



FORCES BETWEEN MOLECULES

1) Van der Waals' forces (also called induced dipole-dipole forces or London dispersion forces)

- These are present in all molecular substances.
- They occur because the electrons are constantly moving around and there will be an uneven electron distribution at any given moment in time. This causes a temporary dipole within a molecule.
- This temporary dipole induces a temporary dipole in a neighbouring molecule. There is then an attraction between these molecules – this is a temporary induced dipole-dipole attraction.
- The bigger the molecule (i.e. the more electrons), the greater the van der Waals' forces (e.g. C₂H₆ boiling point -89°C, C₃H₈ boiling point -42°C).

2) Permanent dipole-dipole attraction

- There are permanent dipole-dipole attractions between polar molecules (e.g. between H-Cl molecules).



- Note – there are only permanent dipole-dipole attractions between polar molecules. Some molecules are non-polar but contain polar bonds (e.g. CCl₄ and CO₂) – these do not have permanent dipole-dipole attractions.

3) Hydrogen bonding

- This is a special case of permanent dipole-dipole attractions – where an H atom is bonded to a very electronegative atom (i.e. F, O, N).
- Common examples of molecules where they occur are HF, H₂O, NH₃, alcohols, carboxylic acids, amines, amino acids.
- The polar bond between the H and N/O/F leaves the H nucleus exposed as H only has one electron.
- Therefore there is a strong attraction from the lone pair on the N/O/F of one molecule to the exposed H nucleus of another molecule.
- This is simply a strong intermolecular force – it is NOT a bond!
- When drawing the hydrogen bonds between two molecules, always show all lone pairs, all $\delta+$ and $\delta-$ charges, and a dotted line between the lone pair on one molecule and the $\delta+$ H on another.

NH ₃		H ₂ O
HF		CH ₃ CH ₂ OH

The strength of intermolecular forces

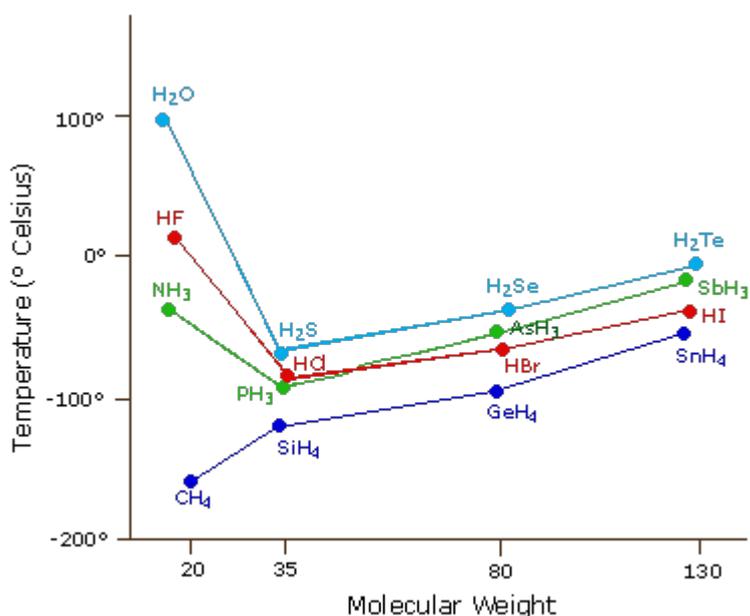
- H-bonding > permanent dipole-dipole > van der Waals'
- Covalent bonds are very strong (values in hundreds of kJ mol^{-1}). The forces between molecules are much weaker, with van der Waals' forces being in units of kJ mol^{-1} and hydrogen bonds in tens of kJ mol^{-1}

Some comparisons

molecule	methane, CH_4	hydrogen chloride, HCl	water, H_2O
boiling point	-162°C	-85°C	100°C
intermolecular forces	van der Waals'	van der Waals' dipole-dipole	van der Waals' hydrogen bonds

TASK 1

Boiling points of hydrides of Groups 4, 5, 6 and 7



Why are H_2O , HF and NH_3 so much higher than other hydrides in their group?

Why is the effect greater for H_2O than for HF and NH_3 ?

Why do boiling points generally increase down a group?

Why are boiling points of Group 4 hydrides lower than hydrides of Groups 5, 6 and 7?

TASK 2 – Which molecule in each pair has a higher boiling point?

	molecule	van der Waals' (✓)	dipole-dipole (✓)	hydrogen bonds (✓)	which molecule is likely to have higher boiling point?
1) CH ₄ & C ₄ H ₁₀	CH ₄				
	C ₄ H ₁₀				
2) H ₂ O & H ₂ S	H ₂ O				
	H ₂ S				
3) CF ₄ & CHF ₃	CF ₄				
	CHF ₃				
4) (CH ₃) ₃ N & (CH ₃) ₂ NH	(CH ₃) ₃ N				
	(CH ₃) ₂ NH				

TASK 3 – Explain why the molecule in each pair has a higher boiling point

pair	molecule	boiling point	why one boiling point is higher than the other
5)	Cl ₂	-34°C	
	Br ₂	59°C	
6)	CO ₂	-78°C	
	SO ₂	-10°C	
7)	HBr	-66°C	
	Br ₂	59°C	
8)	CH ₃ OCH ₃	-24°C	
	CH ₃ CH ₂ OH	78°C	
9)	H ₂ O	100°C	
	HF	20°C	