

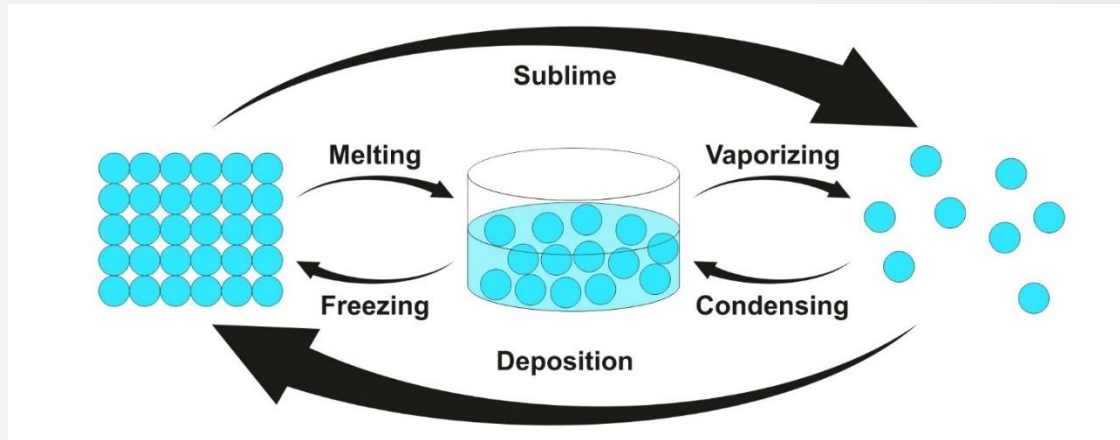
PHASES OF MATTER

1: INTERMOLECULAR FORCES

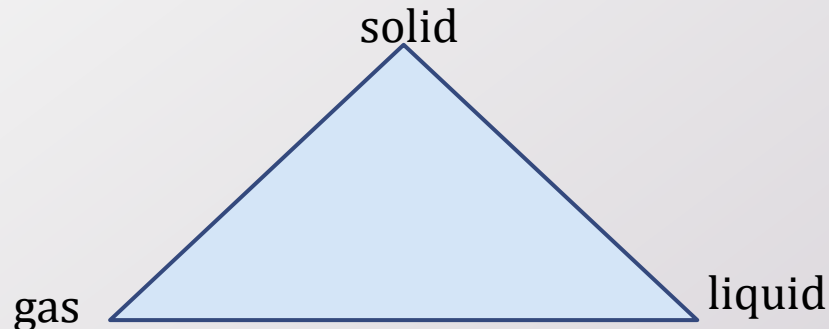
Dr. Sapna Gupta

PHASES OF MATTER

- Solid, liquid and gas.
- All the convertible to each other.
- Type of intermolecular forces will determine the phase of the matter.



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INTERMOLECULAR FORCES

These are forces that exist between molecules.

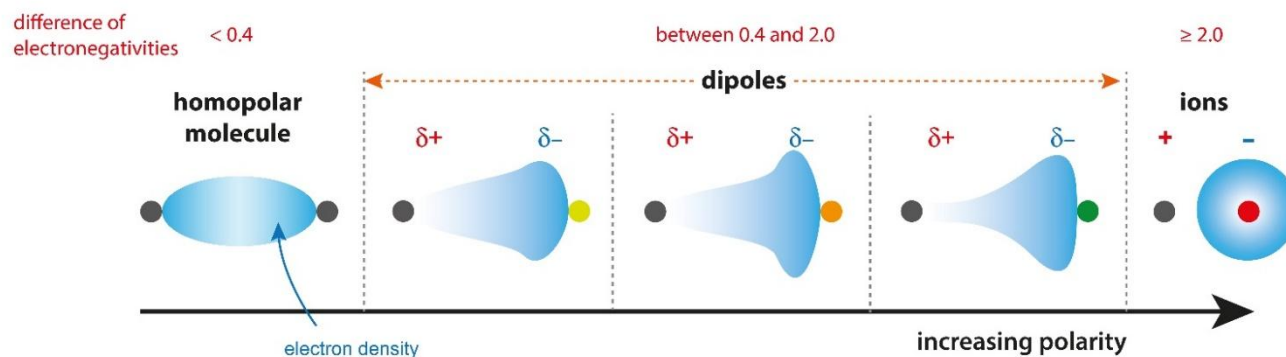
- The strength of the forces will cause a substance to be gas, liquid or solid.
- The higher the intermolecular forces the larger the amount of energy it takes to separate the molecules.
- The higher the intermolecular forces the higher the vapor pressure; i.e. the higher the boiling point or melting point.
- The higher the intermolecular forces the more chances of a substance to be a solid vs a liquid vs a gas; i.e. gases have the least intermolecular forces.
- The higher the dipole moment the higher the intermolecular forces.

Compound	Formula	Dipole Moment (D)	Boiling Point (°C)
Propane	CH ₃ CH ₂ CH ₃	0.1	-42
Dimethyl ether	CH ₃ OCH ₃	1.3	-25
Methyl Chloride	CH ₃ Cl	1.9	-24
Acetaldehyde	CH ₃ CHO	2.7	21
Acetonitrile	CH ₃ CN	2.9	82

TYPES OF INTERMOLECULAR FORCES

- **London or Dispersion forces** – forces from instantaneous dipoles and induced dipoles
- **Dipole-dipole interactions** – forces between polar molecules
- **Hydrogen bonding** – force in polar molecules containing a H atom bonded to a small, highly electronegative element (N, O and F)

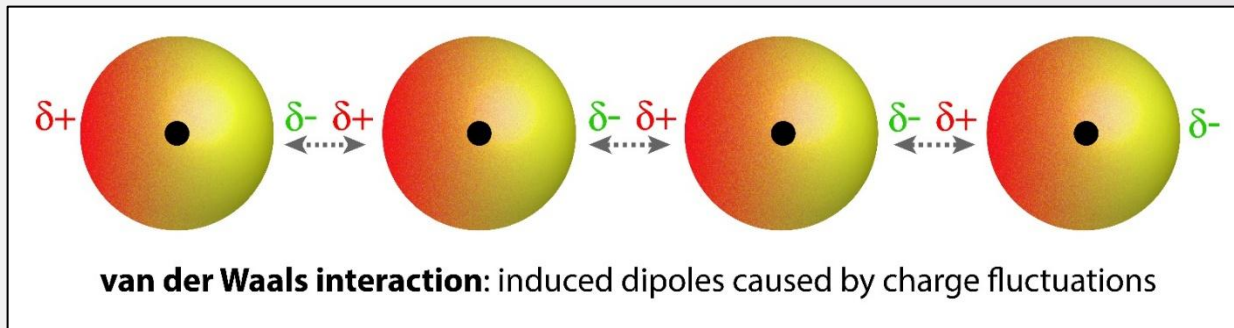
Type of Interaction	Approximate Energy (kJ/mol)
<u>Intermolecular forces:</u>	
Van der Waals	0.1 to 10
Hydrogen bonding	10 to 40
<u>Bonding:</u>	
Ionic	100 to 1000
Covalent	100 to 1000



LONDON FORCES/DISPERSION FORCES

London forces exist in nonpolar molecules. In these molecules, charge is uniformly distributed; but if a molecule has large density of electrons (large molecule) then it causes an unequal distribution of electrons.

- For example, in neon, the electrons will localize on one side and protons on another causing an attraction with another molecule.
- This is called “induced dipole”.



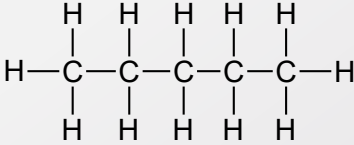
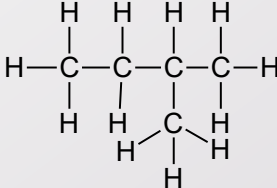
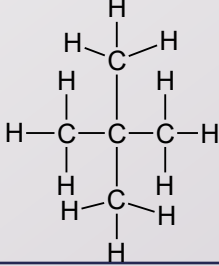
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LONDON FORCES – CONTD...

- Induced dipole is also observed in increased molecular weight e.g. I_2 vs Br_2

Molecule	Molar mass (g/mol)	Boiling pt (°C)	State at RT
F_2	38.0	-188	Gas
Cl_2	70.9	-34	Gas
Br_2	159.8	59	Liquid
I_2	253.8	184	Solid

- Branching in molecules causes the intermolecular forces to be lower (less interaction)

		
Pentane Boiling point: 36 °C DH_{vap} : 25.8 kJ/mol	Pentane Boiling point: 28 °C DH_{vap} : 24.7 kJ/mol	Pentane Boiling point: 9.5 °C DH_{vap} : 22.8 kJ/mol

DIPOLE-DIPOLE FORCES

Dipole-dipole force occurs in molecules that are polar or have a dipole moment, e.g., HCl, CH₃Cl, CH₃OCH₃.

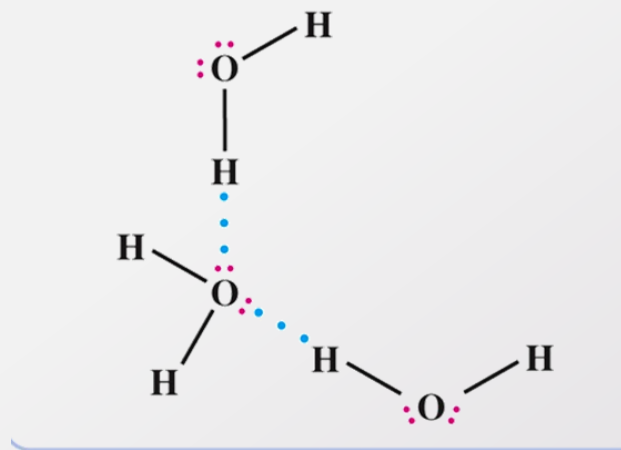
- One has to determine the Lewis structure and then the shape of the molecule to know if there is dipole moment (or the molecule is polar). The charge dispersion occurs due to difference in electronegativity.
- The higher the dipole moment the higher the dipole – dipole forces thus the higher the boiling point/melting point.

Compound	Structural Formula	Dipole Moment (D)	Boiling Point (°C)
Propane	CH ₃ CH ₂ CH ₃	0.1	-42
Dimethyl ether	CH ₃ OCH ₃	1.3	-25
Methyl chloride	CH ₃ Cl	1.9	-24
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HYDROGEN BONDING

Hydrogen bonding is a type of dipole-dipole interaction but very specific to H bonded to O, N or F. It is also one of the strongest intermolecular force. It is found for example, in H_2O , HF and NH_3 .

- $\text{—X—H} \cdots \text{Y—}$

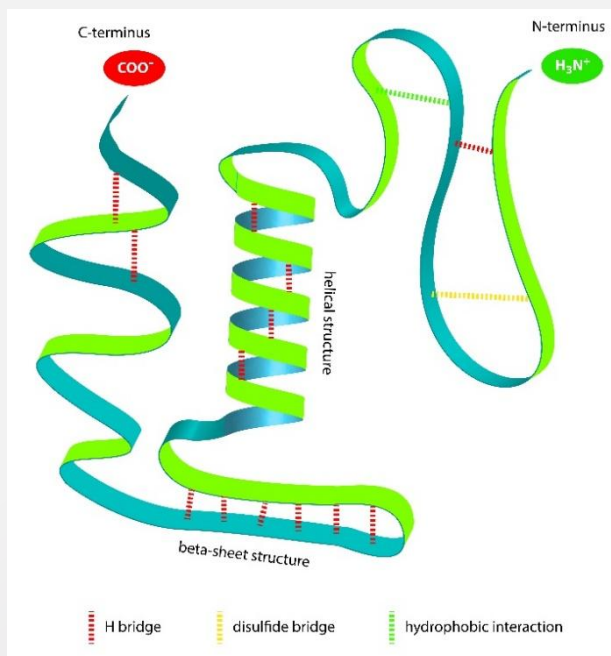


- HF will have hydrogen bonding but HCl will not.

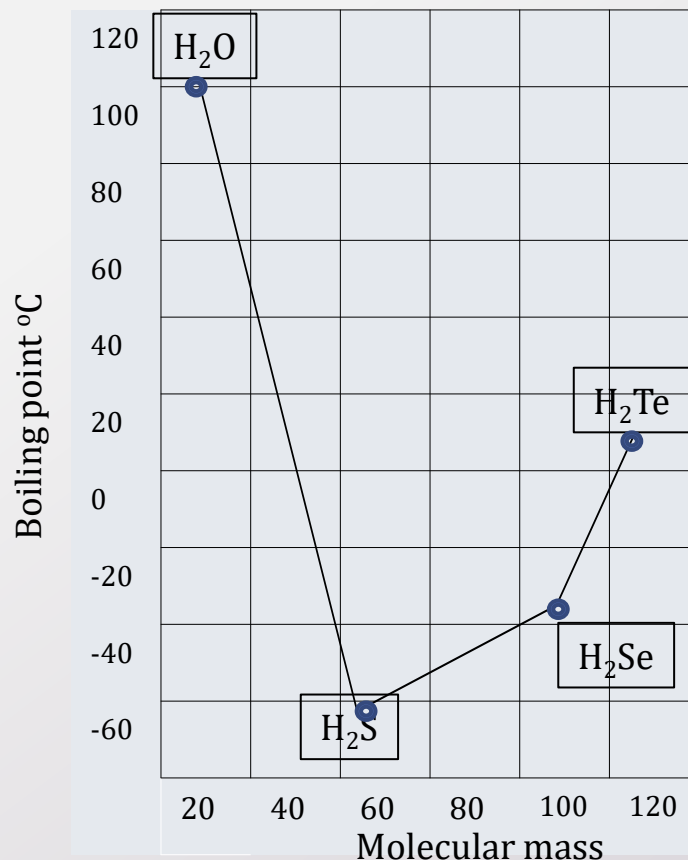
HYDROGEN BONDING – CONTD...

- Impact of H-bonding in group VI is shown in the graph on the right.
- H-bonding is responsible for protein and DNA structures.

Protein



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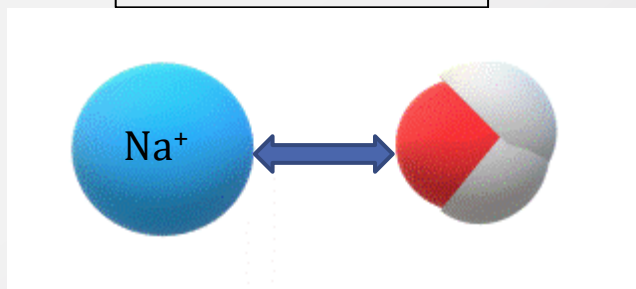


ION-DIPOLE INTERACTIONS

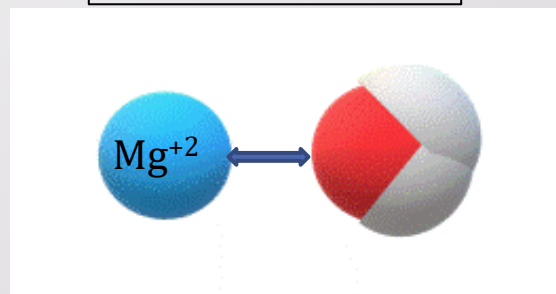
These interactions occur in mixtures of ionic and polar species for example during the solubility of NaCl in water.

- It is a charged, coulombic attraction, between ions and polar molecules.
- Dependent upon
 - Size and charge of ion
 - Dipole moment of the molecule
 - Size of the molecule

Weak Interaction



Strong Interaction



EXAMPLE: INTERMOLECULAR FORCE

Identify the intermolecular forces that you would expect for each of the following substances:

- a. O_2
- b. H_2O_2
- c. CHBr_3

Answer:

- a. Nonpolar molecule: London forces
- b. Polar molecule with O—H bond: dipole-dipole forces, hydrogen bonding
- c. Polar molecule: London forces, dipole-dipole forces

KEY CONCEPTS

- Changes of phases
- Intermolecular forces:
 - London forces
 - Dipole-dipole forces
 - Hydrogen bonding
 - Ion – dipole forces
- Forces involved in determining phase of substance.