



Noncovalent bonding and its Concept: A Study

Jaibir Singh

Department of Chemistry, Government P.G. College, Jhalawar -326001 Rajasthan (India)

Abstract:

A noncovalent bond is a type of chemical bond, usually between macromolecules, that does not involve the sharing of electrons, but rather involves more dispersed variations of electromagnetic interactions. Super molecular chemistry primarily uses noncovalent bonds between supermolecules. Unlike covalent bonds, noncovalent bonds are used to bond large molecules, such as proteins and nucleic acids. They are weaker than covalent bonds, but they are important for biochemical processes, such as double helix formation.

Keywords: *Noncovalent Bond, Molecular Chemistry, Biochemical Process, Double Felix Formation.*

INTRODUCTION

Noncovalent bonds are chemical bonds, usually between macromolecules, that do not involve electron sharing, but rather involve more dispersed electromagnetic interactions. The noncovalent bond is the dominant type of bond between supermolecules in super molecular chemistry.¹

Proteins and nucleic acids require noncovalent bonds to maintain their three-dimensional structure, and they are involved in a number of biological processes that require large molecules to bind to one another specifically but transiently.²

It is estimated that noncovalent bonds release 1-5 kcal of energy per molecule. There are four main types of noncovalent bonds: hydrogen bonds, ionic interactions, Van der Waals interactions, and hydrophobic bonds.³

Noncovalent bonds include: those binding interactions that bind DNA double helix strands together, those binding interactions that fold polypeptides into secondary structures such as the alpha helix and beta conformation, those that enable enzymes to bind to their substrates, and those that enable antibodies to bind to their antigens.⁴

Noncovalent bonding is the primary type of force in supramolecular chemistry. It encompasses a wide range of interactions such as ionic, hydrophobic, hydrogen, Van der Waals ("London dispersion") and dipole-dipole bonds that keep molecules or sections of molecules together in an exact orientation or structure. The terms "noncovalent bonding," "noncovalent interactions," and "noncovalent forces" cover a variety of forces that act between molecules, with several usually acting in tandem to bring about a significant result. Noncovalent bonds are naturally weak, but together they can become much stronger than the sum of the individual bonds would imply. This is due to entropic effects which increase the free energy of multiple bonds between two molecules.⁵

TYPES OF NONCOVALENT BONDS

An interaction between dipoles occurs in non-covalent bonds. Since there is a strong electrostatic interaction between two oppositely charged ions (cations and anions), ionic bonds are the strongest non-covalent bonds. Van der Waals forces of attraction are the weakest non-covalent bonds.⁶

¹ Franz L. Dickert. 2007. Christoph A. Schalley (Ed.): Analytical methods in supramolecular chemistry. Anal. Bioanal. Chem. 389, 7–8 (2007), 2039–2040. DOI:<https://doi.org/10.1007/s00216-007-1677-1>

² Franz L. Dickert. 2007. Christoph A. Schalley (Ed.): Analytical methods in supramolecular chemistry. Anal. Bioanal. Chem. 389, 7–8 (2007), 2039–2040. DOI:<https://doi.org/10.1007/s00216-007-1677-1>

³ Franz L. Dickert. 2007. Christoph A. Schalley (Ed.): Analytical methods in supramolecular chemistry. Anal. Bioanal. Chem. 389, 7–8 (2007), 2039–2040. DOI:<https://doi.org/10.1007/s00216-007-1677-1>

⁴ "Nih.gov. Retrieved from <https://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mcb.section.285>"

⁵ "Nih.gov. Retrieved from <https://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mcb.section.285>"

⁶ "2021. What are the types of noncovalent bonds? Vedantu.com. Retrieved from <https://www.vedantu.com/question-answer/are-the-types-of-noncovalent-bonds-class-11-chemistry-cbse-60da90aeb254d358afaf5c5f>"



The types of non-covalent bonds are:

- **Ionic bonds:** Due to the difference in electronegativity between metals and nonmetals, ionic bonds are formed. Electropositive metals donate electrons to electronegative nonmetals, and electronegative nonmetals accept those electrons. For example, sodium chloride salts form these bonds. An ion induced dipole occurs when the approach of an ion induces a dipole in an atom or in a nonpolar molecule by distributing electron arrangements. In a dipole-induced dipole interaction, a charged molecule shifts the electron density of a nonpolar molecule. When a negatively charged species with an evenly distributed charge molecule is brought near a species with an electron density centered around the oxygen atom, the electrons move towards the positive species and away from the opposite side, creating an artificial dipole.⁷
- **Hydrogen bonds:** hydrogen bonds between hydrogen and oxygen of water molecules form hydrogen bonds between hydrogen and an electronegative element, such as oxygen, fluorine, or nitrogen. Hydrogen bonds occur when hydrogen atoms interact with electronegative atoms from another chemical group. The electronegative atoms may be nitrogen, oxygen, or fluorine. Two electronegative atoms, such as nitrogen or oxygen, share the hydrogen atom in a hydrogen bond in order to form specific base pairs in the DNA double helix. Hydrogen-bond donors include electronegative atoms with which the hydrogen atom is tightly bound, while hydrogen-bond acceptors include electronegative atoms with which the hydrogen atom is less tightly bound. An electronegative atom where the hydrogen atom covalently bonds can pull electron density away from the hydrogen atom, creating a positive electronegativity charge. An atom with a negative electronegativity charge can also interact with the hydrogen atom.
- **Van der Waals interactions:** When two atoms are in close proximity or approaching each other, they have non-specific and weak interactions or attraction. As molecules approach each other, the van der Waals interaction occurs. The charge distribution is not perfectly symmetrical. It is the sum of the attractive and repulsive forces between molecules. As two atoms get closer to each other, the attraction increases until the van der Waals contact distance is reached. In the case of a very short energy distance compared to a van der Waals contact distance, a strong repulsive force is dominant.
- **Hydrophobic interactions:** Interactions between nonpolar molecules are called hydrophobic interactions. Hydrophobic molecules, such as alkanes and hydrocarbons, repel water. It is the tendency of hydrocarbon molecules to form intermolecular aggregates in an aqueous medium, and analogous intramolecular interactions, which cause a hydrophobic interaction.⁸

IMPORTANCE OF NONCOVALENT BONDS

The non-covalent interaction in chemistry differs from a covalent bond in that it does not involve the sharing of electrons, but rather more dispersed variations of electromagnetic interactions between molecules. In biochemical processes such as the formation of double helix, noncovalent bonds are used to bond large molecules such as proteins and nucleic acids.⁹

In biological function, non-covalent forces are important because they are specific without imparting as much rigidity as covalent forces. Covalent forces are the quantum mechanical forces that determine electron-pair chemical bonds. Unlike covalent forces, non-covalent forces play an essential role in determining the shape of all molecules, including macromolecules, which are crucial to biology. There are many examples where non-covalent forces determine shape, such as base stacking and hydrogen bonding in DNA's double helix, hydrogen bonding in peptides, and the U shape of prostaglandin molecules.¹⁰

A non-covalent force plays a role in the specificity of intermolecular association between proteins and nucleic acids, and between enzymes and their inhibitors. In aqueous solution, electrostatic, dispersion, and hydrophobic forces are the most attractive noncovalent forces for biological association. In most protein-ligand interactions, electrostatic interactions provide more specificity than thermodynamic driving forces. It is likely that dispersion plays an essential role and hydrophobic terms contribute to the overall association force.

⁷ “2021. What are the types of noncovalent bonds? Vedantu.com. Retrieved from <https://www.vedantu.com/question-answer/are-the-types-of-noncovalent-bonds-class-11-chemistry-cbse-60da90aeb254d358afaf5c5f>”

⁸ “2021. What are the types of noncovalent bonds? Vedantu.com. Retrieved from <https://www.vedantu.com/question-answer/are-the-types-of-noncovalent-bonds-class-11-chemistry-cbse-60da90aeb254d358afaf5c5f>”

⁹ “Peter Kollman. 1984. Chapter 2 Non-covalent forces of importance in biochemistry. In *New Comprehensive Biochemistry*, Michael I. Page (ed.). Elsevier, 55–71.”

¹⁰ “Peter Kollman. 1984. Chapter 2 Non-covalent forces of importance in biochemistry. In *New Comprehensive Biochemistry*, Michael I. Page (ed.). Elsevier, 55–71.”



COVALENT BONDS V/S NONCOVALENT BONDS

Two types of interactions (bonds) occur between atoms: covalent and noncovalent. It is convenient to consider covalent bonds as intramolecular (i.e. defining the molecule's structure) and noncovalent interactions as intermolecular for small organic molecules. In macromolecules such as proteins, covalent bonds and intramolecular noncovalent bonds both determine their structure, so this view is not helpful. There is a difference between covalent and noncovalent bonds. Two atoms form a covalent bond when they share electrons. These electrons are simultaneously attracted by the two atomic nuclei, which form a covalent bond. An electron transfer to form ions cannot occur when the difference between the electronegativities of two atoms is too small.¹¹

A covalent bond is a chemical bond formed by the exchange of electrons between two atoms. As their nuclei are electrostatically attracted to the same electrons, they form covalent bonds. A covalent bond forms when the atoms that are bonded have a lower total energy than those that are widely separated.¹²

There are a number of molecules that contain covalent links, including hydrogen, nitrogen, chlorine, water, and ammonia (H_2 , N_2 , Cl_2 , H_2O , NH_3) as well as all organic compounds. Covalent bonds are indicated by solid lines connecting pairs of atoms in structural representations of molecules; Atoms in covalent bonds prefer specific orientations relative to one another, which, in turn, gives molecules definite shapes, such as the angular (bent) structure of H_2O . Covalent bonds are strongest when two atoms share an electron pair. Noncovalent interactions are weaker.¹³

In addition to van der Waals interactions, hydrogen bonds, and electrostatic interactions (also known as ionic bonds), noncovalent interactions arise through a variety of mechanisms.

An electron is shared between two non-metal elements in a covalent bond. Ionic bonds are non-covalent bonds that transfer electrons from a metal to a non-metal. Polar molecules have one positive end and one negative end. As an example, H_2O , water is a polar molecule since Oxygen has a slightly negative charge and Hydrogen has a slightly positive charge. Non-polar molecules have no negative or positive charges.¹⁴

CONCLUSION

Non-covalent bonds, which do not involve the sharing of electron pairs, are largely responsible for bonding macromolecules. They are integral to the stability of large molecules such as proteins and DNA, allowing them to remain in their three-dimensional shape. DNA's double helix is stabilized by base pairing between purines and pyrimidines through hydrogen bonds ($A=T$ and $C=G$) and base stacking interactions. Such noncovalent forces enable numerous biological processes in which large molecules bind together but only temporarily. Biological processes in which large molecules bind specifically and transiently involve noncovalent bonds, which maintain the three-dimensional structure of large molecules, such as proteins and nucleic acids.

¹¹ "Difference between covalent and non-covalent interactions. Chemistry Stack Exchange. Retrieved January 12, 2023 from <https://chemistry.stackexchange.com/questions/93851/difference-between-covalent-and-non-covalent-interactions>"

¹² "Difference between covalent and non-covalent interactions. Chemistry Stack Exchange. Retrieved January 12, 2023 from <https://chemistry.stackexchange.com/questions/93851/difference-between-covalent-and-non-covalent-interactions>"

¹³ "Difference between covalent and non-covalent interactions. Chemistry Stack Exchange. Retrieved January 12, 2023 from <https://chemistry.stackexchange.com/questions/93851/difference-between-covalent-and-non-covalent-interactions>"

¹⁴ "Difference between covalent and non-covalent interactions. Chemistry Stack Exchange. Retrieved January 12, 2023 from <https://chemistry.stackexchange.com/questions/93851/difference-between-covalent-and-non-covalent-interactions>"