The Lecture Contains:

Types of Forces

Forces that are important in colloidal systems are:

1. Van der Waals Force
2. Acid- Base
3. Double layer interactions-Electrostatics
4. Due to adsorption or depletion

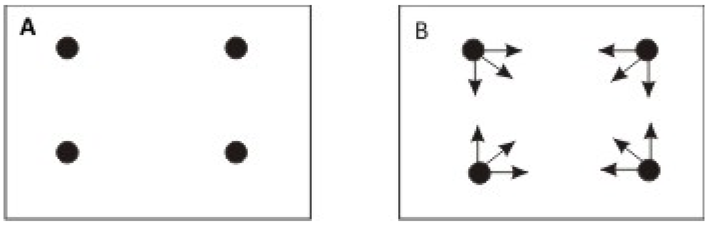

Fig 8.1 : A) Boyle Law B) Van der Waals attraction among four atoms/molecules

Van der Waals Force

Van der Waals force, named after Johannes Diderik Van der Waals (1837-1923) exists between any combination of molecules, atoms and surfaces. These are not fundamental forces. In fact they are the outcome of electrostatic/electrodynamic interaction. Van der Waal forces are always attractive. Three types of van der Waal forces known are:

- Induced Dipole-Induced Dipole: Due to high frequency (range 10^{15}-10^{16} Hz) fluctuations in the electron cloud of a neutral molecule, instantaneous dipole characteristics are developed in the nearby molecules. The coupling of these dipoles in order to minimize their mutual energy results in an attractive force known as Van der Waals force. This force was explained by London in 1930 and thus is commonly known as London force or dispersion force.

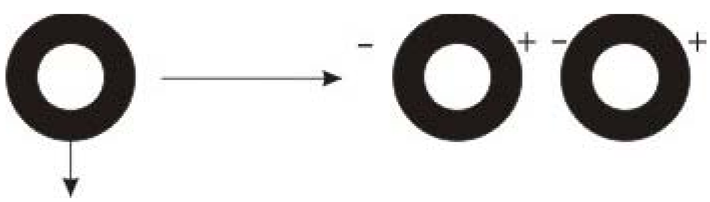

Fig. 8.2: Electron Cloud (fluctuation of e^- cloud results in induced dipole)

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The London interactions free energy at an intermolecular distance x is expressed by

$$\Phi_L = -C_L x^{-6}$$

Where, C_L is London constant.

- Permanent Dipole-Induced Dipole: If a molecule has permanent dipole moment, it will induce dipole characteristics in nearby non-polar molecule hence inducing attraction. These are also called Debye forces. The Debye interactions free energy at an intermolecular distance x is expressed by

$$\Phi_D = -C_D x^{-6}$$

Where C_D is Debye constant.

- Permanent Dipole-Permanent Dipole: When the two molecules have a permanent dipole moment they experience attraction. These are known as Keesom forces. The Keesom interactions free energy at an intermolecular distance x is expressed by

$$\Phi_K = -C_K x^{-6}$$

Where C_K is a constant considered for a particular type of molecule.

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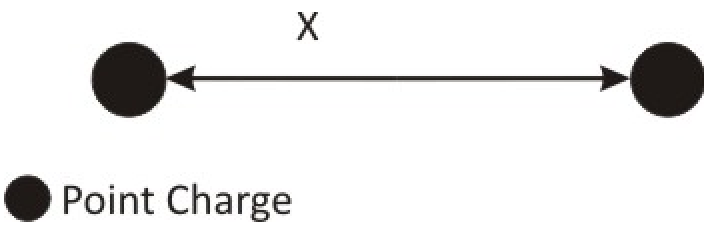
The van der Waals force is the sum of Keesom, Debye and London dispersion attractive forces. Potential energy of interaction between two molecules or atoms due to van der Waals force is given by

$$\phi = -\beta x^{-6}$$



Negative sign shows that the force is always attractive, where β is the proportionality constant

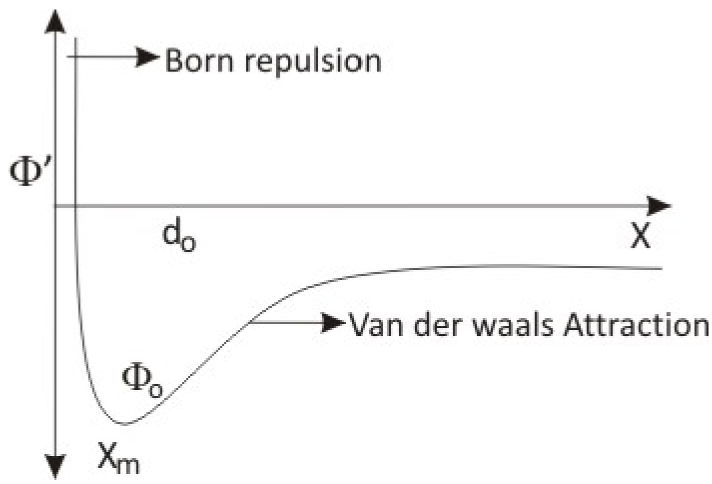


Figure 8.3: Lennard Jones Potential

When the separation between molecules is small, they repel each other strongly, so when this force is added to attractive van der Waals force it gives what is called Lennard Jones Potential (LJP) which is given by:

$$\phi' = -\beta x^{-6} + \zeta x^{-12}$$

$$Force = -\frac{\partial \emptyset'}{\partial x}$$

Therefore the minimum distance or equilibrium distance is given by

$$d_0 = \left(\frac{2\xi}{\beta}\right)^{\frac{1}{6}}$$

Let's evaluate d_0 for methane and also the corresponding equilibrium potential

For methane

$$\xi = 6.2^{*}10^{-134}\mathrm{Jm}^{12}$$

$$\beta = 2.3^{*}10^{-71}\mathrm{Jm}^{6}$$

$$\mathrm{d}_0 = 4.2\text{Å} = 0.42\mathrm{nm}$$

$$\phi_0 = -2.1^{*}10^{-21}\mathrm{J}$$

Physical significance of this value of d_0 is that in the condensed state the distance between two molecules will be nearly 4Å.

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Did You Know: Geckos are able to move on vertical wall and even along ceiling head downwards with assistance of Van der Waals forces. Their feet have millions of tiny foot hair called setae with a distribution of 14000 setae per mm^2. This allows an intimate contact with a rough surface and a high contact area providing a Gecko strong enough van der Waals forces to carry several times its weight.

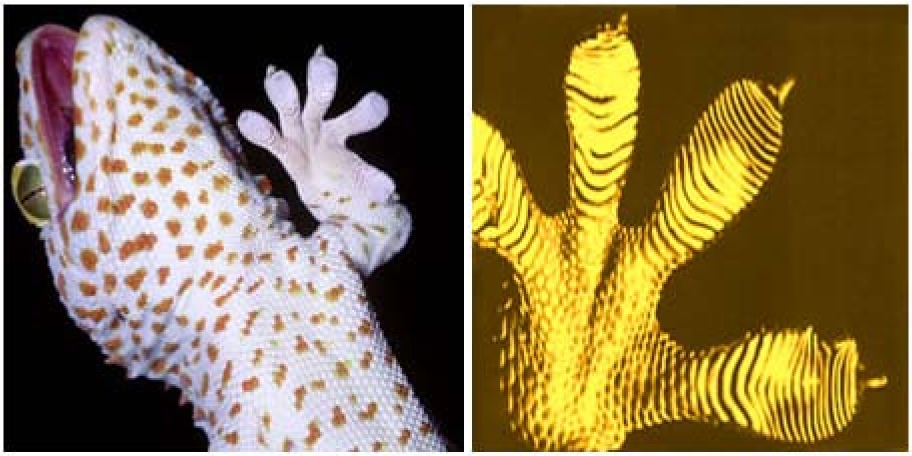

Fig. 8.4: Mechanism of adhesion in Geckos (K. Autumn, Anne M Piattie, Integr. Comp. Biol., 2002)

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