2.3: Chemical bonds

Atoms form bonds to make molecules. Covalent bonds are strong. They can involve unequal or equal sharing of a pair of electrons, leading to polar covalent bonds and non-polar covalent bonds respectively. Ionic bonds are weaker than covalent bonds, created by electrostatic interactions between elements that can gain or lose electrons. Hydrogen (H-) bonds are in a class by themselves! These electrostatic interactions account for the physical and chemical properties of water. They are also involved in interactions between and within other molecules. While atoms can share, gain or lose electrons in chemical reactions, they will neither gain nor lose protons or neutrons. Let's look more closely at chemical bonds and how even the weak bonds are essential to life.

A. Covalent Bonds

Electrons are shared in covalent bonds. Hydrogen gas (H2) is a molecule, not an atom! H atoms in the H2 molecule share their electrons equally. Likewise, the carbon atom in methane (CH4) shares electrons equally with four hydrogen atoms. The equal sharing of electrons in non-polar covalent bonds in H2 and CH4 is shown below.
A single pair of electrons in H\textsubscript{2} forms the covalent bond between two H atoms in the hydrogen molecule. In methane, the carbon (C) atom has four electrons in its outer shell that it can share. Each H atom has a single electron to share. If the C atom shares its four electrons with the four electrons in the four H atoms, there will be four paired electrons (8 electrons in all) moving in filled orbitals around the nucleus of the C atom some of the time, and one pair moving around each of the H atomic nuclei some of the time. Thus, the outer shell of the C atom and each of the H atoms are filled at least some of the time. This stabilizes the molecule. Recall that atoms are most stable when their outer shells are filled and when each electron orbital is filled (i.e., with a pair of electrons).

**Polar covalent bonds** form when electrons in a molecule are shared unequally. This happens if the atomic nuclei in a molecule are very different in size. This is the case with water, shown below.

The larger nucleus of the oxygen atom in H\textsubscript{2}O attracts electrons more strongly than do either of the two H atoms. As a result, the shared electrons spend more of their time orbiting the O atom, such that the O atom carries a *partial negative charge* while each of the H atoms carry a *partial positive charge*. The Greek letter delta (\(\delta\)) indicates partial charges in polar covalent bonds. In the two illustrations above, compare the position of the paired electrons in water with those illustrated for hydrogen gas or methane.

Water’s polar covalent bonds allow it to attract and interact with other polar covalent molecules, including other water molecules. The polar covalent nature of water also goes a long way to explaining its physical and chemical properties, and why water is essential to life on this planet!

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Both polar and non-polar covalent bonds play a major role on the structure of macromolecules, like insulin, the protein hormone shown below.
The X-ray image of a space-filling model of the hexameric form of stored insulin (above left) emphasizes its tertiary structure in great detail. Regions of internal secondary structure are highlighted in the ribbon diagram on the right; as secreted from Islets of Langerhans cells of the pancreas, active insulin is a dimer of two polypeptides (A and B), shown here in blue and cyan respectively. The subunit structure and the interactions holding the subunits together result from many electrostatic interactions (including H-bonds) and other weak interactions. The disulfide bonds (bridges) seen as yellow ‘Vs’ in the ribbon diagram stabilize the associated A and B monomers. We will look at protein structure in more detail in an upcoming chapter.

B. Ionic Bonds

Atoms that gain or lose electrons to achieve a filled outer shell form ions, acquiring a negative or a positive charge, respectively. Despite being electrically charged, ions are stable because their outer electron shells are filled. Common table salt is a good example (illustrated below).

Na (sodium) can donate a single electron to Cl (chlorine) atoms, generating Na+ and Cl- ions. The oppositely charged ions then come together forming an ionic bond, an electrostatic interaction of opposite charges that holds the Na+ and Cl- ions together in crystal salt. Look up the Bohr models of these two elements and see how ionization of each leaves filled outer shells (energy levels) in the ions.