6.1: Rings and Chains of Carbon Atoms

Most of the molecules of chemical compounds studied so far have been clusters of only a few atoms. Therefore, molecules of water, H_2O, exist as individual clusters of 2 H atoms bonded to 1O atom and molecules of ammonia, NH_3, each consist of an atom of N to which are bonded 3 H atoms. In cases where atoms of a particular element in chemical compounds have a tendency to bond with atoms of the same element, the number of possible compounds is increased tremendously. This is the case with carbon, C. Groups of carbon atoms can bond together to form straight chains, branched chains, and rings, leading to a virtually limitless number of chemical compounds. Such carbon-containing compounds are **organic chemicals**, the study of which is **organic chemistry**. Adding to the enormous diversity of organic chemistry is the fact that two carbon atoms may be connected by **single bonds** consisting of 2 shared electrons, **double bonds** composed of 4 shared electrons, and even **triple bonds** that contain 6 shared electrons.

Organic chemicals comprise most of the substances with which chemists are involved. Petroleum, which serves as the raw material for vast polymer, plastics, rubber, and other industries consists of hundreds of compounds composed of hydrogen and carbon called **hydrocarbons**.Among organic chemicals are included the majority of important industrial compounds, synthetic polymers, agricultural chemicals, and most substances that are of concern because of their toxicities and other hazards. The carbohydrates, proteins, lipids (fats and oils), and nucleic acids(DNA) that make up the biomass of living organisms are organic chemicals made by biological processes. The feedstock chemicals needed to manufacture a wide range of chemical products are mostly organic chemicals, and their acquisition and processing are of great concern in the practice of green chemistry. The largest fraction of organic chemicals acquired from petroleum and natural gas sources are burned to fuel vehicles, airplanes, home furnaces, and power plants. Prior to burning, these substances may be processed to give them desired properties. This is particularly true of the constituents of gasoline, the molecules of which are processed and modified to give gasoline desired properties of smooth burning (good antiknock properties) and low air pollution potential. Pollution of the water, air, and soil environments by organic chemicals is an area of significant concern. Much of the effort put into green chemistry has involved the safe manufacture, recycling, and disposal of organic compounds.

A number of organic compounds are made by very sophisticated techniques to possess precisely tailored properties. This is especially true of pharmaceuticals, which must be customized to deliver the desired effects with minimum undesirable side effects. A single organic compound that is effective against one of the major health problems — usually one out of hundreds or even thousands tested — has the potential for hundreds of millions of dollars per year in profits.

Organic chemicals differ widely in their toxicities. Some compounds are made and used because of their toxicities to undesirable organisms. These are the **pesticides**, including, especially, **insecticides** used to kill unwanted insects and **herbicides** used to eradicate weeds that compete with desired crops. Green chemistry is very much involved with these kinds of applications. One of the more widely applied uses of genetically modified crops has been the development of crops that produce their own insecticides in the form of insecticidal proteins normally made by certain kinds of bacteria whose genes have been spliced into field crops. Another application of green chemistry through genetic engineering is the development of crops that resist the effects of specific organic molecules commonly used as herbicides. These herbicides may be applied directly to target crops, leaving them unscathed while competing weeds are killed.

It should be obvious from this brief discussion that organic chemistry is a vast, diverse, highly useful discipline based upon the unique bonding properties of the carbon atom. The remainder of this chapter discusses major aspects of organic chemistry. Many of the most interesting and important organic chemicals are made by biological processes. Indeed, until 1828, it was generally believed that only organisms could synthesize organic chemicals. In that year, Friedrich Wöhlers succeeded in making urea, an organic chemical that is found in urine, from ammonium cyanate, an inorganic material. Because of the important role of organisms in making organic chemicals, several of the most significant kinds of these chemicals made biologically are also discussed in this chapter. Additional details regarding the ways in which living organisms make and process chemicals are given in Chapters 9 and 13.