2.1J: Hydrogen Bonding and Van der Waals Forces

Hydrogen bonds and van der Waals interactions are two types of weak bonds that are necessary to the basic building blocks of life.

LEARNING OBJECTIVES

Describe how hydrogen bonds and van der Waals interactions occur

KEY TAKEAWAYS

Key Points

- Hydrogen bonds provide many of the critical, life-sustaining properties of water and also stabilize the structures of proteins and DNA, the building block of cells.
- Hydrogen bonds occur in inorganic molecules, such as water, and organic molecules, such as DNA and proteins.
- Van der Waals attractions can occur between any two or more molecules and are dependent on slight fluctuations of the electron densities.
- While hydrogen bonds and van der Waals interactions are weak individually, they are strong combined in vast numbers.
Key Terms

- **van der Waals interactions**: A weak force of attraction between electrically neutral molecules that collide with or pass very close to each other. The van der Waals force is caused by temporary attractions between electron-rich regions of one molecule and electron-poor regions of another.

- **electronegativity**: The tendency of an atom or molecule to draw electrons towards itself, form dipoles, and thus form bonds.

- **hydrogen bond**: The attraction between a partially positively-charged hydrogen atom attached to a highly electronegative atom (such as nitrogen, oxygen, or fluorine) and another nearby electronegative atom.

Ionic and covalent bonds between elements require energy to break. Ionic bonds are not as strong as covalent, which determines their behavior in biological systems. However, not all bonds are ionic or covalent bonds. Weaker bonds can also form between molecules. Two weak bonds that occur frequently are hydrogen bonds and van der Waals interactions.

Hydrogen Bonding

Hydrogen bonds provide many of the critical, life-sustaining properties of water and also stabilize the structures of proteins and DNA, the building block of cells. When polar covalent bonds containing hydrogen form, the hydrogen in that bond has a slightly positive charge because hydrogen’s one electron is pulled more strongly toward the other element and away from the hydrogen. Because the hydrogen is slightly positive, it will be attracted to neighboring negative charges. When this happens, an interaction occurs between the $\delta^+$ of the hydrogen from one molecule and the $\delta^-$ charge on the more electronegative atoms of another molecule, usually oxygen or nitrogen, or within the same molecule.

Hydrogen bonds between water molecules: The slightly negative oxygen side of the water molecule and the slightly positive hydrogen side of the water molecule are attracted to each other and form a hydrogen bond.
This interaction is called a hydrogen bond. This type of bond is common and occurs regularly between water molecules. Individual hydrogen bonds are weak and easily broken; however, they occur in very large numbers in water and in organic polymers, creating a major force in combination. Hydrogen bonds are also responsible for zipping together the DNA double helix.

Applications for Hydrogen Bonds

Hydrogen bonds occur in inorganic molecules, such as water, and organic molecules, such as DNA and proteins. The two complementary strands of DNA are held together by hydrogen bonds between complementary nucleotides (A&T, C&G). Hydrogen bonding in water contributes to its unique properties, including its high boiling point (100 °C) and surface tension.

Water droplets on a leaf: The hydrogen bonds formed between water molecules in water droplets are stronger than the other intermolecular forces between the water molecules and the leaf, contributing to high surface tension and distinct water droplets.

In biology, intramolecular hydrogen bonding is partly responsible for the secondary, tertiary, and quaternary structures of proteins and nucleic acids. The hydrogen bonds help the proteins and nucleic acids form and maintain specific shapes.

Van der Waals Interactions

Like hydrogen bonds, van der Waals interactions are weak attractions or interactions between molecules. Van der Waals attractions can occur between any two or more molecules and are dependent on slight fluctuations of the electron densities, which are not always symmetrical around an atom. For these attractions to happen, the molecules need to be very close to one another. These bonds—along with ionic, covalent, and hydrogen bonds—contribute to the three-dimensional structure of proteins that is necessary for their proper function.
Van der Waals attraction: Explore how Van der Waals attractions and temperature affect intermolecular interactions.

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