Continued...

26. Draw the major product of each reaction.

(a) $CH_3CH{=}CH_2 + Br_2 \rightarrow$ (c) $CH_2{=}CHCH_2CH_3 + HBr \rightarrow$

(b) $CH_2{=}CH_2 + HOH \rightarrow$ (d) $(CH_3)_2C{=}CHCH_2CH_2CH_3 + HCl \rightarrow$

27. For each reaction, name and draw the reactants that are needed to produce the given product.

(a) $? + ? \rightarrow CH_3CH(Cl)CH_3$

(b) $? + ? \rightarrow Br{-}CH_2CH_2{-}Br$

(c) $? + HOH \rightarrow$

```
        OH
        |
CH3CH2CCH2CH3
        |
        CH3
```

(d) $CH_2{=}CHCH_3 + ? \rightarrow CH_3CH_2CH_3$

Alkynes

Carbon and hydrogen atoms can be arranged in many ways to produce a great variety of compounds. Yet another way involves triple bonds in the structure of compounds. This bond structure creates a class of aliphatic compounds called alkynes. **Alkynes** are aliphatic compounds that contain one or more triple bonds.

Naming and Drawing Alkynes

Both double and triple bonds are multiple bonds. Therefore alkynes are unsaturated hydrocarbons, just as alkenes are. To name alkynes and draw their structures, follow the same rules that you used for alkenes. The only difference is the suffix *-yne*, which you use when naming alkyne compounds. Also, remember to count the number of bonds for each carbon. An alkyne bond counts as three bonds.

As you might expect, the shapes of alkynes are different from the shapes of alkanes and alkenes. A structure with a triple bond must be linear around the bond. (See Figure 9.25.)

Alkynes are similar to both alkanes and alkenes because they form a homologous series. Alkynes have the general formula of C_nH_{2n-2}. So, for example, the first member of the alkyne series, ethyne, has the formula C_2H_2. (You may know this compound by its common name: acetylene.) The next member, propyne, has the formula C_3H_4. The Practice Problems on the next page give you an opportunity to name and draw some alkynes.

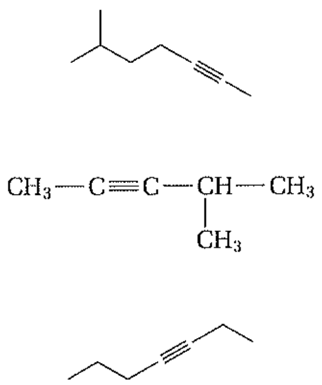


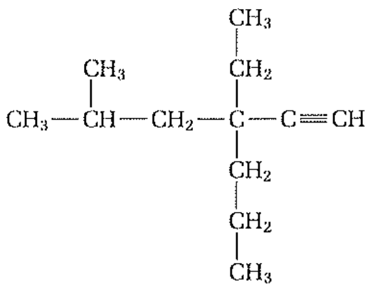
Figure 9.25 Alkynes are linear around the triple bond, as these examples show.

Practice Problems

28. Name each alkyne.

(a)

```
      CH3
      |
CH3—C—C≡C—CH3
      |
      CH3
```

(b) 

29. Draw a condensed structural diagram for each compound.
(a) 2-pentyne
(b) 4,5-dimethyl-2-heptyne
(c) 3-ethyl-4-methyl-1-hexyne
(d) 2,5,7-trimethyl-3-octyne

Physical Properties of Alkynes

Alkynes are non-polar compounds, like other hydrocarbons. They are not very soluble in water. Alkynes with low molecular masses exist as gases.

The boiling points of alkynes are in the same range as those of alkenes and alkanes. Interestingly, however, the boiling points of alkynes are slightly higher than either alkenes or alkanes that have the same number of carbon atoms. The boiling points of a few straight chain alkanes, alkenes, and alkynes are given in Table 9.5 for comparison.

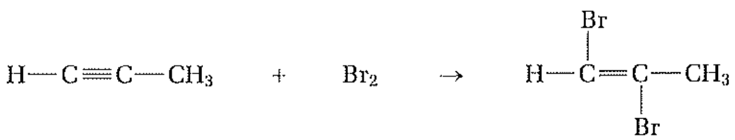
Alkanes	Boiling Point (°C)	Alkenes	Boiling Point (°C)	Alkynes	Boiling Point (°C)
Ethane	–89	ethene	–104	ethyne	–84
Propane	–42	propene	–47	propyne	–23
Butane	–0.5	1-butene	–6.3	1-butyne	8.1
Pentane	36	1-pentene	30	1-pentyne	39
Hexane	69	1-hexene	63	1-hexyne	71

Reactions of Alkynes

The presence of the triple bond makes alkynes even more reactive than alkenes. In fact, alkynes are so reactive that few of these compounds occur naturally. Like other hydrocarbons, alkynes are flammable compounds that react with oxygen in combustion reactions. Alkynes also undergo addition reactions similar to those of alkenes.

Addition Reactions of Alkynes

Since alkynes have triple bonds, two addition reactions can take place in a row. If one mole of a reactant, such as HCl, Br_2, or H_2O, is added to one mole of an alkyne, the result is a substituted alkene.



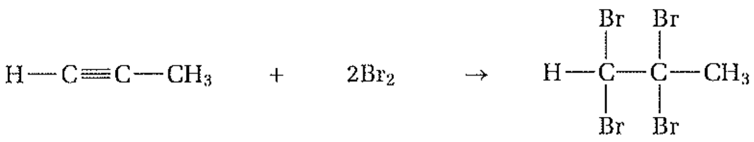
propyne (1 mol) bromine (1 mol) 1,2-dibromopropene

Math LINK

www.mcgrawhill.ca/links/atlchemistry

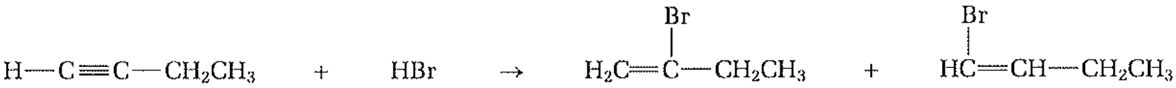
Go to the web site above and click on **Electronic Learning Partner** for more information about the bonding in ethyne.

If two moles of the reactant are added to one mole of an alkyne, the reaction continues one step further. A second addition reaction takes place, producing an alkane.



propyne (1 mol) bromine (2 mol) 1,1,2,2-tetrabromopropane

Like alkenes, asymmetrical alkynes follow Markovnikov's rule when an asymmetrical molecule, such as H_2O or HBr, is added to the triple bond. An example is given below.



1-butyne (1 mol) hydrobromic acid (1 mol) 2-bromo-1-butene (major product) 1-bromo-1-butene (minor product)

Cyclic Hydrocarbons

You have probably heard the term "steroid" used in the context of athletics. (See Figure 9.26.) Our bodies contain steroids, such as testosterone (a male sex hormone) and estrone (a female sex hormone). Steroids also have important medicinal uses. For example, budesonide is a steroid that is used to treat asthma. One of the most common steroids is cholesterol. This compound is essential to your normal body functions, but it has been linked to blocked artery walls and heart disease, as well.

Steroids have also been associated with misuse, especially at the Olympics and other sporting events. Some athletes have tried to gain an advantage by using steroids to increase their muscle mass.

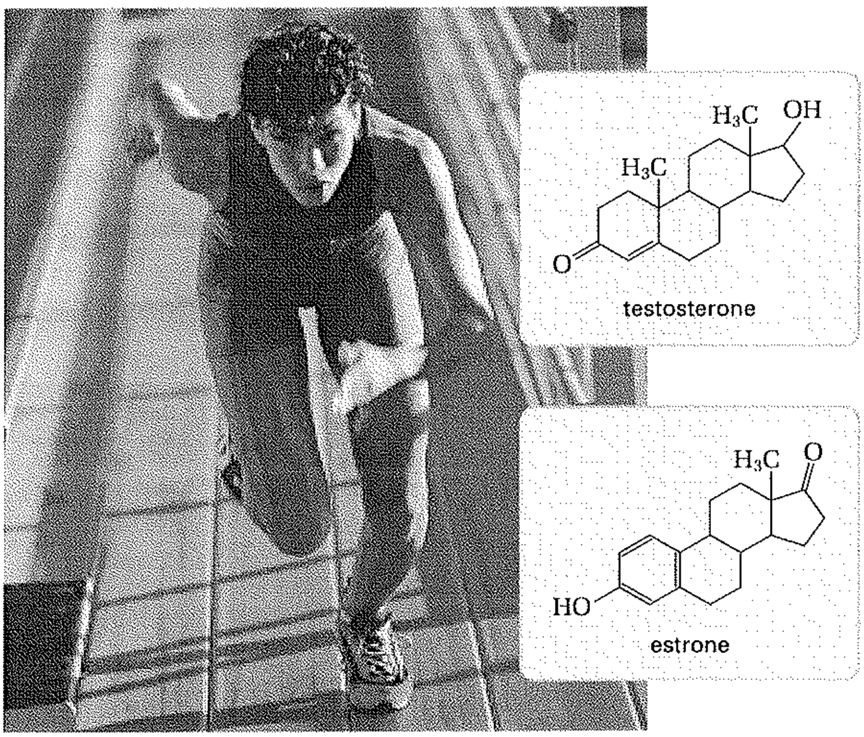


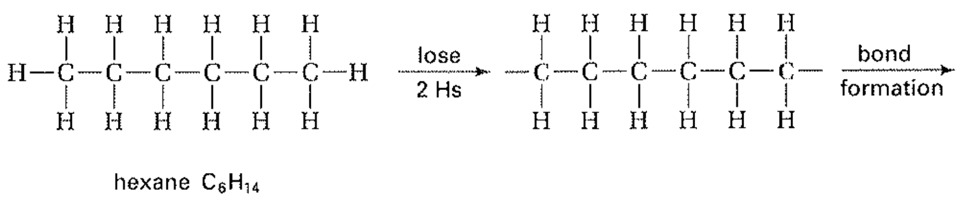
Figure 9.26 **Steroids are organic compounds. Our bodies make steroids naturally. Steroids may also be synthesized in chemical laboratories. What do the structures of these steroids have in common?**

What do steroids have to do with hydrocarbons? Steroids are unsaturated compounds. Although they are complex organic molecules, their basic structure centres on four rings of carbon atoms. In other words, steroids are built around ring structures of alkanes and alkenes.

Hydrocarbon ring structures are called **cyclic hydrocarbons**. They occur when the two ends of a hydrocarbon chain join together. In order to do this, a hydrogen atom from each end carbon must be removed, just as in the formation of a multiple bond. (See Figure 9.27 on the next page.)

Naming and Drawing Cyclic Hydrocarbons

To draw the structure of a cyclic hydrocarbon, use a line diagram in a ring-like shape, such as the one shown in Figure 9.27. Each carbon-carbon bond is shown as a straight line. Each corner of the ring represents a carbon atom. Hydrogen atoms are not shown, but they are assumed to be present in the correct numbers. Cyclohexane is a member of the alkane family. Notice, however, that cycloalkanes, such as cyclohexane, have two fewer hydrogen atoms compared with other alkanes. Thus they have the general formula C_nH_{2n}. (This is the same as the general formula for alkenes.)



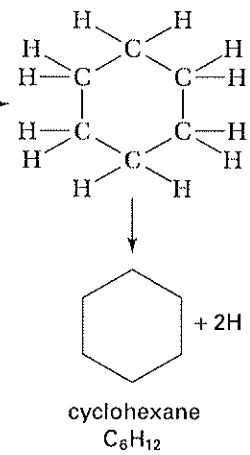


Figure 9.27 **How hexane, C_6H_{14}, can become cyclohexane, C_6H_{12}**

Because of the ring structure, the naming rules for cyclic hydrocarbons, including cycloalkanes and cycloalkenes, are slightly different from those for alkanes and alkenes. Below are four examples.

To draw cyclic hydrocarbons, start with the rules you learned for drawing other types of compounds. To place multiple bonds and branches, you have the option of counting in either direction around the ring.

Naming Cyclic Hydrocarbons

Example 1: Use the general formula: prefix + root + suffix. In Figure 9.28, there are only single carbon-carbon bonds. There are also five corners (carbon atoms) in the ring, which is the main chain. Since there are no branches, the name of this compound is cyclopentane. Notice the addition of *cyclo-* to indicate the ring structure.
Example 2: When naming cycloalkanes, all carbon atoms in the ring are treated as equal. This means that any carbon can be carbon number 1. In Figure 9.29, only one branch is attached to the ring. Therefore the carbon that the branch is attached to is carbon number 1. Because this branch automatically gets the lowest possible position number, no position number is required in the name. Thus the name of this compound is methylcyclohexane.
Example 3: When two or more branches are on a ring structure, each must have the lowest possible position number. Which way do you count the carbons around the ring? You can count in either direction around the ring. In Figure 9.30, a good choice is to make the ethyl branch carbon number 1 and then count counterclockwise. This allows you to sequence the branches in alphabetical order and to add the position numbers in ascending order. So the name of this structure is 1-ethyl-3-methylcyclohexane.

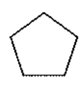


Figure 9.28
cyclopentane

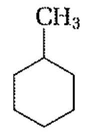


Figure 9.29
methylcyclohexane

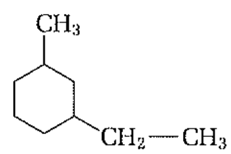


Figure 9.30
1-ethyl-3-methylcyclohexane

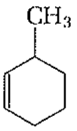
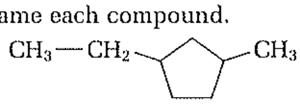


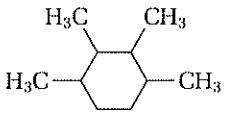
Figure 9.31
3-methyl-1-cyclohexene

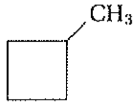
Example 4: In Figure 9.31, there is a double bond, represented by the extra vertical line inside the ring structure. You must follow the same rules as for alkenes. That is, the double bond gets priority for the lowest number. This means that one of the carbon atoms, on either end of the double bond, must be carbon number 1. The carbon atom at the other end must be carbon number 2. Next you have to decide in which direction to count so that the branch gets the lowest possible position number. In this compound, the carbon atom on the bottom end of the double bond is carbon number 1. Then you can count clockwise so that the methyl group on the top carbon of the ring has position number 3. (Counting in the other direction would give a higher locating number for the branch.) The name of this structure is 3-methyl-1-cyclohexene.

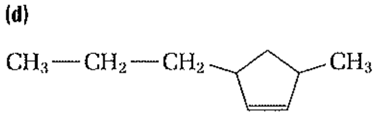
Practice Problems

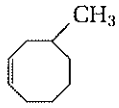
30. Name each compound.

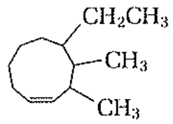
(a)


(b)


(c)


(d)


(e)


(f)


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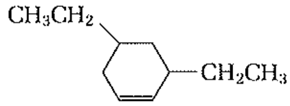
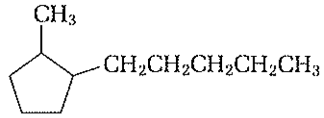


(h)


31. Draw a condensed structural diagram for each compound.

(a) 1,2,4-trimethylcycloheptane
(b) 2-ethyl-3-propyl-1-cyclobutene
(c) 3-methyl-2-cyclopentene
(d) cyclopentene
(e) 1,3-ethyl-2-methylcyclopentane
(f) 4-butyl-3-methyl-1-cyclohexene
(g) 1,1-dimethylcyclopentane
(h) 1,2,3,4,5,6-hexamethyl cyclohexane

Physical Properties and Reactions of Cyclic Hydrocarbons

Cyclic hydrocarbons are non-polar, and have similar physical properties to alkanes, alkenes, and alkynes. They are flammable, and react with oxygen in combustion reactions. Cycloalkenes and cycloalkynes react in addition reactions following the same patterns as alkenes and alkynes. In the next investigation, you will develop a more thorough understanding of aliphatic compounds by examining their structural and physical properties.