19.9: Van der Waals Forces

Figure 19.9.1(Public Domain; User:MartinSaunders/Wikimedia Commons via Wikipedia)

How to Keep it Cool?

Magnetic resonance imaging (MRI) devices use liquid nitrogen to cool the superconducting magnets. Nitrogen is a gas at room temperature and liquefies at -195.8^{o}C. Its neighbor on the periodic table (oxygen) boils at -182.95^{o}C. The interactions between nitrogen molecules (N_2) are weaker, so the boiling point is lower. Interactions between nonpolar molecules depend on the degree of electron fluctuation within the molecule.

Van der Waals Forces

The first type of intermolecular forces that we consider are van der Waals forces, after Dutch chemist Johannes van der Waals (1837-1923). **Van der Waals forces** are the weakest intermolecular force, and consist of dipole-dipole forces and dispersion forces.

Dipole-Dipole Forces

Dipole-dipole forces are the attractive forces that occur between polar molecules. A molecule of hydrogen chloride has a partially positive hydrogen atom and a partially negative chlorine atom. In a collection of many hydrogen chloride molecules, the molecules will align themselves so that the oppositely charged regions of neighboring molecules are near each other.

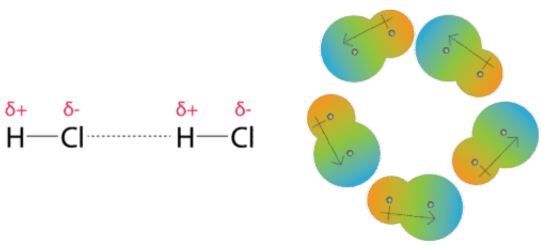


Figure 19.9.2 Dipole-dipole forces are a result of the attraction of the positive end of one dipole to the negative end of a neighboring dipole. (CC BY-NC 3.0; Joy Sheng via CK-12 Foundation)

Dipole-dipole forces are similar in nature to ionic bonds, but much weaker.

London Dispersion Forces

Dispersion forces are also considered a type of van der Waals force and are the weakest of all intermolecular forces. They are often called London dispersion forces after Fritz London (1900-1954), who first proposed their existence in 1930. **London dispersion forces** are the intermolecular forces that occur between atoms, and between nonpolar molecules as a result of the motion of electrons.

The electron cloud of a helium atom contains two electrons, which can normally be expected to be equally distributed spatially around the nucleus. However, at any given moment the electron distribution may be uneven, resulting in an instantaneous dipole. This weak and temporary dipole subsequently influences neighboring helium atoms through electrostatic attraction and repulsion. It induces a dipole on nearby helium atoms (see figure below).

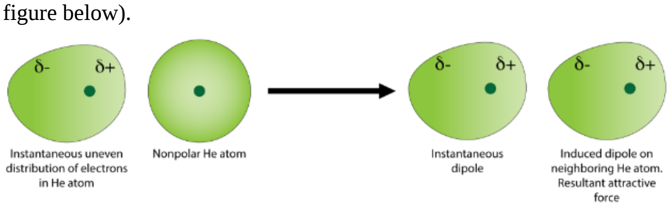


Figure 19.9.3 A short-lived or instantaneous dipole in a helium atom. (CC BY-NC 3.0; Zachary Wilson via CK-12 Foundation)

The instantaneous and induced dipoles are weakly attracted to one another. The strength of dispersion forces increases as the number of electrons in the atoms or nonpolar molecules increases.

The halogen group consists of four elements that all take the form of nonpolar diatomic molecules. The table below shows a comparison of the melting and boiling points for each.

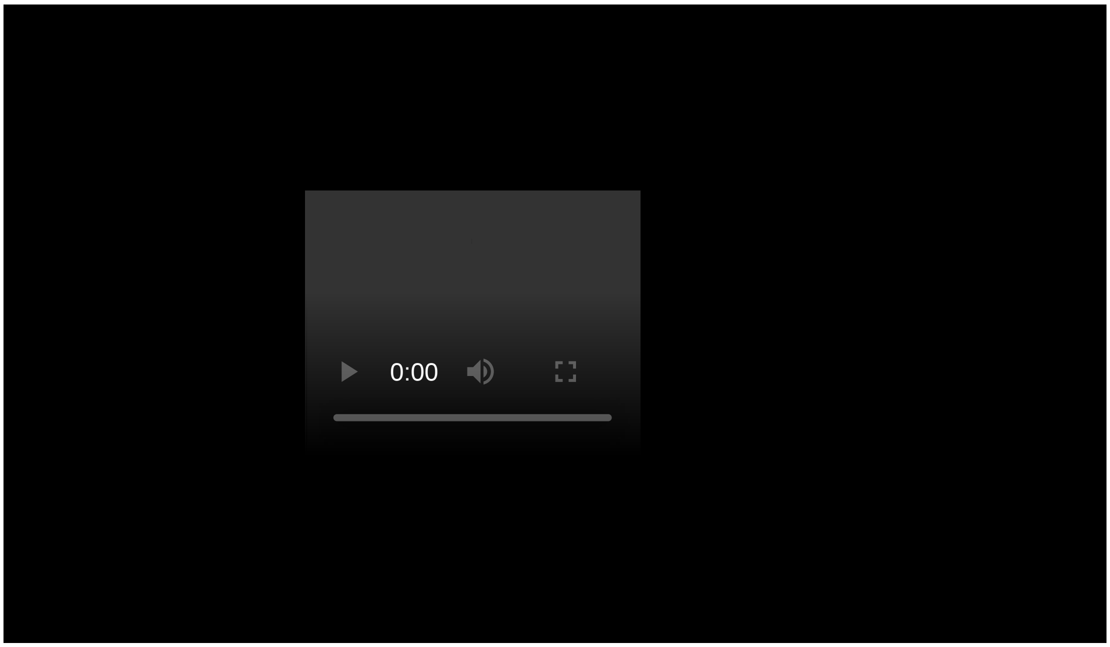
Melting and Boiling Points of Halogens

Table 19.9.1 : Melting and Boiling Points of Halogens

Molecule	Total Number of Electrons	Melting Point $(^{\circ}C)$	Boiling Point $(^{\circ}C)$	Physical State at Room Temperature
F_2	18	-220	-188	gas
Cl_2	34	-102	-34	gas
Br_2	70	-7	59	liquid
I_2	106	114	184	solid

Table 19.9.1 : Melting and Boiling Points of Halogens

The dispersion forces are strongest for iodine molecules because they have the greatest number of electrons. The relatively stronger forces result in melting and boiling points that are the highest of the halogen group. These forces are strong enough to hold iodine molecules close together in the solid state at room temperature. The dispersion forces are progressively weaker for bromine, chloride, and fluorine; this is illustrated in their steadily lower melting and boiling points. Bromine is a liquid at room temperature, while chlorine and fluorine are gases whose molecules are much further apart from one another. Intermolecular forces are nearly nonexistent in the gas state, and so the dispersion forces in chlorine and fluorine only become measurable as the temperature decreases and they condense into the liquid state.



Summary

- Van der Waals forces are weak interactions between molecules that involve dipoles.
- Polar molecules have permanent dipole-dipole interactions.
- Nonpolar molecules can interact by way of London dispersion forces.

Review

1. What attractive forces develop between polar molecules?
2. What creates London dispersion forces?
3. Are London dispersion forces permanent or temporary?
4. Are the dispersion forces for Cl_2 stronger or weaker than the ones for Br_2?