4.4 Intermolecular forces

Nature of science:

Obtain evidence for scientific theories by making and testing predictions based on them—London (dispersion) forces and hydrogen bonding can be used to explain special interactions. For example, molecular covalent compounds can exist in the liquid and solid states. To explain this, there must be attractive forces between their particles which are significantly greater than those that could be attributed to gravity. (2.2)

Understandings:

- Intermolecular forces include London (dispersion) forces, dipole-dipole forces and hydrogen bonding.
- The relative strengths of these interactions are London (dispersion) forces < dipole-dipole forces < hydrogen bonds.

Applications and skills

- Deduction of the types of intermolecular force present in substances, based on their structure and chemical formula.
- Explanation of the physical properties of covalent compounds (volatility, electrical conductivity and solubility) in terms of their structure and intermolecular forces.

Guidance:

- The term "London (dispersion) forces" refers to instantaneous induced dipole-induced dipole forces that exist between any atoms or groups of atoms and should be used for non-polar entities. The term "van der Waals" is an inclusive term, which includes dipole–dipole, dipole-induced dipole and London (dispersion) forces.

Theory of knowledge:

- The nature of the hydrogen bond is the topic of much discussion and the current definition from the IUPAC gives six criteria which should be used as evidence for the occurrence of hydrogen bonding. How does a specialized vocabulary help and hinder the growth of knowledge?

Utilization:

Syllabus and cross-curricular links:
Option A.5—using plasticizers
Option A.7—controlling biodegradability
Option B.3—melting points of *cis-/trans-* fats
Biology topics 2.2, 2.3, 2.4 and 2.6—understanding of intermolecular forces to work with molecules in the body

Aims:

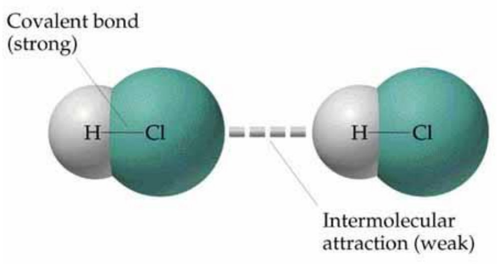
- **Aim 7**: Computer simulations could be used to show intermolecular forces interactions.

UNIT 4.4 – INTERMOLECULAR FORCES

COMPARISON

The **Intermolecular** forces (forces between molecules) and weaker than **Intramolecular** forces (chemical bonds within an individual molecule.

Water changing from a solid, to a liquid, to a gas, is a result of intermolecular forces changing, not the chemical bonds within the molecules.



The slightly negative part of the molecule is attracted to the slightly positive part of the molecule.

The **strength** of intermolecular forces is determined by the strength of the electrostatic attraction between the molecules. This is determined by polarity, and the size of the atoms.

VAN DER WAALS FORCES

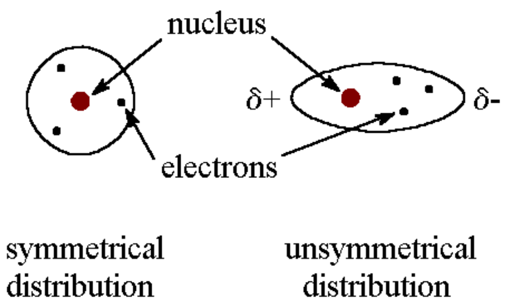
Van der Waals forces are the three types of intermolecular forces that we believe exist today.

Hydrogen bonds > dipole-dipole forces > London forces

LONDON FORCES

London forces exist in all molecules.

Even though non-polar molecules do not have a distinctive positive end and negative end, they still have an **instantaneous or temporary dipole** moment. This is because electrons are not locked in place, so at any time they could be more electrons at one side of the molecule than the other, creating a temporary dipole.



INDUCED DIPOLES

Once a temporary dipole has been formed, it influences the orientation of the electrons in molecules close to it (chain reaction). This is because electrons in neighbouring molecules will be rebelled by the negative dipole.

NUMBER OF ELECTRONS

The greater number of electrons, the larger the distance between the valence shell and the nucleus. This means the electron cloud can be polarized more easily = higher boiling point.

SIZE (VOLUME) OF THE ELCTRON CLOUD

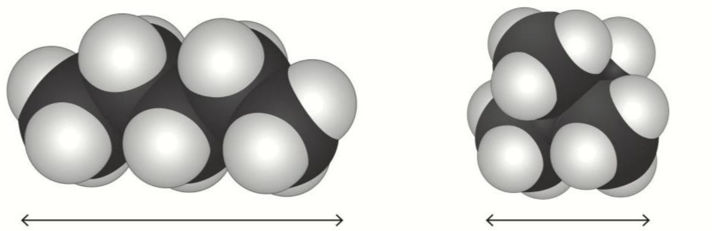
In a large electron cloud, the attraction of electrons to the nucleus will not be as great as in a smaller electron cloud. Hence a higher boiling point.

Alkane	Boiling point / °C	Space-filling model
propane (C_3H_8)	−42.0	
octane (C_8H_{18})	125	

▲ Table 2 Boiling points of two alkanes

SHAPES OF MOLECULES

In molecules with a larger surface area, the boiling point will be higher as more interactions can take place with the electrons.



▲ Figure 6 Space-filling models of pentane and 2,2-dimethylpropane showing areas of contact between adjacent molecules for London forces of attraction

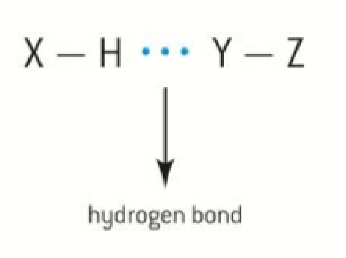
DIPOLE-DIPOLE FORCES

These forces exist only within polar molecules, which have **permanent dipoles**. It's the attraction between the positive end of one dipole and the negative end of another dipole.

$$\overset{\delta+}{H}—\overset{\delta-}{Cl}\text{- - - - -}\overset{\delta+}{H}—\overset{\delta-}{Cl}$$

HYDROGEN BONDING

Hydrogen bonding can occur between molecules when there is a **H-F**, an **O-H**, or an **N-H** bond present.



*Remember that we are still talking about **intermolecular forces** and not chemical bonds.*

Hydrogen bonds are represented by the three dots though dashes are sometimes used.

Examples:

a) Water molecules, H_20
b) Ammonia molecules, NH_3
c) Hydrogen fluoride molecules, HF
d) Water molecules and dimethyl ether molecules, $(CH_3)_2O$