Lecture 32

Intermolecular Forces

Intermolecular forces are forces of attraction or repulsion which act between neighboring particles (atoms, molecules, or ions). They are weak compared to the intramolecular forces, the forces which keep a molecule together. For example the covalent bond, involving the sharing of electron pairs between atoms is much stronger than the forces present between the neighboring molecules. There are several types of intermolecular interactions. Ionic compounds held together by means of electrostatic interactions which are much stronger than inter molecular forces. Covalent compounds are composed of discrete molecules. There are three different types of interactions, in order of their increasing strength Van der Waals forces, Dipole-dipole interactions and Hydrogen bonding.

Vander waals forces:

Van der Waals forces' is a general term used to define the attraction of intermolecular forces between molecules. There are two kinds of Van der Waals forces: weak London Dispersion Forces and stronger dipole-dipole forces. They are the only attractive forces present in non-polar compounds. Methane (CH_4) has no net dipole. Temporary dipole between molecules might be resulted due to imbalance. This can induce a temporary dipole in another molecule. The weak interaction between these temporary dipoles constitutes van der Waals forces.

Vander walls interaction Strength:

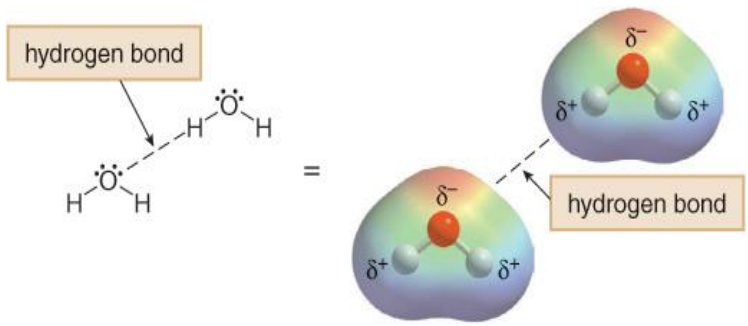
All compounds exhibit van der Waals forces. The surface area of a molecule determines the strength of the van der Waals interactions the larger the surface area, the grester the attractive force. Vander waals forces are also influenced by polarizability. Polarizability is a measure of how the electron cloud around an atom responds to changes in its electronic environment. As polarizability increases, the dispersion forces also become stronger. Thus, molecules attract one another more vigorously and melting and boiling points of covalent substances increase with larger molecular mass.

Dipole Dipole Interaction:

Dipole-Dipole interactions result when two dipolar molecules interact with each other through space. When this occurs, the partially negative portion of one of the polar molecules is attracted to the partially positive portion of the second polar molecule. This type of interaction between molecules accounts for many physically and biologically significant phenomena such as the elevated boiling point of water. These attractive forces caused by permanent dipoles and are much stronger than van der Waals forces.

Hydrogen Bonding:

Hydrogen bonding results when a hydrogen atom bonded to a strong electronegative atom such as Oxygen, Nitrogen and Fluorine. These atoms attract shared pair of electrons more tightly as compared to Hydrogen. These atoms are electrostatically attracted to a lone pair of electrons on an O, N, or F atom in another molecule. So partial positive charged H-atom makes hydrogen bond being attracted towards lone pair of electrons held by other molecular electronegative atom.



Trend of Intermolecular forces:

Greater polarity of an organic molecule raises the strength of its intermolecular forces. The vander waals forces are weak forces and are exhibited by all molecules. Dipole dipole forces are moderate forces present in molecules with net dipole and ion-ion are very strong forces present in ionic compounds.

Table 3.4 Summary of Types of Intermolecular Forces

Type of force	Relative strength	Exhibited by	Example
van der Waals	weak	all molecules	$CH_3CH_2CH_2CH_2CH_3$ $CH_3CH_2CH_2CHO$ $CH_3CH_2CH_2CH_2OH$
dipole–dipole	moderate	molecules with a net dipole	$CH_3CH_2CH_2CHO$ $CH_3CH_2CH_2CH_2OH$
hydrogen bonding	strong	molecules with an O−H, N−H, or H−F bond	$CH_3CH_2CH_2CH_2OH$
ion–ion	very strong	ionic compounds	NaCl, LiF

Boiling Point:

The boiling point of a compound is the temperature at which liquid molecules are converted into gas. In boiling, energy is needed to overcome the attractive forces in the more ordered liquid state. The stronger the intermolecular forces, the higher the boiling point.

Melting Point:

The melting point is the temperature at which a solid is converted to its liquid phase. In melting, energy is needed to overcome the attractive forces in the more ordered crystalline solid. The stronger the intermolecular forces, the higher the melting point. Ionic compounds held together by extremely strong interactions due to this reason they have very high melting points. While in case of covalent molecules, the melting point depends upon the strength of intermolecular forces. Symmetry also plays a role in determining the melting points of compounds irrespective of having the similar molecular weights, but very different shapes. Neopentane has a much higher melting point due to compact molecular symmetry.

Solubility:

Solubility is the extent to which a compound, called a solute, dissolves in a liquid, called a solvent. Energy is needed to break up the interactions between the molecules. Compounds dissolve in solvents having similar kinds of intermolecular forces. As there is a universal rule "Like dissolves like." So Polar compounds dissolve in polar solvents, Nonpolar or weakly polar compounds dissolve in nonpolar or weakly polar solvents, Water and organic solvents are two different kinds of solvents. Water is very polar. Many organic solvents are either nonpolar, like carbon tetrachloride (CCl_4) and hexane [$CH_3(CH_2)4CH_3$], or weakly polar, like diethyl ether ($CH_3CH_2OCH_2CH_3$). Most ionic compounds are soluble in water, but insoluble in organic solvents. An organic compound is water soluble only if it contains one polar functional group. For example if we compare compare the solubility of butane and acetone in H_2O and CCl_4. Butane is soluble in CCl_4 but insoluble in water while acetone is soluble in both water and carbon tetrachloride due to presence of polar functional group. The oxygen of acetone makes hydrogen bond with hydrogen of water molecule. To dissolve an ionic compound the strong ion-ion interaction are broken down and these interactions are replaced by ion dipole interactions. The larger the molecules of the solute are, the larger is their molecular weight and their size. It is more difficult it is for solvent molecules to surround bigger molecules. The larger particles are generally less soluble if the pressure and temperature are kept constant than out of two solutes of the same polarity, the one with smaller particles is usually more soluble. For example Ethanol is water soluble. Cholesterol is insoluble in water due to its bigger size.

Hydrophilic and Hydrophobic Ends:

Hydrophobic and Hydrophilic have a lot to do with water. Like hydrophobic means "water repelling" and hydrophilic means "water loving" Hydro' means water. The nonpolar part of a molecule is hydrophobic while the polar part of a molecule is hydrophilic. In cholesterol, the hydroxy group is hydrophilic, whereas the carbon skeleton is hydrophobic.

References:

https://researchthetopic.wikispaces.com/The+difference+between+hydrophobic+and+hydrophilic+Part+2
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