Functional Group

These are specific names given to certain compounds that describe their chemical reactivity.

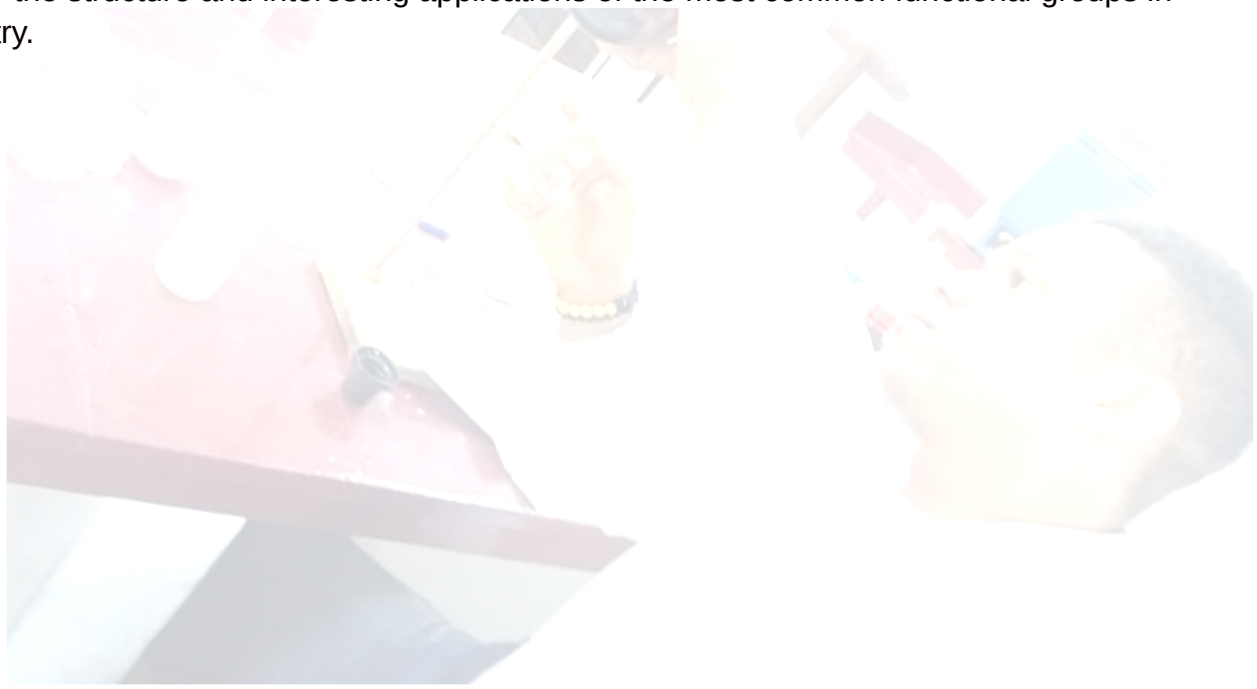
Or

A functional group is a group of atoms or bonds inside a substance that is responsible for the substance's unique chemical reactions in organic chemistry.

Or

A functional group is an atom or a group of atoms that are responsible for the chemical properties of the molecule.

Knowing the functional groups is a must in organic chemistry and in this post, we will go over the structure and interesting applications of the most common functional groups in mistry.



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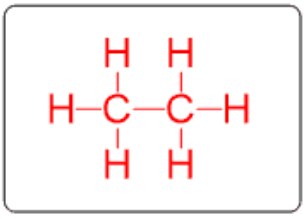
Functional Group	Structure	Nomenclature	Examples
alkanes	$R—CH_3$	-ane	methane, butane, hexane, heptane
alkenes	$R_1—CH=CH—R_2$	-ene	ethene, butene, hexene, heptene
alkynes	$R_1—C\equiv C—R_2$	-yne	ethyne, butyne, hexyne, heptyne
diene	$CH_2=CH—CH=CH_2$	-diene	butadiene, hexadiene
alcohols	$R—OH$	-ol	methanol, butanol, hexanol, heptanol
ethers	$R_1—O—R_2$	-oxy-	ethoxyethane or diethyl ether
aldehydes	$R—C(=O)H$	-al	methanal, butanal, hexanal, heptanal
ketones	$R—C(=O)—R$	-one	propanone, butanone
carboxylic acids	$R—C(=O)—OH$	-oic acid	ethanoic acid, butanoic acid
esters	$R_1—C(=O)—O—R_2$	-oate	ethyl ethanoate or ethyl acetate
amides	$R_1—C(=O)—NH—R_2$	-amide	N-methylethanamide
amines	$R—NH_2$	-amine	ethanamine
nitriles	$R—C\equiv N$	-nitrile	ethanenitrile
Thiols	$R—S—H$	-thiol	ethanethiol

Alkanes



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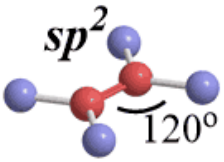
are the first group of organic compounds. They are made of carbons and hydrogens that are only connected with **single (σ) bonds no pi bond.**

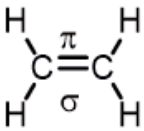
all the carbons are **sp3 hybridized**, with only single bonds, and all the bonds are non-polar, therefore, alkanes and all the other hydrocarbons are non-polar, hydrophobic molecules.

Alkenes

are similar to alkanes, the only difference being the presence of a double bond.

The two carbons with the double bond are ***sp*₂–**hybridized, and the geometry is **trigonal planar** with a **120₀ angle** between the atoms. The double bond is made of **one σ** and **one π** bond.





Alkynes

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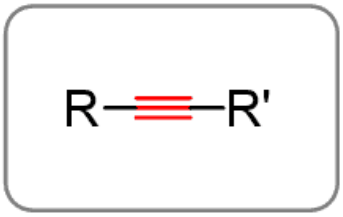
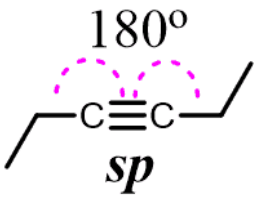
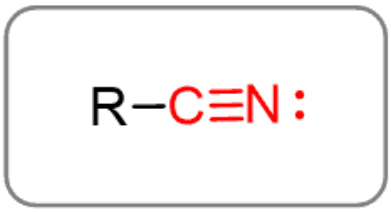


The difference between alkynes and alkenes is the change of the double bond to a triple bond. The ending changes from ***-yne:***

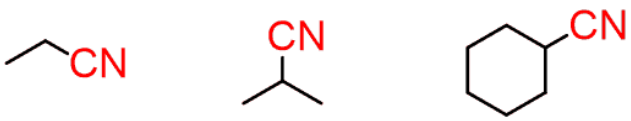
The hybridization of triple-bonded carbons is ***sp*** which corresponds to **the liner geometry** – **180**:



Nitriles



Alkyl groups together with the -CN (cyano) group make the nitriles:



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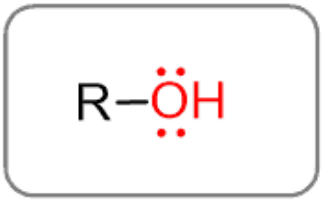
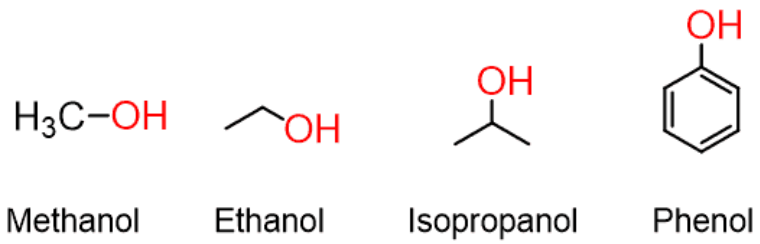
Alcohols



If instead of the halogen, we put an OH (hydroxyl group) on an alkyl halide, we get alcohol.

For the general formula, we have R-OH, and below are some common examples:



Methanol Ethanol Isopropanol Phenol

Ethers

Ethers are different from alcohols in that the hydrogen of the hydroxyl group is replaced with another alkyl group. So, to recognize the ether in an organic molecule, look for the bridging oxygen:

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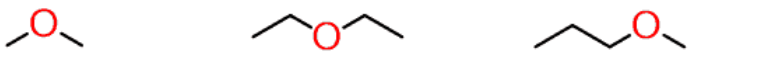
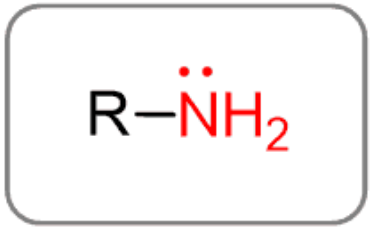
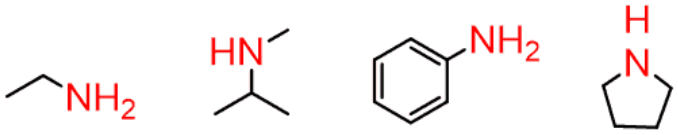


Dimethyl ether Diethyl ether Methyl propyl ether

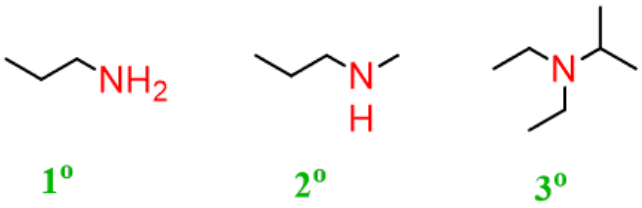
Amines



Amines are the derivatives of ammonia (remember NH_3 from General chemistry). Replacing one hydrogen of ammonia with an alkyl group forms an amine with a general formula of $R\text{-}NH_2$:



Depending on how many alkyl groups are connected to the nitrogen, we have primary, secondary and tertiary amines,



1° 2° 3°

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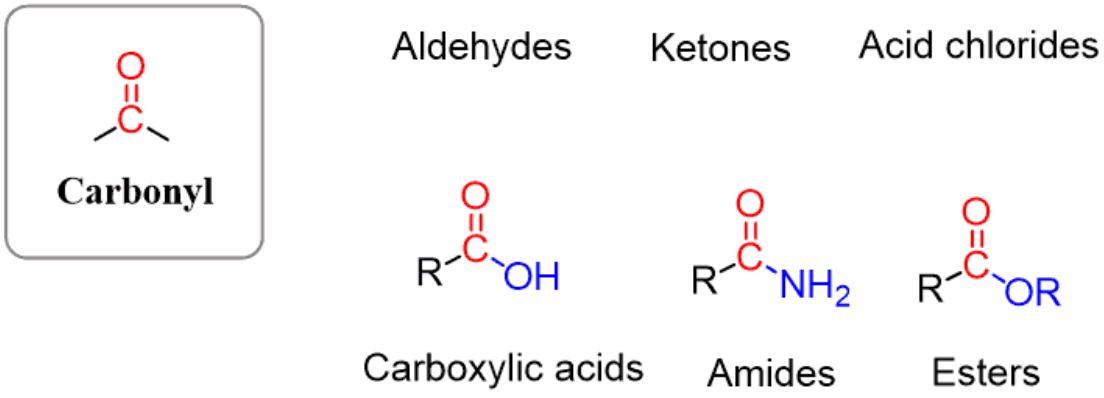
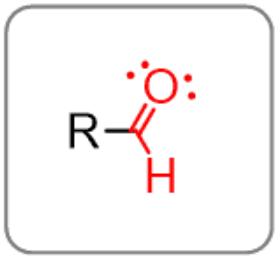
Carbonyl-containing functional groups

Carbonyl (C=O) is an extremely important and common group that is part of many functional groups:



Aldehydes



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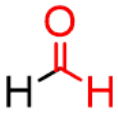
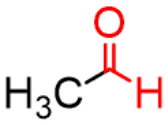
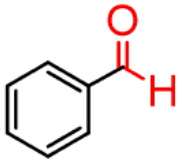
Connecting hydrogen with a carbonyl group gives an aldehyde:



Formaldehyde



Acetaldehyde

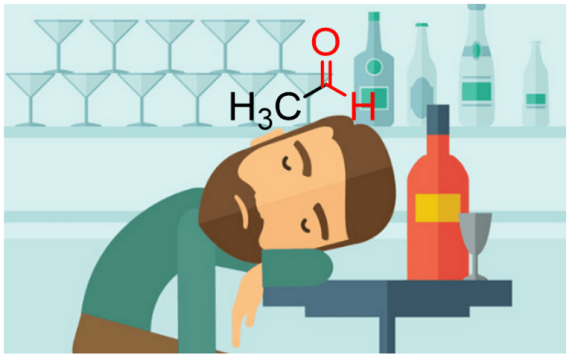


Benzaldehyde

The simplest aldehyde with one carbon atom is formaldehyde followed by acetaldehyde.

Formaldehyde is widely used in medicine a preservative agent and also as a precursor for the synthesis of many chemicals.

Acetaldehyde is a naturally occurring aldehyde which is also produced on a very large scale for the chemical industry. It is also produced in the human body from ethanol by the Alcohol dehydrogenase enzymes and is partly responsible for the cause of the hangover.



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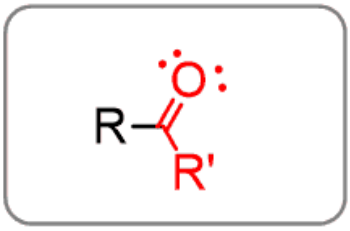
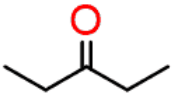
Ketones

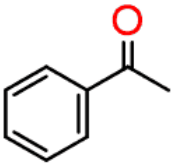


Putting alkyl groups on both sides of the carbonyl switches from aldehydes to ketones:

Acetone



Diethyl ketone



Acetophenone

Some of the ketones such as Ketoses (e.g. fructose) are of great biological importance. Acetone is a commonly used solvent in organic labs and a nail polish remover.

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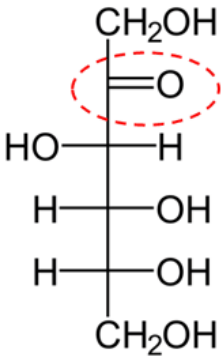
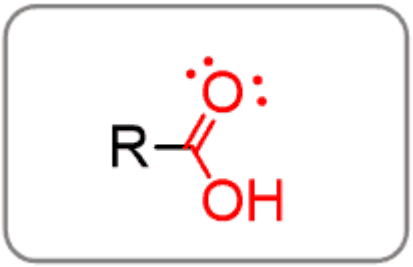


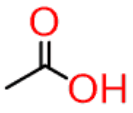
Fructose

Acetone

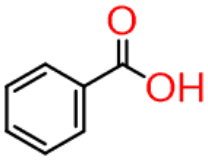
Carboxylic acids



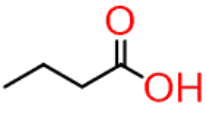
The combination of the carbonyl with OH gives the carboxylic acid functional group:



Acetic acid



Benzoic acid



Butanoic acid

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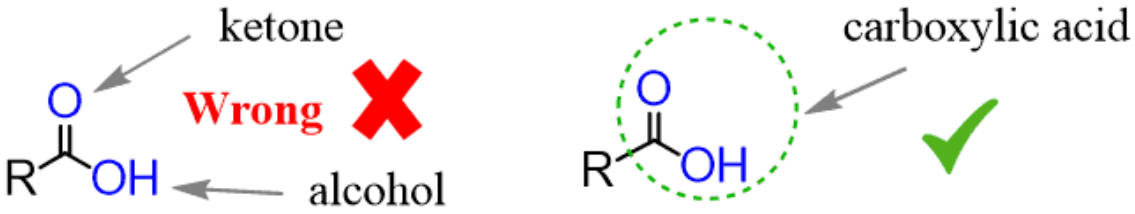
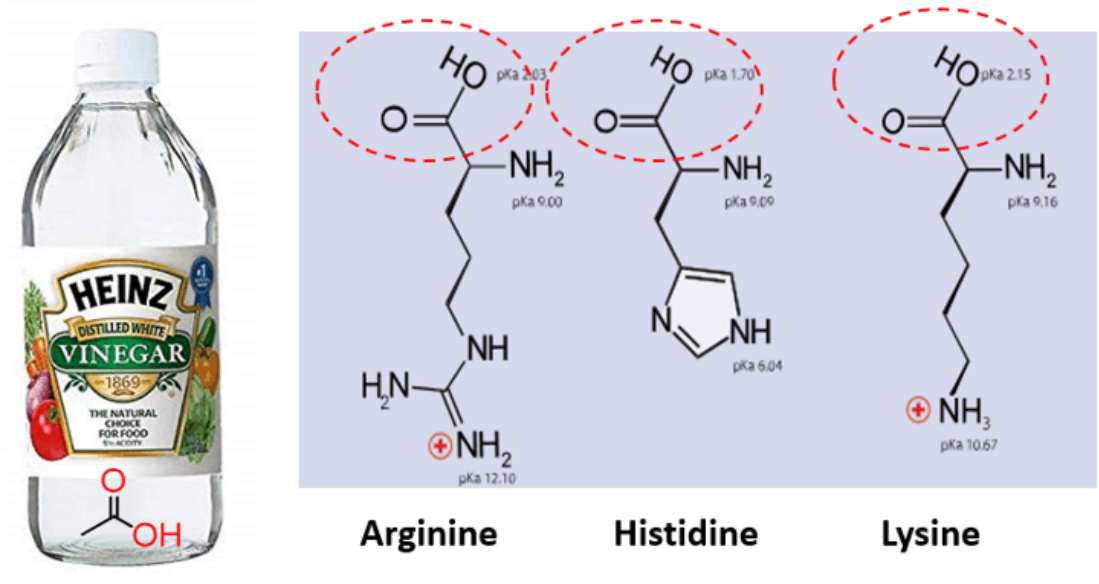
Remember, however, that you cannot indicate them as two different functional groups! If they are together it is the carboxy group.



As the name suggests, these are organic acids and therefore are very common and widely used for different applications. For example, vinegar is a ~5% aqueous solution of acetic acid. Carboxylic acids are also part of the amino acids which are central in life:



Esters

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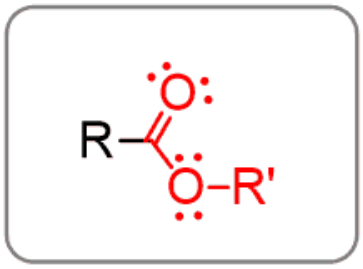
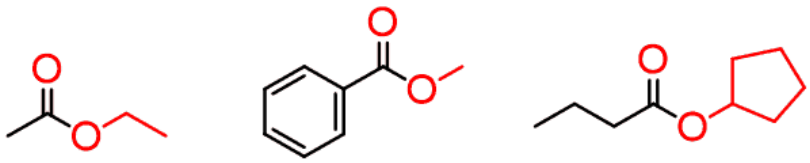
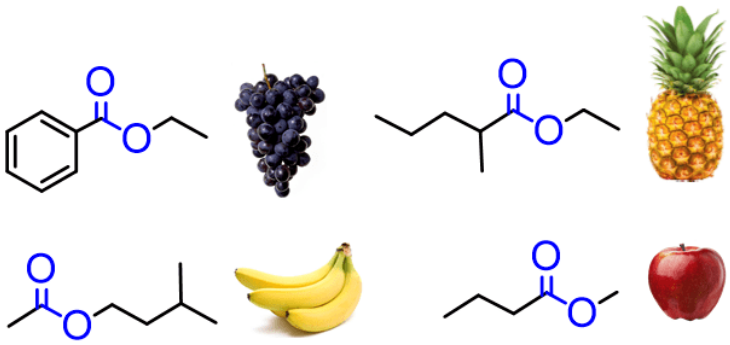


Having another alkyl group in place of the hydrogen of carboxylic acid, makes the esters:



Esters are extremely abundant, occurring both naturally and synthetically. Most esters have a characteristic smell responsible for the aroma of fruits, flowers, wine, perfumes and etc.



A large portion of industrial application goes to synthetic polyesters. Polyesters such as polyethylene terephthalate (PET) are widely used in clothing, plastics, furniture, tires, and many other products.

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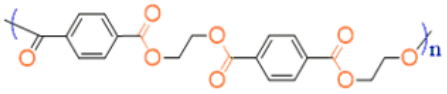
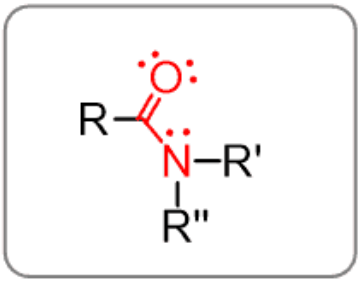


Polyesters

Amides



Amides are the combination of carbonyl and amines:

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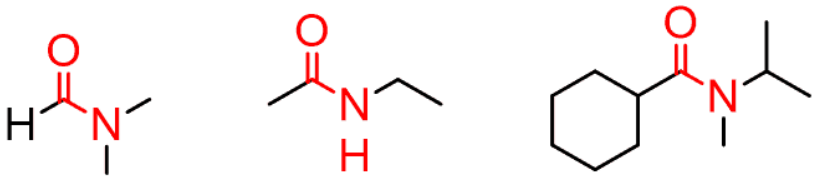
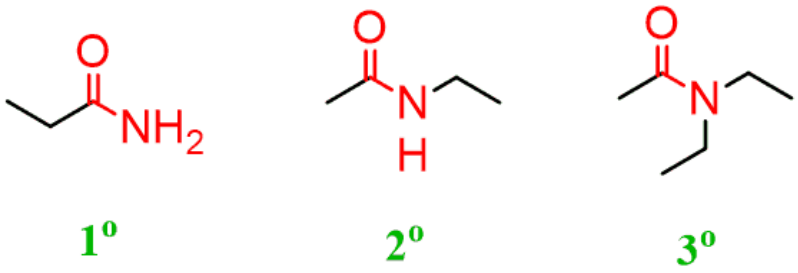
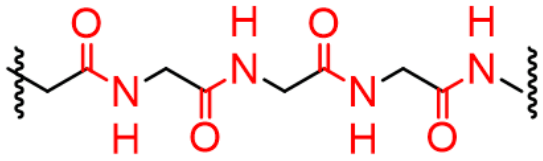


Just like for the amines, depending on the number of carbons connected to the nitrogen, we have primary, secondary, and tertiary amides. Notice that the carbonyl carbon is also counted:



Amides are essential in chemistry and biology as they are part of many peptides and nucleobases. In fact, the amide is also known as the peptide bond since it is the linkage of aminoamides in peptides and proteins.



As expected, amides are very stable and that is why they are also used in synthetic polymers such as nylon and Kevlar, used in the production of bullet-proof material:

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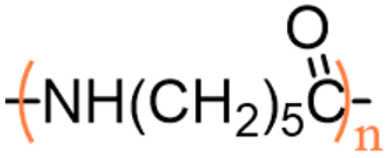
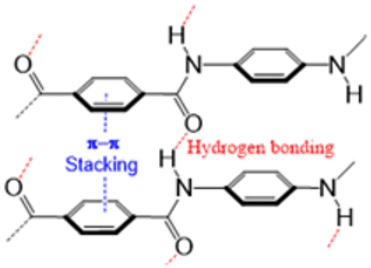
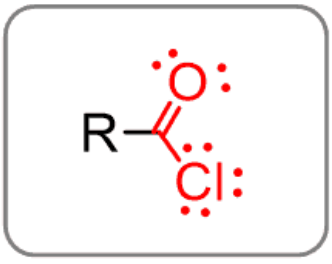


Nylon



Kevlar

[1]Acid Chlorides



Acid chlorides are derivatives of carboxylic acids where the acidic proton is replaced by chlorine:

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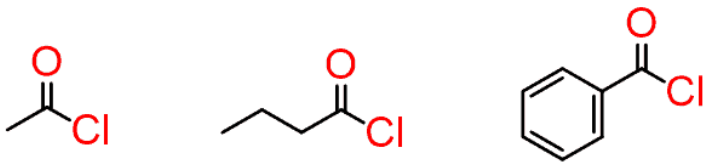
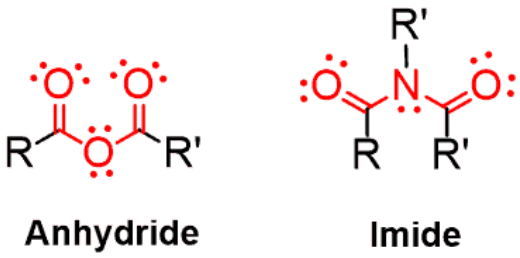


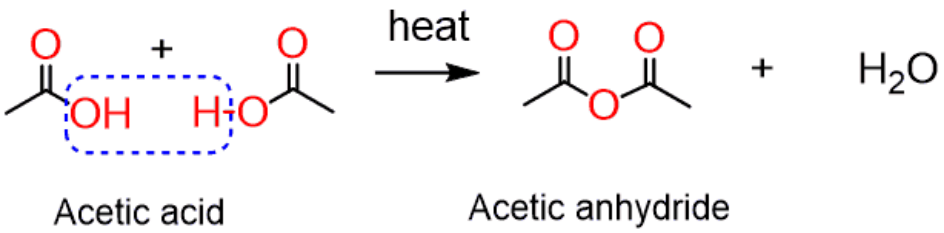
These are very reactive and are mainly used in organic synthesis.

Functional groups with two carbonyls

You may not see them as often, but acid anhydrides and imides are also important functional groups in organic chemistry:



Anhydrides are prepared by removing one water molecule (dehydrating) from two carboxylic acids which are indicated by the name of the functional group:



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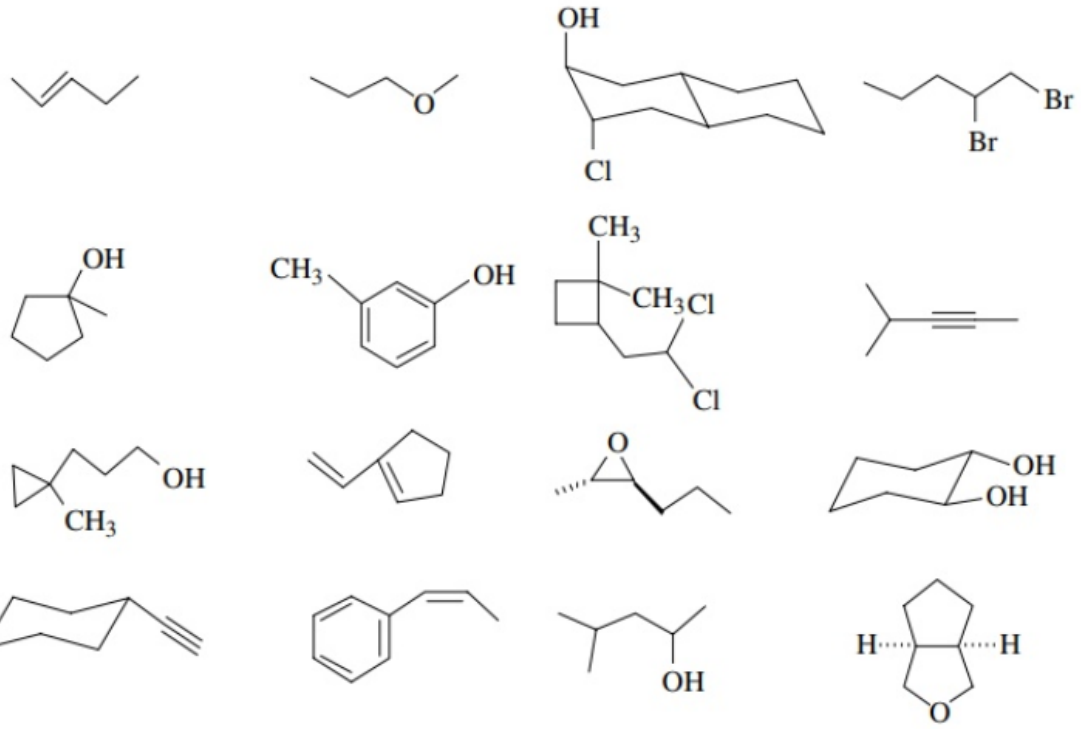
1 Excluding alkyl groups, name and point out the functional groups in the following molecules:



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