SESSION 4: INTERMOLECULAR FORCES

Key Concepts

In this session we

- Compare intramolecular forces and intermolecular forces
- Identify types of intermolecular forces
- Identify the relationship between the state of substances and the intermolecular forces present

X-planation

What forces exist inside matter?

The forces inside matter are electrostatic in nature. Oppositely charged particles attract each other and like charges repel each other.

We classify the forces in matter based on the type of particles matter is made of. The basic building blocks of all matter are atoms which have positively charged protons in the nucleus and negatively charged electrons in orbitals around the nucleus. These sub-atomic charged particles are responsible for the forces in all the types of matter.

Atoms combined to force molecules or a large structure called a giant lattice. The forces between atoms are referred to as intramolecular force.

Molecules are all electrically neutral. However, the distribution of charge around the molecule may be even (non-polar molecules) or there may be a separation of charge, where one end of the molecule becomes positive and the other end is negative (polar molecules). The forces between molecules are called intermolecular forces. The size of these forces depends on the size of the charges and the distance between the molecules.

Types of Intermolecular forces

- **London Forces**
  The forces are between non-polar molecules. These force are formed between temporary induced dipoles and are generally weak and non-directional.

- **Van der Waals Forces**
  The forces are between polar molecules or molecules and ions. There are two types:
  - Dipole – Dipole
  - Dipole -Ion
  These forces are permanent but non-directional. The strength of these forces depends on the size of the charges on the dipoles.

- **Hydrogen bonding**
  This not chemical bonding – there is no sharing of electrons.
The forces are between very polar molecules containing a hydrogen atom. The hydrogen end of the dipole is very positive and the other end where there is a non-metal atom, is negative. The forces in hydrogen bonds are very strong, permanent and directional.

**States of matter and Intermolecular forces**
When a substance changes state from a solid to a liquid to a gas, chemical bonds do not change but the strength of inter-molecular forces changes.

For example, in a solid, molecules are close together and do not move very much. When the temperature increases, the kinetic energy of the molecules increases and molecules move further apart from each other and so the intermolecular forces become weaker.

**Physical Properties and Intermolecular forces**
When comparing the strength of intermolecular forces in different substances we look at:
- Melting point
- Boiling point
- Density

When the melting point and boiling point of a substance is at a low temperature, we can conclude that the intermolecular forces are weak. It does not take lots of energy to break the intermolecular forces and cause a change in state.

The density of a substance gives an indication of how closely molecules are packed together. The higher the density, the closer molecules are packed together and the stronger the intermolecular forces.

**Properties of Liquids**
Liquids have special properties that give an indication of the strength of intermolecular forces. These include:
- Surface tension
- Vapour pressure
- Capillarity

**Intermolecular forces in solutions**
In solutions, there are intermolecular forces between different molecules or molecules and ions. In general, two liquids will mix together when the type of intermolecular forces are the same. For example, a non-polar solvent will not mix with a polar solvent.

A salt, which is an example of an ionic solid, has strong ion-ion forces in the crystal lattice. When a small amount of salt is placed in a polar solvent, like water, the salt will dissolve. A large number of water molecules can surround an ion and break the ion-ion forces in the lattice.
X-ample Questions

Question 1
Identify the type of bonding and inter-molecular forces present in each of the following substances:

a.) Hydrogen sulphide
b.) Water
c.) Iodine
d.) Methane (CH₄)

Question 2
The boiling points for four chemical substances are given below:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen sulphide</td>
<td>-60°C</td>
</tr>
<tr>
<td>Ammonia</td>
<td>-33°C</td>
</tr>
<tr>
<td>Hydrogen fluoride</td>
<td>20°C</td>
</tr>
<tr>
<td>Water</td>
<td>100°C</td>
</tr>
</tbody>
</table>

(a) Which one of the substances exhibits the strongest forces of attraction between its molecules in the liquid state?

(b) Give the name of the force responsible for the relatively high boiling points of ammonia and water and explain how this force originates.

(c) The shapes of the molecules of hydrogen sulfide and water are similar, yet their boiling points differ. Explain.

Question 3
Describe the intermolecular forces present in each of the following solutions:

a.) water and ethanol
b.) sodium chloride and water
c.) carbon dioxide and water
d.) ammonia and water

X-ercises

Question 1
Select substances in the list to answer the questions below:

bromine, hydrogen fluoride, sulphur, hydrogen sulphide

a.) A liquid that has London forces between its molecules
b.) A substance that has hydrogen bonds
c.) A substance that has van der Waals present
Answers to X-ercises

1 a.) bromine
b.) hydrogen fluoride
c.) hydrogen sulphide