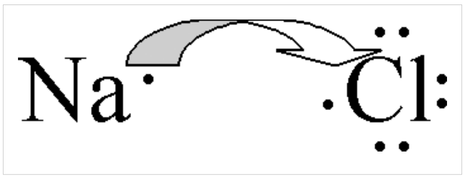
Structural Biochemistry/Chemical Bonding

Introduction

Atoms form bonds by gaining, losing, or sharing electrons; typically they seek to achieve the electron configuration of a noble gas. Bonding occurs because it lowers the energy of a system and makes the atom more stable.

Ionic Bonds

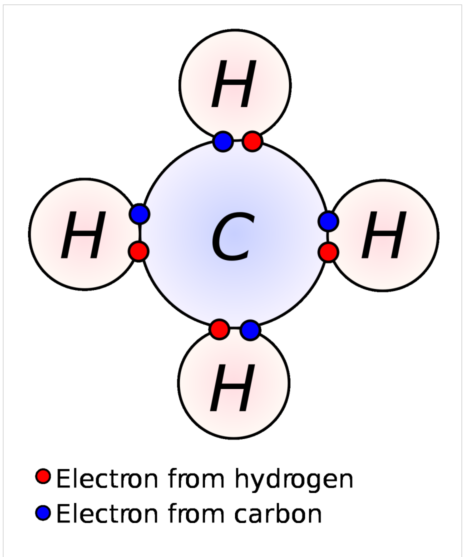


An ionic bond is the transfer of electrons between a metal and a nonmetal. An example of an ionic bond is that between sodium and chlorine atoms. The sodium atom transfers its lone electron in the 3s state to the chlorine atom. After the electron transfer, the sodium atom bears a +1 charge while the chlorine atom now bears a -1 charge. With this transfer of electrons, the sodium now has the electron configuration of the noble gas neon, while chlorine now has that of the noble gas argon.

Ionic bonding will occur only if the overall energy change for the reaction is favorable – when the bonded atoms have a lower energy than the free ones. The larger the resulting energy change the stronger the bond. The low electronegativity of metals and high electronegativity of non-metals means that the energy change of the reaction is most favorable when metals lose electrons and non-metals gain electrons.

Pure ionic bonding is not known to exist. All ionic compounds have a degree of covalent bonding, which means, ionic bond could be consider as a special type of covalent bond. The larger the difference in electronegativity between two atoms, the more ionic the bond. Ionic compounds conduct electricity when molten or in solution. They generally have a high melting point and tend to be soluble in water.

Covalent Bonds



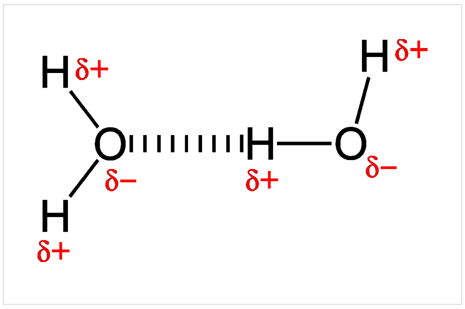
Covalent bonds are another type of chemical bond used to achieve a noble gas configuration, or an octet of electrons. Covalent bonds are formed between nonmetals, usually from the Boron, Carbon, Nitrogen, Oxygen, and Halogen families. Metals are rarely involved in covalent bonds. Each covalent bond consists of two electrons, one usually from each atom involved in the bond. The atoms form enough covalent bonds that when the electrons in the bonds are added with the valence electrons, they will have an octet. The key difference between ionic and covalent bonds lies in how the electrons are distributed between the two atoms. In ionic bonds, the electrons are transferred from one atom to the other, giving the atoms effective +1 and -1 charges. However, in covalent bonds, the valence electrons from both of the two atoms are shared between two atoms. Thus, neither atom is given a full positive or negative charge. Instead, the electrons shared between the two atoms - whether it be 2, 4, or 6 electrons - varies from molecule to molecule.

There are two types of covalent bonds: pure covalent bonds and polar covalent bonds. Pure covalent bonds exist when there is no difference between the two atoms sharing the electrons. The electronegativity of the two atoms is identical. Because the electronegativity values do not differ, they pull the electrons that are being shared between them with the same force. Thus, the electrons are shared equally and none of the atoms bears a partial positive or negative charge. An example of a pure covalent bond is a Cl-Cl or a Br-Br bond. Pure covalent bonds rarely exist for bonds that are not between identical atoms. Another example would be the covalent bonds between the carbons in long alkane chains.

Polar covalent bonds are those that exist between atoms of different electronegativities. The electrons in the bond are still being shared, but not equally between the two atoms. Though the exact ratio of the electron density that each atom bears cannot be determined easily, it is very easy to determine which atom pulls more electron density towards itself. The more electronegative atom will pull the shared electrons more, causing it to now bear a slightly negative charge. Because charge has to be conserved, the less electronegative atom must now bear a slight positive charge, equal in magnitude to the negative charge. As an example, consider a bond between carbon and chlorine. Chlorine is much more electronegative than carbon, thus it pulls more of the electrons towards itself. This gives the chlorine a slightly negative charge and the carbon a slightly positive charge. If the difference between the two atoms is so great causing one of the two atoms to posess a lot of the electron density, the bond becomes increasingly ionic and less covalent. For this reason, though H-Cl is considered a covalent bond, it is classified as a very strong acid, meaning it dissociates completely. Because the electronegativity difference is so vast, the chlorine molecule pulls all the electron density towards itself, thereby dissociating into H+ and Cl- ions in the presence in water.

However, it is important to note that a molecule that contains polar bonds can be nonpolar. For example, take the molecule carbon tetrachloride. This molecule has four polar C-Cl bonds. However, due to the orientation of the polar bonds, they cancel out and the molecule as a whole is nonpolar.

Hydrogen Bonds



A hydrogen bond is a bond created by the dipole-dipole interaction of a hydrogen atom and an electronegative atom such as an oxygen or nitrogen atom due to dipole dipole interactions. A common example of this is water where the electronegativity of the oxygen allows it to have a slight negative charge while the two hydrogen atoms have a slight positive charge. The negative charge on the oxygen forms a weak bond with the slight positive charge of another water molecule's hydrogen. This type of bonding is also present in organic fluorine compounds between C and F groups. This force is weaker than covalent bond and ionic bonds, but stronger than Van der Waals interactions.

Intermolecular hydrogen bonding is responsible for the high boiling point of water (100 °C), or most of the solutions that use water as the solvent. This is because of the strong hydrogen bond, as opposed to other group 16 hydrides. Intramolecular hydrogen bonding is partly responsible for the secondary, tertiary, and quaternary structures of proteins and nucleic acids.

Role of Noncovalent Interactions in Macromolecules

In macromolecules such as proteins, DNA, and RNA, noncovalent interactions are essential. Noncovalent interactions include hydrogen, ionic, hydrophobic, and Van Der Waals bonding. These interactions are described in more specificity in the list that follows this group. When compared to covalent bonds, noncovalent bonds are weak and continuously form and break bonds. However, when several noncovalent bonds are formed, there is a net increase in bond strength. Their combined participation in a macromolecule makes a difference (i.e. substrate binding to enzyme and the lipid bilayer's role in transport). With several hydrogen bonds, ionic, and hydrophobic interactions existent at the same time, it is unlikely that these several weak interactions will break the substrate and enzyme without external energy. This property is the reason why enzymes have specific catalytic power. Protein folding and the unique properties and structures of proteins also depend on these noncovalent interactions.

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