Intermolecular Forces

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Types of Intermolecular Forces

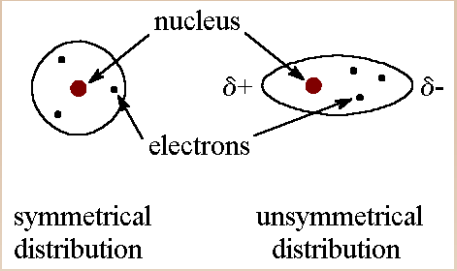
- Intermolecular forces help determine physical properties of substances e.g. melting and boiling points, surface tension, viscosity and solubility. Covalent and ionic substances have different kinds of intermolecular forces.
  - Ionic Compounds: All ionic substances have electrostatic forces. These are the strongest forces resulting in high melting points.
  - Covalent compounds there are three kinds of forces:
    - Dispersion forces
    - Dipole-dipole forces
    - Hydrogen bonding
- The stronger the forces the higher the melting point and boiling pts; molecules with similar IM forces dissolve in each other.

Dispersion Forces/Van der Waals Forces/ London Forces

- It is the forces between internal electron distribution in molecules. This is also called induced dipole.
- These kind of forces are found in molecules that have a high electron density, which could be because of a large molecule or large size of atom.
- Best example are the halogens: F_2, Cl_2, Br_2 and I_2. As one goes down the group the phase changes from gas to liquid to solid. This is because the atomic size of iodine is so large that an internal charge distribution occurs. Because of this charge separation molecules interact differently.

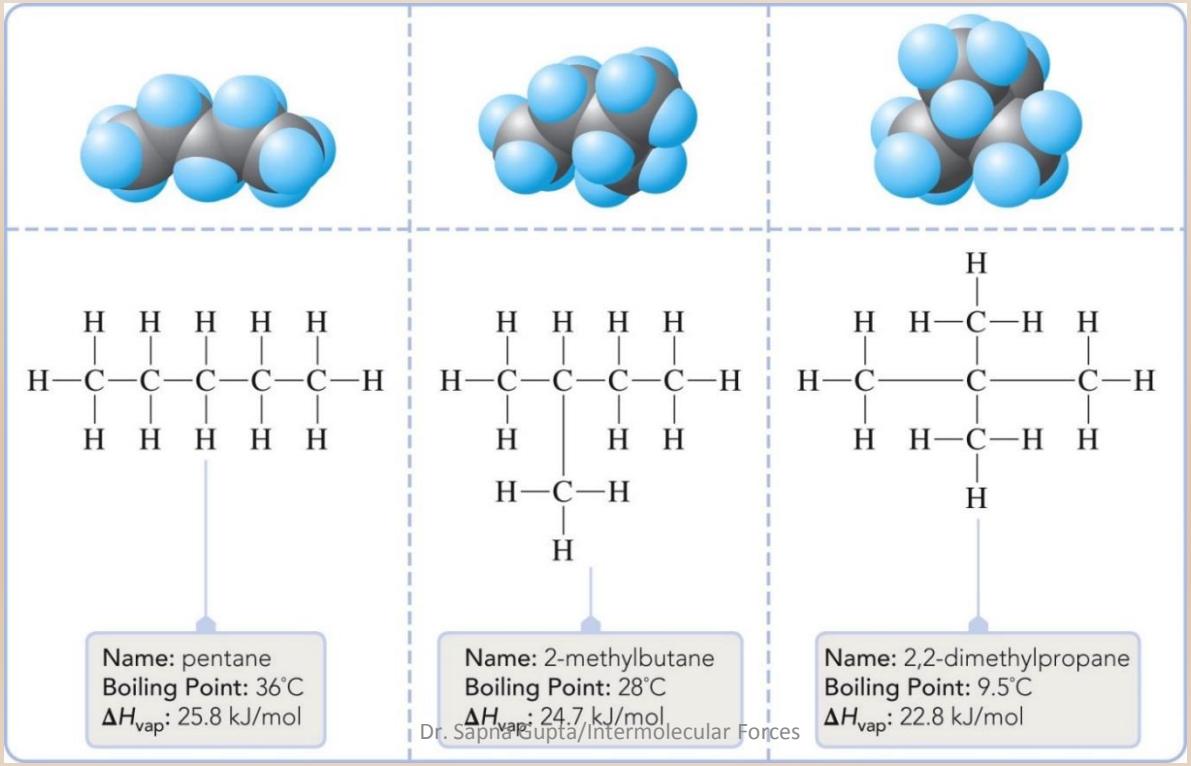
Molecule	Molar Mass (g/mol)	Boiling Point (°C)	State (Room Temp.)
F_2	38.0	−188	Gas
Cl_2	70.9	−34	Gas
Br_2	159.8	59	Liquid
I_2	253.8	184	Solid

- The diagram below shows how the charge distribution occurs.



Dispersion Forces in Straight Chain vs Compact Molecules

- For the compound with the formula, C_5H_{12}, we can draw three different structures, however, in each compound, the carbon atoms are bonded in a different structure. Note how the heats of vaporization differ for the molecules.
- The straight-chain compound has the strongest intermolecular forces and the highest heat of vaporization because it is most flexible and, therefore, most polarizable.



Dipole-Dipole Moment

- Forces between molecules that have a dipole moment. The higher the dipole moment the stronger the dipole-dipole interaction.
- E.g. HCl has stronger IM forces than HBr because the bond between HCl is more polar.
- The table below shows some molecules of the same molecular weight but different dipole moment and how that affects the boiling point of the substances.

Formula	μ (D)	Formula	μ (D)
H_2	0	CH_4	0
Cl_2	0	CH_3Cl	1.87
HF	1.91	CH_2Cl_2	1.55
HCl	1.08	$CHCl_3$	1.02
HBr	0.80	CCl_4	0
HI	0.42	NH_3	1.47
BF_3	0	NF_3	0.24
CO_2	0	H_2O	1.85

TABLE 12.1 Dipole Moments and Boiling Points of Compounds with Similar Molecular Masses

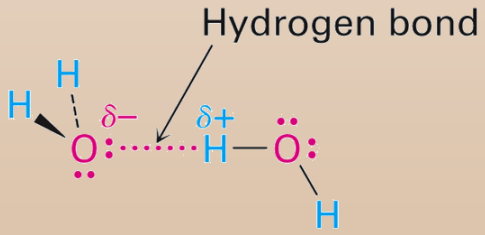
Compound	Structural Formula	Dipole Moment (D)	Boiling Point (°C)
Propane	$CH_3CH_2CH_3$	0.1	−42
Dimethyl ether	CH_3OCH_3	1.3	−25
Methyl chloride	CH_3Cl	1.9	−24
Acetaldehyde	CH_3CHO	2.7	21
Acetonitrile	CH_3CN	2.9	82

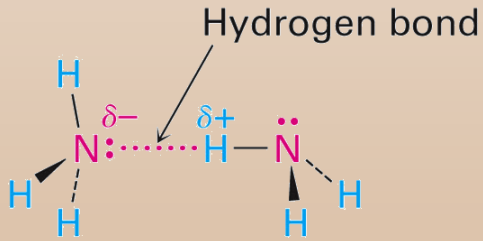
Hydrogen Bonding

Hydrogen bonding is quite an strong attractive force that exists between hydrogen atoms bonded to a very electronegative atom, F, O, or N, and a lone pair of electrons on another small, electronegative atom, Y.

—X—H ··· Y—

This is the strongest of all the IM forces. It holds the proteins and DNA together. Because of this force water is a liquid and has a high boiling point.

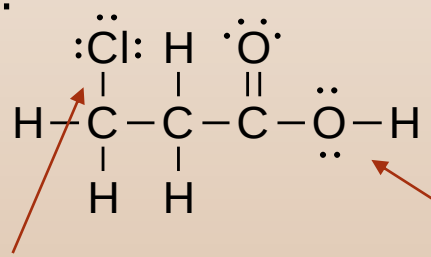




Comparison of IM Forces

- H-bonding > dipole-dipole> dispersion
- In organic chemistry all these forces are key to understanding the physical properties of substances.

- **<u>Solved Example</u>**: what are the two key IM forces in the following molecule?



Dipole-dipole and hydrogen bonding

More Solved Problems

1) What are the IM forces between the following molecules?

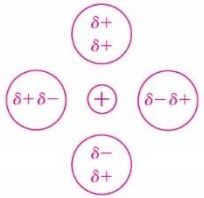
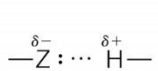
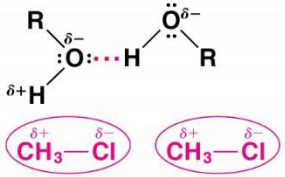
Molecule	Answer
$CHCl_3$	Dispersion force dipole dipole forces
Br_2	Dispersion force
Ca_2NO_3	Electrostatic force
CH_3OH	Hydrogen bonding

2) Which of the following has the highest dispersion force?

a) C_4H_{10} b) C_5H_{12} c) C_6H_{14} d) C_7H_{16} e) C_8H_{18}

Key Words/Concepts

- Electrostatic Force
- Dispersion force
- Dipole dipole force
- Hydrogen bonding
- Effect of intermolecular forces on melting and boiling points and solubility of substances.

Electric Force	Relative Strength	Type	Example
Cation–anion (in a crystal)	Very strong		Lithium fluoride crystal lattice
Covalent bonds	Strong (140–523 kJ mol^{-1})	Shared electron pairs	H—H (436 kJ mol^{-1}) CH_3—CH_3 (378 kJ mol^{-1}) I—I (151 kJ mol^{-1})
Ion–dipole	Moderate		Na^+ in water (see Fig. 2.9)
Dipole–dipole (including hydrogen bonds)	Moderate to weak (4–38 kJ mol^{-1})	 and 	
van der Waals	Variable	Transient dipole	Interactions between methane molecules