USE THE STRATEGY

PROBLEM 2 ♦

What is the molecular formula for each of the following?

a. a 4-carbon hydrocarbon with two π bonds and no rings
b. a 10-carbon hydrocarbon with one π bond and 2 rings

LEARN THE STRATEGY

PROBLEM 3 SOLVED

Determine the degree of unsaturation for a hydrocarbon with a molecular formula of $C_{10}H_{16}$.

SOLUTION For a 10-carbon hydrocarbon with no π bonds and no rings, $C_nH_{2n+2} = C_{10}H_{22}$. A 10-carbon compound with molecular formula $C_{10}H_{16}$ has six fewer hydrogens, so the degree of unsaturation is $6/2 = 3$.

USE THE STRATEGY

PROBLEM 4 ♦

Determine the degree of unsaturation for hydrocarbons with the following molecular formulas:

a. $C_{20}H_{34}$ **b.** C_8H_{16} **c.** $C_{12}H_{20}$ **d.** $C_{40}H_{56}$

PROBLEM 5

Determine the degree of unsaturation and then draw possible structures for noncyclic compounds with the following molecular formulas:

a. C_3H_6 **b.** C_3H_4 **c.** C_4H_6

PROBLEM 6 ♦

Several studies have shown that β-carotene, a precursor of vitamin A, may play a role in preventing cancer. β-Carotene has a molecular formula of $C_{40}H_{56}$, and it contains two rings and no triple bonds. How many double bonds does it have?

β-Carotene is an orange colored compound found in carrots, apricots, and flamingo feathers (Sections 13.21 and 16.13).

5.2 THE NOMENCLATURE OF ALKENES

We saw that the IUPAC system uses a suffix to denote certain functional groups (Sections 3.6 and 3.7). The double bond is the functional group of an alkene; its presence is denoted by the suffix "ene." Therefore, the systematic (IUPAC) name of an alkene is obtained by replacing the "ane" ending of the corresponding alkane with "ene." For example, a two-carbon alkene is called ethene, and a three-carbon alkene is called propene. Ethene also is frequently called by its common name: ethylene.

	$H_2C{=}CH_2$	$CH_3CH{=}CH_2$		
systematic name:	Ethene	Propene	Cyclopentene	Cyclohexene
common name:	Ethylene	Propylene		

Most alkene names need a number to indicate the position of the double bond. (The four names above do not because there is no ambiguity.) The IUPAC rules you learned in Sections 3.3 and 3.6 apply to alkenes as well:

LEARN THE STRATEGY

1. The longest continuous chain that contains the functional group (in this case, the carbon–carbon double bond) is numbered in the direction that gives the functional group suffix the lowest possible number. For example, 1-butene signifies that the double bond is between the first and second carbons of butene; 2-hexene signifies that the double bond is between the second and third carbons of hexene.

Number the longest continuous chain containing the functional group in the direction that gives the functional group suffix the lowest possible number.

$^{4}CH_3{}^{3}CH_2{}^{2}CH{=}{}^{1}CH_2$ 1-butene

$^{1}CH_3{}^{2}CH{=}{}^{3}CHCH_3$ 2-butene

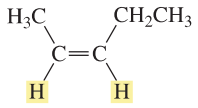
$^{1}CH_3{}^{2}CH{=}{}^{3}CH{}^{4}CH_2{}^{5}CH_2{}^{6}CH_3$ 2-hexene

$^{6}CH_3{}^{5}CH_2{}^{4}CH_2{}^{3}CH_2{}^{2}C(=CH_2)CH_2CH_2CH_3$ (1-CH_2) 2-propyl-1-hexene

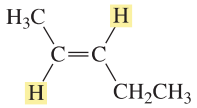
the longest continuous chain has 8 carbons, but the longest continuous chain containing the functional group has 6 carbons, so the parent name of the compound is hexene

Notice that 1-butene does not have a common name. You might be tempted to call it "butylene," which is analogous to "propylene" for propene. Butylene, however, is not an appropriate name because it could signify either 1-butene or 2-butene, and a name must be unambiguous.

Recall that the stereoisomers of an alkene are named using a *cis* or *trans* (or *E* or *Z*) prefix (Sections 4.1 and 4.2).

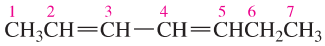


***cis*-2-pentene**
or
(*Z*)-2-pentene



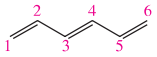
***trans*-2-pentene**
or
(*E*)-2-pentene

2. For a compound with two or more double bonds, the "ne" ending of the corresponding alkane is replaced with "diene," "triene," "tetraene," and so on, depending on the number of double bonds in the parent hydrocarbon.



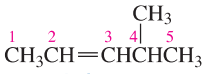
2,4-heptadiene

1,3-pentadiene

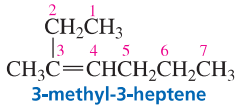


(3*E*)-1,3,5-hexatriene

3. The name of a substituent is stated before the name of the longest continuous chain that contains the functional group, together with a number to designate the carbon to which the substituent is attached. Notice that *if a compound's name contains both a functional group suffix and a substituent, the chain is numbered so that the functional group suffix gets the lowest possible number.*

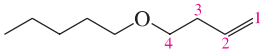


4-methyl-2-pentene

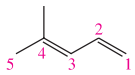


3-methyl-3-heptene

When there are both a functional group and a substituent, the functional group suffix gets the lowest possible number.

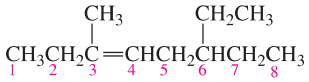


4-pentoxy-1-butene

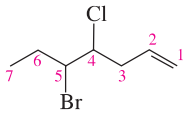


4-methyl-1,3-pentadiene

4. If a chain has more than one substituent, the substituents are stated in alphabetical order, using the same rules for alphabetizing discussed in Section 3.2. Then the appropriate number is assigned to each substituent.



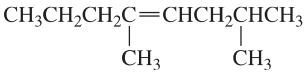
6-ethyl-3-methyl-3-octene



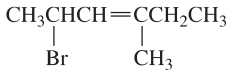
5-bromo-4-chloro-1-heptene

Substituents are stated in alphabetical order.

5. If counting in either direction results in the same number for the functional group suffix, the correct name is the one containing the lowest substituent number. For example, the compound shown below on the left is a 4-octene whether the longest continuous chain is numbered from left to right or from right to left. If you number from left to right, then the substituents are at positions 4 and 7, but if you number from right to left, they are at positions 2 and 5. Of those four substituent numbers, 2 is the lowest, so the compound is named 2,5-dimethyl-4-octene.



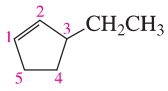
2,5-dimethyl-4-octene
not
4,7-dimethyl-4-octene
because 2 < 4



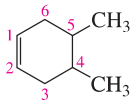
2-bromo-4-methyl-3-hexene
not
5-bromo-3-methyl-3-hexene
because 2 < 3

A substituent receives the lowest possible number only when there is no functional group suffix or the same number for the functional group suffix is obtained in both directions.

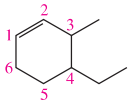
6. A number is not needed to denote the position of the double bond in a cyclic alkene because the ring is always numbered so that the double bond is between carbons 1 and 2. To assign numbers to any substituents, count around the ring in the direction (clockwise or counterclockwise) that puts the lowest number into the name.



3-ethylcyclopentene

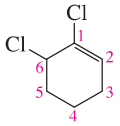


4,5-dimethylcyclohexene

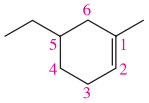


4-ethyl-3-methylcyclohexene

Notice that 1,6-dichlorocyclohexene is *not* called 2,3-dichlorocyclohexene because the former has the lowest substituent number (1), even though it does not have the lowest sum of substituent numbers (1 + 6 = 7 versus 2 + 3 = 5).

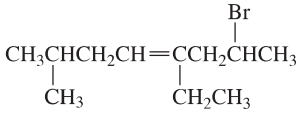


1,6-dichlorocyclohexene
not
2,3-dichlorocyclohexene
because 1 < 2

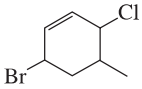


5-ethyl-1-methylcyclohexene
not
4-ethyl-2-methylcyclohexene
because 1 < 2

7. If counting in either direction leads to the same number for the alkene functional group suffix and the same lowest number or numbers for one or more of the substituents, then ignore those substituents and choose the direction that gives the lowest number to one of the remaining substituents.



2-bromo-4-ethyl-7-methyl-4-octene
not
7-bromo-5-ethyl-2-methyl-4-octene
because 4 < 5



6-bromo-3-chloro-4-methylcyclohexene
not
3-bromo-6-chloro-5-methylcyclohexene
because 4 < 5

Remember that the name of a substituent is stated *before* the name of the parent hydrocarbon and that a functional group suffix is stated *after* the name of the parent hydrocarbon.

USE THE STRATEGY

PROBLEM 7 ♦

What is each compound's systematic name?

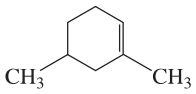
a. $CH_3CHCH{=}CHCH_3$ (CH_3 on the first carbon)

b. $CH_3CH_2C{=}CCHCH_3$ (CH_3 and Cl on the first carbon)

c.

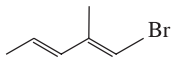
d. $BrCH_2CH_2CH{=}CCH_3$ (CH_2CH_3 on the third carbon)

e.

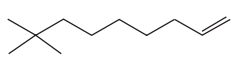


f. $CH_3CH{=}CHCH_2OCH_2CH_2CH_2CH_3$

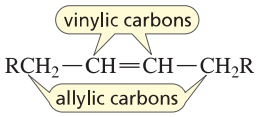
g.



h.



The sp^2 carbons of an alkene are called **vinylic carbons.** An sp^3 carbon that is adjacent to a vinylic carbon is called an **allylic carbon.** A hydrogen bonded to a vinylic carbon is called a **vinylic hydrogen,** and a hydrogen bonded to an allylic carbon is called an **allylic hydrogen.**



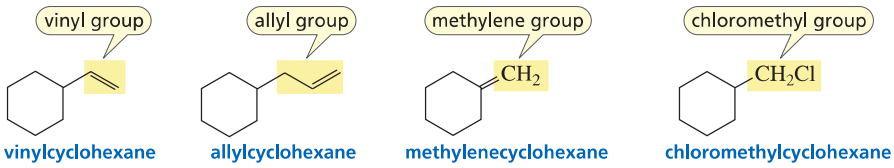
PROBLEM 8 ♦

a. How many vinylic hydrogens does cyclopentene have?
b. How many allylic hydrogens does it have?

Two groups containing a carbon–carbon double bond are used in common names—the **vinyl group** and the **allyl group.** The vinyl group is the smallest possible group that contains a vinylic carbon, and the allyl group is the smallest possible group that contains an allylic carbon. When "vinyl" or "allyl" is used in a name, the substituent must be attached to the vinylic or allylic carbon, respectively.

	$CH_2{=}CH-$	$CH_2{=}CHCH_2-$
	vinyl group	**allyl group**
	$CH_2{=}CHCl$	$CH_2{=}CHCH_2Br$
common name:	vinyl chloride	allyl bromide
systematic name:	chloroethene	3-bromopropene

Notice how these groups and some others can be used as substituent names in systematic nomenclature.



PROBLEM 9 ♦

Draw the structure for each of the following:

a. 3,3-dimethylcyclopentene
b. 6-bromo-2,3-dimethyl-2-hexene
c. ethyl vinyl ether
d. allyl alcohol

5.3 THE STRUCTURE OF ALKENES

Alkenes have structures similar to that of ethene, the smallest alkene, whose structure was described in Section 1.8. Each double bonded carbon of an alkene has three sp^2 orbitals. Each of these orbitals overlaps an orbital of another atom to form a σ bond, one of which is one of the bonds in the double bond. Thus, the σ bond of the double bond is formed by the overlap of an sp^2 orbital of one carbon with an sp^2 orbital of the other carbon. The other bond of the double bond is a π bond formed from side-to-side overlap of the remaining p orbital on each of the sp^2 carbons.