AL- MUSTAQBAL UNIVERSITY
College Of Health And Medical Techniques
Prosthetic Dental Techniques Department
Second Grade
Second Semester

Advanced chemistry

Lecture 10 (The theoretical part)

(Organic compounds)

By:

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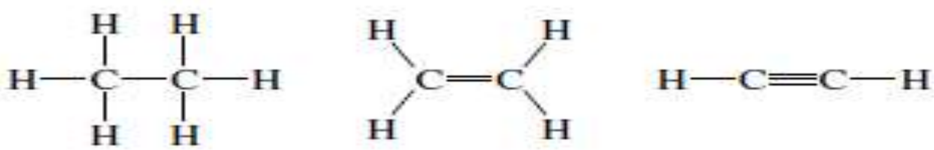
Organic compounds

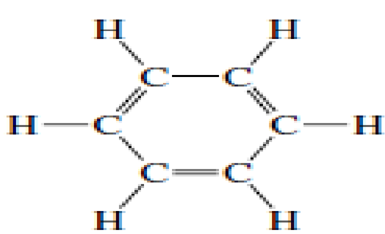
1.ALKANES

Hydrocarbons are compounds that contain only carbon and hydrogen and are divided into two main classes: **aliphatic** hydrocarbons and **aromatic** hydrocarbons. This classification dates from the nineteenth century, when organic chemistry was almost exclusively devoted to the study of materials from natural sources, and terms were coined that reflected a substance's origin. Two sources were fats and oils, and the word *aliphatic* was derived from the Greek word *aleiphar* ("fat"). Aromatic hydrocarbons, irrespective of their own odor, were typically obtained by chemical treatment of pleasant-smelling plant extracts. Aliphatic hydrocarbons include three major groups: *alkanes, alkenes,* and *alkynes.* **Alkanes** are hydrocarbons in which all the bonds are single bonds, **alkenes** contain a carbon–carbon double bond, and **alkynes** contain a carbon–carbon triple bond. Examples of the three classes of aliphatic hydrocarbons are the two-carbon compounds *ethane,ethylene,* and *acetylene.*



Ethane (alkane) Ethylene (alkene) Acetylene (alkyne)

Another name for aromatic hydrocarbons is **arenes.** Arenes have properties that are much different from alkanes, alkenes, and alkynes. The most important aromatic hydrocarbon is *benzene.*



Benzene (arene)

8.1.1. REACTIVE SITES IN HYDROCARBONS

A functional group is the structural unit responsible for a given molecule's reactivity under a particular set of conditions. It can be as small as a single hydrogen atom, or it can encompass several atoms. The functional group of an alkane is any one of its hydrogen substituent's.

$$\underset{\text{Ethane}}{CH_3CH_3} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{Chloroethane}}{CH_3CH_2Cl} + \underset{\text{Hydrogen chloride}}{HCl}$$

One of the hydrogen atoms of ethane is replaced by chlorine. This replacement of hydrogen by chlorine is a characteristic reaction of all alkanes and can be represented for the general case by the equation:

$$\underset{\text{Alkane}}{R{-}H} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{Alkyl chloride}}{R{-}Cl} + \underset{\text{Hydrogen chloride}}{HCl}$$

8.1.2.THE KEY FUNCTIONAL GROUPS

As a class, alkanes are not particularly reactive compounds, and the H in RH is not a particularly reactive functional group. Indeed, when a group other than hydrogen is present on an alkane framework, that group is almost always the functional group. **TABLE 2** Functional Groups in Some Important Classes of Organic Compounds.

Class	Generalized abbreviation	Representative example	Name of example*
Alcohol	ROH	CH_3CH_2OH	Ethanol
Alkyl halide	RCl	CH_3CH_2Cl	Chloroethane
Amine†	RNH_2	$CH_3CH_2NH_2$	Ethanamine
Epoxide	$\underset{O}{R_2C{-}CR_2}$	$\underset{O}{H_2C{-}CH_2}$	Oxirane
Ether	ROR	$CH_3CH_2OCH_2CH_3$	Diethyl ether
Nitrile	$RC{\equiv}N$	$CH_3CH_2C{\equiv}N$	Propanenitrile
Nitroalkane	RNO_2	$CH_3CH_2NO_2$	Nitroethane
Thiol	RSH	CH_3CH_2SH	Ethanethiol

*Most compounds have more than one acceptable name.
†The example given is a *primary* amine (RNH_2). *Secondary* amines have the general structure R_2NH; *tertiary*

TABLE 3 Classes of Compounds That Contain a Carbonyl Group

Class	Generalized abbreviation	Representative example	Name of example
Aldehyde	$R\overset{\overset{O}{\parallel}}{C}H$	$CH_3\overset{\overset{O}{\parallel}}{C}H$	Ethanal
Ketone	$R\overset{\overset{O}{\parallel}}{C}R$	$CH_3\overset{\overset{O}{\parallel}}{C}CH_3$	2-Propanone
Carboxylic acid	$R\overset{\overset{O}{\parallel}}{C}OH$	$CH_3\overset{\overset{O}{\parallel}}{C}OH$	Ethanoic acid
Carboxylic acid derivatives:			
Acyl halide	$R\overset{\overset{O}{\parallel}}{C}X$	$CH_3\overset{\overset{O}{\parallel}}{C}Cl$	Ethanoyl chloride
Acid anhydride	$R\overset{\overset{O}{\parallel}}{C}O\overset{\overset{O}{\parallel}}{C}R$	$CH_3\overset{\overset{O}{\parallel}}{C}O\overset{\overset{O}{\parallel}}{C}CH_3$	Ethanoic anhydride
Ester	$R\overset{\overset{O}{\parallel}}{C}OR$	$CH_3\overset{\overset{O}{\parallel}}{C}OCH_2CH_3$	Ethyl ethanoate
Amide	$R\overset{\overset{O}{\parallel}}{C}NR_2$	$CH_3\overset{\overset{O}{\parallel}}{C}NH_2$	Ethanamide

8.1.3.METHANE, ETHANE, AND PROPANE

Alkanes have the general molecular formula C_nH_{2n+2}. The simplest one, **methane** (CH_4), is also the most abundant. Large amounts are present in our atmosphere, in the ground, and in the oceans. Methane has been found on Jupiter, Saturn, Uranus, Neptune, and Pluto, and even on Halley's Comet.

Ethane (C_2H_6: CH_3CH_3) and **propane** (C_3H_8: $CH_3CH_2CH_3$) are second and third, respectively, to methane in many ways. Ethane is the alkane next to methane in structural simplicity, followed by propane. Ethane (10%) is the second and propane (5%) the third most abundant component of natural gas, which is 75% methane. The characteristic odor of natural gas we use for heating our homes and cooking comes from

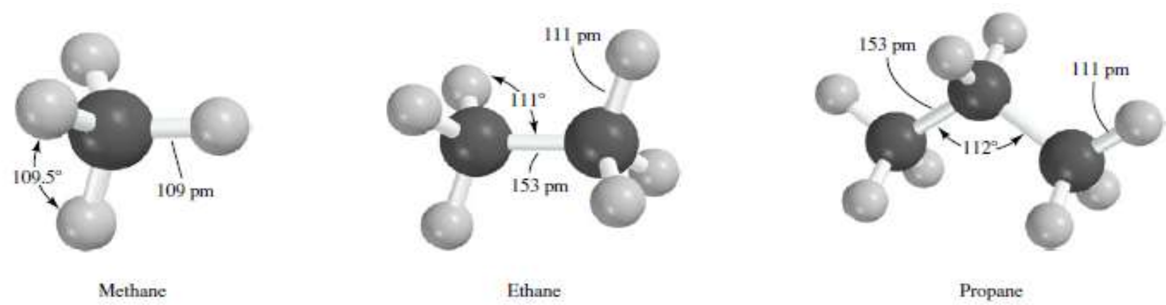


FIGURE 22 Structures of methane, ethane, and propane showing bond distances and bond angles.

trace amounts of unpleasant-smelling sulfur-containing compounds such as ethanethiol (see Table 2) that are deliberately added to it in order to warn us of potentially dangerous leaks. Natural gas is colorless and nearly odorless, as are methane, ethane, and propane. Methane is the lowest boiling alkane, followed by ethane, then propane.

8.1.4. IUPAC NOMENCLATURE OF UNBRANCHED ALKANES

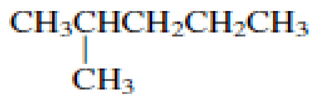
Nomenclature in organic chemistry is of two types: **common** (or "trivial") and **systematic.** Some common names existed long before organic chemistry became an organizedbranch of chemical science. Methane, ethane, propane, *n*-butane, isobutane, *n*-pentane,isopentane, and neopentane are common names. One simply memorizes the name thatgoes with a compound in just the same way that one matches names with faces. So longas there are only a few names and a few compounds, the task is manageable. But thereare millions of organic compounds already known, and the list continues to grow! A systembuilt on common names is not adequate to the task of communicating structuralinformation. Beginning in 1892, chemists developed a set of rules for naming organiccompounds based on their structures, which we now call the **IUPAC rules,** in which*IUPAC* stands for the "International Union of Pure and Applied ChemistryThe IUPAC rules assign names to unbranched alkanes as shown in Table 4.Methane, ethane, propane, and butane are retained for CH_4, CH_3CH_3, $CH_3CH_2CH_3$, and$CH_3CH_2CH_2CH_3$, respectively. Thereafter, the number of carbon atoms in the chain isspecified by a Latin or Greek prefix preceding the suffix *-ane,* which identifies the compoundas a member of the alkane family. Notice that the prefix *n-* is not part of theIUPAC system. The IUPAC name for $CH_3CH_2CH_2CH_3$ is butane, not *n*-butane.

TABLE 4 IUPAC Names of Unbranched Alkanes

Number of carbon atoms	Name	Number of carbon atoms	Name	Number of carbon atoms	Name
1	Methane	11	Undecane	21	Henicosane
2	Ethane	12	Dodecane	22	Docosane
3	Propane	13	Tridecane	23	Tricosane
4	Butane	14	Tetradecane	24	Tetracosane
5	Pentane	15	Pentadecane	30	Triacontane
6	Hexane	16	Hexadecane	31	Hentriacontane
7	Heptane	17	Heptadecane	32	Dotriacontane
8	Octane	18	Octadecane	40	Tetracontane
9	Nonane	19	Nonadecane	50	Pentacontane
10	Decane	20	Icosane*	100	Hectane

*Spelled "eicosane" prior to 1979 version of IUPAC rules.

The IUPAC rules name branched alkanes as *substituted derivatives* of the unbranched alkanes listed in Table 4. Consider the C6H14 isomer represented by the structure



Step 1

Pick out the *longest continuous carbon chain,* and find the IUPAC name in Table 4 that corresponds to the unbranched alkane having that number of carbons. This is the parent alkane from which the IUPAC name is to be derived.

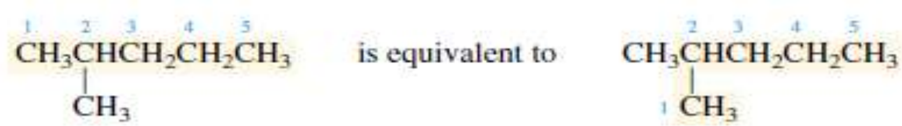
In this case, the longest continuous chain has *five* carbon atoms; the compound is named as a derivative of pentane. The key word here is *continuous*. It does not matter whether the carbon skeleton is drawn in an extended straight-chain form or in one with many bends and turns. All that matters is the number of carbons linked together in an uninterrupted sequence.

Step 2

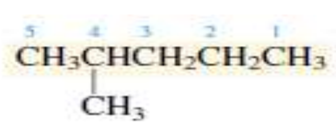
Identify the substituent groups attached to the parent chain. The parent pentane chain bears a methyl (CH_3) group as a substituent.

Step 3

Number the longest continuous chain in the direction that gives the lowest number to the substituent group at the first point of branching. The numbering scheme



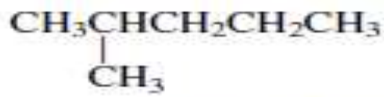
Both schemes count five carbon atoms in their longest continuous chain and bear a methyl group as a substituent at the second carbon. An alternative numbering sequence that begins at the other end of the chain is incorrect:



(methyl group attached to C-4)

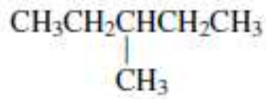
Step 4

Write the name of the compound. The parent alkane is the last part of the name and is preceded by the names of the substituent groups and their numerical locations **(locants).** Hyphens separate the locants from the words.



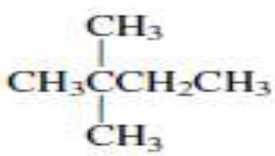
IUPAC name: 2-methylpentane

The same sequence of four steps gives the IUPAC name for the isomer that has its methyl group attached to the middle carbon of the five-carbon chain.

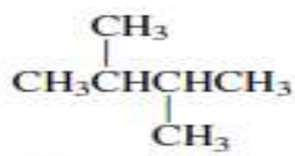


IUPAC name: 3-methylpentane

Both remaining C_6H_{14} isomers have two methyl groups as substituents on a fourcarbon chain. Thus the parent chain is butane. When the same substituent appears more than once, use the multiplying prefixes *di*-, *tri*-, *tetra*-, and so on. A separate locant is used for each substituent, and the locants are separated from each other by commas and from the words by hyphens.



IUPAC name: 2,2-dimethylbutane



IUPAC name: 2,3-dimethylbutane

8.1.5.SUMMARY

1- The classes of hydrocarbons are **alkanes, alkenes, alkynes,** and **arenes.** Alkanes are hydrocarbons in which all of the bonds are *single* bonds and are characterized by the molecular formula C*n*H2*n*+2.

2- **Functional groups** are the structural units responsible for the characteristic reactions of a molecule. The functional groups in an alkane are its hydrogen atoms.

3- The families of organic compounds listed on the inside front cover and in Tables 2 and 3bear functional groups that are more reactive than H, and the hydrocarbon chain to which they are attached can often be considered as simply a supporting framework. For example, ethanolamine (H2NCH2CH2OH) contains both amine (RNH2) and alcohol (ROH) functional groups.

4-The first three alkanes are **methane** (CH4), **ethane** (CH3CH3), and **propane** (CH3CH2CH3). All can be described according to the orbital hybridization model of bonding based on *sp*3 hybridization of carbon.

5 -Two constitutionally isomeric alkanes have the molecular formula C_4H_{10}. One has an unbranched chain (CH3CH2CH2CH3) and is called ***n*-butane;** the other has a branched chain [(CH3)3CH] and is called **isobutane.** Both *n*-butane and isobutane are **common names.**

6- Unbranched alkanes of the type CH3(CH2)*n*CH3 are often referred to as *n*-alkanes.

7- There are three constitutional isomers of C_5H_{12}: ***n*-pentane** ($CH_3CH_2CH_2CH_2CH_3$), **isopentane** [$(CH_3)_2CHCH_2CH_3$], and **neopentane** [$(CH_3)_4C$].

8- Natural gas is an abundant source of methane, ethane, and propane. Petroleum is a liquid mixture of many hydrocarbons, including alkanes. Alkanes also occur naturally in the waxy coating of leaves and fruits.

9- Alkanes and cycloalkanes are nonpolar and insoluble in water. The forces of attraction between alkane molecules are **induced-dipole/induceddipole** attractive forces. The boiling points of alkanes increase as the number of carbon atoms increases. Branched alkanes have lower boiling points than their unbranched isomers. There is a limit to how closely two molecules can approach each other, which is given by the sum of their **van der Waals radii.**

10-Alkanes and cycloalkanes burn in air to give carbon dioxide, water, and heat. This process is called combustion.

$$\underset{\text{2-Methylbutane}}{(CH_3)_2CHCH_2CH_3} + \underset{\text{Oxygen}}{8O_2} \longrightarrow \underset{\text{Carbon dioxide}}{5CO_2} + \underset{\text{Water}}{6H_2O}$$

$$\Delta H^\circ = -3529\ \text{kJ}\ (-843.4\ \text{kcal})$$

The heat evolved on burning an alkane increases with the number of carbon atoms. The relative stability of isomers may be determined by comparing their respective **heats of combustion.** The more stable of two isomers has the lower heat of combustion.

11-Combustion of alkanes is an example of **oxidation–reduction.** Although it is possible to calculate oxidation numbers of carbon in organic molecules, it is more convenient to regard oxidation of an organic substance as an increase in its oxygen content or a decrease in its hydrogen content.