Interactions between ions, dipoles, and induced dipoles account for many properties of molecules - deviations from ideal gas behavior in the vapor state, and the condensation of gases to the liquid or solid states. In general, stronger interactions allow the solid and liquid states to persist to higher temperatures. However, non-polar molecules show similar behavior, indicating that there are some types of intermolecular interactions that cannot be attributed to simple electrostatic attractions. These interactions are generally called dispersion forces. The London dispersion force is the weakest intermolecular force. It is a temporary attractive force that results when the electrons in two adjacent atoms occupy positions that make the atoms form temporary dipoles.

Introduction

Electrostatic forces operate when the molecules are several molecular diameters apart, and become stronger as the molecules or ions approach each other. Dispersion forces are very weak until the molecules or ions are almost touching each other, as in the liquid state. These forces appear to increase with the number of "contact points" with other molecules, so that long non-polar molecules such as n-octane \((\text{C}_8\text{H}_{18})\) may have stronger intermolecular interactions than very polar molecules such as water \((\text{H}_2\text{O})\), and the boiling point of n-octane is actually higher than that of water.

Unequal sharing of electrons causes rapid polarization and counter-polarization of the electron cloud forming short lived dipoles. These dipole interact with the electron clouds of neighboring molecules forming more dipoles. The attractive interaction of these dipole are called dispersion or London Dispersion forces. These forces are weaker than other intermolecular forces and do not extend over long distances. The strength of these interactions within a given molecule depends directly on how easily the electrons in the molecules can move (i.e., be polarized). Large molecules in which the electrons are far from the nucleus are relatively easy to polarize and therefore possess greater dispersion.

If it were not for dispersion forces, the noble gases would not liquefy at any temperature since no other intermolecular force exists between the noble gas atoms. The low temperature at which the noble gases liquefy is to some extent indicative of the magnitude of dispersion forces between the atoms. Electron distribution around an atom or molecule can be distorted. This distortion is called the polarizability.
Figure 2: Dispersion interaction in the gas phase

It is possible that these forces arise from the fluctuating dipole of one molecule inducing an opposing dipole in the other molecule, giving an electrical attraction. It is also possible that these interactions are due to some sharing of electrons between the molecules in “intermolecular orbitals”, similar to the "molecular orbitals" in which electrons from two atoms are shared to form a chemical bond. These dispersion forces are assumed to exist between all molecules and/or ions when they are sufficiently close to each other. The stronger farther-reaching electrical forces from ions and dipoles are considered to operate in addition to these forces.

Polarizability

The polarizability is used to describe the tendency of molecules to form charge separation. Induced dipole occurs when a molecule with an instantaneous dipole induces a charge separation on other molecule. The result is a dipole-dipole attraction. The strength of the induced dipole moment, \(\mu\), is directly proportional to the strength of the electric field, \(E\) with a proportionality constant \(\alpha\) called the polarizability. The strength of the electric field causes the distortion in the molecule. Therefore, greater the strength of the electric field, the greater the distortion and to a larger interaction:

\[
\mu = \alpha' E
\]

where,

- \(\mu\) = the induced dipole moment
- \(\alpha\) = the polarizability
- \(E\) = the electric field

Interaction Energy

Interaction energy can be approximated using the London formula (Equation 1). A German physicist, Fritz London
proved that potential energy of two uncharged molecules or identical atoms can be measured by following equation:

\[ V_{11} = -\dfrac{3}{4} \dfrac{\alpha_2}{r^6} \tag{1} \]

Equation 1 is modified for non-identical atoms or molecules

\[ V_{12} = -\dfrac{3}{2} \dfrac{I_1I_2}{I_1 + I_2} \dfrac{\alpha _1' \alpha _2'}{r^6} \tag{2} \]

with

- \( I \) is the first ionization energy of each molecule
- \( \alpha \) is the polarizability
- \( r \) is the distance between molecules

Example

Calculate the potential energy between two Ar atoms separated by 4.0 Angstroms (\(10^{-10}\)).

**Solution:** -0.77 KJ/mol

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**Contributors and Attributions**

- Ryan Ilagan (UCD)
- Gary L Bertrand, Professor of Chemistry, University of Missouri-Rolla