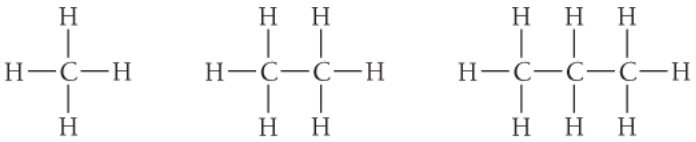
Pearson

21.4: Alkanes: Saturated Hydrocarbons

We often refer to alkanes (hydrocarbons containing only single bonds) as **saturated hydrocarbons** because they are saturated (loaded to capacity) with hydrogen. The simplest hydrocarbons are methane (CH_4), the main component of natural gas; ethane (C_2H_6), a minority component in natural gas; and propane (C_3H_8), the main component of liquid petroleum (LP) gas.



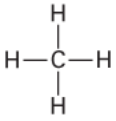
Alkanes containing four or more carbon atoms may be straight or branched (as we have already seen). The straight-chain isomers are often called normal alkanes, or *n*-alkanes. As the number of carbon atoms increases in the *n*-alkanes, so does their boiling point (as shown in Table 21.2). The increase is due to the increasing dispersion force with increasing molar mass (see Section 11.3). Methane, ethane, propane, and *n*-butane are all gases at room temperature, but the next *n*-alkane in the series, pentane, is a liquid at room temperature. Pentane is a component of gasoline.

Table 21.2 ***n*-Alkane Boiling Points**

n-Alkane	Boiling Point (°C)
methane	−161.5
ethane	−88.6
propane	−42.1
n-butane	−0.5
n-pentane	36.0
n-hexane	68.7
n-heptane	98.5
n-octane	125.6

Table 21.3 summarizes the *n*-alkanes through decane, which contains ten carbon atoms. Like pentane, hexane through decane are all components of gasoline. Table 21.4 summarizes the uses of hydrocarbons.

Table 21.3 ***n*-Alkanes**

n	Name	Molecular Formula C_nH_{2n+2}	Structural Formula	Condensed Struc
1	methane	CH_4		CH

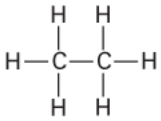
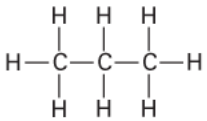
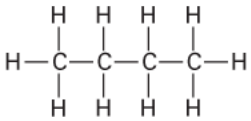
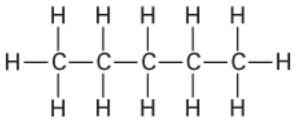
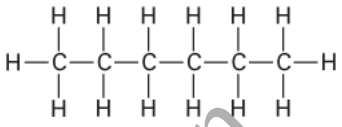
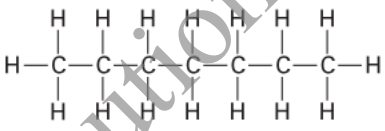
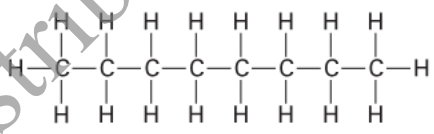
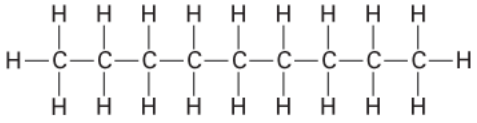
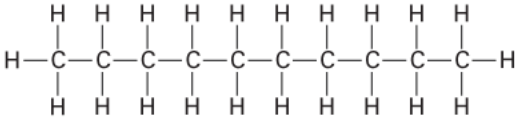
2	ethane	C_2H_6		CH_3(
3	propane	C_3H_8		CH_3CH
4	*n*-butane	C_4H_{10}		CH_3CH_2(
5	*n*-pentane	C_5H_{12}		CH_3CH_2CH
6	*n*-hexane	C_6H_{14}		$CH_3CH_2CH_2C$
7	*n*-heptane	C_7H_{16}		$CH_3CH_2CH_2CH$
8	*n*-octane	C_8H_{18}		$CH_3CH_2CH_2CH_2C$
9	*n*-nonane	C_9H_{20}		$CH_3CH_2CH_2CH_2CH$
10	*n*-decane	$C_{10}H_{22}$		$CH_3CH_2CH_2CH_2CH_2C$

Table 21.4 **Uses of Hydrocarbons**

Number of Carbon Atoms	State (at 25 °C)	Major Uses
1–4	Gas	Heating fuel, cooking fuel
5–7	Low-boiling liquid	Solvents, gasoline
6–18	Liquid	Gasoline
12–24	Liquid	Jet fuel, portable-stove fuel
18–50	High-boiling liquid	Diesel fuel, lubricants, heating oil
50+	Solid	Petroleum jelly, paraffin wax

Naming Alkanes

Many organic compounds have common names that we can learn only through familiarity. Because of the sheer number of organic compounds, however, chemists need a systematic method of nomenclature. In this book, we adopt the nomenclature system recommended by the IUPAC (International Union of Pure and Applied Chemistry), which is used throughout the world.

In the IUPAC system, the longest continuous chain of carbon atoms—called the base chain—determines the base name of the compound. The root of the base name depends on the number of carbon atoms in the base chain, as shown in Table 21.5. Base names for alkanes always have the ending *-ane*. Groups of carbon atoms branching off the base chain are alkyl groups and are named as substituents. Recall from Section 21.3 that a *substituent* is an atom or group of atoms that has been substituted for a hydrogen atom in an organic compound. Common alkyl groups are shown in Table 21.6.

Table 21.5 Prefixes for Base Names of Alkane Chains

Number of Carbon Atoms	Prefix
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-
9	non-
10	dec-

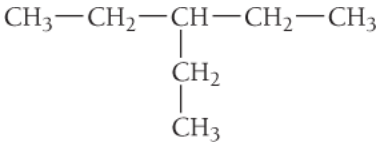
Table 21.6 Common Alkyl Groups

Condensed Structural Formula	Name	Condensed Structural Formula	Name
$-CH_3$	methyl	$-CHCH_3$ $\quad\quad\vert$ $\quad\quad CH_3$	isopropyl
$-CH_2CH_3$	ethyl	$-CH_2CHCH_3$ $\quad\quad\quad\vert$ $\quad\quad\quad CH_3$	isobutyl
$-CH_2CH_2CH_3$	propyl	$-CHCH_2CH_3$ $\quad\quad\vert$ $\quad\quad CH_3$	*sec*-butyl
$-CH_2CH_2CH_2CH_3$	butyl	CH_3 $\quad\vert$ $-CCH_3$ $\quad\vert$	*tert*-butyl

The procedure demonstrated in Examples 21.2 and 21.3 allows us to systematically name many alkanes. The procedure is presented in the left column, and two examples of applying the procedure are shown in the center and right columns.

Example 21.2 Naming Alkanes

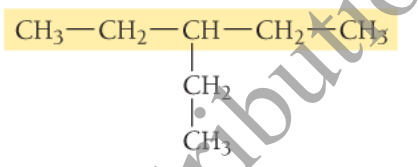
PROCEDURE FOR Name this alkane.



1. Count the number of carbon atoms in the longest continuous carbon chain to determine the base name of the compound (which may not be the horizontal chain). Locate the prefix corresponding to this number of atoms in Table 21.5 and add the ending *-ane* to form the base name.

SOLUTION

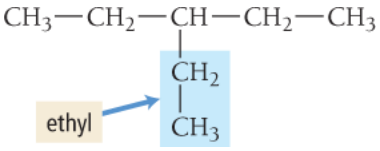
This compound has five carbon atoms in its longest continuous chain.



The correct prefix from Table 21.5 is *pent-*. The base name is pentane.

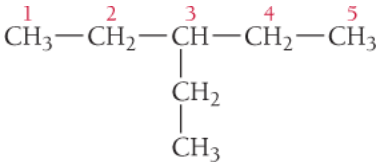
2. Consider every branch from the base chain to be a substituent. Name each substituent according to Table 21.6.

This compound has one substituent named *ethyl*.



3. Beginning with the end closest to the branching, number the base chain and assign a number to each substituent. (If two substituents occur at equal distances from each end, go to the next substituent to determine from which end to start numbering.)

Number the base chain as follows:



Assign the number 3 to the ethyl substituent.

4. Write the name of the compound in the following format: (substituent number)-(substituent name) (base name). If there are two or more substituents, give each one a number and list them alphabetically with hyphens between words and numbers.

The name of the compound is:

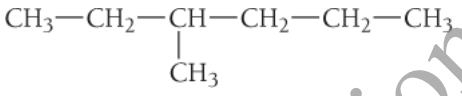
3-ethylpentane

5. If a compound has two or more identical substituents, indicate the number of identical substituents with the prefix *di-* (2), *tri-* (3), or *tetra-* (4) before the substituent's name. Separate the numbers indicating the positions of the substituents relative to each other with a comma. Do not take the prefixes into account when alphabetizing.

This step does not apply to this compound.

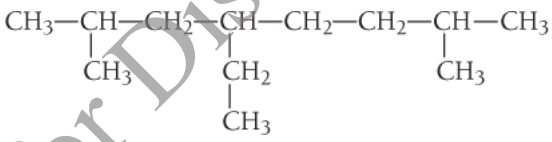
FOR PRACTICE 21.2

Name this alkane.



Example 21.3 Naming Alkanes

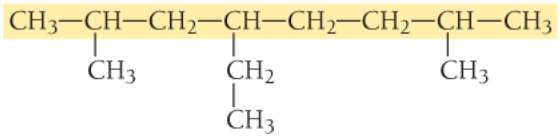
PROCEDURE FOR Name this alkane.



1. Count the number of carbon atoms in the longest continuous carbon chain to determine the base name of the compound (which may not be the horizontal chain). Locate the prefix corresponding to this number of atoms in Table 21.5 and add the ending *-ane* to form the base name.

SOLUTION

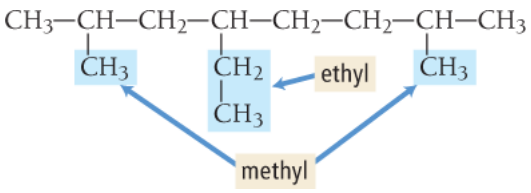
This compound has eight carbon atoms in its longest continuous chain.



The correct prefix from Table 21.5 is *oct-*. The base name is octane.

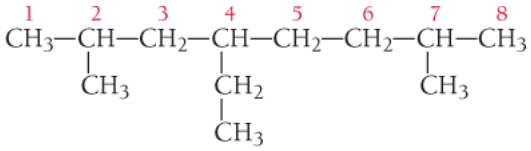
2. Consider every branch from the base chain to be a substituent. Name each substituent according to Table 21.6.

This compound has one substituent named *ethyl* and two named *methyl*.



3. Beginning with the end closest to the branching, number the base chain and assign a number to each substituent. (If two substituents occur at equal distances from each end, go to the next substituent to determine from which end to start numbering.)

Number the base chain as follows:



Assign the number 4 to the ethyl substituent and the numbers 2 and 7 to the two methyl substituents.

4. Write the name of the compound in the following format: (substituent number)-(substituent name) (base name). If there are two or more substituents, give each one a number and list them alphabetically with hyphens between words and numbers.

The basic form of the name of the compound is:

4-ethyl-2, 7-methyloctane

List ethyl before methyl because substituents are listed in alphabetical order.

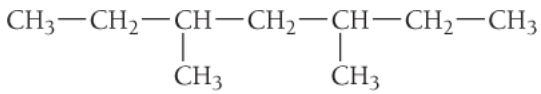
5. If a compound has two or more identical substituents, indicate the number of identical substituents with the prefix *di-* (2), *tri-* (3), or *tetra-* (4) before the substituent's name. Separate the numbers indicating the positions of the substituents relative to each other with a comma. Do not take the prefixes into account when alphabetizing.

This compound has two methyl substituents; therefore, the name of the compound is:

4-ethyl-2, 7-dimethyloctane

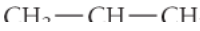
FOR PRACTICE 21.3

Name this alkane.

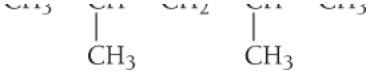


Interactive Worked Example 21.3 Naming Alkanes

Example 21.4 Naming Alkanes

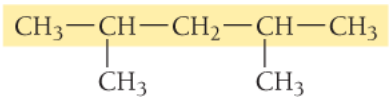


Name this alkane.

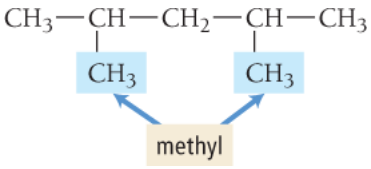


SOLUTION

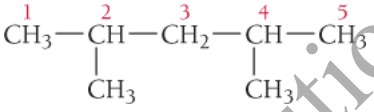
1. The longest continuous carbon chain has five atoms. Therefore, the base name is pentane.



2. This compound has two substituents, both named methyl.



3. Since both substituents are equidistant from the ends, it does not matter from which end you start numbering.



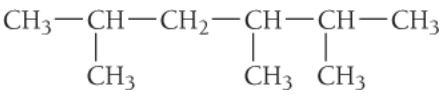
4. Use the general form for the name:

(substituent number)-(substituent name) (base name)

Because this compound contains two identical substituents, Step 5 from the naming procedure applies and you use the prefix *di-*. Indicate the position of each substituent with a number separated by a comma.

2,4-dimethylpentane

FOR PRACTICE 21.4 Name this alkane.



Conceptual Connection 21.3 Alkane Base Names

Interactive