

2.8: HYDROCARBONS AND THE HOMOLOGOUS SERIES

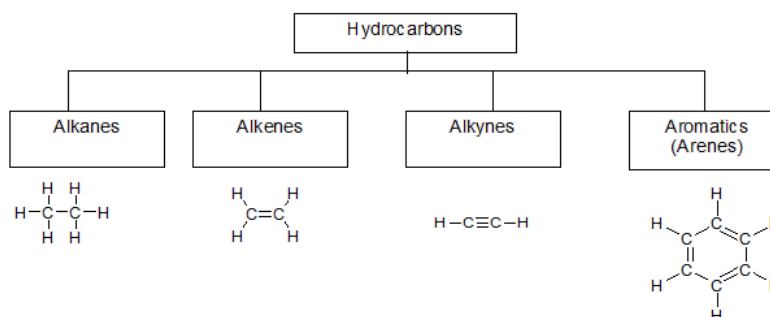
Learning Objective

- classify hydrocarbons as saturated or unsaturated
- classify hydrocarbons as alkanes, alkenes, alkynes, cycloalkanes, or aromatics (arenes)
- apply the homologous series to organic molecules with 1-10 carbons

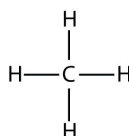
Hydrocarbon Classifications

Hydrocarbons are organic compounds that contain **only** carbon and hydrogen. The inherent ability of hydrocarbons to bond to themselves is known as catenation, and allows hydrocarbon to form more complex molecules, such as cyclohexane and benzene. Catenation comes from the fact that the bond character between carbon atoms is entirely non-polar.

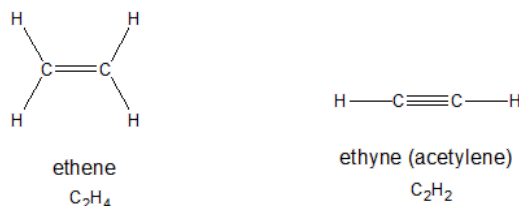
The four general classes of hydrocarbons are: alkanes, alkenes, alkynes and arenes. Aromatic compounds derive their names from the fact that many of these compounds in the early days of discovery were grouped because they were oils with fragrant odors. The classifications for hydrocarbons are summarized below.



Saturated hydrocarbons (alkanes) are the simplest of the hydrocarbon species. They are composed entirely of single bonds and are saturated with hydrogen. The general formula for saturated hydrocarbons is C_nH_{2n+2} (assuming non-cyclic structures). Saturated hydrocarbons are the basis of petroleum fuels and are found as either linear or branched species. The simplest alkanes have their C atoms bonded in a straight chain; these are called *normal* alkanes. They are named according to the number of carbon atoms in the chain. The smallest alkane is methane:



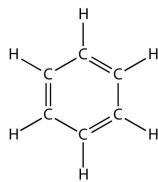
Unsaturated hydrocarbons have double and/or triple bonds between carbon atoms. Those with double bond are called alkenes and have the general formula C_nH_{2n} (assuming non-cyclic structures). Those containing triple bonds are called alkynes and have general formula C_nH_{2n-2} . The smallest alkene—ethene—has two C atoms and is also known by its common name ethylene and the smallest alkyne is ethyne, also known as acetylene.



Cycloalkanes are hydrocarbons containing one or more carbon rings to which hydrogen atoms are attached. The prefix "cyclo" is added to the name to communicate the ring structure. The general formula for a saturated hydrocarbon containing one ring is C_nH_{2n} .

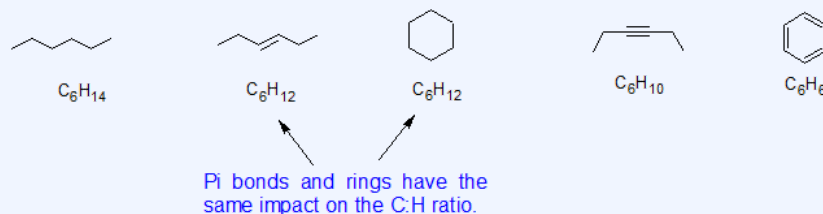


Aromatic hydrocarbons, also known as arenes, are hydrocarbons that have at least one aromatic ring. Aromatic compounds contain the benzene unit. Benzene itself is composed of six C atoms in a ring, with alternating single and double C–C bonds:



For most compounds, information beyond the chemical formula will be needed to elucidate their structure. However, the ratio of C:H in a chemical formula can provide insights into the chemical structure.

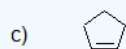
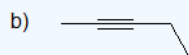
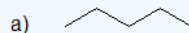
For example, let's look at some of the possible structures and chemical formulas for hydrocarbons containing six carbon atoms.



The saturated alkane has the highest ratio of hydrogen to carbon. The unsaturated alkene and the six membered alkane ring share the same chemical formula. It is important to remember this relationship. The unsaturated alkyne has a lower ratio of hydrogen to carbon than alkenes with a second pi bond. Benzene rings have the lowest hydrogen ratio to carbon at 1:1.

Exercise

1. Classify the following compounds as saturated or unsaturated. For unsaturated hydrocarbons, refine the classification by indicating whether the compound is an alkene, alkyne, or arene.



Answer

1.

- a) saturated; alkane
- b) unsaturated; alkyne
- c) unsaturated; alkene

The number of carbons continuously bonded together is an important structural feature and is described using the Homologous Series. In first year organic chemistry, the first ten names of the Homologous Series are usually all that need to be memorized. Of course, your professor will set the standard. Most of the prefixes are familiar from the Greek prefixes for binary covalent compounds. It is the prefixes for the first four carbon chain lengths that may be unfamiliar. Interestingly, three of these hydrocarbons frequently appear in every day life. Methane gas is a primary component of flatulence and is the ingredient that ignites when farts are lit - don't try this at home. Propane and butane are gases at room temperature. They are stored under pressure to create the liquid state. Propane is the fuel for bbqs, while butane is used in lighters. The suffix "ane" is used to distinguish between the longest continuous carbon chain, while the shorter carbon branches (substituents) are indicated with "yl" as the suffix.

THE HOMOLOGOUS SERIES

# C's	Alkane Structure	Parent name	Substituent name
1	CH ₄	methane	methyl
2	CH ₃ CH ₃	ethane	ethyl
3	CH ₃ CH ₂ CH ₃	propane	propyl
4	CH ₃ CH ₂ CH ₂ CH ₃	butane	butyl
5	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	pentane	pentyl
6	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	hexane	hexyl
7	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	heptane	heptyl
8	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	octane	octyl
9	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	nonane	nonyl
10	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	decane	decyl

Exercise

2. Complete the table below.

Condensed Structural Formula	Chemical Name
	propane
C ₆ H ₆	
CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	

Answer

2.

Condensed Structural Formula	Chemical Name
CH ₃ CH ₂ CH ₃	propane
C ₆ H ₆	benzene
CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	hexane

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