8.1: Prelude to Organic Compounds

In our discussion of ionic substances, we described a number of macroscopic properties, such as electrical conductivity, crystal shape and cleavage, and characteristic chemical behavior of ions. These were understandable in terms of the microscopic picture of individual ions packed into a crystal lattice in a solid ionic compound or able to move past one another in a liquid or solution. The macroscopic properties of covalent and polar covalent substances can likewise be attributed to microscopic structure. We will see how the nature of the molecules in a covalently bonded substance influences its behavior.

The number of covalent substances is far larger than the number of ionic compounds, largely because of the ability of one element, carbon, to form strong bonds with itself, as in ethane, the compound shown below.

Hydrogen, oxygen, nitrogen, and a number of other elements also bond strongly to carbon, and a tremendous variety of compounds can result. In the early days of chemistry such compounds were obtained from plants or animals rather than being synthesized by chemists, and so they came to be known as organic compounds. This distinguished them from the inorganic compounds available from nonliving portions of the earth's surface. Today literally millions of carbon compounds can be synthesized in laboratories, and so this historical distinction is no longer valid. Nevertheless, the study of carbon compounds is still referred to as organic chemistry. Since organic compounds all involve covalent bonds, we will describe a number of them as we discuss covalent substances. Many are of considerable commercial importance, and you probably encounter them, perhaps without knowing it, every day.

Macroscopic physical properties such as melting and boiling points depend on the strengths of the forces which hold microscopic particles together. In the case of molecules whose atoms are connected by covalent bonds, such intermolecular forces may be of three types. All molecules are attracted together by weak London forces. These depend on instantaneous polarization and increase in strength with the size of the molecular electron cloud. When a molecule contains atoms whose electronegativities differ significantly and the resulting bond dipoles do not cancel each other's effects, dipole forces occur. This results in higher melting and boiling points than for nonpolar substances.

The third type of intermolecular force, the hydrogen bond, occurs when one molecule contains a hydrogen atom connected to a highly electronegative partner. The other molecule must contain an electronegative atom, like fluorine, oxygen, or nitrogen, which has a lone pair. Although each hydrogen bond is weak compared with a covalent bond, large numbers of hydrogen bonds can have very significant effects. One example of this is in the properties of water. This highly unusual liquid plays a major role in making living systems and the earth's environment behave as they do.

Carbon normally forms four bonds, and carbon-carbon bonds are quite strong, allowing formation of long chains to which side branches and a variety of functional groups may be attached. Hence the number of molecular structures which can be adopted by organic compounds is extremely large. Functional groups containing oxygen atoms, nitrogen atoms, and multiple bonds often determine the chemical and physical properties of carbon compounds. Therefore organic chemistry may be systematized by studying related groups of compounds such as alkanes, cycloalkanes, aromatic compounds, alkenes and alkynes, alcohols, ethers, aldehydes and ketones, carboxylic acids, esters, amines, and so on. Within each of these categories chemical and physical behaviors are closely related to molecular structures. Some covalently bonded substances do not consist of individual small molecules. Instead, giant macromolecules form. Examples include most of the rocks in the crust of the earth as well as modern plastics. Properties of such substances depend on whether the macromolecules are three dimensional (like diamond), two dimensional (like graphite or sheets of mica) or one dimensional (like polyethylene). In the latter two cases the strengths of forces between adjacent macromolecules have a significant effect on the properties of the substances.