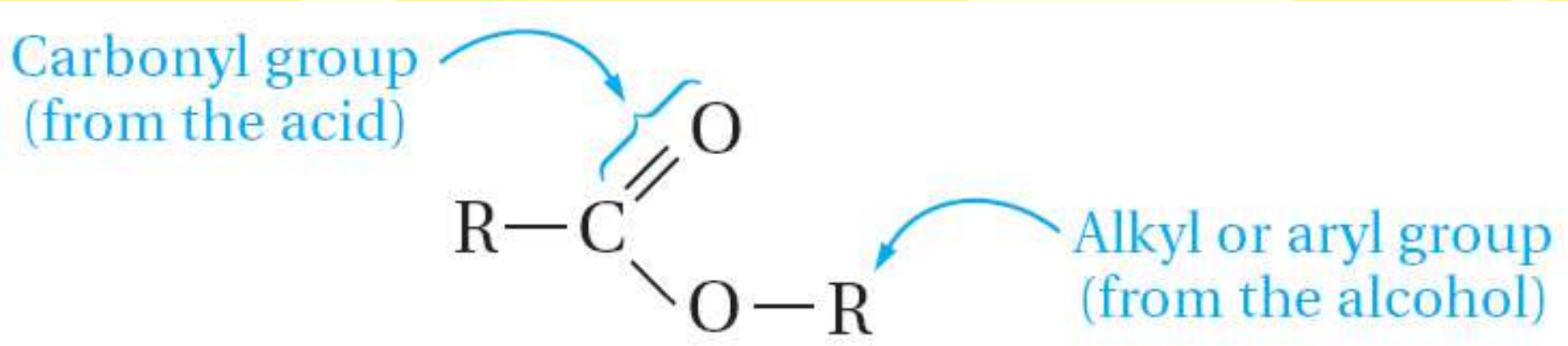
- Stearic acid, an 18-carbon acid obtained from beef fat, is used to make inexpensive wax candles.

Esters

Esters contain a carbonyl group and an ether link to the carbonyl carbon. The general formula for an ester is RCOOR.

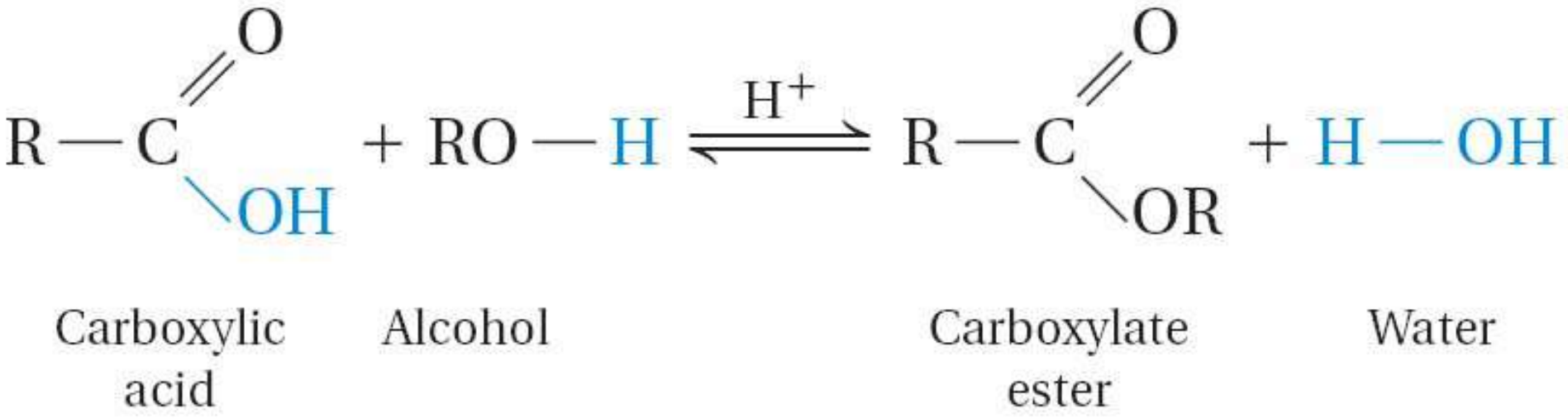
Esters

Esters are derivatives of carboxylic acids in which the —OH of the carboxyl group has been replaced by an —OR from an alcohol.



Esters

- Esters may be prepared from a carboxylic acid and an alcohol.



Esters

Esters impart the characteristic aromas and flavors of many flowers and fruits. Marigolds, raspberries, and bananas all contain esters.

23.3 Section Quiz

1. Which compound is a ketone?
   - CH_3COOH
   - CH_3CH_2OH
   - CH_3CHO
   - CH_3COCH_3

23.3 Section Quiz.

2.The IUPAC name for the structure CH_3CH_2COOH is

- ethanoic acid.
- acetic acid.
- propanoic acid.
- propionic acid.

23.3 Section Quiz.

3. The product of the reaction between an alcohol and a carboxylic acid is called

- a ketone.
- an ether.
- an ester.
- an aldehyde.

Chapter 23

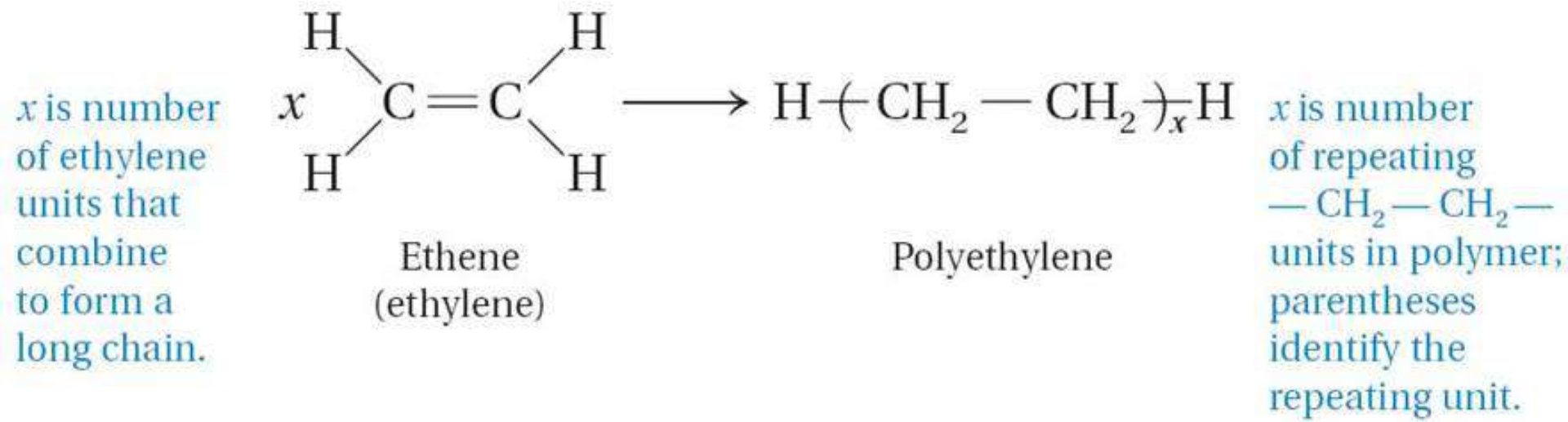
23.4 Polymerization

Addition Polymers

- A **polymer** is a large molecule formed by the covalent bonding of repeating smaller molecules.
- The smaller molecules that combine to form a polymer are called **monomers**.

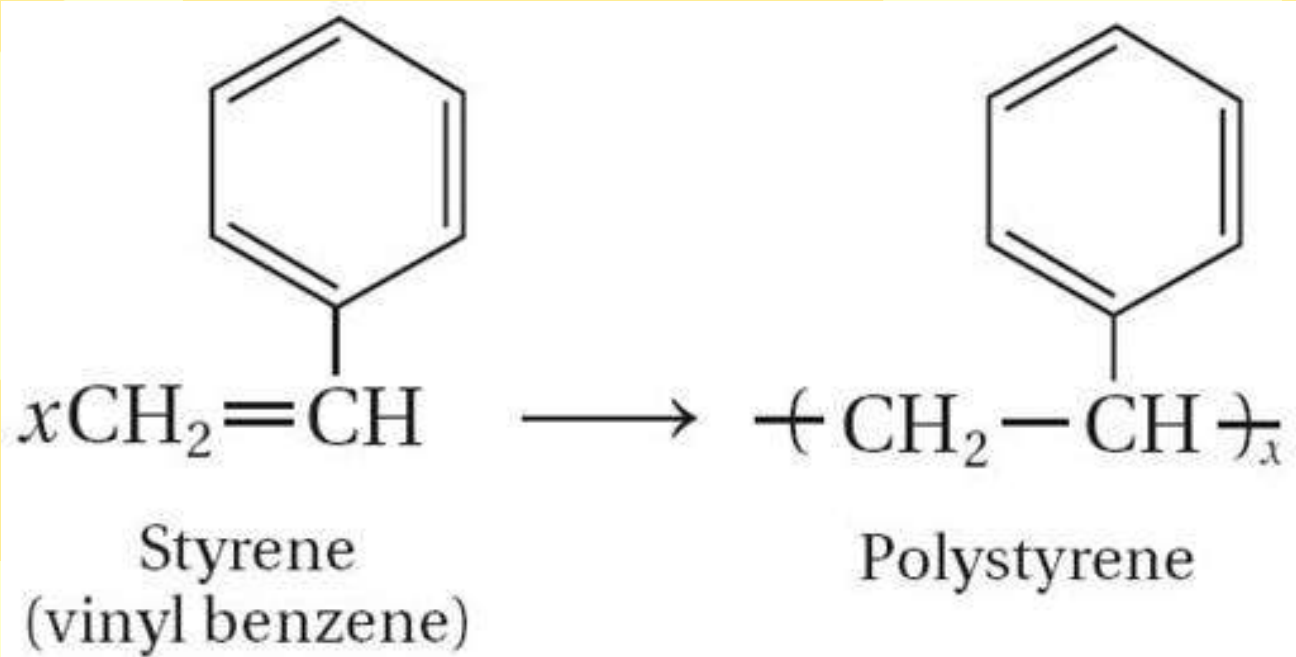
Addition Polymers

- **An addition polymer forms when unsaturated monomers react to form a polymer.**



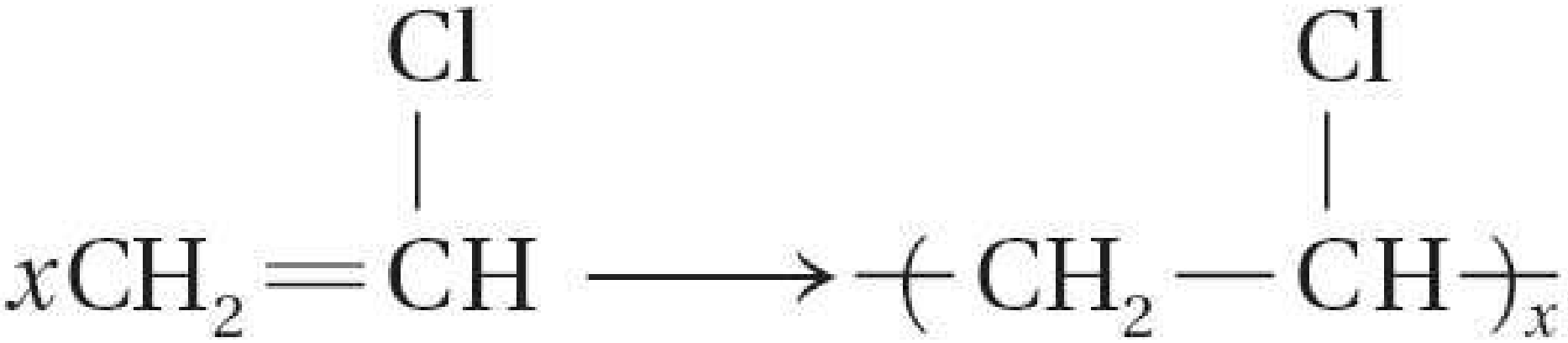
Addition Polymers

Polystyrene foam is a poor heat conductor, useful for insulating homes and for molded items such as coffee cups and picnic coolers.



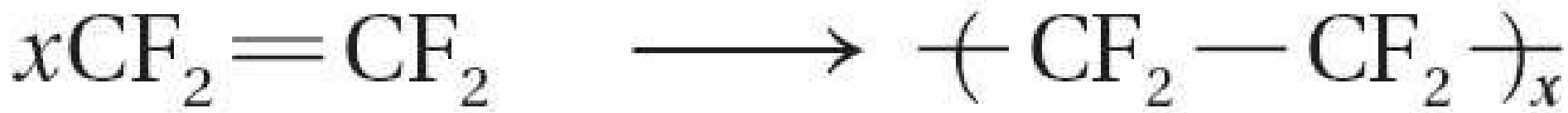
Addition Polymers

Polyvinyl chloride (PVC) is a halocarbon polymer. Vinyl chloride is the monomer of polyvinyl chloride.



Addition Polymers

Polytetrafluoroethene (Teflon™or PTFE) is the product of the polymerization of tetrafluoroethene monomers.

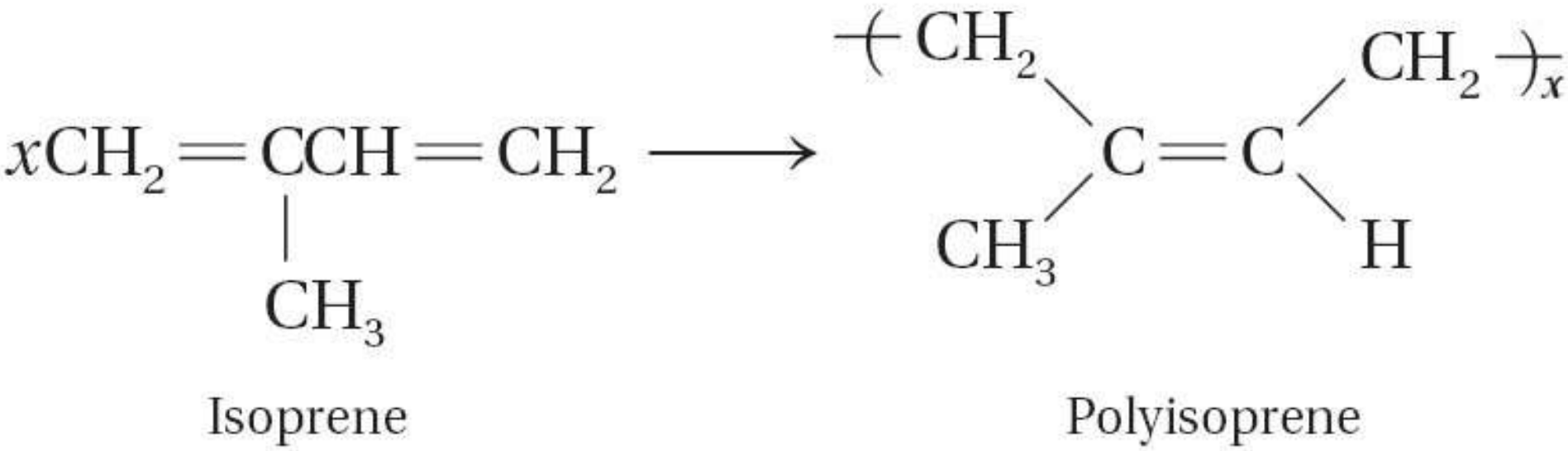


Tetrafluoroethene

Teflon (PTFE)

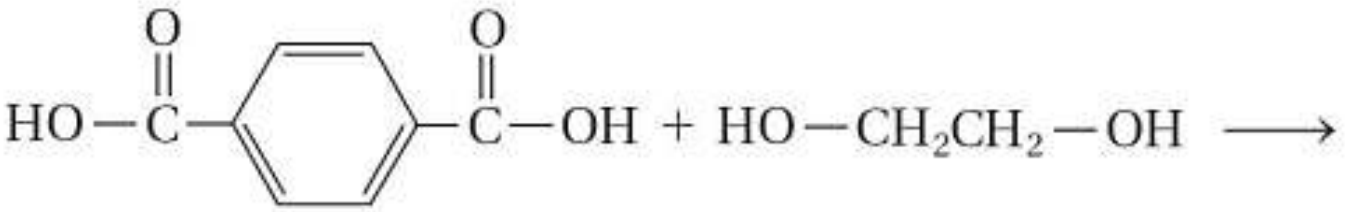
Addition Polymers

Polyisoprene, harvested from tropical plants such as a rubber tree, is the polymer that constitutes rubber.

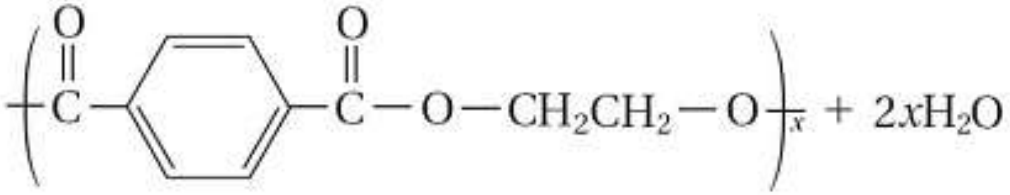


Condensation Polymers

Polyesters are made by linking dicarboxylic acids and dihydroxy alcohols. The polyester polyethylene terephthalate (PET) is formed from terephthalic acid and ethylene glycol.



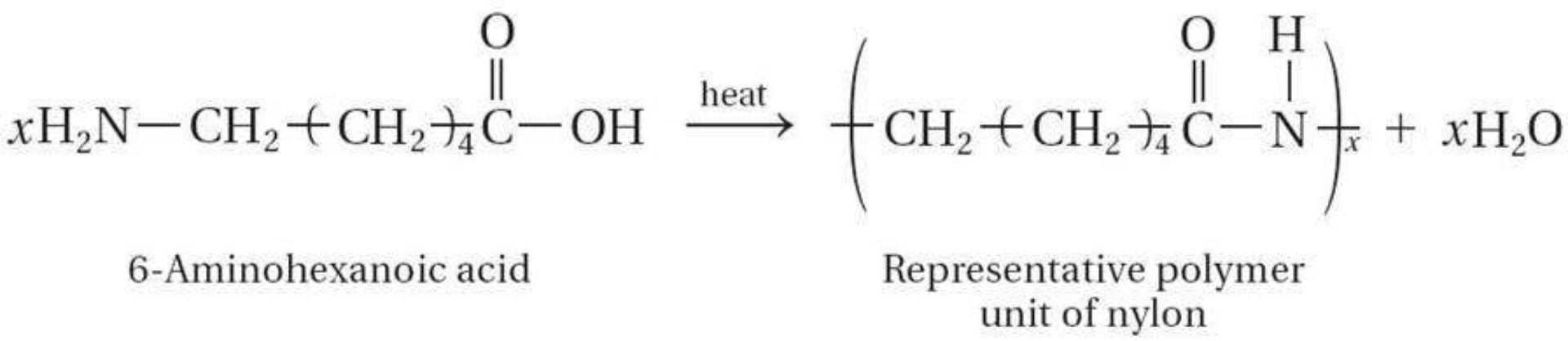
Terephthalic acid Ethylene glycol



Representative polymer unit of polyethylene terephthalate (PET)

Condensation Polymers

The representative polymer unit of nylon is derived from 6-aminohexanoic acid, a compound that contains both carboxyl and amino functional groups.



Condensation Polymers

Kevlar™is a polyamide made from terephthalic acid and p-phenylenediamine.