

CHEM 1106
Hydrocarbons
A Laboratory Study assignment

Objectives

This study exercise is an outline of organic chemistry nomenclature and structure. It should help you learn and do the following:

1. State from memory the names and formulas for the first ten compounds of the alkane series
2. Define: alkane alkyl group unsaturated cycloalkane
 alkene aliphatic saturated
 alkyne hydrocarbon substituent group
3. derive the correct names of any given compound from its molecular structure for the alkanes, alkenes or alkynes, including cyclic hydrocarbons and substituent groups.
4. Given the name of any hydrocarbon, draw the molecular structural formula for that compound.
5. State from memory the names of the substituent groups -F, -Cl, -Br, -I; or give the formula when the name is stated.
6. Define isomer, and draw structural formulas for the isomers from a given formula.
7. Given the formula, name simple aromatic compounds as benzene derivatives
8. Given the IUPAC names, diagram structural formulas for the aromatic compounds and their derivatives.

I. NONAROMATIC HYDROCARBONS (also called Aliphatic Hydrocarbons)

Hydrocarbons are the simplest types of organic compounds. They are composed of the elements carbon and hydrogen which are covalently bonded. There are two general kinds of hydrocarbons, the aliphatic or chain-like hydrocarbons, which are covered here, and the aromatic or benzene-like hydrocarbons, which will be covered in a later section.

Carbon has four valence electrons. It also has the ability to form strong bonds with other carbon atoms, creating long chains. Hydrogen has one valence electron with which it can form one bond to a carbon atom. When a carbon atom is bonded to only 2 or 3 other atoms, either carbon or hydrogen, the carbon atom must form either double or triple bonds with an adjoining carbon atom. These compounds are said to be **unsaturated**.

Alkanes

Alkanes are hydrocarbons which contain only carbon-carbon single bonds. If a

hydrocarbon contains only single bonds, it is described as being **saturated**. The simplest hydrocarbon is **methane** which contains only one carbon atom bonded covalently to 4 hydrogen atoms. Another familiar alkane is **octane**. Octane consists of 8 single bonded carbon atoms and 18 hydrogen atoms. The ratio of carbon to hydrogen atoms can be determined for any open-chain alkane from the formula:

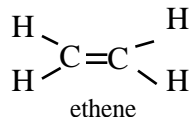


where **N** = number of carbon atoms in the compound. Look at the following examples to see how the first 12 alkanes (1--> 12 carbons) are named:

methane (CH ₄)	butane (C ₄ H ₁₀)	heptane (C ₇ H ₁₆)	decane (C ₁₀ H ₂₂)
ethane (C ₂ H ₆)	pentane (C ₅ H ₁₂)	octane (C ₈ H ₁₈)	undecane (C ₁₁ H ₂₄)
propane (C ₃ H ₈)	hexane (C ₆ H ₁₄)	nonane (C ₉ H ₂₀)	dodecane (C ₁₂ H ₂₆)

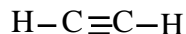
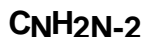
Alkenes

Alkenes are hydrocarbons which contain at least one double bond between two carbon atoms in their structure. Hydrocarbons with one or more double bonds are described as being **unsaturated**. They are named much the same way alkanes are, except that their name ends in “-ene” for alkene, vs the “-ane” of alkanes. The simplest alkene is ethene, which contains 2 carbon atoms. Each carbon in ethene participates in one double bond, and is bonded to two other hydrogen atoms. The ratio of carbon to hydrogen in the alkenes is:



Alkynes

Alkynes contain a triple bond between two carbon atoms. These are also called unsaturated compounds. Alkynes have a ratio of carbon to hydrogen atoms of:

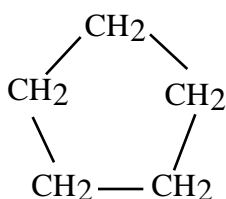


ethyne
(acetylene)

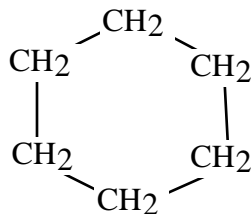
like the alkanes and alkenes, alkyne names end with the the last few letters “-yne”.

Cyclic Hydrocarbons

There exists a second group of hydrocarbons in which the bonded carbon atoms make a closed loop or ring. These are known as **cyclic hydrocarbons**.



Cyclopentane is C₅H₁₀



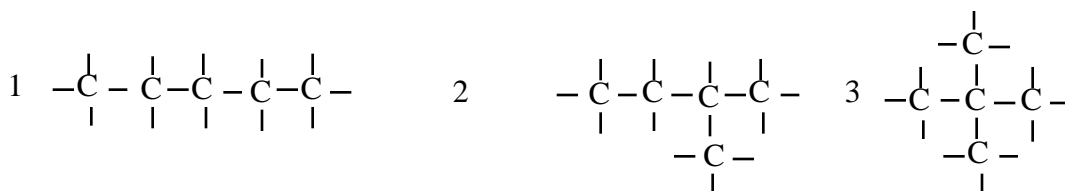
Cyclohexane is C₆H₁₂

cyclic hydrocarbons are typically either alkanes or alkenes, and their names reflect the degree of unsaturation by ending with the familiar “-ane” or “-ene”. However, their formal names begin with the prefix “cyclo-” to indicate the cyclic nature of their structure.

II. ISOMERS

Isomers among Alkanes

Compounds of a given molecular formula can have more than one possible different arrangement of atoms. For example, C₅H₁₂ has 3 such arrangements:



The number of isomers possible for each of the first 10 alkanes are:

methane (1)	butanes (2)	heptanes (9)	decane (75)
ethane (1)	pentanes (3)	octanes (18)	
propane (1)	hexanes (5)	nonanes (35)	

III. AROMATIC HYDROCARBONS

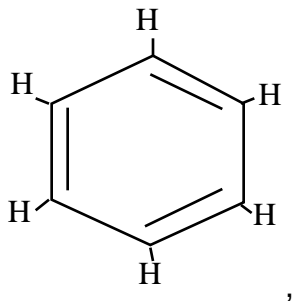
In the nineteenth century a large group of compounds were isolated and given the name “aromatic” because many of them had a pleasant odor. Benzene, C₆H₆, was found to be the **parent compound** for this series. Today, aromatic refers to a compound that has a structural similarity to benzene, though it may not be necessarily sweet-smelling.

BENZENE - C₆H₆

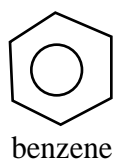
Properties

Benzene was found to have a high degree of unsaturation, but unlike the alkene series, it

showed very little reactivity. Heat and catalysts were needed to get it to react even slowly. In 1865 Friedrich Kekule proposed that benzene was a ring with alternating double bonds and single bonds:



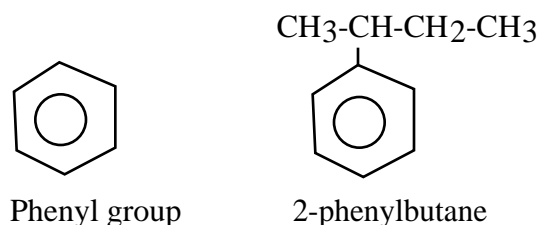
Today it is known that there are no true double bonds in the benzene molecule. Rather, all carbon-to-carbon bonds are equivalent, with properties intermediate between those of single and double bonds, and involve 6 electrons existing in molecular orbitals that give rise to the “aromatic” properties. These intermediate, equivalent bonds are often drawn as a circle inside of the cyclohexane type-structure:



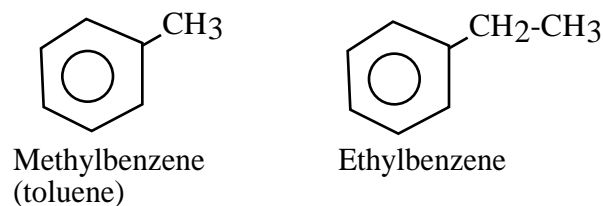
BENZENE DERIVATIVES

Alkylbenzenes

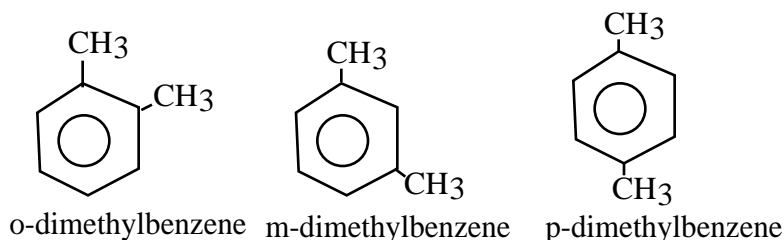
There are several acceptable ways of naming alkylbenzenes. When benzene rings are treated as substituents (a “secondary” group bound to a primary hydrocarbon structure) they are referred to as **phenyl groups**. In these situations, the **phenyl group** is named as a substituent of an alkane, alkene or alkyne. This is seen below in the compound 2-phenylbutane, where the 4 carbon butane alkyl group is considered to be the primary compound, and the benzene (phenyl group) is treated as a secondary substituent:



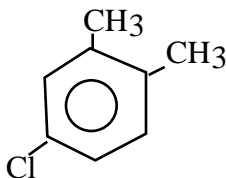
This is the preferred method of nomenclature when the alkyl group is complex (more than 2 carbons in alkyl group). The more common nomenclature consists of naming the alkyl group first and following it with the word benzene. This is the preferred method for simple alkyl groups.



When there are two substituents on a benzene ring, the words **ortho (o-)**, **meta (m-)** and **para (p-)** are used to describe their positions. **Dimethylbenzenes** are also called “**xylene**s”.



When more than two substituents are on a benzene ring, the substituents are named by numbering them so that the lowest possible numbers are used, and then listing the substituents alphabetically, ending the name with **-benzene**. For example, the following compound would be named as 4-Chloro-1,2-dimethylbenzene:



IV. NAMING ORGANIC COMPOUNDS (NOMENCLATURE)

Alkanes

The following are general rules for naming alkanes:

1. The parent name is the name of the longest continuous chain of carbon atoms in the structure.
2. The C atoms in this longest continuous chain are numbered consecutively from one end to the other in order to designate the positions of the attached substituent groups. Numbering proceeds from the carbon that is nearest to an attached substituent group
3. The parent name is placed at the end of the whole name. Substituent groups are alphabetized in front of the parent name.
4. If there are two or more of a particular substituent group, use the numerical prefix that designates that number (i.e., di- for 2, tri- for 3, tetra- for 4, etc.)

