In a liquid or solid state, there must be forces between the particles that will hold the particles together. If there were no such forces, the molecules would move apart and become a gas.

These forces are known as intermolecular forces. Inter means between, so it is the force between the molecules.

Ionic and metallic bonds are strong. The bonding energy of the electrostatic ion-ion attraction is between 400 – 4 000 $kJ \cdot mol^{-1}$. Due to the strength of these bonds, these compounds are usually found as solids at room temperature.

Intermolecular forces are mainly found between small covalent molecules.

Quick facts

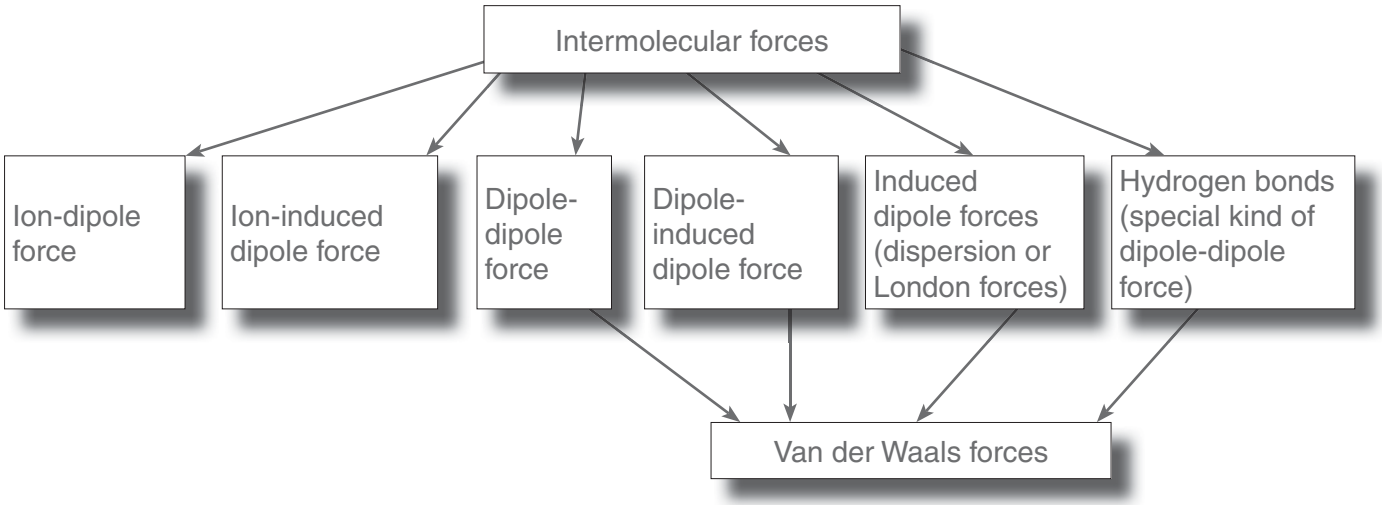
A small covalent molecule has a specific formula.

Why are intermolecular forces necessary?
There a various reasons, amongst others:
Water vapour would not be able to condense into a liquid or solid without intermolecular forces.
Most properties of materials would not exist, e.g. melting and boiling points, viscosity, liquification, condensation, surface tension, density. Crystal structures and specific shapes of molecules would not exist, for example there would be no enzymes.

Without intermolecular forces, life as we know it would not exist.

2.1 Types of intermolecular forces

The following are the different types of intermolecular forces.



The last four types are called Van der Waals forces. Van der Waals forces include all forces between neutral molecules. They can vary in strength, but all are relatively weak.

Hydrogen bonds are a specific type of a dipole-dipole force and therefore also a Van der Waals force.

Interesting facts

Van der Waals forces were named after a Dutch theoretical physicist, Johannes Diderik van der Waals. He was awarded the Nobel prize for his work in 1910.

The following table is a summary of different types of particles and the forces associated with them.

Particles	Type of bond
Ions	Coulombic forces
Ion and polar molecule	Ion-dipole
Two polar molecules	Dipole-dipole
Ion and non-polar molecule	Ion-induced dipole
Polar and non-polar molecule	Dipole-induced dipole
Non-polar molecules	Dispersion (London) forces

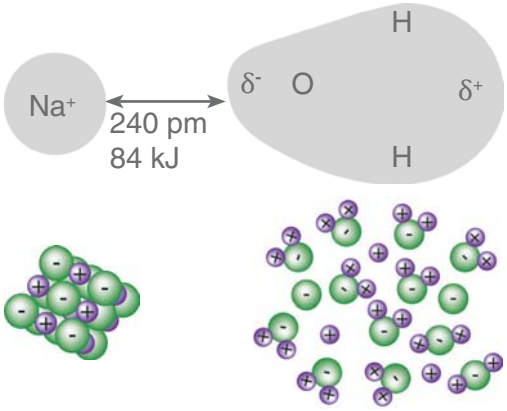
2.1.1 Ion-dipole forces

This occurs when a dipole approaches a positive or negative ion.
The dipole will move so that the side closest to the ion has the opposite charge.

Example:
When NaCℓ is dissolved in water.
This type of force is extremely important in the dissolution process.
All ions would be hydrated in an aqueous solution.

$NaC\ell(s) \xrightarrow{H_2O(\ell)} Na^+(aq) + C\ell^-(aq)$

Dissolving process:



Quick facts

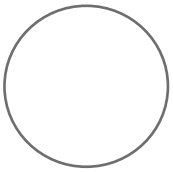
A formula like $Na^+(aq)$ means that the Na^+ ion is hydrated (surrounded by water molecules).

Quick facts

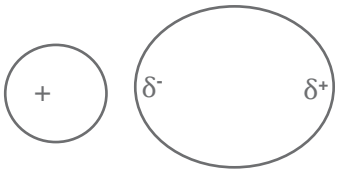
The hydrogen ion is just a proton with a very small volume. The hydrogen ion exists in its hydrated form, H_3O^+, in an aqueous solution.

2.1.2 Ion-induced dipole force

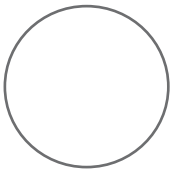
An ion affects the electron cloud around an atom or molecule when it is nearby, causing a temporary dipole.



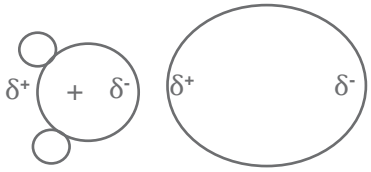
Spherical atom with no dipole



Ion responds and the atom develops a dipole.



Spherical atom with no dipole



Molecule with a dipole responds and the atom develops a dipole.

Examples: Na^+ and hexane