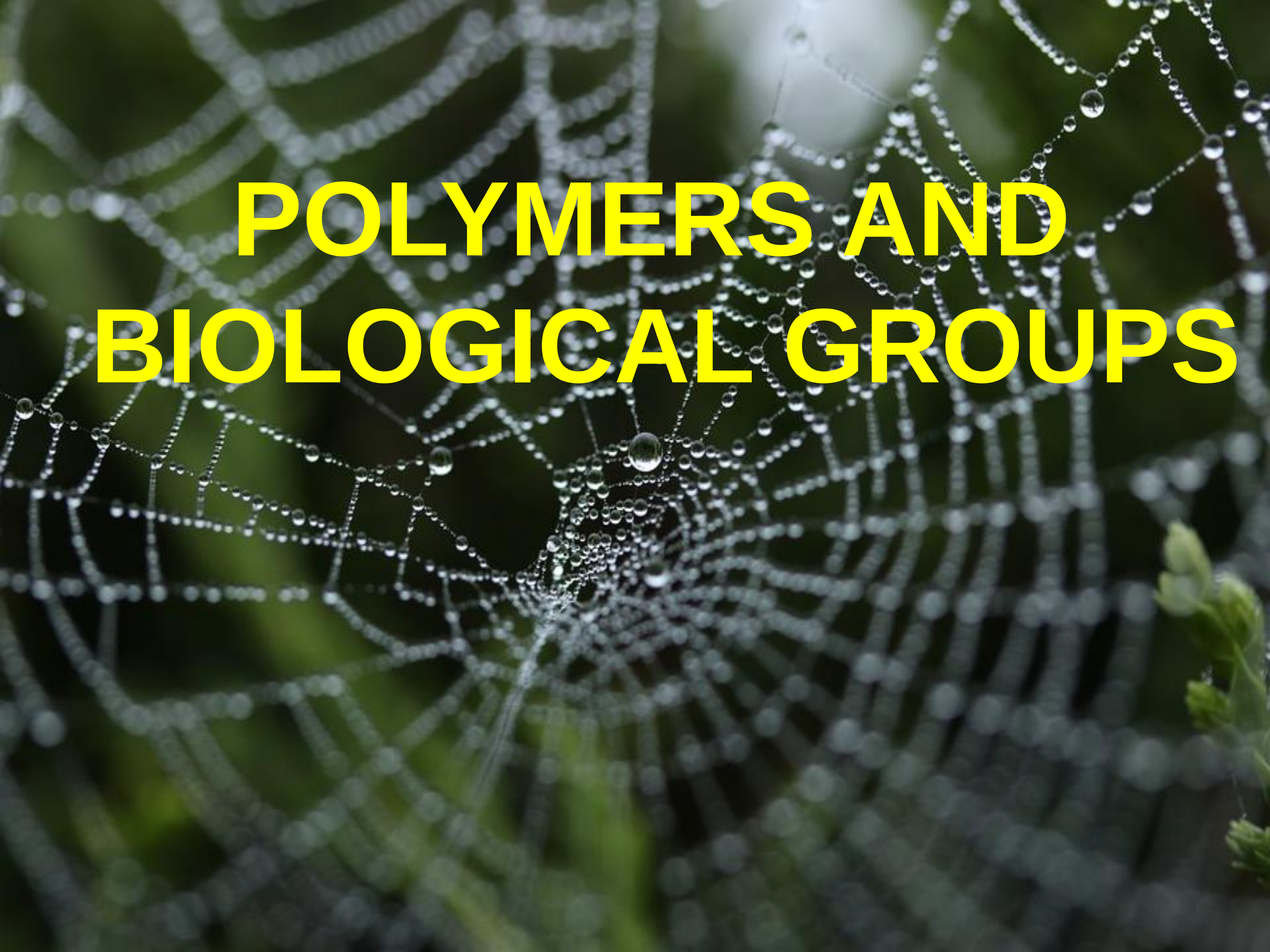
POLYMERS AND BIOLOGICAL GROUPS

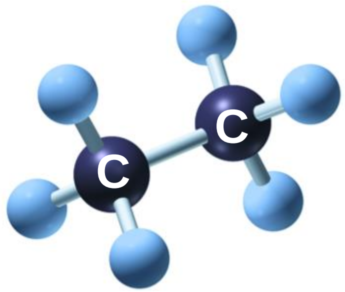


Functional groups

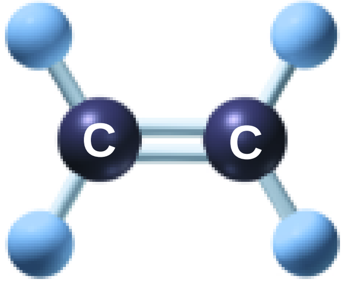
Family	Functional group	Example	Name
Alcohol	$-OH$	CH_3CH_2OH	Ethanol
Amine	$-NH_2$	$CH_3CH_2NH_2$	Ethanamine
Aldehyde	$-\overset{\overset{\displaystyle O}{\|}}{C}-H$	$CH_3\overset{\overset{\displaystyle O}{\|}}{C}H$	Ethanal
Ketone	$-\overset{\overset{\displaystyle O}{\|}}{C}-$	$CH_3\overset{\overset{\displaystyle O}{\|}}{C}CH_3$	Acetone
Carboxylic acid	$-\overset{\overset{\displaystyle O}{\|}}{C}-OH$	$CH_3\overset{\overset{\displaystyle O}{\|}}{C}OH$	Acetic acid
Carboxylic ester	$-\overset{\overset{\displaystyle O}{\|}}{C}-OR$	$CH_3\overset{\overset{\displaystyle O}{\|}}{C}OCH_2CH_3$	Ethyl acetate

Alkanes, Alkenes, and Alkynes

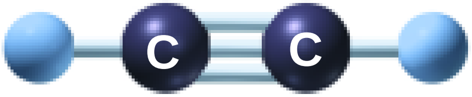
- **Alkanes:** contain single bonds between carbon atoms.



- **Alkenes:** contain one or more double bonds.



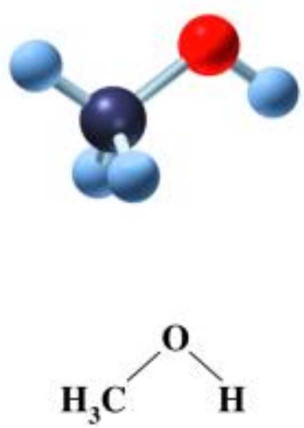
- **Alkynes:** contain one or more triple bonds.



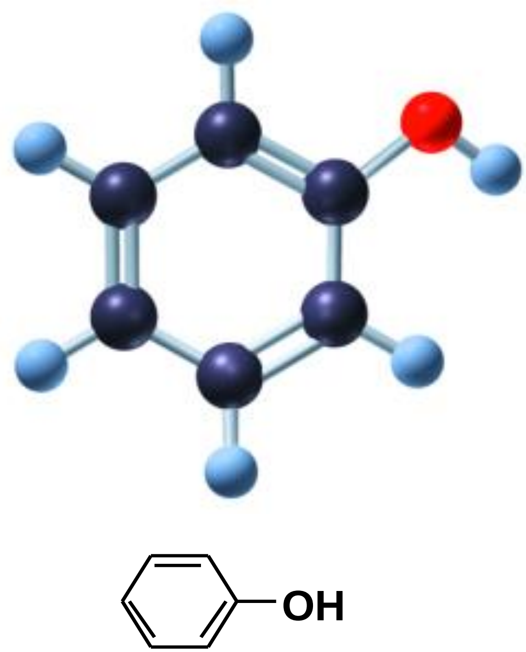
Alcohols

Alcohols Contain a hydroxyl group (-OH).

Phenols Contain a benzene ring with a hydroxyl group (-OH).



Methanol



Phenol

Naming Alcohols

- IUPAC name: We replace the -e in alkane name with -ol.
- Common name: As simple alcohols using the name of the alkyl group followed by "*alcohol*".

CH_4	Methane	
$CH_3{-}OH$	Methanol	(Methyl alcohol)
$CH_3{-}CH_3$	Ethane	
$CH_3{-}CH_2{-}OH$	Ethanol	(Ethyl alcohol)

Naming Alcohols

Step 1

Select the longest carbon chain that contains the -OH group.

Step 2

Number from the end nearest -OH group.

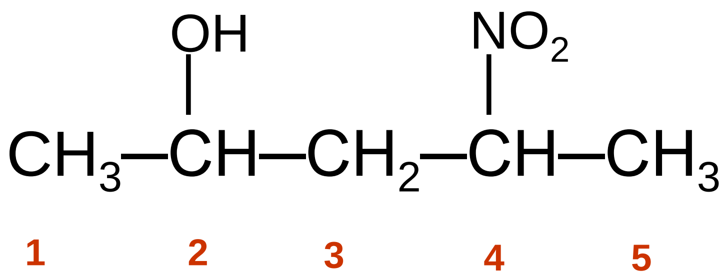
Step 3

Change the ending of parent alkane from -e to -ol. Use the number to show the location of -OH.

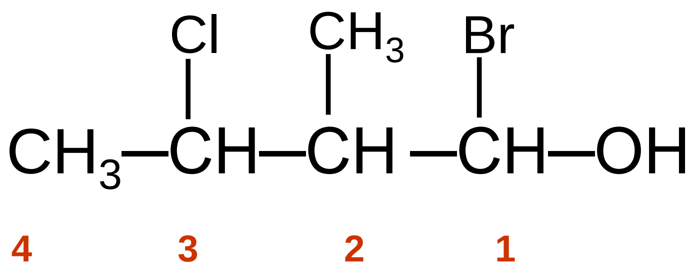
Step 4

Give the location and name of each substituent (alphabetical order) as a prefix to the name of the main chain.

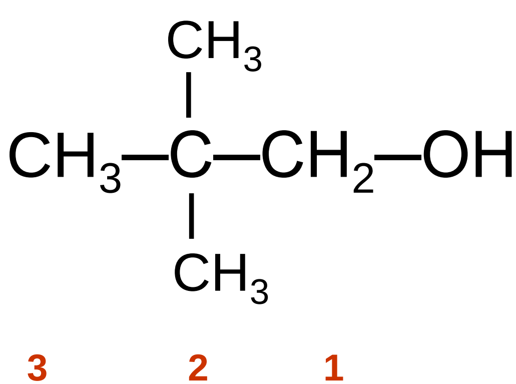
Naming Alcohols



4-Nitro-2-pentanol



1-Bromo-3-chloro-2-methyl-1-butanol



2,2-dimethyl-1-propanol

Physical Properties of Alcohols

1. Alcohols are polar molecules (because of O-H and C-O).

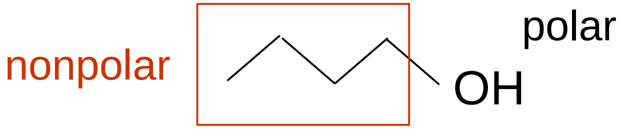
   C-O: (3.5 – 2.5 = 1.0) O-H : (3.5 – 2.1 = 1.4)

2. Hydrogen bonding between alcohols molecules.

3. Have higher boiling points than Alkanes, Alkenes, and Alkynes.

4. Molecular weight ↑ : London dispersion forces ↑ : bp ↑

5. More soluble in water (Molecular weight ↑ : solubility ↓).



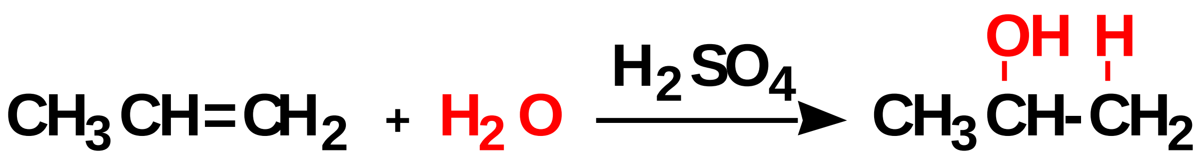
6. They are weak acids (weaker than Phenol).

Formation of Alcohols

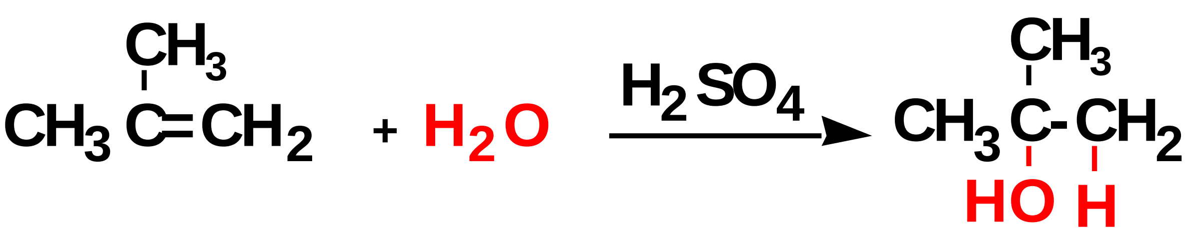
Hydration (addition of water):

- Water adds to C=C to give an alcohol.
- Acid catalyst (concentrated sulfuric acid).
- **Markovnikov's rule:** H adds to double bonded carbon that has the greater number of H and halogen adds to the other carbon.

The rich get richer!



Propene → 2-Propanol



2-Methylpropene → 2-Methyl-2-propanol

Ethers

An ether:

- Contains an -O- between two carbon atoms.
- Is named from *alkyl* names of the attached groups (in alphabetical order) followed by *ether.*

$CH_3{-}O{-}CH_3$

dimethyl ether

$CH_3{-}CH_2{-}O{-}CH_3$

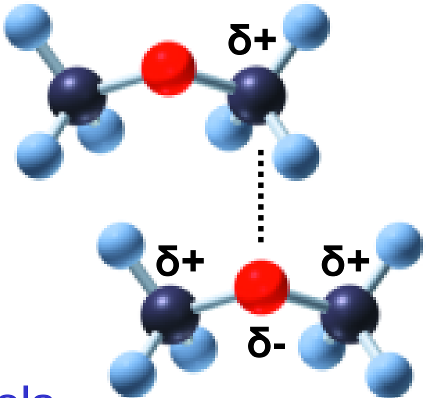
ethyl methyl ether

Physical Properties of Ethers

1. They are polar compounds (because of C-O).

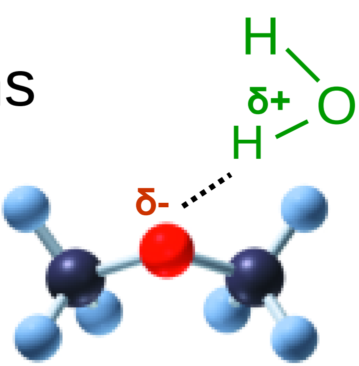
   C-O (3.5 – 2.5 = 1)

2. Weak dipole-dipole interactions.



3. Low boiling points: hydrocarbons < ethers < alcohols.

4. More soluble in water than other hydrocarbons of similar molecular weight (H-bond with water).



Chemical Properties of Ethers

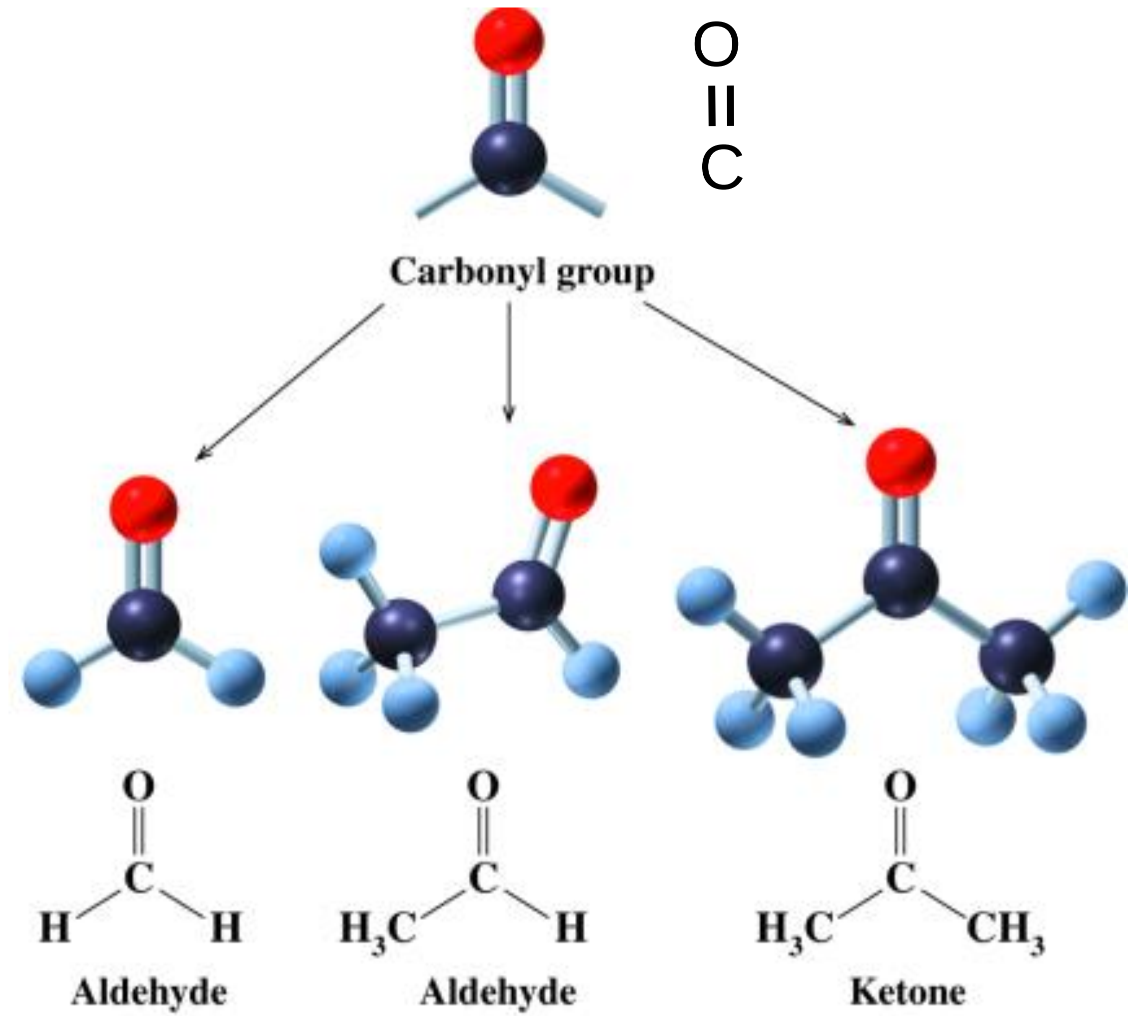
Ethers are resistant to chemical reactions (inert).

~~Oxidation~~ ~~Reduction~~

Good solvent for organic reactions.

Aldehydes and Ketones

- In an aldehyde, at least one H atom is attached to a carbonyl group.
- In a ketone, two carbon groups are attached to a carbonyl group.



Naming Aldehydes

Step 1

Select the longest carbon chain
that contains the carbonyl group (C=O).

Step 2

Number from the end nearest C=O group.

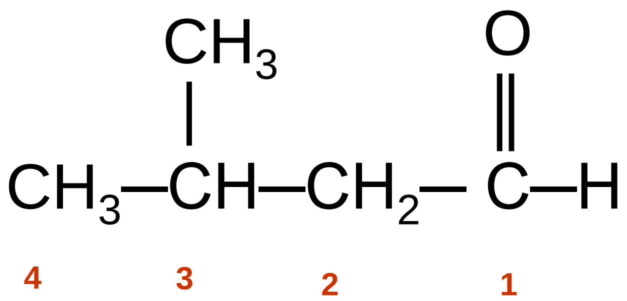
Step 3

Change the ending of parent alkane from -e to -al.

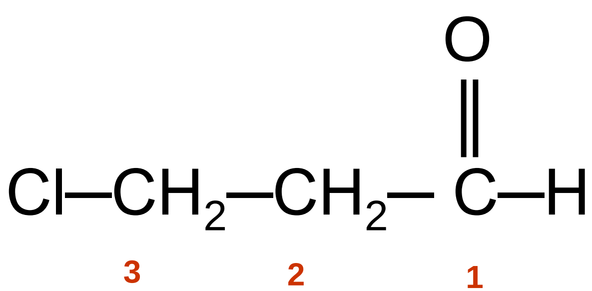
No number for carbonyl group C=O (it always comes first).

Step 4

Give the location and name of each substituent (alphabetical order) as a prefix to the name of the main chain.



3-Methylbutanal



3-chloropropanal

Naming Ketones

Step 1

Select the longest carbon chain
that contains the carbonyl group (C=O).

Step 2

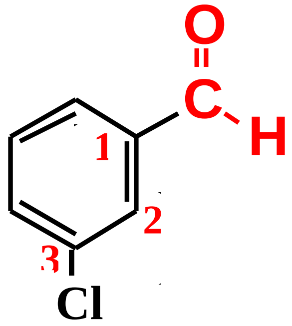
Number from the end nearest C=O group.

Step 3

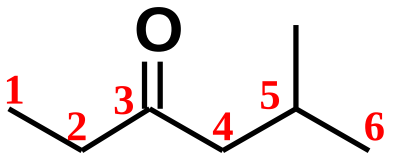
Change the ending of parent alkane from -e to -one.
Use the number to show the location of C=O.

Step 4

Give the location and name of each substituent (alphabetical order) as a prefix to the name of the main chain.



3-ChloroBenzaldehyde

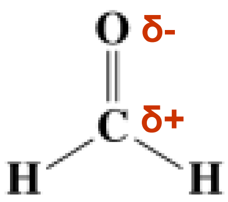


5-Methyl-3-hexanone

Physical properties of Aldehydes and Ketones

1. They have strong odors (ketones have pleasant odors).

2. They are polar compounds.



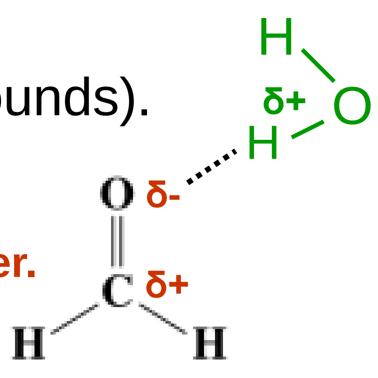
C-O 3.5-2.5 = 1

3. Only dipole-dipole interactions (no hydrogen bonding).

4. Low boiling points compare to amines and alcohols.

Higher than hydrocarbons.

5. Soluble in water (no soluble in nonpolar compounds).



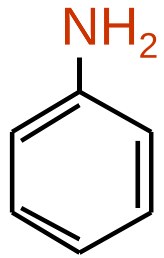
Hydrogen bond with water.

Amines:

- Are derivatives of ammonia NH_3.
- Contain N attached to one or more alkyl (Aliphatic amine) or aromatic groups (Aromatic amine).

$-NH_2$ amino group

CH_3-NH_2 $CH_3-NH-CH_3$



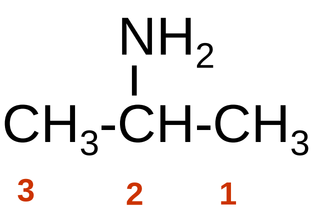
Naming Amines

IUPAC name – 1° amines

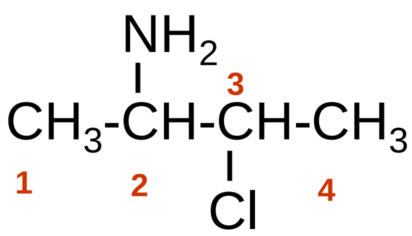
The same method as we did for alcohols.

- Drop the final "-e" of the parent alkane and replace it by "-amine".

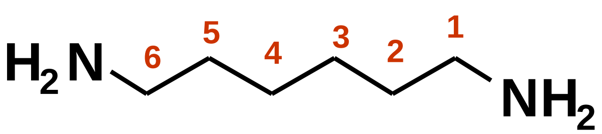
- Use a number to locate the amino group ($-NH_2$) on the parent chain.



2-propanamine



3-chloro-2-butanamine



1,6-hexanediamine

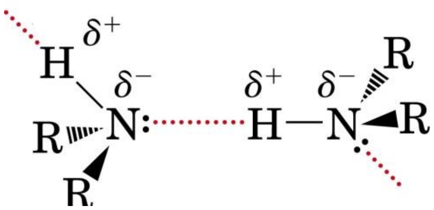
Physical properties of Amines

1. They have unpleasant odors (rotting fish like ammonia).

2. They are polar compounds.

Difference in electronegativity between N - H (3.0 – 2.1 = 0.9)

3. 1° and 2° amines have hydrogen bonds (N-H).



Weaker than alcohols (O-H).

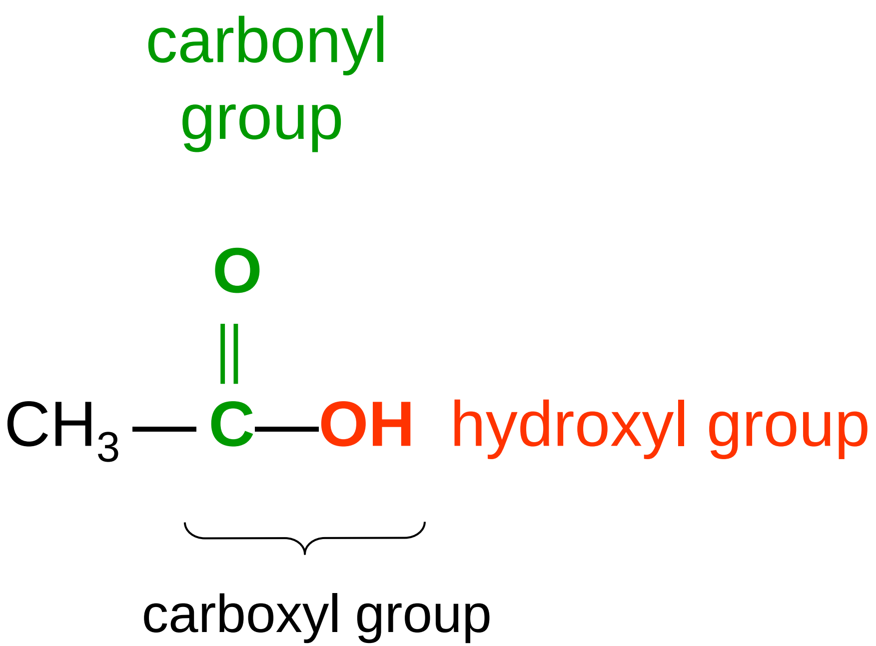
3° amines do not form hydrogen bonds (no H atom).

4. Boiling points: Hydrocarbons< Amines < Alcohols

5. Almost soluble in water (hydrogen bonding).

Carboxylic Acids

A carboxylic acid contains a *carboxyl group*, which is a carbonyl group attach to a hydroxyl group.



or CH_3COOH

CH_3CO_2H

Naming Carboxylic Acids

- In the IUPAC name of carboxylic acids, the "-e" in the name of the longest chain is replaced by "-oic acid".

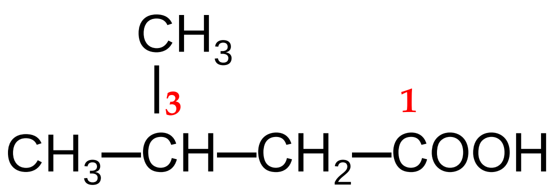
- The common names use prefixes "form-" and "acet-" for the first two carboxylic acids.

H-COOH	methanoic acid	formic acid
CH_3-COOH	ethanoic acid	acetic acid
CH_3-CH_2-COOH	propanoic acid	
CH_3-CH_2-CH_2-COOH	butanoic acid	

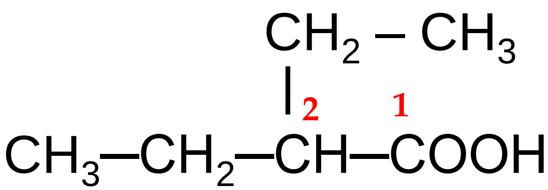
Naming Carboxylic Acids

– Number the chain beginning with the carbon of the carboxyl group.

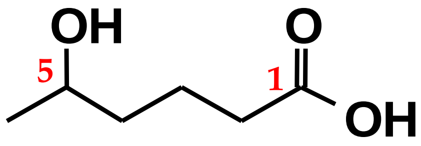
– Because the carboxyl carbon is understood to be carbon 1, there is no need to give it a number.



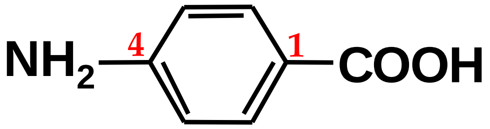
3-Methylbutanoic acid



2-Ethylbutanoic acid



5-Hydroxylhexanoic acid



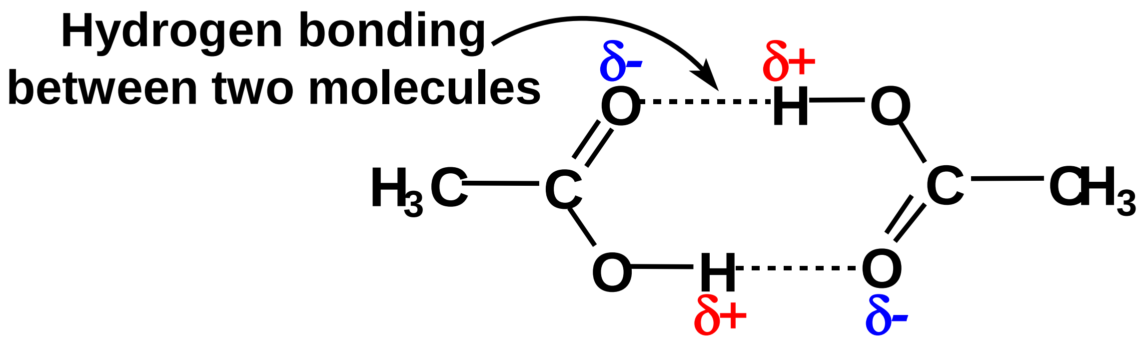
4-Aminobenzoic acid

Physical properties of Carboxylic Acids

1- The carboxyl group contains three polar covalent bonds;

C=O, C-O, and O-H. So they are so polar.

2- Carboxylic acids have higher boiling points than other types of organic compounds (with the same molecular weight) because of hydrogen bonding.



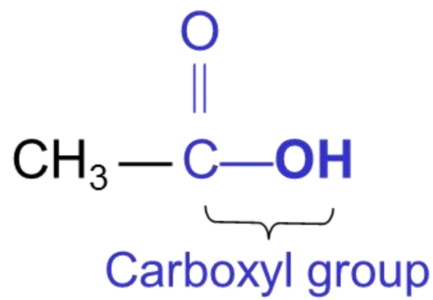
3- They are more soluble in water than alcohols, ethers, aldehydes, and ketones because of stronger hydrogen bonding.

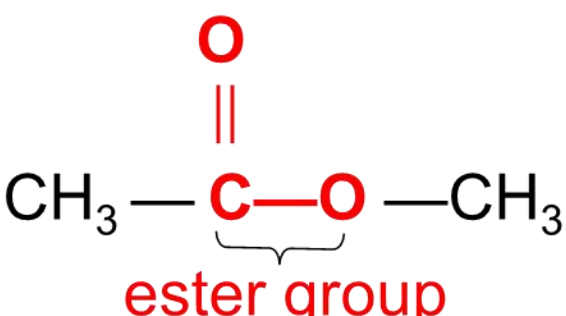
4- Liquid carboxylic acids have sharp and disagreeable odors.

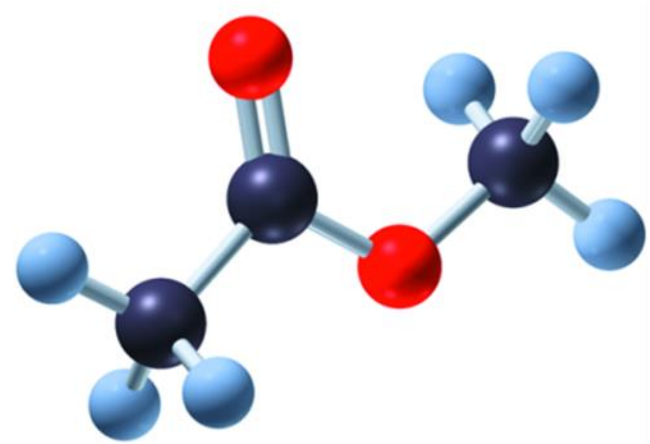
5- They taste sour (exist in pickle, lime, and lemon).

Esters

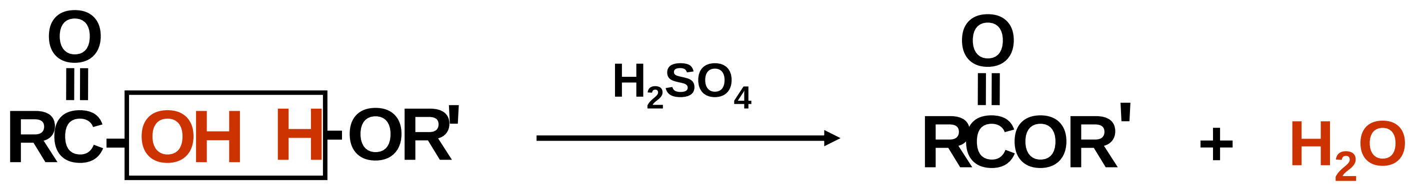
In an ester, the H in the carboxyl group of a carboxylic acid is replaced with and alkyl group.





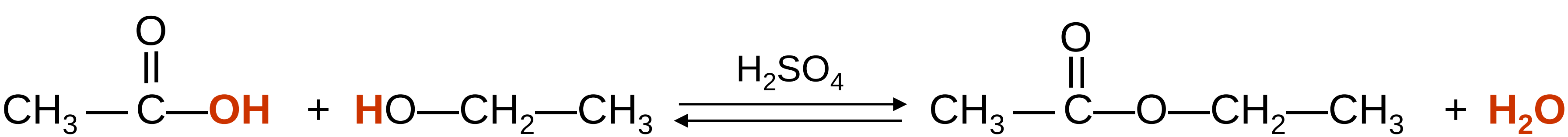


Formation of Esters



A carboxylic acid An alcohol An ester

Fischer Esterification



Ethanoic acid (Acetic acid)

Ethanol (Ethyl alcohol)

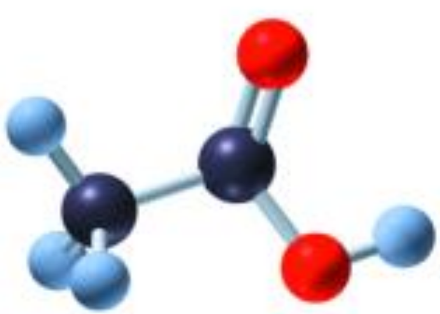
Ethyl ethanoate (Ethyl acetate)

Amides

In an amide, the -OH group in the carboxyl group of a carboxylic acid is replaced by an Amino group ($-NH_2$).

$$CH_3-\overset{\displaystyle O}{\overset{\|}{C}}-\mathbf{OH}$$

Carboxylic acid



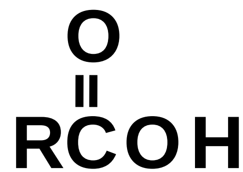
Ethanoic acid
(Acetic acid)

$$CH_3-\overset{\displaystyle O}{\overset{\|}{C}}-\mathbf{NH_2}$$

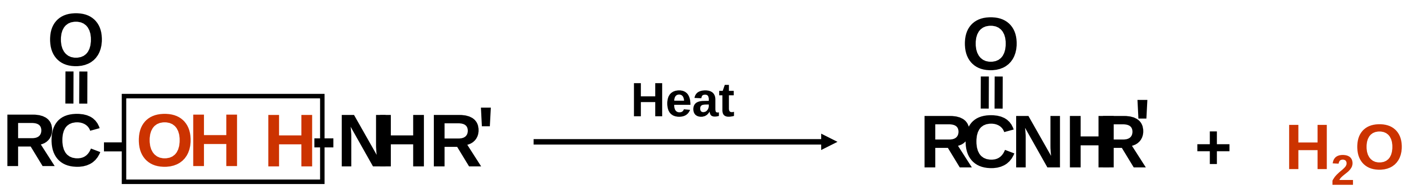
Amide

Ethanamide
(Acetamide)

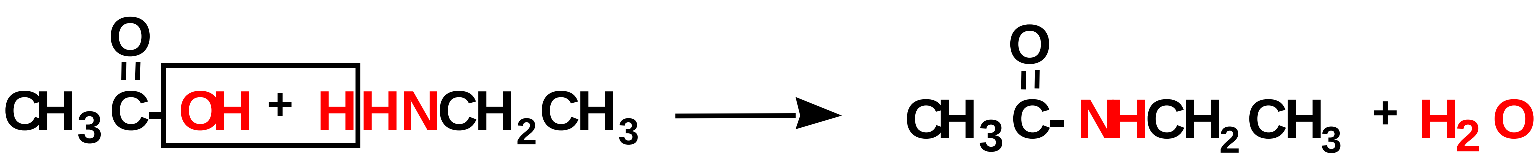
Formation of Amides



A carboxylic acid



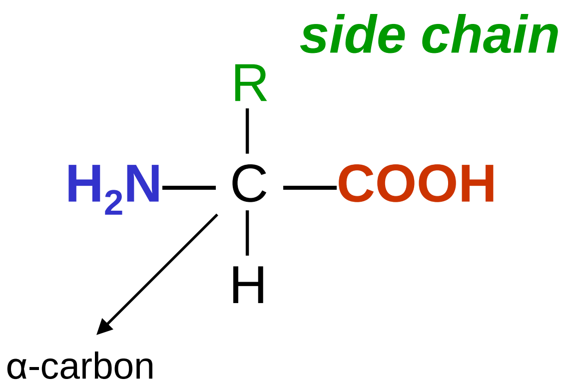
A carboxylic acid An Amine An amide



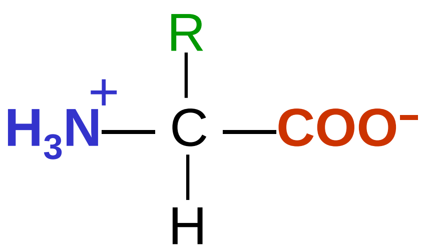
Acetic acid Ethanamine N-ethylethanamide

Amino acids

- Are the building blocks of proteins.
- Contain carboxylic acid and amino groups.
- Are ionized in solution (soluble in water).
- They are ionic compounds (solids-high melting points).
- Contain a different side group (R) for each.



This form never exist in nature.



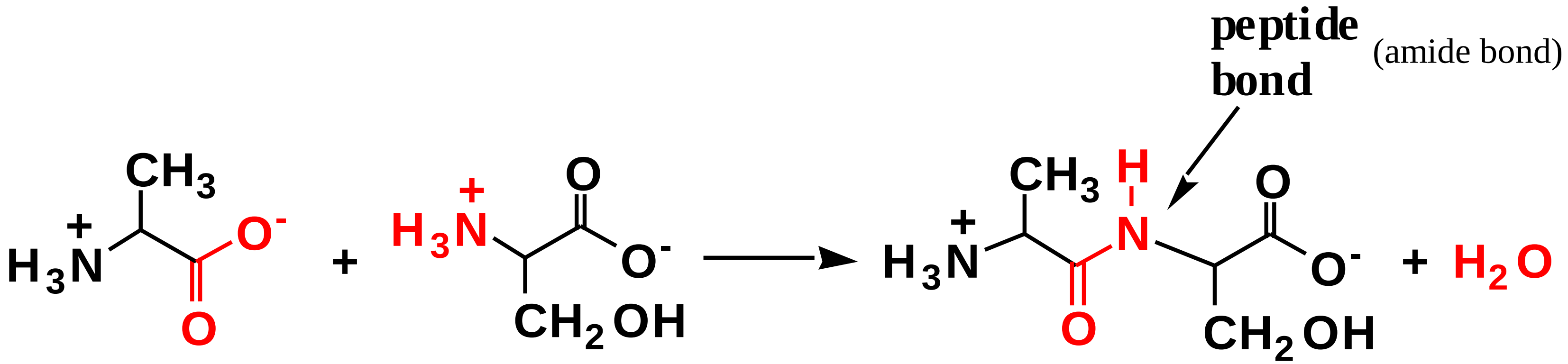
Zwitterion

Ionized form (Salt)

Proteins

- Peptide bond: When an amide links two amino acids.

- Between the COO^{-} of one amino acid and the $NH_3{}^{+}$ of the next amino acid.



Alanine (Ala)

Serine (Ser)

Alanylserine (Ala-Ser)

Protein: **A biological macromolecule containing at least 30 to 50 amino acids joined by peptide bonds.**

Polymerization

Polymer: a long-chain molecule produced by bonding together many single parts called monomers.

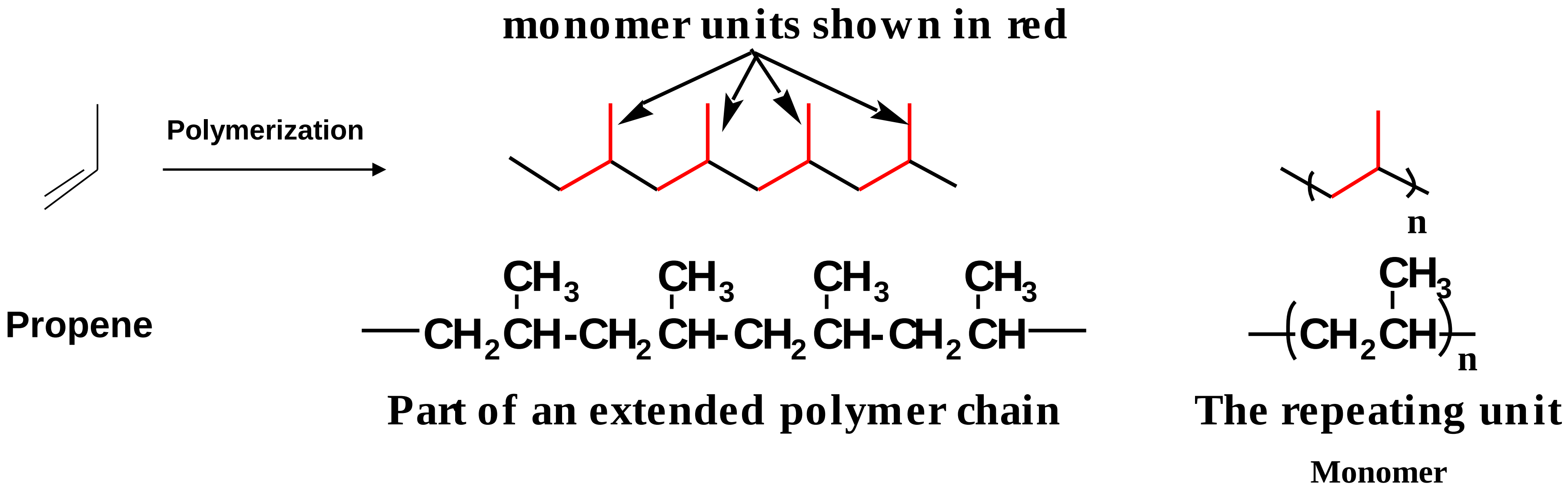
The most important reactions of alkenes in industry.

$$nCH_2{=}CH_2 \xrightarrow[\text{(polymerization)}]{\text{initiator}} \left(CH_2CH_2 \right)_n$$

Ethylene **Polyethylene**

Polymerization

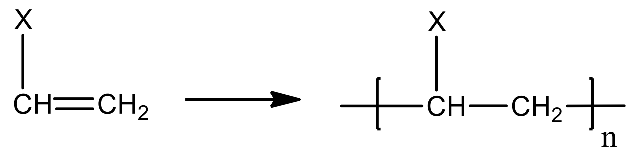
Polypropene (Polypropylene)



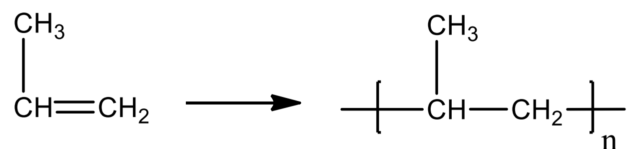
Polymers in our life

Addition Polymerization

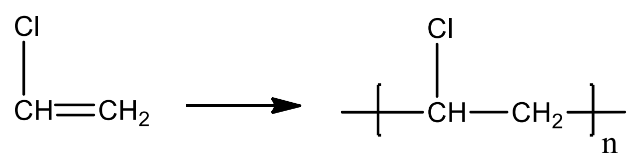
Alkenes can react with themselves to form long chains in a process called addition polymerization.



substituted ethenes — poly- (many)



propylene — polypropylene



vinyl chloride — polyvinyl chloride

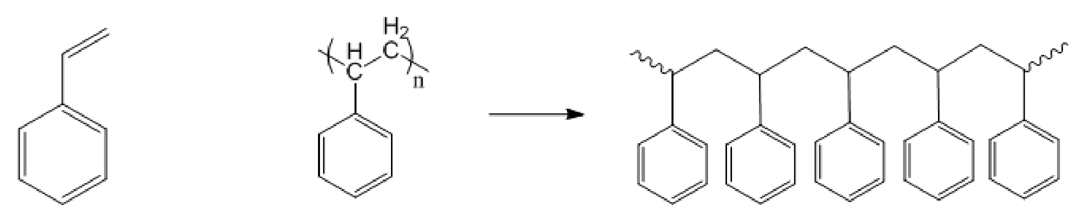
$CF_2{=}CF_2 \longrightarrow -(CF_2-CF_2)_n-$

tetrafluoro ethylene — Teflon (PTFE)

Addition Polymerization

Many plastic materials made of addition polymers can be recycled by melting and reprocessing.

Recycling code	Polymer	Recycling code	Polymer
1 (1, PETE)	polyethylene terephthalate	5 (5, PP)	polypropylene
2 (2, HDPE) 130°C	high-density polyethylene	6 (6, PS)	polystyrene
3 (3, PVC)	polyvinyl chloride	7 (7, OTHER)	other
4 (4, LDPE) 110°C	low-density polyethylene		



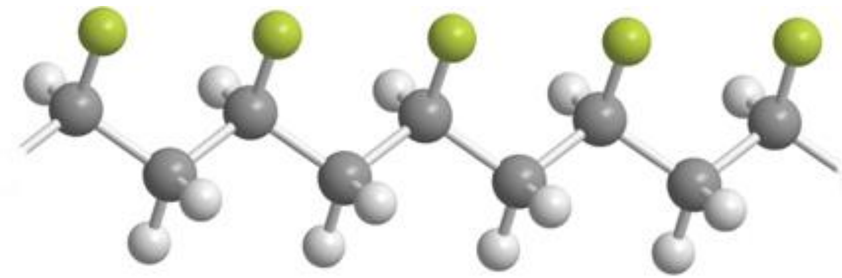
Monomer
Styrene

Repeating Unit
Poly(styrene)

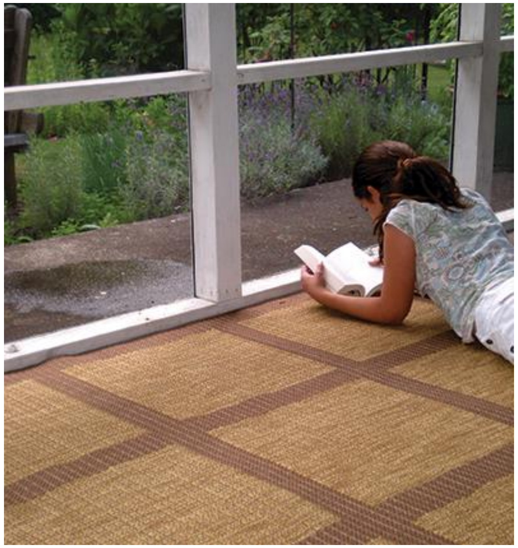
Polymer
Poly(styrene)

Addition Polymerization

Karl Ziegler and Giulio Natta (1950's) discovered $TiCl_4$ and $Al(CH_2CH_3)_3$ (**Ziegler-Natta Catalysts**) could polymerize stereoregular polypropylene.

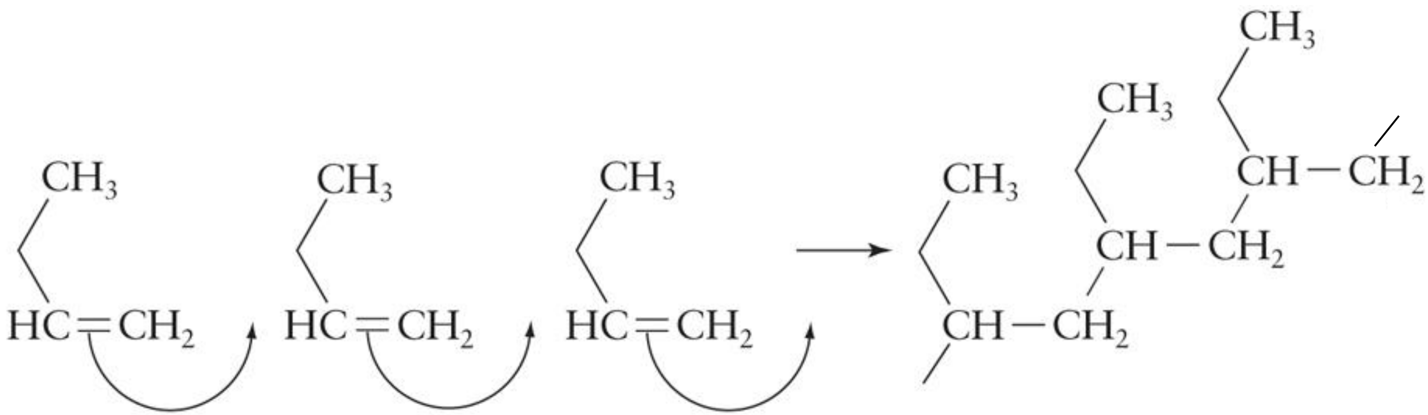


isotactic



Methyl groups are all on the same side, producing densely, highly crystalline material. These are durable, with high melting points.

Example 1: write the formula of the polymer when three monomer units of $CH_3CH_2CH{=}CH_2$ is added at a high temperature and pressure (peroxide is in this reaction as an initiator).



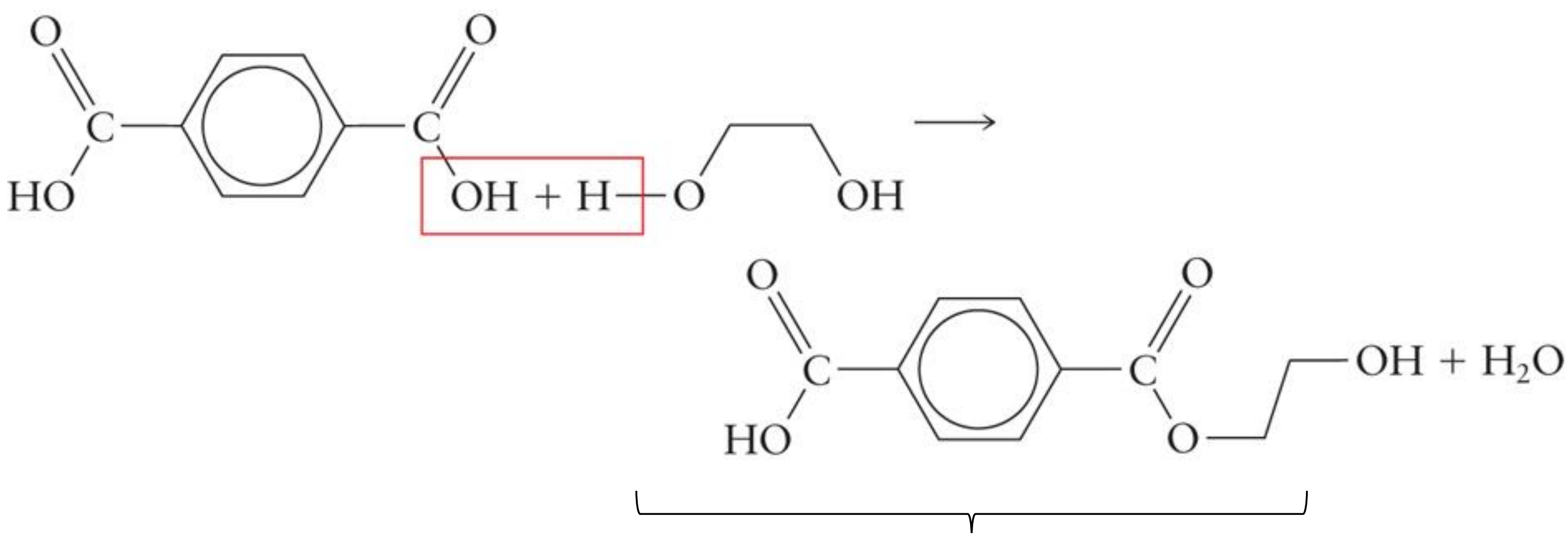
The monomer is an alkene; so it forms an addition polymer. Replace each π-bond by an additional σ-bond to an adjacent monomer.

Condensation Polymerization

Condensation polymerization produces a polymer and often water.

Commonly used to polymerize **esters** and amides.

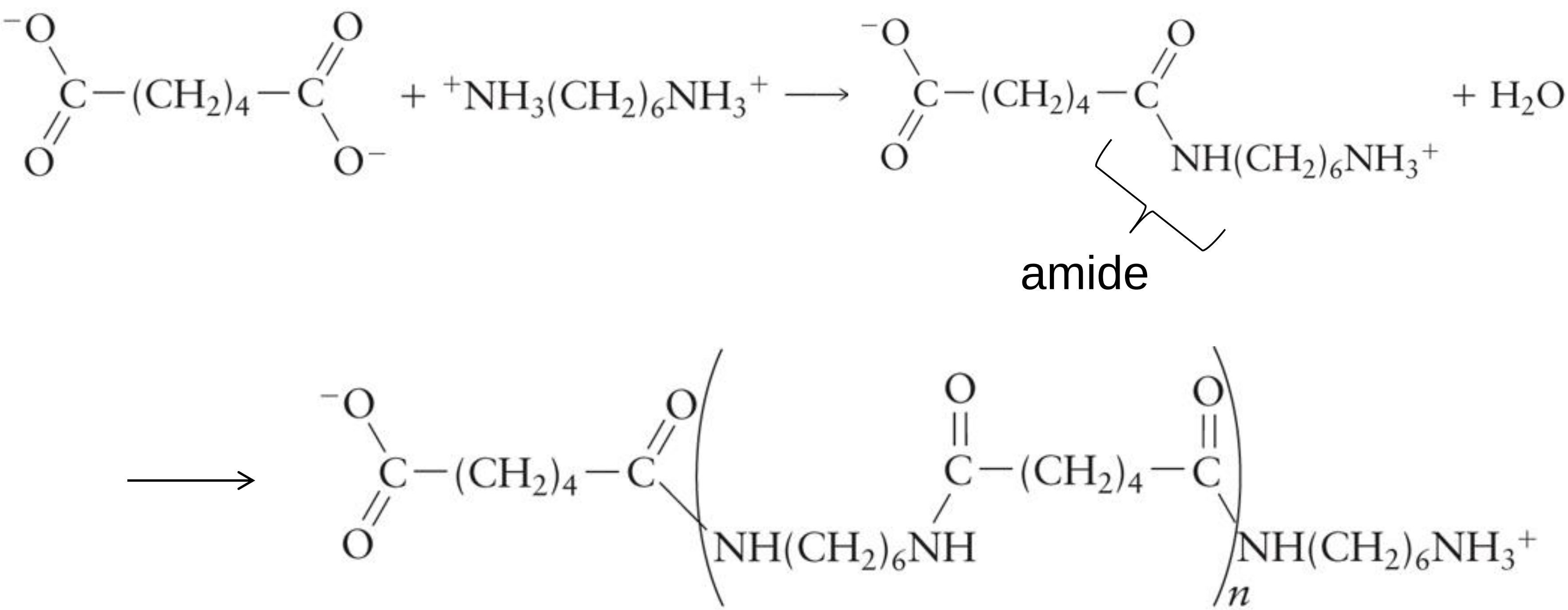
Carboxylic acid and an alcohol make **polyesters**.



Ester + water

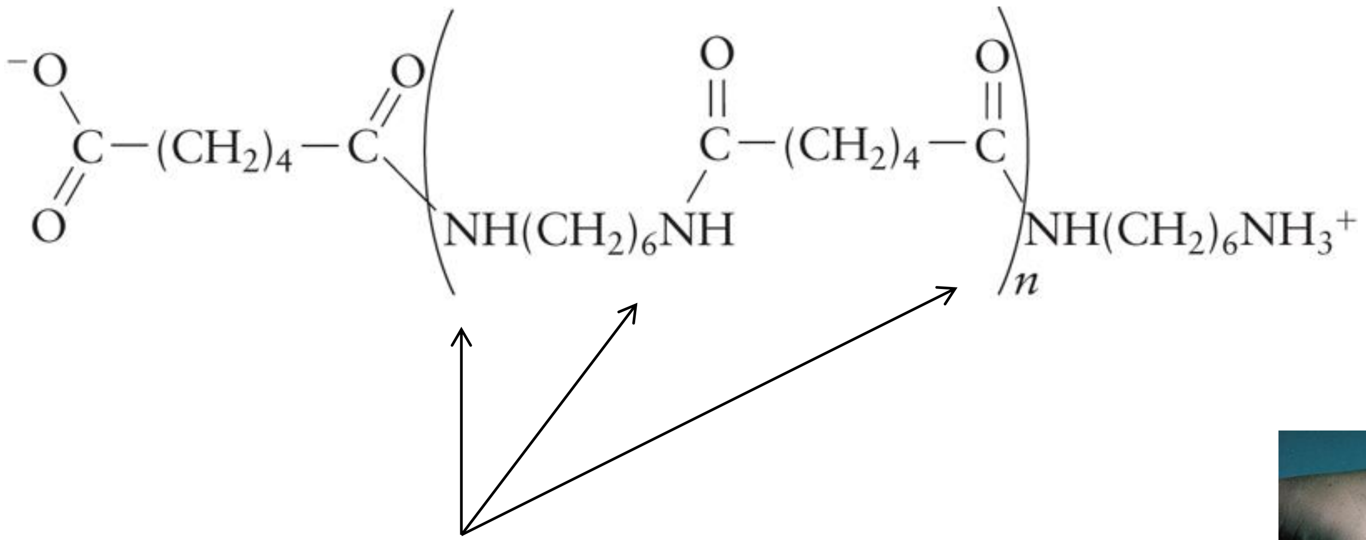
Condensation Polymerization

Polyamides, are commonly known as **nylons**. The most common is nylon-66, made with 1,6-diaminohexane, $H_2N(CH_2)_6NH_2$, and adipic acid, $HOOC(CH_2)_4COOH$. The **66** in the name indicates the numbers of carbon atoms in the two monomers.

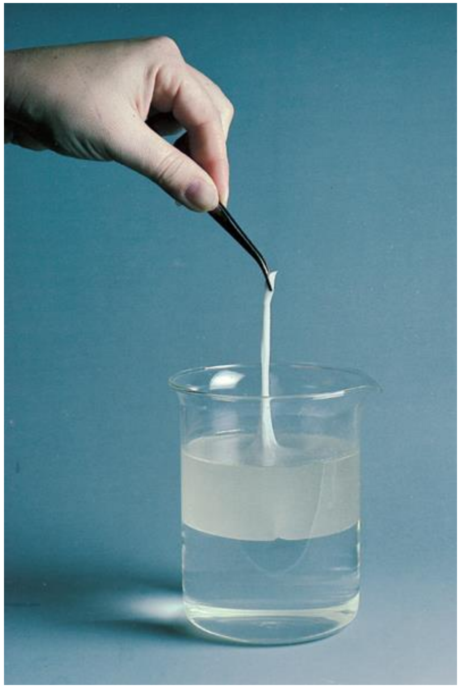


Polyamides

Condensation Polymerization



N-H's can hydrogen bond

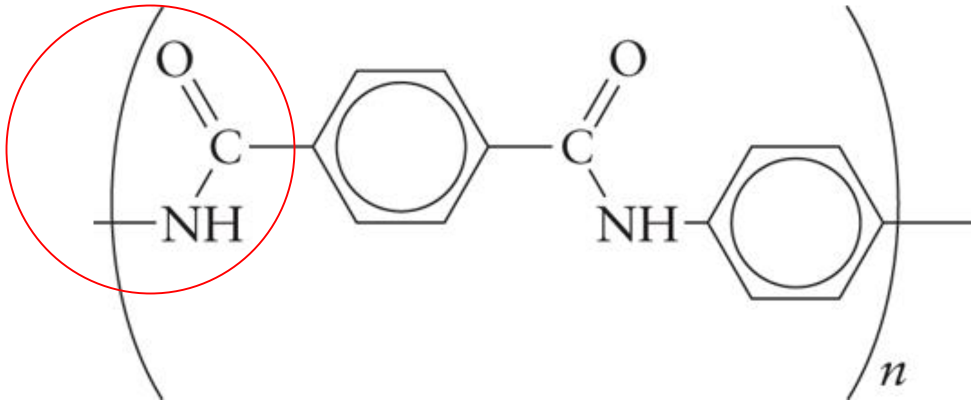


The long polyamide (nylon) chains can be spun into fibers (like polyesters) or molded.

Hydrogen bonding between **neighboring chains** accounts for much of the strength of nylon fibers.

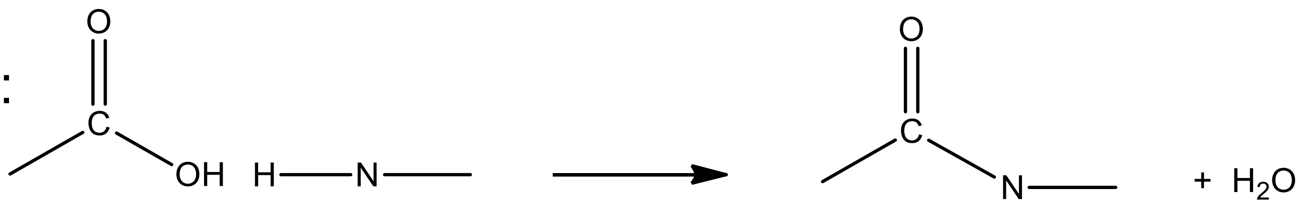
Example 2: Write the formulas of (a) the monomers of Kevlar, a strong fiber used to make bulletproof vests:

Amide link

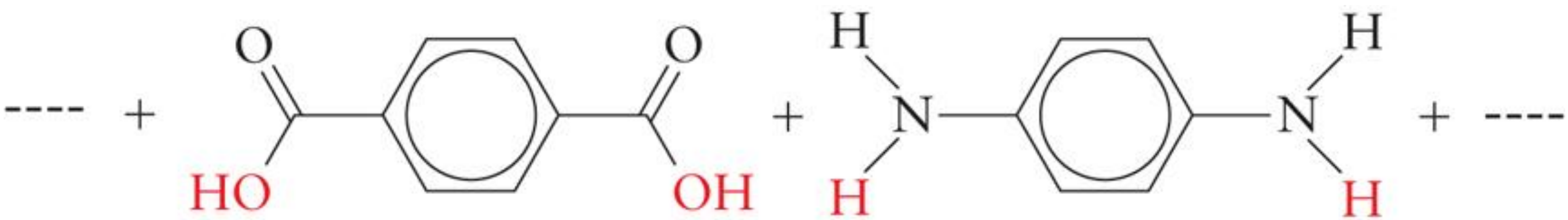


Looking at the backbone we notice the amide link.

Amides are made by:



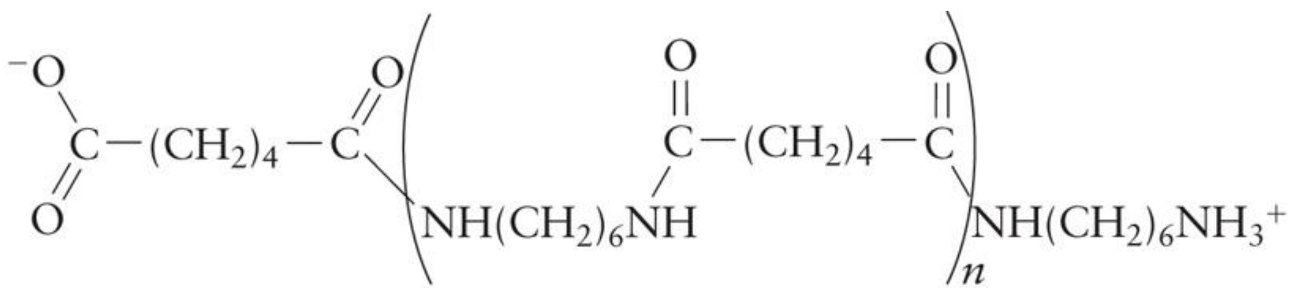
We break the C-N bonds and group accordingly:



Simple & Copolymers

(a) Simple polymer

Nylon is a **copolymer** with with 1,6-diaminohexane, $H_2N(CH_2)_6NH_2$, and adipic acid, $HOOC(CH_2)_4COOH$.



(b) Alternating copolymer

Simple & Copolymers

Block polymers are long segments of polymer of different polymers joined together.

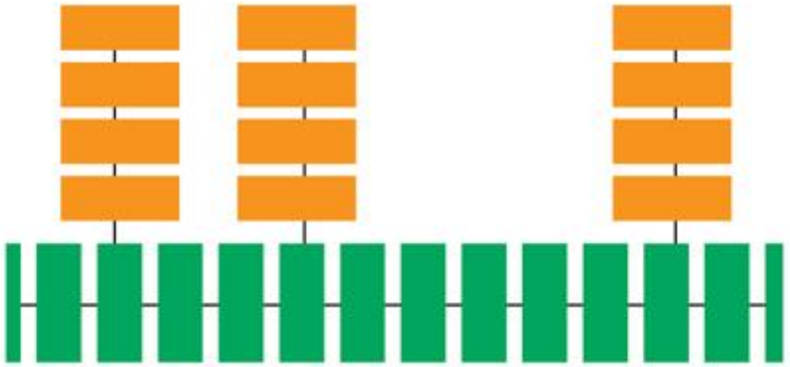
Pure polystyrene is a transparent, brittle material that is easily broken; polybutadiene is a synthetic rubber that is very resilient, but soft and opaque.

(c) Block copolymer

One formulation of these two produces styrene-butadiene rubber (SBR), which is used mainly for automobile tires and running shoes, but also in chewing gum.

Simple & Copolymers

Graft copolymers consist of long chains with shorter chains attached as side groups.



(d) Graft copolymer

For example hard contact lenses use a nonpolar hydrocarbon that repels water. The side chains can absorb 50% of the volume is water, making it pliable, soft, and more comfortable to wear.

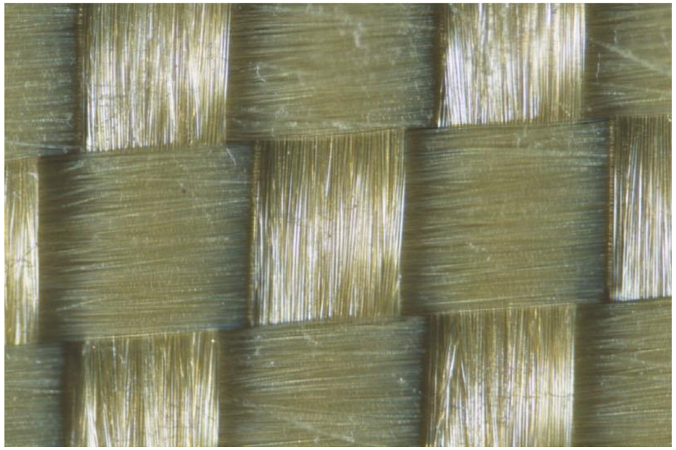
Physical Properties of Polymers

Mechanical strength is the length of the polymer. Hydrogen bonding also helps to hold strands together.

Chain packing is the density. The fewer branches in a polymer the better the polymer strands can pack.

Bullet-proof vests of high density polyethylene; 15 time stronger than steel, flexible, and floats in water.

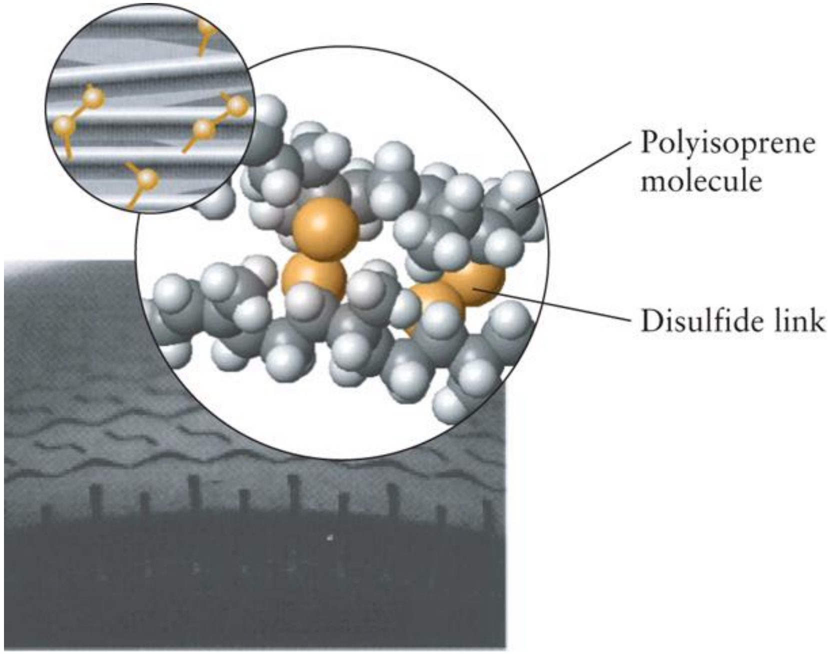
(a)



Physical Properties of Polymers

Elasticity is the ability to return to its original shape.

Natural rubber has low elasticity.
Vulcanization increases its elasticity.

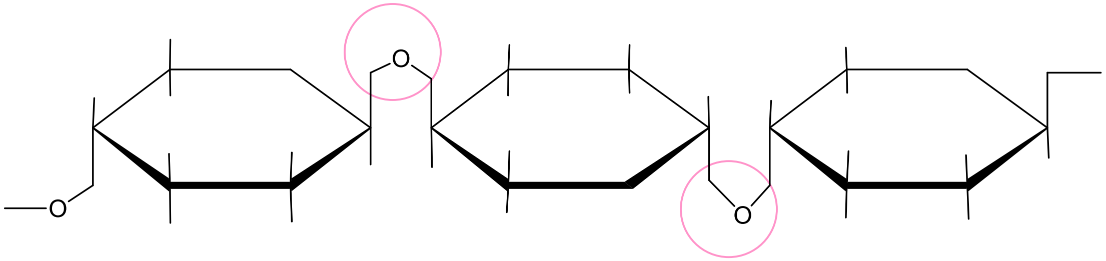


Vulcanization <u>is heating rubber with sulfur</u>. The sulfur forms cross-links.

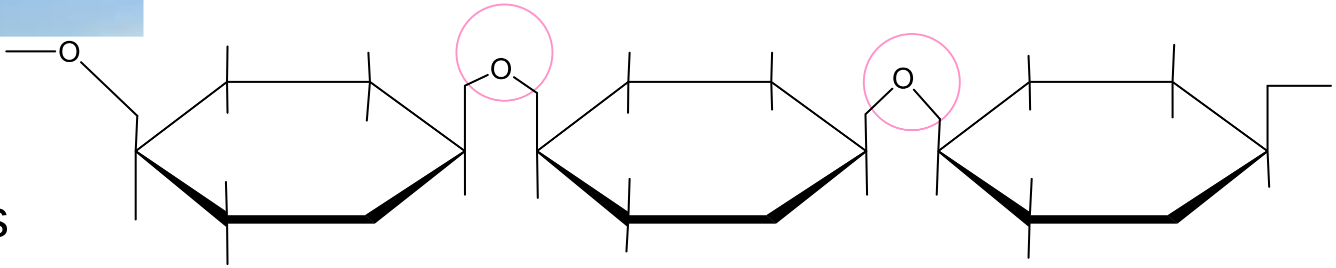
To much sulfur causes extensive cross-linking, producing a hard material called ebonite.

Biological Polymers - Carbohydrates

There are many organic polymers including the **cellulose of wood**, natural fibers such as **cotton.**



cellulose



carbohydrates

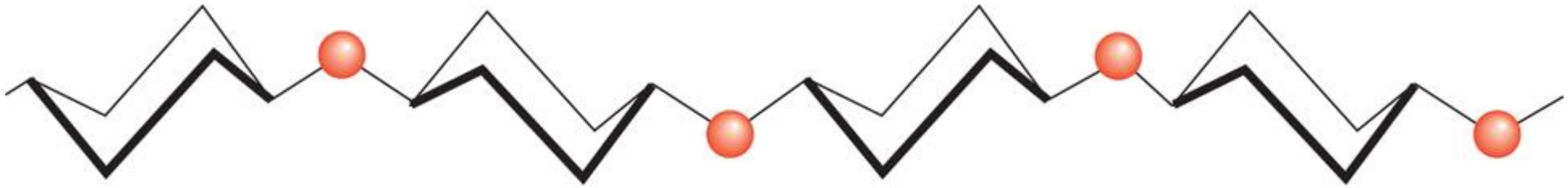
Biological Polymers - Carbohydrates

Polysaccharides are polymers of glucose, including starch.

Starch is made up of two components: amylose and amylopectin.

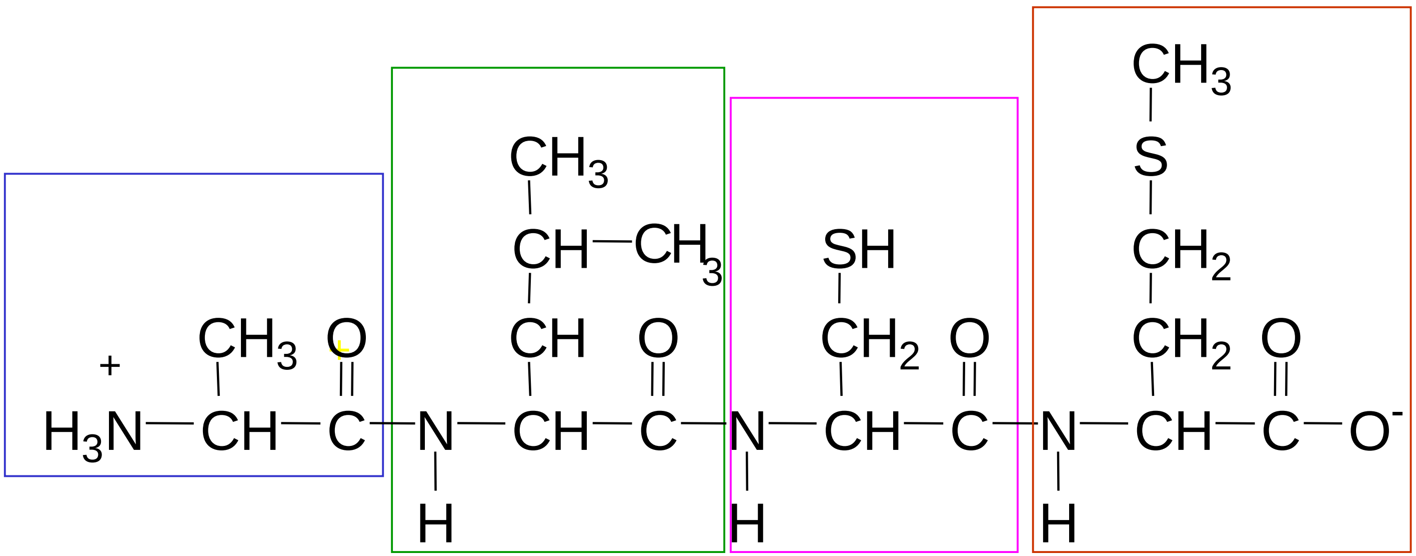
amylose

Cellulose has the same glucose molecules, linked differently, forming flat, ribbon like strands.

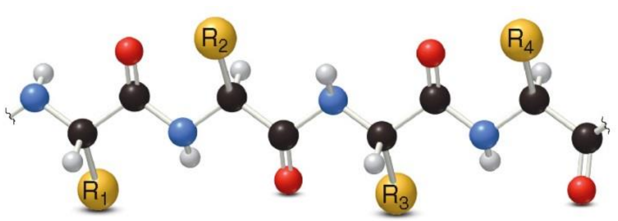


Biological Polymers - Proteins

- The order of amino acids held together by peptide bonds.
- Each protein in our body has a unique sequence of amino acids.
- The backbone of a protein.
- All bond angles are 120º, giving the protein a zigzag arrangement.

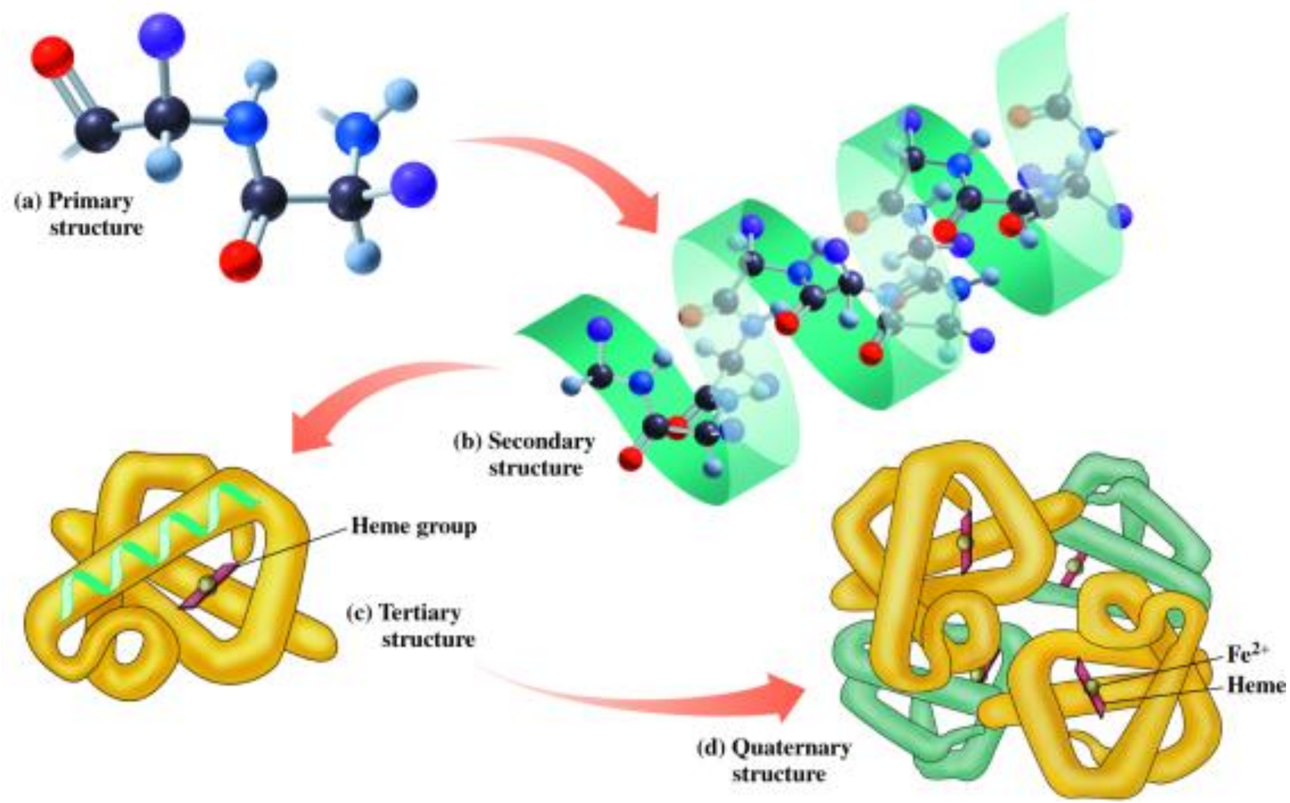


Ala–Leu–Cys–Met



Biological Polymers - Proteins

1. Primary structure
2. Secondary structure
3. Tertiary structure
4. Quaternary structure

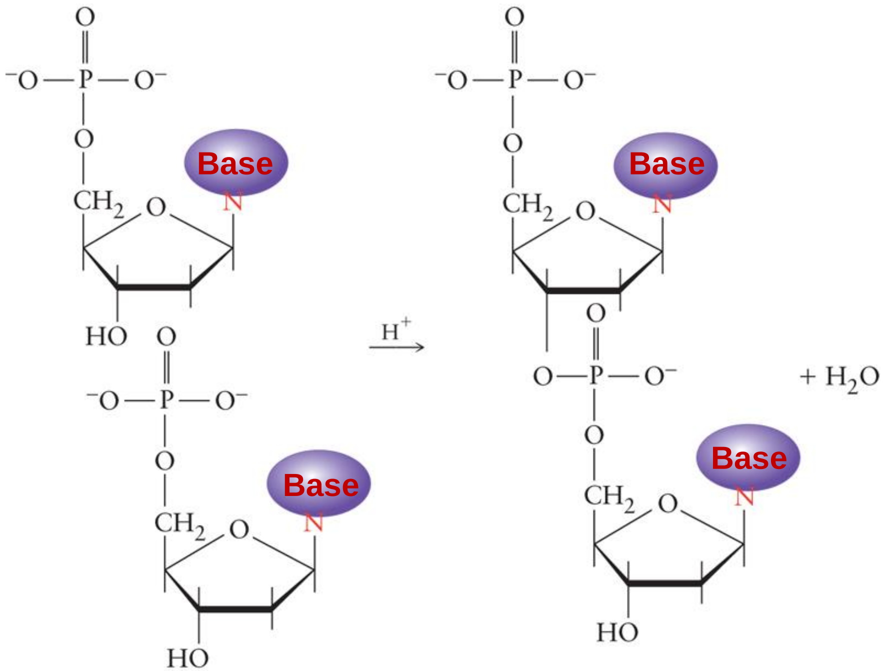


Biological Polymers – Nucleic Acids

DNA and RNA are polynucleotides, polymeric species built from nucleotide units, wrapped into a double helix.

Polymerization takes place when the phosphate group of one nucleotide reacts with OH group of another nucleotide.

One nucleotide one nucleic acid

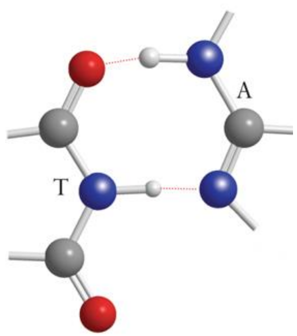


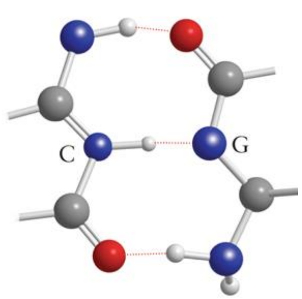
A polymer nucleotides is called a nucleic acid.

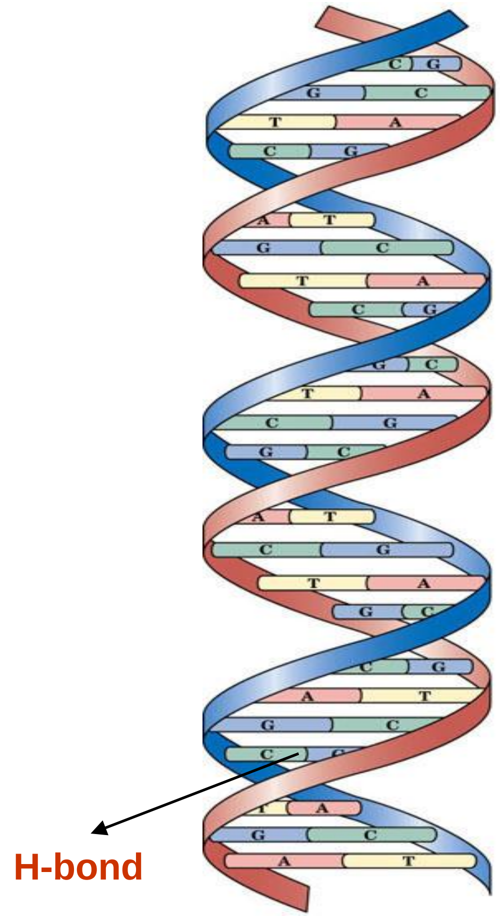
Biological Polymers – Nucleic Acids

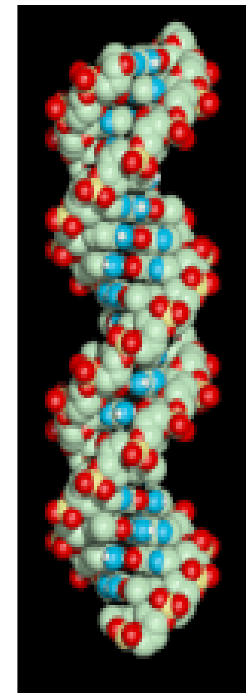
The base pairs line up on opposite sides of the nucleic acids strands, forming the double helix.

During DNA replication, the hydrogen bonds are broken with an enzyme.









DNA