ORGANIC FUNCTIONAL GROUPS

Organic Functional Groups come up as tossups and, oftentimes, as bonus parts. Here are a few of the most commonly asked functional groups with brief descriptions of each.
(Study Guide by Adam Silverman)

Brief Description:
The simplest organic functional groups are those of hydrocarbons, compounds which contain just hydrogen and carbon. These come in three types: alkanes, alkenes, and alkynes.

Alkanes:
- Contain only **single carbon-carbon bonds** (**C-C**). Because of this, they are considered "**saturated**" with hydrogen. General formula: C_nH_{2n+2}
- Examples include methane, ethane, propane, and so on. Alkanes end in –ane.
- Alkanes are generally unreactive. They can be formed by the hydrogenation of alkenes, or in the **Wolff-Kishner Reduction** of aldehydes/ketones.

Alkenes:
- Have at least one **double carbon-carbon bond** (**C=C**). Alkenes end in –ene.
- General formula: C_nH_{2n}.
- Also known as "**olefins**"
- They are much more reactive than alkanes, formed in elimination reaction of alcohols or alkyl halides. In the **Wittig Reaction**, alkenes are formed from aldehydes and ketones.

Alkynes:
- Have a **carbon-carbon triple bond** (**C≡C**). Their names end in –yne, like ethyne and propyne.
- General formula: C_nH_{2n-2}.
- Alkynes can be hydrogenated to form alkenes. They are formed from aldehydes in the **Corey-Fuchs** reaction.

Alcohols:
- Contain an oxygen atom bonded to hydrogen (O-H, or **hydroxyl**, group).
- Alcohols end in –ol. Examples include **methanol** (CH_3OH), **ethanol** (found in alcoholic beverages), and butanol.

- Alcohols participate in many reactions: they are oxidized into carboxylic acids and ketones, and they are dehydrated to form alkenes.

Carbonyl Compounds:

- A **carbonyl** functional group consists of a carbon atom double bonded to an oxygen atom **(C=O)**. These are present in two forms in organic compounds: **aldehydes** and **ketones**.

Aldehydes:

- Have a "**terminal**" **carbonyl group**, meaning that the carbonyl is at the **end of a carbon chain**, or that the carbonyl carbon is bonded to hydrogen.
- The simplest aldehyde is **formaldehyde** ($H_2C=O$). Other aldehydes end in –al.
- When reacted with the Grignard reagent, aldehydes form tertiary alcohols.
- When mixed with the Tollens reagent, aldehydes form a silver mirror.

Ketones:

- Have a **non-terminal carbonyl group**, with the carbonyl carbon occurring **inside the carbon chain**.
- The simplest ketone is **acetone**, $(CH_3)_2C=O$.
- Ketones do not react with the Tollens reagent.
- They can be formed by the oxidation of secondary alcohols.

Carboxylic Acids:

- Consist of a carbon double bonded to oxygen and single bonded to a hydroxyl (-OH) group. The carboxyl group is usually written **–COOH**.
- Per their name, carboxylic acids are **acidic**; examples include acetic acid (CH_3COOH). The simplest carboxylic acid is **formic acid**, HCOOH, which is found in ant venom.
- They are formed from aldehydes in the Cannizzaro Reaction.

Esters:

- Contain a carbon double bonded to one oxygen, and single bonded to another (a carbonyl group bonded to oxygen). Formula: **R-COO-R**
- Esters smell **fruity**.
- Esters are commonly formed in the **Fischer esterification**, from treating a carboxylic acid with an alcohol. They also are used in the Claisen condensation.

Other Functional Groups

Ethers:

- Contain an oxygen atom that is bonded to two carbon atoms (**R-O-R**).
- Ethers were originally used as **anesthetics**, particularly the dimethyl ether (CH_3OCH_3).

- Ethers are formed in the **Williamson Synthesis** from alkyl halides and alcohols.

Amines, Amides, and Nitriles:

- There are several nitrogen-containing function groups, but the most commonly encountered at the high school level are amines, amides, and nitriles.
- Amines consist of a nitrogen atom with a lone pair, or, essentially, ammonia with at least one hydrogen replaced with a carbon (**N-R_3**).
- Amides consist of a nitrogen atom bonded to a carbonyl group (-**NC=O**).
- Nitriles consist of a nitrogen atom triple bonded to a carbon atom.

Phenyls:

- The phenyl group (C_6H_5) is essentially a **benzene** ring. Phenyls are called **aromatic** compounds because they alternate between single and double bonds.
- Phenyl containing compounds include **phenol** (an alcohol, C_6H_5OH), **toluene** (a substituted methyl group, $C_6H_5CH_3$), and **aniline** (an amine, $C_6H_5NH_2$).