

PHASES OF MATTER

2: PROPERTIES DUE TO INTERMOLECULAR FORCES

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PROPERTIES OF INTERMOLECULAR FORCES

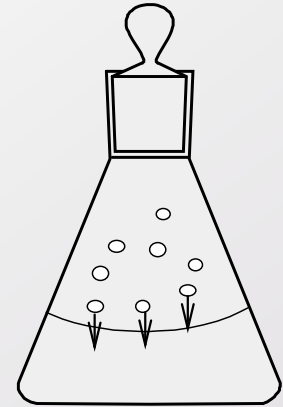
The type of intermolecular forces will determine:

- Vapor Pressure
- Boiling point
- Freezing point
- Surface tension
- Viscosity
- Adhesion and cohesion
- Solubility of substances

VAPOR PRESSURE

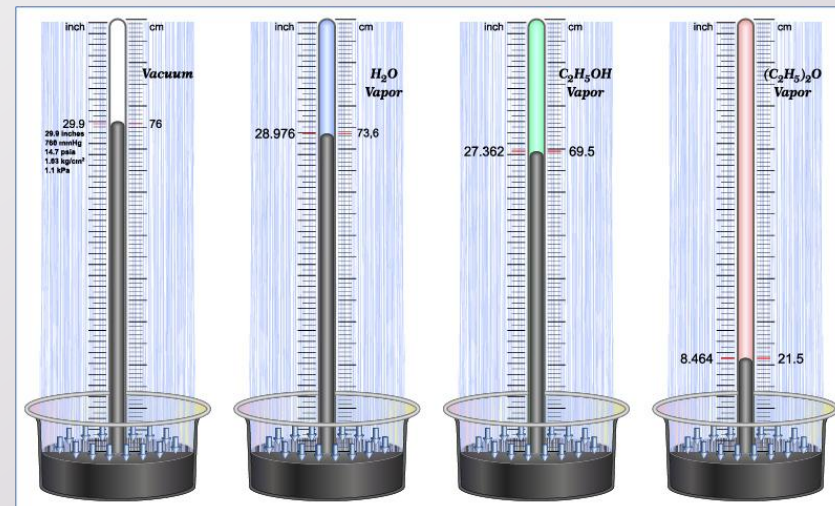
Vapor pressure of a liquid is the partial pressure of the vapor **over** the liquid at a particular temperature.

- When a liquid is placed in a closed vessel, the partial pressure of its vapor increases over time until it reaches equilibrium. At equilibrium, evaporation and condensation continue to occur at the same rate called dynamic equilibrium.



Vapor pressure depends on IM forces and temperature

- If the IM forces are more then molecules will tend to stick together and not vaporize hence VP will be less.
- If the temperature is increased, the kinetic energy of molecules increases, and they will break free of the IM forces and increase the VP.



BOILING POINT

Boiling point is the temperature at which the vapor pressure is equal to the atmospheric pressure (external pressure).

- At this temperature bubbles form within the liquid – looks like boiling.
- As the pressure on the liquid increases the boiling point increases – e.g. in a pressure cooker. Boiling point at a higher altitude will be lower than normal atmospheric pressure.
- Heat of vaporization – heat required to vaporize a liquid.
e.g. $\text{H}_2\text{O}_{(l)} \rightarrow \text{H}_2\text{O}_{(g)}; \Delta H_{\text{vap}} = 40.7 \text{ kJ/mol}$
- If the IM forces are high then bpt. will also be higher.
e.g. $\text{H}_2\text{O} > \text{H}_2\text{S}$

SURFACE TENSION

Surface tension is a quantitative measure of the elastic force on the surface of a liquid.

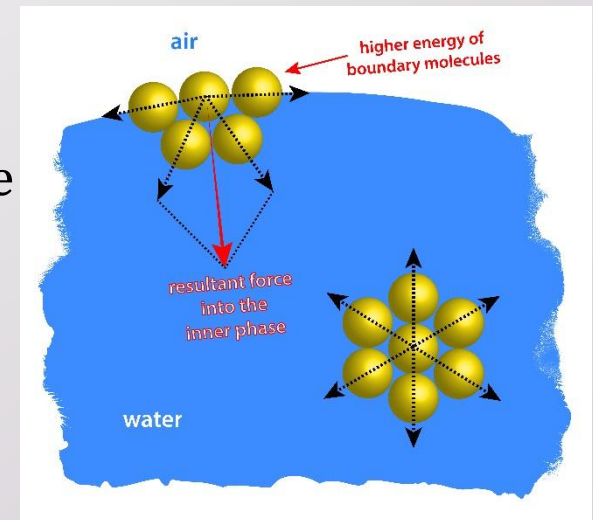
- Surface tension occurs because the molecules at the surface of a liquid experience a net force toward the center of the liquid.
- The stronger the intermolecular forces the higher the surface tension.
- Energy of molecules on the surface is more so they want to vaporize, but if IM forces are more they will be pulled inside – thus creating a thin film of tension.

e.g. H_2O (water) > C_6H_{14} (hexane)

- To break the surface tension, one will need to reduce the IM forces.



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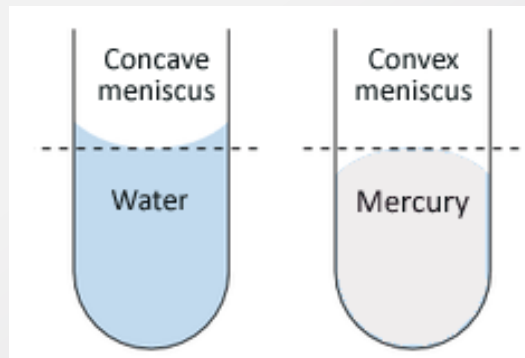
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CAPILLARY ACTION: COHESION AND ADHESION

Formation of a **meniscus** is a result of surface tension.

- Capillary action which results from a combination of
 - **Cohesion**: attractions between like molecules, cohesive forces
 - **Adhesion**: attractions between unlike molecules, adhesive forces

Water and glass
Adhesion > cohesion



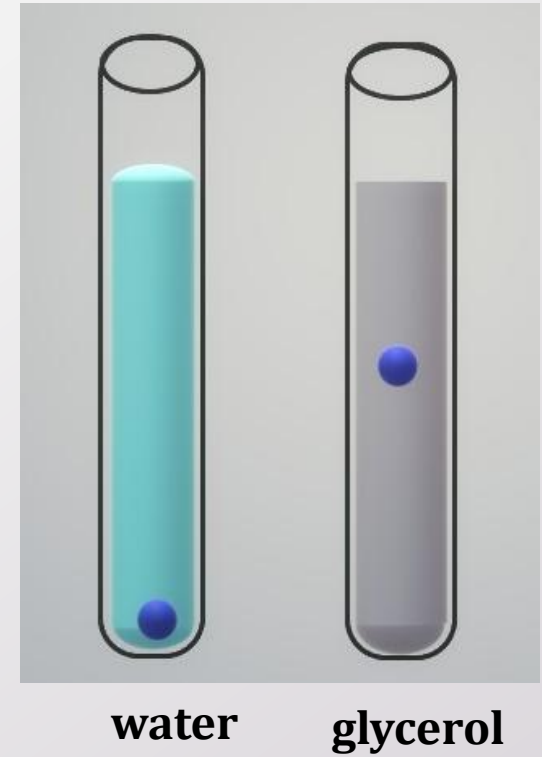
Mercury and glass
cohesion > adhesion

- Car waxing is cohesion, whereas pulling up blood in a capillary is adhesion.
- Similar IM forces lead to adhesion; dissimilar IM forces lead to cohesion.

VISCOSITY

Viscosity is the resistance to flow exhibited by liquids and gases; e.g. the difference in the flow of syrup vs water.

- In the figure, steel balls were dropped into the glycerol and the water at the same time. Glycerol has higher viscosity (1.49 N s/m^2) so ball will drop slower than in water ($1.01 \times 10^{-3} \text{ N s/m}^2$).
- Higher IM forces causes higher viscosity.



PHYSICAL PROPERTIES - COMPARISON

Properties of some liquids at 20 °C.

Substance	Structure	Molecular Wt (amu)	Vapor Pressure (mmHg)	Surface Tension (J/m ²)	Viscosity (kg/m s)
Water,	H ₂ O	18	1.8×10^1	7.3×10^{-2}	1.0×10^{-3}
Carbon dioxide	CO ₂	44	4.3×10^4	1.2×10^{-3}	7.1×10^{-5}
Pentane	C ₅ H ₁₂	72	4.4×10^2	1.6×10^{-2}	2.4×10^{-4}
Glycerol	C ₃ H ₈ O ₃	92	1.6×10^{-4}	6.3×10^{-2}	1.5×10^0
Chloroform	CHCl ₃	119	1.7×10^2	2.7×10^{-2}	5.8×10^{-4}
Carbon Tetrachloride	CCl ₄	154	8.7×10^1	2.7×10^{-2}	9.7×10^{-4}
Bromoform	CHBr ₃	253	3.9×10^0	4.2×10^{-2}	2.0×10^{-3}

SOLUBILITY

Rule of solubility is: “like dissolves like”. which means that substances with the same IM forces will dissolve in each other.

- IM interactions are between solvent and solute molecules.
- The nonpolar substances will dissolve primarily in nonpolar substances – not in substances with dipole-dipole or H-bonding forces.
- Substances with dipole-dipole, H-bonding and ion-dipole IM forces should be soluble in each other.
- E.g. H_2O will dissolve CH_3OH , NaCl , sugar through different IM forces. It will not dissolve hexane C_6H_6 since the IM forces don't match up.
- Hexane, C_6H_{14} , should dissolve CH_3OCH_3 (ether) easily. However, the ether will be slightly soluble in H_2O due dipole-dipole interactions.

KEY CONCEPTS

- Vapor Pressure
- Boiling point
- Surface tension
- Viscosity
- Adhesion and cohesion
- Solubility of substances