a9 Chemical bonds < Pauling >

Nothing exists but atoms [Gk. *A-tomos* means *unable to be cut*] and void [empty space].
—Democritus of Abdera (ca. 460 - ca. 270 BCE).[1]

Lorenzo Romano *Amedeo* Carlo *Avogadro* conte di Quaregna e di Cerreto (1776-1856) stated in 1811 that most matter, be it gas, liquid, or solid, is made up of particles containing two or more atoms held in a tight embrace. He named those particles (of chemically bonded atoms) "molecules."[2] But his analogy must have been his name as our concept of chemical bonds began in 1897 when J. J. Thomson (1856-1940), in his announcement of the electron as a subatomic particle, speculated on the electron's role in chemistry, and used the term "ionic bond" in *Electricity and Matter*, 1904.[3]

Three types of chemical bonds are:

Ionic bonds, which hold say Na^+ and Cl^- together in common salt crystals, are understood to result from the attraction that opposite electric charges exert on each other.

Covalent bonds, which hold say oxygen molecules, O_2, together in spite of ions of each having the same electric charge (negative in the case of atomic oxygen, O^{2-}), are understood to be a sharing of electrons to complete the valence shells of each.

Qualitatively different from ionic and covalent bonds is a relatively weak chemical bond called a *hydrogen bond*, that holds, for example, water molecules together in an ice crystal with the open structure that lets it float in water itself.

In 1935, Linus Pauling (***Figure a9.1***) reasoned that the hydrogen bond is a chimera involving components of both ionic and covalent parts. In water, hydrogen bonds forge links between hydrogen and oxygen atoms in adjacent molecules. Such a bond's character derives mostly from attraction between unlike electric charges that hydrogen bonded molecules acquire. A study of ice (reported in 1999)[4] has provided experimental proof that the electron contributing to that charge separation spends roughly 10 percent of its time mingling with an electron covalently binding the hydrogen and oxygen atoms within adjacent water molecules.

Life owes its existence to the hydrogen bond, which joins DNA and protein molecules or regions within these molecules and is loose enough to allow biological machinery to function. ❑

Figure a9.1 **Linus Pauling** (1901-1994)

Chemistry can [be now] understood rather than being memorized.
—Mary Jo Nye, 2000, *referring to Pauling's contributions.*[5]

Modern chemistry began when Linus Pauling in 1931 theorized that in order to create stronger bonds, the electron orbitals in atoms can hybridize as "petal shaped waves." In *The Nature of the Chemical Bond and the Structure of Molecules and Crystals: An Introduction to Modern Structural Chemistry*, first published in 1939, he laid out six rules which could help scientists determine molecular structure.[6]

The first three were derivative of other's work: 1) electron-pair bonds are formed by the interaction of two unpaired electrons, one on each of the two bonding atoms. 2) the spins of the electrons must be opposite (one positive, one negative) so the magnetism of the substance is unchanged; 3) the two electrons form a part that can't form additional pairs. The next three were intuitive guesses (inspired by his, new for chemists of the day, understanding of quantum mechanics), later confirmed: 4) a method to mathematically estimate valence; (*cont.*)