EXPERIMENT 0

Organic Compounds: Alkanes

A. Goal

The goal of this laboratory experiment is to practice unit conversions and carry out calculations with the correct number of significant figures.

B. Materials

☐ This is theory-based experiment.

C. Background

Alkanes

This first section will introduce organic chemistry, covering the most simple organic compounds: the alkanes. Alkanes–also called hydrocarbons–are simply made of carbon and hydrogen with all C-C bonds being single bonds. First, you will be introduced to a few organic chemicals and you will learn about a series of different organic formulas that can represent the same compound. Then, you will learn the basic naming rule of alkanes, which extend to other–more complex–organic chemicals.

Molecular formula for alkanes

The naming of alkanes results from the combination of a prefix and a suffix. On one hand, the suffix is always *ane*. On the other hand, the prefix depends on the number of carbons in the molecule. Table **??** shows a list of the different prefixes. For example, the alkane with a single carbon is called methane (CH_4). Other examples of alkanes are ethane that contains two carbons (C_2H_6) or propane with three carbons (C_3H_8). The molecular formula for an alkane with n carbon atoms is:

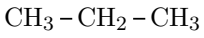
$$C_nH_{2n+2} \tag{1}$$

Hence, we have that the molecular formula for methane ($n = 1$) is CH_4 and the molecular formula for octane ($n = 8$) is C_8H_{18}. *Molecular formulas* represent only the molecular compositions, showing only the elements in the molecule.

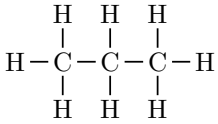
A review of the different structural formulas

At this point, you have seen four different ways to represent organic molecules. Using propane as example, here all the formulas:We have that the *molecular formula* (e.g. C_3H_8 for propane) is mainly used to indicate the composition of the molecule in the form of Carbon and Hydrogen atoms. A second way to represent propane is using its *expanded structural formula*, that is by representing all atoms in the molecule and all atomic connections. A third molecular representation is the *condensed structural formula* that uses CH_3 and CH_2 units, only representing the C-C bonds. Finally, the *skeletal formula* is perhaps the most simplistic representation as only the C-C bonds are represented in the form of simple lines. It is important to understand that *all formulas are just different ways to represent the same molecule*.

Molecular formula



Condensed structural formula



Expanded structural formula

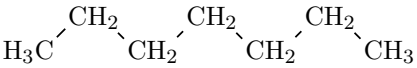
Skeletal structural formula

Sample Problem 1

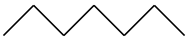
Write down the condensed and skeletal formulas for heptane.

SOLUTION

Heptane has seven carbons, hence its condensed formula will have two CH_3 units and five CH_2 units:



The skeletal formula for would be:

Answer: 

STUDY CHECK

Draw the skeletal formula of decane.

Table 1 Prefixed for alkane naming

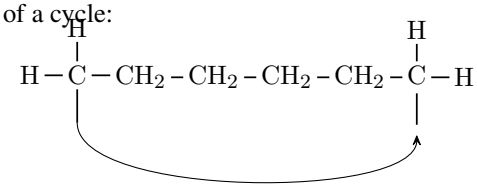
# Carbons	prefix	# Carbons	prefix
1	Meth	6	Hex
2	Eth	7	Hepta
3	Prop	8	Octa
4	But	9	Nona
5	Pent	10	Deca

Cycloalkanes

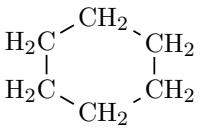
Alkanes are perfect examples of hydrocarbons, with C-C chains and all carbon atoms saturated with hydrogen. Cycloalkanes are simply alkanes with a cyclic structure. We will cover the molecular, condensed, and skeletal formulas for these chemicals.

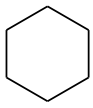
Cyclic alkanes

Consider the expanded structure of hexane. A cycloalkane results from removing the left and right hydrogen while connecting the molecule in the form of a cycle:



As the most stable structure for six lines is the hexagon, the resulting structure of cyclohexanes would be:

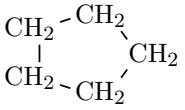


or 

cyclohexane

Naming cycloalkanes

The naming of alkanes and cycloalkanes is very similar. You just need to add the cyclo prefix to the name. For example, the alkane with five carbons is called pentane, whereas the corresponding cycloalkane is called cyclopentane:

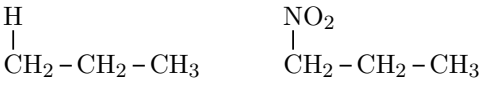


or

Cyclopentane

Alkanes with substituents

Oftentimes alkanes have other groups of atoms called substituents attached to the hydrocarbon chain. This section covers the naming of alkanes with substituents. Here is an example of an alkane and an alkane with a substituent:



Propane Nitropropane

In the substituted molecule, a nitro group has replaced a hydrogen atom.

Substituents

There are many different substituents–also called groups–that can be found attached to an alkane chain. Their names are indicated in Table 1. The easiest substituents are halogens; atoms of chorine (Cl —), bromine (Br —) or iodine (I —) can replace hydrogen atoms in an alkane. The name of these substituents–chloro, bromo and iodo– resembles the name of the corresponding atom. Other substituents can contain carbon, like a methyl (CH_3 —) or a ethyl (CH_3CH_2 —). There are even more complex substituents such as tert-butyl in which a central carbon atom is connected to three different methyl groups. The name of substituents (methyl) comes from the name of the alkane (methane) by replacing the *-ane* suffix with *-yl*.

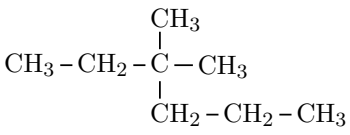
Naming rules for branched alkanes

Overall, the rules to name branched alkanes are:

1. **Step one:** Look for the longest carbon-carbon chain that will give the ending name of the molecule (e.g. four carbons would be butane).
2. **Step two:** Number the main chain starting at the end closest to the substituents so that the numbers for the substituents are small.
3. **Step three:** Name the substituents with their position and order them alphabetically.

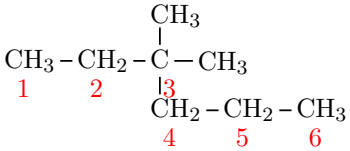
Sample Problem 2

Name the following hydrocarbon:



SOLUTION

First we locate the longest chain. We have five possible chains, and the longest one has six carbons. Hence the name of the hydrocarbon would be hexane. Now we need to number the carbons so that we start numbering the closes to the substituents the possible.

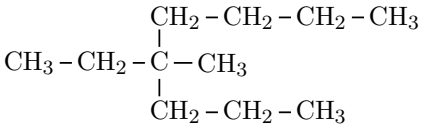


We have two methyl connected to carbon number three. Hence the final name will be:

▶Answer: 3-dimethylhexane.

STUDY CHECK

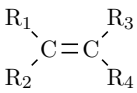
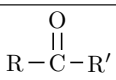
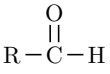
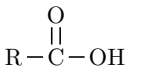
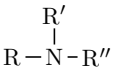
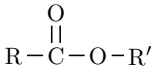
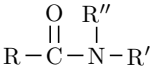
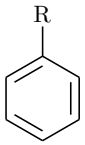
Name the following hydrocarbon:



Molecular diversity

You have certainly taken painkillers for a headache or over-the-counter drugs to get over a cold. Maybe you drink coffee and perhaps you like tea. All these substances contain active organic molecules. These active molecules are hydrocarbon derivatives and differ from plain hydrocarbons, which are simply made of carbon and hydrogen. Active molecules contain functional groups such as alcohol, ethers, carboxylic acids, amines, amides, or aromatic groups. These groups of atoms have a specific function and give activity to the molecule. The goal of this section is simply to identify the different groups.

Table 2 Names of several functional groups

Functional group	Name	Functional group	Name	Functional group	Name
	Alkene		Ketone	$R-OH$	Alcohol
$R-C\equiv C-R'$	Alkyne		Aldehyde	$R-SH$	Thiol
	Carboxylic acid		Amine	$R-O-R'$	Ether
	Ester		Amide		Phenyl

STUDENT INFO

Name: _____ Date: _____

Pre-lab Questions

Organic Compounds: Alkanes

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1. Given the following molecular formula, name the following linear alkanes (hydrocarbons):

CH_4	_____	C_2H_6	_____
C_4H_{10}	_____	C_3H_8	_____
C_5H_{12}	_____	C_9H_{20}	_____

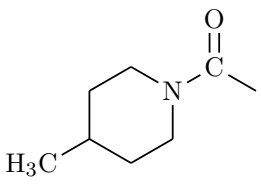
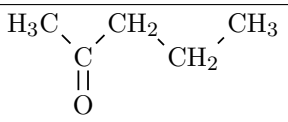
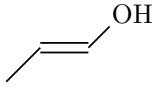
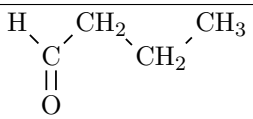
2. Given the following molecular formula, name the following cyclic alkanes (hydrocarbons):

C_3H_6	_____	C_6H_{12}	_____
C_4H_8	_____	C_7H_{14}	_____
C_5H_{10}	_____	C_9H_{18}	_____

3. Indicate the molecular, expanded, condensed and skeletal formula for the following linear alkanes:

	Molecular Formula	Expanded Formula	Condensed Formula	Skeletal Formula
Hexane				
Pentane				

4. Identify the functional groups:

Molecule	Functional Group	Molecule	Functional Group
			
			

STUDENT INFO

Name: _____ Date: _____

Results
EXPERIMENT

Organic Compounds: Alkanes

___ **Linear Alkanes** Use the molecular models set for this experiment. Each sphere represents an element. Carbon is black, hydrogen white, oxygen red and nitrogen blue. Build up the following molecules and complete the table. Show your professor all molecular models before proceeding to next part.

	Expanded Formula	Condensed Formula	Skeletal Formula
Methane			N/A
Ethane			
Propane			
Butane			

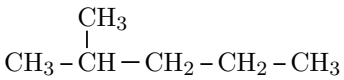
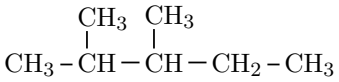
Cyclic Alkanes Use the molecular models set for this experiment. Each sphere represents an element. Carbon is black, hydrogen white, oxygen red and nitrogen blue. Build up the following molecules and complete the table. Show your professor all molecular models before proceeding to next part.

	Expanded Formula	Condensed Formula	Skeletal Formula
Cyclopropane			
Cyclobutane			
Cyclopentane			
Cyclohexane			

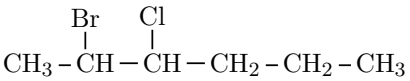
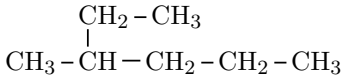
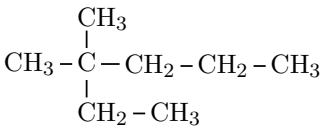
Short alkanes with substituents Use the molecular models set for this experiment. Each sphere represents an element. Carbon is black, hydrogen white, oxygen red and nitrogen blue. Build up the following molecules and complete the table. Show your professor all molecular models before proceeding to next part.

	Expanded Formula	Molecular Formula
Chloromethane		
Dichloromethane		
BromoChloro -Fluoromethane		
Chloroethane		

Long alkanes with substituents Use the molecular models set for this experiment. Each sphere represents an element. Carbon is black, hydrogen white, oxygen red and nitrogen blue. Build up the following molecules and complete the table. Show your professor all molecular models before proceeding to next part.

Name	Condensed Formula	Skeletal Formula
		
		

More alkanes with substituents There is no need to use the molecular models at this point. Now, name the following molecules:

Formula	name
	
	
	

Functional Groups Identity the following functional groups:

Formula	name