2.1.3 Dipole-dipole forces

Dipole-dipole forces are attraction forces between the slightly positive pole of one atom in the polar molecule and the slightly negative pole of the other atom in a polar molecule. If two dipoles approach each other, they will turn so that their oppositely-charged ends are closer. An attractive force will exist between these sides of the dipoles. It is a relatively small force of attraction (bond energy: 5–25 kJ mol\(^{-1}\)) between two permanent dipoles. Examples of polar molecules with dipole-dipole forces are: \(\text{NH}_3, \text{SO}_2, \text{HBr}, \text{H}_2\text{S}, \text{ICl}, \text{HCl}, \text{H}_2\text{O}\)

**Example**

\[
\begin{align*}
\text{ICl} & \\
\delta^- & \delta^- \\
\text{I} & \text{Cl} \\
\delta^+ & \delta^+ \\
\end{align*}
\]

\[
\begin{align*}
\text{H}_2\text{O} & \\
\delta^- & \delta^- \\
\text{O} & \text{H} \\
\delta^- & \delta^- \\
\text{O} & \text{H} \\
\end{align*}
\]

**QUICK FACTS**

\(\delta\) (read as “delta”) means “slightly” – so \(\delta^+\) means “slightly positive” and \(\delta^-\) means “slightly negative”.

**QUICK FACTS**

Hydrogen bonds are a specific type of dipole-dipole force.

**REMEMBER**

Polar molecules occur when one atom is more electronegative than the other atom. The shared electron pair(s) is/are pulled more towards the more electronegative atom, causing a dipole. The side where the electron pair spends more time is slightly negative and the other side is slightly positive.

2.1.4 Dipole-induced dipole forces

A polar molecule (permanent dipole) can induce a temporary dipole in a non-polar molecule or atom. This results in an attractive force between the two oppositely-charged dipoles. This force is usually very weak.

Example: \(\text{O}_2\) in water

2.1.5 Induced dipole force (dispersion forces or London forces)

When two non-polar molecules or atoms approach each other, there is a slight change in the charge distribution in the electron cloud of both molecules or atoms.
The electrons will not be exactly equally arranged around the atom/molecule. These attractive forces are not due to permanent dipoles. They are temporary and will disappear and reform between other particles in a different direction. Weak forces (bond energy: 0.05–40 kJ\cdot mol^{-1}) can now exist. The larger the molecule, the stronger the attraction. These attractive forces are only seen if there are no other forces of attraction in the situation. These forces are also known as dispersion or London forces.

**2.1.6 Hydrogen bonds**

Occur between molecules in which hydrogen is bonded to a small atom which has at least one lone pair of electrons as well as an extremely high electronegativity, as in compounds with oxygen, nitrogen and fluorine. The interatomic bond is polar covalent. A hydrogen bond is an electrostatic force between the slightly negative charge on the electronegative atom of one of the molecules and the slightly positive charge on the hydrogen of one of the other molecules. These forces are very strong (bond energy: 10–25 kJ\cdot mol^{-1}) compared to other dipole-dipole forces. However, it is weaker than covalent and ionic bonds.

Proton of H atom with strong electrostatic bond to negative side of another molecule.

Hydrogen bonds are also found in organic compounds. Examples are alcohols and carboxylic acids both containing -O-H in the molecule.

**QUICK FACTS**

Noble gases and non-polar molecules like H\(_2\) and N\(_2\) can condense to form liquids. This is due to the fact that attractive forces exist between the particles.
2.2 Difference between intermolecular forces and interatomic forces

Interatomic bonds are those bonds that hold the different atoms together in a molecule. Chemical bonds (strong bonds inside molecules or structures)

<table>
<thead>
<tr>
<th>Covalent bond</th>
<th>Ionic bond</th>
<th>Metallic bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bond</td>
<td>Usually between metals and non-metals</td>
<td>Within metals</td>
</tr>
<tr>
<td>Between two non-metals</td>
<td>and non-metals Electron transfer</td>
<td>Positive atomic core and sea of electrons</td>
</tr>
<tr>
<td>Sharing of electrons</td>
<td>Electron transfer</td>
<td></td>
</tr>
<tr>
<td>2. Bonds</td>
<td>Covalent bonds</td>
<td>Electrostatic attraction/ Coulombic forces</td>
</tr>
<tr>
<td>3. Examples</td>
<td>O₂, Cl₂, H₂O, HCl</td>
<td>NaCl, MgSO₄, KCl</td>
</tr>
<tr>
<td>Giant structures: diamond and graphite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Structure</td>
<td>E.g. H₂O</td>
<td>E.g. NaCl</td>
</tr>
</tbody>
</table>

Intermolecular forces are the forces that attract molecules to each other.

<table>
<thead>
<tr>
<th>Hydrogen bond</th>
<th>Other Van der Waals forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Strong dipole-dipole force)</td>
<td>Dipole-dipole, dipole-induced dipole and induced dipole forces (dispersion or London forces)</td>
</tr>
<tr>
<td>(Weak)</td>
<td>The remainder of the covalent bonds, e.g. H₂, HCl, SO₂</td>
</tr>
</tbody>
</table>

Van der Waals forces

dipole-dipole forces