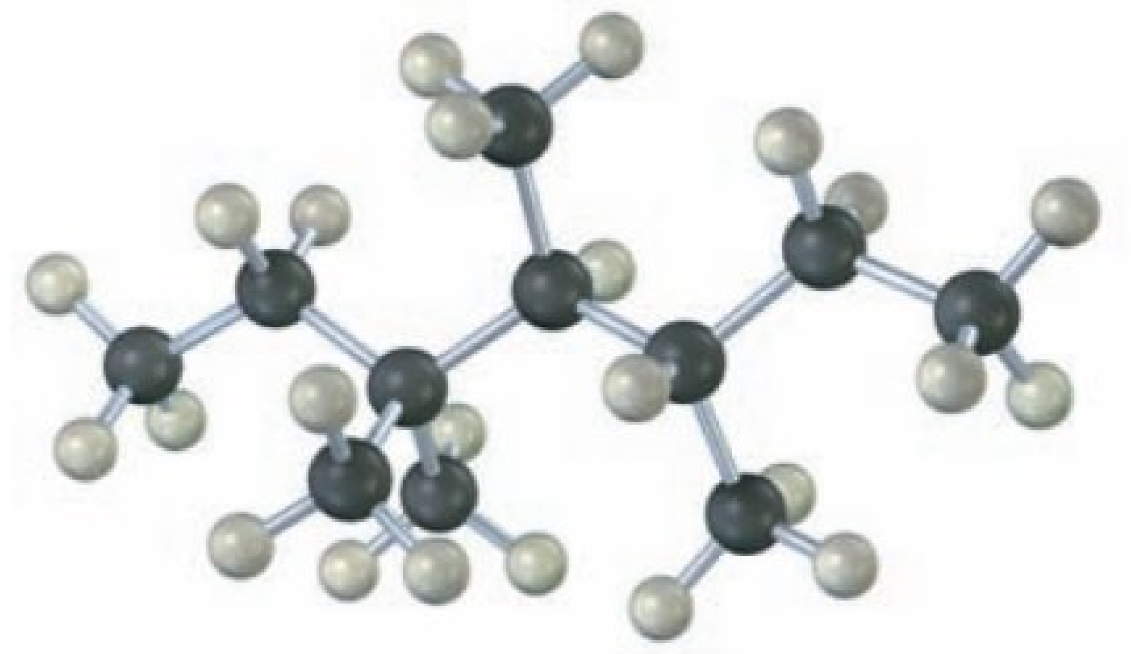
Problem 2.11 Name the following alkane:



2.4 Properties of Alkanes

Many alkanes occur naturally in the plant and animal world. For example, the waxy coating on cabbage leaves contains nonacosane ($C_{29}H_{60}$), and the wood oil of the Jeffrey pine common to the Sierra Nevada mountains of California contains heptane (C_7H_{16}). By far the major sources of alkanes, however, are the world's natural gas and petroleum deposits. Laid down eons ago, these natural deposits are derived from the decomposition of plant and animal matter, primarily of marine origin. *Natural gas* consists chiefly of methane but also contains ethane, propane, and butane. *Petroleum* is a complex mixture of hydrocarbons that must first be separated into various fractions and then further refined before it can be used.

Petroleum refining begins by fractional distillation of crude oil into three principal cuts, according to their boiling points (bp): straight-run gasoline (bp 20–200 °C), kerosene (bp 175–275 °C), and heating oil, or diesel fuel (bp 250–400 °C). Finally, distillation under reduced pressure yields lubricating oils and waxes, and leaves an undistillable tarry residue of asphalt (Figure 2.4).

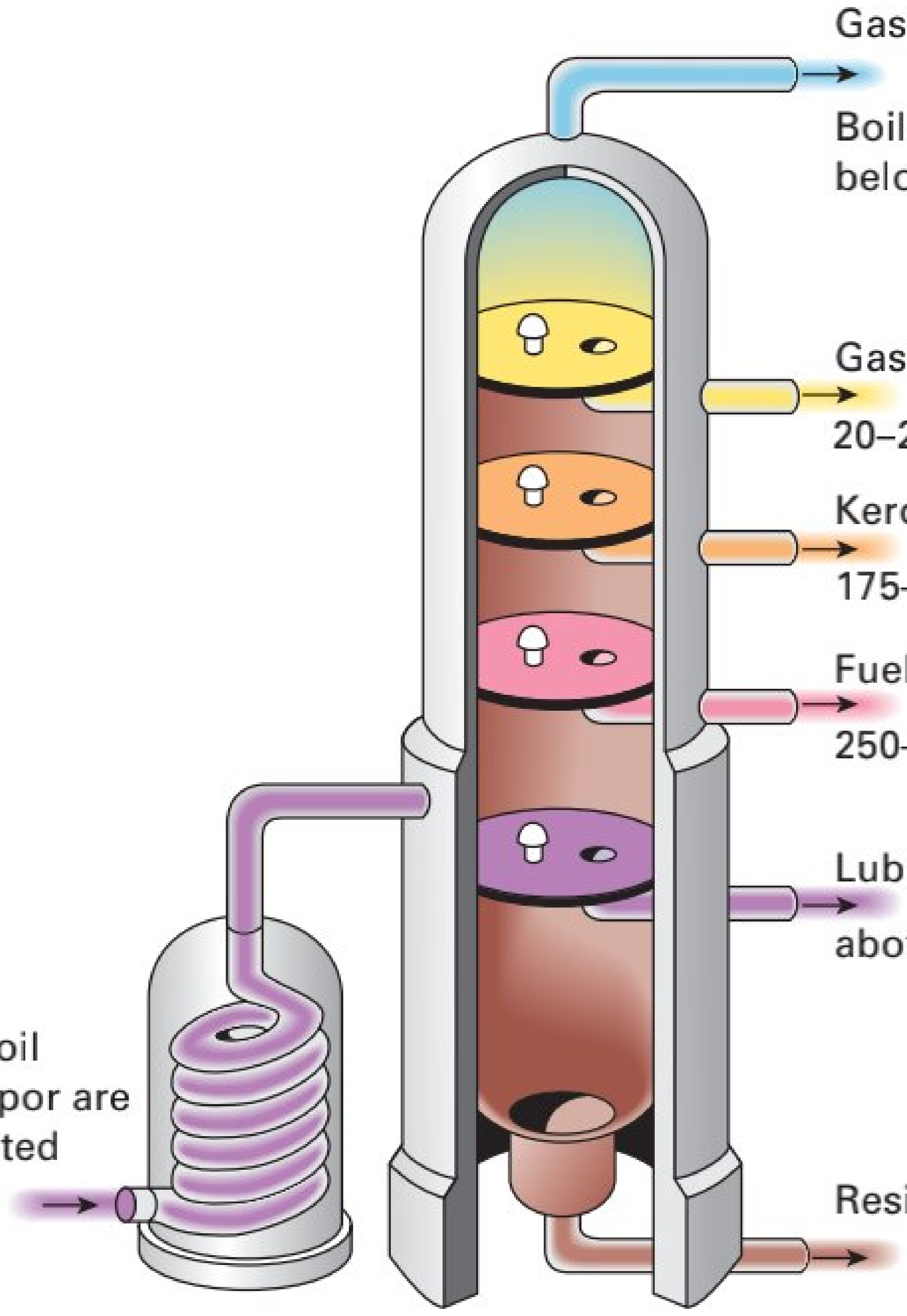


Figure 2.4 **Fractional distillation separates petroleum into fractions according to boiling point. The temperature in the tower decreases with increasing height, allowing condensation of the vapors and collection of different components.**

Alkanes are sometimes referred to as *paraffins,* a word derived from the Latin *parum affinis,* meaning "slight affinity." This term aptly describes their behavior, for alkanes show little chemical affinity for other substances and are inert to most laboratory reagents. They do, however, react under appropriate conditions with oxygen, chlorine, and a few other substances.

The reaction of an alkane with O_2 occurs during combustion in an engine or furnace when the alkane is used as a fuel. Carbon dioxide and water are formed as products, and a large amount of heat is released. For example, methane reacts with oxygen according to the equation:

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O + 890\text{ kJ }(213\text{ kcal})$$

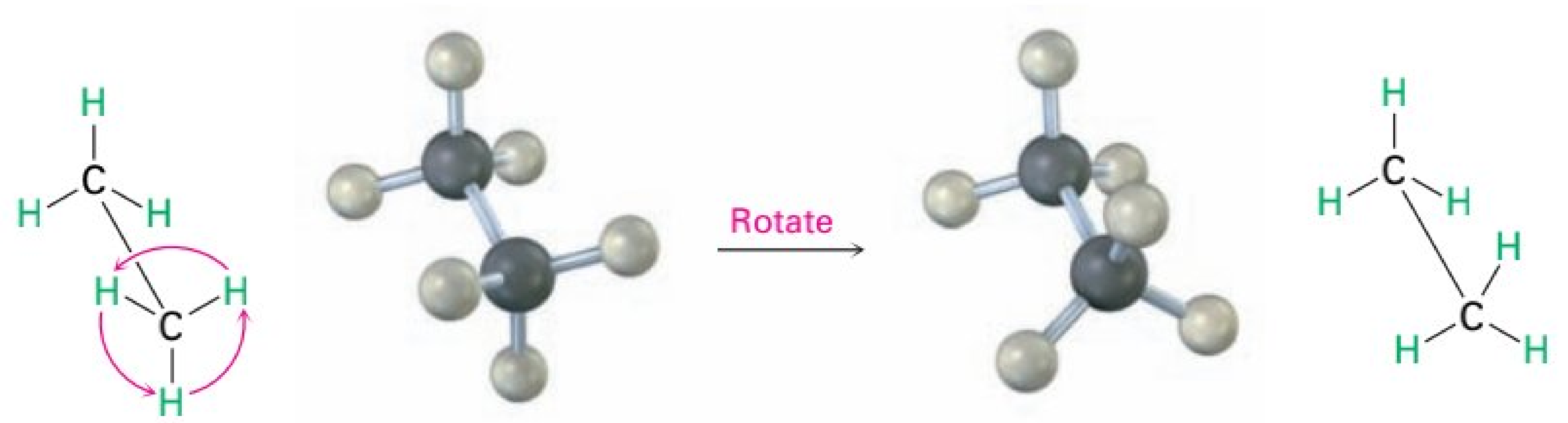
The reaction of an alkane with Cl_2 occurs when a mixture of the two is irradiated with ultraviolet light (denoted $h\nu$, where ν is the lowercase Greek letter nu). Depending on the relative amounts of the two reactants and on the time allowed for reaction, a sequential replacement of the alkane hydrogen atoms by chlorine occurs, leading to a mixture of chlorinated products. Methane, for instance, reacts with chlorine to yield a mixture of chloromethane (CH_3Cl), dichloromethane (CH_2Cl_2), trichloromethane ($CHCl_3$), and tetrachloromethane (CCl_4).

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$
$$CH_3Cl \xrightarrow{Cl_2} CH_2Cl_2 + HCl$$
$$CH_2Cl_2 \xrightarrow{Cl_2} CHCl_3 + HCl$$
$$CHCl_3 \xrightarrow{Cl_2} CCl_4 + HCl$$

2.5 Conformations of Ethane

We know from Section 1.7 that a carbon–carbon single bond results from the head-on overlap of two atomic orbitals. Because the amount of this orbital overlap is the same regardless of the geometric arrangements of other atoms attached to the carbons, *rotation* is possible around carbon–carbon single bonds. In ethane, for instance, rotation around the C–C bond occurs freely, constantly changing the geometric relationships between the hydrogens on one carbon and those on the other (Figure 2.5). The different arrangements of atoms that result from bond rotation are called **conformations**, and molecules that have different arrangements are called conformational isomers, or *conformers.* Unlike constitutional isomers, however, different conformers can't usually be isolated because they interconvert too rapidly.

Figure 2.5 Two conformations of ethane. Rotation around the C–C single bond interconverts the different conformations.



Chemists represent different conformations in two ways, as shown in Figure 2.6. A **sawhorse representation** views the C–C bond from an oblique angle and indicates spatial relationships by showing all the C–H bonds. A **Newman projection** views the C–C bond directly end-on and represents the two carbon atoms by a circle. Bonds attached to the front carbon are represented by lines to a dot in the center of the circle, and bonds attached to the rear carbon are represented by lines to the edge of the circle.

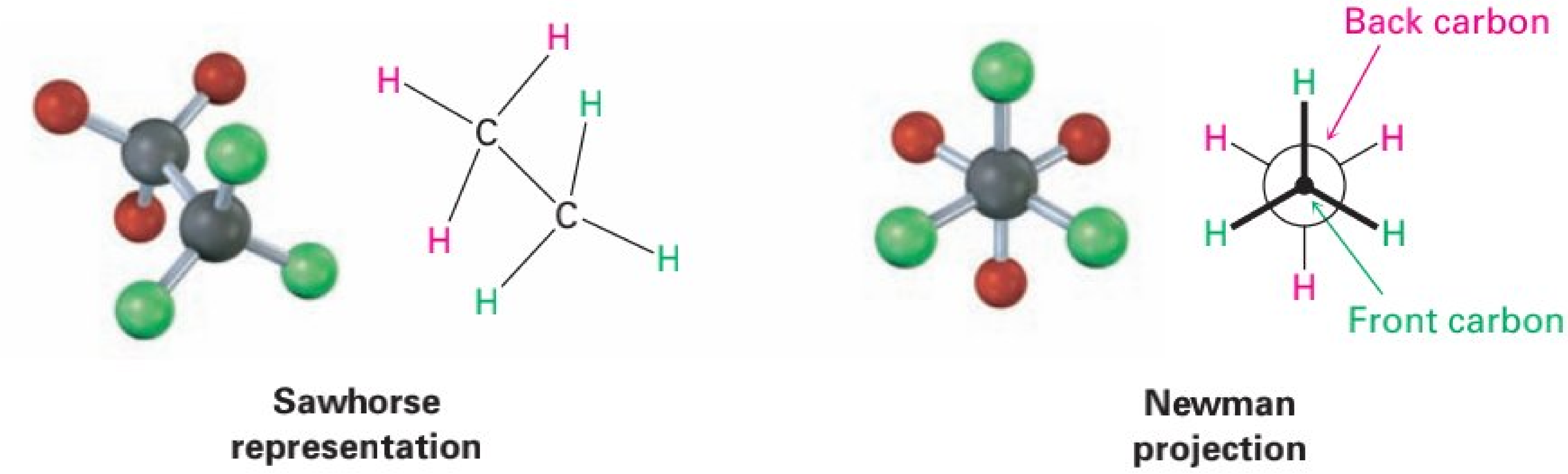


Figure 2.6 **A sawhorse representation and a Newman projection of ethane. The sawhorse representation views the molecule from an oblique angle, while the Newman projection views the molecule end-on. Note that the molecular model of the Newman projection appears at first to have six atoms attached to a single carbon. Actually, the front carbon, with three attached green atoms, is directly in front of the rear carbon, with three attached red atoms.**

Despite what we've just said, we actually don't observe *perfectly* free rotation in ethane. Experiments show that there is a slight (12 kJ/mol; 2.9 kcal/mol) barrier to rotation and that some conformations are more stable than others. The lowest-energy, most stable conformation is the one in which all six C–H bonds are as far away from one another as possible (**staggered** when viewed end-on in a Newman projection). The highest-energy, least stable conformation is the one in which the six C–H bonds are as close as possible (**eclipsed** in a Newman projection). At any given instant, about 99% of ethane molecules have an approximately staggered conformation, and only about 1% are close to the eclipsed conformation (Figure 2.7).

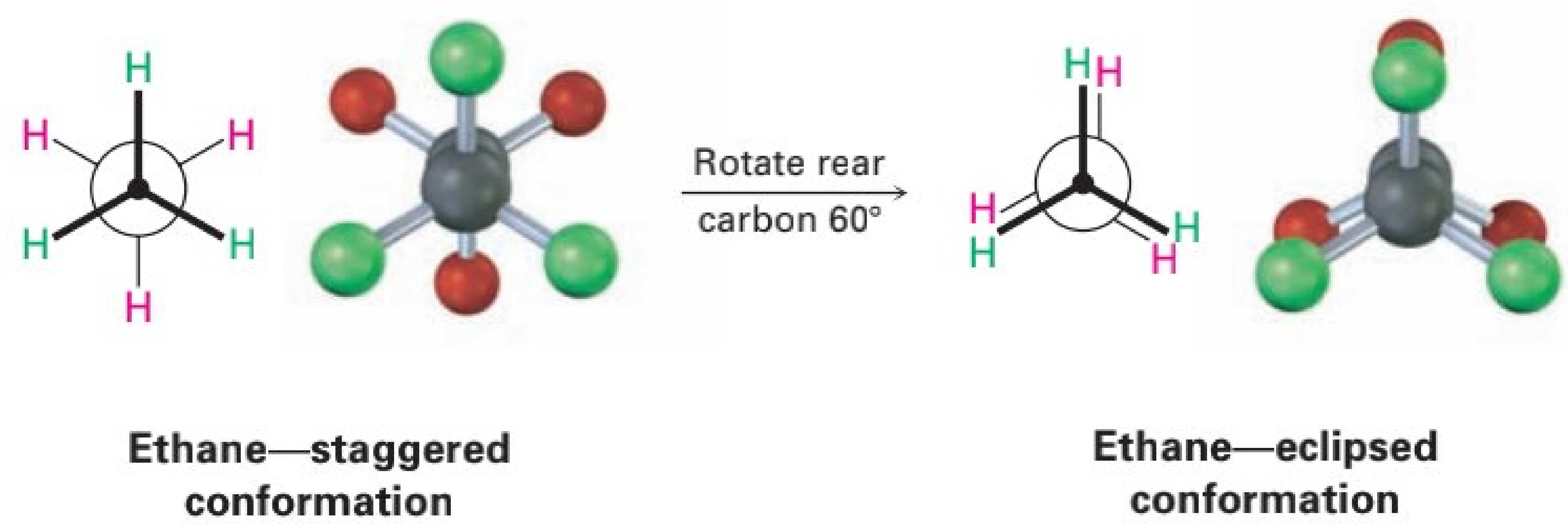


Figure 2.7 **Staggered and eclipsed conformations of ethane. The staggered conformation is lower in energy and more stable by 12.0 kJ/mol.**

What is true for ethane is also true for propane, butane, and all higher alkanes. The most favored conformation for any alkane is the one in which all bonds have staggered arrangements (Figure 2.8).

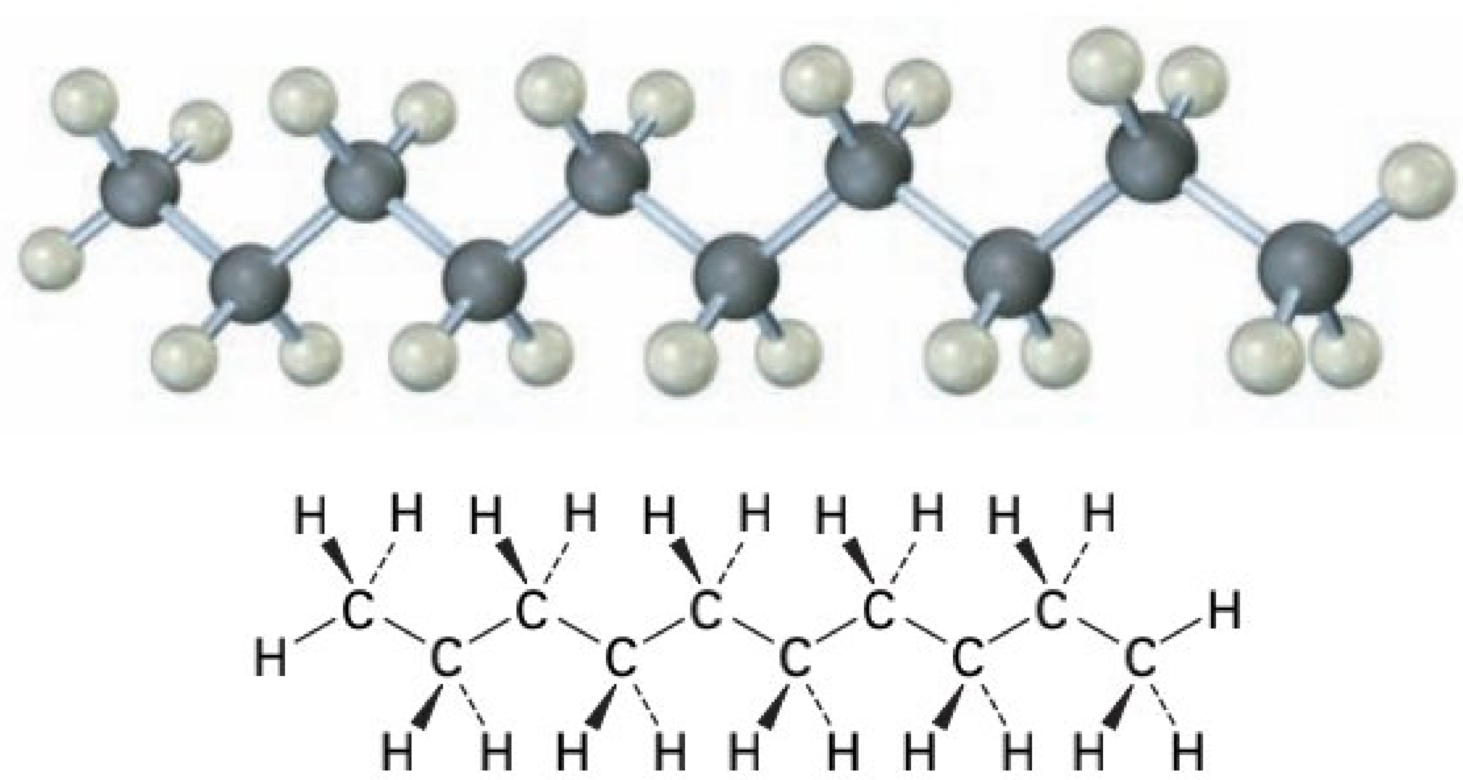


Figure 2.8 **The most stable conformation of any alkane is the one in which the bonds on adjacent carbons are staggered and the carbon chain is fully extended so that large groups are far away from one another, as in this model of decane.**