By-Shailendra Shukla Sir

Intermolecular Forces

Intermolecular forces are the forces of attraction and repulsion between interacting particles (atoms and molecules). This term does not include the electrostatic forces that exist between the two oppositely charged ions and the forces that hold atoms of a molecule together i.e., covalent bonds.

Attractive intermolecular forces are known as van der Waals forces.

However, the attractive forces between an ion and a dipole (i.e. ion-dipole forces) are not van der Waals forces.

van der Waals forces

It is one of the weakest physical forces of nature which operates between non-bonded atoms and molecules. It arises due to following three types of interactions-

(1) Dipole - Dipole interaction
(2) Dipole – Induced dipole interaction
(3) Induced dipole – Induced dipole interaction (London Dispersion)

(1) Dipole - Dipole Interactions

Dipole-dipole interactions operates between polar molecules (i.e. between the molecules possessing permanent dipole such as HCl, NH_3, H_2O etc.). Here, positively charged pole of one molecule attracts the negatively charged pole of another molecule.

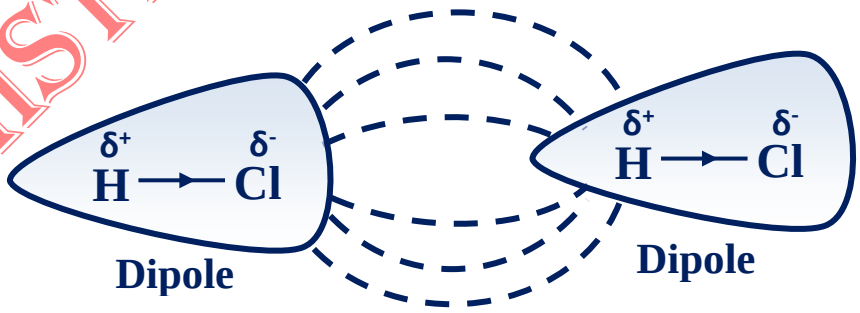

Fig- Dipole-dipole interaction between two HCl molecules

Here, the attractive force decreases with the increase of distance between the dipoles.

Dipole-dipole interaction energy between stationary polar molecules (as in solids) is proportional to $1/r^3$ and that between rotating polar molecules is proportional to $1/r^6$, where r is the distance between polar molecules.

- **This interaction is stronger than the London forces but is weaker than ion-ion interaction as it involves only partial charges.**
- **Besides dipole-dipole interaction, polar molecules can also interact by London forces. Thus, due to cumulative effect this type of intermolecular forces is strongest amongst three.**
- **Hydrogen bonding is a special case of dipole-dipole interaction between highly polar molecules.**

2. Dipole – Induced Dipole Interactions

This type of attractive forces operate between the polar molecules having permanent dipole and the non-polar molecules lacking permanent dipole.

For example, between HCl and O_2 molecules.

Here, permanent dipole of the polar molecule induces dipole in non-polar molecule by deforming its electron cloud and therefore attraction starts operating between them.

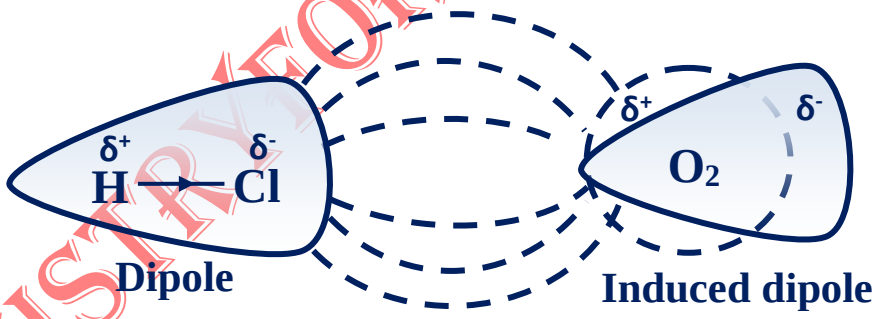

Fig.- Dipole - Induced dipole interaction

Here, the interaction energy is proportional to $1/r^6$, where r is the distance between two molecules.

Induced dipole moment depends upon the dipole moment present in the permanent dipole and the polarizability of the non-polar molecule.

- **Here, in fact, a cumulative effect of dispersion forces (London dispersion) and dipole-induced dipole interactions operates.**

(3) Induced Dipole–Induced Dipole Interactions (London Dispersion Forces or London Forces)

It operates between non-bonded atoms (e.g. between atoms of Inert gases) and non-polar molecules (e.g. O_2, N_2, CH_4 etc.), where the electron clouds are symmetrically distributed and therefore they have no dipole moment. However, in these atoms and molecules a dipole may develop momentarily due to disturbance of their electron clouds either by heating or jerk.

Suppose two atoms He are in the close vicinity of each other. Let, the electronic charge distribution of one atom becomes unsymmetrical momentarily *i.e.*, the charge cloud becomes more on one side than the other. This results in the development of instantaneous dipole in the atom for a very short time. This instantaneous or transient dipole distorts the electron density of the other He atom and therefore, a dipole also gets induced in this atom. The temporary dipoles of these atoms start attracting each other.

Similarly, temporary dipoles get induced in non-polar molecules and they attract each other.

This force of attraction between two temporary dipoles was first proposed by Fritz London, and therefore it is termed as London force or London dispersion.

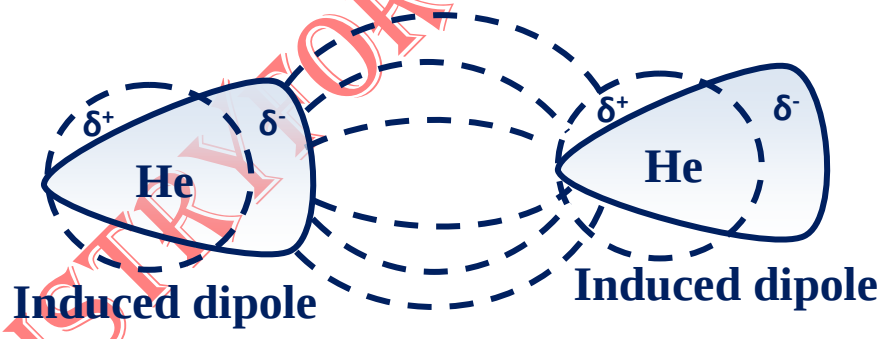

Fig.- Dispersion forces or London forces between He atoms

These forces are always attractive and interaction energy is inversely proportional to the sixth power of the distance between two interacting particles (i.e., $1/r^6$ where r is the distance between two particles). These forces are important only at short distances (~500 pm) and their magnitude depends on the polarizability of the particle.

In addition to attractive forces, molecules also exert repulsive forces on one another. When two molecules are brought into close contact with each other, then a repulsion starts operating between their electron clouds

and their nuclei. The magnitude of this repulsion rises rapidly with decrease of the distance separating the molecules. This is the reason that solids and liquids are hard to compress. In fact, in solids and liquids, the molecules are already in close contact and therefore they resist further compression as it would result in the increase of repulsive interactions.

Thermal Energy

It is the energy of a body arising from motion of its atoms or molecules. It is directly proportional to the temperature of the substance. It is the measure of average kinetic energy of the particles of the matter and is thus responsible for movement of particles. This movement of particles is called thermal motion.

Intermolecular Forces *vs* Thermal Interactions

We know that, intermolecular forces tend to keep the molecules together but thermal energy of the molecules tends to keep them apart. In fact, the three states of matter are the result of balance between intermolecular forces and the thermal energy of the molecules.

When molecular interactions are very weak, molecules do not cling together to make liquid or solid unless thermal energy is reduced by lowering the temperature. Gases do not liquify on compression only, although molecules come very close to each other and intermolecular forces operate to the maximum. However, when thermal energy of molecules is reduced by lowering the temperature, the gases can be liquified very easily.