Introductory Chemistry

Fourth Edition

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Chapter 18

Organic Chemistry

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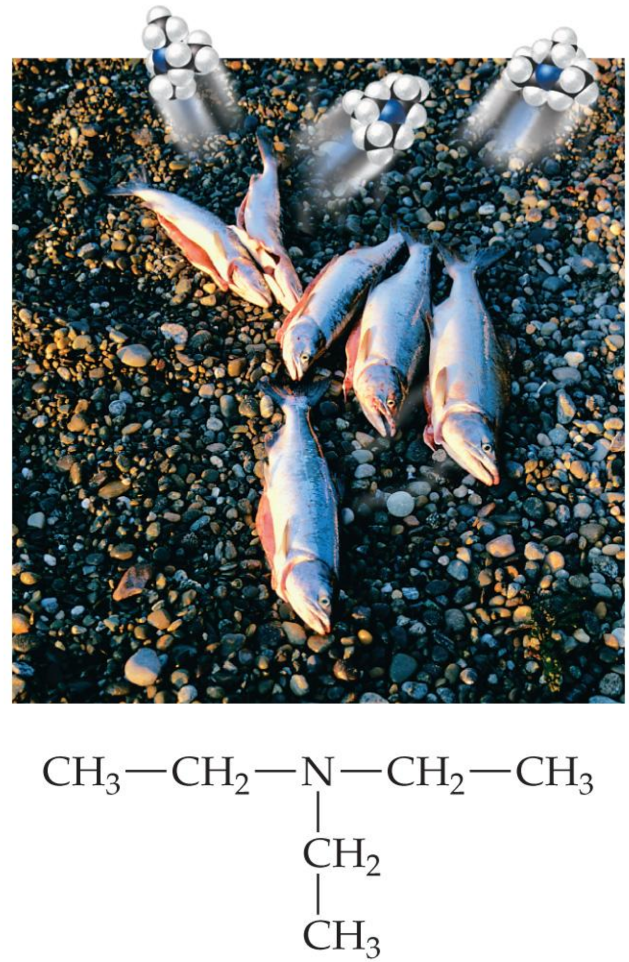
18.1 What Do I Smell?

- The sweet smell of jasmine is produced by ***benzyl acetate***, an organic compound.
- When you smell the jasmine scent, ***benzyl acetate*** molecules emitted from the flower bind with molecular receptors in your nose, triggering a nerve signal to your brain.

18.1 What Do I Smell?

- Most of the smells that we experience are caused by **organic molecules**, molecules containing carbon combined with several other elements.
- Carbon-containing molecules—especially triethylamine—are responsible for the smell of dead fish.



Triethylamine

Carbon-containing molecules are responsible for the smell of vanilla beans and cinnamon sticks.

Vanillin   Cinnamaldehyde

18.2 Vitalism: The Difference between Organic and Inorganic

- By the end of the eighteenth century, chemists had divided compounds into two broad categories: organic and inorganic.

Organic compounds came from living things.

- Sugar—obtained from sugarcane or the sugar beet—is an example of an organic compound.

Inorganic compounds came from Earth.

- Salt—mined from the ground or extracted from the ocean—is an example of an inorganic compound.

Sugar, obtained from sugarcane or sugar beets, is an example of an organic compound. Salt, obtained from a salt mine or from the ocean, is an example of an inorganic compound.

18.2 Vitalism: The Difference between Organic and Inorganic

- Early chemists realized that organic and inorganic compounds are different in their properties.

Organic compounds are easily decomposed.

- Sugar easily decomposes into carbon and water when heated.

Inorganic compounds are more difficult to decompose.

- Salt must be heated to very high temperatures before it decomposes.

Organic compounds are difficult to synthesize in the laboratory.

Many inorganic compounds could be easily synthesized, but organic compounds could not.

18.2 Vitalism: The Difference between Organic and Inorganic

- The origin and properties of organic compounds led early chemists to postulate that organic compounds are ***unique to living organisms***.
- They postulated that living organisms employed a **vital force**—a mystical or supernatural power—that allowed them to produce organic compounds.
- They thought it impossible to produce an organic compound outside of a living organism because the vital force is not present.
- This belief—which became known as **vitalism**—was thought to explain why no chemist had succeeded in synthesizing an organic compound in the laboratory.

Laboratory Synthesis of Urea

- In 1828, a German chemist named Friedrich Wöhler (1800–1882) proved vitalism wrong.
- Wöhler heated ammonium cyanate (an inorganic compound) and formed urea (an organic compound).

$$\underset{\text{Ammonium cyanate}}{NH_4OCN} \xrightarrow{\text{Heat}} \underset{\text{Urea}}{H_2NCONH_2}$$

- Urea was a known organic compound that had previously been isolated only from the urine of living organisms.
- Wöhler's experiment was a crucial step in opening all of life to scientific investigation.
- Wöhler showed that the compounds that compose living organisms follow scientific laws and can be studied and understood.

Chemistry in the Media: The Origin of Life

- In 1953, a young scientist named Stanley Miller, working with Harold C. Urey at the University of Chicago, re-created the environment of primordial Earth.
- In a flask containing water and certain gases, including methane, ammonia, and hydrogen, Miller passed an electrical current through the system to simulate lightning.
- After several days, Miller analyzed the contents of the flask. Not only did the flask contain organic compounds, it contained organic compounds central to life—amino acids.
- Amino acids are the building blocks of biological proteins.
- Apparently, the foundational compounds of life could be synthesized rather simply under conditions believed to be similar to the early atmosphere on Earth.

Chemistry in the Media: The Origin of Life

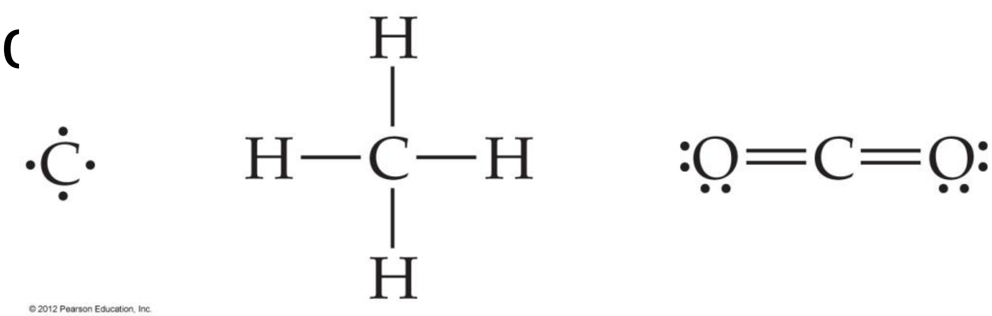
- Some scientists investigating the origin of life have a basic hypothesis of how life may have started.
- A group of molecules developed the ***ability to copy*** themselves, but not quite perfectly—some of the copies contained ***inheritable mistakes***.
- In a few cases, these alterations may have allowed the molecular “offspring” to replicate even ***more efficiently***.
- Chemical evolution got its start producing generation after generation of molecules that slowly got better at copying themselves as they assembled into more complex structures.
- This process eventually produced a living cell, which is a very efficient self-replicating machine.

Chemistry in the Media: The Origin of Life

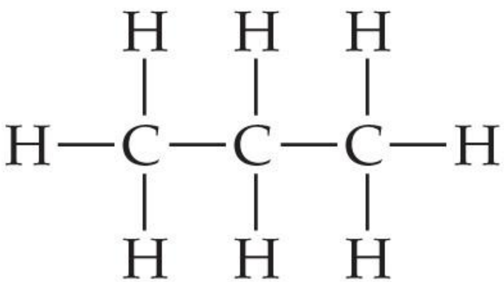
- The complexity of these molecules and their inability to replicate independently of one another have caused some researchers to look at other materials that may have been involved in the process, such as clays and sulfur-based compounds.
- The origin of life continues to be an area of ongoing research.
- Toward the end of his life, Stanley Miller, who was a professor of chemistry at the University of California at San Diego at the time, said, “The problem of the origin of life has turned out to be much more difficult than I and most people envisioned.”

18.3 Carbon: A Versatile Atom

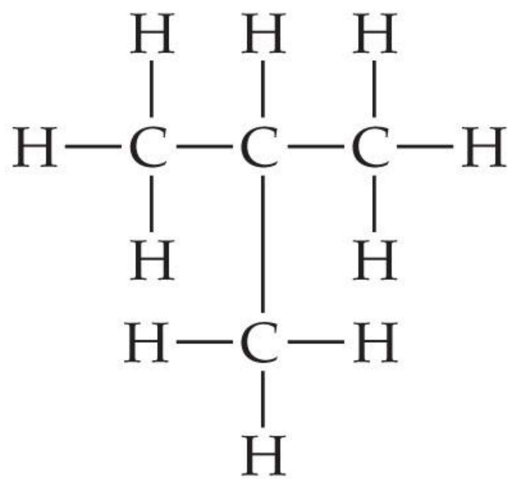
- The number of compounds containing carbon is greater than the number of compounds of all the rest of the elements in the periodic table combined.
- One of the reasons for this complex chemistry is that carbon—with its four valence electrons—can form four covalent bonds.
- Recall these Lewis structures of carbon and some carbon c



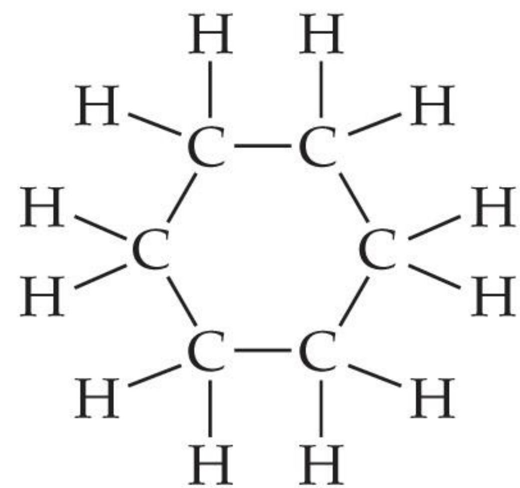
A second reason for carbon’s complex chemistry is that carbon, more than any other element, can bond to itself to form chain, branched, and ring structures.



Propane



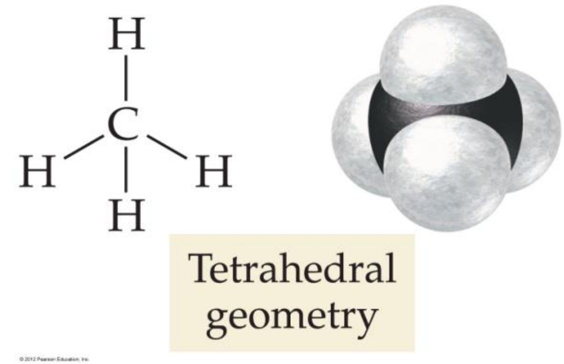
Isobutane

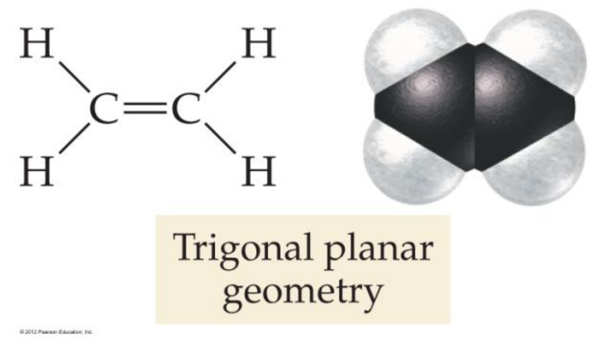


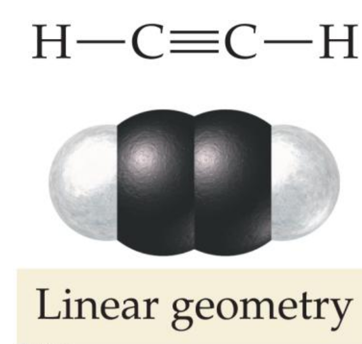
Cyclohexane

Molecular Geometry

- With four single bonds, there are four electron groups around carbon, and VSEPR theory predicts a ***tetrahedral*** geometry.
- With a double bond and two single bonds, there are three electron groups around each carbon atom, and VSEPR theory predicts a ***trigonal planar*** geometry.
- With a triple bond and a single bond (or two double bonds), there are two electron groups around each carbon atom, resulting in a ***linear*** geometry.





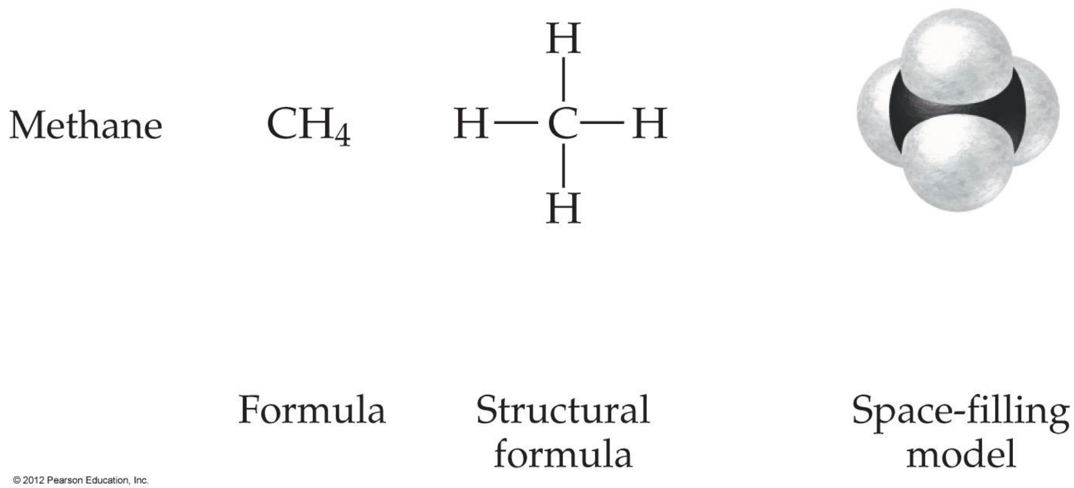


18.4 Hydrocarbons: Compounds Containing Only Carbon and Hydrogen

- Hydrocarbons can be classified broadly into four different types: alkanes, alkenes, alkynes, and aromatic hydrocarbons.
- Alkanes are saturated with hydrogen, while alkenes, alkynes, and aromatic hydrocarbons are all unsaturated with respect to hydrogen.
- Alkanes, alkenes, and alkynes can be differentiated based the amount of hydrogen in their molecular formulas.
- **Alkanes C_nH_{2n+2} Alkenes C_nH_{2n} Alkynes C_nH_{2n-2}**

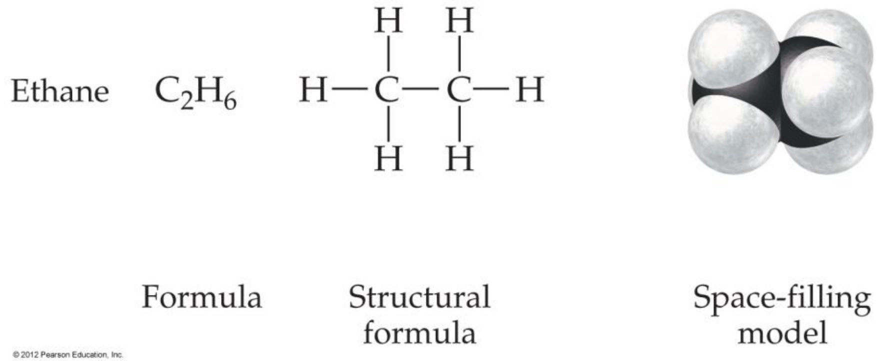
18.5 Alkanes: Saturated Hydrocarbons

- The simplest alkane is methane, the main component of natural gas.

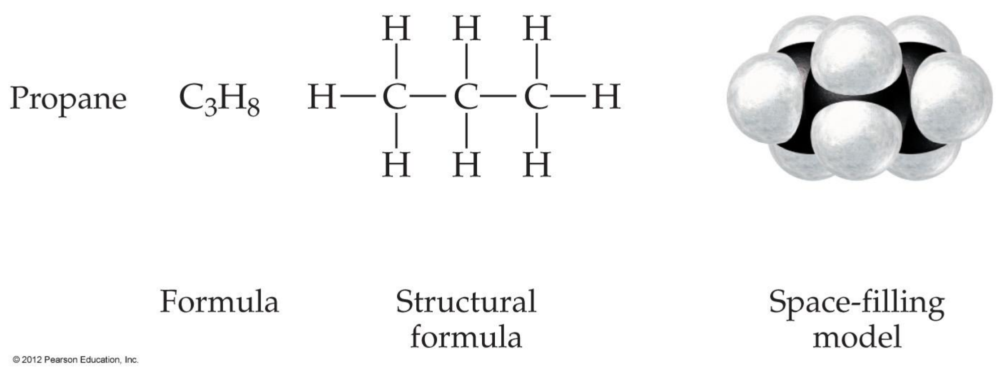


- A structural formula is like a Lewis structure, but it typically depicts bonding electron pairs as dashes and omits lone pairs.

18.5 Alkanes: Saturated Hydrocarbons



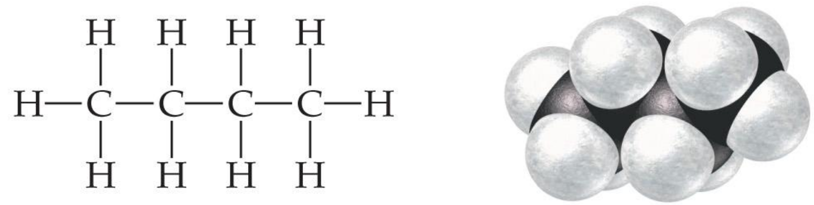
Ethane is a minority component of natural gas.



Propane is the main component of LP (liquid propane) gas.

18.5 Alkanes: Saturated Hydrocarbons

Butane C_4H_{10}

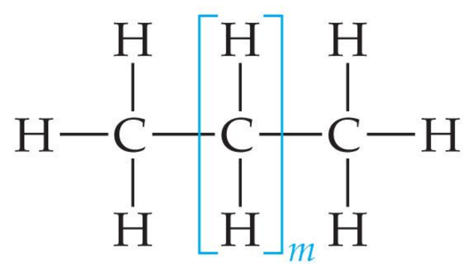


Formula — Structural formula — Space-filling model

A ***condensed structural formula*** is a shorthand way of writing a structural formula in which you eliminate many or all of the bonds and group like atoms together.

$CH_3(CH_2)_mCH_3$

Condensed structural formula



Structural formula

18.5 Alkanes: Saturated Hydrocarbons

- As the number of carbon atoms increases in *n*-alkanes, so does their boiling point.
- Methane, ethane, propane, and butane are all gases at room temperature.
- Pentane is a liquid at room temperature.

Alkane	Boiling Point (°C)
methane	−161.5
ethane	−88.6
propane	−42.1
butane	−0.5
pentane	36.0
hexane	68.7
heptane	98.5
octane	125.6

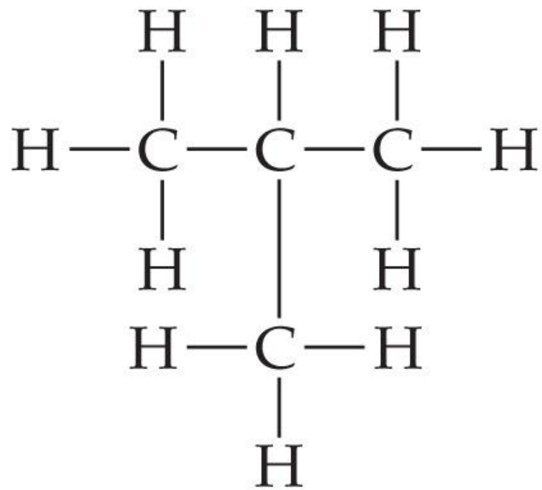
18.5 Alkanes: Saturated Hydrocarbons

- Alkanes composed of carbon atoms bonded in a straight chain without any branching—like the ones we have just seen—are called normal alkanes or *n*-alkanes.
- In addition to linking together in straight chains to form the *n*-alkanes, carbon atoms can form branched structures called branched alkanes. The simplest branched alkane is isobutane.
- Isobutane and butane are isomers, molecules with the same molecular formula but different structures. Because of their different structures, they have different properties.

18.5 Alkanes: Saturated Hydrocarbons

Isobutane

C_4H_{10}



Formula

Structural formula

Space-filling model

18.7 Naming Alkanes

- In the nomenclature system recommended by the International Union of Pure and Applied Chemistry (IUPAC), the base name of an organic compound consists of a prefix and an ending.
- The prefix is determined by the number of carbon atoms in the **base chain** (the longest continuous chain of carbon atoms).

TABLE 18.3 Prefixes for Base Names of Alkane Chains

Number of Carbon Atoms	Prefix
1	*meth-*
2	*eth-*
3	*prop-*
4	*but-*
5	*pent-*
6	*hex-*
7	*hept-*
8	*oct-*
9	*non-*
10	*dec-*

- Groups of carbon atoms branching off the base chain are called **alkyl groups** and are named as *substituents*.
- A **substituent** is an atom or group of atoms that has been *substituted* for a hydrogen atom in an organic compound.

TABLE 18.4 Common Alkyl Groups

Condensed Structural Formula	Name
$-CH_3$	methyl
$-CH_2CH_3$	ethyl
$-CH_2CH_2CH_3$	propyl
$-CH_2CH_2CH_2CH_3$	butyl
$-CHCH_3$ | CH_3	isopropyl
$-CH_2CHCH_3$ | CH_3	isobutyl
$-CHCH_2CH_3$ | CH_3	*sec*-butyl
CH_3 | $-CCH_3$ | CH_3	*tert*-butyl

The rules to systematically name alkanes

1. Count the number of carbon atoms in the longest continuous carbon chain to determine the base name of the compound. Use the prefix corresponding to this number of atoms and add the ending *–ane* to form the base name.
2. Consider every branch from the base chain to be a substituent. Name each substituent according to Table 18.4.
3. Beginning with the end closest to the branching, number the carbon atoms in the base chain and assign a number to each substituent. (If two substituents occur at equal distances from each end, go to the next substituent to determine from which end to start numbering.)

The rules to systematically name alkanes

4. Write the name of the compound in the format:

(subst. number)–(subst. name) (base name)

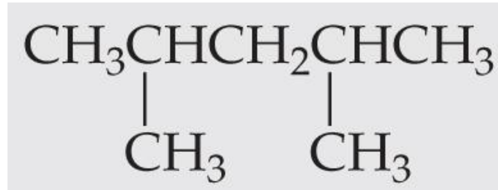
If there are two or more substituents, give each one a number and ***list them alphabetically*** with hyphens between words and numbers.

5. If a compound has two or more identical substituents, designate the number of identical substituents with the prefix *di-* (2), *tri-* (3), or *tetra-* (4) before the substituent's name.

Separate the numbers indicating the positions of the substituents relative to each other with a comma.

The prefixes are not taken into account when alphabetizing.

EXAMPLE Name the alkane.



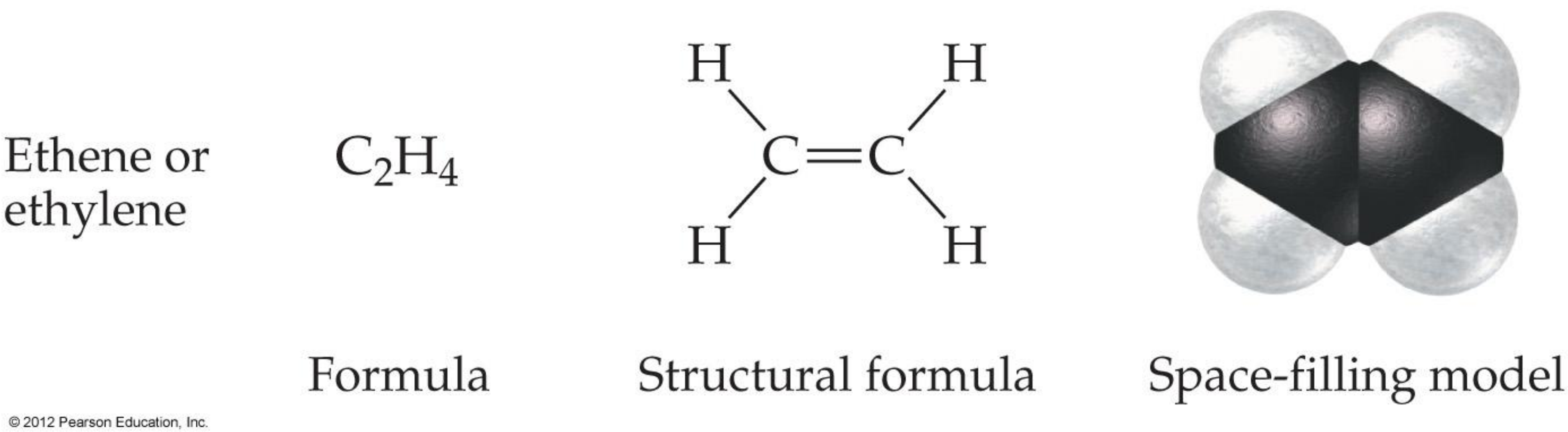
1. The longest continuous carbon chain has five atoms. Therefore, the base name is *pentane.*
2. This compound has two substituents, both of which are named *methyl*.
3. Since both substituents are equidistant from the ends, it does not matter which end you start numbering from.
4. and **5.** Since this compound contains two identical substituents, Rule 5 applies and we use the prefix *di.*

Answer: 2,4-dimethylpentane

18.8 Alkenes and Alkynes

- **Alkenes** are hydrocarbons containing at least one ***double bond*** between carbon atoms.
- **Alkynes** are hydrocarbons containing at least one ***triple bond*** between carbon atoms.
- Because of the double or triple bond, alkenes and alkynes have fewer hydrogen atoms than the corresponding alkane and are called **unsaturated hydrocarbons** because they are not loaded to capacity with hydrogen.
- Alkenes have the formula $\mathbf{C_{\mathit{n}}H_{2\mathit{n}}}$.
- Alkynes have the formula $\mathbf{C_{\mathit{n}}H_{2\mathit{n}-2}}$.

The simplest alkene is ethene, also called *ethylene*. The geometry about each carbon atom in ethene is trigonal planar, making ethene a flat, rigid molecule.



- Ethene is emitted by ripening bananas.
- It acts as a chemical messenger, inducing bananas in a bunch to ripen together.

- Banana farmers usually pick bananas green for ease of shipping.
- When the bananas arrive at their destination, they are often “gassed” with ethene to initiate ripening so that they will be ready to sell.

The simplest alkyne is ethyne, also called acetylene. The geometry about each carbon atom in ethyne is linear, making ethyne a linear molecule.

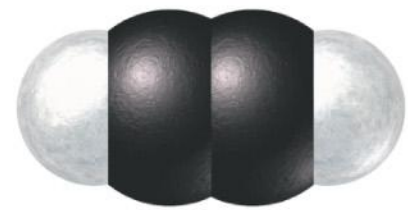
Ethyne or acetylene

C_2H_2

Formula

H—C≡C—H

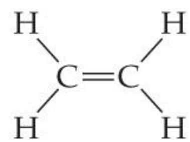
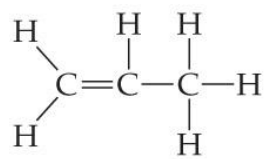
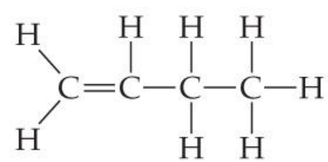
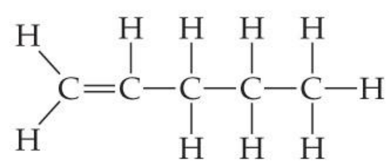
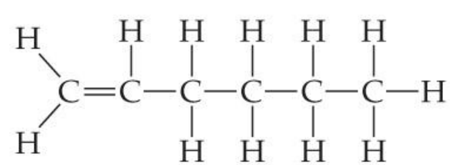
Structural formula



Space-filling model

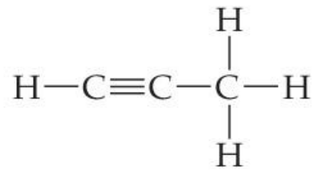
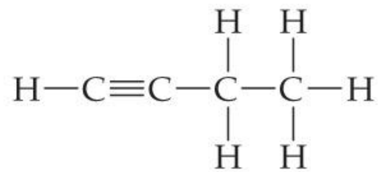
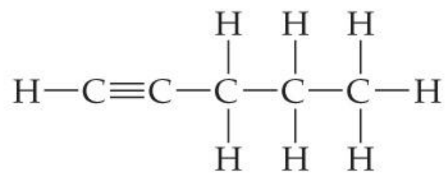
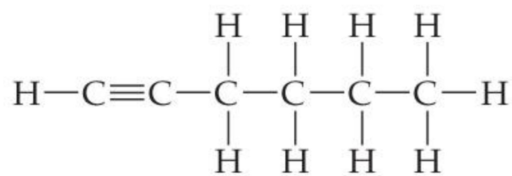
Most of the alkenes do not have familiar uses other than their presence as minority components of fuels.

TABLE 18.5 Alkenes

n	Name	Molecular Formula (C_nH_{2n})	Structural Formula	Condensed Structural Formula
2	ethene	C_2H_4		$CH_2{=}CH_2$
3	propene	C_3H_6		$CH_2{=}CHCH_3$
4	1-butene	C_4H_8		$CH_2{=}CHCH_2CH_3$
5	1-pentene	C_5H_{10}		$CH_2{=}CHCH_2CH_2CH_3$
6	1-hexene	C_6H_{12}		$CH_2{=}CHCH_2CH_2CH_2CH_3$

The alkynes do not have familiar uses other than their presence as minority components of gasoline.

TABLE 18.6 Alkynes

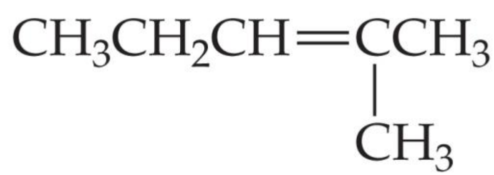
n	Name	Molecular Formula (C_nH_{2n-2})	Structural Formula	Condensed Structural Formula
2	ethyne	C_2H_2	$H-C\equiv C-H$	$CH\equiv CH$
3	propyne	C_3H_4		$CH\equiv CCH_3$
4	1-butyne	C_4H_6		$CH\equiv CCH_2CH_3$
5	1-pentyne	C_5H_8		$CH\equiv CCH_2CH_2CH_3$
6	1-hexyne	C_6H_{10}		$CH\equiv CCH_2CH_2CH_2CH_3$

NAMING ALKENES AND ALKYNES

Alkenes and alkynes are named in the same way as alkanes with the following exceptions:

- The base chain is the longest continuous carbon chain that *contains the double or triple bond.*
- The base name has the ending *-ene* for alkenes and *-yne* for alkynes.
- The base chain is numbered to *give the double or triple bond the lowest possible number*.
- A number indicating the position of the double or triple bond (lowest possible number) is inserted just before the base name.

1-Butyne



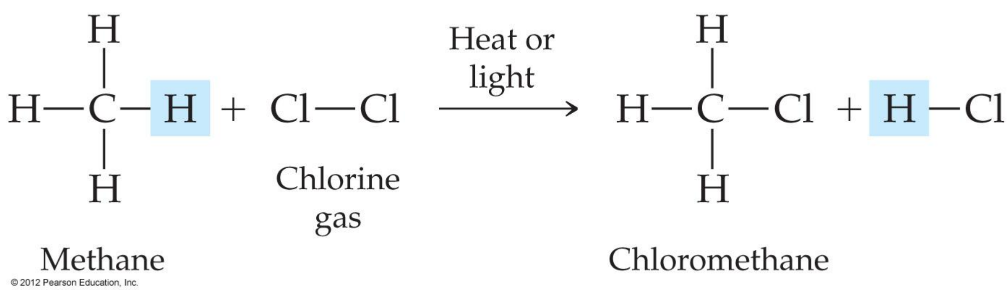
2-Methyl-2-pentene

18.9 Hydrocarbon Reactions

- One of the most common hydrocarbon reactions is **combustion**, the burning of hydrocarbons in the presence of oxygen.
- Alkanes, alkenes, and alkynes all undergo combustion.
- In a combustion reaction, the hydrocarbon reacts with oxygen to form carbon dioxide and water.
- Hydrocarbon combustion reactions are highly exothermic: they emit large amounts of heat.
- This heat can be used to warm homes and buildings, to generate electricity, or to expand the gas in a cylinder and drive a car forward.

18.9 Hydrocarbon Reactions

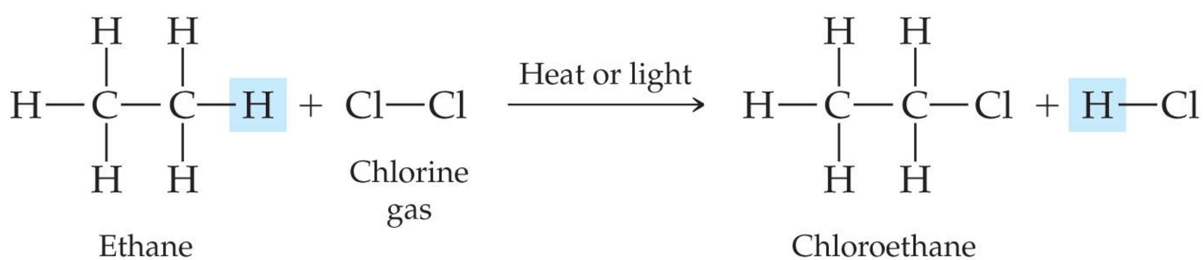
- **In alkane substitution reactions,** one or more hydrogen atoms on an alkane are replaced by one or more other types of atoms.
- The most common substitution reaction is halogen substitution.
- Methane reacts with chlorine gas to form chloromethane.



$$CH_4(g) + Cl_2(g) \xrightarrow[\text{}]{\text{Heat or light}} CH_3Cl(g) + HCl(g)$$

18.9 Hydrocarbon Reactions

- **In alkene and alkyne addition reactions,** atoms add across the multiple bond.
- Ethene reacts with chlorine gas to form dichloroethane.



$$CH_2{=}CH_2(g) + Cl_2(g) \longrightarrow CH_2ClCH_2Cl(g)$$

Ethene 1,2-Dichloroethane

18.9 Hydrocarbon Reactions

- Alkenes and alkynes can add hydrogen in **hydrogenation** reactions.
- Hydrogenation reactions convert unsaturated hydrocarbons into saturated hydrocarbons.
- Vegetable oil is an unsaturated fat—its carbon chains contain double bonds. Unsaturated fats tend to be liquids at room temperature.
- By means of hydrogenation reactions, hydrogen is added across the double bonds, converting the unsaturated fat into *partially hydrogenated vegetable oil*, a saturated fat, which tends to be solid at room temperature.

18.9 Hydrocarbon Reactions

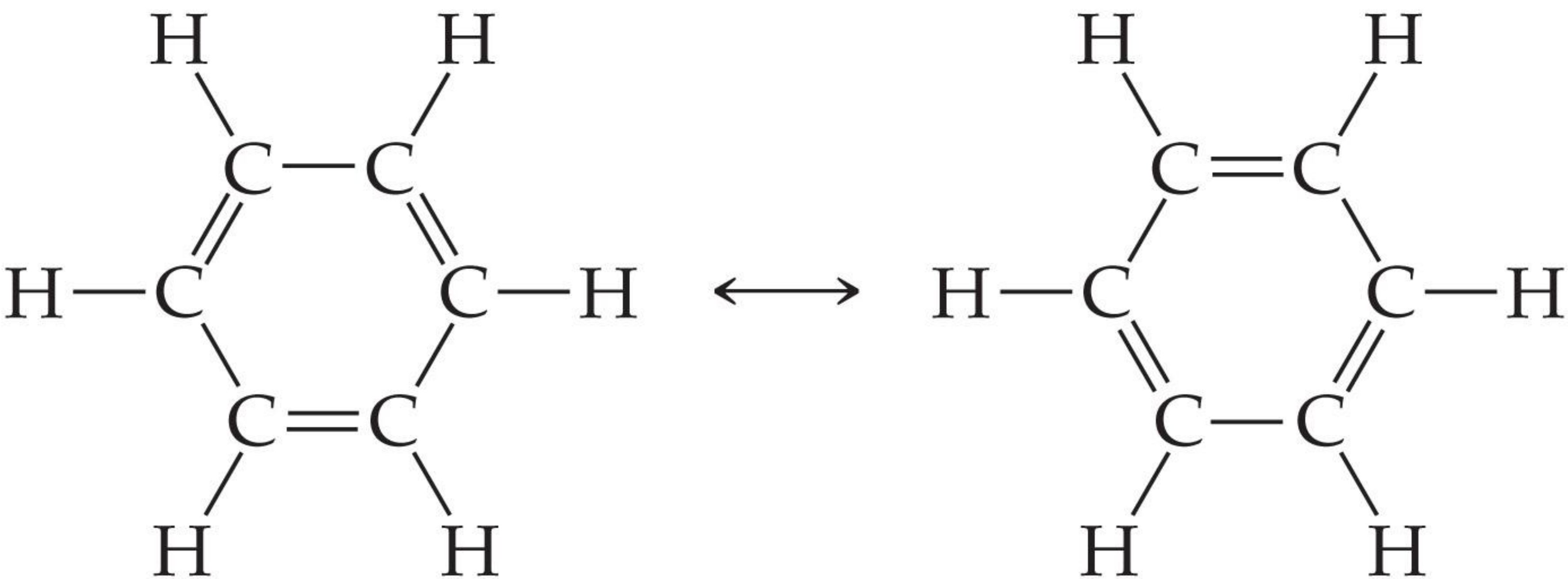
To summarize:

- All hydrocarbons undergo combustion reactions.
- Alkanes undergo substitution reactions.
- Alkenes and alkynes undergo addition reactions.

18.10 Aromatic Hydrocarbons

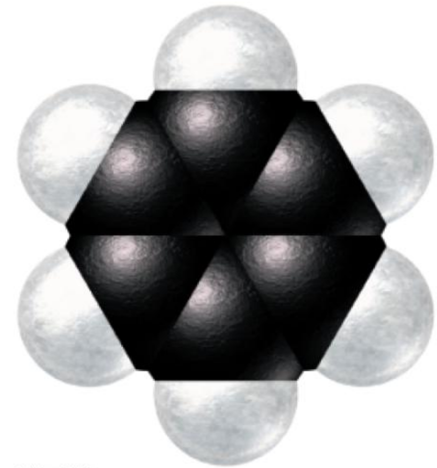
- In the mid-1800s chemists were trying to determine the structure of a particularly stable organic compound named **benzene** that had the formula C_6H_6.
- In 1865, Friedrich August Kekulé (1829–1896) had a dream in which he envisioned chains of carbon atoms as snakes.
- The snakes danced before him and one of them twisted around and bit its tail.
- Based on that vision, Kekulé proposed the structure for benzene.

The bond lengths in benzene are all the same length. The structure of benzene is better represented by resonance structures.

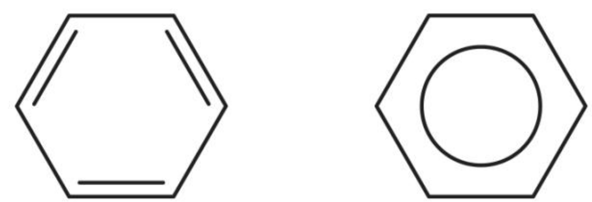


All carbon–carbon bonds in benzene are equivalent and are midway between a single and double bond.

- The space-filling model of benzene is:



- Benzene is often represented with the shorthand notations:

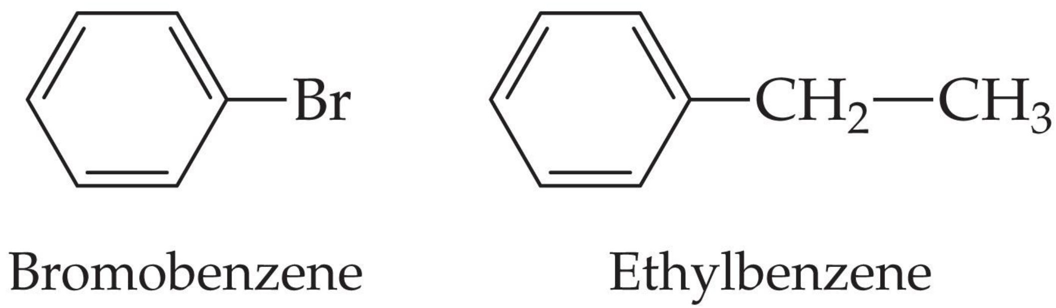


Commonly recognized representations of benzene

- Each point in the hexagon represents a carbon atom with a hydrogen atom attached to it.

Naming Aromatic Hydrocarbons

- **Monosubstituted benzenes**—benzenes in which only one of the hydrogen atoms has been substituted—are often named as derivatives of benzene.

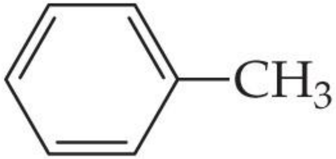


The names of monsubstituted benzenes have the general form:

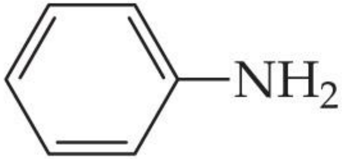
- (name of substituent)*benzene*

Naming Aromatic Hydrocarbons

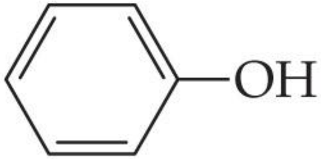
- Many monosubstituted benzenes also have common names that can be learned only through familiarity.



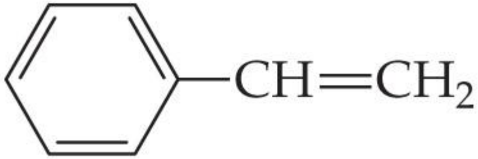
Toluene



Aniline



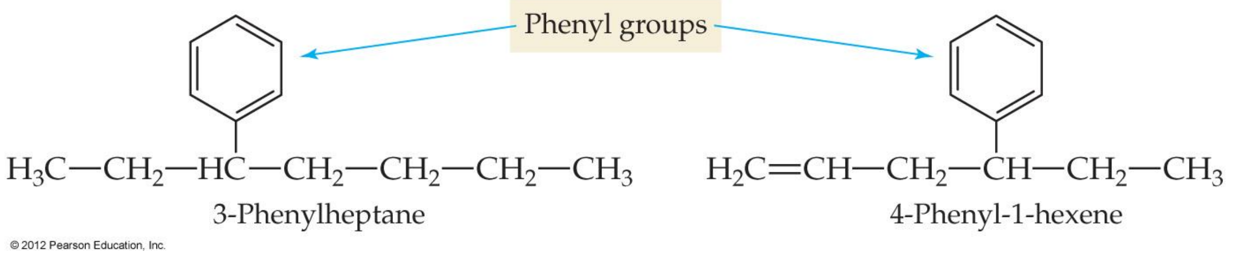
Phenol



Styrene

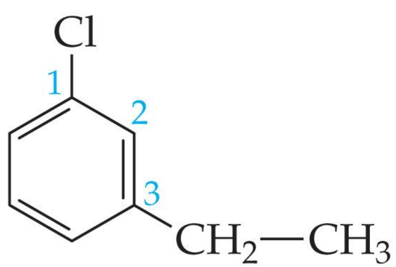
Naming Aromatic Hydrocarbons

- Some substituted benzenes, especially those with large substituents, are named by treating the benzene ring as the substituent.
- In these cases, the benzene substituent is called a **phenyl group.**

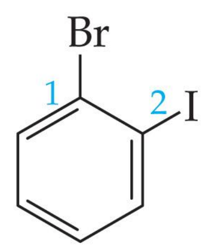


Naming Aromatic Hydrocarbons

- **Disubstituted benzenes**, benzenes in which two hydrogen atoms have been substituted, are numbered and the substituents are listed alphabetically. The order of numbering within the ring is then determined by the alphabetical order of the substituents.



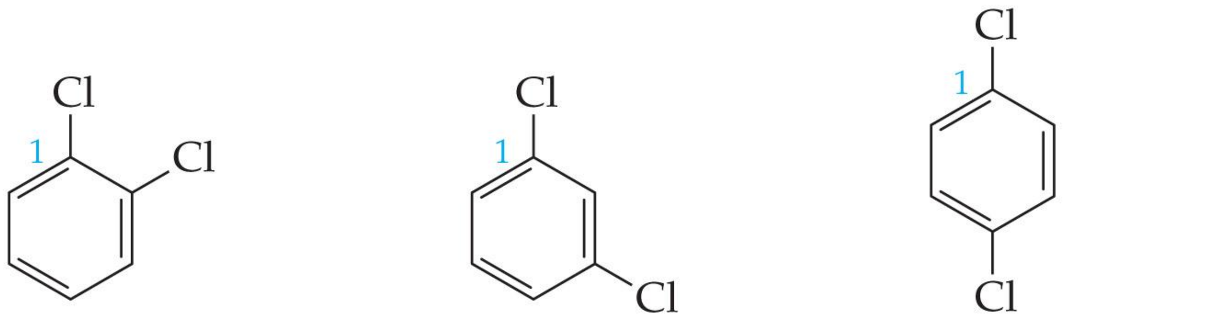
1-Chloro-3-ethylbenzene



1-Bromo-2-iodobenzene

Naming Aromatic Hydrocarbons

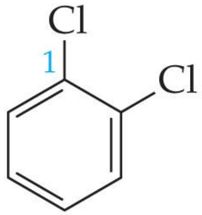
- When the two substituents are identical, we use the prefix *di-*.



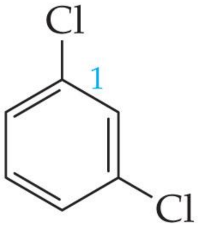
1,2-Dichlorobenzene   1,3-Dichlorobenzene   1,4-Dichlorobenzene

Naming Aromatic Hydrocarbons

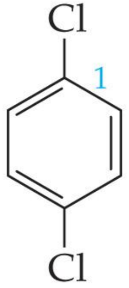
- Also in common use are the prefixes *ortho-* (1,2 disubstituted), *meta-* (1,3 disubstituted), and *para-* (1,4 disubstituted).



ortho-Dichlorobenzene
or
o-Dichlorobenzene



meta-Dichlorobenzene
or
m-Dichlorobenzene



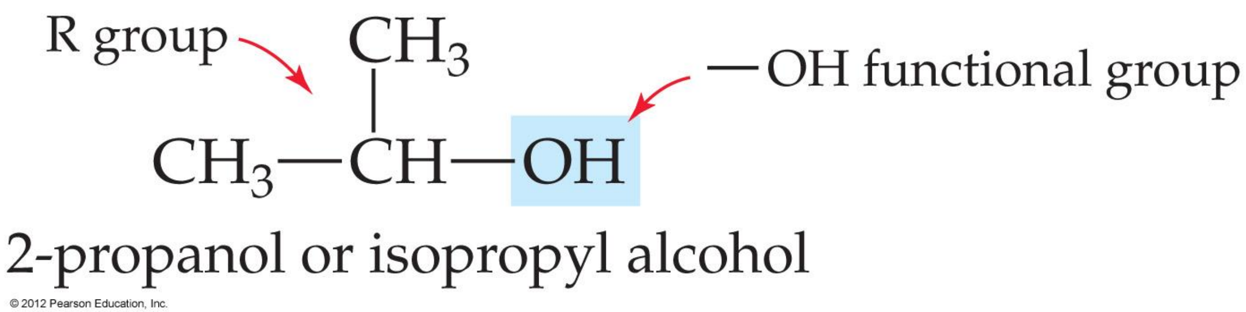
para-Dichlorobenzene
or
p-Dichlorobenzene

18.11 Functional Groups

- Several families of organic compounds can be thought of as hydrocarbons in which a **functional group**—a characteristic atom or group of atoms—has been inserted into the hydrocarbon.
- The letter R is often used to represent a hydrocarbon group.
- Let the letter G represent a functional group. A generic formula for families of organic compounds is:

The members of the family of **alcohols** have an −OH functional group and the general formula R−OH.

Methanol



2-propanol or isopropyl alcohol

Some common functional groups, their general formulas, and examples.

TABLE 18.7 **Functional Groups**

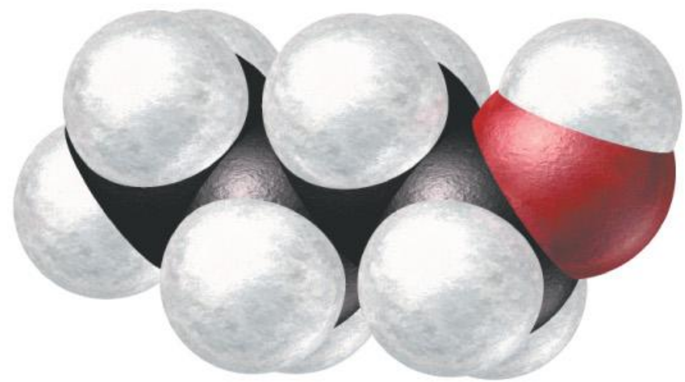
Family	General Formula	Condensed General Formula	Example	Name
alcohols	R—OH	ROH	CH_3CH_2—OH	ethanol (ethyl alcohol)
ethers	R—O—R	ROR	CH_3—O—CH_3	dimethyl ether
aldehydes	R—C(=O)—H	RCHO	H_3C—C(=O)—H	ethanal (acetaldehyde)
ketones	R—C(=O)—R	RCOR	H_3C—C(=O)—CH_3	propanone (acetone)
carboxylic acids	R—C(=O)—OH	RCOOH	H_3C—C(=O)—OH	acetic acid
esters	R—C(=O)—OR	RCOOR	H_3C—C(=O)—OCH_3	methyl acetate
amines	R—N(R)—R	R_3N	H_3CH_2C—N(H)—H	ethyl amine

18.12 Alcohols

- Alcohols are organic compounds containing the −OH functional group. They have the general formula R−OH.

H_3C-CH_2-OH

Ethanol



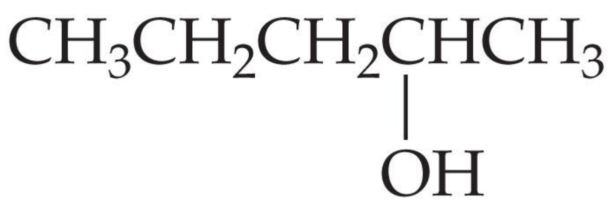
$H_3C-CH_2-CH_2-CH_2-OH$

1-Butanol

NAMING ALCOHOLS

Alcohols are named similarly to alkanes with the following exceptions.

- The base chain is the longest continuous carbon chain that *contains the* −OH *functional group*.
- The base name has the ending *-ol*.
- The base chain is numbered to *give the* −OH *group the lowest possible number*.
- A number indicating the position of the −OH group is inserted just before the base name.



2-Pentanol

3-Methyl-1-butanol

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About Alcohols

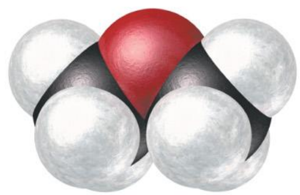
- Beer usually contains 3 to 6% ethanol. Wine contains about 12 to 15% ethanol, and spirits—such as whiskey, rum, or tequila—range from 40 to 80% ethanol, depending on their *proof*.
- The proof of an alcoholic beverage is twice the percentage of its ethanol content, so an 80-proof whiskey contains 40% ethanol.
- Ethanol is used as a gasoline additive because it increases the octane rating of gasoline (which is related to how smoothly the gasoline burns) and promotes complete combustion, reducing certain pollutants such as carbon monoxide and the precursors of ground-level ozone.

About Alcohols

- Isopropyl alcohol (or 2-propanol) can be purchased at any drugstore as rubbing alcohol.
- It is commonly used as a disinfectant for wounds and to sterilize medical instruments.
- Isopropyl alcohol should never be consumed internally, as it is highly toxic. A few ounces of isopropyl alcohol can cause death.
- A third common alcohol is methanol, also called wood alcohol. Methanol is commonly used as a laboratory solvent and as a fuel additive. Methanol is toxic and should never be consumed.

18.13 Ethers

Ethers are organic compounds with the general formula R−O−R. The R groups may be the same or different.



$H_3C-O-CH_3$

Dimethyl ether

$H_3C-O-CH_2-CH_3$

Ethyl methyl ether

$H_3C-CH_2-O-CH_2-CH_3$

Diethyl ether

NAMING ETHERS

The IUPAC names for ethers are beyond the scope of this text. Common names for ethers have the format:

(R group 1)(R group 2)ether

If the two R groups are different, use each of their names. If the two R groups are the same, use the prefix *di-*.

$$H_3C-CH_2-CH_2-O-CH_2-CH_2-CH_3$$

Dipropyl ether

$$H_3C-CH_2-O-CH_2-CH_2-CH_3$$

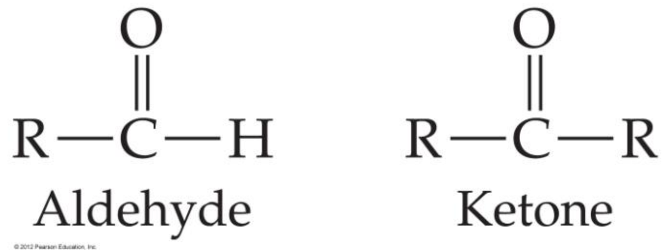
Ethyl propyl ether

About Ethers

- The most common ether is diethyl ether.
- Diethyl ether is frequently used as a laboratory solvent because of its ability to dissolve many organic compounds and its low boiling point (34.6 °C).
- The low boiling point allows for easy removal of the solvent when necessary.
- Diethyl ether was used as a general anesthetic for many years. When inhaled, diethyl ether depresses the central nervous system, causing unconsciousness and insensitivity to pain. Its use as an anesthetic has decreased in recent years because other compounds have the same anesthetic effect with fewer side effects (such as nausea).

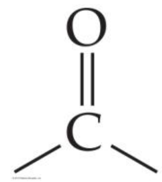
18.14 Aldehydes and Ketones

- **Aldehydes** and **ketones** have the general formulas:

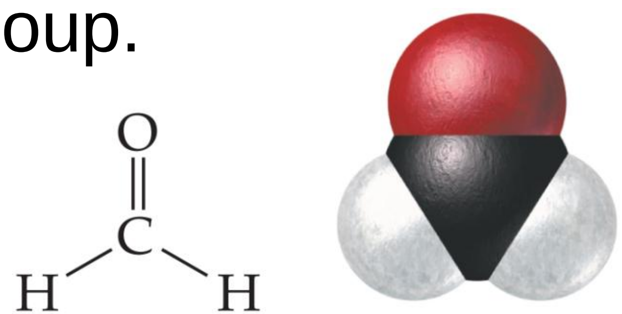


- The condensed structural formula for aldehydes is RCHO, and for ketones it is RCOR.
- In ketones the R groups may be the same or different.

- Both aldehydes and ketones contain a carbonyl group:



- Ketones have an R group attached to both sides of the carbonyl group
- Aldehydes have an R group on one side of the carbonyl group and a hydrogen atom on the other.
- An exception is formaldehyde, which is an aldehyde with H atoms attached on both sides of the carbonyl group.

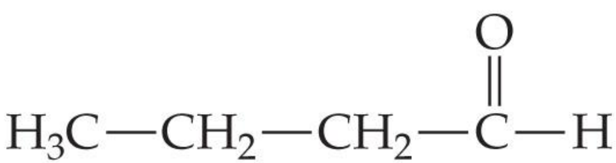


Methanal or formaldehyde

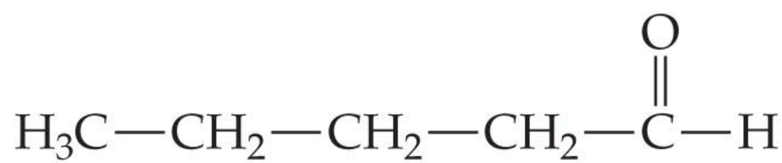
NAMING ALDEHYDES AND KETONES

Simple aldehydes are systematically named according to the number of carbon atoms in the longest continuous carbon chain that contains the carbonyl group. The base name is formed by dropping the -*e* and adding the ending -*al*.

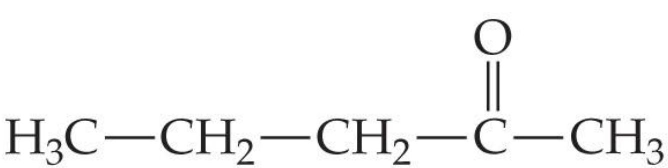
Simple ketones are systematically named according to the longest continuous carbon chain containing the carbonyl group. The base name is formed by dropping the -*e* and adding the ending -*one*. For ketones, the chain is numbered to give the carbonyl group the lowest possible number (when necessary).



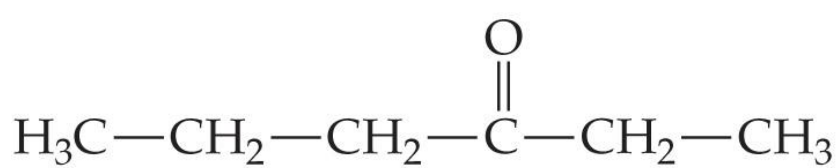
Butanal



Pentanal



2-Pentanone

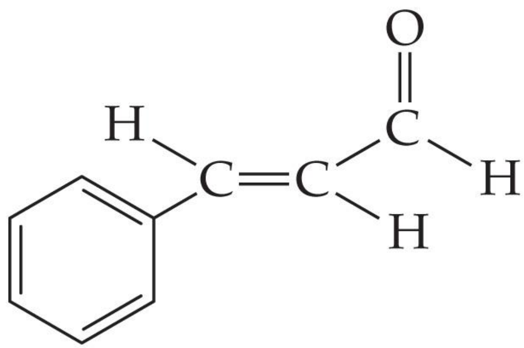


3-Hexanone

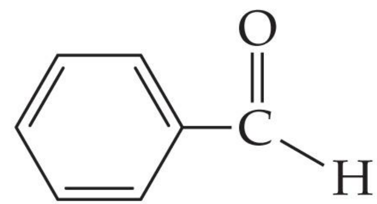
About Aldehydes and Ketones

- Formaldehyde is a gas with a pungent odor. It is often mixed with water to make formalin, a preservative and disinfectant.
- Formaldehyde is also found in wood smoke, which is one reason that smoking foods preserves them—the formaldehyde kills the bacteria.
- Aromatic aldehydes, those that contain an aromatic ring, have pleasant aromas.

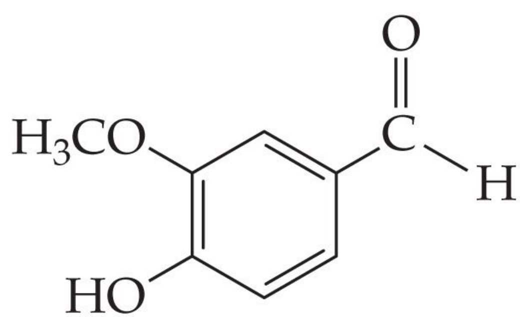
Aromatic aldehydes have pleasant aromas.



Cinnamaldehyde

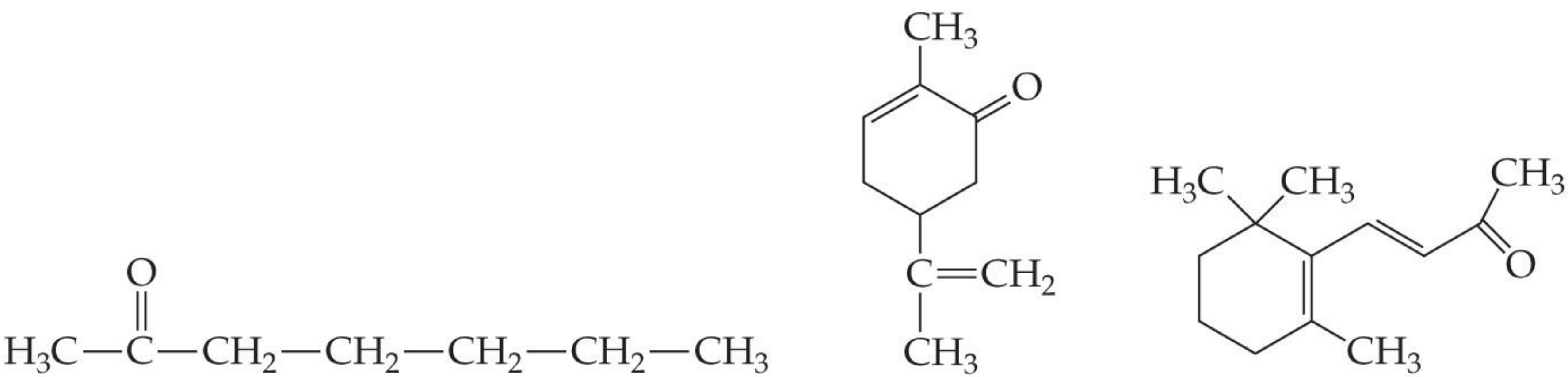


Benzaldehyde



Vanillin

Many ketones have pleasant aromas. 2-Heptanone is responsible for the smell of cloves, carvone for the smell of spearmint, and ionone for the smell of raspberries.



2-Heptanone Carvone Ionone

18.15 Carboxylic Acids and Esters

- **Carboxylic acids** and **esters** have the general formulas:

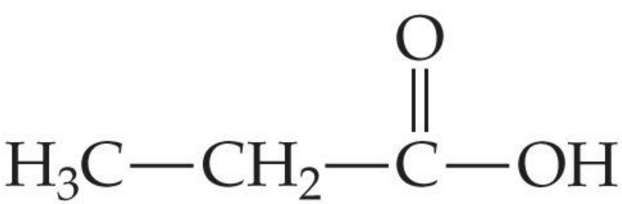
Carboxylic acid   Ester

- The condensed structural formula for carboxylic acids is RCOOH and for esters it is RCOOR.
- The R groups in esters may be the same or different.
- Carboxylic acids act as weak acids in solution according to the equation:

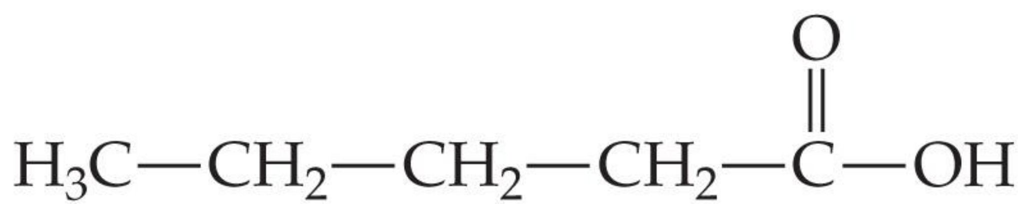
$$RCOOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + RCOO^-(aq)$$

NAMING CARBOXYLIC ACIDS

- Carboxylic acids are systematically named according to the number of carbon atoms in the longest chain containing the –COOH functional group. The base name is formed by dropping the –*e* and adding the ending –*oic acid*.



Propanoic acid



Pentanoic acid

NAMING ESTERS

- Esters are systematically named as if they were derived from a carboxylic acid. The R group from the parent acid forms the base name of the compound. The *–ic* on the name of the corresponding carboxylic acid is changed to *–ate*. The R group that replaced the H on the carboxylic acid is named as an alkyl group with the ending *–yl*.

CH_3CH_2COOH
Propano**ic** acid

$CH_3CH_2CH_2CH_2COOH$
Pentano**ic** acid

$CH_3CH_2COOCH_3$
Methyl propano**ate**

$CH_3CH_2CH_2CH_2COOCH_2CH_3$
Ethyl pentano**ate**

About Carboxylic Acids

- The most familiar carboxylic acid is ethanoic acid, which is known by its common name, *acetic acid*.
- Acetic acid is the active ingredient in vinegar.
- Some yeasts and bacteria form acetic acid when they metabolize sugars in bread dough. These are often added to bread dough to make sourdough bread.

Other common carboxylic acids include:

- methanoic acid (usually called formic acid), the acid present in bee stings and ant bites;
- citric acid, the acid present in limes, lemons, and oranges;
- lactic acid, the acid that causes muscle soreness after intense exercise.

About Esters

Esters are best known for their sweet smells.

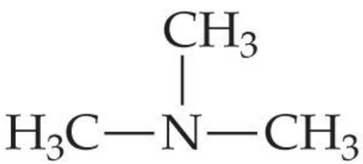
Ethyl butanoate is responsible for the smell and taste of pineapples.

Methyl butanoate is responsible for the smell and taste of apples.

- Esters are formed from the reaction of a carboxylic acid and an alcohol.
- An important example of this reaction is the formation of acetylsalicylic acid (aspirin) from acetic acid and salicylic acid (originally obtained from the bark of the willow tree).

18.16 Amines

- **Amines** are organic compounds containing nitrogen. The simplest nitrogen-containing compound is ammonia (NH_3).
- All other amines are derivatives of ammonia with one or more of the hydrogen atoms replaced by alkyl groups. They are systematically named according to the hydrocarbon groups attached to the nitrogen and given the ending –*amine*.



Trimethylamine

Cadaverine

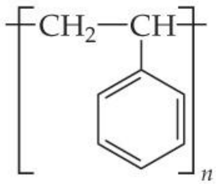
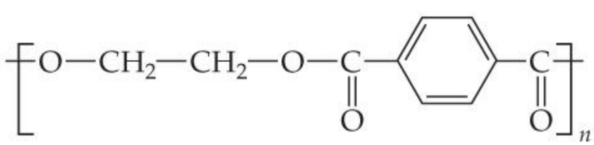
Putrescine

About Amines

- Amines are best known for their awful odors.
- When a living organism dies, bacteria that metabolize its proteins emit amines.
- Trimethylamine causes the smell of rotten fish.
- Cadaverine and putrescine are responsible for the smell of decaying animal flesh.

- **Polymers** are long chainlike molecules composed of repeating units. The individual repeating units are called **monomers.**
- Synthetic polymers compose many plastic products such as PVC tubing, Styrofoam coffee cups, nylon rope, and Plexiglas windows.
- Ethene (also called ethylene) monomers can be made to react with each other, breaking the double bond between carbons and joining together to make a long polymer chain.
- Polyethylene is the plastic that composes milk jugs, juice containers, and garbage bags. It is an example of an **addition polymer**, a polymer in which the monomers link together without eliminating any atoms.
- Some polymers—called **copolymers**—consist of two different kinds of monomers.
- The monomers that compose nylon 6,6 are hexamethylenediamine and adipic acid. These two monomers add together by eliminating a water molecule for each bond that forms between monomers.
- Polymers that eliminate an atom or a small group of atoms during polymerization are called **condensation polymers.**

TABLE 18.8 Polymers of Commercial Importance

Polymer	Structure	Uses
Addition polymers		
polyethylene	$\left(-CH_2-CH_2-\right)_n$	films, packaging, bottles
polypropylene	$\left[-CH_2-CH(CH_3)-\right]_n$	kitchenware, fibers, appliances
polystyrene		packaging, disposable food containers, insulation
polyvinyl chloride	$\left[-CH_2-CH(Cl)-\right]_n$	pipe fittings, clear film for meat packaging
Condensation polymers		
polyurethane	$\left[-C(=O)-NH-R-NH-C(=O)-O-R'-O-\right]_n$ R, R′ = $-CH_2-CH_2-$ (for example)	"foam" furniture stuffing, spray-on insulation, automotive parts, footwear, water-protective coatings
polyethylene terephthalate (a polyester)		tire cord, magnetic tape, apparel, soft-drink bottles
nylon 6,6	$\left[-NH-(CH_2)_6-NH-C(=O)-(CH_2)_4-C(=O)-\right]_n$	home furnishings, apparel, carpet fibers, fish line, polymer blends

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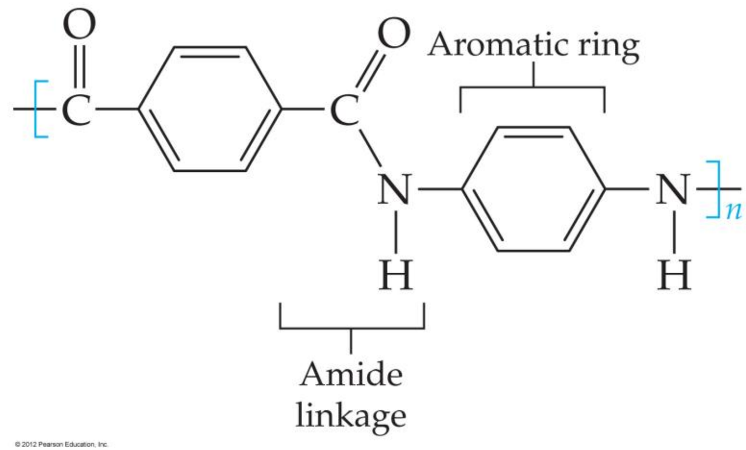
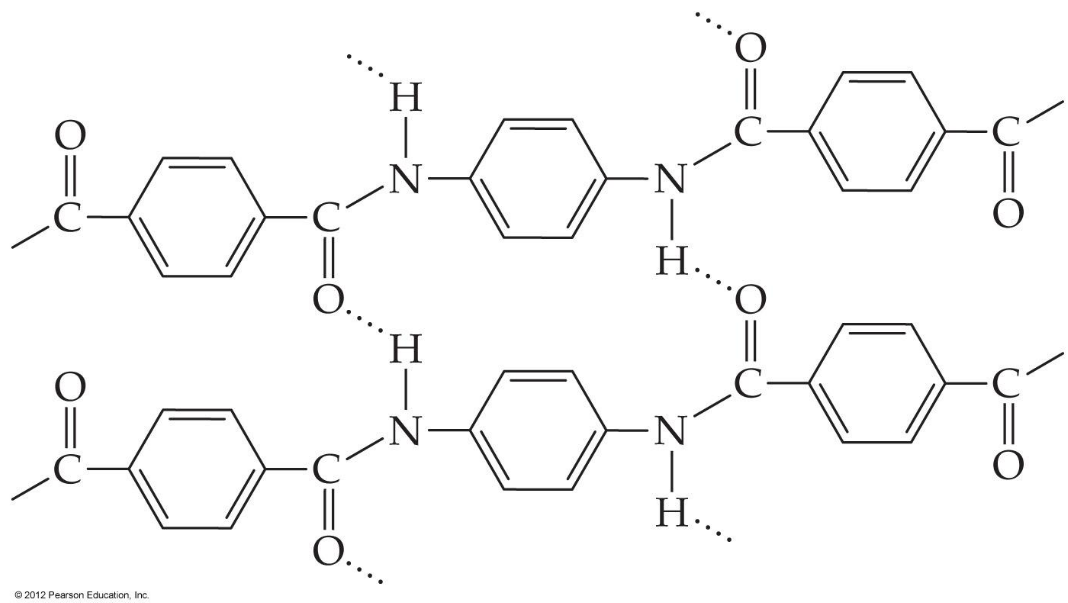
Everyday Chemistry
Kevlar: Stronger Than Steel

- Kevlar is a condensation polymer containing aromatic rings and *amide linkages.*
- The polymeric chains within Kevlar crystallize in parallel, with strong cross-linking between neighboring chains due to hydrogen bonding.
- This structure is responsible for Kevlar's high strength and its other properties, including chemical resistance and flame resistance.
- Kevlar is particularly well known for its use in bulletproof vests.





Chapter 18 in Review

Vitalism is the belief that living things contain a mystical force that allows them to produce organic compounds. Vitalism was overthrown when Friedrich Wöhler synthesized urea, an organic compound, in his laboratory.

Hydrocarbons are organic compounds containing only carbon and hydrogen. They can be classified into four different types: alkanes, alkenes, alkynes, and aromatic hydrocarbons, which contain six-carbon-atom ring structures.

Isomers are two or more compounds with the same chemical formula but different structures.

Hydrocarbon reactions: All hydrocarbons undergo combustion. Alkanes undergo substitution reactions. Alkenes and alkynes undergo addition reactions.

Several families of organic compounds are substituted hydrocarbons in which a **functional group** has been inserted. The main families of organic compounds, classified according to their functional groups, are alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, and amines.

Two types of **polymers** are addition polymers and condensation polymers.

Chemical Skills

- Differentiating between alkanes, alkenes, and alkynes based on their molecular formulas
- Writing structural formulas for hydrocarbon isomers
- Naming alkanes
- Naming alkenes and alkynes
- Naming aromatic compounds