8.1: Hydrogen Bonding

In Chapter 7, we explored the unique properties of water that allow it to serve as a powerful solvent with the ability to dissolve both ionic compounds, as well as polar molecular compounds. We attributed this to the ability of water molecules to align themselves so that the polarized hydrogen-oxygen bonds could stabilize cations, anions, and virtually any compound that also contained a significantly polarized covalent bond. By this logic, it is not at all surprising that water can also react strongly with itself, and indeed water exists as a vast network of molecules aligned so that their positive and negative dipoles interact with each other. A bond that is formed from a hydrogen atom, which is part of a polar covalent bond (such as the O—H bond) to another, more electronegative atom (that has at least one unshared pair of electrons in its valence shell) is called a **hydrogen bond**. Recall that oxygen has two unshared pairs in its valence shell, and the hydrogen-oxygen interaction in water is the classic example of a hydrogen bond. Hydrogen bonds are weak, relative to covalent bonds. The energy required to break the O—H covalent bond (the **bond dissociation energy**) is about 111 kcal/mole, or in more proper *SI* units, 464 kJ/mole. The energy required to break an O—H••••O hydrogen bond is about 5 kcal/mole (21 kJ/mole), or less than 5% of the energy of a "real" covalent bond. Even though hydrogen bonds are relatively weak, if you consider that every water molecule is participating in a least four hydrogen bonds, the total energy of hydrogen bonding interactions can rapidly become significant. Hydrogen bonding is generally used to explain the high boiling point of water (100 ˚C). For many compounds which do not possess highly polarized bonds, boiling points parallel the molar mass of the compound. Methane, CH_4, has a molar mass of 16 and a boiling point of –164 ˚C. Water, with a molar mass of 18, has a boiling point of +100 ˚C. Although these two compounds have similar molar masses, a significant amount of energy must be put into the polar molecule, water, in order to move into the gas phase, relative to the non-polar methane. The extra energy that is required is necessary to break down the hydrogen bonding network.

Hydrogen bonding is also important is DNA. According to the Watson-Crick model, the double helix of DNA is assembled and stabilized by hydrogen pairing between matching "bases". The hydrogen bonds are formed between the oxygen atoms (red) and the adjacent N—H bonds, and between the central nitrogen (blue) and the adjacent N—H bond. It is suggested that the precise alignment of these hydrogen bonds contributes to stability of the double helix and ensures the proper alignment of the corresponding base pairs.