Carbon and Organic Chemistry

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Carbon

Allotropic forms

Coal

Amorphous – no definite crystal structure

Bituminous Coal:
Great pressure results in the creation of bituminous, or “soft” coal. This is the type most commonly used for electric power generation in the U.S. It has a lower heating value than anthracite.

Anthracite:
Sometimes also called “hard coal”. Formed from bituminous coal when great pressures developed in folded rock strata during the creation of mountain ranges. Anthracite has the highest energy content of all coals.

The Pioneer Coal Mine
Ashland, PA


PIONEER-TUNNEL

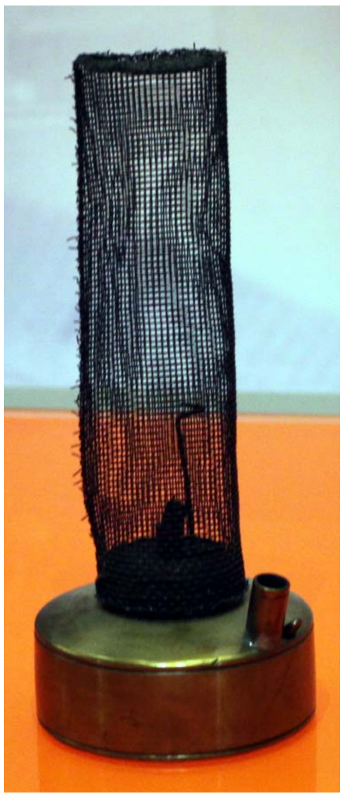

REMAIN SEATED


PIONEER
TUNNEL
ASHLAND, PENNA. 17921
OWNED & OPERATED BY—
"ASHLAND COMMUNITY ENTERPRISES"
400 FT.
BUCK MTN.
SEVEN FOOT
SKIDMORE
FOUR FOOT
HOLMES
PRIMROSE
ORCHARD
LITTLE ORCHARD


WEST 7 FOOT
GANGWAY

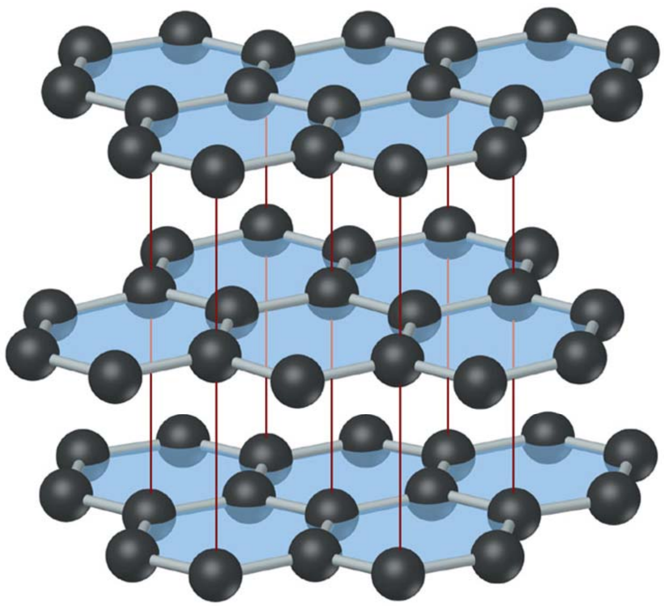

VEIN
OF
COAL

Miner's carbide lamp and safety lamps



Davy's safety lamp, 1815

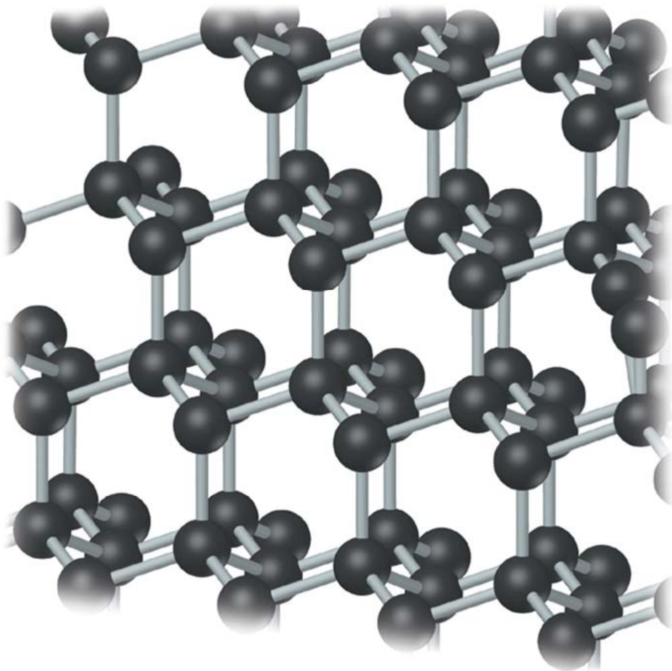

4 TON



Graphite

Graphite

Graphite consists of layers of carbon atoms in a hexagonal arrangement. There are only weak bonds between layers, allowing the layers to slide over one another. Graphite is used in the “lead” of lead pencils, as a dry lubricant, and in electroplating of substances.

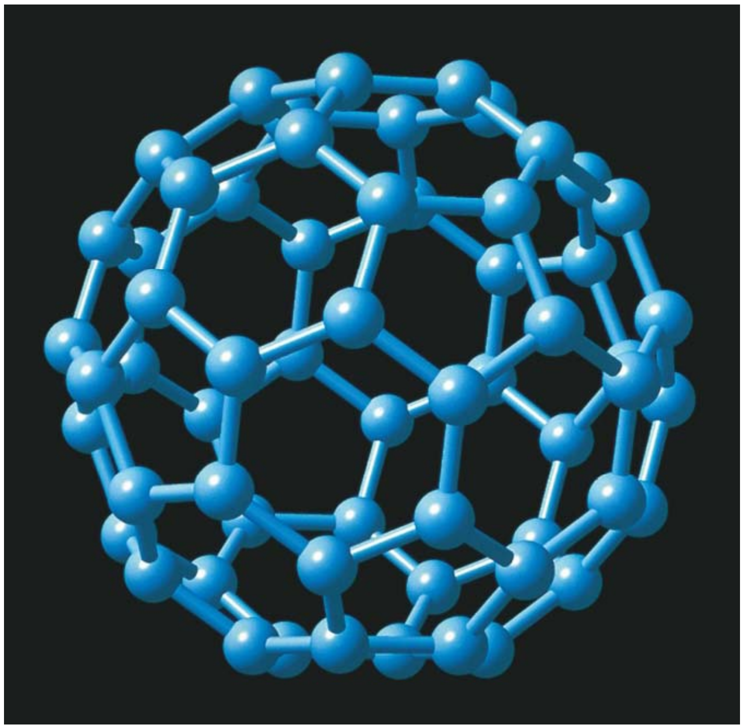


Diamond

Diamond

Diamond has a framework structure where each carbon atom is bonded to 4 other carbons in a three-dimensional structure. Diamond is the hardest naturally occurring mineral found in nature. Used for drills, cutting wheels, and polishing of many substances, as well as for jewelery.

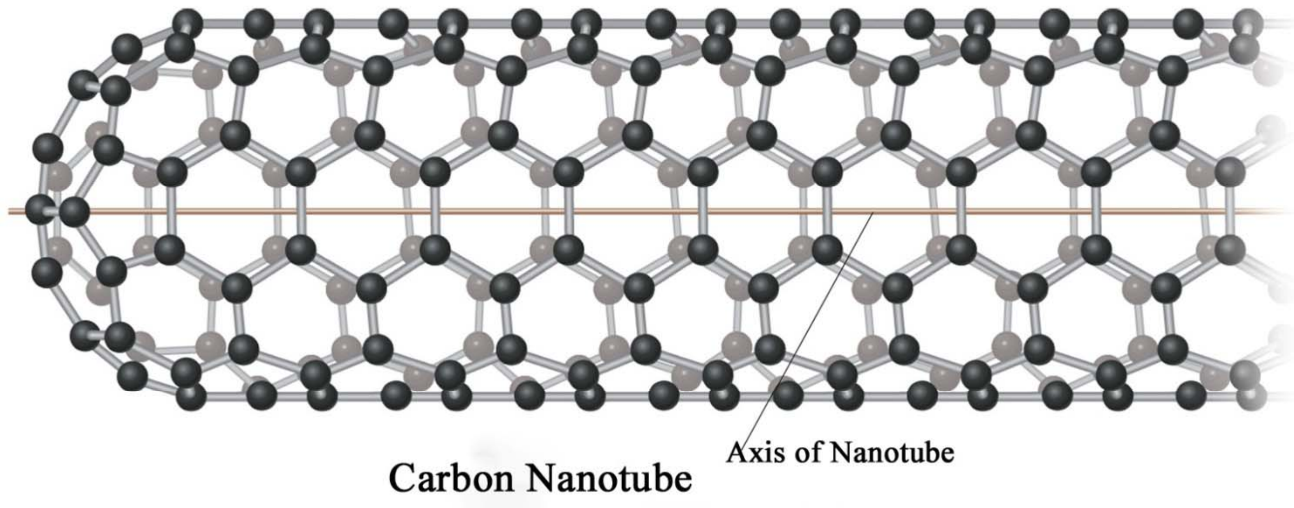
Buckminsterfullerene



Buckminsterfullerene, consisting of 60 carbon atoms in a spherical shape similar to a soccer ball, is formed electrically evaporating graphite in an atmosphere of He gas. Note that the structure consists of both 5 and 6 member carbon rings. Because the shape is similar to that of a geodesic dome invented by R. Buckminster Fuller, it was named buckminsterfullerene or **"Bucky Ball"** for short. Fullerenes have been prepared with as few as 20 carbon atoms and more than 80 atoms.

Applications include superconductors, along with compounds with interesting electrical, magnetic, and optical properties.

Carbon Nanotubes

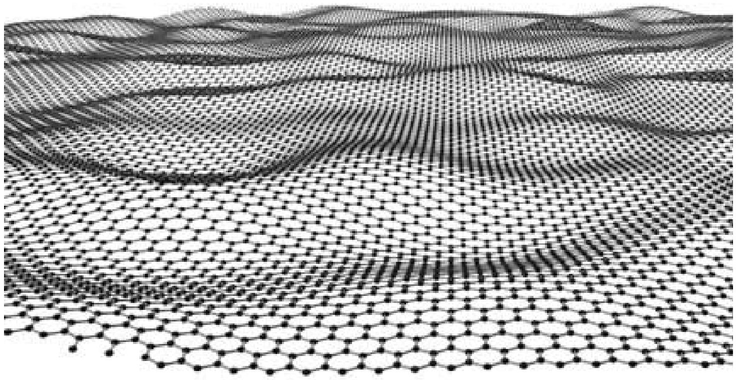


Discovered in 1952, and again noted in subsequent years, they were overlooked until about 1991. Carbon nanotubes are essentially a sheet of graphite rolled into a seamless tube approximately 1 nm in diameter. They have very high strength and high electrical and heat conductivity. (Multi-wall carbon nanotubes have been synthesized.)

Uses include wires or structural elements, special conductors, transistors, computer memory elements, nanoscale motors, and medical delivery systems.

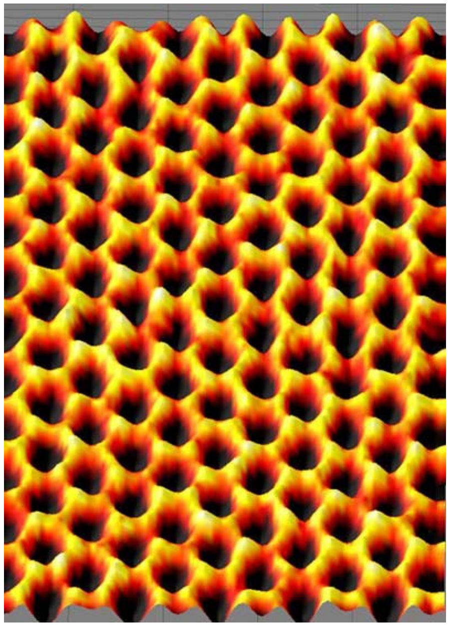
Graphene

Graphene is a single planar sheet of carbon atoms that are densely packed in a honeycomb crystal lattice. Graphene is the basic structural element for all other graphitic materials including graphite, carbon nanotubes and fullerenes.
Made by high temperature reduction of SiC and also by microelectronic methods, it was made in 2004 when physicists from University of Manchester and Institute for Microelectronics Technology, Chernogolovka, Russia, found a way to isolate graphene by peeling it off from graphite with Scotch tape and optically identify it by transferring them to a silicon dioxide layer on Si. Graphene's high electrical conductivity and high optical transparency make it a candidate for transparent conducting electrodes, required for such applications as touchscreens, liquid crystal displays, organic photovoltaic cells, and Organic light-emitting diodes.



Above: A sheet of graphene (note its rippled structure)

Right: An atomic force microscope image of graphene



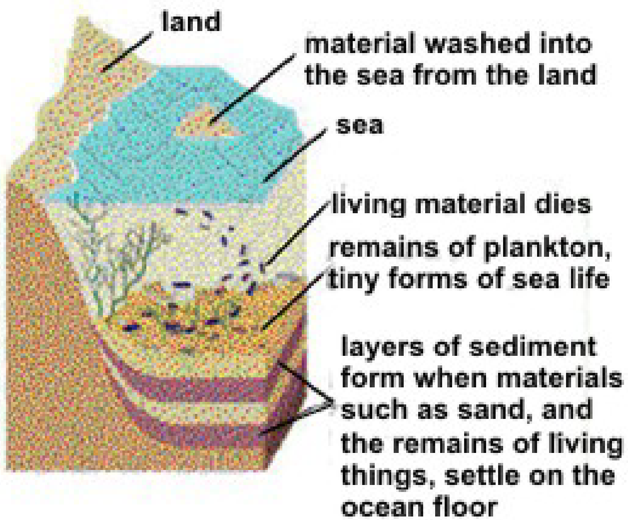
Carbon has an almost unique ability among the elements to bond with itself forming long continuous chains of carbon atoms.

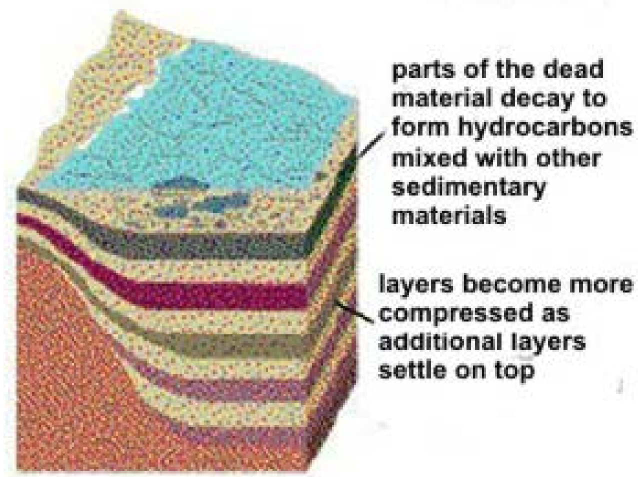
The only other common element that can do this is silicon.

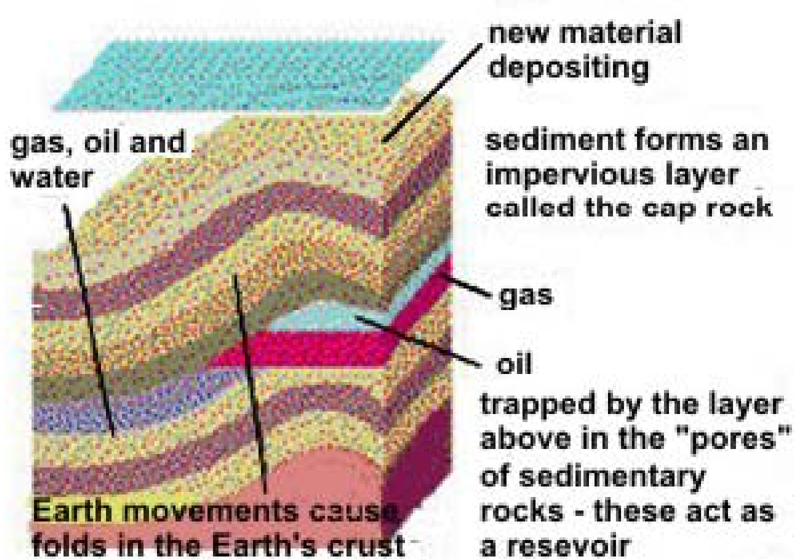
The major naturally occurring source of carbon compounds is petroleum.

Many complex compounds are extracted from plants or animals.

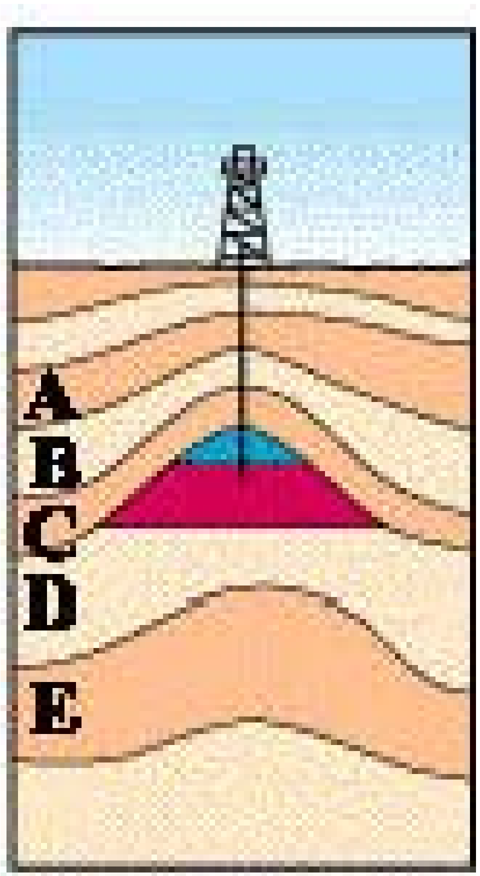
Formation of Petroleum



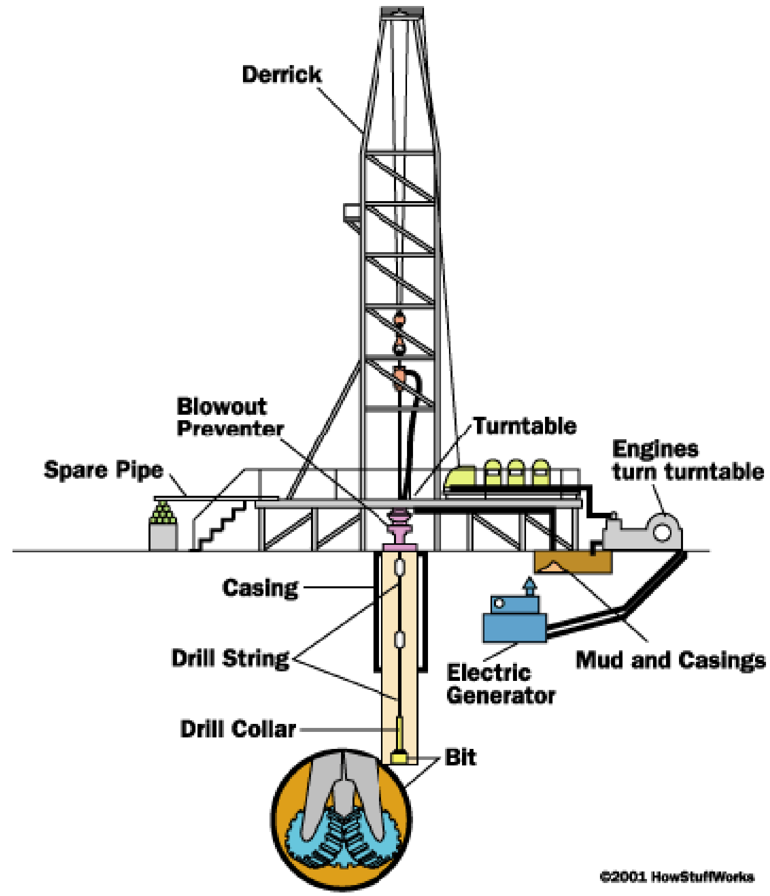




Drilling for Petroleum

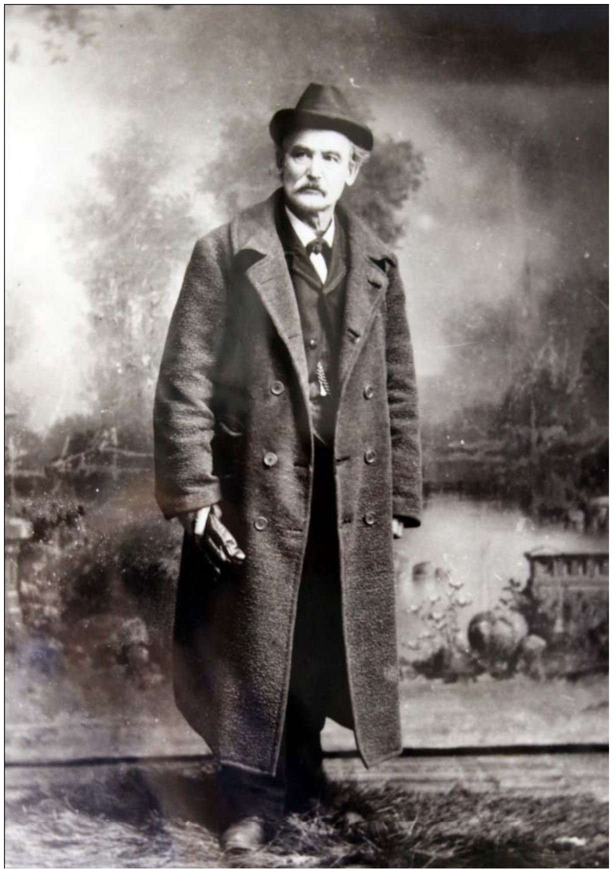


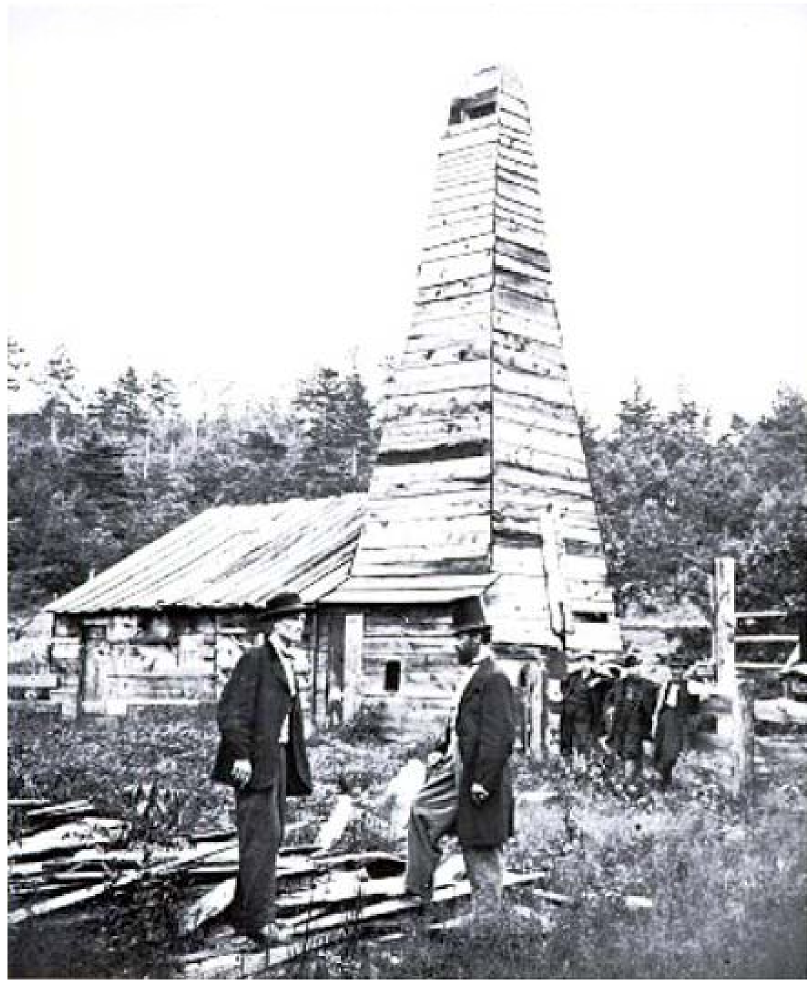
For land deposits, an oil rig needs to drill through the cap rock into the oil deposit



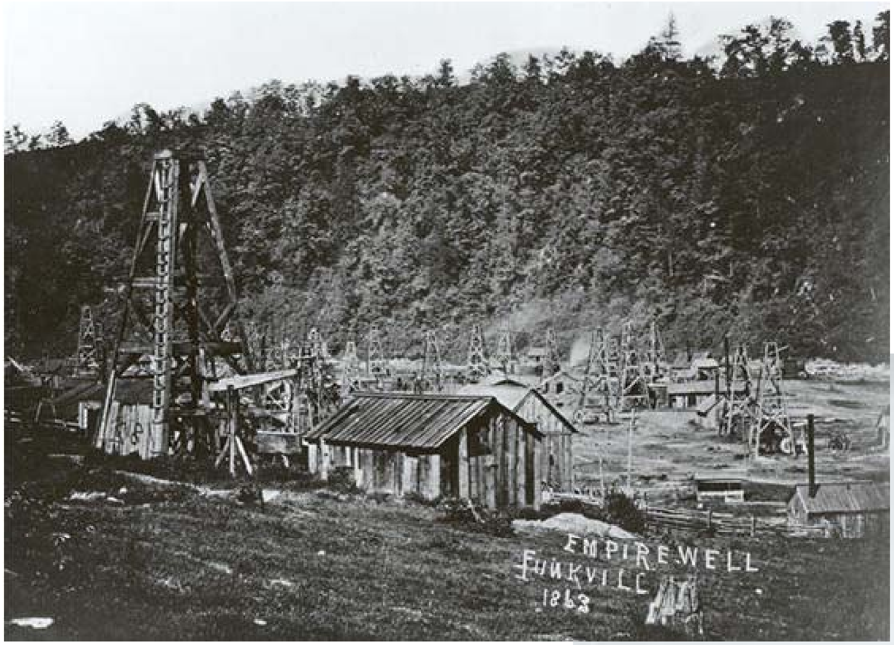
An oil rig system

Colonel Edwin Drake and the first commercial oil well Titusville, PA 1858



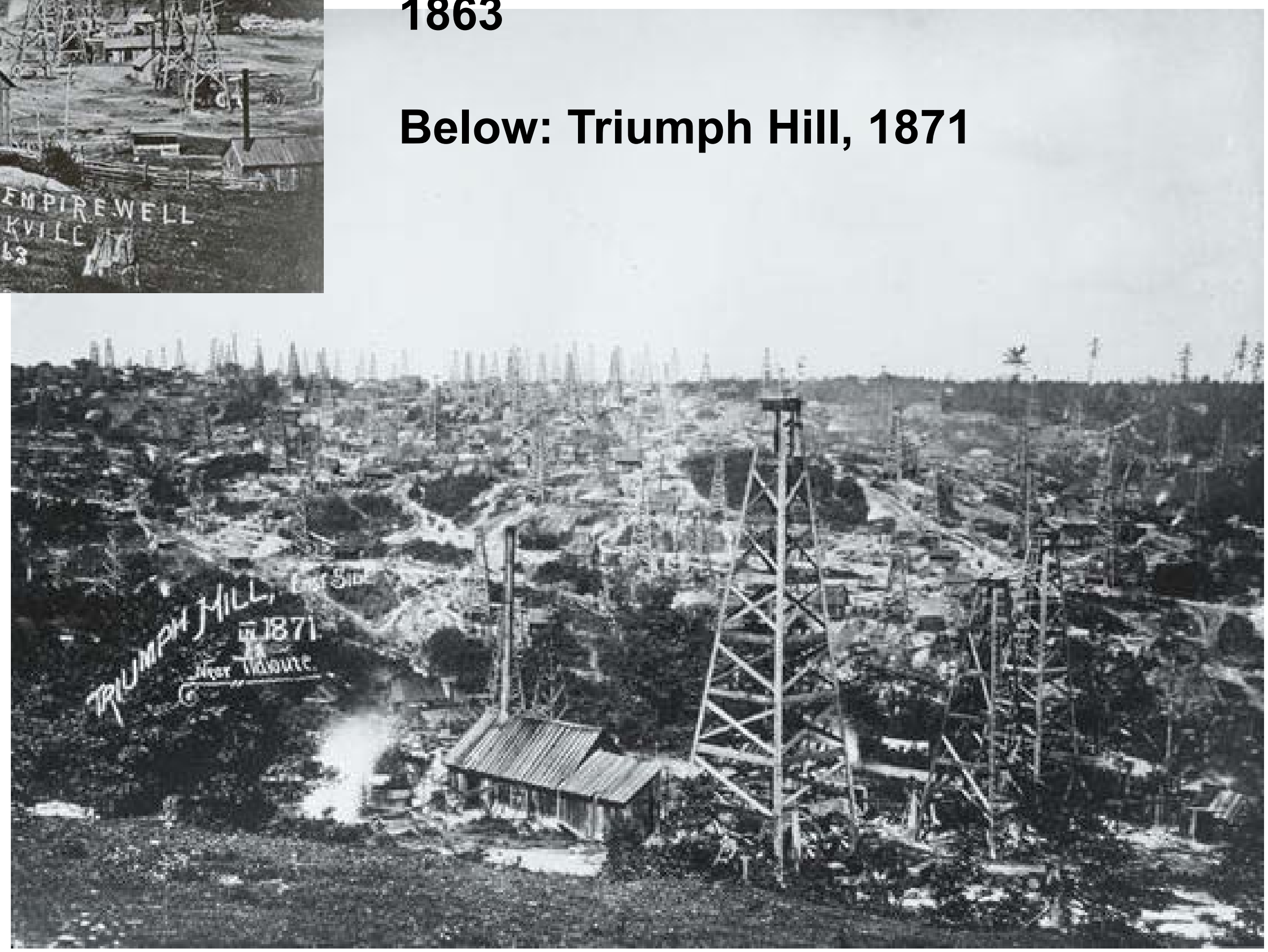


Drilling for oil in Pennsylvania

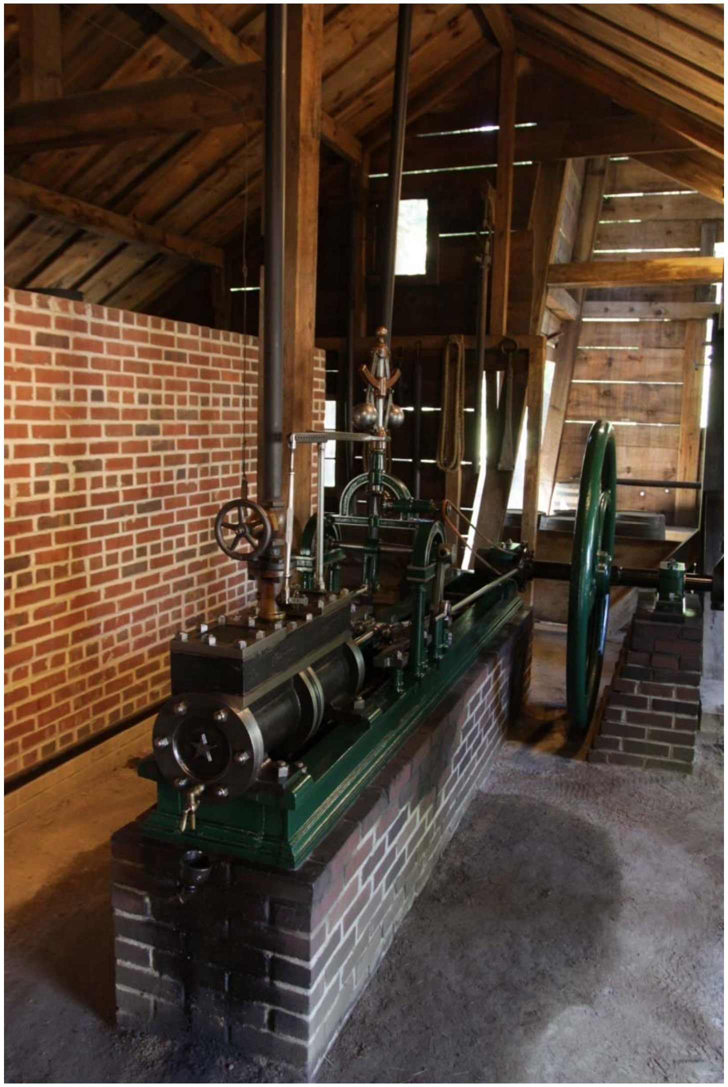


Left: Empire Well, Funkville, PA, 1863

Below: Triumph Hill, 1871



The rebuilt Drake well at the Drake Museum, Titusville, PA



The rebuilt pump in the Drake well, Titusville, PA

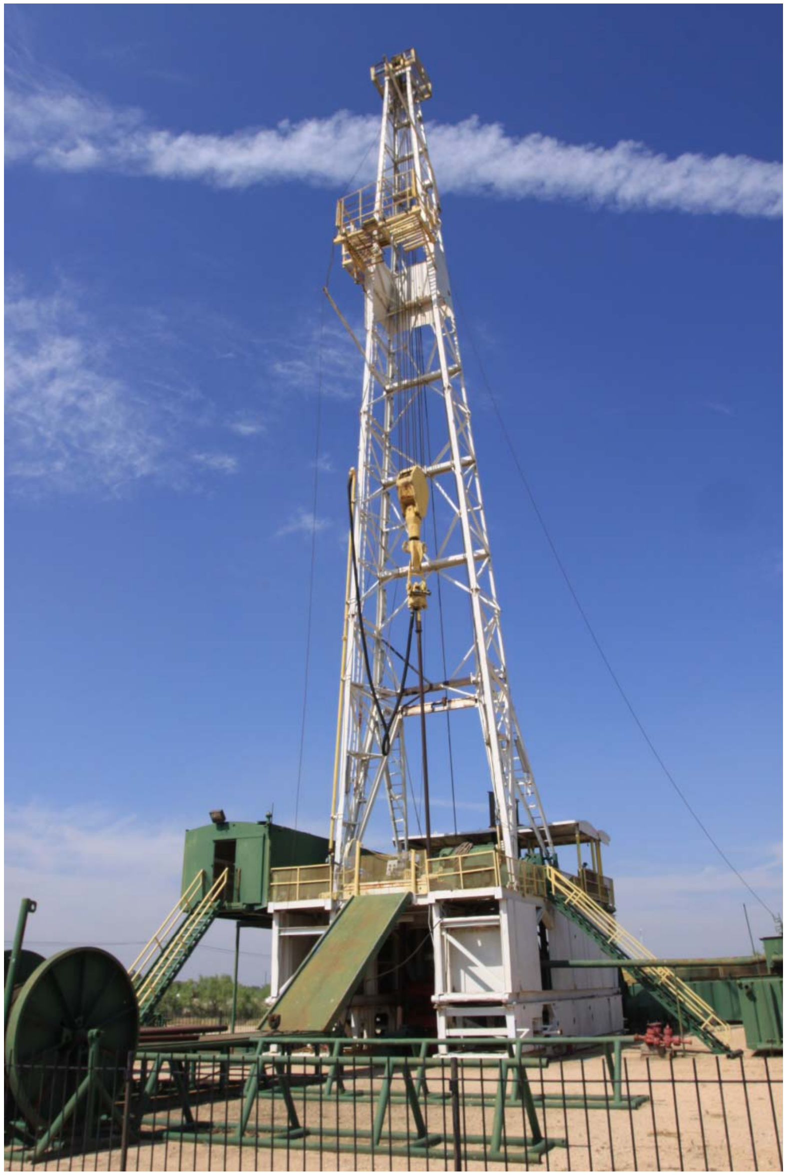
Vaseline

MARCH 18, 1874

The New York Tribune gives an account of a new product of petroleum called vaseline, which promises to be of considerable value, both in the arts, for toilet purposes and as a remedial agent. It is described as "a highly concentrated essence of petroleum, refined without distillation of chemicals, by a process discovered by Mr. Robert A. Chesebrough, of New York. It appears as a dense, oleaginous substance of a light translucent opal color and is of the consistency of jelly, which it resembles, and possesses neither odor nor taste.." If the crude petroleum is refined without distillation of chemicals, it must necessarily be filtered to make it of the color indicated, and how it is converted into a jelly without chemicals, or mincing it with other substances, is not very clearly apparent.




THE PETROLEUM MUSEUM

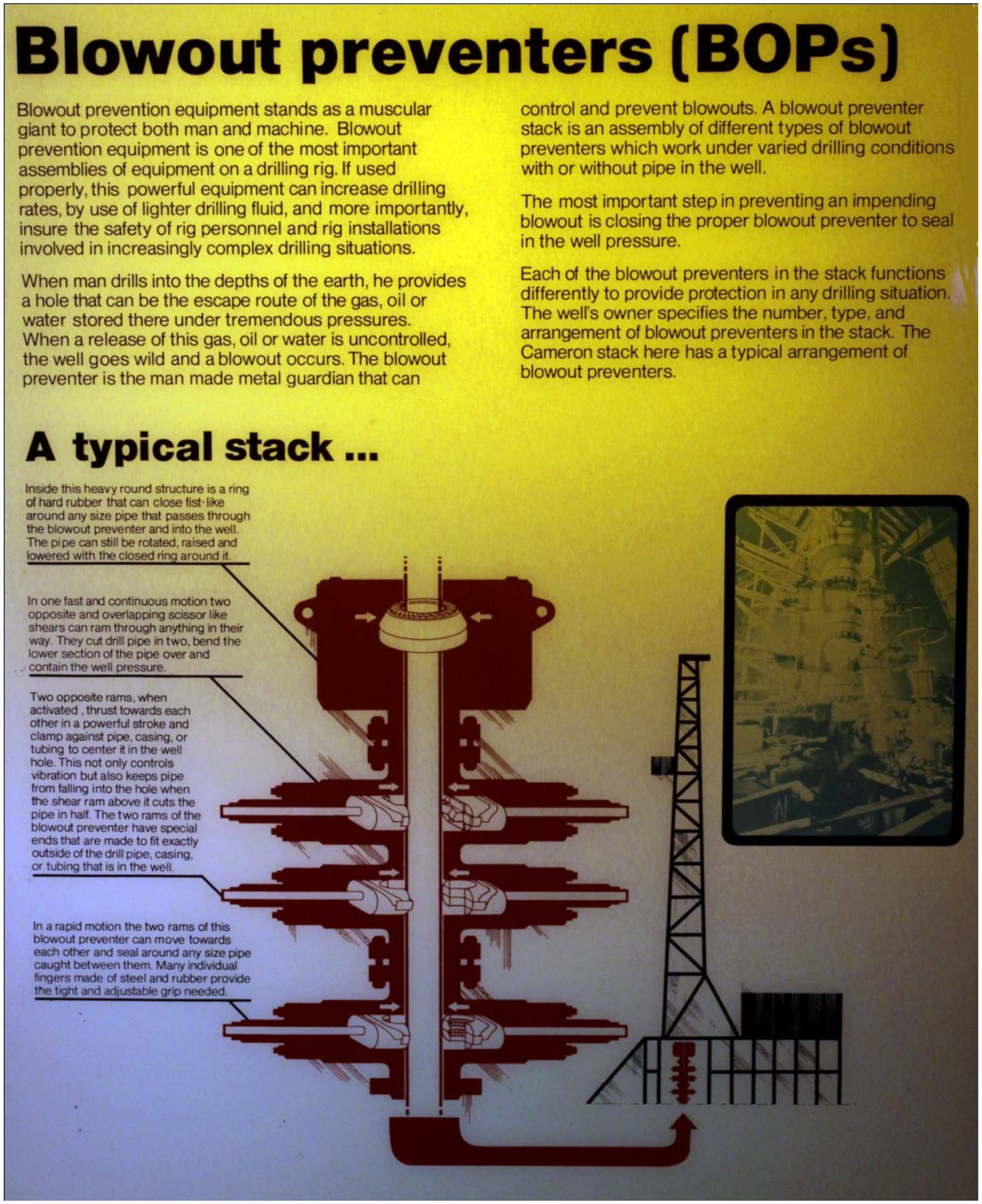


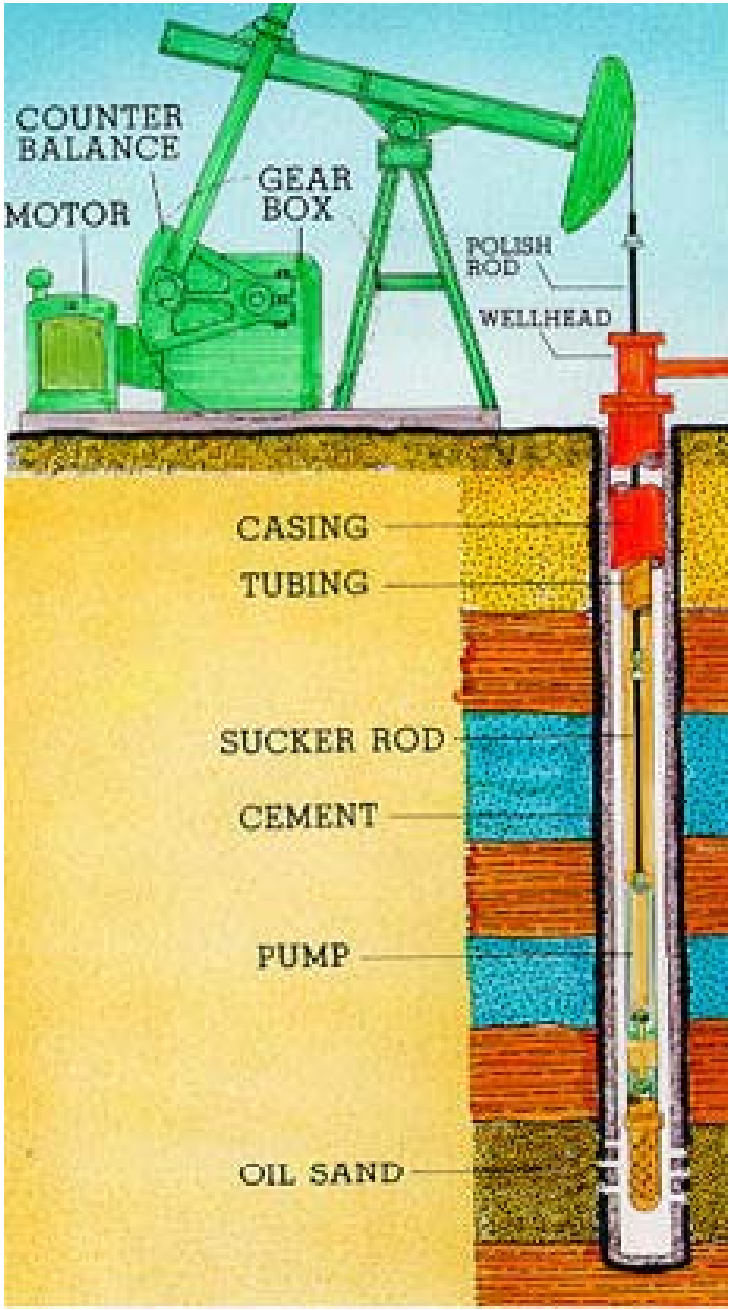
Fish tail bit

Early cross roller bit

Cross roller bit

Early tungsten carbide bit


Blowout preventers (BOPs)
Blowout prevention equipment stands as a muscular giant to protect both man and machine. Blowout prevention equipment is one of the most important assemblies of equipment on a drilling rig. If used properly, this powerful equipment can increase drilling rates, by use of lighter drilling fluid, and more importantly, insure the safety of rig personnel and rig installations involved in increasingly complex drilling situations.
When man drills into the depths of the earth, he provides a hole that can be the escape route of the gas, oil or water stored there under tremendous pressures. When a release of this gas, oil or water is uncontrolled, the well goes wild and a blowout occurs. The blowout preventer is the man made metal guardian that can control and prevent blowouts. A blowout preventer stack is an assembly of different types of blowout preventers which work under varied drilling conditions with or without pipe in the well.
The most important step in preventing an impending blowout is closing the proper blowout preventer to seal in the well pressure.
Each of the blowout preventers in the stack functions differently to provide protection in any drilling situation. The well's owner specifies the number, type, and arrangement of blowout preventers in the stack. The Cameron stack here has a typical arrangement of blowout preventers.
A typical stack ...
Inside this heavy round structure is a ring of hard rubber that can close fist-like around any size pipe that passes through the blowout preventer and into the well. The pipe can still be rotated, raised and lowered with the closed ring around it.
In one fast and continuous motion two opposite and overlapping scissor like shears can ram through anything in their way. They cut drill pipe in two, bend the lower section of the pipe over and contain the well pressure.
Two opposite rams, when activated , thrust towards each other in a powerful stroke and clamp against pipe, casing, or tubing to center it in the well hole. This not only controls vibration but also keeps pipe from falling into the hole when the shear ram above it cuts the pipe in half. The two rams of the blowout preventer have special ends that are made to fit exactly outside of the drill pipe, casing, or tubing that is in the well.
In a rapid motion the two rams of this blowout preventer can move towards each other and seal around any size pipe caught between them. Many individual fingers made of steel and rubber provide the tight and adjustable grip needed.



Once the petroleum is found, the rig is removed and a pump is placed on the well head.

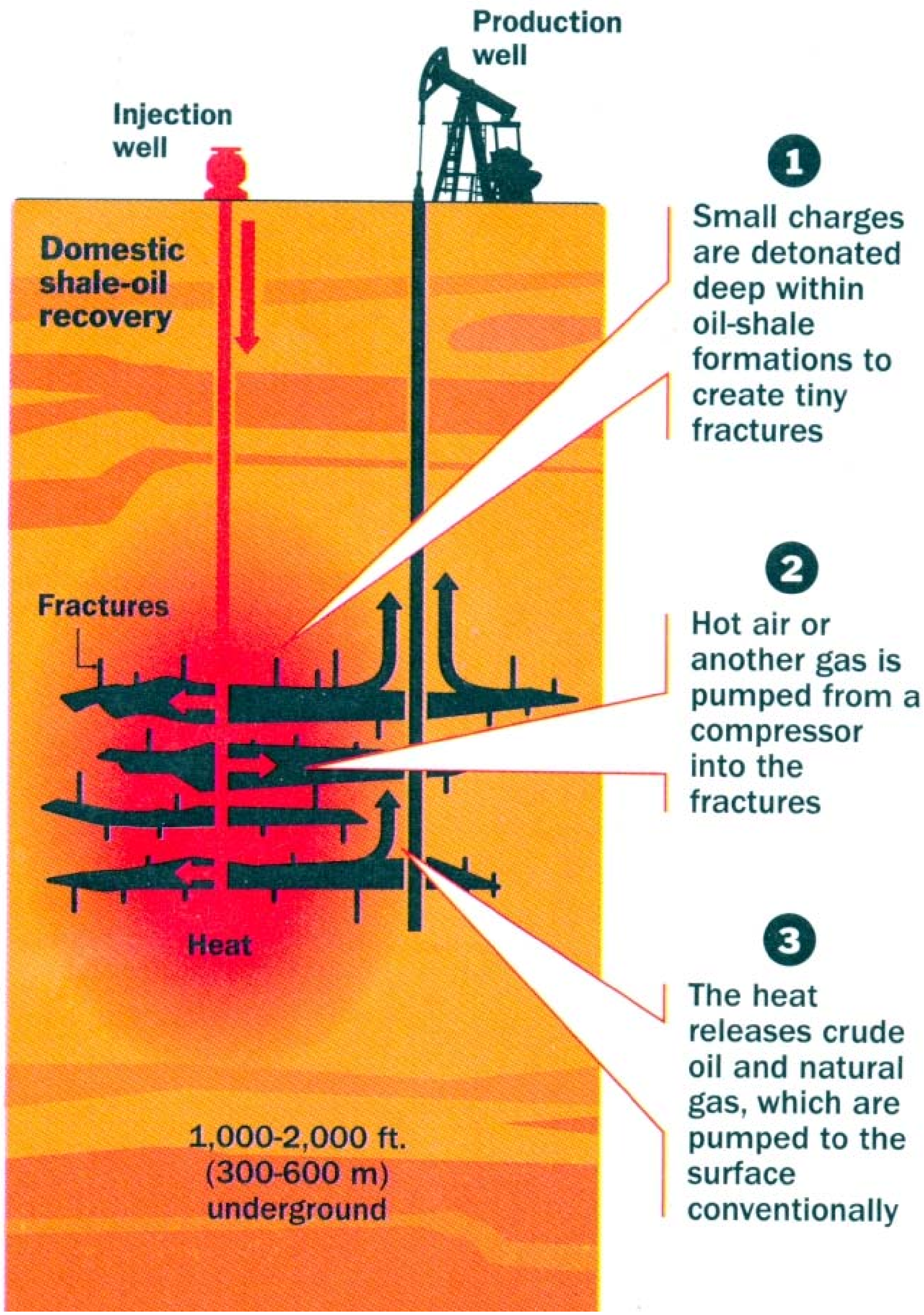
The Athabasca Tar Sands

Fort McMurray, Alberta, Canada

Oil Shale

Colorado, Wyoming and Utah

Estimates of global deposits range from 2.8 trillion to 3.3 trillion barrels of recoverable oil

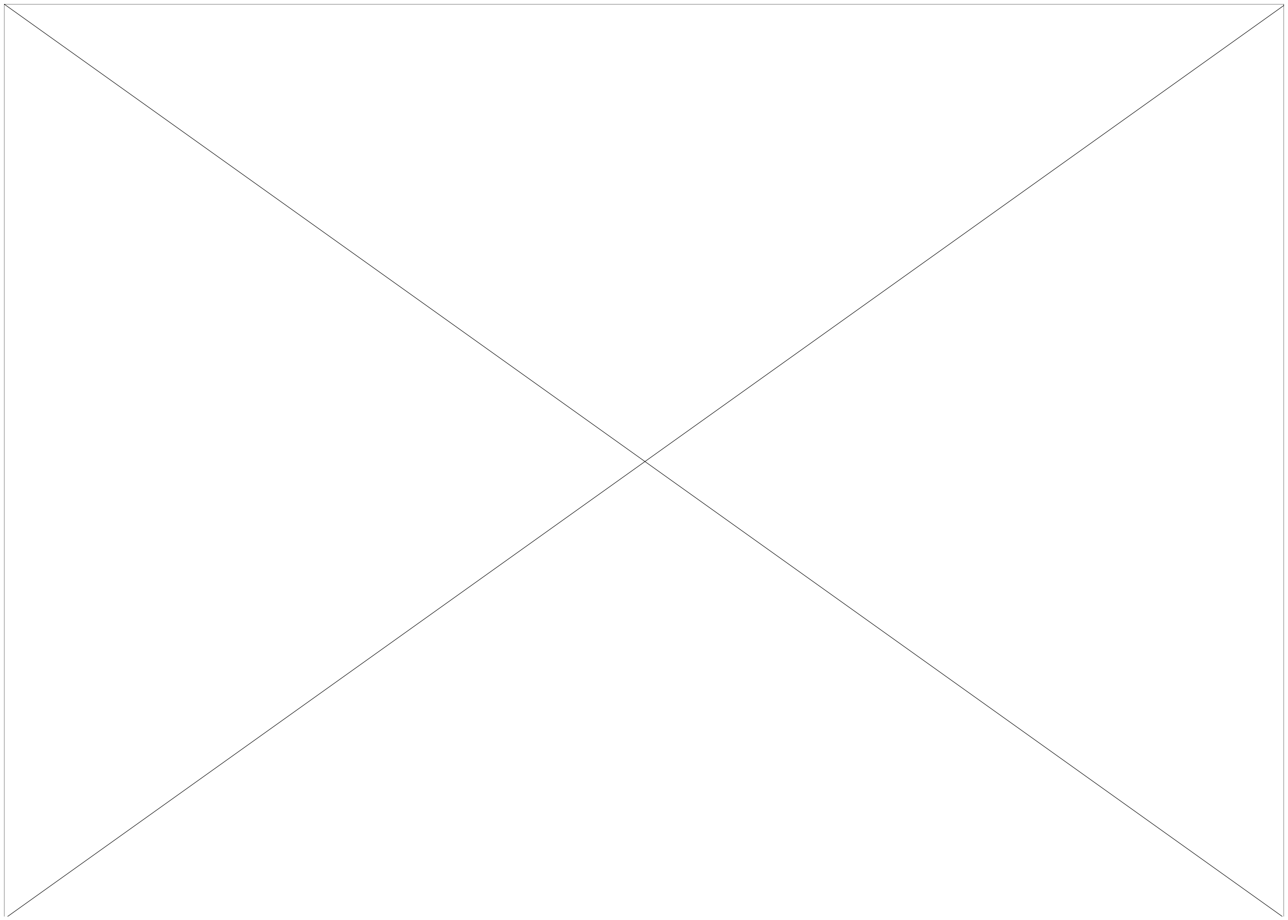


Refining Petroleum

Anacortes Refinery, north end of March Point southeast of Anacortes, Washington

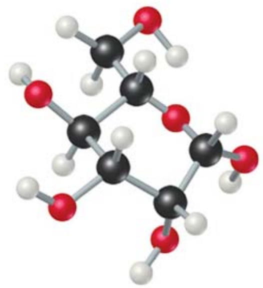
Fractional Distillation of Petroleum

Crude oil contains hundreds of different hydrocarbons mixed together. To obtain useful products, the process of fractional distillation is used.
The following diagram shows a schematic of a fractional distillation column.

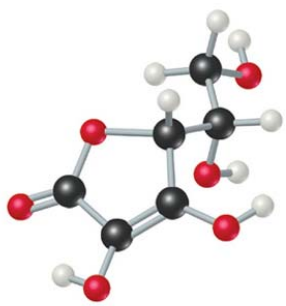


Longer hydrocarbon chain lengths have progressively higher boiling points, so they can all be separated by distillation. Crude oil is heated and the different chains are separated by boiling temperatures.

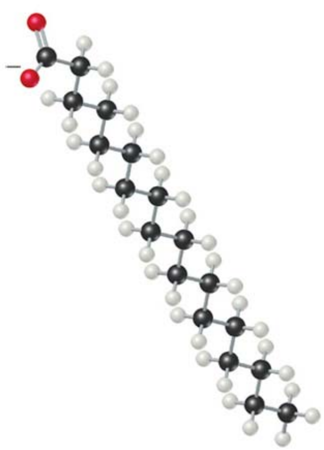
Organic Chemistry



Glucose ($C_6H_{12}O_6$)



Ascorbic acid ($HC_6H_7O_6$)

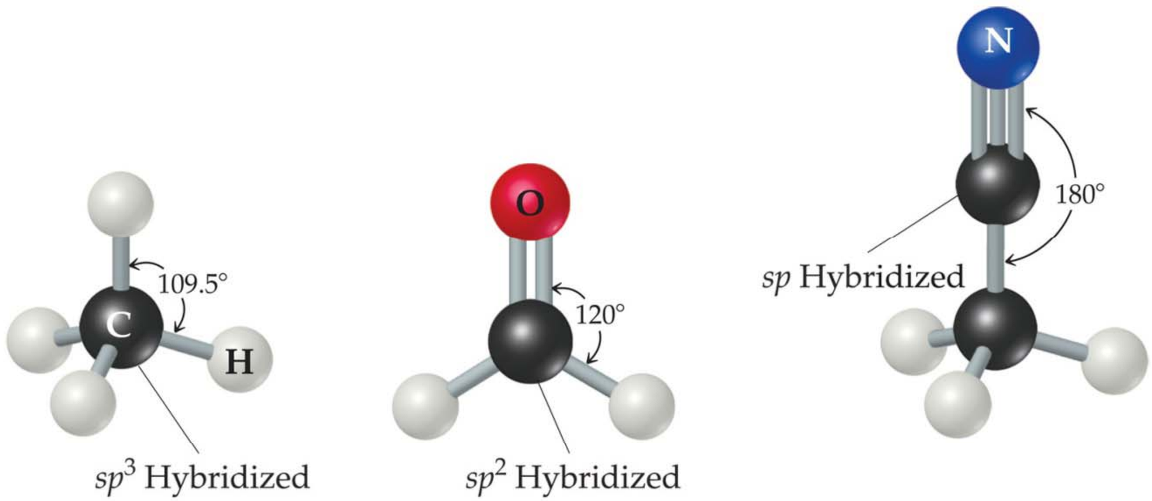


Surfactant ($C_{17}H_{35}COO^-$)

- The chemistry of carbon compounds.
- Carbon has the ability to bond with itself to form long chains.
- Without this property, large biomolecules such as proteins, lipids, carbohydrates, and nucleic acids could not form.
- Originally believed that these compounds had to come from a living organism, now they are synthesized in the laboratory.

Structure of Carbon Compounds

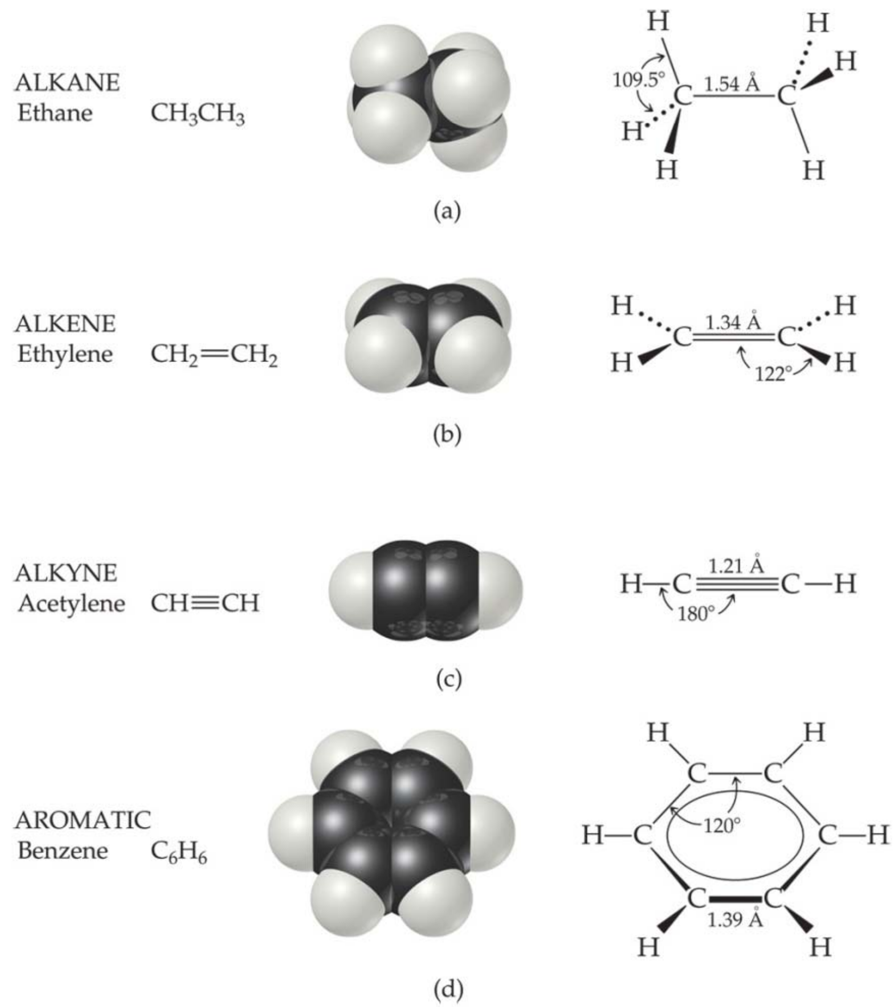
- **There are three hybridization states and geometries found in organic compounds:**
  - ➢ ***sp*^{3} Tetrahedral: C-C and C-H single bonds**
  - ➢ ***sp*^{2} Trigonal planar: C=C and C=O double bonds**
  - ➢ ***sp* Linear: C≡C and C≡N triples bonds**



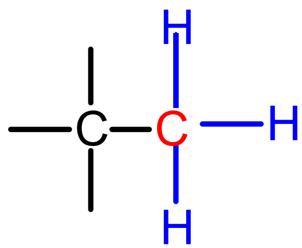
(a) Tetrahedral (b) Trigonal planar (c) Linear

Hydrocarbons

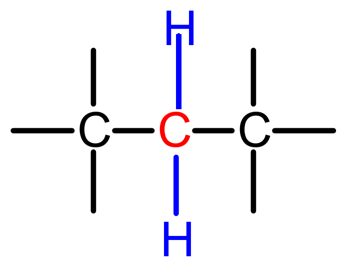
- Four basic types:
  - ➢ Alkanes: all C-C single bonds
  - ➢ Alkenes: contain a C=C double bond
  - ➢ Alkynes: contain a C≡C triple bond
  - ➢ Aromatic hydrocarbons: contain a benzene structure



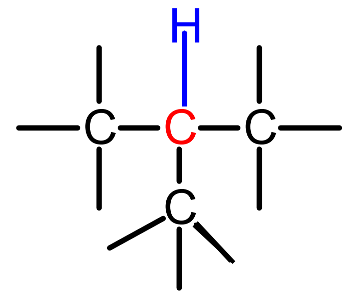
Carbon Bonding in Hydrocarbons



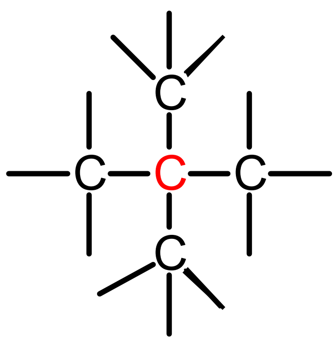
A C atom single-bonded to one other C atom is bonded to three H atoms.



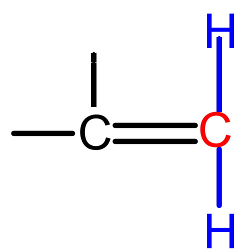
A C atom single-bonded to two other C atoms is bonded to two H atoms.



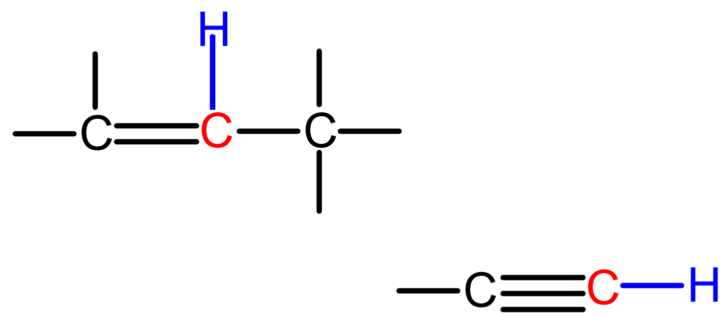
A C atom single-bonded to three other C atoms is bonded to one H atom.



A C atom single-bonded to four other atom is already fully bonded (no H atoms).



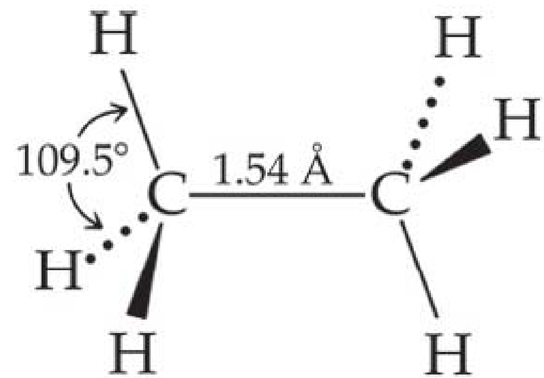
A double-bonded C atom is treated as if it were bonded to two other atoms.



A double- and single-bonded C atom or a triple-bonded C atom is treated as if it were bonded to three other atoms.

Alkanes

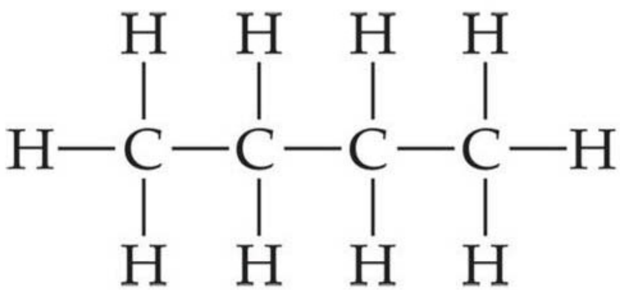
ALKANE
Ethane CH_3CH_3



- **Only carbon-carbon single bonds.**
- **Called *saturated hydrocarbons*.**
  - **"Saturated" with hydrogens**
  - **All carbons have tetrahedral arrangement of bonds**

Formulas

- Lewis structures of alkanes look like this.



Butane

- Also called **structural formulas**.
- Since these take up a lot of space…

Formulas

…so more often **condensed structural formulas** are used.

$$H_3C{-}CH_2{-}CH_2{-}CH_3$$

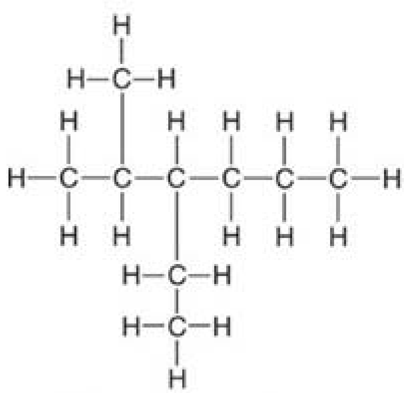
or

$$CH_3CH_2CH_2CH_3$$

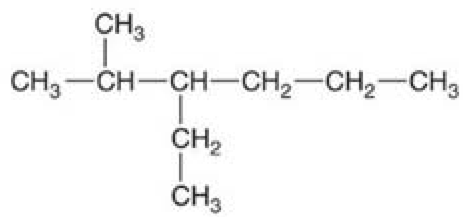
Even simpler than condensed structures are **skeletal or line structures**

Formulas

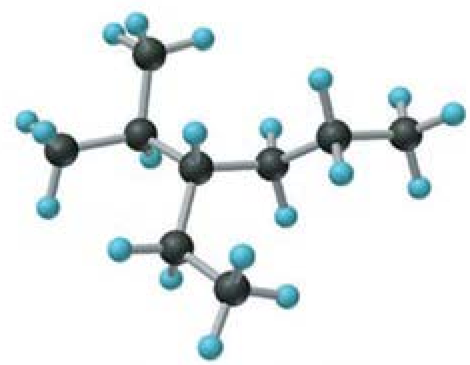
A summary of different organic formulas:



Expanded formula



Condensed formula



Ball-and-stick model

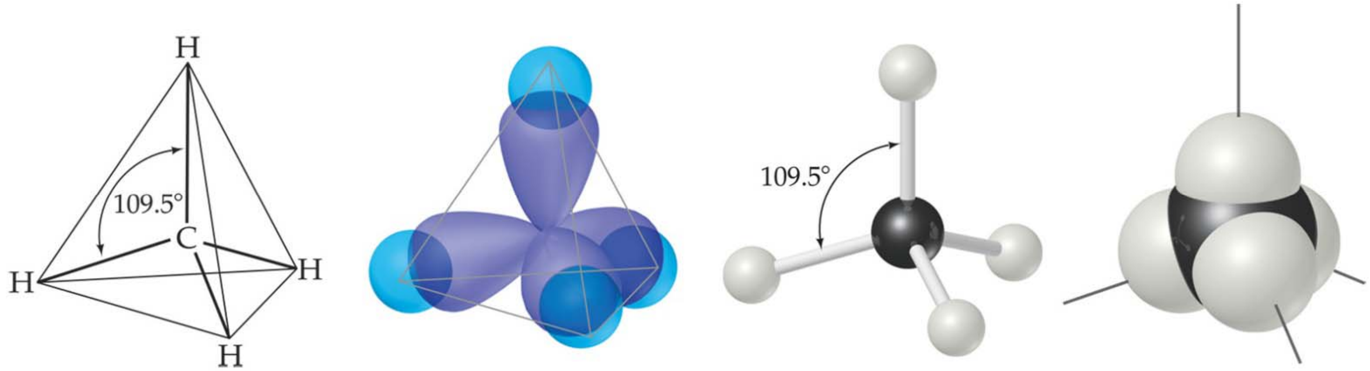
Space-filling model

Names and Properties of Alkanes

Molecular Formula	Condensed Structural Formula	Name	Boiling Point (°C)
CH_4	CH_4	Methane	−161
C_2H_6	CH_3CH_3	Ethane	−89
C_3H_8	$CH_3CH_2CH_3$	Propane	−44
C_4H_{10}	$CH_3CH_2CH_2CH_3$	Butane	−0.5
C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	Pentane	36
C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	Hexane	68
C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	Heptane	98
C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Octane	125
C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Nonane	151
$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Decane	174

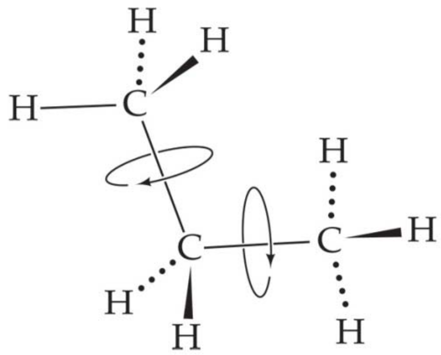
- Only van der Waals forces: London forces.
- Boiling point increases with length of chain.

Structure of Alkanes



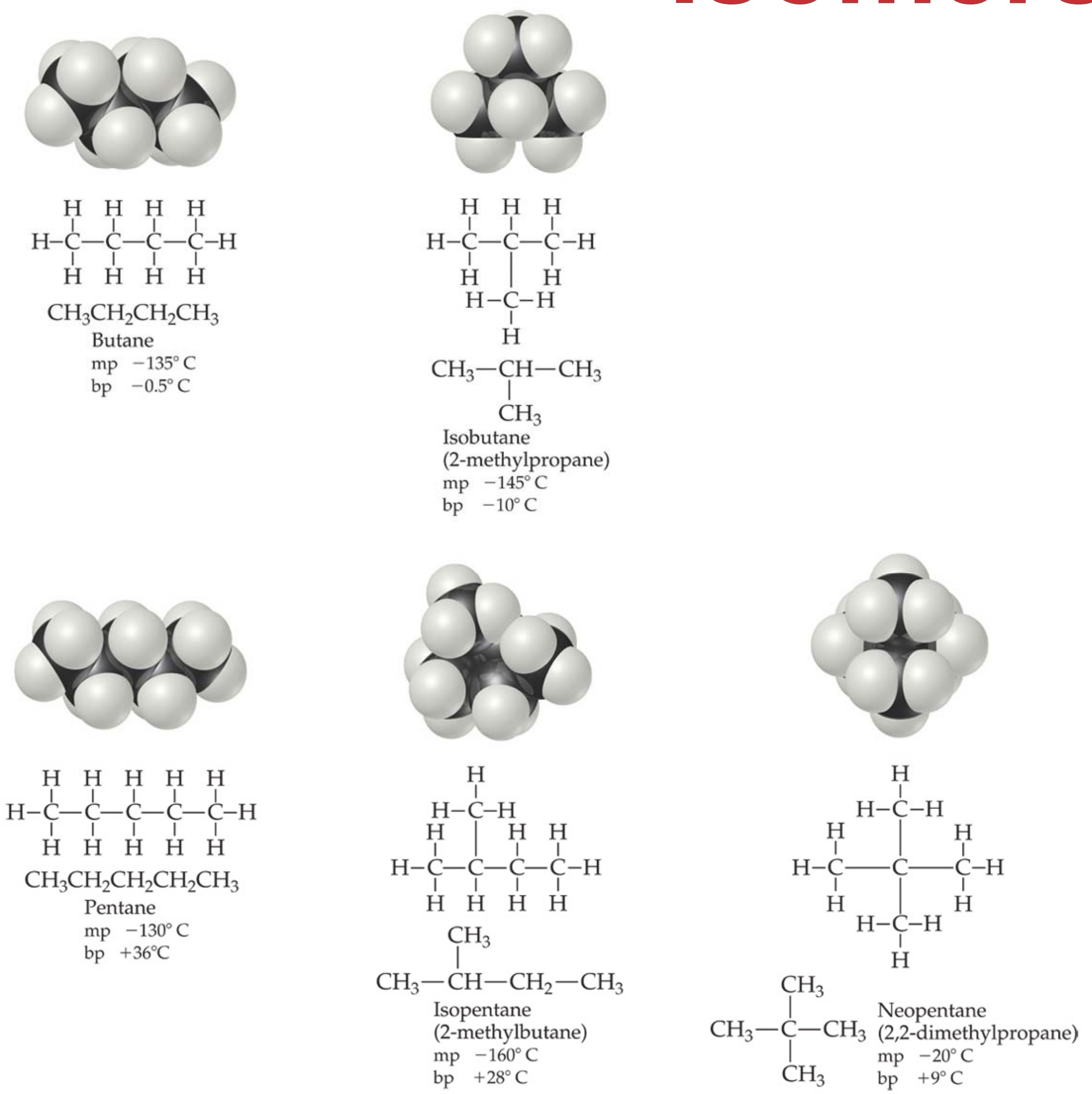
- Carbons in alkanes *sp*^{3} hybrids.
- Tetrahedral geometry.
- 109.5° bond angles.

Structure of Alkanes



- Only σ-bonds in alkanes
- Free rotation about C—C bonds.

Isomers



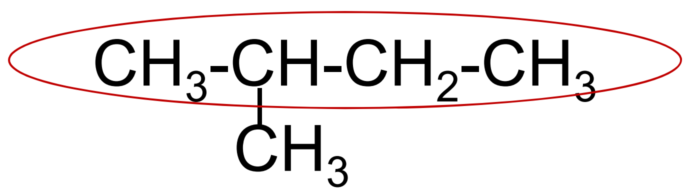
Have same molecular formulas, but atoms are bonded in different order or arrangement.

Organic Nomenclature

- Four parts to a compound name:
  - *Parent chain*: Tells how many carbons are in the longest continuous chain.

    meth = 1   eth = 2   prop = 3   but = 4 etc.

location prefix **parent chain** suffix



The parent chain on this molecule is 4 carbon atoms long. 4 = but

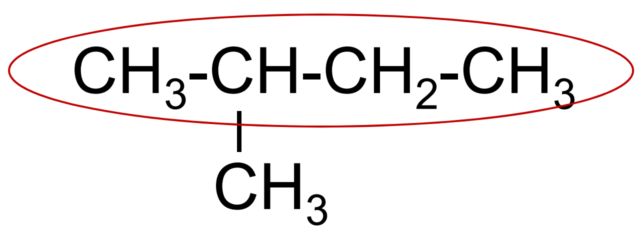
Organic Nomenclature

- Four parts to a compound name:
  - Parent chain: Tells how many carbons are in the **longest continuous chain:**

    meth = 1 eth = 2 prop = 3 but = 4 etc.
  - Suffix: Tells what type of compound it is:

    ane = alkane ene = alkene yne = alkyne

location prefix parent chain **suffix**



The parent chain contains all carbon-carbon single bonds. It is an alkane. Its name is butane.

Organic Nomenclature

- Four parts to a compound name:
  - Parent chain: Tells how many carbons are in the longest continuous chain.
  - Suffix: Tells what type of compound it is.
  - Prefix: Tells what groups, or branches are attached to chain:

$-CH_3$ = methyl $-CH_2CH_3$ = ethyl $-CH_2CH_2CH_3$ = propyl

location **prefix** parent chain suffix

$CH_3-CH-CH_2-CH_3$

$\quad\quad\;\; | $

$\quad\quad\; CH_3$

This compound has a single branch consisting of $-CH_3$ = methyl

Its name is methylbutane (Note: this is written as a single word.)

Organic Nomenclature

- Four parts to a compound name:
  - Parent chain: Tells how many carbons are in the longest continuous chain.
  - Suffix: Tells what type of compound it is.
  - Prefix: Tells what groups, or branches are attached to chain.
  - Location: Tells where groups, or branches, are attached to chain.

2 = 2nd carbon   3 = 3rd carbon 4 = 4th carbon

Note: alkyl groups cannot be located on the 1st or last carbon

location prefix parent chain suffix

- Location: Tells where groups, or branches, are attached to chain.

2 = 2nd carbon   3 = 3rd carbon 4 = 4th carbon

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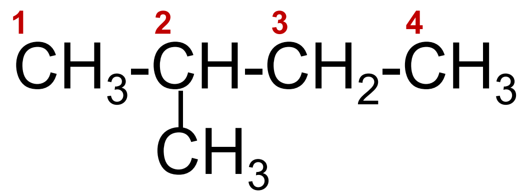
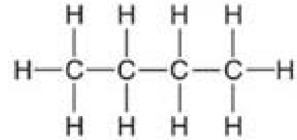
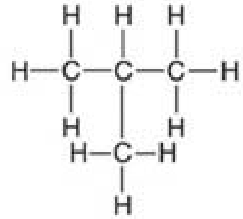
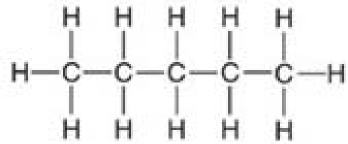
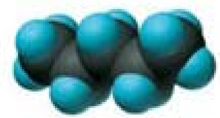
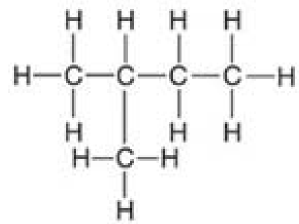
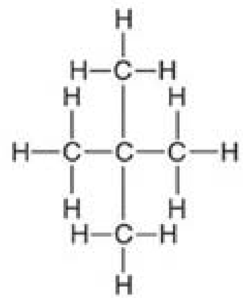


The methyl group is located on the second carbon atom of the parent chain, so the complete name for the compound is   **2-methylbutane**

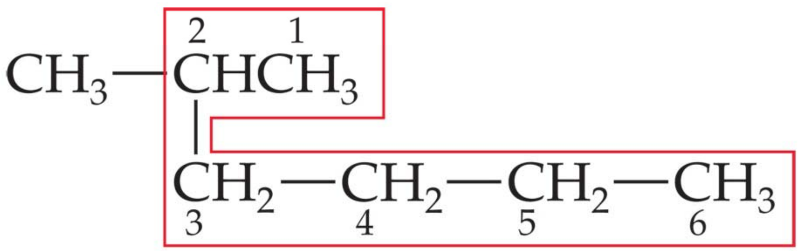
Note 1: Always count from the end of the molecule closest to the branches to get the lowest possible numbers for their location.

Note 2: Separate numbers from names by a dash (-)

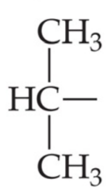
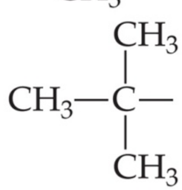
Isomers of butane and pentane

Systematic Name (Common Name)	Condensed Formula	Expanded Formula	Space-filling Model	Density (g/mL)	Boiling Point (°C)
Butane (*n*-butane)	$CH_3-CH_2-CH_2-CH_3$			0.579	−0.5
2-Methylpropane (isobutane)	$CH_3-CH(CH_3)-CH_3$			0.549	−11.6
Pentane (*n*-pentane)	$CH_3-CH_2-CH_2-CH_2-CH_3$			0.626	36.1
2-Methylbutane (isopentane)	$CH_3-CH(CH_3)-CH_2-CH_3$			0.620	27.8
2,2-Dimethylpropane (neopentane)	$CH_3-C(CH_3)_2-CH_3$			0.614	9.5

To Name a Compound…

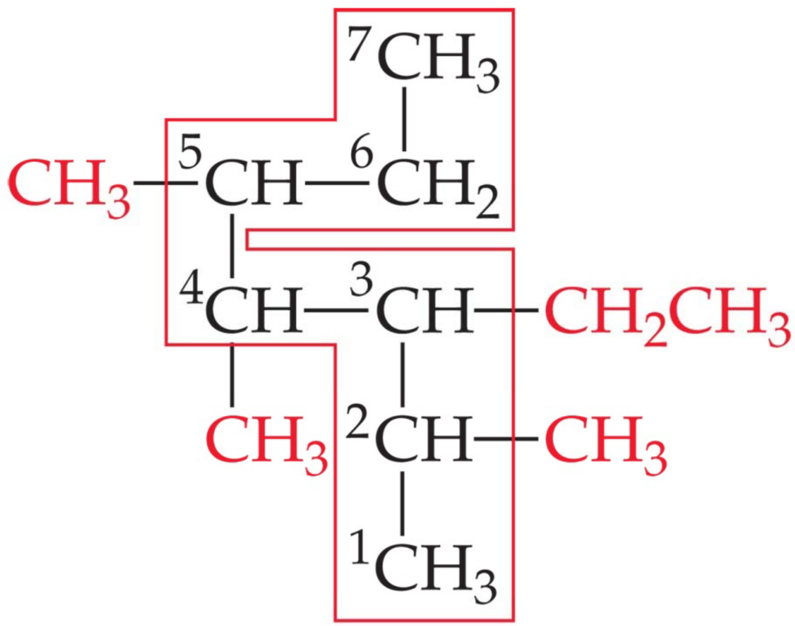


2-Methyl*hexane*

Group	Name
CH_3—	Methyl
CH_3CH_2—	Ethyl
$CH_3CH_2CH_2$—	Propyl
$CH_3CH_2CH_2CH_2$—	Butyl
	Isopropyl
	*tert*-Butyl

1. Find the longest chain in the molecule.
2. Number the chain from the end nearest the first substituent (or branch) encountered.
3. List the substituents (branches) as prefixes along with the number(s) (locations) of the carbon(s) to which they are attached.

To Name a Compound…



3-Ethyl-2,4,5-trimethylheptane

If there is more than one type of substituent in the molecule, list them alphabetically.

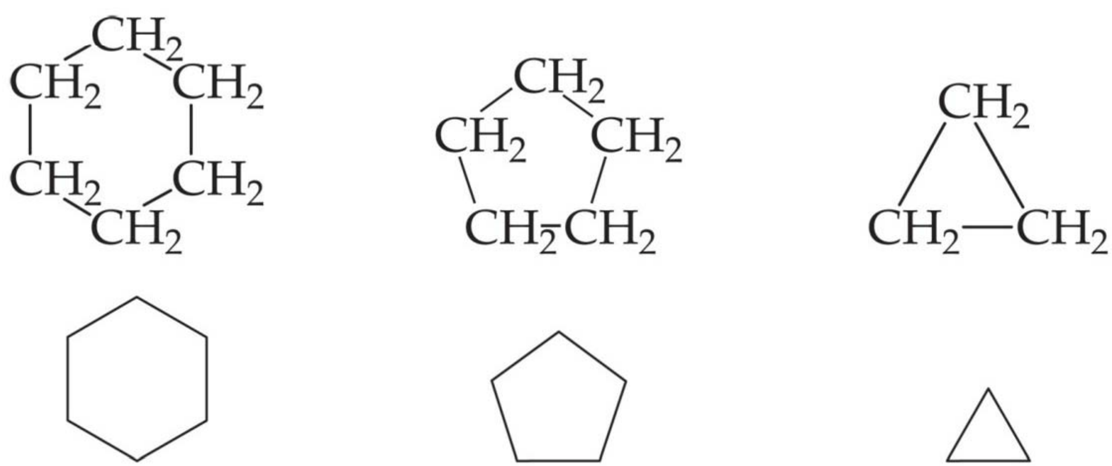
If there are more than one substituent of the same type, use the prefixes:

di = 2 tri = 3 tetra = 4

There must be a number assigned to tell the location of each substituent group.

Cycloalkanes

- Carbon can also form ringed structures.
- Five- and six-membered rings are most stable.
  - Can take on conformation in which angles are very close to tetrahedral angle.
  - Smaller rings are quite strained.



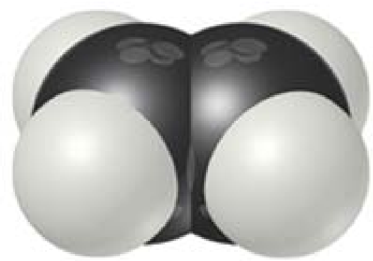
Cyclohexane Cyclopentane Cyclopropane

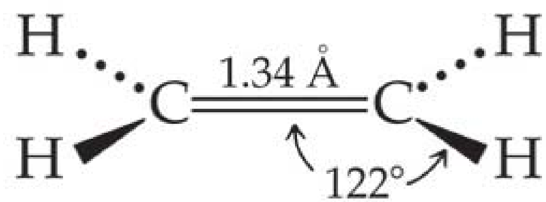
Reactions of Alkanes

- Rather unreactive due to presence of only C—C and C—H single bonds.
- Therefore, great nonpolar solvents.

Alkenes

ALKENE
Ethylene $CH_2{=}CH_2$

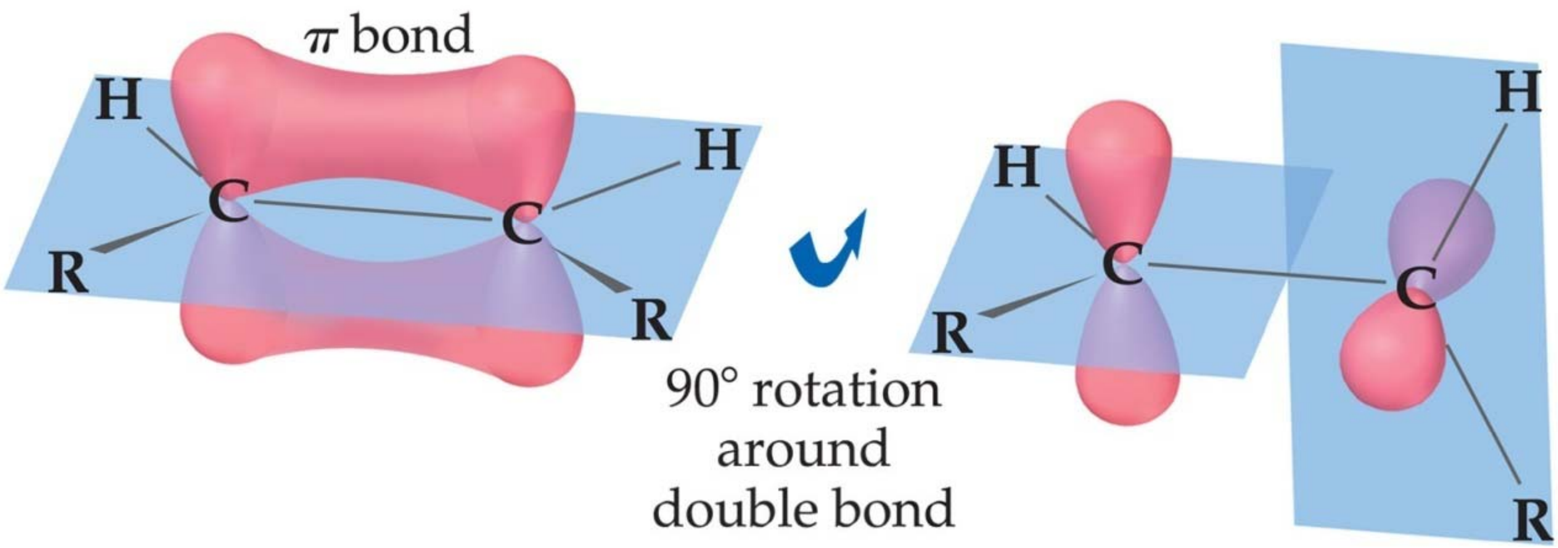




- Contain at least one carbon–carbon double bond.
- Unsaturated.
  - Have fewer than maximum number of hydrogens.

Structure of Alkenes

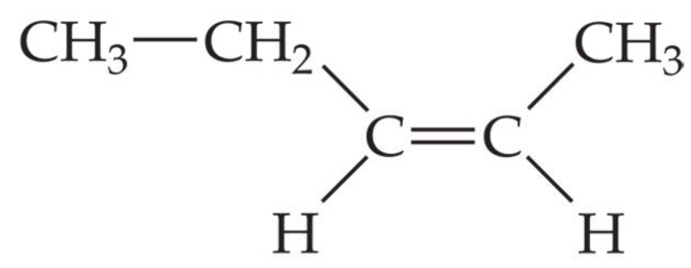
- Unlike alkanes, alkenes cannot rotate freely about the double bond.
  - ➢ Side-to-side overlap makes this impossible without breaking π-bond.



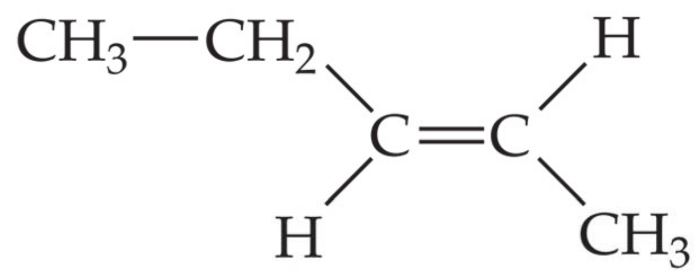
Structure of Alkenes

This creates geometric isomers, which differ from each other in the spatial arrangement of groups about the double bond.

Geometric isomers are noted by the prefix *cis*- or *trans*-.

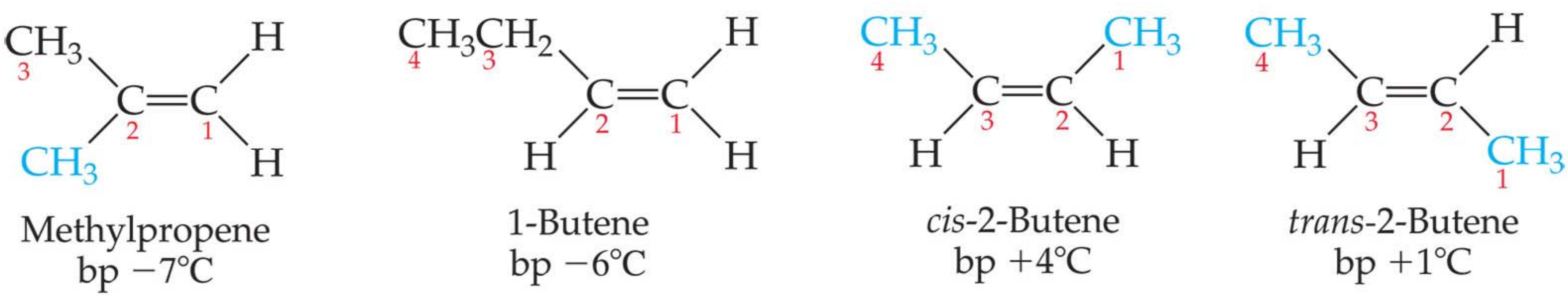


cis-2-Pentene



trans-2-Pentene

Properties of Alkenes



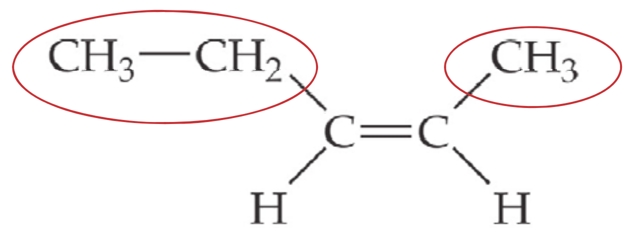
Structure affects physical properties of alkenes such as their boiling points.

Nomenclature of Alkenes

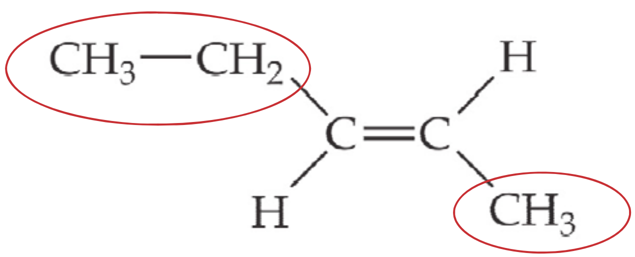
- Chain numbered so double bond gets smallest possible number.
- *cis*- alkenes have carbons in chain on same side of molecule. (Note: parts of chain are circled)
- *trans*- alkenes have carbons in chain on opposite side of molecule.

$$CH_3-CH_2-CH_2-CH=CH_2$$

1-Pentene



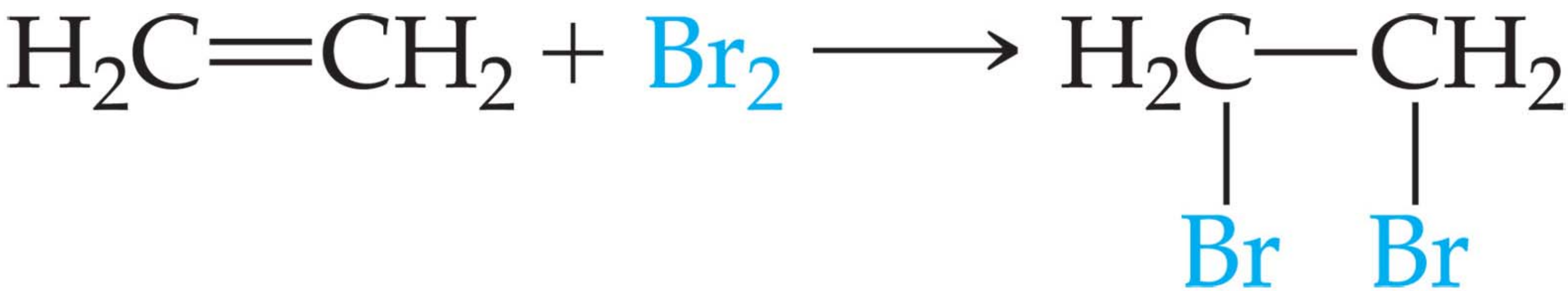
cis-2-Pentene



trans-2-Pentene

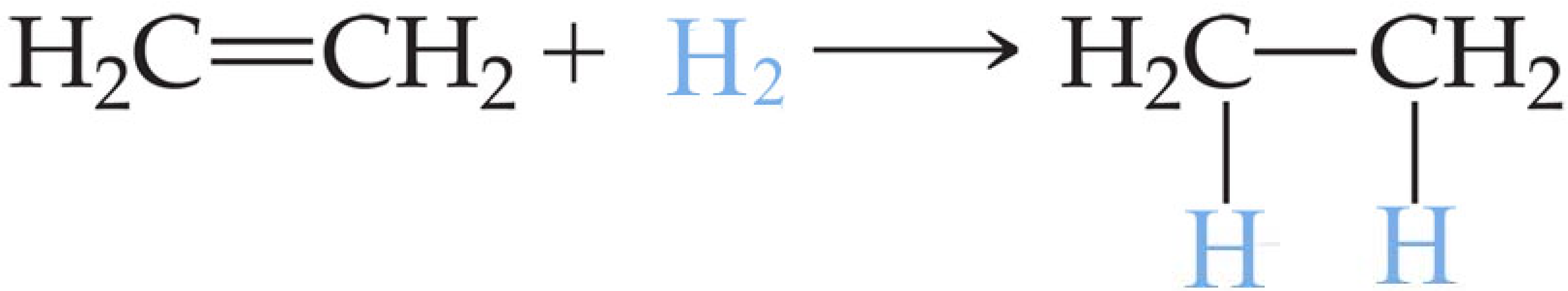
Suffix to name of parent chain is –ene = alkene

Reactions of Alkenes



- Addition Reactions
  - Two atoms (e.g., bromine) can add across the double bond.
  - One π-bond and one σ-bond are replaced by two σ-bonds; therefore, ΔH is negative.
  - This reaction is called a bromination reaction (i.e., addition of bromine).

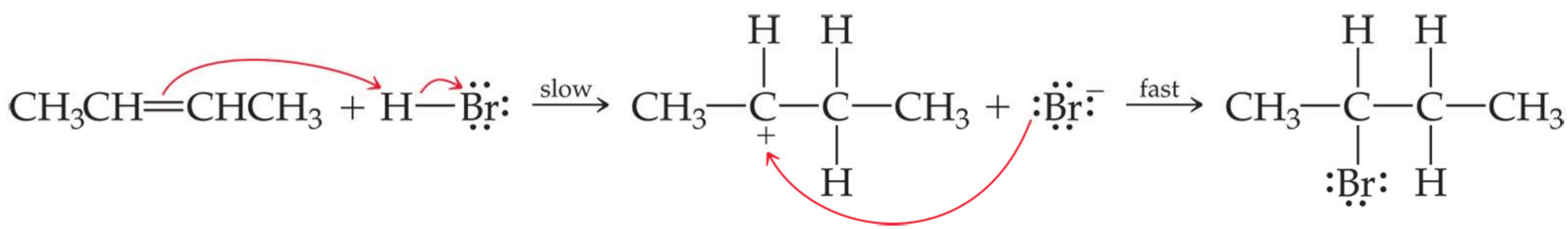
Reactions of Alkenes



- Addition Reactions
  - Two atoms (e.g., hydrogen) can add across the double bond.
  - One π-bond and one σ-bond are replaced by two σ-bonds; therefore, ΔH is negative.
  - This reaction is called a hydrogenation reaction (i.e., addition of hydrogen).

Mechanism of Addition Reactions

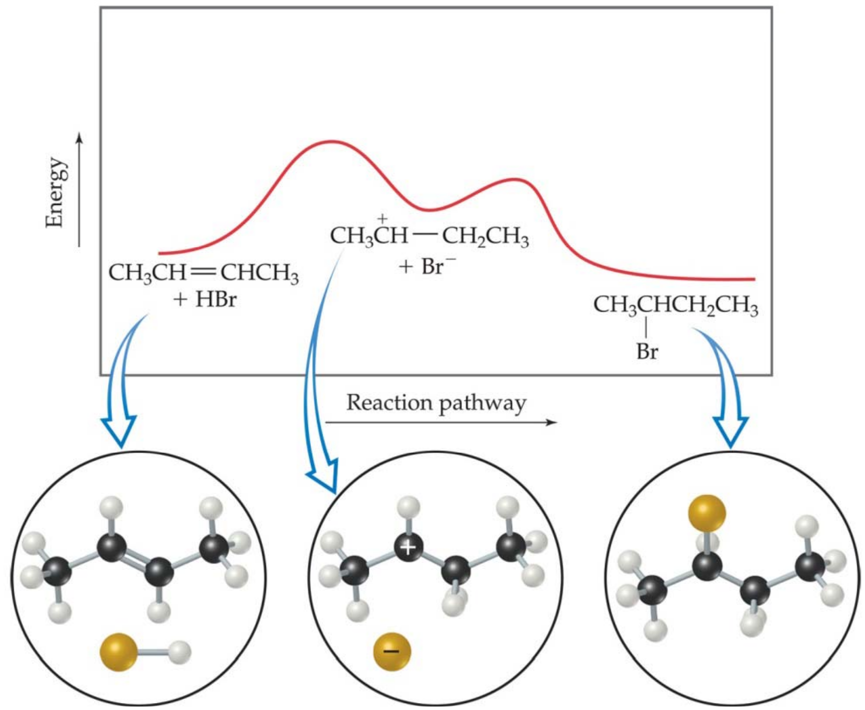
The addition of HBr

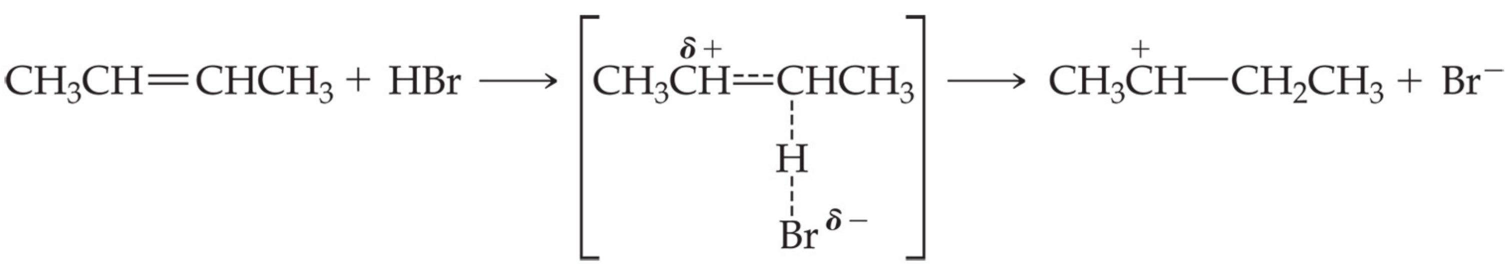


- Two-step mechanism:
  - First step is slow, rate-determining step.
  - Second step is fast.

Mechanism of Addition Reactions

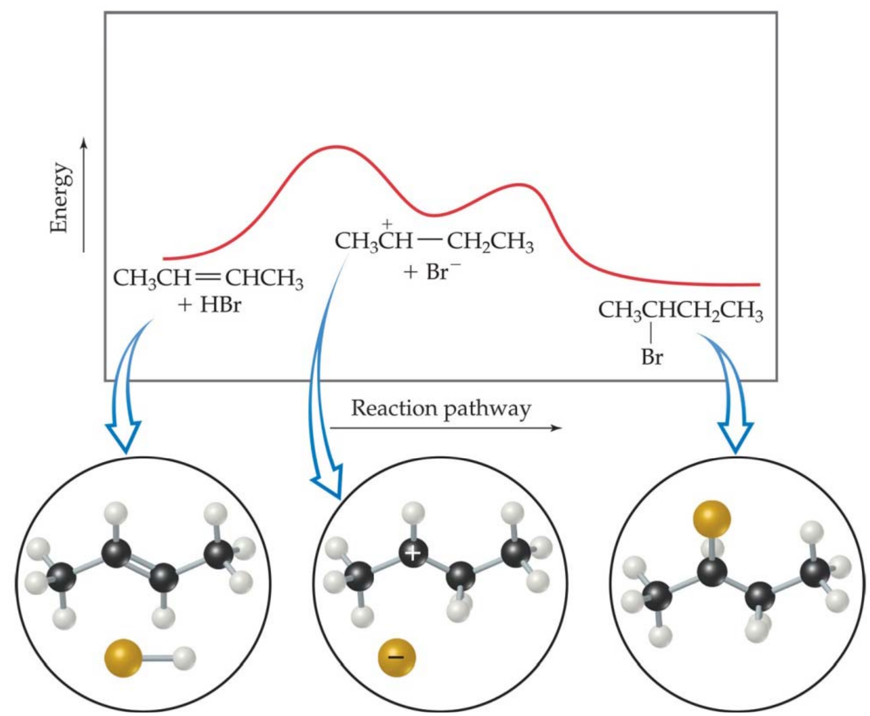
In first step, π-bond breaks and new C—H bond and cation form.

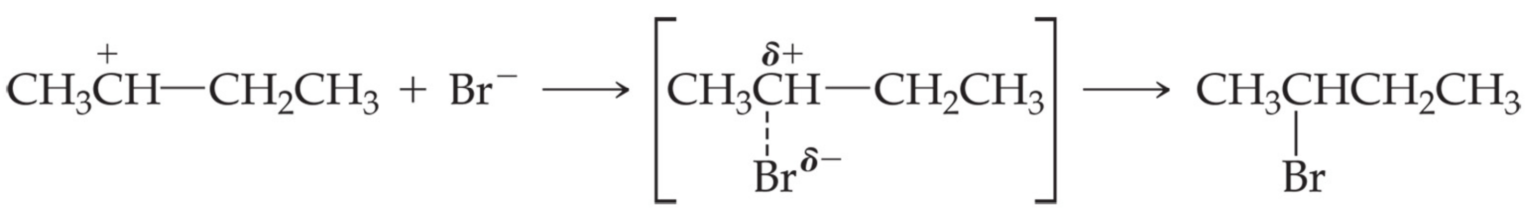




Mechanism of Addition Reactions

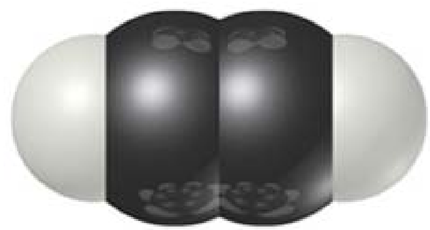
In second step, new bond forms between negative bromide ion and positive carbon.

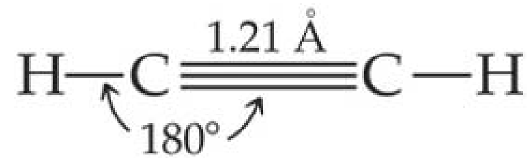




Alkynes

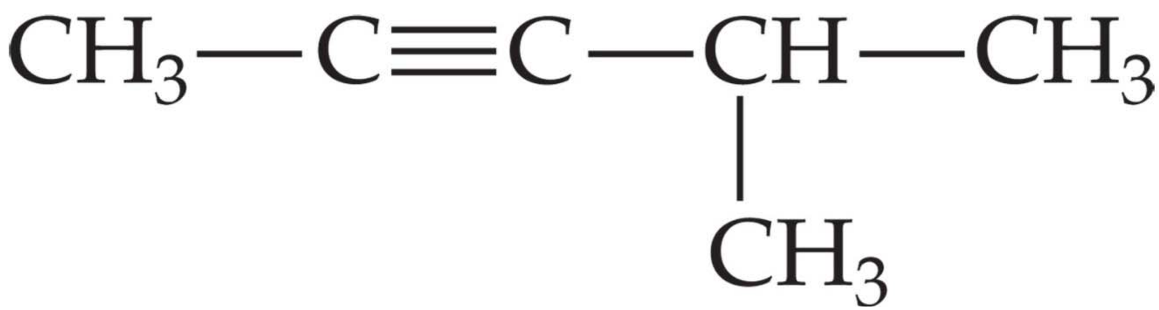
ALKYNE
Acetylene $CH{\equiv}CH$





- Contain at least one carbon–carbon triple bond.
- Carbons in triple bond *sp*-hybridized and have linear geometry.
- Also unsaturated.

Nomenclature of Alkynes

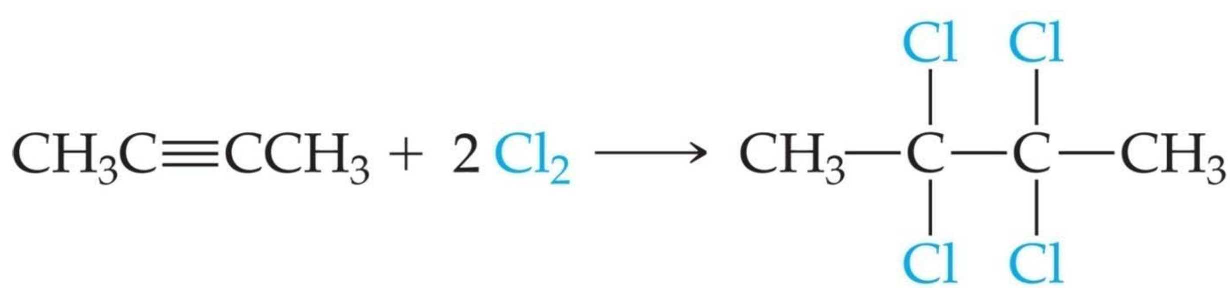


4-methyl-2-pentyne

- Analogous to naming of alkenes.
- Suffix is *-yne* rather than *–ene.*

Reactions of Alkynes

- Undergo many of the same reactions alkenes do.
- As with alkenes, impetus for reaction is replacement of π-bonds with σ-bonds.

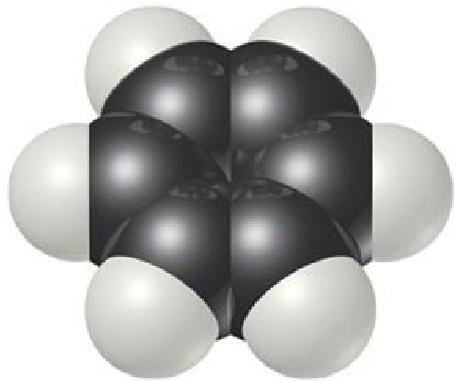


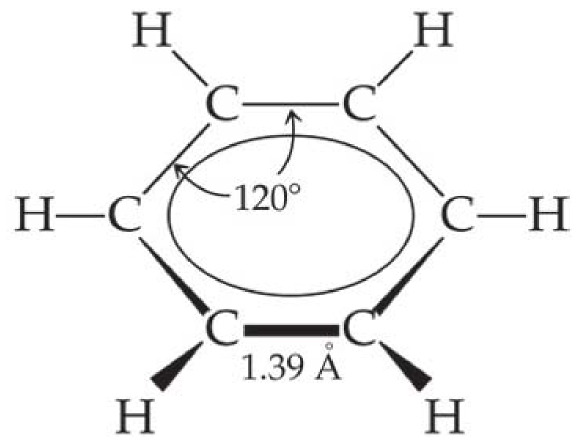
2-Butyne

2,2,3,3-Tetrachlorobutane

Aromatic Hydrocarbons

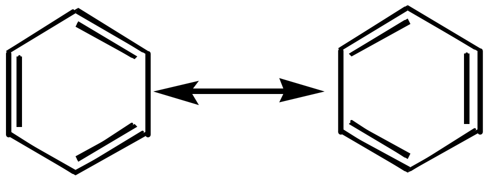
AROMATIC
Benzene C_6H_6





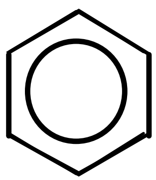
- Cyclic hydrocarbons containing a benzene structure.
- *p*-Orbitals on each atom result in delocalized electrons throughout the ring.
  - Molecule is planar.
- Odd number of electron pairs in π-system.

Some representations of benzene

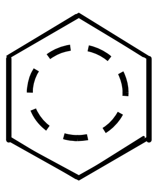


Resonance structures

If the bonds are shown,
only one of these is used.



or

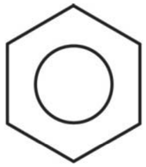


Resonance hybrid structures

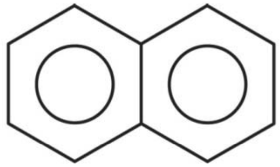
A resonance hybrid diagram showing the delocalized π-electrons

Aromatic Nomenclature

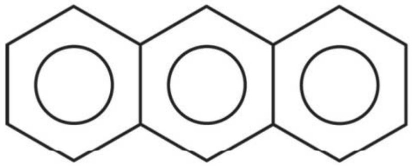
Many aromatic hydrocarbons are known by their common names.



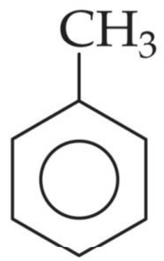
Benzene



Naphthalene

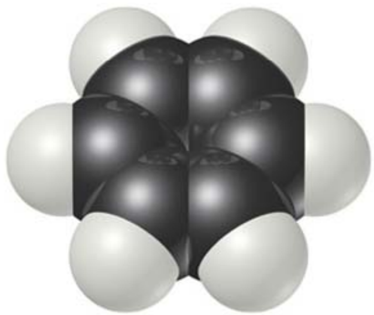


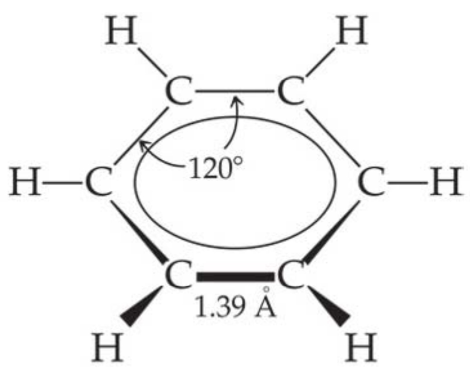
Anthracene



Toluene
Methylbenzene

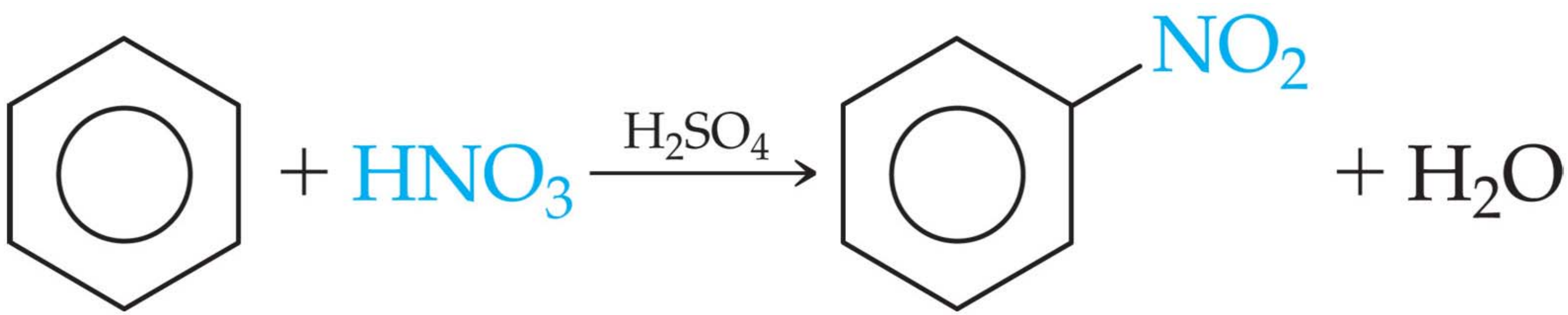
Reactions of Aromatic Compounds





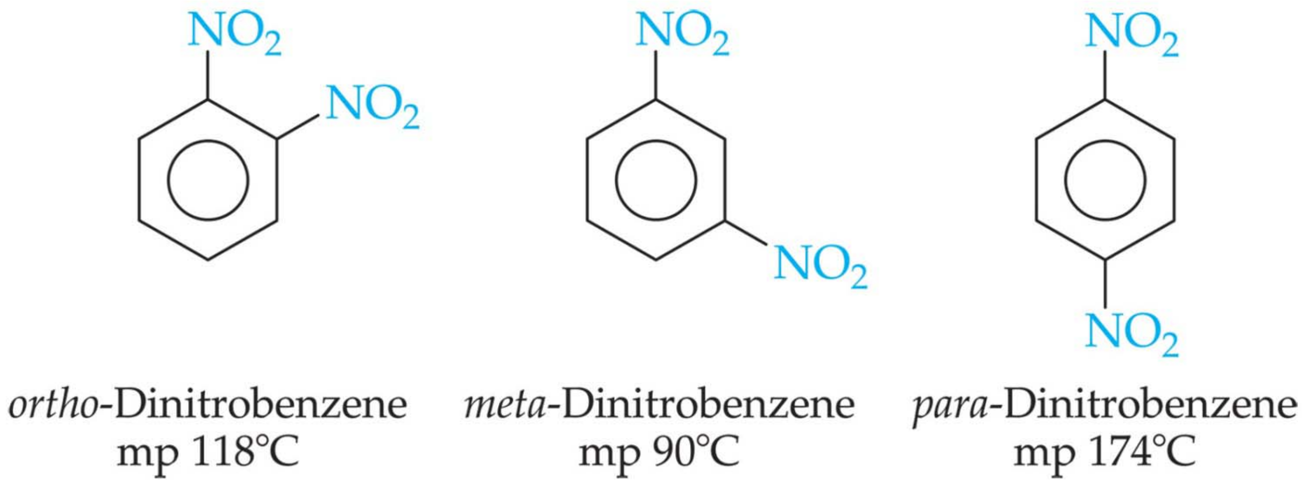
- Unlike in alkenes and alkynes, π-electrons do not sit between two atoms.
- Electrons are delocalized; this stabilizes aromatic compounds.

Reactions of Aromatic Compounds



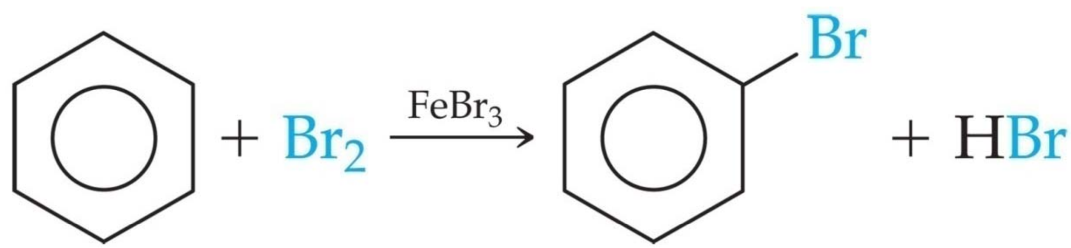
- Due to stabilization, aromatic compounds do not undergo addition reactions; they undergo substitution.
- Hydrogen is replaced by substituent.

Structure of Aromatic Compounds

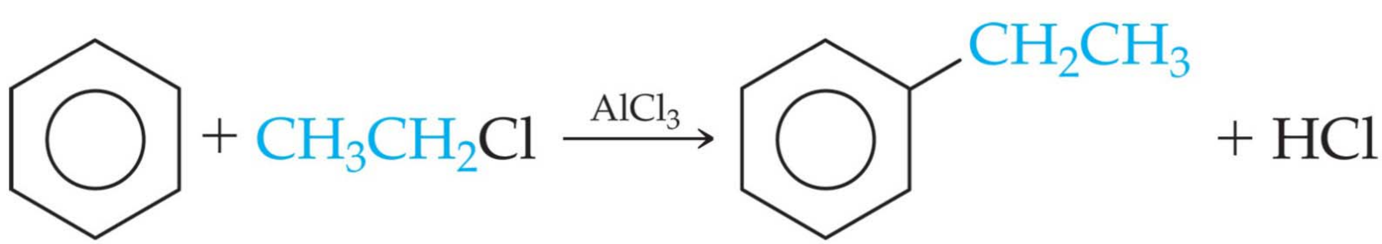


- If there are two substituents on a benzene ring, their positions are noted as part of their names
  - *ortho-*: On adjacent carbons.
  - *meta-*: One carbon between them.
  - *para-*: On opposite sides of ring.

Reactions of Aromatic Compounds



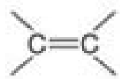
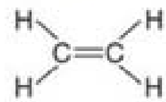
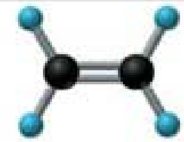
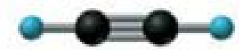
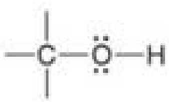
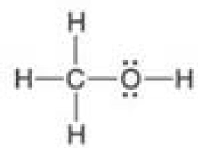
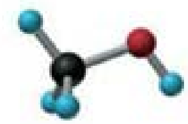
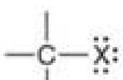
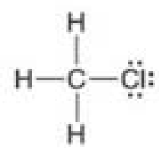
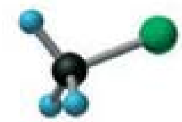
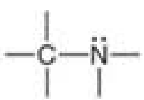
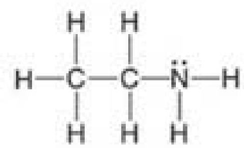
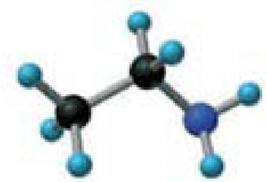
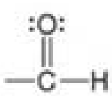
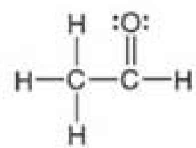
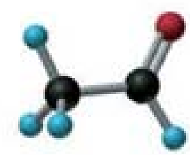
Halogenation



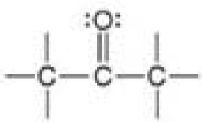
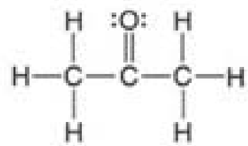
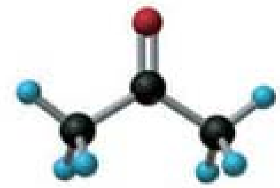
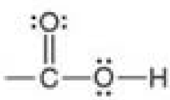
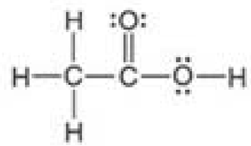
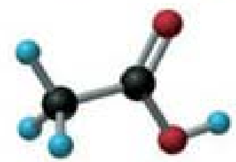
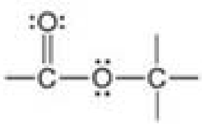
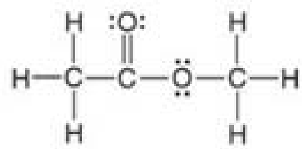
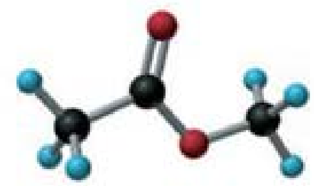
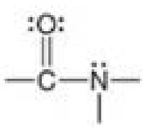
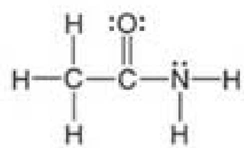
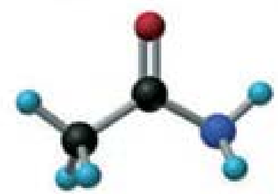
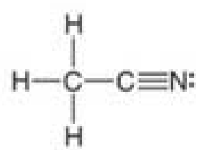
Friedel-Crafts Reaction

Reactions of aromatic compounds often require a catalyst.

Functional Group Compounds

Functional Group	Compound Type	Suffix or Prefix of Name	Example		Systematic Name (Common Name)
	alkene	-ene			ethene (ethylene)
	alkyne	-yne			ethyne (acetylene)
	alcohol	-ol			methanol (methyl alcohol)
 (X=halogen)	haloalkane	halo-			chloromethane (methyl chloride)
	amine	-amine			ethylamine
	aldehyde	-al			ethanal (acetaldehyde)

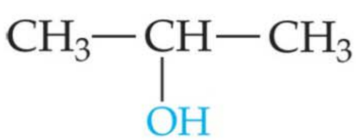
Functional Group Compounds (continued)

Functional Group	Compound Type	Suffix or Prefix of Name	Example		Systematic Name (Common Name)
	ketone	-one			2-propanone (acetone)
	carboxylic acid	-oic acid			ethanoic acid (acetic acid)
	ester	-oate			methyl ethanoate (methyl acetate)
	amide	-amide			ethanamide (acetamide)
	nitrile	-nitrile			ethanenitrile (acetonitrile, methyl cyanide)

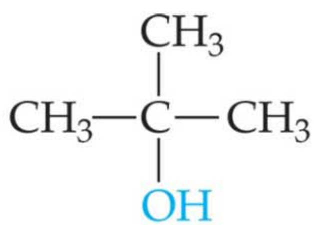
Alcohols

- Contain one or more hydroxyl groups, —OH

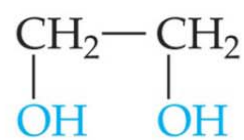
- Named from parent hydrocarbon; suffix changed to *-ol* and number designates carbon to which hydroxyl is attached.



2-Propanol
Isopropyl alcohol; rubbing alcohol

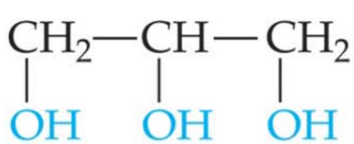


2-Methyl-2-propanol
t-Butyl alcohol

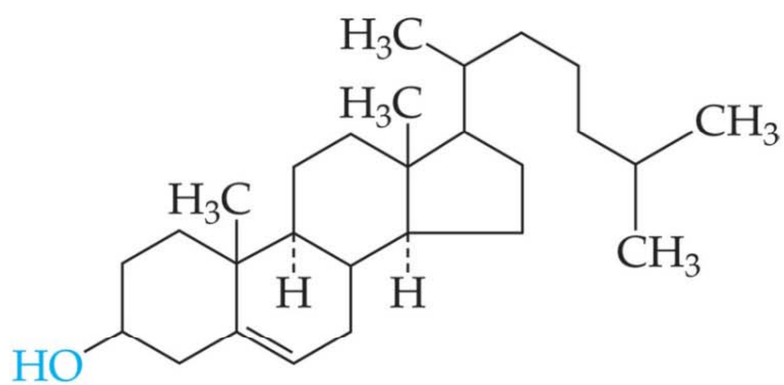


1,2-Ethanediol
Ethylene glycol

Phenol



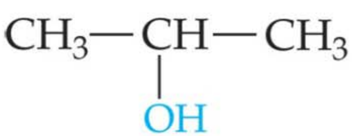
1,2,3-Propanetriol
Glycerol; glycerin



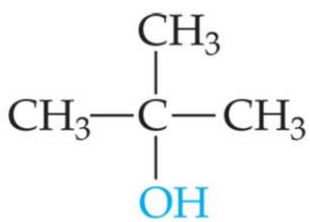
Cholesterol

Alcohols

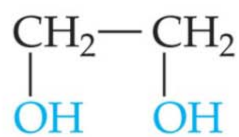
- Much more acidic than hydrocarbons.
  - ➢ pK_a ~15 for most alcohols.
  - ➢ Aromatic alcohols have pK_a ~10.



2-Propanol
Isopropyl alcohol; rubbing alcohol

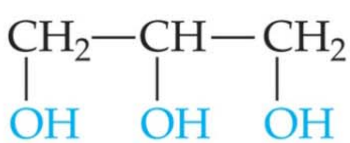


2-Methyl-2-propanol
t-Butyl alcohol

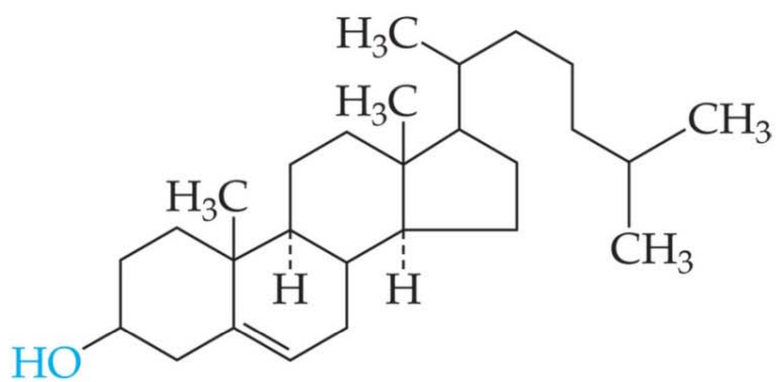


1,2-Ethanediol
Ethylene glycol

Phenol



1,2,3-Propanetriol
Glycerol; glycerin



Cholesterol

Some common alcohols

Methanol, CH_3OH

- Common names: methyl alcohol, wood alcohol
- Poison, oral and by inhalation, LD50 Rat 5600 mg/Kg
- Boiling point: 64.7° C
- Uses: solvent, antifreeze, fuel

Ethanol, CH_3CH_2OH

- Common names: ethyl alcohol, grain alcohol, vodka
- Poison, oral and by inhalation, LD50 Rat 7060 mg/Kg
- Boiling point: 78° C
- Uses: beverage, solvent, antifreeze, fuel

Some common alcohols

2-propanol, $CH_3CHOHCH_3$

- Common names: isopropyl alcohol, rubbing alcohol
- Poison, oral and by inhalation, LD50 Rat 5045 mg/Kg
- Boiling point: 82° C
- Uses: cleaner, solvent, antifreeze

Ethers

$$CH_3\text{-}CH_2\text{-}O\text{-}CH_2\text{-}CH_3$$

- Tend to be quite unreactive.
- Good solvents (slighly polar).
- Most common ether:

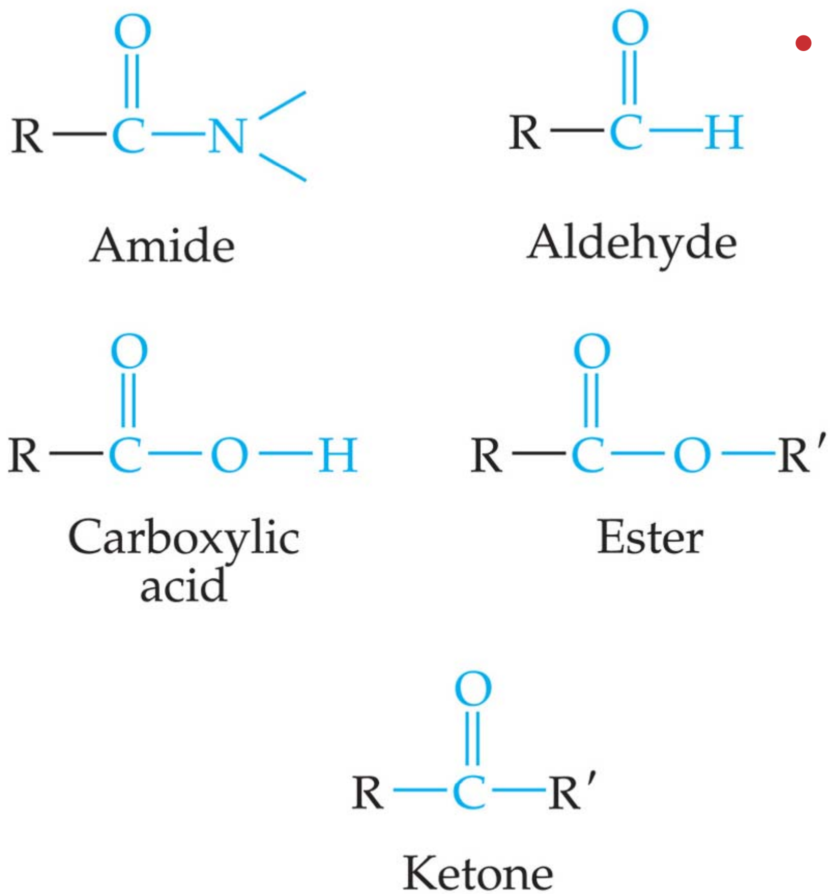
  Diethyl ether or ethoxyethane (formula, above)

  Boiling point: 34.6° C

  Uses: anesthetic, solvent

  (Other ethers, such as methyl propyl ether, have replaced diethyl ether as an anesthetic.)

Carbonyl Compounds



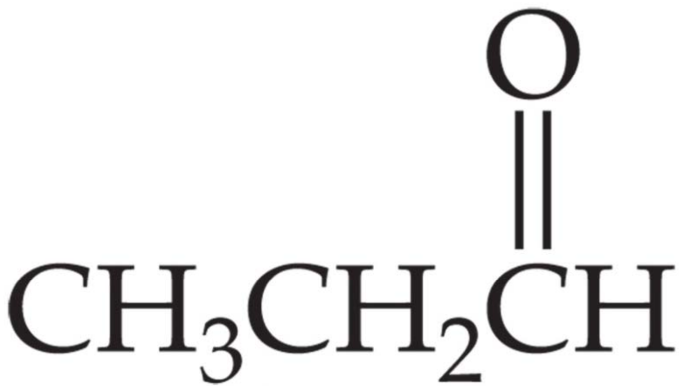
- Contain C=O double bond.
- Includes several classes of compounds:
  - Amides
  - Aldehydes
  - Ketones
  - Carboxylic acids
  - Esters

Aldehydes

Carbonyl group is on an end carbon.

At least one hydrogen attached to carbonyl carbon.

Named from parent hydrocarbon; suffix changed to *-al*



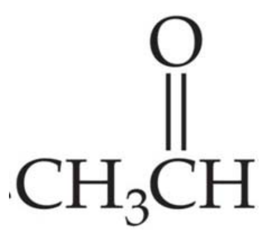
propanal

Some common aldehydes

Methanal, 

common name: methyl aldehyde, formaldehyde

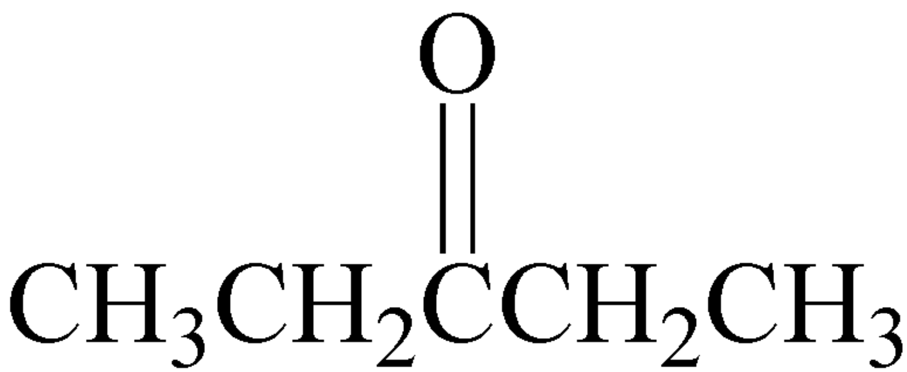
Uses: solvent, preservative

Ethanal, 

common name: ethyl aldehyde, acetaldehyde

Uses: solvent, intermediate for manufacture of other compounds

Ketones



3-pentanone

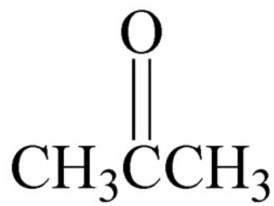
Two carbons bonded to carbonyl carbon.

Carbonyl group is in the parent chain, not on the end.

Name is similar to alkenes: prefix is number of carbonyl carbon, suffix is -one

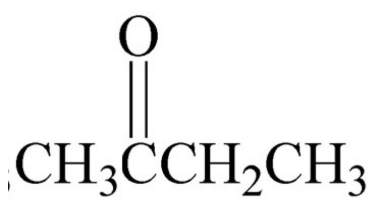
Some common ketones

2-propanone



common name:
dimethyl ketone, acetone
use: solvent

2-butanone



common name:
methyl ethyl ketone
use: solvent

Carboxylic Acids

Have hydroxyl group bonded to carbonyl group.

Sour taste.

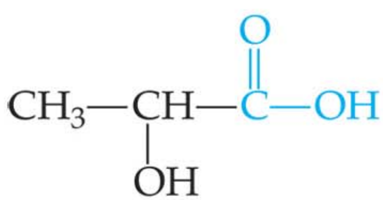
Carboxylic acids are weak acids.

Name as parent chain with suffix: -oic acid

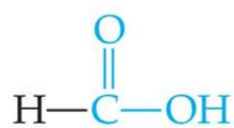
$$CH_3COOH$$

ethanoic acid

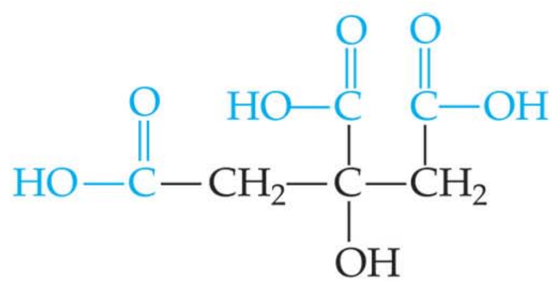
Some common carboxylic acids



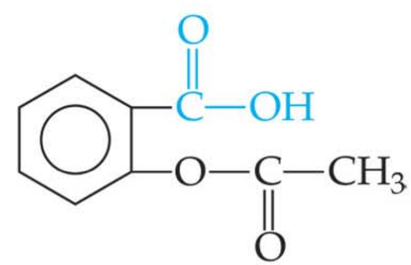
Lactic acid



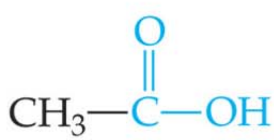
Methanoic acid
Formic acid



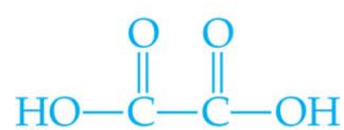
Citric acid



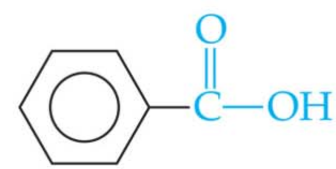
Acetylsalicylic acid
Aspirin



Ethanoic acid
Acetic acid



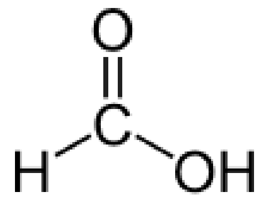
Oxalic acid



Phenyl methanoic acid
Benzoic acid

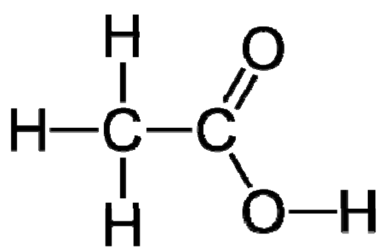
Some common carboxylic acids

methanoic acid



common name:
formic acid
occurrence:
venom in bee and ant stings
use: intermediate in chemical synthesis

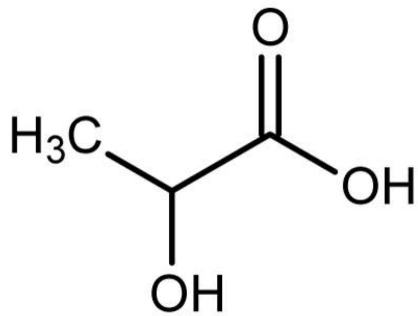
ethanoic acid



common names:
acetic acid, vinegar
occurrence:
oxidation of ethanol
use: foods (vinegar), polymers, glues, synthetic fibers

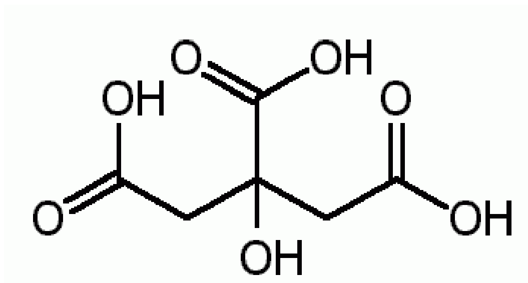
Some common carboxylic acids

lactic acid



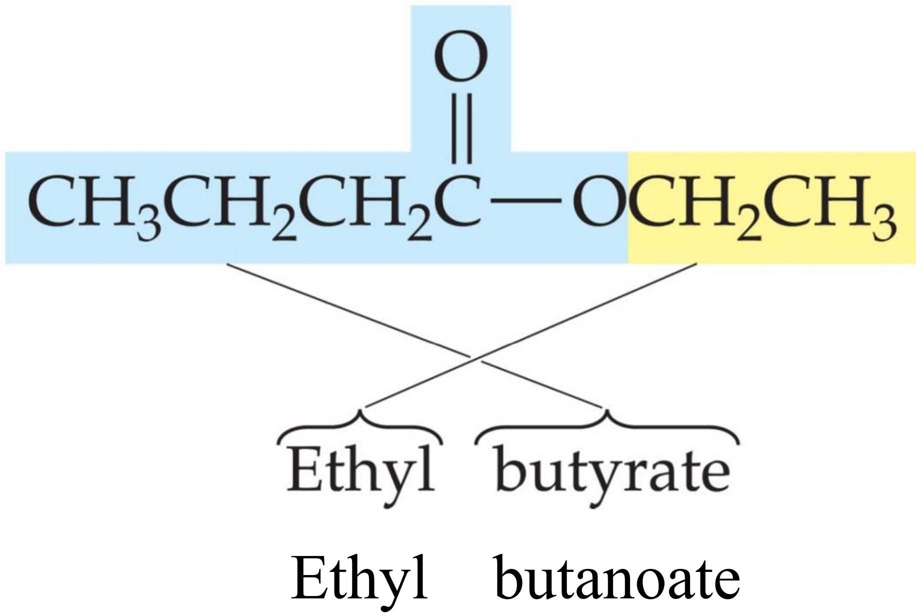
common name:
milk acid
occurrence:
milk, fermentation in normal exercise
use: polymers, foods

citric acid



common name:
sour salt
occurrence:
fruits and vegetables
use: foods, cosmetics, cleaning materials

Esters



- Products of reaction between carboxylic acids and alcohols.
- Found in many fruits and perfumes.
- Name alcohol portion as alkyl group (i.e., methyl, ethyl, etc.) and acid portion as alkane minus –e (last letter) and add –oate ending.

Note: Common names for acids are often used.

Some common esters

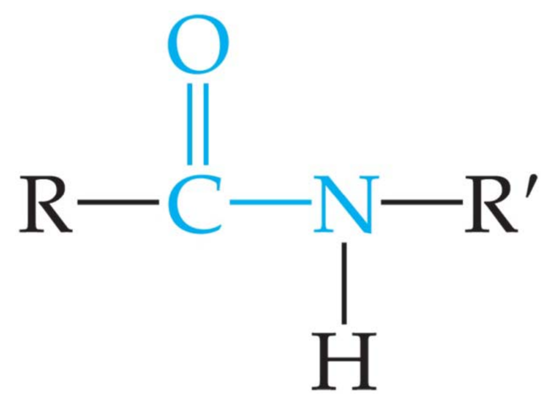
Formula	Common name	IUPAC name	Flavor/odor
O II $HC-O-CH_2-CH_3$	ethyl formate	ethyl methanoate	rum
O II $H_3C-C-O-CH_2-(CH_2)_3-CH_3$	n-amyl acetate	pentyl ethanoate	pears, bananas
O II $H_3C-C-O-CH_2-CH_2-CH(CH_3)_2$	isoamyl acetate	3-methylbutyl ethanoate	pears, bananas
O II $H_3C-C-O-CH_2-(CH_2)_6-CH_3$	n-octyl acetate	octyl ethanoate	oranges
O II $H_3C-CH_2-C-O-CH_2-CH(CH_3)_2$	isobutyl propionate	2-methylpropyl propanoate	rum
O II $H_3C-CH_2-CH_2-C-O-CH_3$	methyl butyrate	methyl butanoate	apples
O II $H_3C-CH_2-CH_2-C-O-CH_2-CH_3$	ethyl butyrate	ethyl butanoate	pineapples

Amides

Formed by reaction of carboxylic acids with amines.

Last part of compound name is -amide

such as ethanamide (or acetamide)



Amines

- Organic bases.
- Generally have strong, unpleasant odors.
- Last part of compound name is –amine

  (Note: common names are often used)

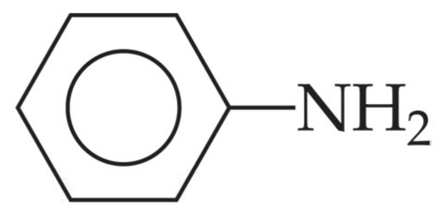
$CH_3CH_2NH_2$

Ethylamine

Ethanamine

$(CH_3)_3N$

Trimethylamine



Phenylamine

Aniline