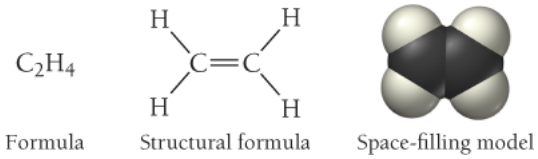
Pearson

21.5: Alkenes and Alkynes

Alkenes are hydrocarbons containing at least one double bond between carbon atoms. Alkynes contain at least one triple bond. Because of the double or triple bond, alkenes and alkynes have fewer hydrogen atoms than the corresponding alkanes. They are therefore **unsaturated hydrocarbons** because they are not loaded to capacity with hydrogen. Recall that noncyclic alkenes have the formula C_nH_{2n} and noncyclic alkynes have the formula C_nH_{2n-2}. The simplest alkene is ethene (C_2H_4). also called ethylene:

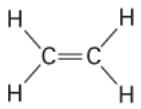
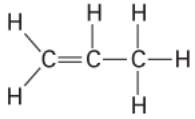
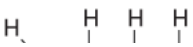
ethene or ethylene

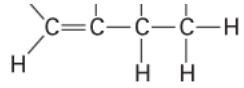
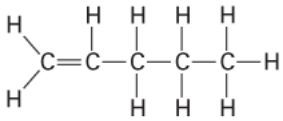
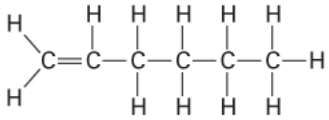


> The general formulas shown here for alkenes and alkynes assume only one multiple bond.

The geometry about each carbon atom in ethene is trigonal planar (see Example 6.3 for the valence bond model of ethene); this makes ethene a flat, rigid molecule. Ethene is a ripening agent in fruit such as bananas. When a banana within a cluster of bananas begins to ripen, it emits ethene. The ethene causes other bananas in the cluster to ripen. Banana farmers usually pick bananas green for ease of shipping. When the bananas arrive at their destination, they are "gassed" with ethene to initiate ripening. Table 21.7 lists the names and structures of several other alkenes. Most of them do not have familiar uses except as minority components in fuels.

Table 21.7 Alkenes

n	Name	Molecular Formula C_nH_{2n}	Structural Formula	Condensed Structural Formula
2	ethene	C_2H_4		$CH_2{=}CH_2$
3	propene	C_3H_6		$CH_2{=}CHCH_3$
				

4	1-butene*	C_4H_8		$CH_2{=}CHCH_2CH_3$
5	1-pentene*	C_5H_{10}		$CH_2{=}CHCH_2CH_2CH_3$
6	1-hexene*	C_6H_{12}		$CH_2{=}CHCH_2CH_2CH_2CH_3$

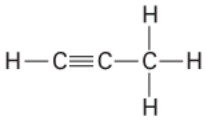
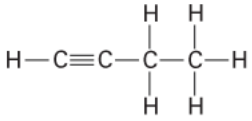
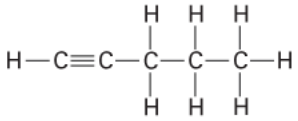
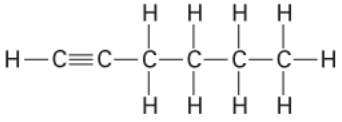
* These alkenes have one or more isomers depending on the position of the double bond. The isomers shown here have the double bond in the 1 position, meaning the first carbon–carbon bond of the chain.

The simplest alkyne is ethyne, C_2H_2, also known as acetylene:

ethyne or acetylene	C_2H_2	$H{-}C{\equiv}C{-}H$	
	Formula	Structural formula	Space-filling model

The geometry about each carbon atom in ethyne is linear, making ethyne a linear molecule. Ethyne (or acetylene) is commonly used as fuel for welding torches. Table 21.8 shows the names and structures of several other alkynes. Like alkenes, the alkynes do not have familiar uses other than as minority components of gasoline.

Table 21.8 Alkynes

n	Name	Molecular Formula C_nH_{2n-2}	Structural Formula	Condensed Structural Formula
2	ethyne	C_2H_2	$H{-}C{\equiv}C{-}H$	$CH{\equiv}CH$
3	propyne	C_3H_4		$CH{\equiv}CCH_3$
4	1-butyne*	C_4H_6		$CH{\equiv}CCH_2CH_3$
5	1-pentyne*	C_5H_8		$CH{\equiv}CCH_2CH_2CH_3$
6	1-hexyne*	C_6H_{10}		$CH{\equiv}CCH_2CH_2CH_2CH_3$

* These alkynes have one or more isomers depending on the position of the triple bond. The isomers shown here have the triple bond in the 1 position, meaning the first carbon–carbon bond of the chain.

Welding torches burn ethyne in pure oxygen to produce the very hot flame needed for melting metals.

Naming Alkenes and Alkynes

We name alkenes and alkynes in the same way we name alkanes with the following exceptions:

- The base chain is the longest continuous carbon chain *that contains the double or triple bond.*
- The base name has the ending *-ene* for alkenes and *-yne* for alkynes.
- We number the base chain to give the double or triple bond the lowest possible number.
- We insert a number indicating the position of the double or triple bond (lowest possible number) just before the base name.

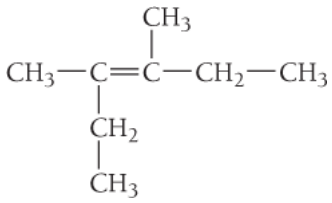
For example, the alkene and alkyne shown here are 2-methyl-2-pentene and 1-butyne:

2-methyl-2-pentene 1-butyne

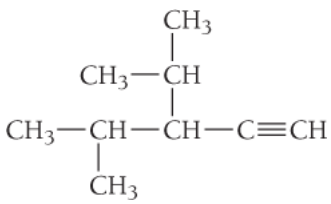
Example 21.5 Naming Alkenes and Alkynes

Name each compound.

a.



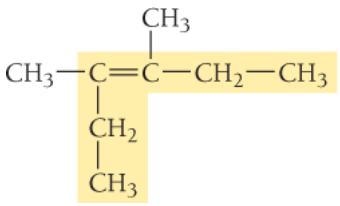
b.



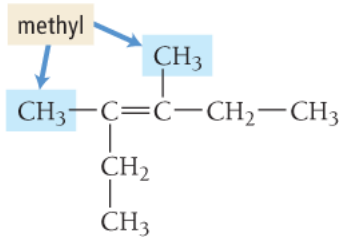
SOLUTION

a.

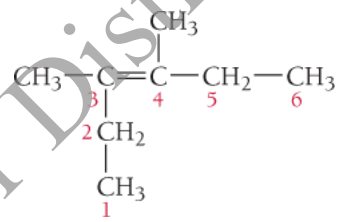
1. The longest continuous carbon chain containing the double bond has six carbon atoms. The base name is therefore *hexene*.



2. The two substituents are both methyl.



3. Recall that one of the exceptions listed previously states that, in naming alkenes, you should number the chain so that the double bond has the lowest number. In this case, the *double bond* is equidistant from the ends. Assign the double bond the number 3. The two methyl groups are then at positions 3 and 4.



4, 5. Use the general form for the name:

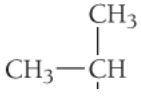
(substituent number) - (substituent name) (base name)

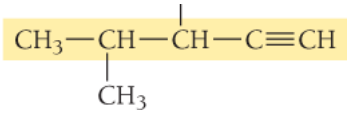
Because this compound contains two identical substituents, Step 5 of the naming procedure applies. Use the prefix *di-*. In addition, indicate the position of each substituent with a number separated by a comma. Because this compound is an alkene, specify the position of the double bond, isolated by hyphens, just before the base name.

3,4-dimethyl-3-hexene

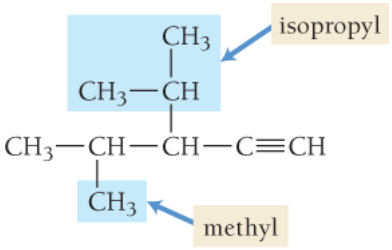
b.

1. The longest continuous carbon chain containing the triple bond is five carbon atoms long; therefore, the base name is *pentyne*.

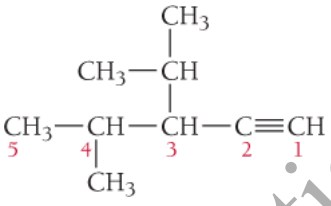




2. There are two substituents; one is a methyl group and the other an isopropyl group.



3. Number the base chain, giving the triple bond the lowest number (1). Assign the isopropyl and methyl groups the numbers 3 and 4, respectively.



4. Use the general form for the name:

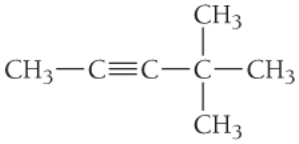
(substituent number)-(substituent name)(base name)

Since there are two substituents, list both of them in alphabetical order. Since this compound is an alkyne, specify the position of the triple bond with a number isolated by hyphens just before the base name.

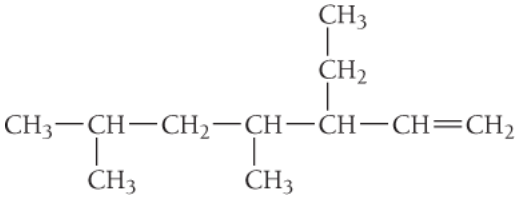
3-isopropyl-4-methyl-1-pentyne

FOR PRACTICE 21.5 Name each compound.

a.



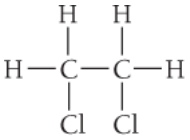
b.



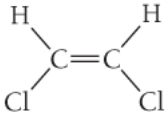
Geometric (Cis–Trans) Isomerism in Alkenes

A major difference between a single bond and a double bond is the degree to which rotation occurs about the bond. As discussed in Section 6.3, rotation about a double bond is highly restricted due to the overlap between unhybridized *p* orbitals on the adjacent carbon atoms.

Consider the difference between 1,2-dichloroethane and 1,2-dichloroethene.

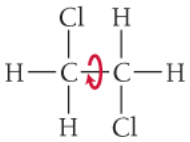


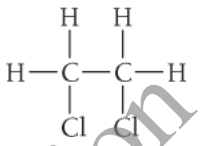
1,2-dichloroethane



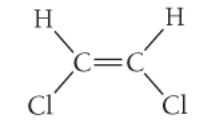
1,2-dichloroethene

The hybridization of the carbon atoms in 1,2-dichloroethane is sp^3, resulting in relatively free rotation about the sigma single bond. Consequently, the two structures are identical at room temperature because they quickly interconvert:

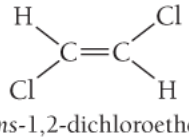




In contrast, rotation about the double bond (sigma + pi) in 1,2-dichloroethene is restricted, so at room temperature, 1,2-dichloroethene exists in two isomeric forms:



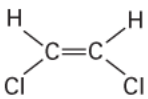
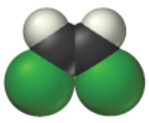
cis-1,2-dichloroethene

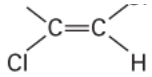
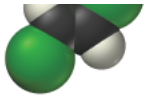


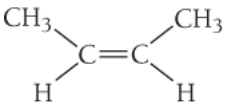
trans-1,2-dichloroethene

These two forms of 1,2-dichloroethene are different compounds with different properties as shown in Table 21.9. This kind of isomerism is a type of stereoisomerism (see Section 21.3) called **geometric (or cis–trans) isomerism**. We distinguish between the two isomers with the designations *cis* (meaning "same side") and *trans* (meaning "opposite sides"). Cis–trans isomerism is common in alkenes. As another example, consider *cis*- and *trans*-2-butene. Like the two isomers of 1,2-dichloroethene, these two isomers have different physical properties. For example, *cis*-2-butene boils at 3.7 °C, and *trans*-2-butene boils at 0.9 °C.

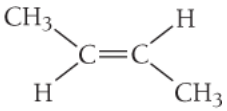
Table 21.9 **Physical Properties of *cis*- and *trans*-1,2-Dichloroethene**

Name	Structure	Space-filling Model	Density (g/mL)	Melting Point (°C)
cis-1,2-dichloroethene			1.284	–80.5
	H Cl			

trans-1,2-dichloroethene			1.257	–49.4



cis-2-butene



trans-2-butene