CHAPTER 12 (MOORE)
FUELS, ORGANIC CHEMICALS AND POLYMERS

This chapter deals “organic” compounds. Organic chemistry is the chemistry of hydrocarbons, which have the general chemical formula, C\text{X}H\text{Y}, and their derivatives, similar compounds made by replacing some of the hydrogen atoms with other “groups.”

Hydrocarbons – Hydrocarbons have the general formula C\text{X}H\text{Y}. The simplest hydrocarbon is methane, CH\text{4}. The simplest hydrocarbons are called paraffins or alkanes and are “saturated” hydrocarbons; all of the carbon-to-carbon bonds in these compounds are single bonds.

Alkanes \( C_nH_{2n+2} \) (-ane suffixes)

<table>
<thead>
<tr>
<th>CH\text{4}</th>
<th>methane</th>
<th>C\text{3}H\text{8}</th>
<th>propane</th>
</tr>
</thead>
<tbody>
<tr>
<td>C\text{2}H\text{6}</td>
<td>ethane</td>
<td>C\text{4}H\text{10}</td>
<td>butane</td>
</tr>
</tbody>
</table>

Prefixes indicate how many carbon atoms are in the molecule.

meth- = 1  hex- = 6
eth- = 2  hept- = 7
prop- = 3  oct- = 8
but- = 4  non- = 9
pent- = 5  dec- = 10

Ex. C\text{8}H\text{18} octane

Lewis Structures for Linear Alkanes

Each carbon atom has four bonds or attachments – these may be other carbon atoms or hydrogen atoms – each hydrogen atom (H-) can form only one bond to a carbon atom, as shown below:

CH\text{3}-CH\text{2}-CH\text{2}-CH\text{2}-CH\text{3} (“condensed” structure for normal pentane)

Alkyl groups are parts of alkane structures that function as building blocks for alkanes -

- methyl group, - CH\text{3}
- methylene group, - CH\text{2}-

Thus, the condensed structure for the normal pentane above was written as CH\text{3}-CH\text{2}-CH\text{2}-CH\text{2}-CH\text{3} using methylene and methylene groups.

So-called straight-chain alkanes are chains of carbon atoms attached to each other .. this ability to form chains is an important property of carbon (and silicon atoms) and is called catenation or “chaining”.

Straight-chains aren’t actually straight since carbon atoms form tetrahedra, which as we saw earlier, have bond angles of about 109.5°.
Branched Alkanes
Branched-chain alkanes are chains of carbon atoms with attached side chains or branches. These occur when the number of carbon atoms exceeds three (3), or for C₄ compounds and above, and allow the formation of isomers, molecules with the same molecular formulas but different molecular structures.

Alkenes
• Alkenes are hydrocarbon chains in which at least one carbon-to-carbon bond is a double bond (C=C). Alkenes are sometimes called “unsaturated” compounds since they can “pick up” more hydrogen atoms (2 H-atoms can be added to each double bond).

Aromatic Hydrocarbons
• Aromatic hydrocarbons are compounds whose Lewis structures consist of six-membered rings with alternating double and single bonds – the compound, benzene, C₆H₆, is the parent compound for many such aromatic compounds.

Benzene is the simplest representative aromatic hydrocarbon.

Functional Groups
• Functional groups are special centers of reactivity in organic molecules and determine, to a great extent, the chemical and physical properties of the compounds which contain them.

A double bond (C=C) in a molecule constitutes a kind of functional group and dictates the reactivity of molecules which have one or more of these groups.

Alkenes (may have one or more C=C)

(R-CH = CH-R, R₂C = CH₂, R-CH = CHR)

Ex.  CH₂ = CH-CH₂-CH₃  1-butene
     CH₃ –CH = CH-CH₃  2-butene
     CH₂ = CH₂  ethene (ethylene)

Alkenes -- Addition Reactions  Addition “across” the double bond

• Halogenation (addition of Cl₂, Br₂ or I₂)

     R-CH = CH-R + Br₂ → R-CH(-Br) – CH(-Br)-R

• Hydration (addition of water to make alcohols)

     R-CH = CH-R + H₂O → R-CH₂ – CH(-OH)-R
Functional Groups -- Reactions

Addition Reactions - addition across a double bond

- **Hydrogenation (addition of \( \text{H}_2 \) produces an alkane)**
  \[
  \text{R-CH} = \text{CH-R} + \text{H}_2 \rightarrow \text{R-CH}_2 - \text{CH}_2 - \text{R (alkane)}
  \]

- **Polymerization (add alkene “monomers” to make a polymer)**
  \[
  \text{R-CH} = \text{CH-R} + \text{R-CH} = \text{CH-R} \rightarrow \text{R-CH}_2 - \text{CH-R-} .....\]

Functional Groups
Functional groups are centers of special reactivity, attached to alkyl chains like alkanes or alkenes and typically replace or substitute for one or more H-atoms in the molecular structure.

Halocarbons R-X \((X = \text{F, Cl, Br, or I})\)

**Ex.** CH\(_3\)-CH\(_2\)-CH\(_2\)-CH\(_2\)-Cl  1-chloropentane

Other halocarbon compounds: polychlorinated biphenyls (PCBs) freons and DDT
Chlorinated hydrocarbons have a high degree of biological activity ... used as pesticides ..

![Image of chlorinated compounds](image)

**Dichlorodiphenyltrichloroethane (DDT)  Chlordane**

These compounds are highly chlorinated, persistent and neurotoxic, but are not selective. PCBs were first detected in wildlife in 1966 by Jensen in Sweden. They are lipophilic, widespread and capable of biomagnification. Not all congeners are equally hazardous. This (above) is one of 209 polychlorinated biphenyl isomers ...these isomers are “congeners” .... PCBs had been produced since 1881 and used as dielectric fluids in transformers due to their lack of flammability ... they are weak carcinogens, and most of the problems come from impurities ..PCDFs ...

Alcohols R-OH

**Ex.** CH\(_3\)-CH\(_2\)-CH\(_2\)-OH  1-propanol  CH\(_3\)-OH  methanol (wood alcohol)
  CH\(_3\)-CH\(_2\)-OH  ethanol (grain alcohol)
Ethanol ("grain" alcohol)
Proof = Volume % x 2  or %%(v/v) x 2
Volume % = Proof/ 2

Ex. 151 proof rums, also known as "overproof" rum, are usually dark, aromatic rum from Guyana and the West Indies that have been bottled at higher proof than usual rums.

Bacardi 151 is probably the best known brand. Overproof rum is not available in several countries because of its high alcohol content.

% (v/v)  = 151/2  =  75.5% ethanol by volume

Overproof rum is usually used floated, and sometimes ignited, on top of shots. It is also used in punches and high proof cocktails. Warning: 151 proof rum is very potent and should not be drunk straight. Be extremely careful when using 151 proof rum for flaming drinks.

Ethers  R-O-R (C-O-C linkages)
Ex.  CH₃-O-CH₃  dimethyl ether
     CH₃-O-CH₂CH₃  ethylmethyl ether
     CH₃CH₂-O-CH₂CH₃  diethyl ether

Ethers are synthesized from “condensation” of alcohols – ethers are good solvents.

2 CH₃-CH₂-OH  → CH₃CH₂-O- CH₂CH₃ + H₂O

Aldehydes  R-C(=O)-H
formaldehyde  acetaldehyde
H-C(=O)-H  CH₃-C(=O)-H

From mild oxidation of terminal alcohols:  CH₃-CH₂-OH + O₂  →  CH₃-C(= O )-H

•Ketones  R-C-(=O)-R’
Ex.  CH₃-C-(=O)-CH₃  dimethyl ketone (acetone)  or 2-propanone

Ketones are synthesized from oxidation of secondary alcohols – good solvents

CH₃-CH(OH)-CH₃  →  CH₃C(=O)CH₃
Carboxylic Acids $\text{R-C(=O)-OH}$

Ex. $\text{H-C(=O)-OH}$ formic acid
$\text{CH}_3\text{-C(=O)-OH}$ acetic acid (vinegar, 5%)
$\text{CH}_3\text{-CH}_2\text{-C(=O)-OH}$ propionic acid

Carboxylic acids are weak acids formed by oxidation of either terminal alcohols or aldehydes

$\text{CH}_3\text{-CH}_2\text{-OH} + \text{O}_2 \rightarrow \text{CH}_3\text{-C(=O)-OH}$

Esters $\text{R-C(=O)-OR'}$ (pleasant smelling)

Ex. $\text{CH}_3\text{-C(=O)-O-CH}_3$ methyl acetate
$\text{CH}_3\text{CH}_2\text{CH}_2\text{-C(=O)-O-CH}_3$ methyl butyrate (“pineapple” smell)

Esters are synthesized from the “condensation” of an alcohol with a carboxylic acid:

$\text{CH}_3\text{-OH} + \text{CH}_3\text{-C(=O)-OH} \rightarrow \text{CH}_3\text{-C(=O)-OCH}_3 + \text{H}_2\text{O}$

AMINES $\text{R-NH}_2$ (unpleasant smells); also, $\text{R-NH-R'}$ and $\text{R-N(R’)} - \text{R’}$

Ex. $\text{CH}_3\text{-NH}_2$ methylamine
$\text{CH}_3\text{-CH}_2\text{-NH}_2$ ethylamine

Amines are often degradation products from the breakdown of protein and are reduced nitrogen compounds. Amines are weak bases like ammonia.

Combinations Of Functional Groups

- **Carbohydrates** -C(=O)- and –OH groups
Sugars and starches: glucose, fructose, sucrose
Monosaccharides (simple sugars)
Polysaccharides (complex sugars, starches)

- **Amino Acids** -NHR- and -C(=O)-OH groups

$\text{R-CH(-NH}_2\text{-C(=O)-OH}$

Amino acids react to form “differentiated” proteins, including enzymes and hormones.