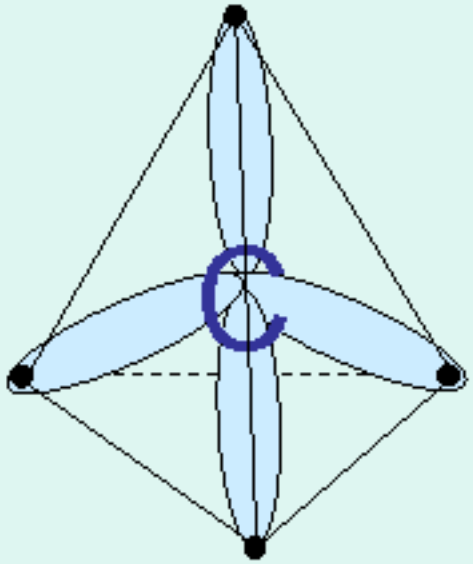
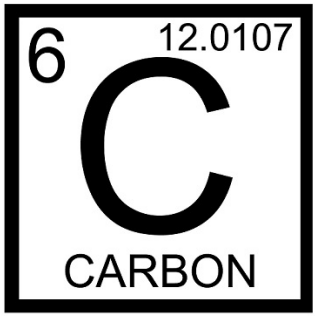
Organic Chemistry

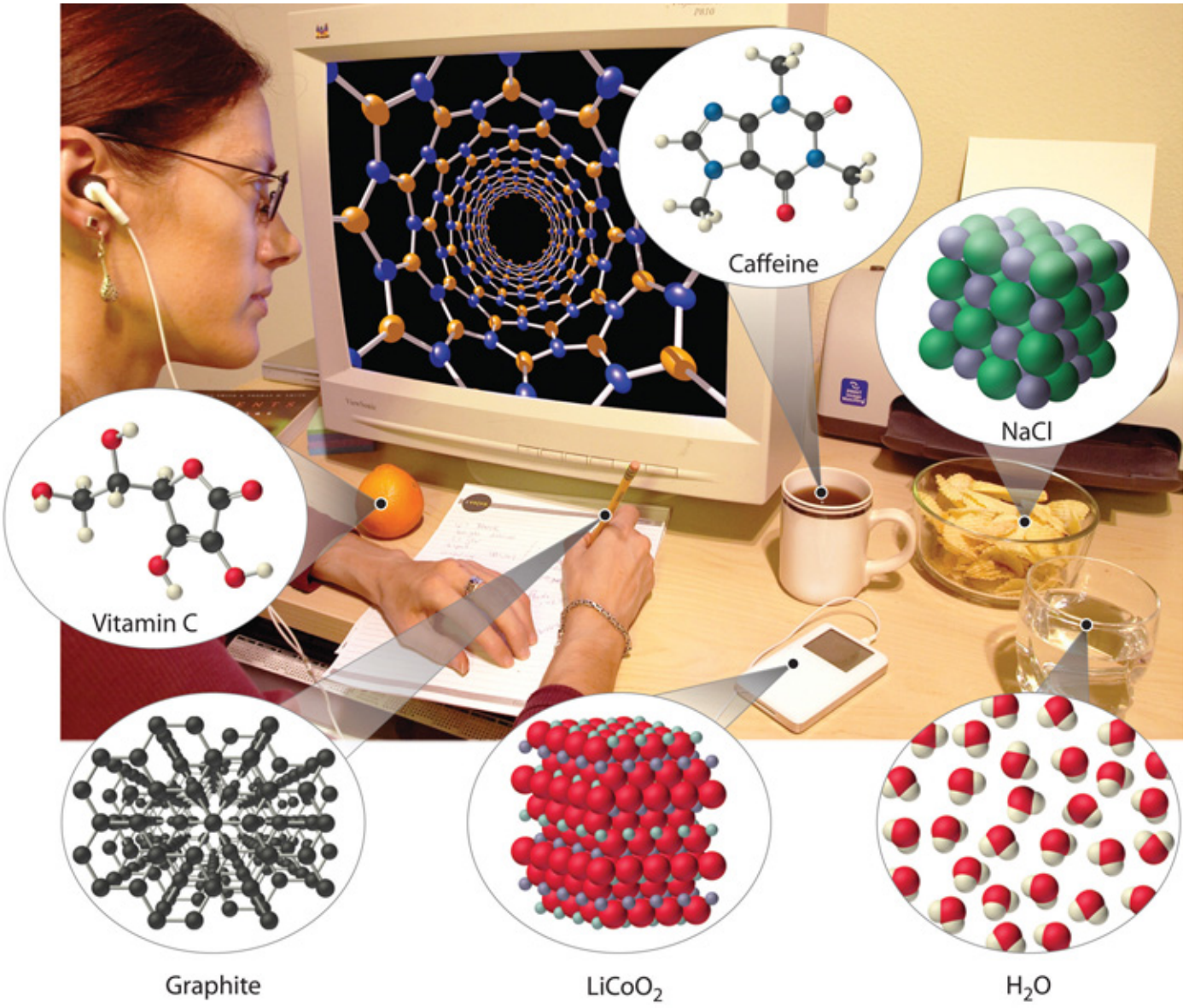


The Chemistry of Carbon



Applications of organic chemistry

Which of these are organic?



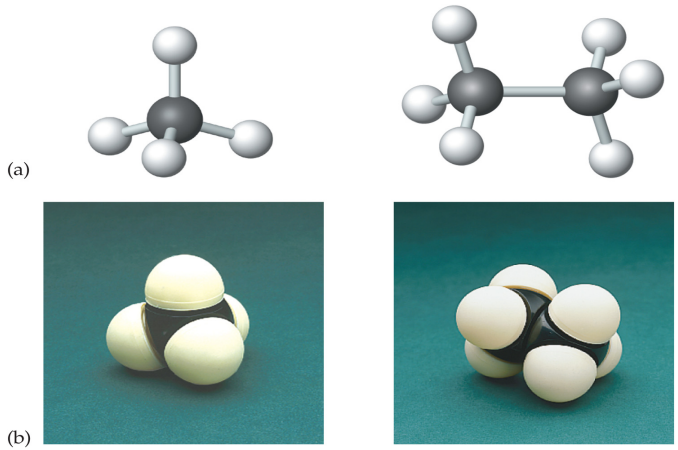
Organic chemistry is defined as the chemistry of carbon compounds.

- Of tens of millions of known chemical compounds, over **95% are compounds of carbon.**

- **Carbon** is unique in that it has carbon atoms which can have four bonds which can attach to other carbon to form long chains and rings.

Alkanes

- **Alkanes** are hydrocarbons that contain only single bonds. Because all carbon-to-carbon bonds are single bonds, alkanes are often called **saturated** hydrocarbons.
- The simplest hydrocarbon is methane (CH_4).
- The general formula of alkanes is $\mathbf{C_nH_{2n+2}}$.



Alkanes

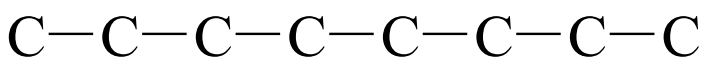
The alkanes represent a **homologous series** that differ by the number of $-CH_2-$ groups. Members show properties that differ in a predictable manner.

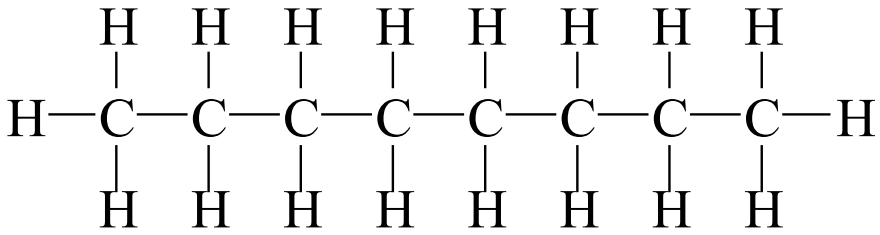
TABLE 25.1 First Several Members of the Straight-Chain Alkane Series

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

Writing the Structural and Condensed Formula for the n-Alkane C_8H_{18}.

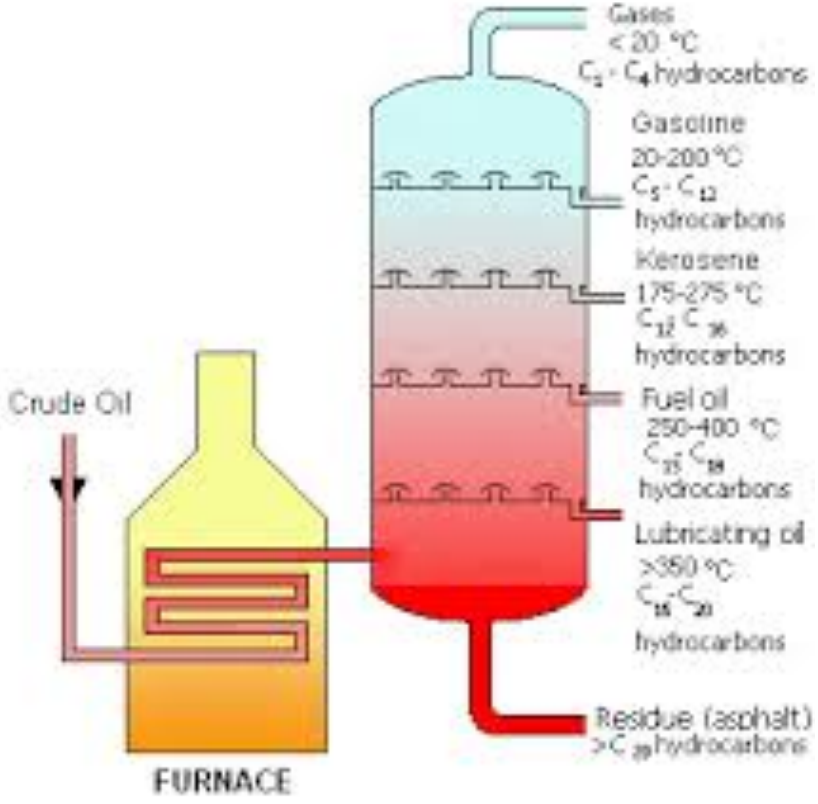
- Connect the C atoms in a row.
  - Carbon skeleton.
- Add H to complete four bonds on each C.
  - Middle C gets 2 Hs.
  - End C gets 3 Hs.
- The condensed formula has the H attached to each C written directly after it.





$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

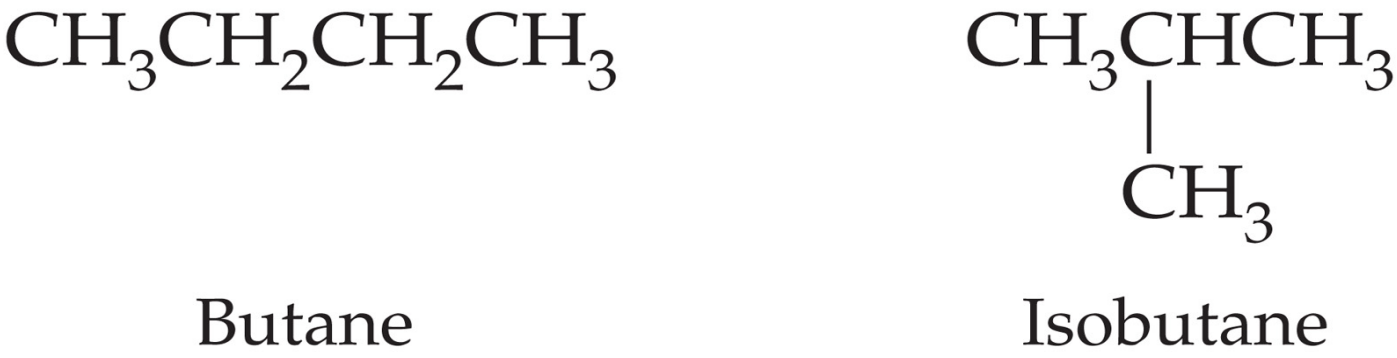
Where do you find alkanes in everyday life?



Alkanes

Isomerism:

Isomers are compounds with the same molecular formula but different structural formulas.



Butane Isobutane

Uses of Alkanes

Number of C atoms	State	Major uses
1–4	Gas	heating and cooking fuel
5–7	Liquids (low boiling)	solvents, gasoline
6–18	Liquids	gasoline
12–24	Liquids	jet fuel, camp stove fuel
18–50	Liquids (high boiling)	diesel fuel, lubricants, heating oil
50+	Solids	petroleum jelly, paraffin wax

Crude Oil

https://www.youtube.com/watch?v=62LvVYYqUFA

Carbon Footprint

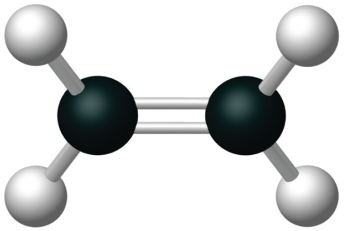
http://www.nature.org/greenliving/carboncalculator/

https://www.youtube.com/watch?v=mAjrnZ-znkY

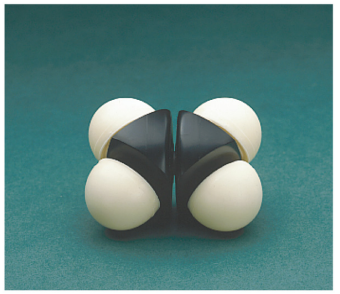
Alkenes

- Unsaturated hydrocarbons that contain C=C are called **alkenes**. General formula is C_nH_{2n}.

- Their names begin with a prefix deno
the number of carbon atoms followed
the suffix **–ene**.



(a)



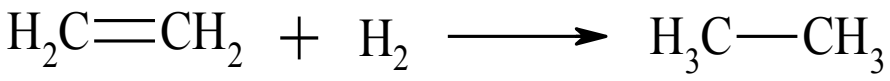
(b)

- **Ethylene** is the simplest alkene.
It ripens fruit and vegetables.

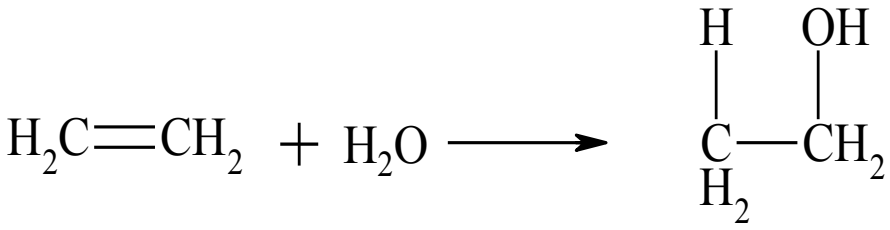
Reactions of Alkenes

Addition Reactions

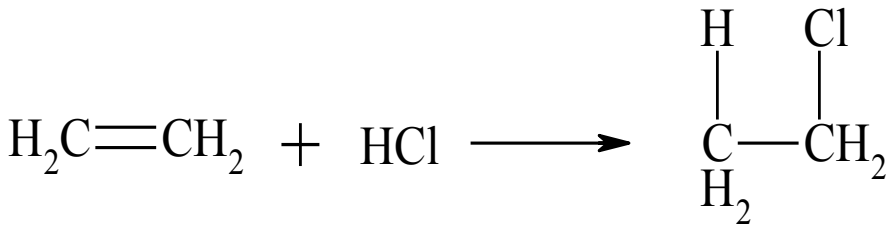
Hydrogenation



Hydration



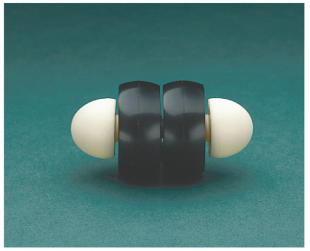
Hydrohalogenation



Alkynes

- Unsaturated hydrocarbons that contain C≡C are called **alkynes**.
- General formula is C_nH_{2n-2}.
- Their names begin with a prefix denoting the number of carbon atoms followed by the suffix –yne.
- **Ethyne (acetylene)** is the simplest alkyne. (torches)

(a)



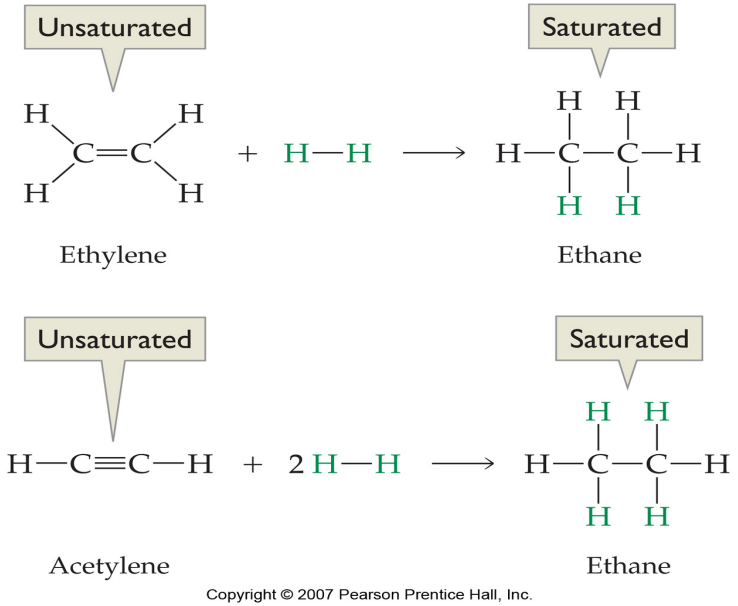
(b)

Unsaturated Hydrocarbons

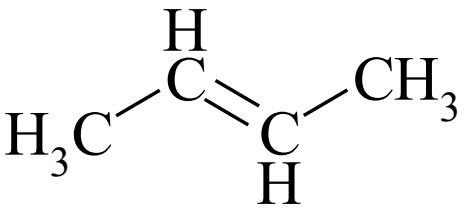
Both alkenes and alkynes are **unsaturated hydrocarbons**.

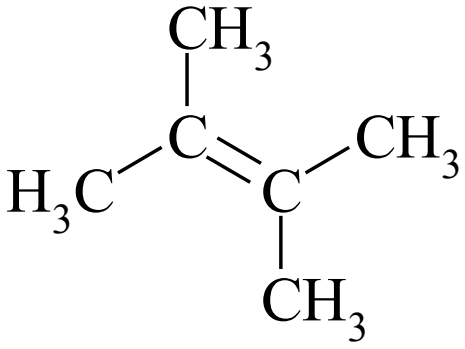
A saturated hydrocarbon has the maximum number of hydrogen atoms attached to each carbon and no double or triple bonds.

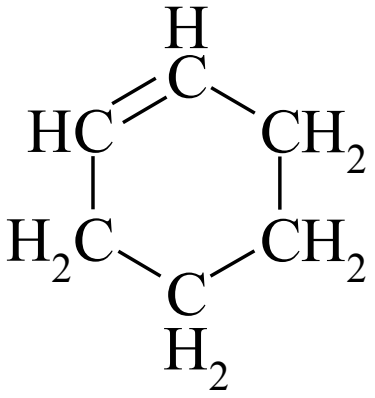
Unsaturated hydrocarbons can undergo an **addition reaction**:

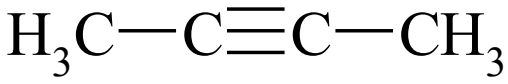


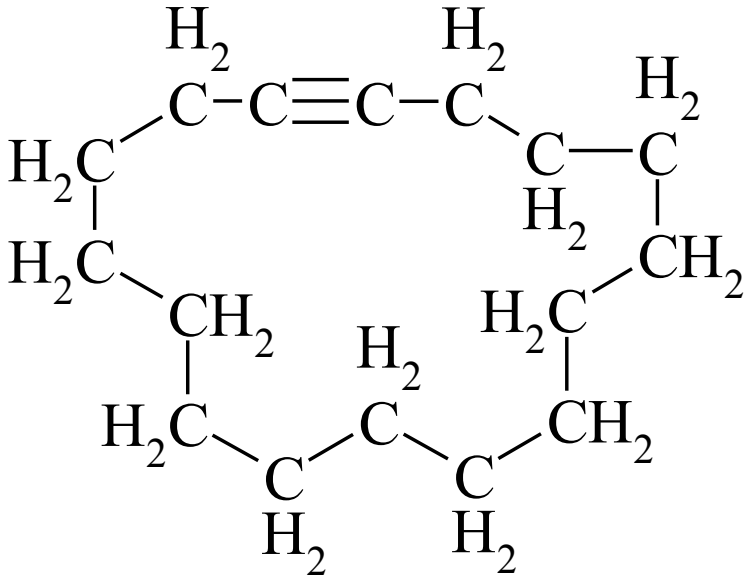
Identify Unsaturated Hydrocarbons



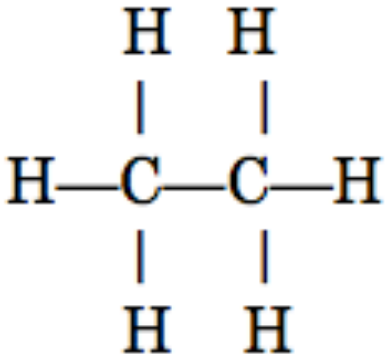


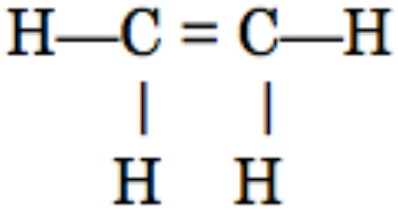


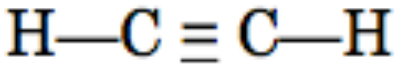




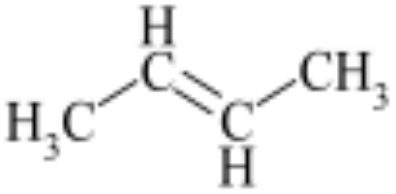
Which of the following is a saturated hydrocarbon?

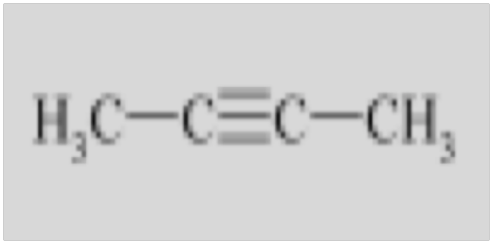
A. 

B. 

C. 

What is the name of the following?

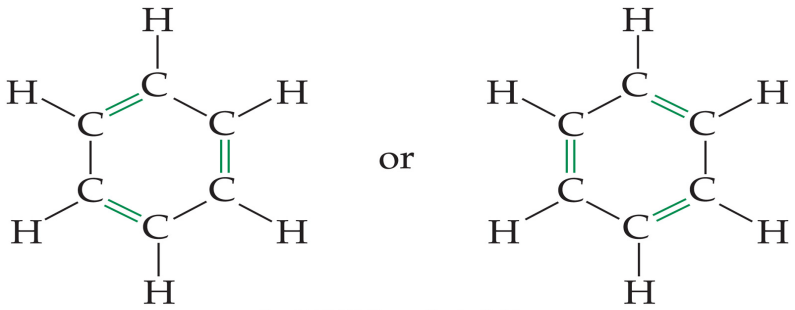
A. 

B. 

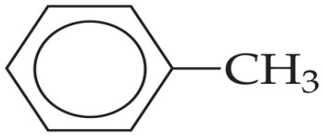
C.

Aromatic Hydrocarbons: Benzene and Relatives

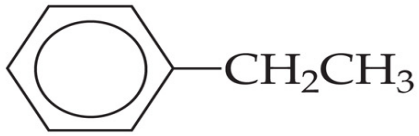
Benzene is a unique organic compound in that it is a very stable six-sided ring. **Aromatic** hydrocarbons contain a benzene ring or have properties similar to those of benzene.



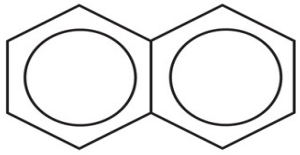
Aromatic Hydrocarbons: Benzene and Relatives



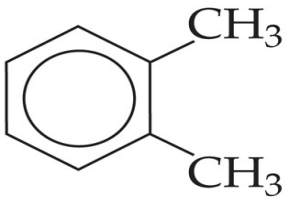
Toluene



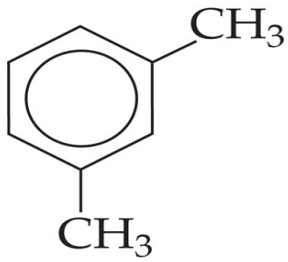
Ethylbenzene



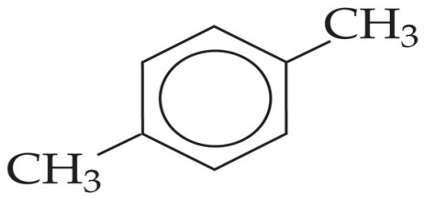
Naphthalene



ortho-Xylene
(1,2-Dimethylbenzene)

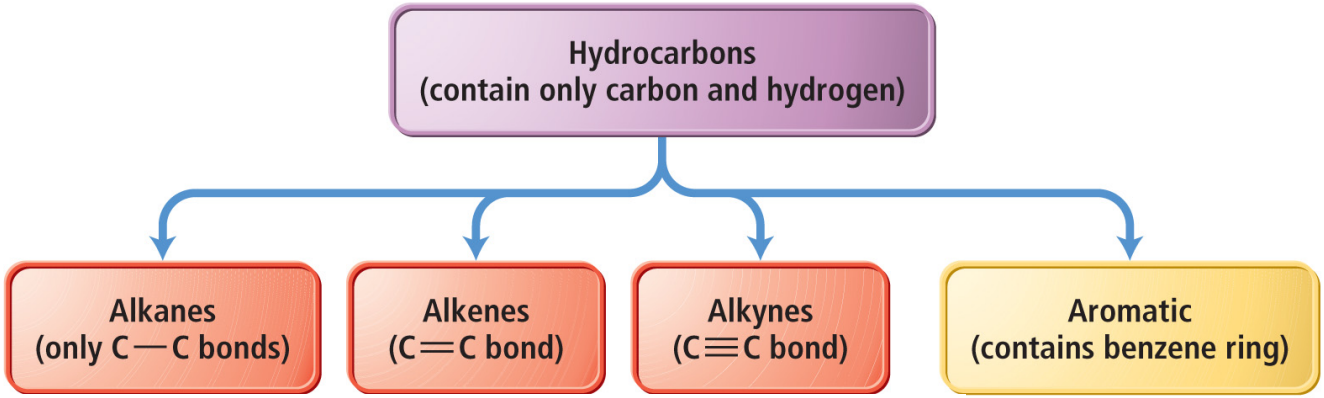


meta-Xylene
(1,3-Dimethylbenzene)

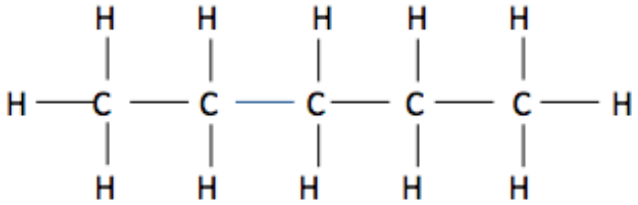


para-Xylene
(1,4-Dimethylbenzene)

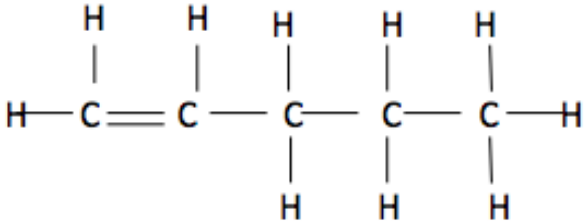
Summary: Types of Hydrocarbons



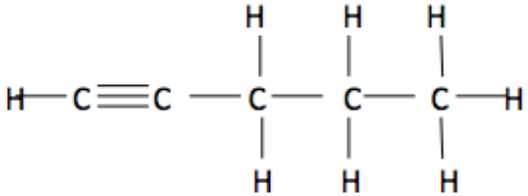
pentane



pentene



pentyne



Practice—Assuming Only Chains with a Maximum of One Unsaturation, Decide if Each of the Following Molecular Formulas Represents an Alkane, Alkene, or Alkyne.

- $C_{14}H_{28}$
- $C_{25}H_{52}$
- C_6H_{10}

Practice—Assuming Only Chains with a Maximum of One Unsaturation, Decide if Each of the Following Molecular Formulas Represents an Alkane, Alkene, or Alkyne, Continued.

- $C_{14}H_{28}$ Alkene.
- $C_{25}H_{52}$ Alkane.
- C_6H_{10} Alkyne.

Chlorinated Hydrocarbons

When hydrogen atom or atoms of a hydrocarbon are substituted by chlorine, a **chlorinated hydrocarbon** is formed. Chlorinated hydrocarbons have many useful properties.

Dichloromethane is used as a solvent and paint remover.

Trichloromethane (chloroform) is also a solvent and at one time was used as an anesthetic. It is now considered hazardous.

Chlorofluorocarbons and Fluorocarbons

Carbon compounds with both chlorine and fluorine are known as **chlorofluorocarbons (CFCs).**

(used previously in spray cans and refrigerants and diffuse into atmosphere and destroy ozone layer)

Functional Groups

Atoms or groups of atoms attached to hydrocarbon skeletons give the compounds characteristic chemical and physical properties and are known as **functional groups**.

Alcohols

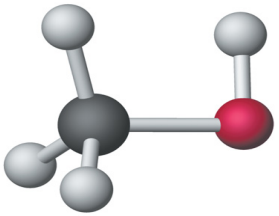
Alcohols contain the hydroxyl (-OH) functional group.

Examples include:

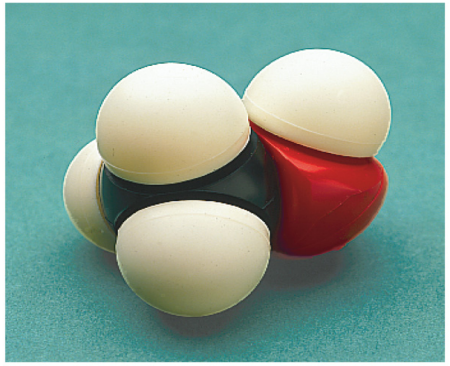
methanol	CH_3OH
ethanol	CH_3CH_2OH
1-propanol	$CH_3CH_2CH_2OH$

Methanol

Methanol or **methyl alcohol** is sometimes called wood alcohol. It is an important solvent and automotive fuel additive and possible fuel replacement.



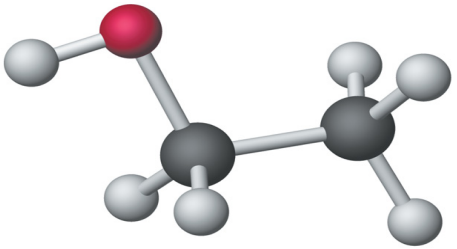
(a)



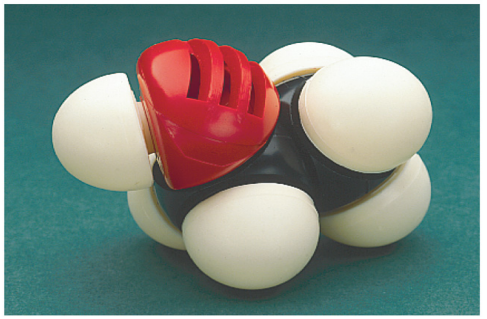
(b)

Ethanol

Ethanol or **ethyl alcohol** is also known as grain alcohol. It is the alcohol of alcoholic beverages. It is also an additive to automotive fuel and is being considered as a gasoline replacement.



(a)



(b)

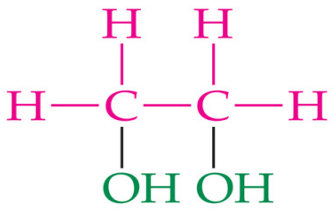
Toxicity of Alcohols

All alcohols are toxic. **Methanol** for instance is oxidized to formaldehyde by liver enzymes. It can lead to blindness and death.

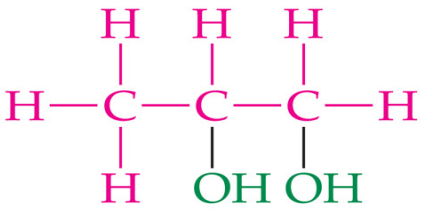
Even **ethanol** is toxic. The effects of drinking ethanol are due to its toxicity. Drunk driving, alcoholism, and fetal alcohol syndrome are all effects due to the toxicity of ethanol.

Multifunctional Alcohols

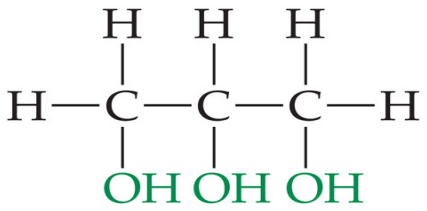
Some alcohols contain more than one hydroxyl group.



Ethylene glycol



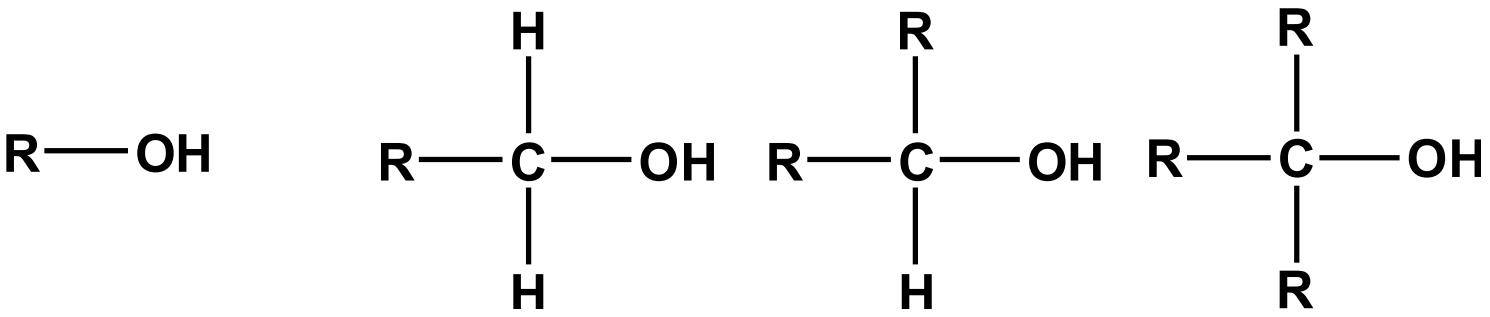
Propylene glycol

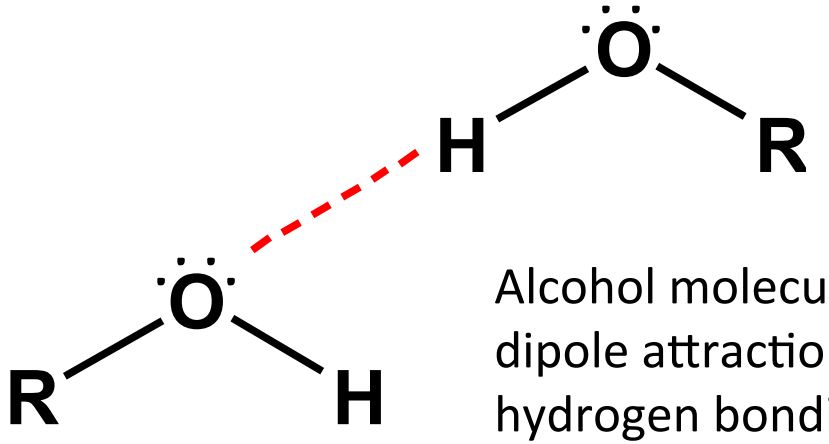


Glycerol

Ethylene glycol – antifreeze that tastes sweet but is poisonous.
Propylene glycol is also used as an antifreeze but it is non-toxic.
Glycerol is a syrup that comes as a byproduct in making soap. It is used in lotions and a food additive in cakes and in making nitrogylcerine.

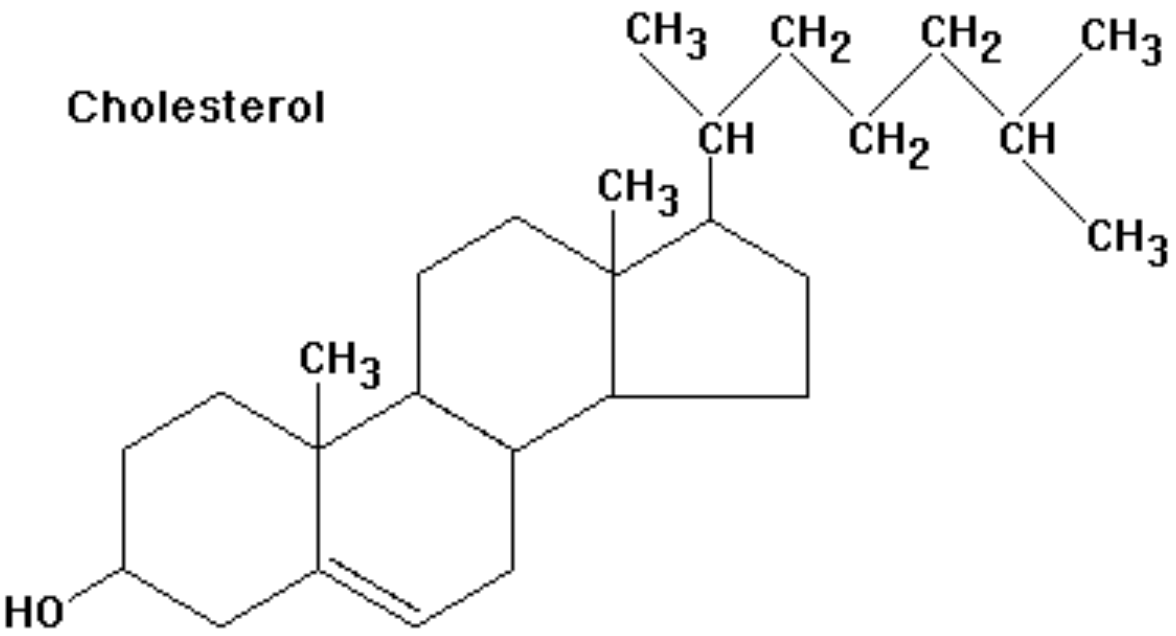
Alcohols





Alcohol molecules interact by dipole-dipole attractions and hydrogen bonding

Cholesterol



The dipole-dipole attraction and hydrogen bonding of one O-H is overpowered by the hydrophobic nature of the rest of the molecule.

Ethers

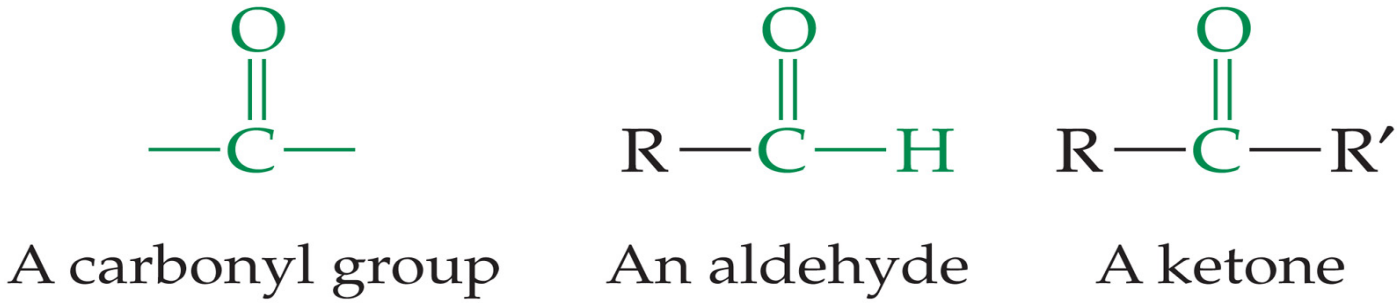
Ethers are compounds with two carbon groups bonded to the same oxygen.

General formula: ROR or ROR'

$CH_3CH_2OCH_2CH_3$ is diethyl ether which was used as an anesthetic.

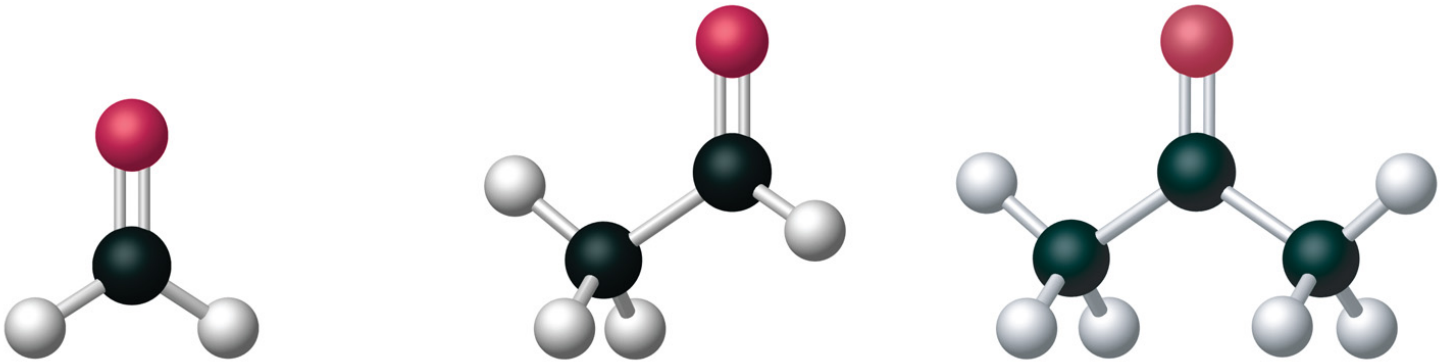
Aldehydes and Ketones

Aldehydes and **ketones** are two families of organic compounds that contain the **carbonyl** (C=O) functional group.



Formaldehyde was used as a preservative for biological specimens and acetone is used as nail polish remover.

Aldehydes and Ketones

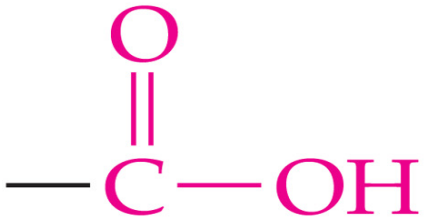


(a)

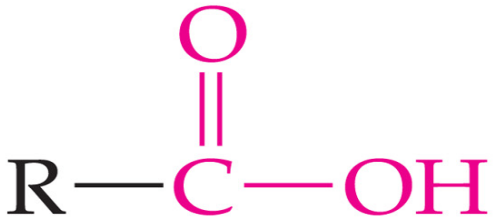
(b)

Carboxylic Acids

Organic acids contain the **carboxyl** (COOH) functional group.



A carboxyl group

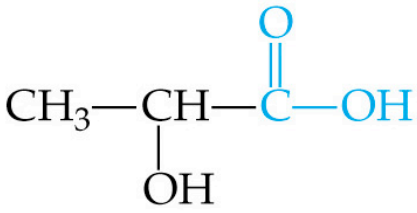


A carboxylic acid

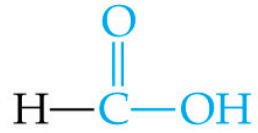
Formic acid is in bee and ant stings and acetic acid is in vinegar.

Carboxylic Acids

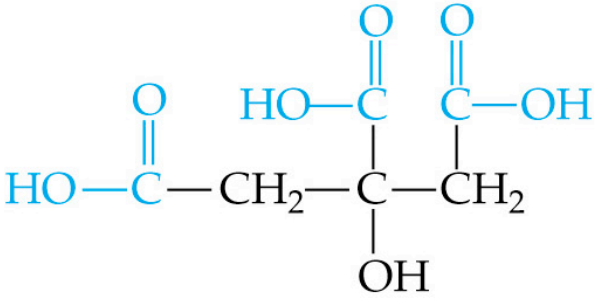
Carboxylic Acids



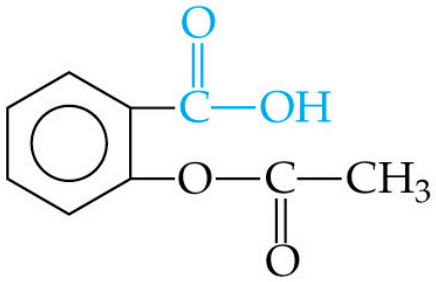
Lactic acid



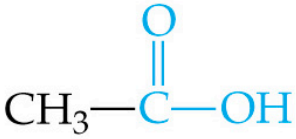
Methanoic acid
Formic acid



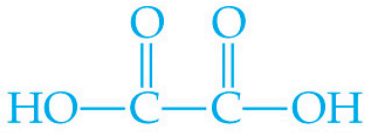
Citric acid



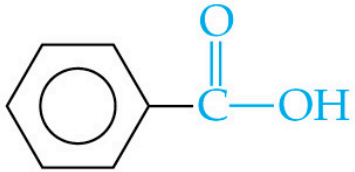
Acetylsalicylic acid
Aspirin



Ethanoic acid
Acetic acid



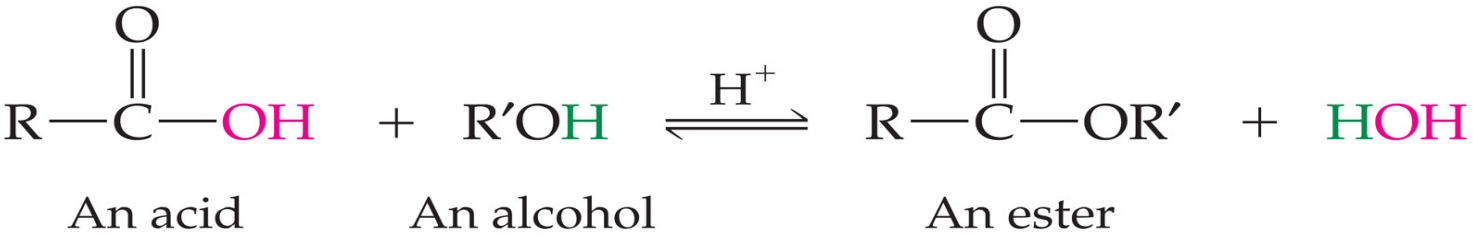
Oxalic acid



Phenyl methanoic acid
Benzoic acid

Esters

Esters are derived from carboxylic acids and alcohols or phenols.



Esters

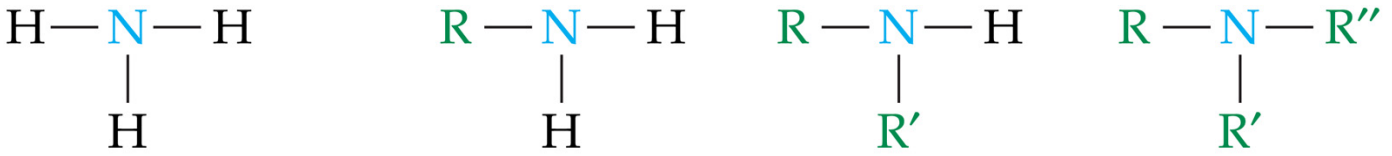
Esters generally have a pleasant odor.

TABLE 9.7 Ester Flavors and Fragrances

Ester	Formula	Flavor/Fragrance
Methyl butyrate	$CH_3CH_2CH_2COOCH_3$	Apple
Ethyl butyrate	$CH_3CH_2CH_2COOCH_2CH_3$	Pineapple
Propyl acetate	$CH_3COOCH_2CH_2CH_3$	Pear
Pentyl acetate	$CH_3COOCH_2CH_2CH_2CH_2CH_3$	Banana
Pentyl butyrate	$CH_3CH_2CH_2COOCH_2CH_2CH_2CH_2CH_3$	Apricot
Octyl acetate	$CH_3COOCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Orange
Methyl benzoate	$C_6H_5COOCH_3$	Ripe kiwifruit
Ethyl formate	$HCOOCH_2CH_3$	Rum
Methyl salicylate	o-$HOC_6H_4COOCH_3$	Wintergreen
Benzyl acetate	$CH_3COOCH_2C_6H_5$	Jasmine

Amines

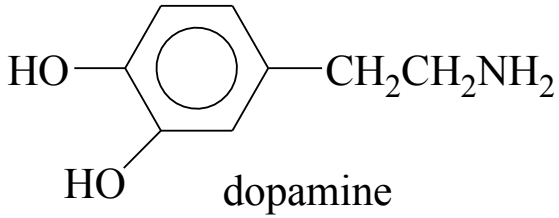
Amines are derivatives of ammonia. When one or more hydrogen of ammonia is replaced by an alkyl group, an amine is the result. Like ammonia, amines tend to be basic and have similar odors.



Ammonia Amines

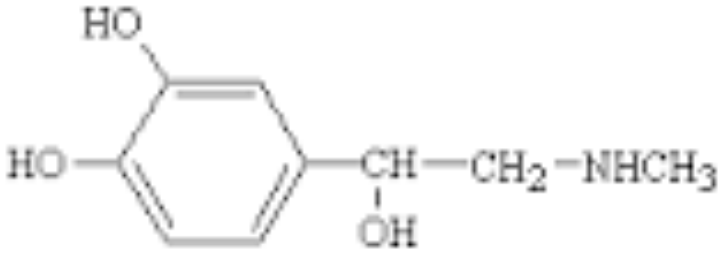
Many amines are biologically active:

- Dopamine—a neurotransmitter.
- Epinephrine—an adrenal hormone.
- Pyridoxine—vitamin B_6.

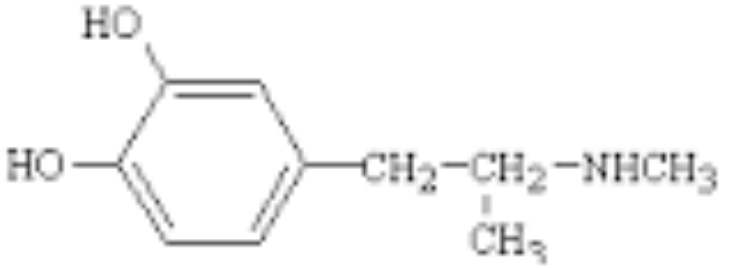


dopamine

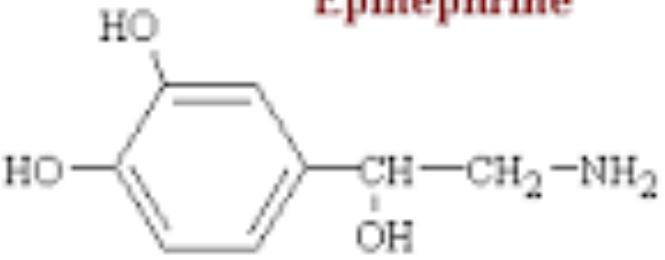
Amines



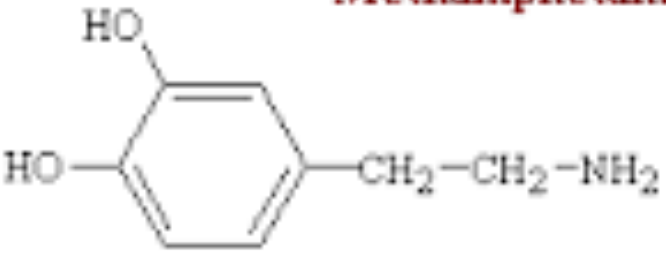
Epinephrine



Methamphetamine



Norepinephrine

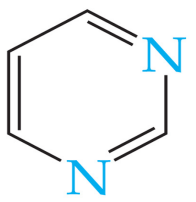


Amphetamine

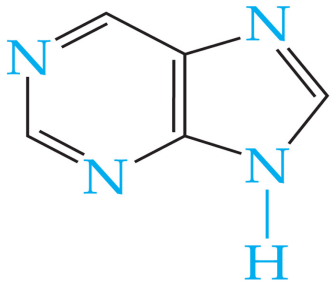
Amphetamines trigger the release of epinephrine (adrenaline) which stimulates the central nervous system. Amphetamines are sold under a variety of different names, but they are commonly known as "speed" or "bennies." Amphetamines are addictive. They have many dangerous side-effects including fatal overdoses.

Alkaloids

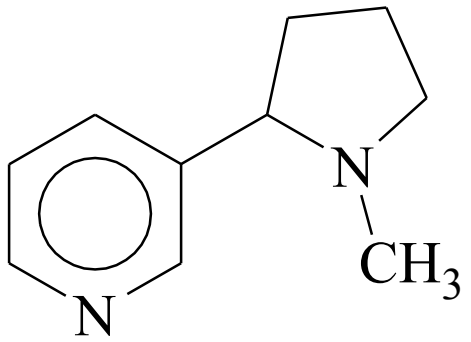
Alkaloids are amines that occur naturally in plants. Many have physiological effects. Morphine (opium poppies), caffeine (coffee beans), nicotine (tobacco leaves), mescaline (peyote cactus) and cocaine (coca leaves).



Pyrimidine



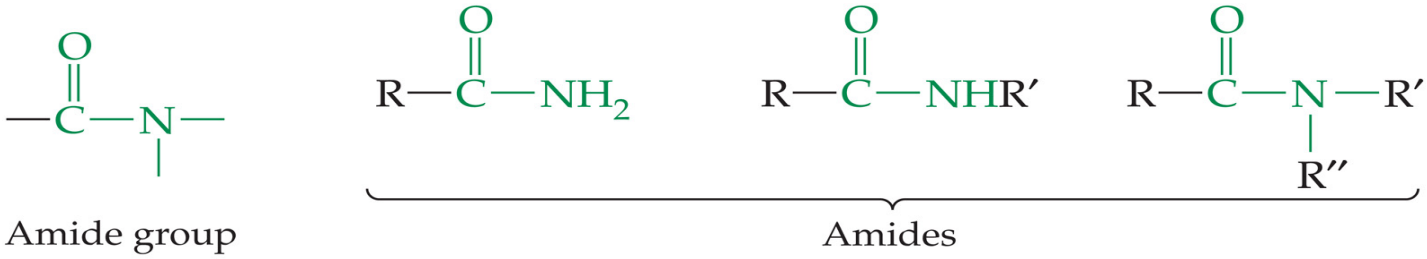
Purine



nicotine

Amides

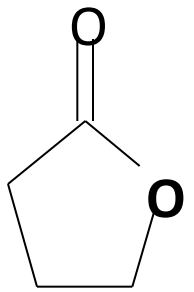
Amides have the nitrogen bonded to a carbonyl carbon.



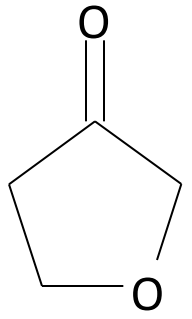
The amino acids of proteins are linked by amide linkages.

Identify the Functional Groups

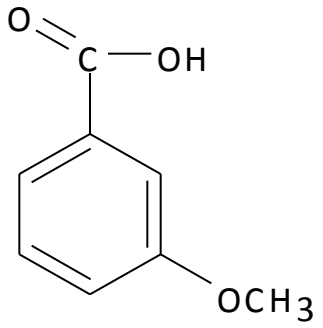
- $CH_3CH_2COOCH_3$.



- $(CH_3CH_2)_2NH$.



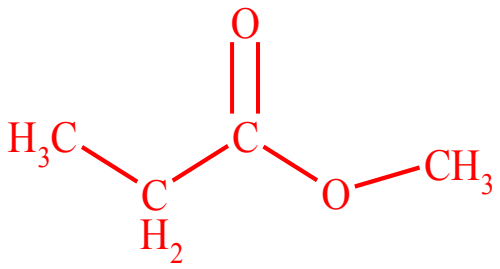
- $CH_3CHCHCH_2CHO$.

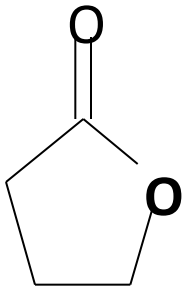


Identify the Functional Groups

- $CH_3CH_2COOCH_3$.

Ester

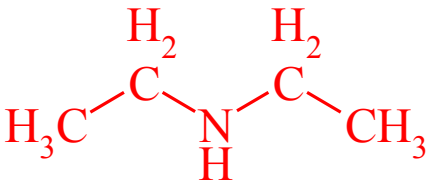


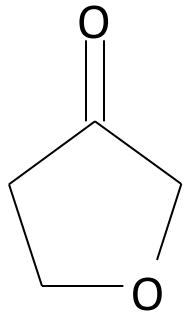


Ester

- $(CH_3CH_2)_2NH$.

Amine

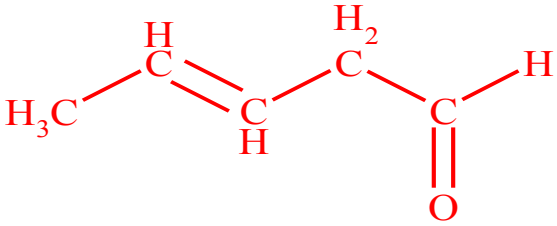


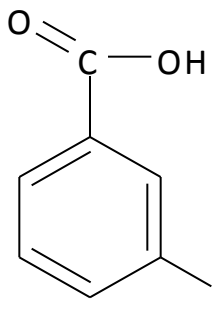


Ketone and ether

- $CH_3CHCHCH_2CHO$.

Double bond and aldehyde





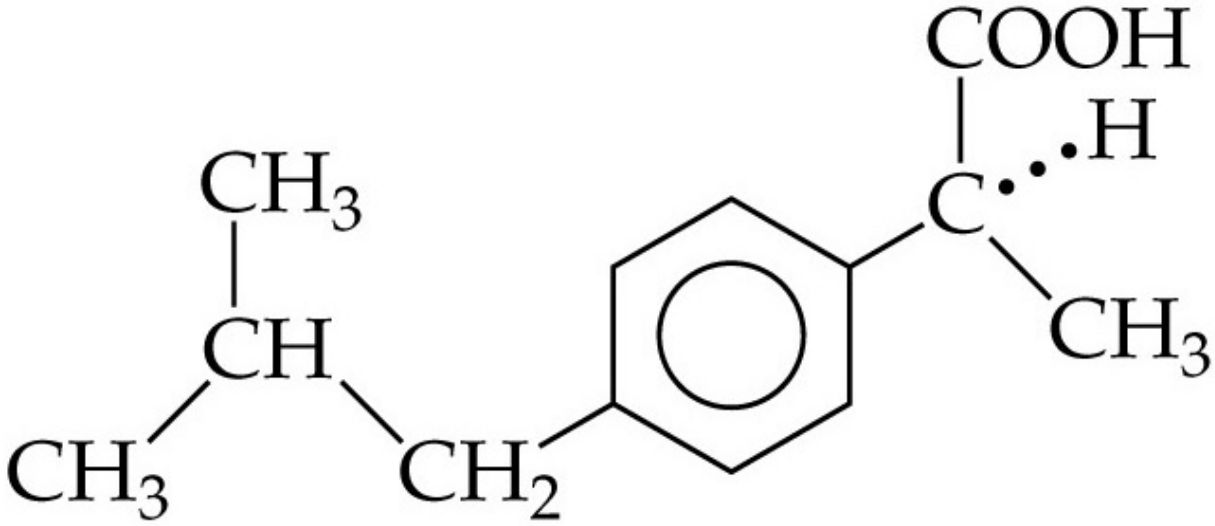
Acid, aromatic ring, ether

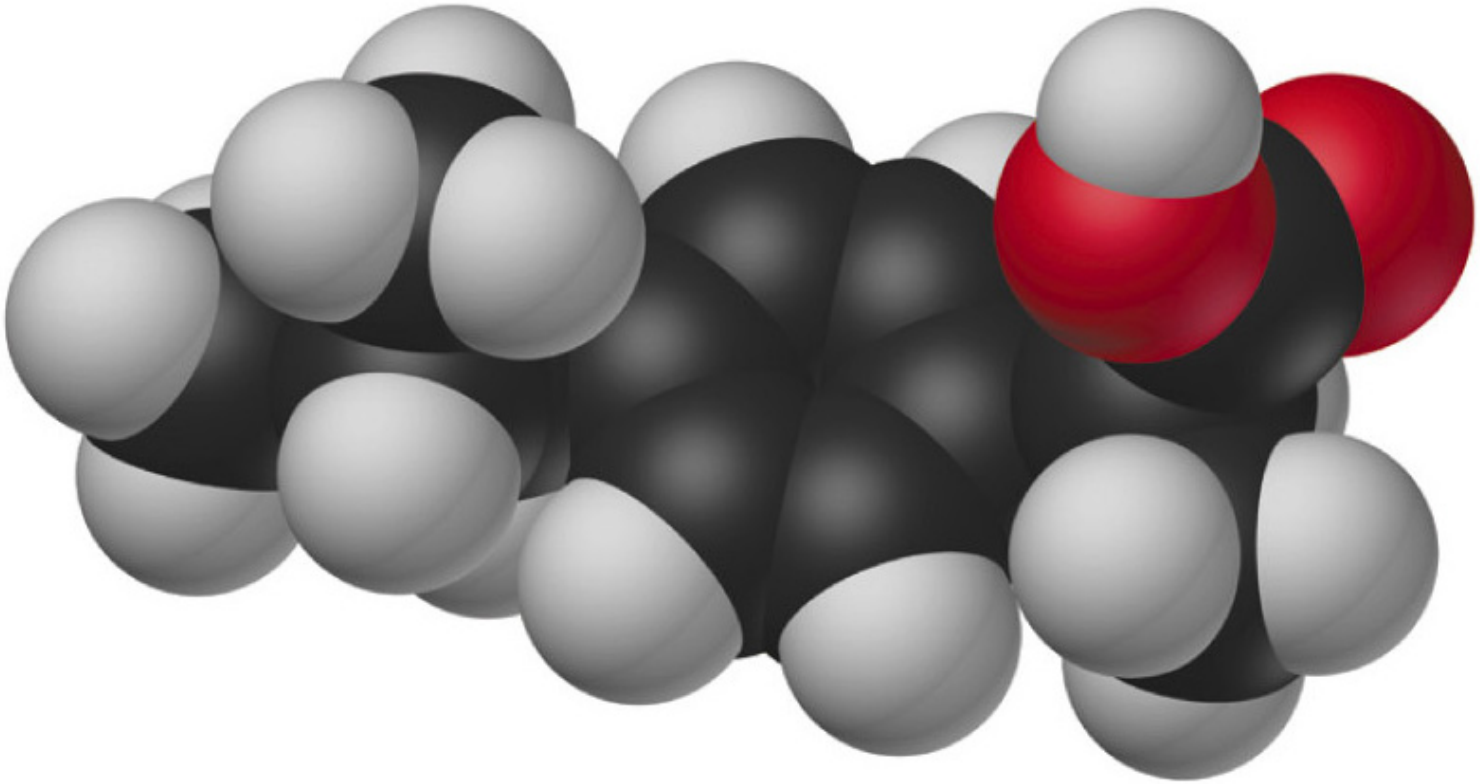
Website

- http://www.sciencegeek.net/APchemistry/organic/functional.htm

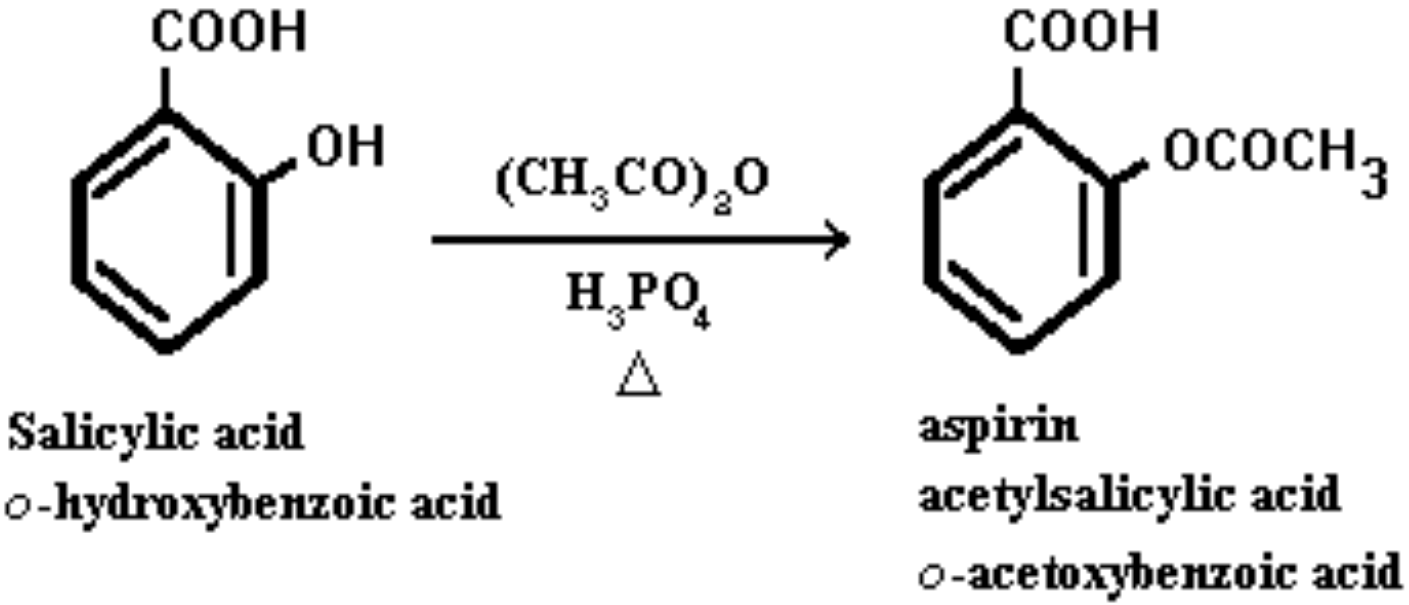
  - Interactive website to practice identifying functional groups

S-ibuprofen:





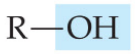
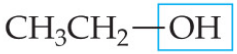
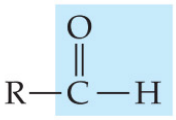
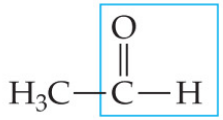
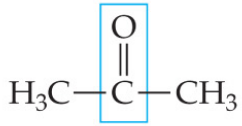
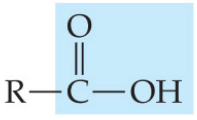
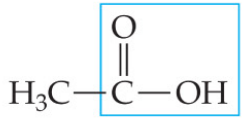
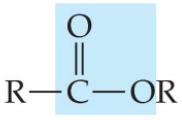
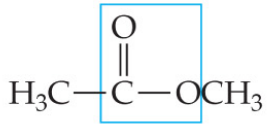
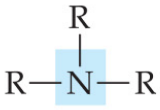
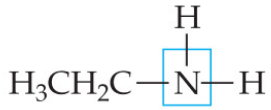
Functional Groups



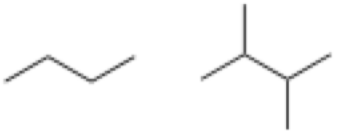
- Functional groups in salicylic acid: carboxylic acid and alcohol
- Functional groups in aspirin: carboxylic acid and ester

Functional Groups

TABLE 18.7 Functional Groups

Family	General Formula	Condensed General Formula	Example	Name
alcohols		ROH		ethanol (ethyl alcohol)
ethers		ROR		dimethyl ether
aldehydes		RCHO		ethanal (acetaldehyde)
ketones		RCOR		propanone (acetone)
carboxylic acids		RCOOH		acetic acid
esters		RCOOR		methyl acetate
amines		R_3N		ethyl amine

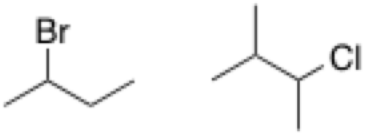
Alkane



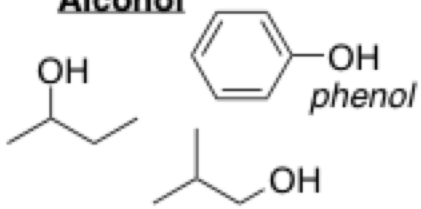
Alkene

Alkyne

Alkyl halide

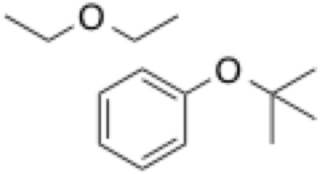


Alcohol

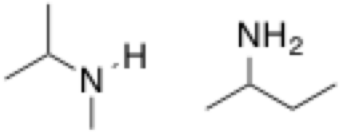


Thiol

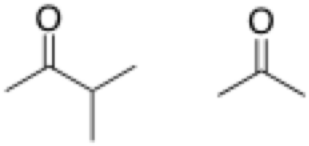
Ether



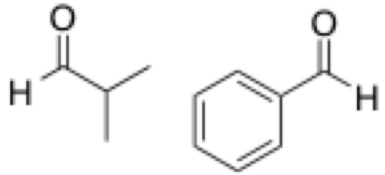
Amine



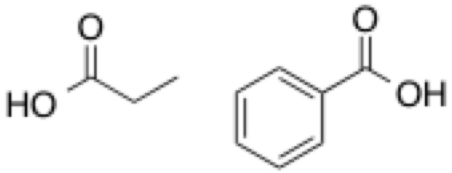
Ketone



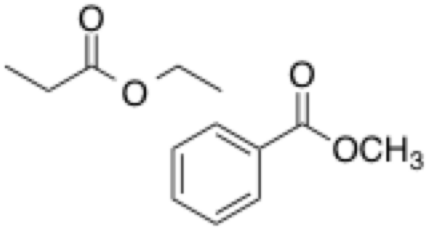
Aldehyde



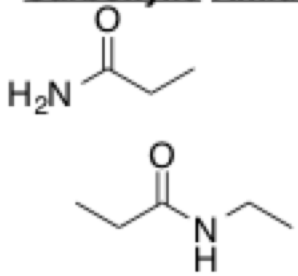
Carboxylic Acid



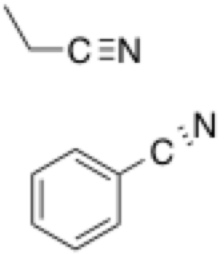
Carboxylic Ester



Carboxylic Amide

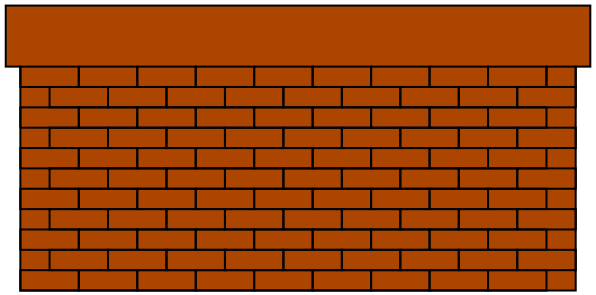


Nitrile

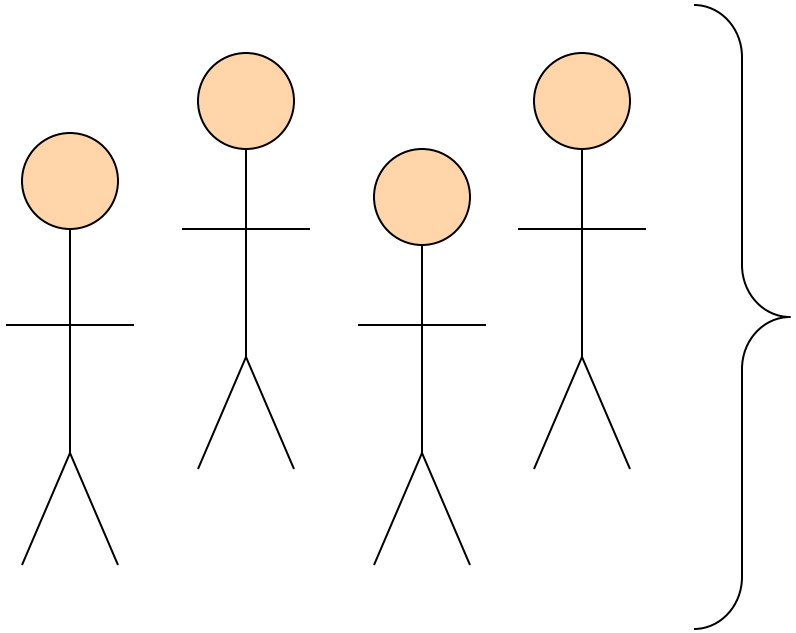


Chap 10- Polymers

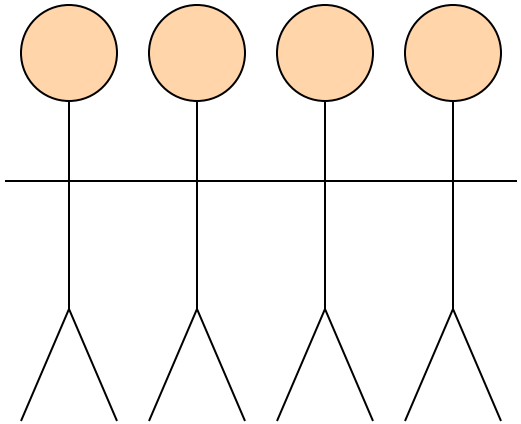
- **Polymer: a very large molecule formed by long chains of repeating units called monomers. "Mono"-means one, while "poly"-means many**
- **80% of the organic chemical industry**
- **approx. 150 kg of polymers per person annually in the United States.**
- **Polymers = Monomer + Monomer + …**



Polymers



monomer



polymer chain

Jaffe, New World of Chemistry, 1955, page 603

Classes of Polymers

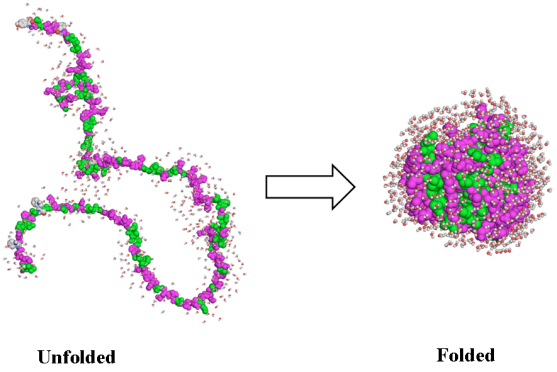
Classes of polymers (based on source)

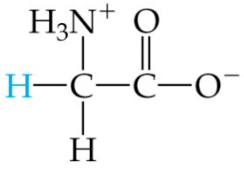
- **<u>Natural</u> polymers are made by living systems**
  - Proteins (amino acids)
  - Carbohydrates (sugars)
  - DNA
  - **Silk**
- **<u>Synthetic</u> polymers are made by the chemical industry, e.g. plastics**
  - Nylon
  - “plastics”
  - Vulcanized rubber

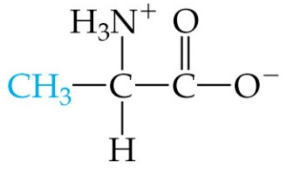
Proteins

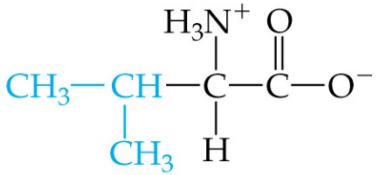
Amino Acids

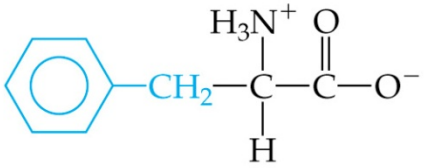
- Proteins are large molecules present in all cells.
- They are made up of α-amino acids.

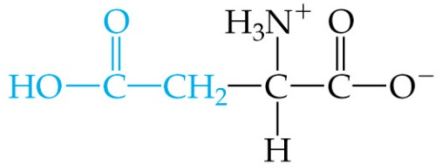


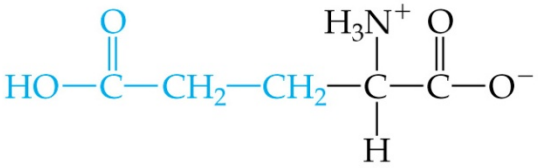

Glycine (Gly)

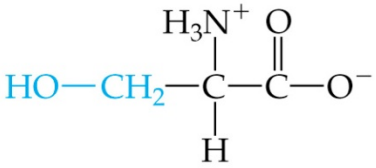

Alanine (Ala)

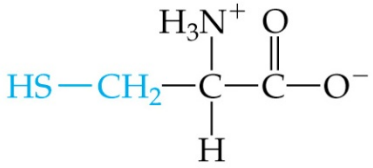

Valine (Val)

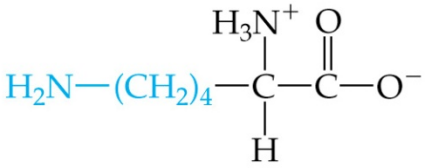

Phenylalanine (Phe)


Aspartic acid (Asp)


Glutamic acid (Glu)


Serine (Ser)

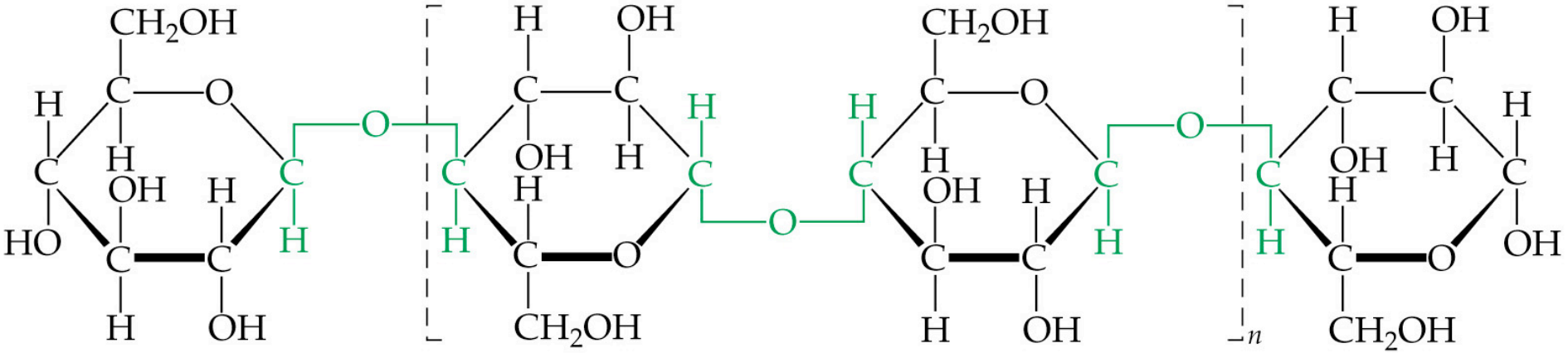

Cysteine (Cys)


Lysine (Lys)

Carbohydrates

Polysaccharides

- Bacteria in the stomach of animals contain cellulases, which are enzymes that enable animals to use cellulose for food.

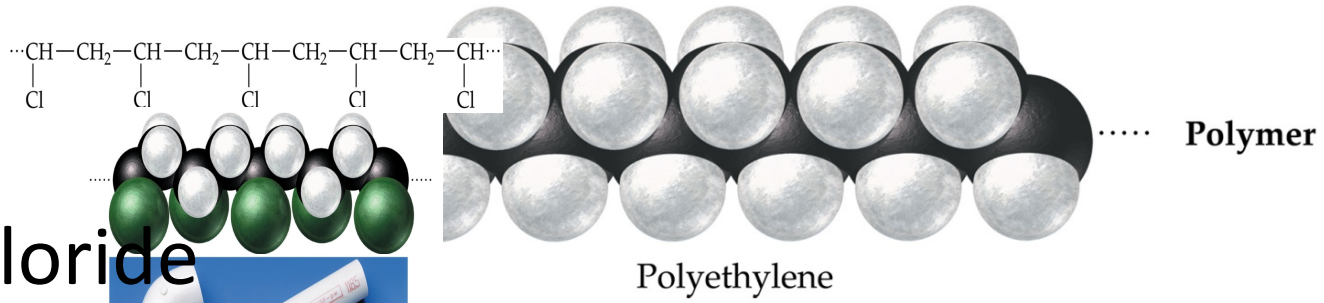


Synthetic Polymers

Polyethylene

HDPE

LDPE



Polyvinyl chloride

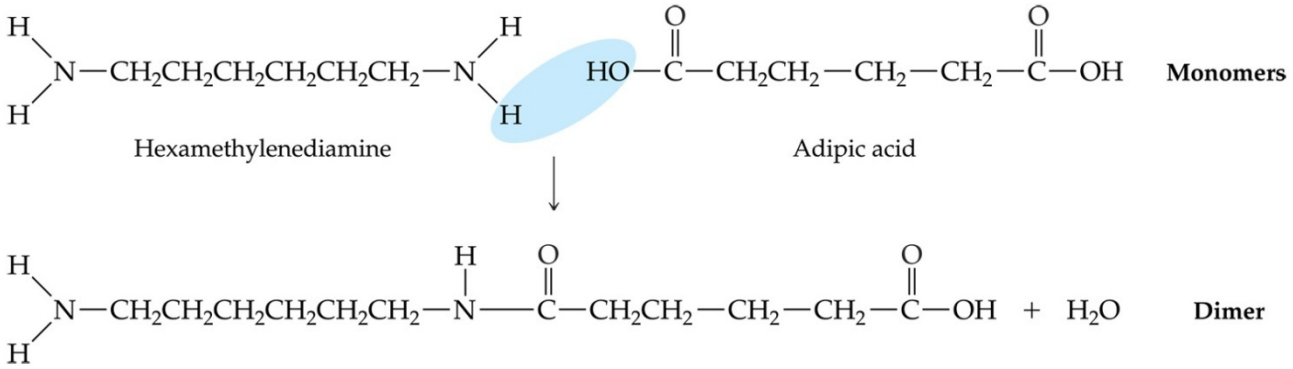
Polyesters

polyethylene terephthalate

Polyamides

nylon

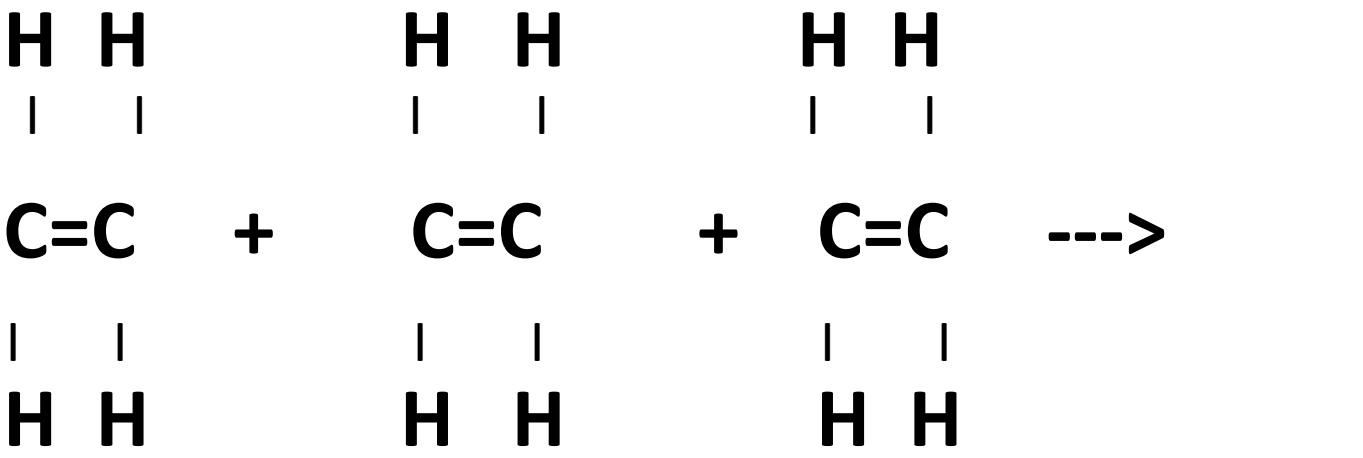
Kevlar



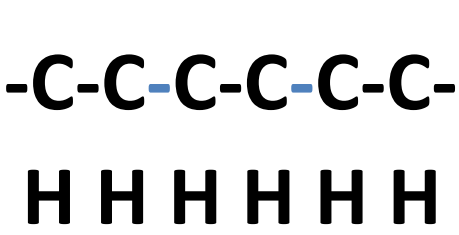
Classes of Proteins

- **Addition Polymer-**addition product without any side products.
- **Condensation polymers**- form with the loss of small molecules e.g. H_2O, HCl, NH_3, etc.

Addition Polymer: Polyethylene

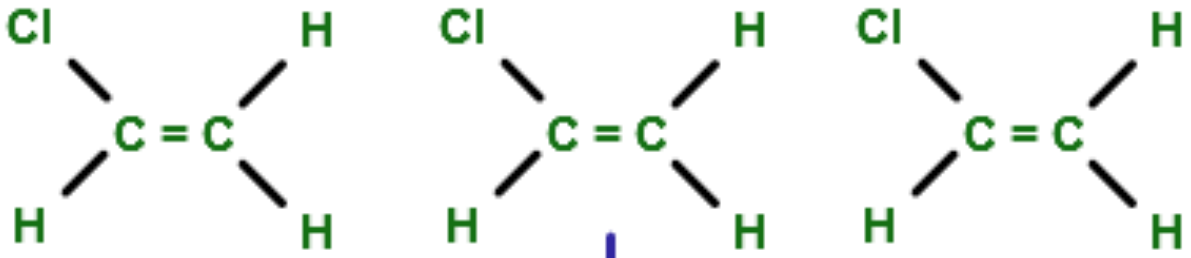


ethene (ethylene)

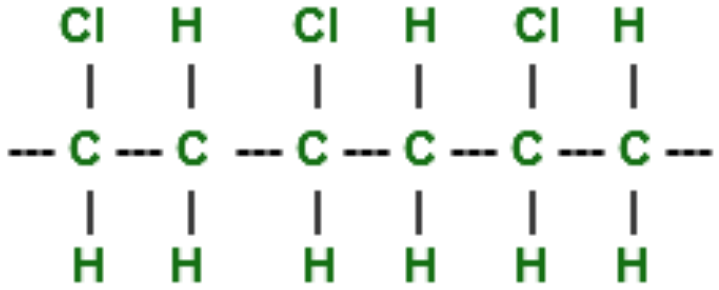


polyethylene

Addition Polymer: PVC

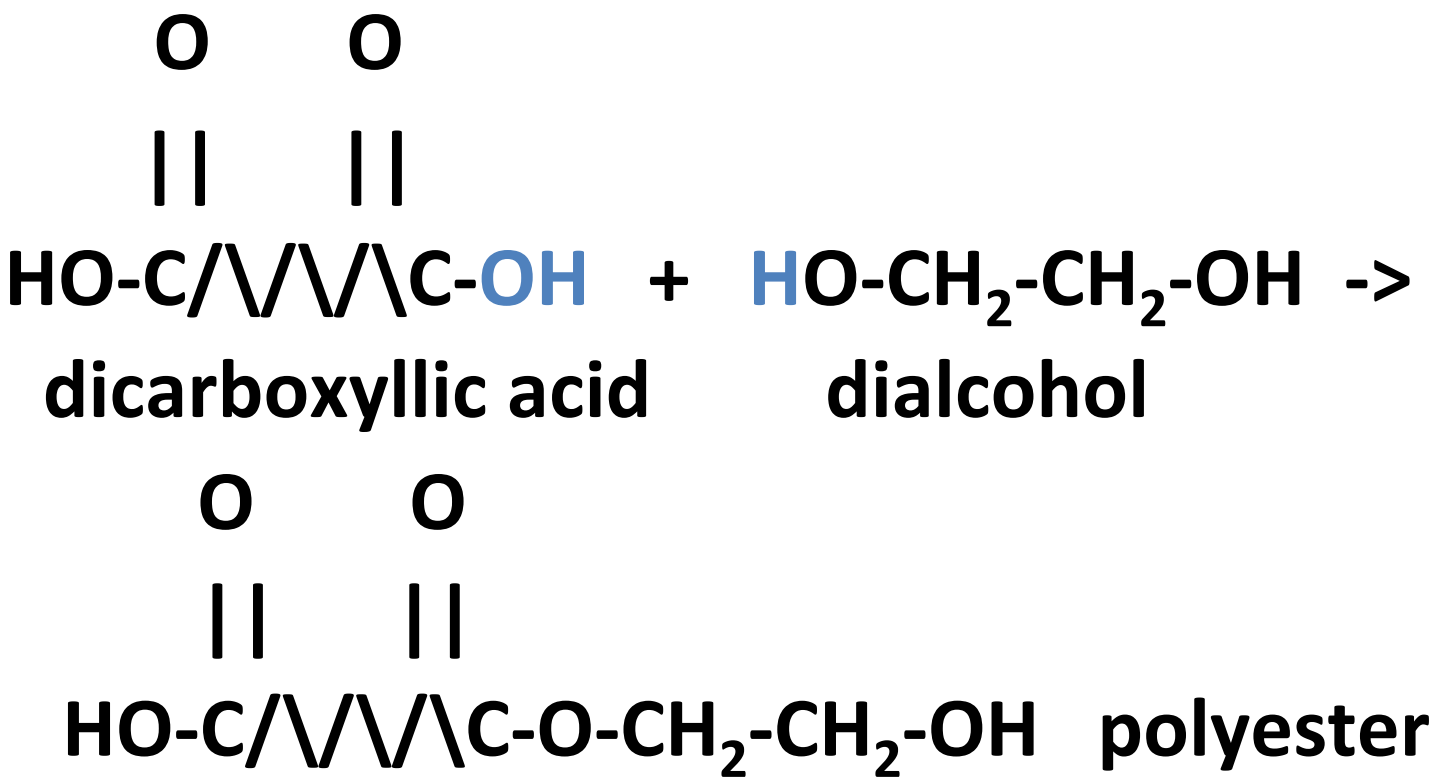


Vinyl chloride

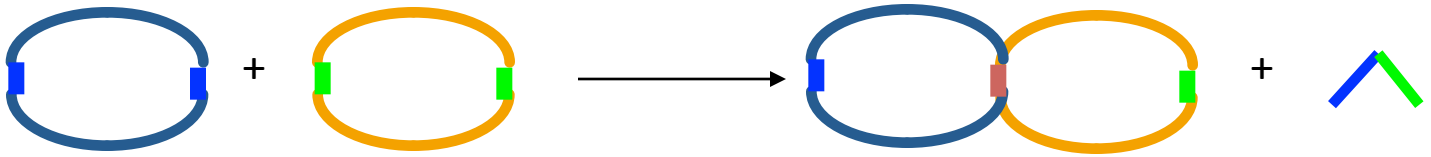


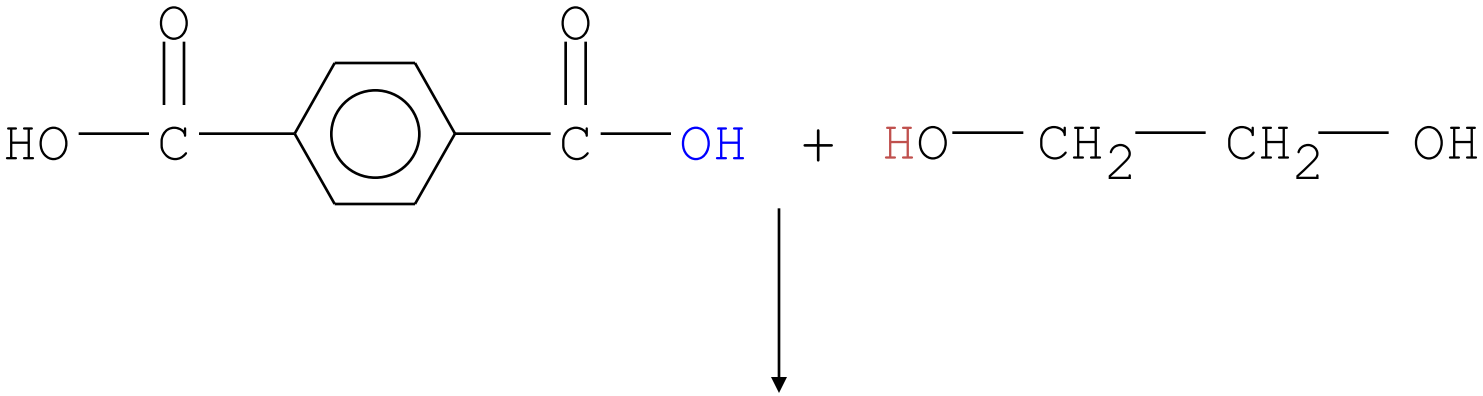
Polyvinyl chloride
PVC

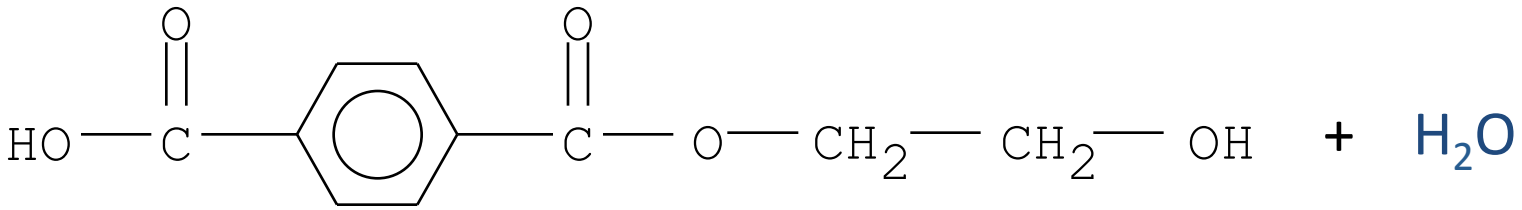
Condensation Polymer: Polyester



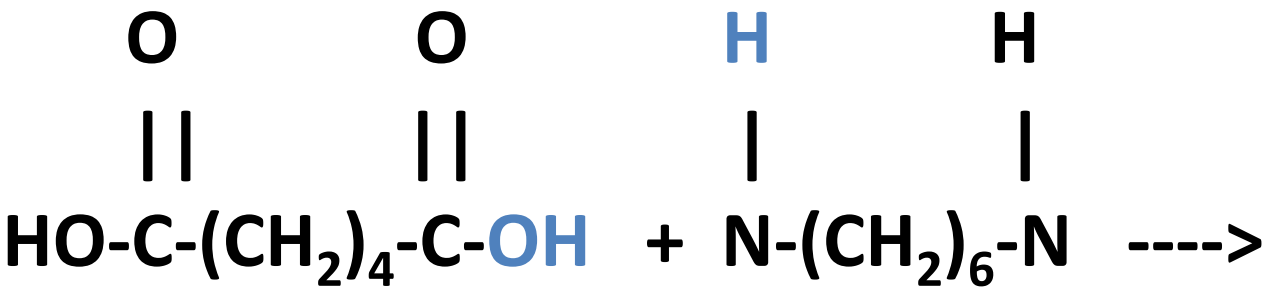
Polyester Example







Condensation Polymer: Nylon



Thermal Properties of Polymers

- **thermosetting** - soften once and harden permanently (cannot be remelted)

  Example: Bakelite (café trays)

- **thermoplastic** -have the property of softening repeatedly when they are heated and hardening when they are cooled (as in fat).

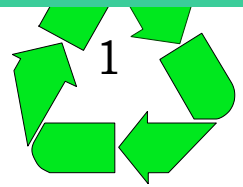
  Examples: polyesters, nylon, polyethylene.

Elastomer Polymers

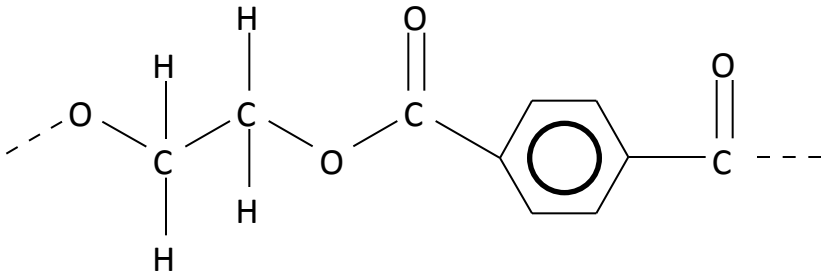
Elastomers has high elongation and flexibility against its breaking or cracking.

Examples: natural rubber, polyurethane
Structure: spaghetti (long chain) with meatballs (crosslinks). When stressed, the chain lengthen and return to original state due to the crosslinks.

Polyethylene Terephthalate (PET)

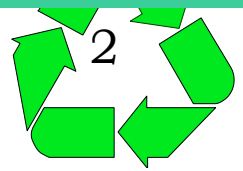


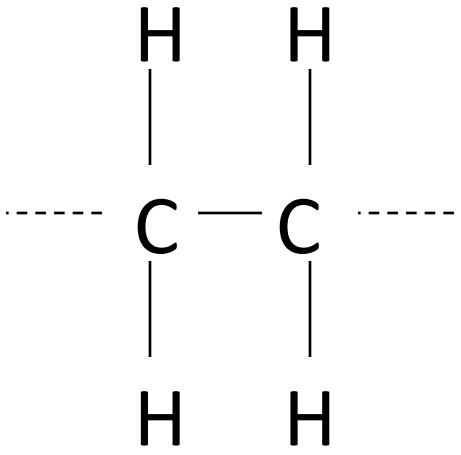
- Condensation copolymer of ethylene glycol + terephthalic acid.
  - A polyester.
- Transparent.
- High-impact strength.



- Nonreactive with acid and atmospheric gases.
- Doesn't stretch.
- Used for soda bottles, Dacron®, Mylar®.

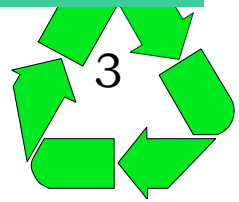
High Density Polyethylene (HDPE)

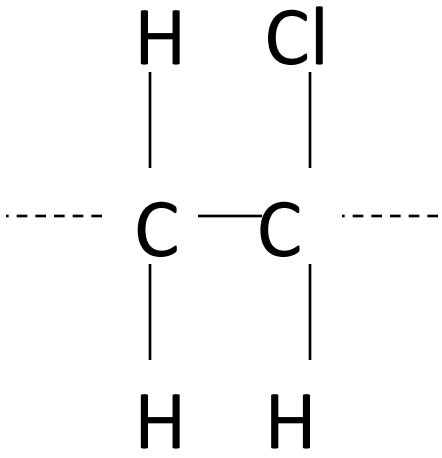




- Addition polymer with linear chains.
- Opaque.
- Denser than LDPE.
- Mechanically stronger than LDPE.
- More rigid than LDPE.
  - More crystalline.
- Higher heat resistance than LDPE.
- Nonreactive to acids and bases.
- Absorbs oils and softens.
- Oxidizes on exposure to air and sunlight.
- Subject to cracking.
- Used for containers, caps, bullet-proof vests, synthetic ice.

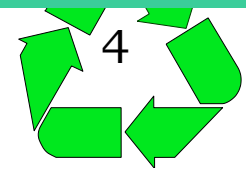
Poly Vinyl Chloride (PVC)



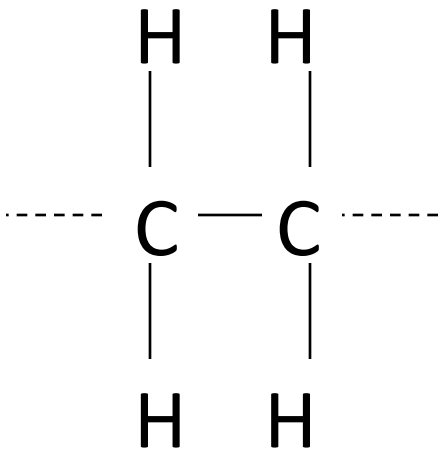


- Addition polymer.
- Transparent to opaque.
- Flame resistant.
- Low heat resistance.
- Good chemical resistance.
- High-impact strength.
- Quite rigid.
- Many additives used to modify properties.
  - Plasticizer adds flexibility.
- Used in food wrap, pipes, flooring and wall covering, toys, hoses, auto trim, squeeze tubes, and appliance housings.

Low Density Polyethylene (LDPE)

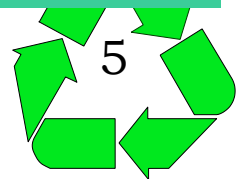


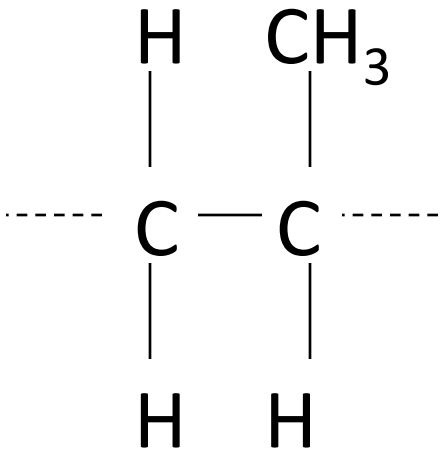
- Addition polymer with branched chains.
- Lower density, strength, heat resistance (100–125 °C), and rigidity than HDPE.
- Used in food, trash, and grocery bags as well as in electrical wire insulation.



Polypropylene (PP)

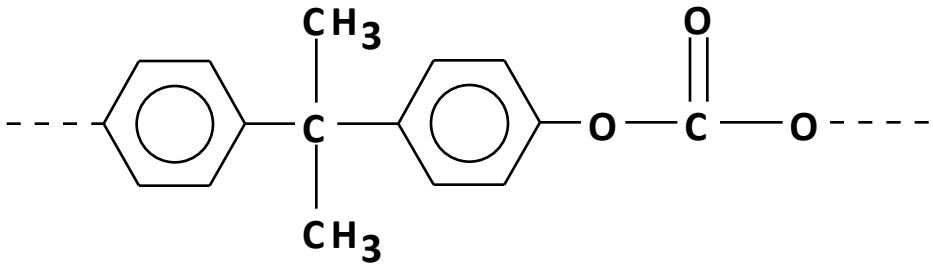
- Addition polymer.
- Opaque.
- High-stretching strength.
- High heat resistance (170 °C).
- Excellent chemical resistance.
- Flexed almost indefinitely without tearing.
- Smooth surface with high luster.
- Used in carpets and upholstery; chemical resistant pipes, containers, and tanks; margarine tubs; and medicine bottles.





Polycarbonates (PC)

- Excellent physical properties.
- Excellent toughness.
- Very good heat resistance.
- Fair chemical resistance.



- Transparent.
- Condensation copolymer of Bisphenol A and phosgene.
- Lexan®, Calibre ®, Makrolon ®, Panlite ®.
- Used in equipment housings, exterior auto parts, outdoor light fixtures, non-auto vehicle windows, structural parts, medical supply parts, scratch-resistant coatings, eye wear, bullet–proof glass, and DVDs.