Chemical Bonding

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Hydrogen bonding

- **Hydrogen bonding**, interaction involving a hydrogen atom located between a pair of other atoms having a high affinity for electrons; such a bond is weaker than an ionic bond or covalent bond but stronger than van der Waals forces.
- Hydrogen bonds can exist between atoms in different molecules or in parts of the same molecule.
- One atom of the pair (the donor), generally a fluorine, nitrogen, or oxygen atom, is covalently bonded to a hydrogen atom (—FH, —NH, or —OH), whose electrons it shares unequally; its high electron affinitycauses the hydrogen to take on a slight positive charge.
- The other atom of the pair, also typically F, N, or O, has an unshared electron pair, which gives it a slight negative charge.

$$\overset{\delta-}{N}-\overset{\delta+}{H} \qquad \overset{\delta-}{O}-\overset{\delta+}{H} \qquad \overset{\delta-}{F}-\overset{\delta+}{H}$$

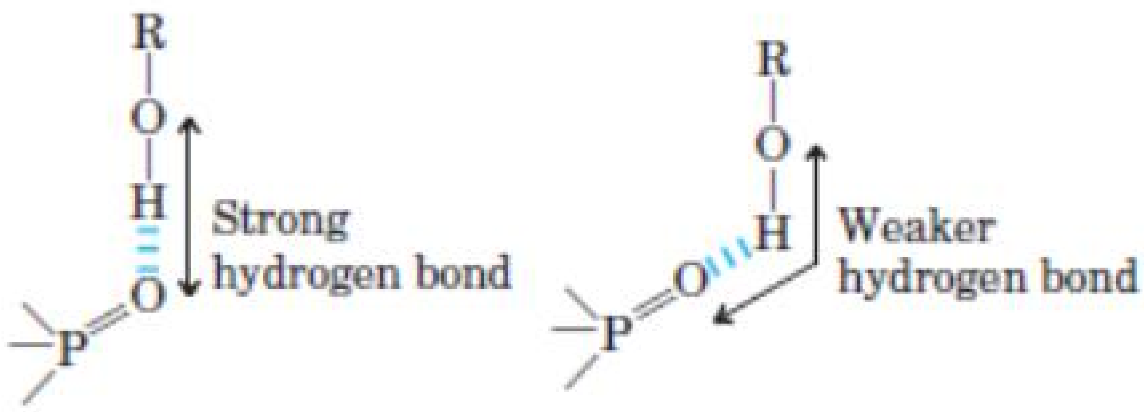
- Hydrogen bonding is a special type of dipole-dipole attraction between molecules, results from the attractive force between a hydrogen atom covalently bonded to a very electronegative atom such as a N, O, or F atom and another very electronegative atom.

Importance of hydrogen bonding

- Because of its extensive hydrogen bonding, water (H_2O) is liquid over a far greater range of temperatures that would be expected for a molecule of its size.
- Water is also a good solvent for ionic compounds and many others because it readily forms hydrogen bonds with the solute.
- Hydrogen bonding between amino acids in a linear protein molecule determines the way it folds up into its functional configuration.
- Hydrogen bonds between nitrogenous bases in nucleotides on the two strands of DNA (guanine pairs with cytosine, adenine with thymine) give rise to the double-helix structure that is crucial to the transmission of genetic information.

Types of hydrogen bonds

- **Intermolecular hydrogen bonds**
- The attraction between the partial electric charges is greatest when the three atoms involved (in this case O, H, and O) lie in a straight line.
- **Intramolecular hydrogen bonds**
- When the hydrogen-bonded moieties are structurally constrained (as when they are parts of a single protein molecule, for example), this ideal geometry may not be possible and the resulting hydrogen bond is weaker.



Ionic Bonding

- **Ions** are atoms or molecules which are electrically charged.
- **Cations** are positively charged and **anions** carry a negative charge.
- Ions form when atoms gain or lose electrons. Since electrons are negatively charged, an atom that loses one or more electrons will become positively charged; an atom that gains one or more electrons becomes negatively charged.
- Ionic bonding is the attraction between positively- and negatively-charged **ions**.
- These oppositely charged ions attract each other to form ionic networks (or lattices).
- Electrostatics explains why this happens: opposite charges attract and like charges repel.
- When many ions attract each other, they form large, ordered, crystal lattices in which each ion is surrounded by ions of the opposite charge.

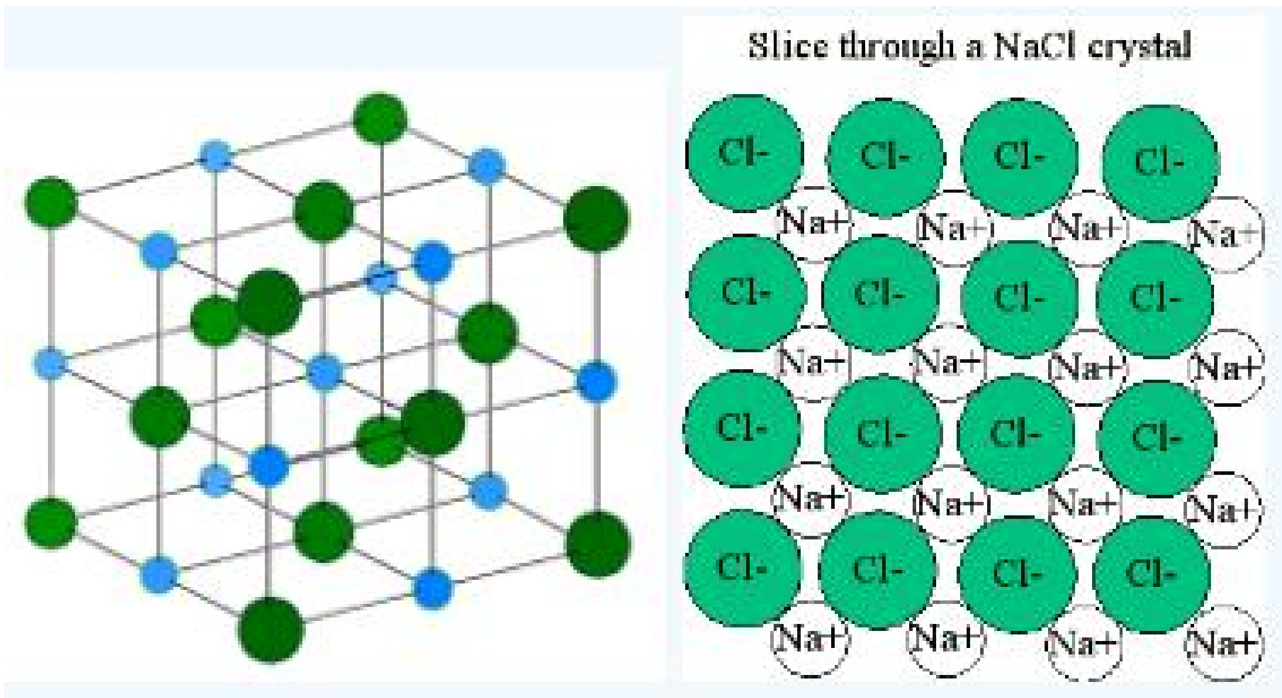
Example of ionic bond: Sodium Chloride

- in the reaction of Na (sodium) and Cl (chlorine), each Cl atom takes one electron from a Na atom.
- Therefore each Na becomes a Na^{+} cation and each Cl atom becomes a Cl^{-} anion.
- Due to their opposite charges, they attract each other to form an ionic lattice.
- The formula (ratio of positive to negative ions) in the lattice is **NaCl**.

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

- The chlorine has a high affinity for electrons, and the sodium has a low ionization potential.
- Thus the chlorine gains an electron from the sodium atom. This can be represented using ***electron-dot symbols*** (here we will consider one chlorine atom, rather than Cl_2):

NaCl lattice. (left) 3-D structure and (right) simple 2D slice through lattes.

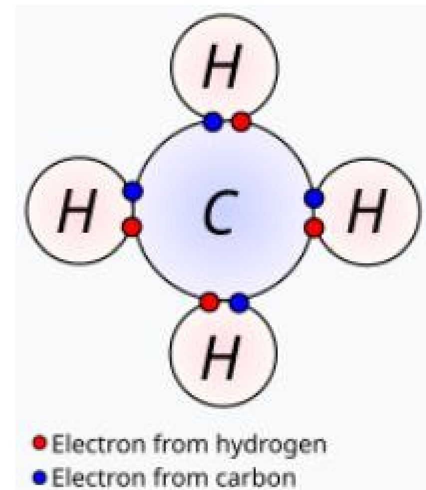


Covalent Bond

- **Covalent bond**, in chemistry, the interatomic linkage that results from the sharing of an electron pair between two atoms.
- The binding arises from the electrostatic attraction of their nuclei for the same electrons.
- For many molecules, the sharing of electrons allows each atom to attain the equivalent of a full valence shell, corresponding to a stable electronic configuration.
- In organic chemistry, covalent bonding is much more common than ionic bonding.
- The idea of covalent bonding can be traced several years before 1919 to Gilbert N. Lewis, who in 1916 described the sharing of electron pairs between atoms.
- He introduced the *Lewis notation* or *electron dot notation* or *Lewis dot structure*, in which valence electrons (those in the outer shell) are represented as dots around the atomic symbols.
- Pairs of electrons located between atoms represent covalent bonds.
- Multiple pairs represent multiple bonds, such as double bonds and triple bonds.

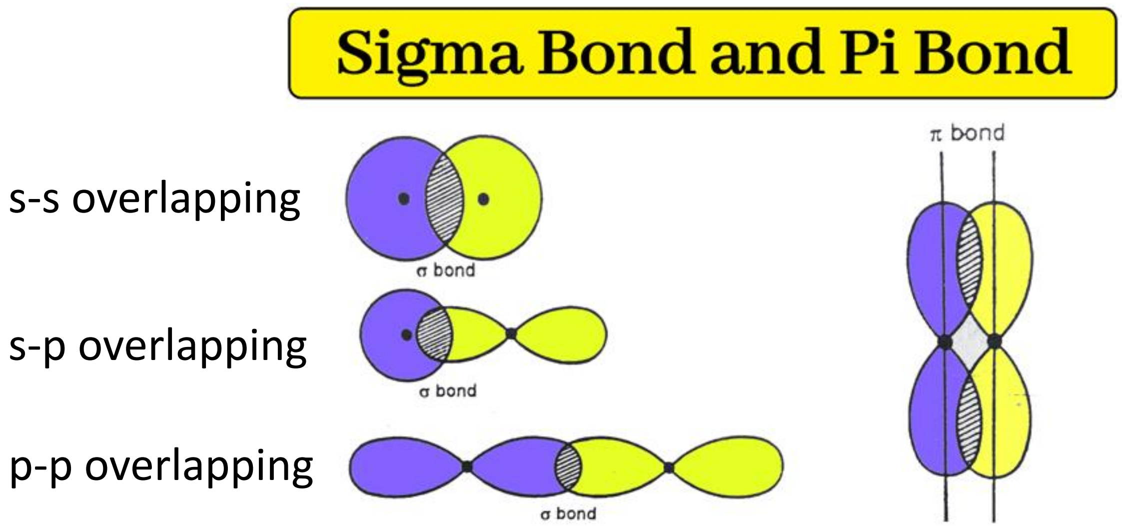
...Covalent bond

- Lewis proposed that an atom forms enough covalent bonds to form a full (or closed) outer electron shell.
- In the diagram of methane shown here, the carbon atom has a valence of four and is, therefore, surrounded by eight electrons (the octet rule), four from the carbon itself and four from the hydrogens bonded to it.
- Each hydrogen has a valence of one and is surrounded by two electrons (a duet rule) – its own one electron plus one from the carbon.
- The numbers of electrons correspond to full shells in the quantum theory of the atom; the outer shell of a carbon atom is the n = 2 shell, which can hold eight electrons, whereas the outer (and only) shell of a hydrogen atom is the n = 1 shell, which can hold only two.



Types of covalent bonds

- Atomic orbitals (except for s orbitals) have specific directional properties leading to different types of covalent bonds.
- Sigma (σ) bonds are the strongest covalent bonds and are due to head-on overlapping of orbitals on two different atoms.
- A single bond is usually a σ bond. Pi (π) bonds are weaker and are due to lateral overlap between p (or d) orbitals.
- A double bond between two given atoms consists of one σ and one π bond, and a triple bond is one σ and two π bonds.



van der Waals

- When two uncharged atoms are brought very close together, their surrounding electron clouds influence each other.
- Random variations in the positions of the electrons around one nucleus may create a transient electric dipole, which induces a transient, opposite electric dipole in the nearby atom.
- The two dipoles weakly attract each other, bringing the two nuclei closer.
- These weak attractions are called **van der Waals interactions.**
- **As** the two nuclei draw closer together, their electron clouds begin to repel each other.
- At the point where the van der Waals attraction exactly balances this repulsive force, the nuclei are said to be in van der Waals contact.
- Each atom has a characteristic **van der Waals radius,** a measure of how close that atom will allow another to approach.