FACTFILE:
GCE CHEMISTRY

INTERMOLECULAR FORCES

Rewarding Learning

Intermolecular Forces

Students should be able to:

1.4.1 describe intermolecular forces as van der Waals' forces (viewed as attractions between induced dipoles), permanent dipole-dipole attractions and hydrogen bonding (between molecules containing N, O or F and the H atom of -OH, -NH or HF);

1.4.2 demonstrate understanding of the relationships between these attractive forces and physical properties, such as melting point, boiling point and solubility of covalent molecular substances.

Intermolecular Forces

Intermolecular forces are between neighbouring molecules (as opposed to intramolecular).

Intermolecular forces exist between covalent molecules. There are three main types.

Van der Waals' forces - these are the attraction between instantaneous and induced dipoles on neighbouring molecules.

As electrons move quickly in orbitals, their position is constantly changing; at any given instant they could be anywhere in an atom. The possibility will exist that one side of the atom will have more electrons than the other. This gives rise to a dipole which induces dipoles on nearby atoms. The atoms are now attracted to each other by a weak force.

The greater the number of electrons in the atom or molecule, the larger the induced dipoles and the stronger the van der Waals' forces. This is evident when comparing the boiling points of the Noble gases:

Noble Gas	Boiling Point/°C
Helium	-269
Neon	-246
Argon	-186
Krypton	-152
Xenon	-108
Radon	-62

Permanent dipole-dipole attractions

A permanent dipole-dipole attraction is the attraction between the positive end, $\delta+$, of the permanent dipole on a molecule with the negative end, $\delta-$, of the permanent dipole of a neighbouring molecule.

A molecule such as HCl has a polar covalent bond; the bonding electrons lie closer to the chlorine atom resulting in partial charges developing on both the hydrogen and the chlorine. The partial charges on a polar molecule attract oppositely charged dipoles on another polar molecule. This gives rise to an intermolecular force known as a permanent dipole-dipole interaction:

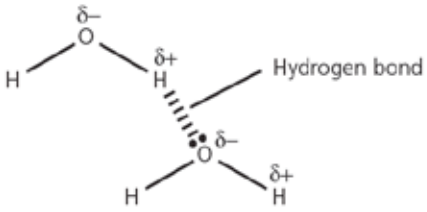
Permanent dipole-dipole interactions exist in addition to van der Waals' forces and are stronger than van der Waals' forces

Hydrogen bonding

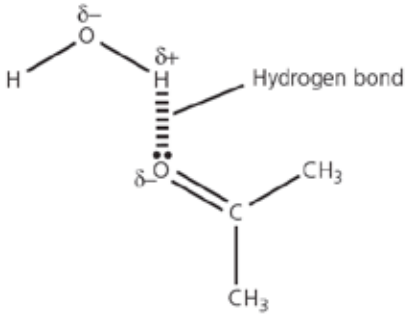
A hydrogen bond is the attraction between a lone pair of electrons on a very electronegative atom (i.e. N,O, F) in one molecule and a hydrogen atom in a neighbouring molecule, in which the hydrogen atom is covalently bonded to a very electronegative atom (N,O,F).

Hydrogen bonding is a special type of permanent dipole-dipole interaction that occurs between molecules containing a hydrogen atom bonded to nitrogen, oxygen or fluorine. A hydrogen bond is a comparatively strong intermolecular force between:

- An electron deficient hydrogen atom, $H^{\delta+}$, on one molecule and
- A lone pair of electrons on a highly electronegative atom of N, O or F on another molecule.



Hydrogen bonds between water molecules



Hydrogen bonds between water and propanone molecules

Intermolecular forces affecting physical properties

When molecular substances are boiled or melted it is the intermolecular forces *between* the molecules that are broken, not the covalent bonds *within* the molecules. When answering questions on melting point or boiling point you must always establish the type of intermolecular force(s) present.

For example ethanol has a higher boiling point than propane, which has a similar relative molecular mass because propane only has relatively weak van der Waals' forces between the molecules. There are strong hydrogen bonds between ethanol molecules (in addition to van der Waals' forces) and it takes a large amount of energy to break these.

Iodine has a higher boiling point than bromine because it has a higher relative molecular mass and so more electrons than Br_2, so there are stronger van der Waals' forces of attraction between the molecules. More energy is needed to break these and so iodine has a higher boiling point than bromine.

Many molecules such as ethanol are soluble in water as they can form hydrogen bonds with water — hydrogen bonds can form between the lone pair of electrons on the oxygen and the $H^{\delta+}$ of the water.

Revision Questions

1 The intermolecular forces of attraction in solid iodine are

A covalent bonds
B hydrogen bonds
C permanent dipole attractions
D van der Waals' forces

2 a) Ammonia is a substance that can form hydrogen bonds.
However, ammonia has a pyramidal structure.

(i) Draw two molecules of ammonia and show the hydrogen bond between the two molecules.

[2]

(ii) Explain why when ammonia reacts with a hydrogen ion it loses the ability to form hydrogen bonds.

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..... [1]

(b) Explain why ammonia is extremely soluble in water.

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..... [2]

3 Which one of the following will have the highest boiling point?

A bromine
B chlorine
C fluorine
D iodine