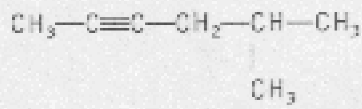
We again distinguish the two isomers by numbering the bonds in such a way that the triple bond has the lowest possible number. Thus the left-hand isomer is 1-butyne and the right-hand structure is 2-butyne.

CONCEPT TEST: Can alkynes ever have geometrical isomers?

SAMPLE EXERCISE 12.10: Name the compound with the following condensed molecular structure.

$$CH_3—C{\equiv}C—CH_2CH(CH_3)_2$$

SOLUTION: The name of the compound is based on the longest carbon chain in its structure. Sometimes it is easier to identify the longest chain by redrawing the structure showing all the carbon-carbon bonds. Doing so, we get:



The carbon backbone is six carbon atoms long. If we number the atoms from left to right to minimize the number of the location of the C≡C triple bond (between C-2 and C-3), then the methyl side chain is attached at C-5 and the name of the compound is 5-methyl-2-hexyne.

PRACTICE EXERCISE: Name the compound with the following condensed molecular structure:

$$CH_3CH_2—C{\equiv}C—CH(CH_3)_2$$

(See Problems 105 and 106.)

CHAPTER REVIEW

Summary

SECTION 12.1

Crude oil forms from decomposing plant and animal tissues under anaerobic conditions followed by additional transformations deep in the earth at high temperatures and pressures. Crude oil is separated into gasoline and other products by fractional distillation. The total vapor pressure of an ideal solution of volatile components is predicted by Raoult's law.

SECTION 12.2

Alkanes have the general formula C_nH_{2n+2}, where n is the number of carbon atoms per molecule. The boiling and melting points of alkanes generally increase with increasing n. Cycloalkanes have the formula C_nH_{2n}. The chair molecular shape of cyclohexane has lower energy than the boat form. Structural isomers have the same molecular formula but different bonding arrangements of their atoms and different properties.

SECTION 12.3

The octane grade of gasoline is boosted by the addition of aromatic compounds with planar, hexagonal rings and delocalized π electrons, as in benzene (C_6H_6). Aromatic compounds, particularly polycyclic aromatic hydrocarbons (PAHs), which consist of fused benzene rings, have very stable molecular structures.

SECTION 12.4

Organic compounds containing alcohol (R—O—H) and ether (R—O—R) functional groups are added to gasoline to promote combustion, though they have lower fuel values than those of hydrocarbons.

SECTION 12.5

Carbohydrates are a class of organic compounds with the general molecular formula $C_x(H_2O)_y$. Among the smallest carbohydrates are simple sugars, such as glucose ($C_6H_{12}O_6$). These sugars in their open-chain form contain either aldehyde or ketone functional groups. These chains undergo intramolecular reactions that result in the formation of ring structures that are the dominant form of sugars. Dissaccharides and polysaccharides, including starch and cellulose, form from condensation reactions of simple sugar molecules. Hydrolysis is the reverse of a condensation reaction, converting insoluble polysaccharides such as starch back into soluble monosaccharides.

SECTION 12.6

The major constituents of wood are cellulose, hemicelluloses, and lignin. Efforts are underway to increase the efficiency of obtaining ethanol from biomass.

SECTION 12.7

Coal, the product of high-pressure and high-temperature plant decomposition over millions of years, is graded according to its carbon content and fuel value. Anthracite has the highest values of both.

SECTION 12.8

Hydrogen has a high fuel value, but its low density and difficulty of storage make it currently unsuitable for large-scale use. Storage media include metals, such as titanium, zirconium, and hafnium, that form metal hydrides with apparent formula MH_2.

~~SECTION 12.9~~

Methanogenic bacteria convert plant biomass into methane. Other products include ethanol and the simplest carboxylic acids: formic acid and acetic acid. Amines are organic compounds containing an $—NR_2$ functional group, where R can be a hydrogen atom or a hydrocarbon substituent. *Methanosarcina* bacteria convert methylamines into methane, carbon dioxide, and ammonia.

SECTION ~~12.10~~ 12.9

The combustion of organic compounds gives CO_2 and H_2O, which can be trapped and weighed to give the atomic carbon and hydrogen content. The oxygen content is generally obtained as the remainder. The results lead to an empirical formula for the sample; the empirical formula can be converted into a molecular formula if the molar mass has been measured.

SECTION ~~12.11~~ 12.10

Alkenes contain one or more double bonds, the rigidity of which leads to the formation of geometric isomers. Simple alkynes contain at least one triple bond.

Key Terms

alcohol (p. 573)
aldehyde (p. 577)
alkene (p. 597)
alkyl group (p. 568)
alkyne (p. 599)
amine (p. 588)
aromatic hydrocarbon (p. 571)
carbohydrate (saccharide) (p. 576)
carbonyl group (p. 578)
carboxylate anion (p. 587)
carboxylic acid (p. 587)
condensation (p. 581)
ether (p. 573)
fractional distillation (p. 558)
functional group (p. 573)
geometric isomer (p. 598)
hemiacetal (p. 576)
hydrolysis (p. 583)
ideal solution (p. 561)
ketone (p. 581)
monosaccharide (p. 576)
organic compound (p. 573)
polysaccharide (p. 576)
structural isomer (p. 567)

Key Skills and Concepts

SECTION 12.1

Know how to calculate the vapor pressure of an ideal solution of volatile components from Raoult's law.

SECTION 12.2

Be able to name and draw the Lewis structures of *n*-alkanes with as many as 19 carbon atoms per molecule.
Be able to sketch the boat and chair conformations of cyclohexane and explain why the chair form is the more stable conformation.
Be able to draw the Lewis structures and name branched alkane isomers.

SECTION 12.3

Be able to draw the structures of benzene and substituted benzene compounds.
Understand the meaning of the term *polycyclic* aromatic hydrocarbons.

SECTION 12.4

Understand the meaning of the term *functional group*.
Be able to recognize the *alcohol* functional group (R–O–H) and the *ether* functional group (R–O–R).
Understand why the fuel values of oxygenated compounds such as alcohols and ethers are lower than those of the corresponding alkanes.

SECTION 12.5

Recognize the *aldehyde* group and the *ketone* group and understand that each includes a *carbonyl* group.
Understand the cyclization reactions that result in the *hemiacetal* forms of aldohexoses.
Understand how monosaccharides are reversibly linked together through condensation reactions to make polysaccharides.
Know that fermentation converts starch into ethanol.

SECTION 12.6

Understand the structural differences between starch and cellulose.

SECTION 12.7

Know the characteristics of the different grades of coal.

SECTION 12.8

Be able to explain the advantages and disadvantages of hydrogen as a fuel.

SECTION 12.9

Be able to list the principal products of the bacterial conversion of cellulose.
Be able to draw the Lewis structures of simple carboxylic acids and the anions formed by their ionization in water.
Be able to draw Lewis structures and give the names of simple primary, secondary, and tertiary amines.

SECTION 12.10

Be able to use combustion analysis data to calculate the empirical formula of a substance containing carbon, hydrogen, and oxygen.

SECTION 12.11

Be able to name and draw molecular structures of simple alkenes and alkynes.

Key Equations and Relations

The total vapor pressure (P_{total}) of a solution of volatile compounds equals the sum of the vapor pressures of each pure component x (P_x^o) multiplied by the mole fraction of that component in the solution (X_x):

$$P_{total} = X_1P_1^o + X_2P_2^o + X_3P_3^o + \cdots \qquad (12.1)$$

QUESTIONS AND PROBLEMS

Alkanes, Aromatic Compounds, and Fuel Values

CONCEPT REVIEW

1. What physical property of the components of crude oil is used to separate them?
2. Do alkanes and cyclic alkanes with the same number of carbon atoms per molecule also have the same number of hydrogen atoms per molecule?
3. What is the hybridization of carbon in alkanes?
4. Are hexane and cyclohexane structural isomers?
5. Why is cyclohexane not planar?
6. Are cycloalkanes saturated hydrocarbons?
7. Do structural isomers always have the same molecular formula?
8. Do structural isomers always have the same chemical properties?
9. Why is benzene a planar molecule?
10. Why are aromatic molecular structures stable?

PROBLEMS

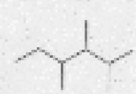
11. At 20°C, the vapor pressure of ethanol is 45 torr and the vapor pressure of methanol is 92 torr. What is the vapor pressure at 20°C of a solution prepared by mixing 25. g of methanol and 75. g of ethanol?
12. A bottle is half-filled with a 50 : 50 (mole-to-mole) mixture of heptane and octane 25°C. What is the mole ratio of heptane vapor to octane vapor in the air space above the liquid in the bottle? The vapor pressures of octane and heptane at 25°C are 11 torr and 31 torr, respectively.
13. How many carbon atoms are there in a molecule of each of the following hydrocarbons? (a) methane; (b) pentane; (c) cycloheptane; (d) cyclodecane.
14. How many carbon atoms are there in a molecule of each of the following hydrocarbons? (a) octane; (b) nonane; (c) cyclobutane; (d) cyclopropane.
15. Draw and name all the structural isomers of C_5H_{12}.
16. Draw and name all the structural isomers of C_6H_{14}.
17. Which of the following molecules are structural isomers of *n*-octane?


a.


b.


c.


d.


e.