1.1 Alkanes

organic compound a molecular compound of carbon, not including $CO(g)$, $CO_2(g)$, and $HCN(g)$

Organic chemistry is the study of carbon compounds. As a general definition, an **organic compound** is a molecular compound containing carbon with the exception of carbon monoxide, $CO(g)$, carbon dioxide, $CO_2(g)$, and hydrogen cyanide, $HCN(g)$. Since carbon has 4 valence electrons, its atoms tend to form 4 covalent bonds. Carbon atoms often bond with one another to form chains. These chain structures become the backbones of a range of molecules, some of them very complex. Carbon-based molecules are the building blocks for life on Earth.

Most fuels are hydrocarbons, whose molecules consist only of carbon atoms and hydrogen atoms connected by covalent bonds. Hydrocarbon fuels include natural gas, gasoline, fuel oil, and diesel fuel. NASCAR racing cars burn an unleaded fuel similar to that used in most cars on the street (**Figure 1**). Natural gas, which is primarily methane, is a major fuel for electric power plants. Butane and propane are used to heat homes and to fuel tools such as soldering torches.

Figure 1 Hydrocarbons are sources of fuel all over the world.

Burning carbon-based fuels is a major contributor to global warming, according to most scientific models, due to the release of carbon dioxide into the atmosphere. Other environmental problems have also been associated with the release of carbon-containing compounds to our atmosphere and oceans. The use of hydrocarbons as fuel needs to be balanced with the ability of Earth's carbon cycle to remove carbon dioxide from the atmosphere.

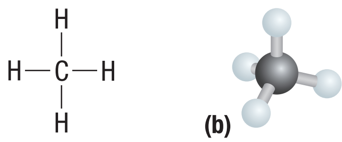
Alkanes: Saturated Hydrocarbons

hydrocarbon a compound containing only carbon and hydrogen atoms

saturated hydrocarbon a hydrocarbon with only single covalent bonds between its carbon atoms

alkane a saturated hydrocarbon

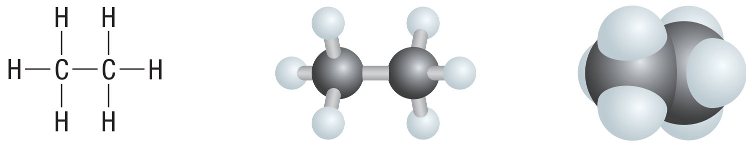
A **hydrocarbon** is a compound that is composed only of carbon and hydrogen atoms. A **saturated hydrocarbon**, also known as an **alkane**, is a hydrocarbon in which all bonds between the carbon atoms are single bonds. The simplest saturated hydrocarbon (alkane) is methane, CH_4, with just 1 carbon atom bonded to 4 hydrogen atoms. Methane has a tetrahedral structure (**Figure 2**).



(a) (b)

Figure 2 Two representations of the methane molecule: (a) the structural formula and (b) the ball-and-stick model

Ethane, C_2H_6, contains 2 carbon atoms. Each carbon atom in ethane is bonded to 4 atoms in a tetrahedral arrangement. **Figure 3** shows three ways of depicting ethane. Figure 3(a) is a structural formula that uses chemical symbols to represent atoms, and lines to represent individual bonds between atoms. Figure 3(b) is a ball-and-stick model that represents the atoms as spheres and incorporates "sticks" to represent the bonds between them. Figure 3(c) is a space-filling model in which atoms are depicted as spheres proportional to the actual size of the atoms. Models (b) and (c) show the three-dimensional arrangement of atoms in the molecule, which is not evident in the structural formula.



(a) (b) (c)

Figure 3 Three representations of ethane, C_2H_6: (a) the structural formula, (b) the ball-and-stick model, and (c) the space-filling model

Table 1 shows the first ten alkanes. As you can see, the compound names all have a prefix, which indicates the number of carbon atoms, and the suffix *-ane*. The general chemical formula for an alkane is C_nH_{2n+2}. Notice how the subscript indicating the number of CH_2 groups increases with the number of carbon atoms in the molecule.

Table 1 The First Ten Alkanes

Number of C atoms	Name	Molecular formula	Condensed formula
1	methane	CH_4	
2	ethane	C_2H_6	CH_3CH_3
3	propane	C_3H_8	$CH_3CH_2CH_3$
4	butane	C_4H_{10}	$CH_3(CH_2)_2CH_3$
5	pentane	C_5H_{12}	$CH_3(CH_2)_3CH_3$
6	hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$
7	heptane	C_7H_{16}	$CH_3(CH_2)_5CH_3$
8	octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$
9	nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$
10	decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

Alkanes in which the carbon atoms form long chains are called straight-chain alkanes. Structural formulas of alkanes typically show the carbon atoms lying along a straight line (**Figure 4(a)**). Empirical evidence indicates, however, that the angle between any two carbon bonds in a chain is 109.5°, not 180°. The physical arrangement of carbon atoms in a straight-chain alkane therefore has a zigzag configuration (**Figure 4(b)**).

LEARNING **TIP**

Line Diagrams
In a line diagram, imagine that there is a carbon atom at the end of every line and at the intersection of every line. Each one is surrounded by the maximum number of hydrogen atoms. For example, there are 8 carbon atoms and 18 hydrogen atoms in Figure 4(c).

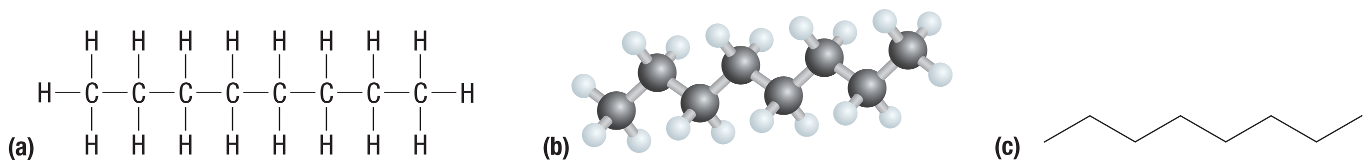


Figure 4 (a) The structural formula, (b) the ball-and-stick model, and (c) the line diagram of octane, C_8H_{18}

Not all alkanes are based on straight chains. Their carbon atoms can also join to form rings and branches. A **cyclic alkane**, or cycloalkane, is a hydrocarbon in which the carbon atoms form a closed loop instead of a chain. Cyclopropane, C_3H_6, is the simplest cyclic alkane. Its carbon atoms form an equilateral triangle with bond angles of 60° (**Figure 5**). The general formula of cyclic alkanes is C_nH_{2n}. WEB LINK

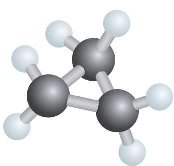


Figure 5 Cyclopropane, C_3H_6

cyclic alkane a hydrocarbon in which the main structure consists of a chain of carbon atoms joined to form a closed ring

Mini **Investigation**

Arranging Carbon Atoms

Skills: Performing, Observing, Communicating

SKILLS HANDBOOK A2.4

Each carbon atom can bond with 4 different atoms. Carbon chains form a variety of configurations, such as long chains, branched chains, and cyclic structures. In this investigation, you will construct models of some different carbon compound structures.

Equipment and Materials: molecular modelling kit

1. Use the molecular modelling kit to build a model of a molecule that contains 5 carbon atoms and 12 hydrogen atoms.
2. Draw a structural formula of your molecule.
3. Using the same model parts, build another molecule that cannot be twisted into the same shape as the original molecule.
4. Draw a structural formula of this molecule.

A. How many different molecules of C_5H_{12} are possible? K/U

B. Predict the number of arrangements that are possible for C_6H_{14}. Test your prediction. T/I

Structural Isomerism

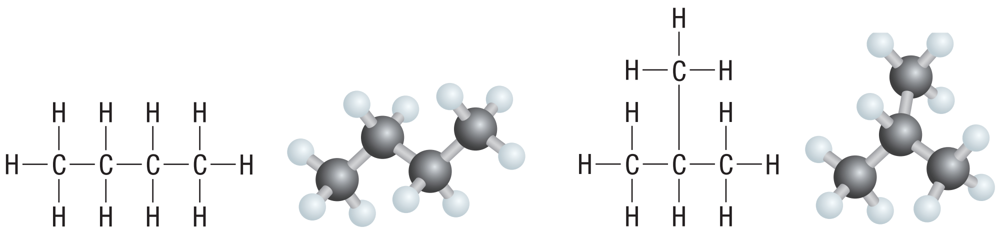
alkyl group one or more carbon atoms that form a branch off the main chain of a hydrocarbon

substituent group an atom or group that replaces a hydrogen atom in an organic compound

structural isomer a compound that has the same molecular formula as another compound, but a different structure

In all of the examples we have examined so far, the molecules form chains or rings in which each carbon atom is bonded to 2 other carbon atoms. The only exceptions are the carbon atoms at the ends of the chains, which are bonded to only 1 other carbon atom. Some hydrocarbons, however, contain one or more hydrocarbon branches attached to the main structure of the molecule. The branch is called an **alkyl group**. Alkyl groups are named with the prefix indicating the number of carbon atoms in the branch (as in Table 1) and a *-yl* suffix. An alkyl group consisting of a single carbon atom and 3 hydrogen atoms ($–CH_3$) is called a methyl group. A group with a 2-carbon chain ($–CH_2CH_3$) is an ethyl group. An alkyl group is a type of **substituent group**, which is any atom or group that replaces hydrogen in an organic molecule.

Most hydrocarbons with 4 or more carbon atoms exhibit structural isomerism. Structural isomerism occurs when 2 molecules each have the same numbers and types of atoms but these atoms are bonded in different ways. Each molecule is a **structural isomer** of the other. For example, there are 2 alkanes that have the molecular formula C_4H_{10} (**Figure 6**). Butane is a straight-chain molecule, while methyl-propane has a branched structure. Both have the formula C_4H_{10}, but because of their different structures, these compounds exhibit different properties. For example, the boiling point of butane is −0.5 °C, whereas that of methylpropane is −12 °C.



(a) butane **(b)** methylpropane

Figure 6 (a) Butane (b) The branched isomer of butane: methylpropane. In this structure, one of the C–C bonds appears to be longer than the others. This is only to make the structure easier to interpret. The bonds are actually the same length.

Naming Alkanes

There are millions of organic compounds, so it would be impossible to have—or to remember—simple common names for all of them. The International Union of Pure and Applied Chemistry (IUPAC) has established a system for naming chemicals that is used worldwide. Other naming systems are still used frequently, though, so you may see compounds named differently in contexts outside this course.

The names of the alkanes beyond butane are obtained by adding the suffix *-ane* to the Greek root for the number of carbon atoms (Table 1). For a branched hydrocarbon, we use the longest continuous chain of carbon atoms to determine the root name for the hydrocarbon. We indicate the length of a branch by the name of the alkyl group, and its location by numbering from the shortest end of the parent chain.

Cyclic hydrocarbons are named in a similar way. The name is based on the number of carbon atoms in the ring, with the prefix *cyclo-* added.

In the following tutorial, you will practise drawing and naming several different types of alkanes. WEB LINK

Structure*	Name†
$—CH_3$	methyl
$—CH_2CH_3$	ethyl
$—CH_2CH_2CH_3$	propyl
$CH_3\overset{\vert}{C}HCH_3$	propan-2-yl, or isopropyl
$—CH_2CH_2CH_2CH_3$	butyl
$CH_3\overset{\vert}{C}HCH_2CH_3$	butan-2-yl, or sec-butyl

* The bond with one end open shows the point of attachment of the substituent to the carbon chain.
† The first name for each group is the IUPAC name. You may see the other names in other contexts.

Figure 7 Alkyl groups through C_4

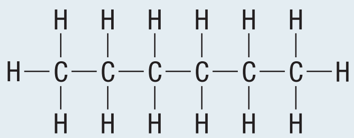
Tutorial 1 Naming and Drawing Alkanes

This tutorial outlines a systematic way of naming an organic compound or drawing its structure. In either case, you need to first recognize the longest carbon chain in the compound and then identify any substituent groups that may be present.

1. Identify the longest carbon chain, called the parent chain.
2. Identify all of the groups (substituents) attached to the parent chain (**Figure 7**).
3. Number the parent chain from the end so that the substituents are attached to the carbon atom with the lowest possible number. If there are two or more groups and the numbering is a tie, the group that comes first alphabetically gets the lowest number.
4. If the same substituent is present more than once, use a prefix to indicate this (*di-*, *tri-*, *tetra-*) and include a number to indicate each substituent's location.
5. When writing the final name, list substituents in alphabetical order, ignoring any prefixes. Separate words by hyphens; separate numbers by commas. If there are two possible ways to arrange a parent chain, use the simplest possible arrangement.

Sample Problem 1: Naming Unbranched Alkanes from Structural Formulas

Determine the correct name for the following compound:



Solution

Step 1. Identify the parent chain.

There are 6 carbon atoms in the chain, so it is hexane.

Step 2. Identify all of the groups (substituents) attached to the parent chain.

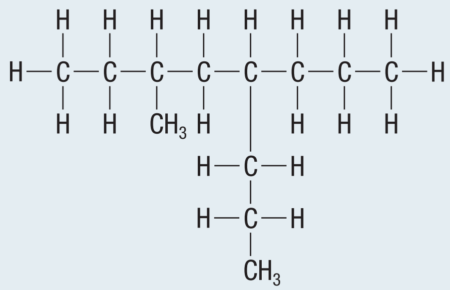
This is an unbranched alkane. It has no substituent groups.

The compound is named hexane.

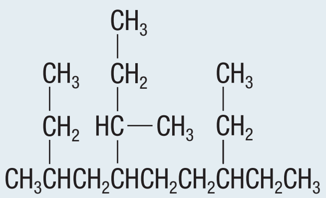
Sample Problem 2: Naming Branched Alkanes from Structural Formulas

Determine the correct name for each of the following compounds:

(a)



(b)



Solution (a)

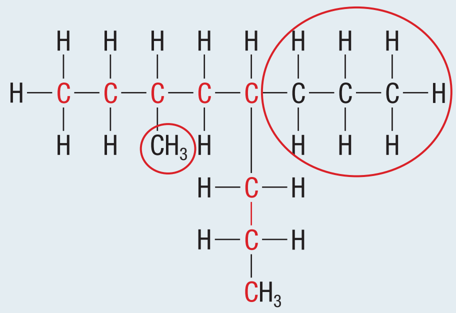
Step 1. Identify the parent chain.

The longest carbon chain has 8 carbon atoms. Its root name is octane.

LEARNING TIP

Memory Aid: Table of Terms
You might find it helpful to create a 3-column table summarizing the naming of alkanes with 1 to 10 carbon atoms. List the unbranched straight-chain alkanes, the unbranched cyclo alkanes, and the alkyl groups.

Step 2. Identify all of the groups (substituents) attached to the parent chain.



Step 3. Number the parent chain from the end so that the substituent is attached to the carbon atom with the lowest possible number. If there are two or more groups and the numbering is a tie, the group that comes first alphabetically gets the lowest number.

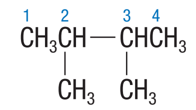
Numbering from the left gives the lowest numbers: 3 for the methyl group and 5 for the propyl group.

Step 4. If the same substituent is present more than once, use a prefix to indicate this (*di-*, *tri-*, *tetra-*) and include a number to indicate each substituent's location.

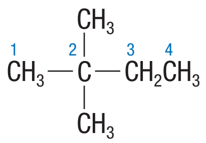
Methyl groups are attached to carbon atoms 3 and 6, so the prefix is *di-*.

Step 5. When writing the final name, list substituents in alphabetical order, ignoring any prefixes. Separate words by hyphens; separate numbers by commas.

"Methyl" comes before "propyl" in the alphabet, so the name begins with 3-methyl-5-propyl. The compound's name is 3-methyl-5-propyloctane.



2,3-dimethylbutane



2,2-dimethylbutane

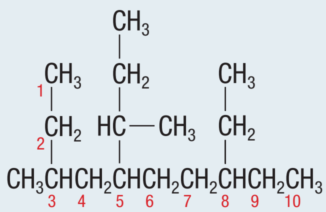
Figure 8 Notice how the two methyl groups are numbered in these structural isomers.

Notice that structural formulas are sometimes condensed, eliminating the bonds around the carbon atoms that do not have substituent groups. This arrangement takes less space and makes it easier to see the substituent groups (**Figure 8**).

Solution (b)

Step 1. Identify the parent chain.

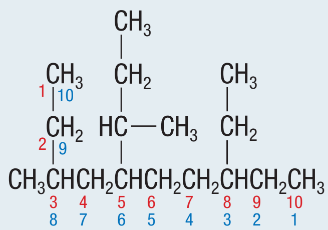
The parent chain has 10 carbon atoms, so its root name is decane.



Step 2. Identify all of the groups (substituents) attached to the parent chain.

This compound has a 1-carbon group, a 4-carbon group, and a 2-carbon group. According to Figure 7, the substituent groups are methyl, butan-2-yl, and ethyl.

Step 3. Number the parent chain from the end so that the substituent is attached to the carbon atom with the lowest possible number. If there are two or more groups and the numbering is a tie, the group that comes first alphabetically gets the lowest number.



Numbering from either end places the first group on carbon atom 3. However, "ethyl" comes before "methyl" in the alphabet, so number from the "ethyl" end of the molecules, using the blue numbers. This places the ethyl group on carbon 3, the butan-2-yl group on carbon 6, and the methyl group on carbon 8.

Step 4. If the same substituent is present more than once, use a prefix to indicate this (*di-*, *tri-*, *tetra-*) and include a number to indicate each substituent's location.

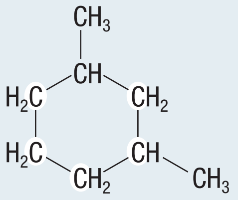
The same substituent does not appear more than once.

Step 5. When writing the name, list substituents in alphabetical order, ignoring prefixes. Separate words by hyphens; separate numbers by commas.

The substituents will be listed in the order butan-2-yl, ethane, and methane. This compound is 6-butan-2-yl-3-ethyl-8-methyldecane.

Sample Problem 3: Naming Cyclic Alkanes from Structural Formulas

Determine the correct name for the compound on the right. Follow the same steps as for naming a branched alkane, except that you are naming the parent carbon ring in Step 1.



Solution

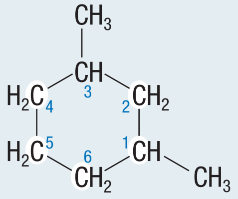
Step 1. Identify the parent carbon ring.

The ring contains 6 carbon atoms, so it is a cyclohexane.

Step 2. Identify all of the groups (substituents) attached to the parent chain.

The ring has two alkyl groups bonded to it: both methyl groups.

Step 3. Number the carbon atoms in the ring to give the two groups the lowest numbers. If there are two or more groups and the numbering is a tie, the group that comes first alphabetically gets the lowest number.



Both groups are "methyl," so the numbering can start with either group and give the same answer: 1 and 3. Note that you do not have to include the number "1" if only one substituent is present on the ring.

Step 4. If the same substituent is present more than once, use a prefix to indicate this (*di*-, *tri*-, *tetra*-) and include a number to indicate each substituent's location.

There are two methyl groups, so the name includes "dimethyl."

Step 5. When writing the name, list substituents in alphabetical order, ignoring prefixes.

The name of the compound is 1,3-dimethylcyclohexane.

When you are given the name of an alkane and asked to draw its structure, follow these steps:

1. Draw the parent chain or carbon ring from the last part of the compound name.
2. Identify the carbon atoms where each of the substituents is attached.
3. Draw the substituents attached to the parent chain or ring.

Sample Problem 4: Drawing Alkanes

Draw structural formulas for each of the following compounds:

(a) 4-ethyl-3,5-dimethylnonane

(b) 7-ethyl-2-methyl-4-(propan-2-yl)decane

(c) 1-ethyl-2-propylcyclobutane

Solution (a)

Step 1. Draw the parent chain from the last part of the compound name.

The root name nonane indicates that the compound has a 9-carbon backbone.

Step 2. Identify the carbon atoms where each of the substituents is attached.

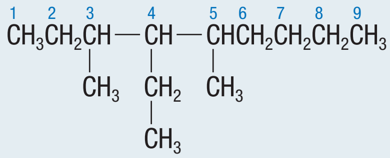
The numbers 4, 3, and 5 indicate that substituents are attached at these carbon atoms.

LEARNING **TIP**

Numbering Carbon Atoms
Always use the lowest possible numbers. For example, the methyl groups in Sample Problem 3 are on carbon atoms 1 and 3, not 1 and 5.

Step 3. Draw the substituents attached to the parent chain.

It has an ethyl group bonded to the fourth carbon atom, and methyl groups bonded to the third and fifth carbon atoms. Therefore, the structure of 4-ethyl-3,5-dimethylnonane is as shown:



Notice that, in this and later structures, the condensed notation is used.

Solution (b)

Step 1. Draw the parent chain from the last part of the compound name.

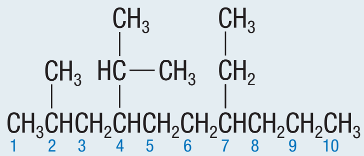
The decane chain has 10 carbon atoms.

Step 2. Identify the carbon atoms where each of the substituents is attached.

There are substituents on carbon atoms 7, 2, and 4.

Step 3. Draw the substituents attached to the parent chain.

The molecule has 3 substituents: a methyl group on carbon 2, a propan-2-yl group (which is a 3-carbon chain bonded at the second carbon atom) on carbon 4, and an ethyl group on carbon 7. 7-ethyl-2-methyl-4-(propan-2-yl)decane therefore has the following structure:



Solution (c)

Step 1. Draw the carbon ring from the last part of the compound name.

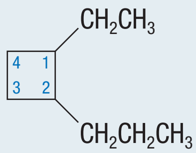
Cyclobutane is a ring of 4 carbon atoms.

Step 2. Identify the carbon atoms where each of the substituents is attached.

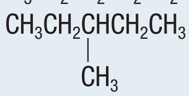
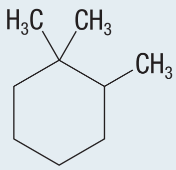
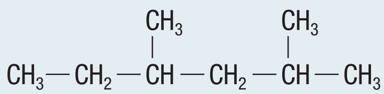
The substituents are attached at carbon atoms 1 and 2.

Step 3. Draw the substituents attached to the ring.

This compound has an ethyl group and a propyl group bonded to adjacent carbon atoms on the ring. Because ethyl comes first alphabetically, it is placed on carbon atom 1. Therefore 1-ethyl-2-propylcyclobutane has the following structure:



Practice

1. Write the name of each of the following compounds: K/U
   (a) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
   (b) 
   (c) 
   (d) 
2. Draw a structural formula for each of the following compounds: K/U C
   (a) decane
   (b) 3-ethyl-5-methylheptane
   (c) 2,3-dimethylpentane
   (d) 1,3-diethylcyclopentane

Properties of Alkanes

The two elements that make up hydrocarbons are carbon and hydrogen. These two elements have similar electronegativities. This means that the bonds between carbon and hydrogen are close to being non-polar. Coupled with the fairly even arrangement of hydrogen atoms within alkane molecules, this causes the molecules to be non-polar. Van der Waals forces are the main intermolecular force in hydrocarbon compounds. These forces are very weak, so alkanes exhibit relatively low boiling and melting points (**Table 2**).

Table 2 Selected Properties of the First Ten Straight-Chain Alkanes

Name	Formula	Molar mass (g/mol)	Melting point (°C)	Boiling point (°C)	Number of structural isomers
methane	CH_4	16	−182	−162	1
ethane	C_2H_6	30	−183	−89	1
propane	C_3H_8	44	−187	−42	1
butane	C_4H_{10}	58	−138	0	2
pentane	C_5H_{12}	72	−130	36	3
hexane	C_6H_{14}	86	−95	68	5
heptane	C_7H_{16}	100	−91	98	9
octane	C_8H_{18}	114	−57	126	18
nonane	C_9H_{20}	128	−54	151	35
decane	$C_{10}H_{22}$	142	−30	174	75

The boiling points of alkanes are related to the length of the carbon chain: as the chain gets longer, the boiling point gets higher. Chemists take advantage of this pattern to separate mixtures of alkanes using a process called fractional distillation. During fractional distillation, the temperature of a mixture of hydrocarbons is slowly increased. As the boiling point of each alkane is reached, the alkane boils out of the mixture. Chemists can collect the vapour and condense it to obtain mixtures of alkanes with similar boiling points and carbon chain lengths.

Fractional distillation (or fractionation) is used on an industrial scale in oil refineries (**Figure 9**). It enables oil and gas companies to separate the crude oil extracted from the ground. Fractional distillation separates the lighter fractions of the crude, such as natural gas and other fuel gases, from the heavier fractions that are used to make waxes, asphalt, and so on. WEB LINK

Figure 9 In a fractionation tower, fractional distillation separates the lighter components of crude oil from the heavier fractions.

Reactions of Alkanes

In general, alkanes are fairly unreactive. For example, at 25 °C, alkanes do not react with acids, bases, or strong oxidizing agents. This chemical inertness makes them valuable as lubricating materials and as the backbone for structural materials such as plastics.

Alkanes are used as fuels because their **complete combustion** releases a lot of energy, along with carbon dioxide and oxygen. For example, the complete combustion of butane with oxygen is represented by the equation

complete combustion a chemical reaction in which a compound reacts with oxygen, O_2; if the compound is a hydrocarbon, the products of the reaction are carbon dioxide, water, and thermal energy

$$2\ C_4H_{10}(g) + 13\ O_2(g) \rightarrow 8\ CO_2(g) + 10\ H_2O(g) + \text{thermal energy}$$

Although all alkanes burn, some are much more combustible than others. Smaller, gaseous alkanes, such as methane and ethane, are highly flammable. Longer-chain alkanes are difficult to ignite until heated to a temperature at which they vaporize. In addition, different hydrocarbons release different quantities of energy per unit of mass when they burn. These and other properties affect how we use alkanes.

UNIT TASK BOOKMARK

Mixtures of alkanes, such as gasoline, are sometimes used as solvents. Consider their effectiveness and their safety as you work on the Unit Task outlined on page 116.

The combustion of fuels to provide energy for transportation and electricity also produces carbon dioxide and water. Carbon dioxide is a naturally occurring greenhouse gas that helps keep Earth warm by reducing the proportion of the Sun's heat that is reflected back into space. While this greenhouse effect is necessary for life on Earth, too much carbon dioxide contributes to climate change. As a result, many countries are investigating alternative energy sources to reduce the consumption of hydrocarbons for energy.

Table 3 lists some common uses of alkanes.

Figure 10 A soldering torch burns propane to produce a flame hot enough to melt some metals.

Table 3 Selected Uses of Alkanes

Length of carbon chain	Uses
1–4	Fuels such as natural gas for heating and cooking, propane for barbecues and soldering torches (**Figure 10**), and butane for lighters
5–12	Fuels such as gasoline
12–18	Fuels such as jet fuel
18–20	Fuels such as home heating oil
20–30	Lubricating oils such as engine oil
30–40	Fuel oils such as ship fuel
40–50	Waxes and thick oils such as paraffin wax and petroleum jelly
More than 50	Tars used in road surfacing

Alkyl Halides

alkyl halide an alkane in which one or more hydrogen atoms have been substituted with one or more halogen atoms

Sometimes alkanes include substituent groups that are halogens, such as chlorine or fluorine. An alkane that contains a halogen is called an **alkyl halide**. Alkyl halides may be formed by substitution reactions:

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

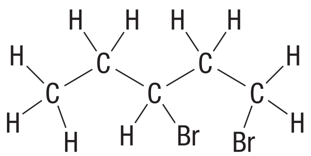
$$CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \rightarrow CHCl_2 + HCl$$

$$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$$

Alkyl halides may include more than one halogen element. For example, substituted methanes containing both chlorine and fluorine are called chlorofluorocarbons (CFCs) or Freons. Their general formula is CF_xCl_y. These compounds are non-toxic and mostly unreactive. They have been extensively used as coolant fluids in refrigerators and air conditioners. Unfortunately, their chemical inertness allows Freons to remain in the atmosphere for so long that they eventually reach the stratosphere, where they react with ozone and damage Earth's protective ozone layer. Therefore, the use of these compounds is being rapidly phased out.

Alkyl halides are named by writing the root of the halogen name first, with the suffix *-o*, followed by the name of the parent alkane. If necessary to avoid ambiguity, the position of the halogen is specified with a number **(Figure 11)**. As usual, the substituent groups are written in alphabetical order.



1,3-dibromopentane

Figure 11 The name of this alkyl halide includes numbers to indicate the position of the 2 bromine atoms.

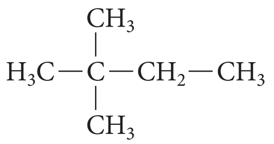
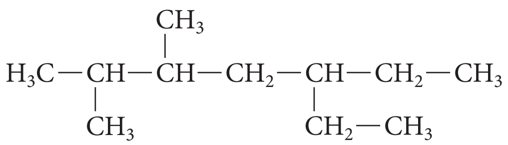
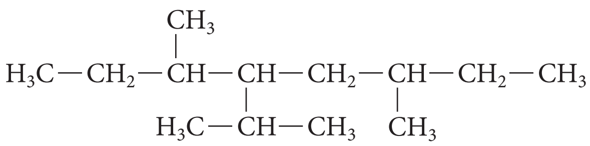
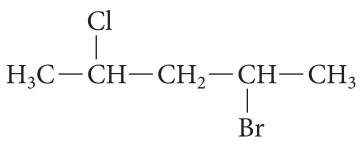
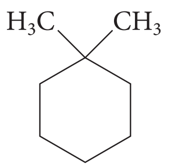
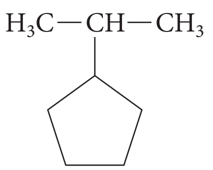
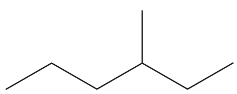
The halogens are much more electronegative than are carbon and hydrogen. When halogens bond to a hydrocarbon chain or ring, they attract electrons, pulling them away from the carbon atoms. This makes the molecule polar. The resulting polarity increases the strength of the intermolecular forces. Since more energy is needed to overcome these forces, the boiling and melting points of alkyl halides are higher than those of the corresponding alkanes.

1.1 Review

Summary

- Hydrocarbons contain hydrogen and carbon. In a saturated hydrocarbon, the atoms of carbon are bonded to each other by single bonds.
- Structural isomers are compounds that have the same molecular formula but different molecular geometry.
- Alkanes may have a straight-chain structure or a ring structure. Substituent groups may be attached to the parent structure.
- Alkyl halides are alkanes in which halogen atoms have substituted for one or more hydrogen atoms.

Questions

1. Define each of the following terms: K/U
   (a) organic compound
   (b) alkane
   (c) structural isomer
   (d) substituent group
   (e) alkyl group
   (f) alkyl halide
2. Name the following compounds: T/I C
   (a) 
   (b) 
   (c) 
   (d) 
   (e) 
   (f) 
   (g) 
3. Draw and name five structural isomers that all have the molecular formula C_6H_{14}. K/U T/I C
4. Draw the structural formula and write the molecular formula for each of the following alkanes: T/I C
   (a) 3,4-dimethylheptane
   (b) 2,2-dimethylpentane
   (c) 4-propyl-3,5-diethyloctane
   (d) 1-ethyl-3-propylcyclohexane
5. Draw the structural formula for each of the following compounds: T/I C
   (a) 1,3-dibromocyclopentane
   (b) 4-chloro-1-fluorobutane
   (c) 3-iodo-4-methylnonane
6. (a) Why does water not mix with liquid hydrocarbons?
   (b) Most hydrocarbons are less dense than water. How does this difference in density affect the cleanup of an oil spill on a still lake?
   (c) Some liquid organic halides are denser than water. How might this difference affect the cleanup of an organic halide spill in a river? K/U A
7. 2,2,4-trimethylpentane (isooctane) is used as a reference for octane ratings for gasoline. Draw the structural formula for isooctane. T/I C
8. A methane leak can pose an extreme fire and explosion hazard, especially in an enclosed area. In contrast, a leak of paraffin is typically not a significant hazard. Use your knowledge of the properties of different types of alkanes (including the information in Tables 2 and 3) to explain the differences in danger of these two substances. T/I A
9. A chemist burns samples of ethane, pentane, nonane, and dodecane (which contains 12 carbon atoms per molecule) and measures the volume of carbon dioxide produced during each reaction. If the chemist starts with the same amount (in moles) of each compound, which will produce the largest volume of carbon dioxide? Explain your answer. T/I A