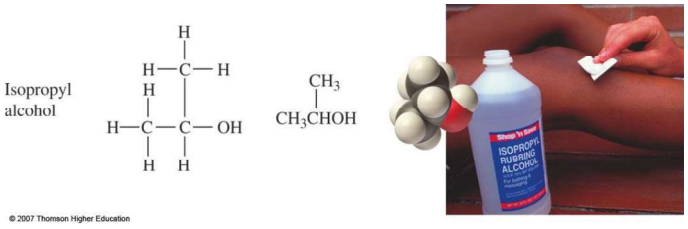
Organic Chemistry

What is organic Chemistry?

- *Organic Chemistry* is the chemistry of carbon compounds.
- Carbon (C) is the principal element in organic compounds, most also contain H, N, O, P, …

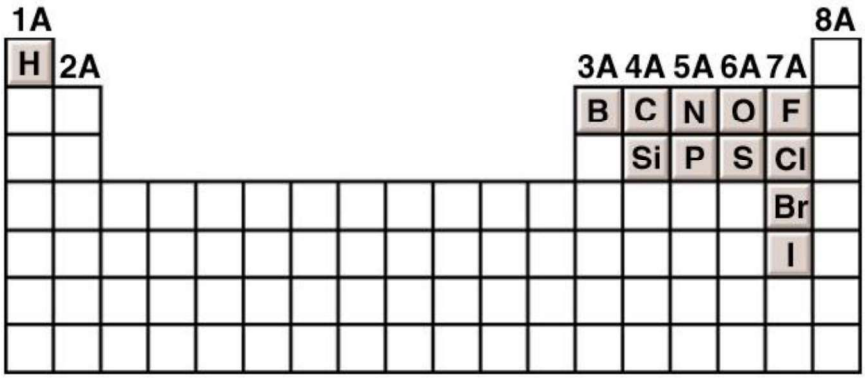


CARBON

- Of the millions of known compounds in our world, 95% have a single element in common – CARBON.

- What is so special about carbon?

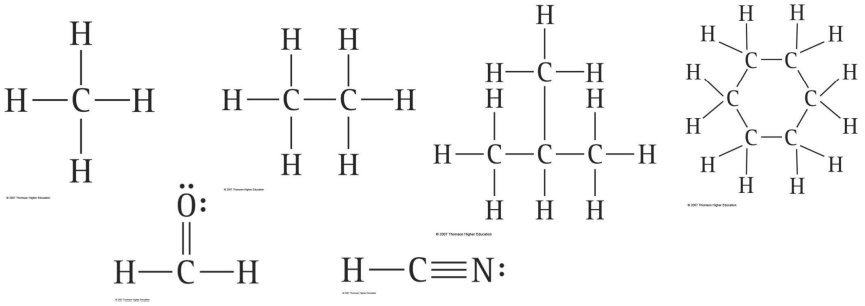
Common Elements in Organic Compounds



•The study of carbon-containing compounds and their chemistry is called organic chemistry.

Carbon

- Smallest member, and only nonmetal, of Group 4
- Forms 4 covalent bonds
- Forms single, double, and triple bonds
- Bonds to itself, forming rings



Types of Organic Compounds

- Hydrocarbons
  - Contain only carbon and hydrogen
- Functionalized Hydrocarbons
  - Hydrocarbons that contain additional atoms or groups of atoms

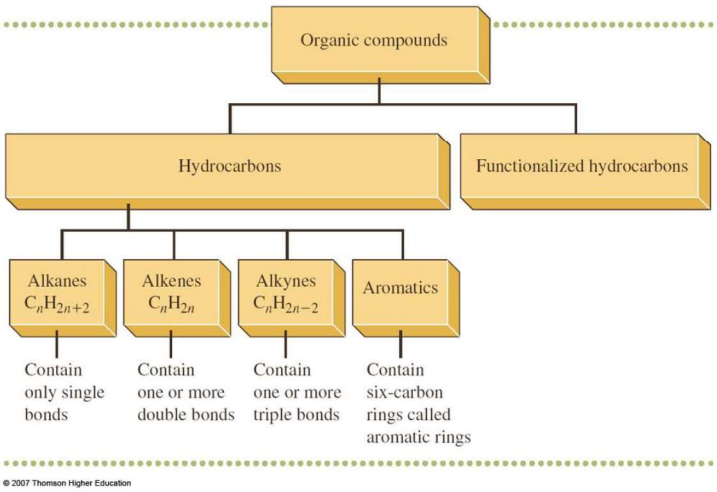
- Both groups can be further divided into subfamilies.

The Hydrocarbon Family

- Alkanes
  - Only single bonds
- Alkenes
  - One or more double bonds
- Alkynes
  - One or more triple bonds
- Aromatic
  - Six-carbon rings

Organic Compounds

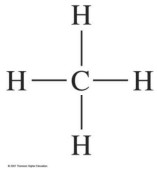
TABLE 1

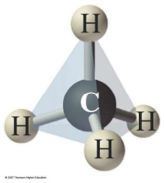


Alkanes

Alkanes

- All carbon atoms connected by single bonds
- General molecular formula: C_nH_{2n+2}
- Simplest is methane, CH_4





- Each atom attains an octet; molecular geometry of methane is tetrahedral.

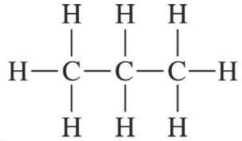
Polarity

- Carbon-hydrogen bonds are mostly polar but any polarity would be symmetrically arranged about the central carbon atom(s).
- Methane's tetrahedral geometry makes it a nonpolar molecule.
  - All other hydrocarbons are nonpolar as well.
- Nonpolar substances are unable to mix with polar substances.

Structural Formulas

- Show the relative positions of atoms in a molecule
- Two-dimensional representation
- Similar to Lewis structures but only bonding electron pairs are shown
- Condensed structural formulas are compactly written structural formulas.

Propane

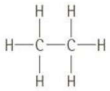
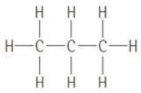
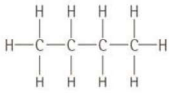


$CH_3CH_2CH_3$

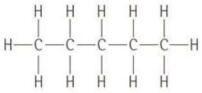
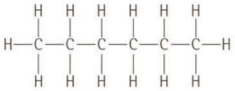
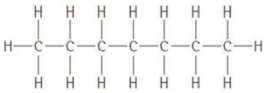
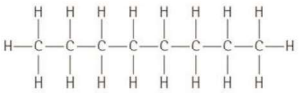
Condensed structural formulas

Alkanes C_nH_{2n+2}

TABLE 2
Alkanes

n	Name	Molecular Formula	Structural Formula	Condensed Structural Formula
$n = 1$	Methane	CH_4		CH_4
$n = 2$	Ethane	C_2H_6		CH_3CH_3
$n = 3$	Propane	C_3H_8		$CH_3CH_2CH_3$
$n = 4$	Butane	C_4H_{10}		$CH_3CH_2CH_2CH_3$

Alkanes

$n = 5$	Pentane	C_5H_{12}		$CH_3CH_2CH_2CH_2CH_3$
$n = 6$	Hexane	C_6H_{14}		$CH_3CH_2CH_2CH_2CH_2CH_3$
$n = 7$	Heptane	C_7H_{16}		$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
$n = 8$	Octane	C_8H_{18}		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_6CH_3$

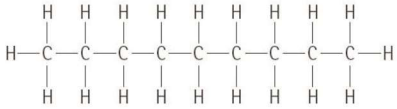
EXAMPLE 6.1

Drawing Structural and Condensed Structural Formulas

Give the molecular formula and draw the structural formula and condensed structural formula for the alkane with nine carbon atoms.

SOLUTION

The molecule contains 9 carbon atoms and therefore $2(9) + 2 = 20$ hydrogen atoms. Its molecular formula is C_9H_{20}. Its structural formula is as follows:



Its condensed structural formula is $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_7CH_3$.

YOUR TURN

Drawing Structural and Condensed Structural Formulas

Give the molecular formula and draw the structural formula and condensed structural formula for the alkane with ten carbon atoms.

The most important property of the alkanes is their flammability:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

TABLE 4

Alkanes and Their Uses

Length of Carbon Chain	Use
$C_1 - C_4$	Fuels such as natural gas, propane, and butane
$C_5 - C_{12}$	Fuels such as gasoline
$C_{12} - C_{18}$	Fuels such as jet fuel
$C_{18} - C_{20}$	Fuels such as central heating fuel
$C_{20} - C_{30}$	Lubricating oils such as engine oil
$C_{30} - C_{40}$	Fuel oils such as ship fuel
$C_{40} - C_{50}$	Waxes and thick oils such as paraffin and petroleum jelly
$> C_{50}$	Tars used in road surfacing

Increasing boiling point

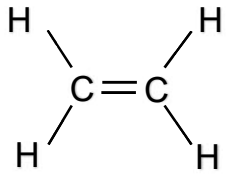
Saturation

- Alkanes C_nH_{2n+2} are saturated; they contain the maximum number of hydrogen atoms per carbon atom.
- Alkenes C_nH_{2n} and alkynes C_nH_{2n-2} are unsaturated. They contain at least one double or triple bond, respectively. They have fewer hydrogen atoms per carbon atom than alkanes.

Alkenes and Alkynes

Alkenes C_nH_{2n}

- Flammable and nonpolar like alkanes
- Double bond makes them more chemically reactive than alkanes



Ethylene

The geometry is trigonal planar about each carbon

TABLE 5 Alkenes C_nH_{2n}

Alkenes

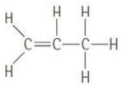
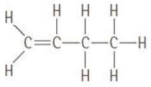
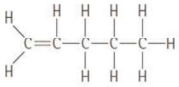
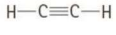
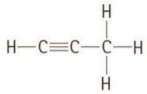
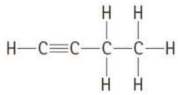
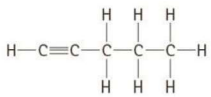
n	Name	Molecular Formula	Structural Formula	Condensed Structural Formula
$n = 2$	Ethene	C_2H_4		$CH_2{=}CH_2$
$n = 3$	Propene	C_3H_6		$CH_2{=}CHCH_3$
$n = 4$	1-Butene	C_4H_8		$CH_2{=}CHCH_2CH_3$
$n = 5$	1-Pentene	C_5H_{10}		$CH_2{=}CHCH_2CH_2CH_3$

TABLE 6 Alkynes C_nH_{2n-2}

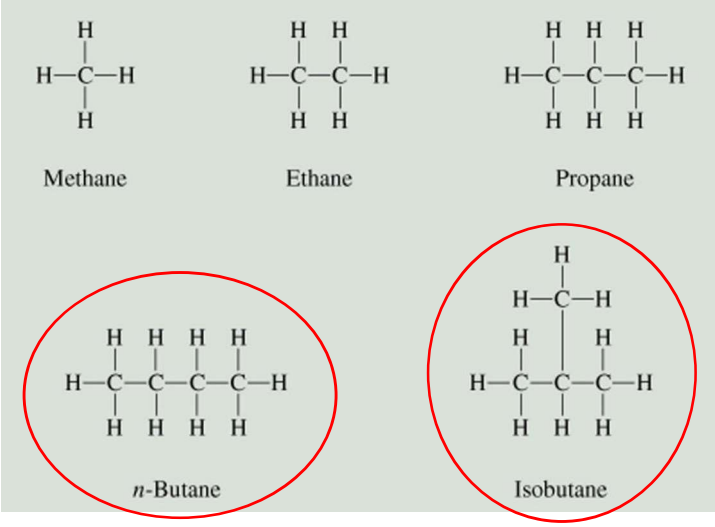
Alkynes

n	Name	Molecular Formula	Structural Formula	Condensed Structural Formula
$n = 2$	Ethyne	C_2H_2		$CH{\equiv}CH$
$n = 3$	Propyne	C_3H_4		$CH{\equiv}CCH_3$
$n = 4$	1-Butyne	C_4H_6		$CH{\equiv}CCH_2CH_3$
$n = 5$	1-Pentyne	C_5H_8		$CH{\equiv}CCH_2CH_2CH_3$

Isomers

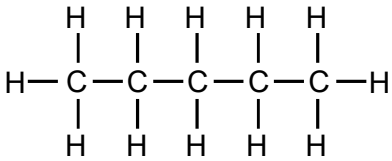
- It is possible for organic compounds to share a molecular formula but have different structures based on the branching of the carbon chain.

- Isomers can differ in their physical and chemical properties.

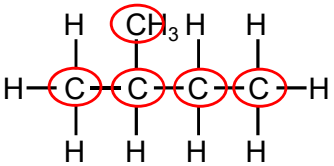


Structural isomers are molecules that have the same molecular formula but different structures

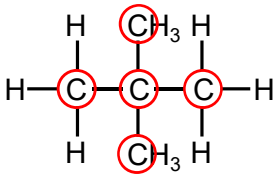
How many structural isomers does pentane, C_5H_{12}, have?



n-pentane



2-methylbutane



2,2-dimethylpropane

How many isomers?

- The number of isomeric alkanes increases as the number of carbons increase.
- There is no simple way to predict how many isomers there are for a particular molecular formula.

Unsaturated Isomers

- Alkenes and alkynes exhibit isomerism based on the position of the multiple bond.

EXAMPLE 6.4

Drawing Structural Formulas for Isomers II

Draw structural formulas for two isomers of pentyne that differ only in the position of the triple bond.

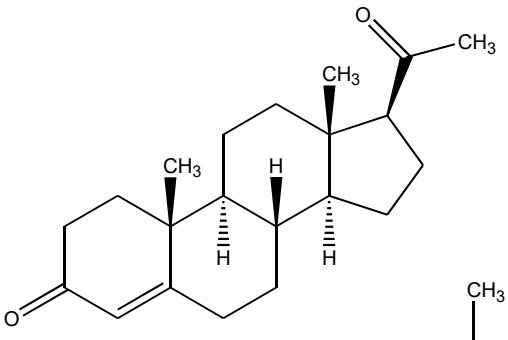
SOLUTION

$CH{\equiv}C{-}CH_2{-}CH_2{-}CH_3$ $CH_3{-}C{\equiv}C{-}CH_2{-}CH_3$

YOUR TURN

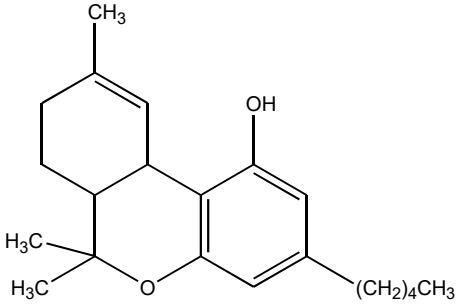
Drawing Structural Formulas for Isomers II

Draw structural formulas for two isomers of hexene that differ only in the position of the double bond.



progesterone
female hormone

tetrahydrocannabinol (THC)
Active component of marijuana



same molecular formula $C_{21}H_{30}O_2$
But very different structures

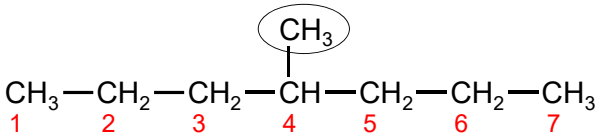
Naming Hydrocarbons

Alkanes

- **Determine the base name of the longest continuous carbon chain.**
- **Consider branches to be substituent of the base chain.**
- **Number the base chain beginning with the end closest to the first branch.**
- **Order the name:**
  - **Number of the substituent followed by a dash**
  - **Name of the substituent**
  - **Base name of the compound**
- **When two or more substituents are present, number each and list them alphabetically.**
- **For two or more substituents on the same carbon, use that number twice.**
- **Use prefixes to denote identical substituents.**

Naming Hydrocarbons

1. select the **longest continuous** chain of carbon atoms in the molecule.



4-methylheptane

2. An alkane less one hydrogen atom is an ***alkyl*** group.

CH_4 methane

CH_3 methyl

✓Number of the substituent followed by a dash
✓Name of the substituent
✓Base name of the compound

Naming Hydrocarbons

2. An alkane less one hydrogen atom is an ***alkyl*** group.

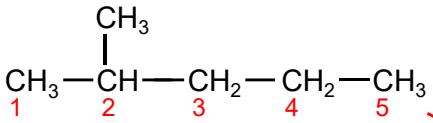
TABLE 24.2 Common Alkyl Groups

Name	Formula
Methyl	$—CH_3$
Ethyl	$—CH_2—CH_3$
n-Propyl	$—CH_2—CH_2—CH_3$
n-Butyl	$—CH_2—CH_2—CH_2—CH_3$
Isopropyl	$—CH(CH_3)_2$
t-Butyl*	$—C(CH_3)_3$

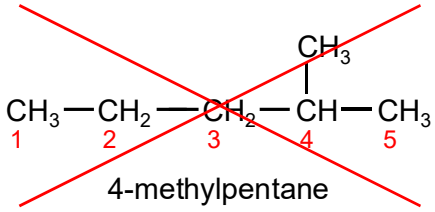
○Other substituents:
-NO_2: Nitro-
-NH_2: Amino-
-Cl : Chloro-
-Br : Bromo-

Alkane Nomenclature

3. Number the chain in the direction that gives the smaller numbers for the first branch.



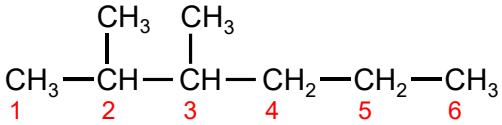
2-methylpentane



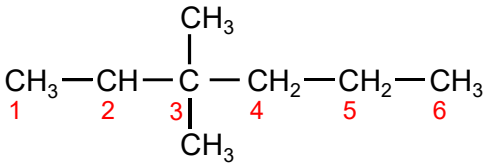
4-methylpentane

Alkane Nomenclature

4. Use prefixes *di-, tri-, tetra-*, when there is more than one alkyl branch of the same kind.



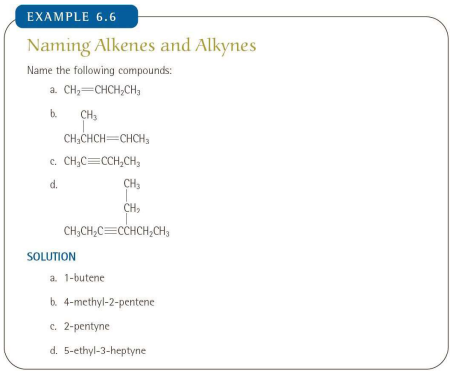
2,3-dimethylhexane



3,3-dimethylhexane

Naming Alkenes and Alkynes

- Similar to alkanes except for the addition of a number at the beginning to indicate the position of the multiple bond(s)
- Number the base chain beginning with the end closest to the double/triple bond.



EXAMPLE 6.6

Naming Alkenes and Alkynes

Name the following compounds:

a. $CH_2{=}CHCH_2CH_3$

b. $CH_3CHCH{=}CHCH_3$ (CH_3 branch on the second carbon)

c. $CH_3C{\equiv}CCH_2CH_3$

d. $CH_3CH_2C{\equiv}CCHCH_2CH_3$ (CH_3 and CH_2 branches on the third carbon)

SOLUTION

a. 1-butene

b. 4-methyl-2-pentene

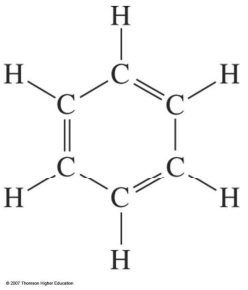
c. 2-pentyne

d. 5-ethyl-3-heptyne

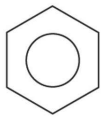
Kekule and Aromaticity

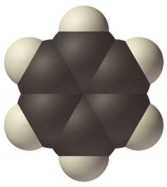
- **Aromatic hydrocarbons are planar molecules, usually with one or more rings of 6 C atoms and are often drawn with alternating single and double bonds.**
- Proposed benzene as a ring of 6 carbon atoms with altering single and double bonds:
- Each bond is now considered to be midway between a double and a single bond.
- Modern representation is a circle within a hexagon.

C_6H_6



Benzene



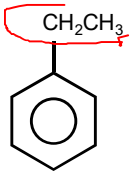


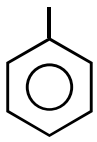
The Benzene Ring

- Particularly stable
- When the ring contains substituents it is called a phenyl ring.
- Also called aromatic ring due to the notable aroma of many compounds containing such a ring
- Two or more fused such rings make polycyclic aromatic hydrocarbons.

Aromatic Compound Nomenclature

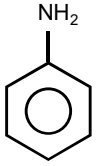
ethylbenzene

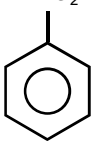




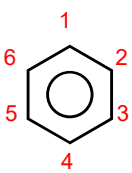
chlorobenzene

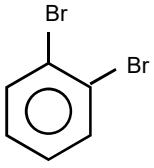
aminobenzene



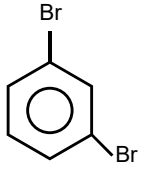


nitrobenzene





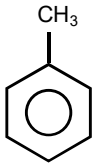
1,2-dibromobenzene



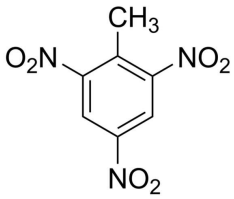
1,3-dibromobenzene

Aromatic Compound Nomenclature

methylbenzene



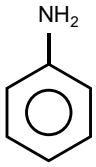
Toluene



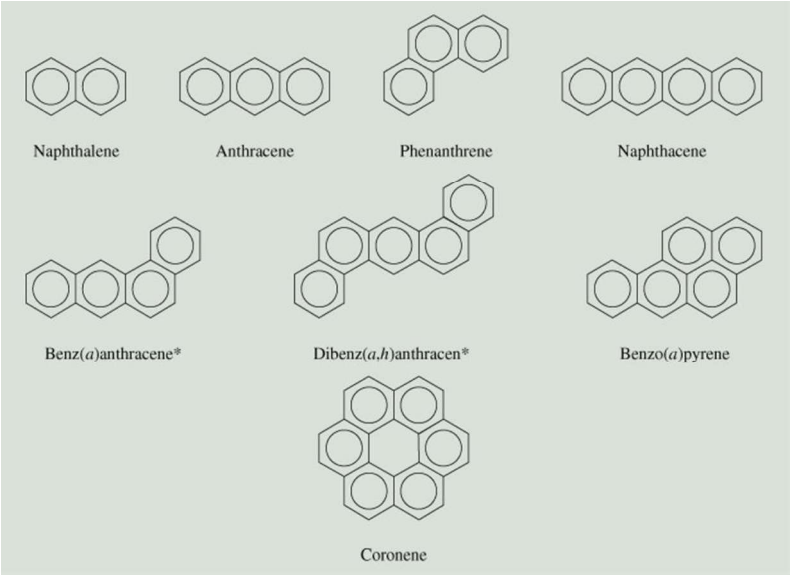
1-methyl-2,4,6-trinitrobenzene

1-Chloro-4-methylbenzene

aminobenzene

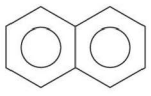


Polycyclic Aromatic Hydrocarbons

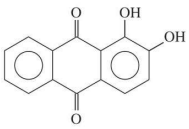


Common Examples

Naphthalene

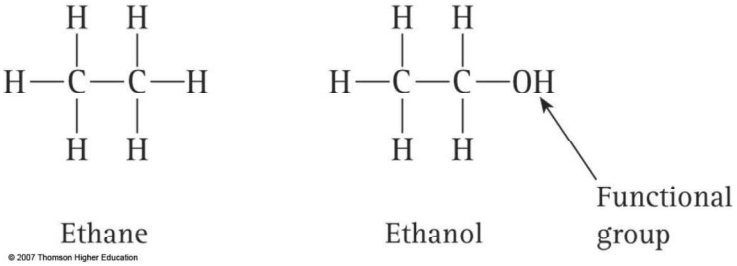


Alizarin



Functionalized Hydrocarbons

- Basic hydrocarbon structures form a foundation for a major grouping of organic compounds.
- Contain additional atoms or groups of atoms (OH, NH_2,
- Insertion of functional groups to a hydrocarbon dramatically alters its properties.



Representing Functionality

Compounds containing the same functional group are called a family.

Generic symbolism is R-FG where R is the hydrocarbon part of the molecule and FG is the functional group.

R-OH symbolizes the alcohols.

Functional groups help organize and classify organic compounds.

Chlorinated Hydrocarbons

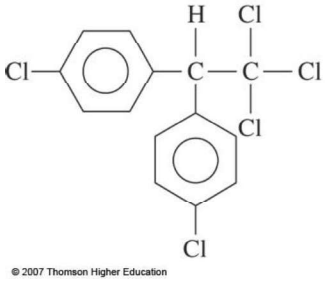
Have the general formula: R-Cl

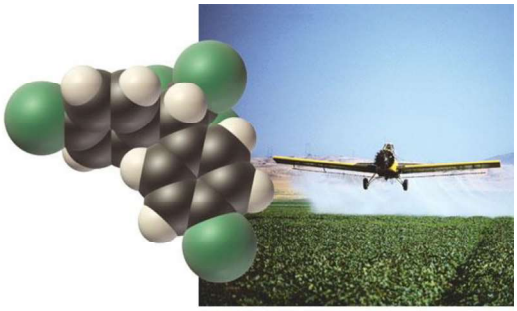
Example: CH_2Cl_2

- 2 Cl atoms have taken the place of 2 H in CH_4
- CH_2Cl_2 is a liquid often used as a solvent.
- CH_2Cl_2 was used to extract caffeine from coffee

Chlorinated Hydrocarbons

- Found in pesticides, solvents, refrigerant liquids
- One or more chlorine atoms substitute for one or more hydrogen atoms
- Lower flammability and reactivity than hydrocarbons





DDT

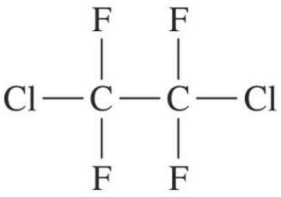
- Muller demonstrated effectiveness against insects and relative non-toxicity to humans.
- DDT attacked insects killing mosquitoes, flies, beetles, …..
- Its Stability made it efficient.
- Dramatically decreased malaria in many countries
- Muller awarded Nobel Prize in 1948

Problems with DDT

- Some insects became resistant to DDT
- DDT began to accumulate in the soil and in water supplies.
- Aquatic plants began to have traces of DDT in their cells.
- Fish that ate the plants and birds that ate the fish began to die
- Today DDT is banned in most developed countries

CFCs (Ozone eaters)

- Chlorofluorocarbons are a subfamily of chlorinated hydrocarbons.
- Chemically stable . . .
- Used for industrial aerosols, solvents, air-conditioning and refrigeration coolants
- Until they reach the high-energy sunlight in the upper atmosphere
- Ozone destruction led to bans (jan.1996)



Alcohols

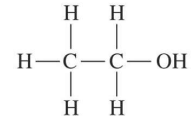
- General formula: R-OH
- Additional of the –OH makes alcohols polar.
- Increased intermolecular attractive forces makes alcohols liquids.
- Naming involves modifying the hydrocarbon name with an ending of –ol.

Ethanol

- Alcoholic beverages
- Gasoline additive
- Sugar fermentation (fruits and grains)

$$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$$

Ethanol

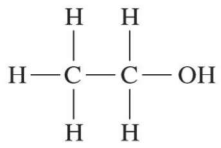


- The proof of a liquor is twice its alcohol percentage by volume (90-proof whiskey)

Ethanol

- CNS depressant-it slows the rate at which nerve impulses travel
- Alcoholics are two to three times more likely to develop heart disease and respiratory diseases.

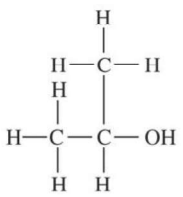
Ethanol



Other Alcohols

- Isopropyl alcohol is commonly known as rubbing alcohol.
- Useful for disinfecting cuts and scratches
- More toxic than ethanol

Isopropyl alcohol



Other Alcohols

- Methanol is toxic to the human liver.
- Methanol is converted into formic acid in the liver
- Formic acid gets into the blood stream and causes acidosis (lethal)

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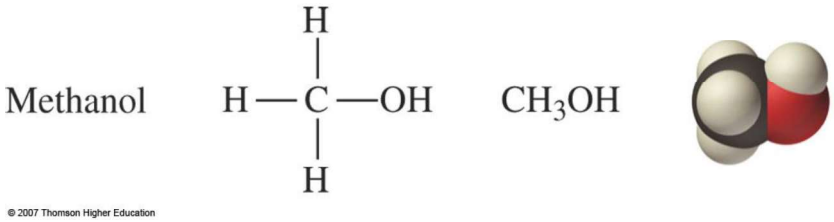
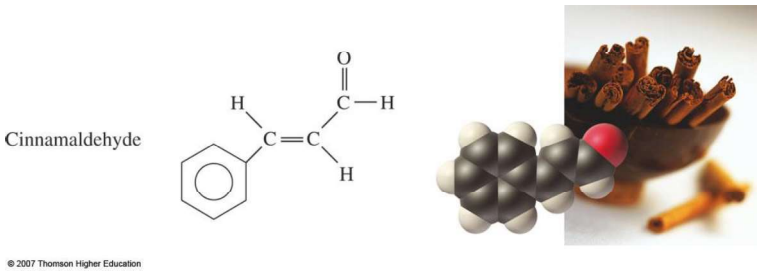


Aldehydes and Ketones

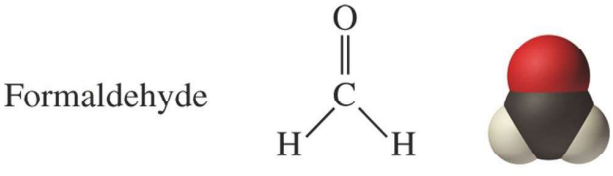
- Commonly found in pleasant flavors and aromas
- Contain the carbonyl group: Carbon double bonded to an oxygen atom (C=O)



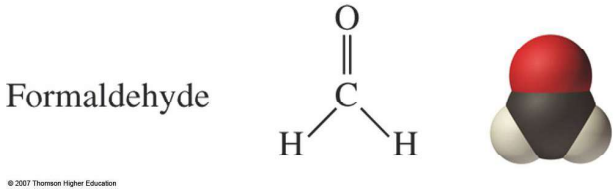
Cinnamaldehyde gives cinnamon its distinctive smell and flavor

Formulas

- Aldehydes
  - General formula: RCHO, includes carbonyl group
  - Named according to length carbon chain with the ending of –al or –aldehyde
  - Methanal or formaldehyde



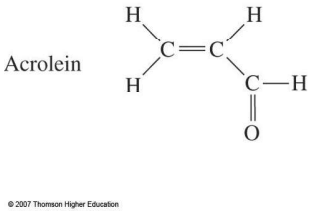
Formaldehyde



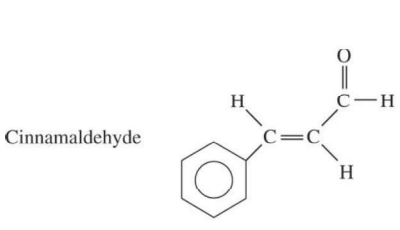
- Very toxic to bacteria
- Preservation of biological specimens
- present in wood smoke.
- It is responsible for the burning and tearing of eyes around a campfire.

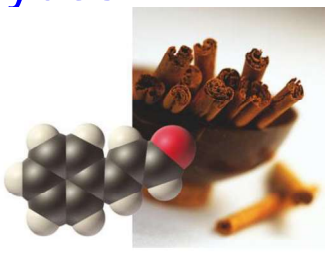
Acrolein

- formed when molecules in some foods decompose during heating
- its smell is enjoyed when barbecuing meats
- Its flavor is found in caramelized sugar



Other Aldehydes





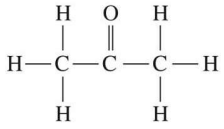
Cinnamaldehyde gives cinnamon its distinctive smell and flavor

Benzaldehyde is also called oil of almond

Formulas

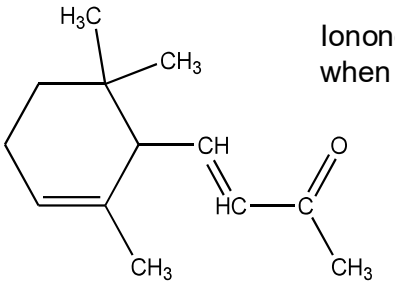
- Ketones
  - Similar to aldehydes but have two R groups with the carbonyl
  - Names end in –one
  - Acetone is the simplest ketone.

Acetone



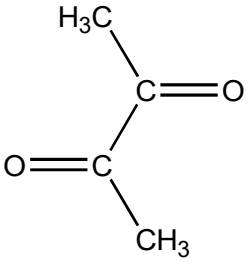
fingernail polish removal

Ketones



Ionone is the molecule you smell when picking and eating raspberries

Butanedione has a cheezy smell, found in butter and body odor

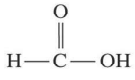


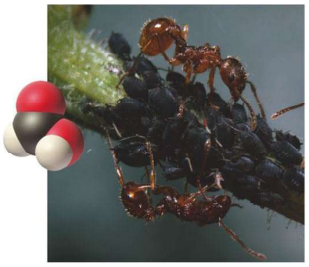
Bacteria feast on fresh sweat and emit butanedione as a waste product

Carboxylic Acids

- Commonly found in sour foods (citrus fruits, vinegar, ….
- General formula: RCOOH
- One of these oxygen atoms is bonded as a carbonyl group, as in aldehydes and ketones.

Formic acid





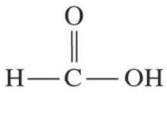
Formic Acid

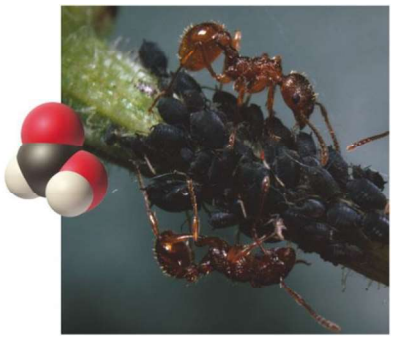
-Its name is derived from the latin *formica* meaning “ant”

-responsible for the sting of biting ants

-also injected by bees and wasps when they sting

Formic acid

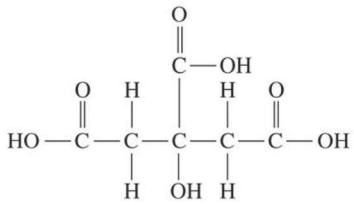




Citric acid

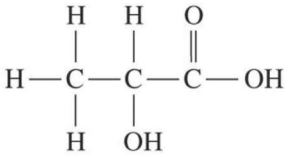
Causes the sour flavor in lemons, limes, and oranges

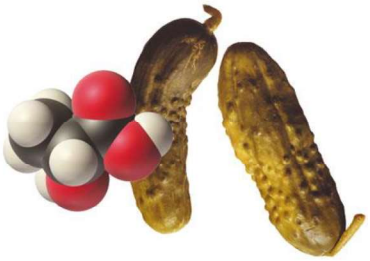
Citric acid



Lactic acid

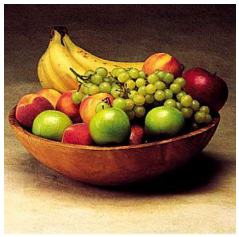
Lactic acid





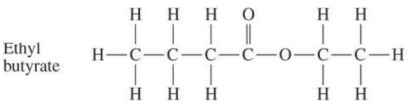
The build-up of lactic acid in muscle tissues during heavy exercises lead to the feeling of tiredness

Esters

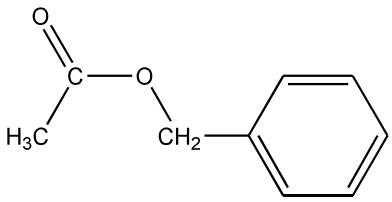


- Esters have pleasant odors.
- General formula: RCOOR
- Named according to the relevant R groups and ending with –ate

Ethyl butyrate



Esters



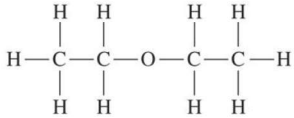
benzyl acetate

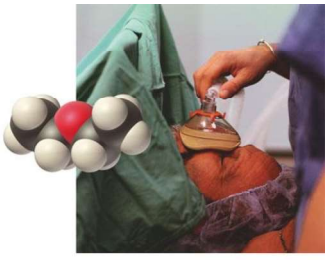
- Several perfumes use esters
- Oil of jasmine contains benzyl acetate
- It is easier and cheaper to synthesize benzyl acetate rather than extract it from Jasmine

Ethers

- Ethers contain the functional group -O-
- General formula: ROR
- Named according to the two R groups and given the ending ether

Diethyl ether

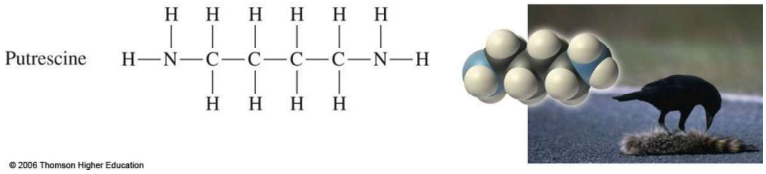




- Formerly used as an anesthetic
- Terminated because of side effects (severe nausea)

Amines

- Amines are organic compounds that contain nitrogen.
- General formula: NR_3
- Notable for unpleasant odors: $(CH_3)_3N$ rotting fish)
- Named for R groups present and ending in –amine



One of the components of decaying animal flesh

Chemical Explosives

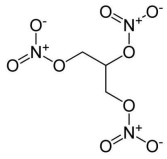
- For a substance to be a chemical explosive, it must undergo a chemical reaction that
  - releases a lot of energy, making the temperature and gas pressure rise rapidly.
  - produces lots of gas, leading to an increase in gas pressure.
  - does this very quickly, leading to a rapid expansion of the gas.

Combustion of Propylamine

$$4C_3H_7NH_2(l) + 21O_2(g) \rightarrow 12CO_2(g) + 18H_2O(g) + 2N_2(g) + 8668\ kJ$$

- Releases a lot of energy
- Produces a lot of gas
- Does this too slowly to yield the high temperature and pressure necessary for the substance to be explosive.
- Goal: to speed up the process
- Solution: add the oxygen atoms necessary for the reaction to the combustible material

Nitroglycerine



$$4C_3H_5N_3O_9(l) \rightarrow 6N_2(g) + 10H_2O(g) + 12CO_2(g) + O_2(g) + 9174\ kJ$$

- First and most widely produced nitrate ester explosive
- Produces gases that would have a volume 1200 times the original volume at room temperature and pressure.
- Temperature rises to about 5000 °C (about 9000 °F)
- Produces a shock wave moving about 30 times speed of sound – detonation velocity ≅ 7700 m/s

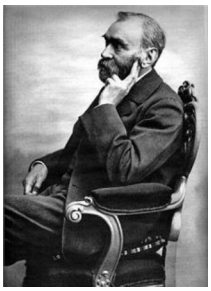
http://www.youtube.com/watch?v=r17czTWHFmU

Nitroglycerine

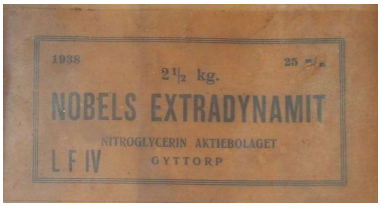
- Very sensitive to impact, so dangerous when pure
- Liquid forms microscopic bubbles that are more likely to react and start the detonation.
- Mixed with other substances and used in dynamite and propellants.
- More stable when absorbed in powdered absorbent (e.g. diatomaceous earth or sawdust), which minimizes microscopic bubbles.
  - Diatomaceous earth = ground up sedimentary rock formed from fossilized diatoms

Alfred Nobel's Contribution

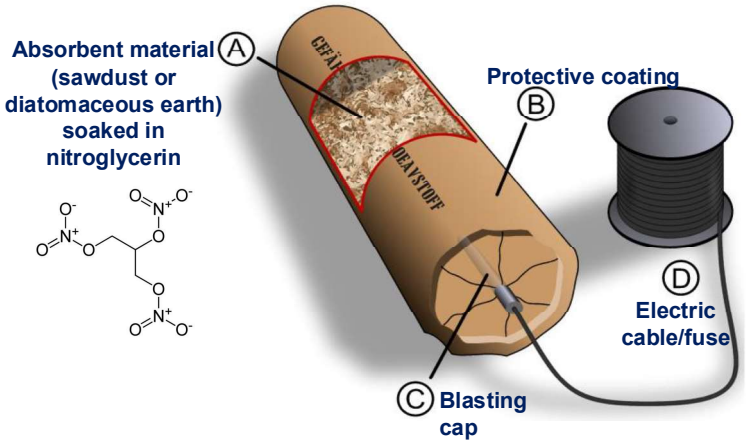
- Swedish chemist, engineer, innovator, and armaments manufacturer with 355 patents
- Most famous patent: Dynamite
- Invented first plastic explosive: Gelignite or 'blasting gelatin'
- Became rich due to these patents
- Willed his fortunes to creation of the "Nobel Prize"



1833-1896



Dynamite
(Originally, "Nobel's Blasting Powder)



At time of it's invention (1860s), dynamite was the first safe and manageable chemical explosive.

Terms Related to Explosives

- **Explosion** = large-scale, noisy, rapid expansion of matter into a volume greater than the original volume
  - Can be due to a very fast *burning* of a material
  - Can be due to *detonating* an explosive material

- **Burning** (or **deflagration**) = relatively slow reaction (propagation less than the speed of sound)

- **Detonation** = very fast reaction (propagation greater than speed of sound, about 340 m/s)

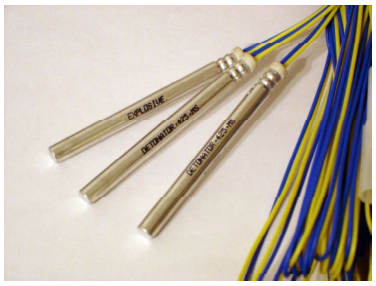
Terms Related to Explosives

- **High explosive** = chemical that can detonate
  - **Primary** = very easy to detonate with flame, heat or shock (e.g. lead azide, PbN_6 or $Pb(N_3)_2$)
  - **Secondary** = do not easily go from burning to detonation (e.g. TNT and RDX)
  - **Tertiary** = hardest to detonate = insensitive high explosives, IHE (e.g. ANFO)

- **Low explosive** = cannot be caused to detonate by a common blasting cap
  - **Pyrotechnics** = when burned, produce heat, light, smoke, gas, and/or sound
  - **Propellants** = produce gases used to do mechanical work, such as propel a projectile or push a piston, e.g. black powder (charcoal, sulfur, and potassium nitrate) or nitrocellulose.

Terms Related to Explosives

- **Blasting cap** = a small, sensitive primary explosive device used to detonate a larger, more powerful and less sensitive secondary explosive, such as TNT, dynamite, or plastic explosive.
  - Main explosive designed to be insensitive enough to be easily handled without worry of detonation.
  - Blasting cap can be added just before detonation.



Terms Related to Explosives

- **Shock wave** = a high-pressure wave that moves through material at a speed faster than the speed of sound in that material.

- **Fragments and shrapnel** = missiles, e.g. from casings and other solid materials, that are scattered from an explosion.

Explosives

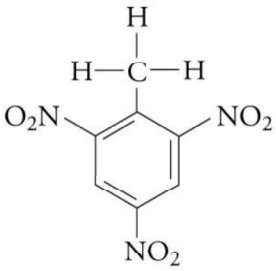
- Most explosives are composed of carbon, nitrogen, hydrogen, and oxygen… $C_cH_hN_nO_o$.

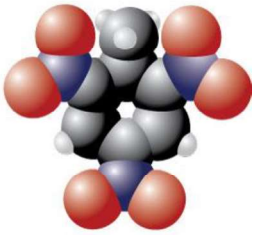
- Guidelines for the order of formation of products
  - Nitrogen forms $N_2(g)$
  - Hydrogen forms $H_2O(g)$
  - Any oxygen left converts carbon to $CO(g)$
  - Any oxygen left converts $CO(g)$ to $CO_2(g)$
  - Any oxygen left forms $O_2(g)$
  - Traces of $NO(g)$ and $NO_2(g)$ are always formed.

Underoxidized or Fuel Rich Explosives

- Not enough oxygen to form CO_2
- Trinitrotoluene, TNT

$$2C_7H_5N_3O_6(s) \rightarrow 3N_2(g) + 5H_2O(g) + 7CO(g) + 7C(s)$$





TNT

- More produced than any other military explosive
- Stable, insensitive to shock, and nontoxic
- Carbon solid formed causes sooty appearance when pure TNT detonated
- Often mixed with oxygen-rich substances (e.g. ammonium nitrate) to convert the carbon to CO or CO_2, yielding more energy.
- Low melting point (81 °C) and relative safety so often blended with other explosives.
- Detonation velocity of ≅ 6900 m/s

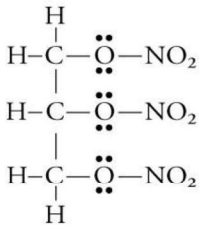
TNT-Equivalent

- **TNT Equivalent** = a measure of the energy released in an explosion
- **Ton** (or tonne) **of TNT** = 4.184 GJ (gigajoule or 10^9 joule) = approximate energy released in the detonation of one metric ton of TNT
- **Megaton** = 1 PJ (petajoule) = 10^{15} J
  = approximate energy released in the detonation of one megaton of TNT

Overoxidized or Fuel Lean Explosives

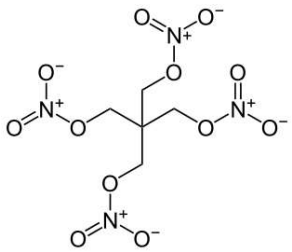
- Enough oxygen to form CO_2
- Nitroglycerine (nitroglycerol)

$4C_3H_5N_3O_9(l) \rightarrow 6N_2(g) + 10H_2O(g) + 12CO_2(g) + O_2(g) + 9174\ kJ$



PETN (pentaerythritol tetranitrate)

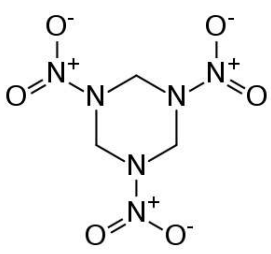
- One of the most sensitive of the secondary explosives
- Rarely used alone
- 1.66 relative effectiveness (R.E.) factor (measurement of explosive power for military purposes compared to TNT as 1)
- Detonation velocity ≅ 8400 m/s



Research Department Explosive, RDX (T4)

- Less sensitive than PETN
- High detonation velocity (≅ 8700 m/s)
- Relative effectiveness factor of 1.6

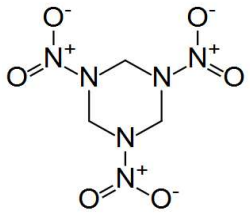
$2C_3H_6N_6O_6(s) \rightarrow 3N_2(g) + 3H_2O(g) + 3CO(g)$



C-4, a Plastic (Putty) Explosive

- **Plastics (putty) explosives** = an explosive that has been mixed with plasticizers, resulting in a moldable clay-like material that can be configured into any shape you want.
- C-4 is a very common explosive, can be molded by hand, used by U.S. military
- Composed of about 91% explosive (RDX), 5.3% plasticizer, 2.1% binder, and odorizing agent (for detection and identification)

"RDX" (cyclotrimethylene trinitramine)



Semtex

- Plastic explosive with both RDX and PETN
- Easily-malleable and waterproof
- Useful over greater temperature range than other plastic explosives
- Widely exported in past
  - Vietnam War: North Vietnam received 14 tons
  - Used in 1988 Pan Am Flight 103 hijacking (~300 killed)
- Producer adds a chemical to aid detection (produces a unique chemical vapor signature)

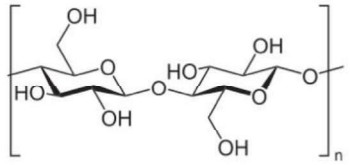
Propellants (Gun Powder)

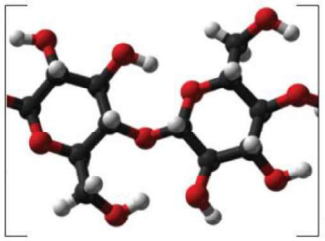
- Low explosives, burn (deflagrate), not detonate
- Produces a lot of gas - $CO_2(g)$, $H_2O(g)$, $N_2(g)$ - which expands rapidly, propelling an object, such as a bullet.
- Example: black powder
  - Fuel: sulfur and charcoal
  - Oxidizer: usually potassium nitrate, KNO_3
  - Produces some solid substances, e.g. $K_2S(s)$, K_2CO_3, K_2SO_4, producing smoke

Propellants – Smokeless Powder

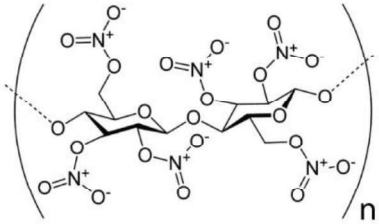
- **Single-base powder –** nitrocellulose, made by reacting cellulose, such as found in cotton, with nitric acid.
- **Double-base powder –** a mixture of nitroglycerine and nitrocellulose, e.g. Cordite

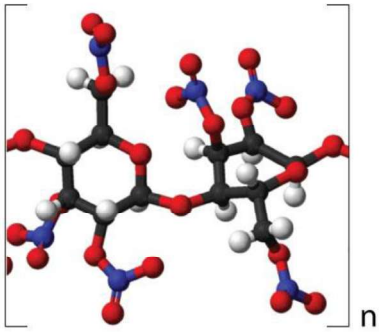
Cellulose





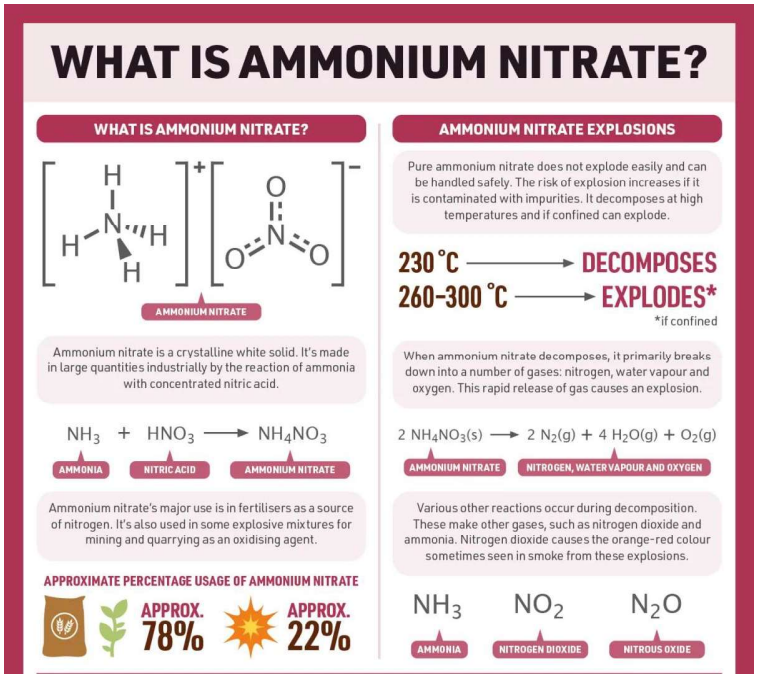
Nitrocellulose



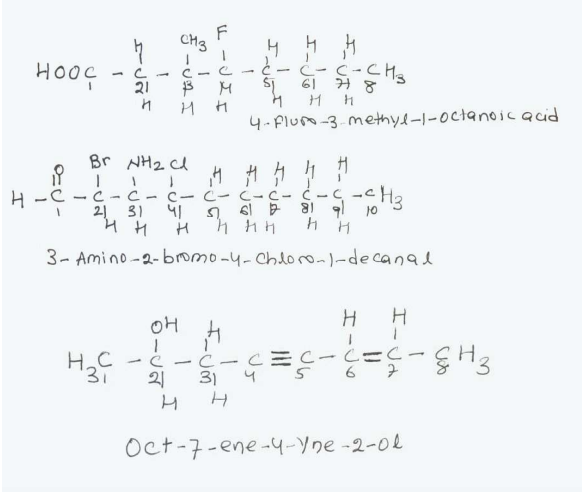


Inorganic Explosives

- Ammonium nitrate, NH_4NO_3
  - Rather poor explosive
  - Very overoxidized
  - Difficult to initiate
  - Mixed with other explosives (e.g. ammonium nitrate fuel oil, ANFO)
- Lead azide, $Pb(N_3)_2$ or PbN_6
  - Extremely sensitive to sparks, friction, and impact
  - Major initiating explosive used in most blasting caps



Q: Write the structure of the following compounds
4-Fluoro-3-methyl-1-octanoic acid
3-Amino-2-bromo-4-chloro-1-decanal
Oct-6-ene-4-yne-2-ol



4,5,6,7-Tetraethyl-2,3-dimethlynon-2-ene-1-ol
4-Bromo-4-methly-2-octanone