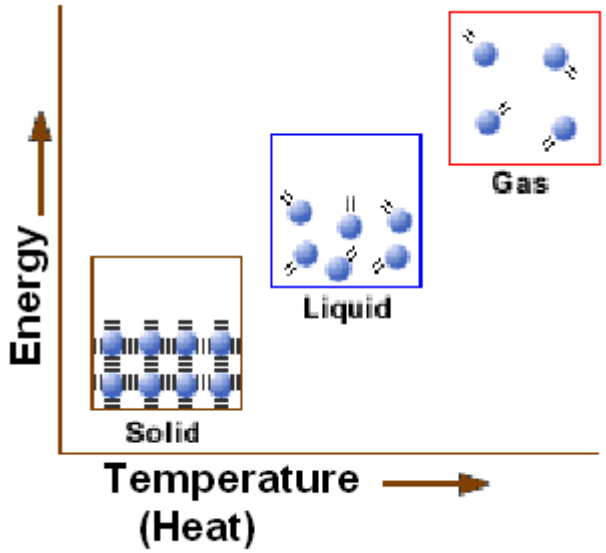
The Liquid State

The liquid state of a material has a definite volume, but it does not have a definite shape and takes the shape of the container, unlike that of the solid state.

Unlike the gas state, a liquid does not occupy the entire volume of the container if the container volume is larger than the volume of the liquid.

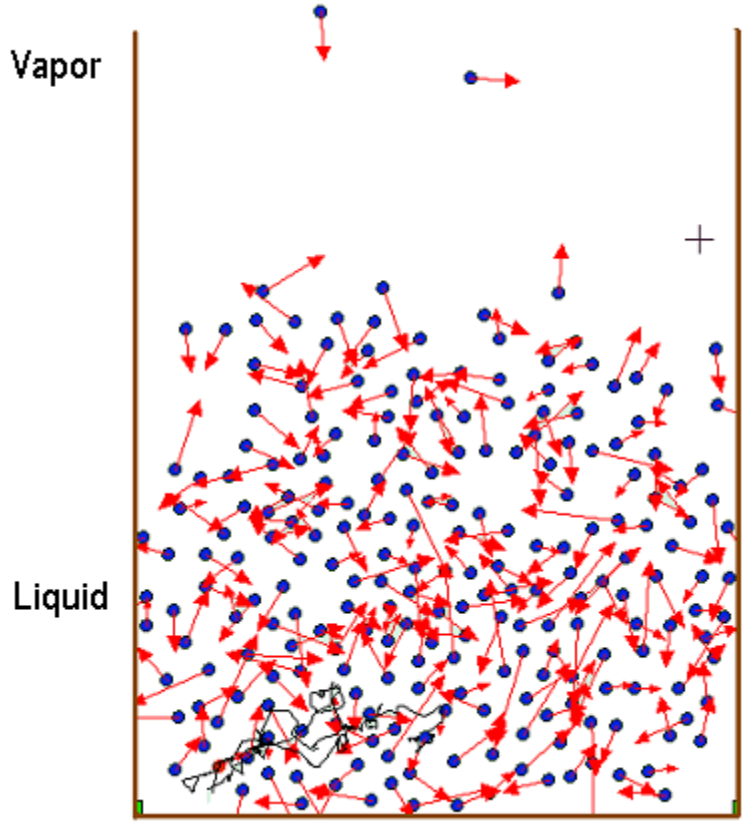


The Liquid State

At the molecular level, the arrangement of the molecules is random, unlike that of the solid state in which the molecules are regular and periodic.

Molecules are still closely packed but they can slip past each other and move around the body of the liquid.

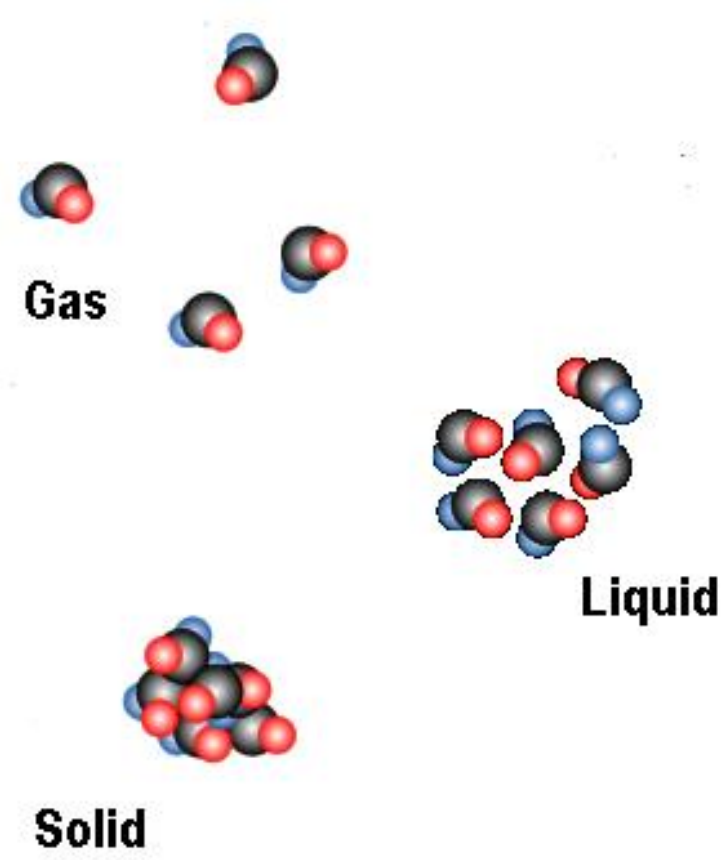
There may be some short order intermolecular ordering or structure, however.



Solids, Liquids and Gases

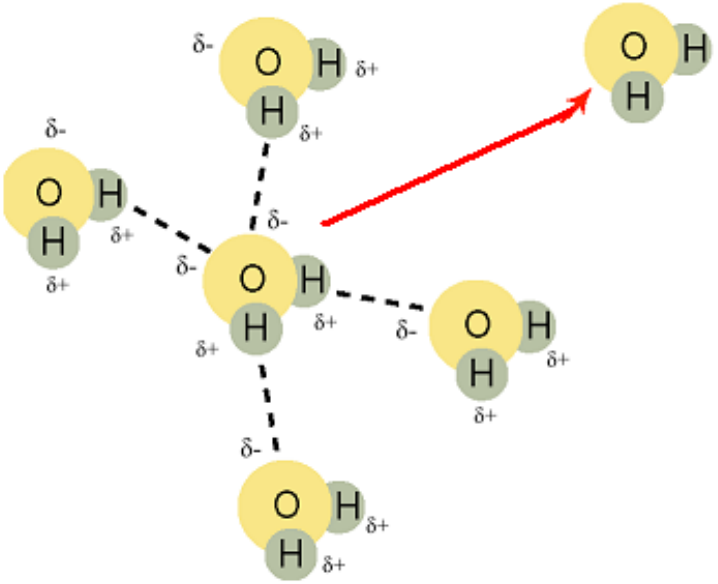
The intermolecular forces between particles become stronger as particles are packed closer together and move less rapidly

Energy is required to convert from solid to liquid to gas



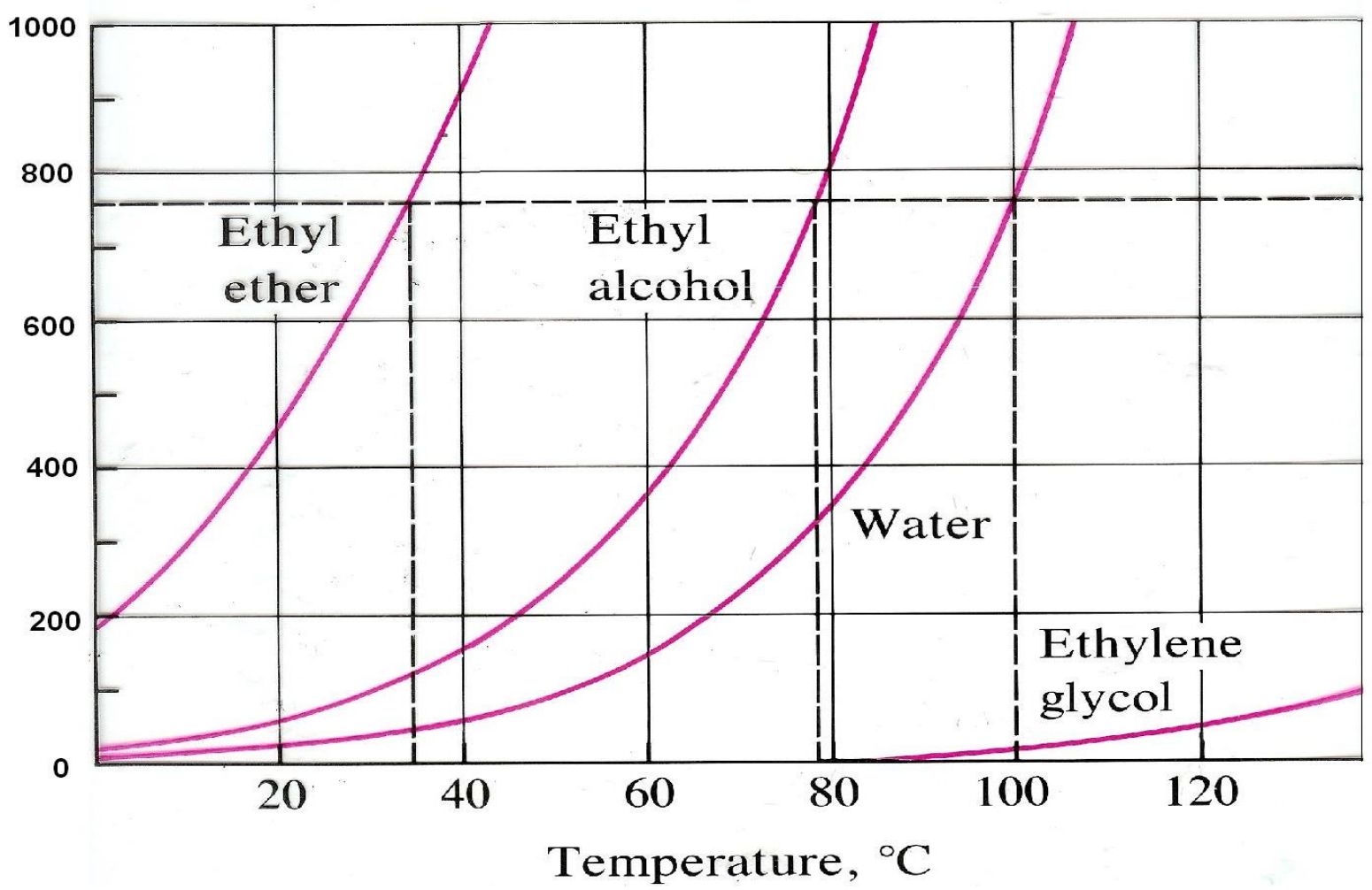
Vapor Pressure and Boiling

- Energy is required for a liquid to evaporate
- The vapor pressure of a liquid depends on the degree to which it will evaporate at a given temperature
- Liquids evaporate at the surface as long as the vapor pressure of the liquid is less than the pressure of the atmosphere above the liquid



In order to evaporate, a water molecule must have enough energy to overcome the hydrogen bonds that hold it in place

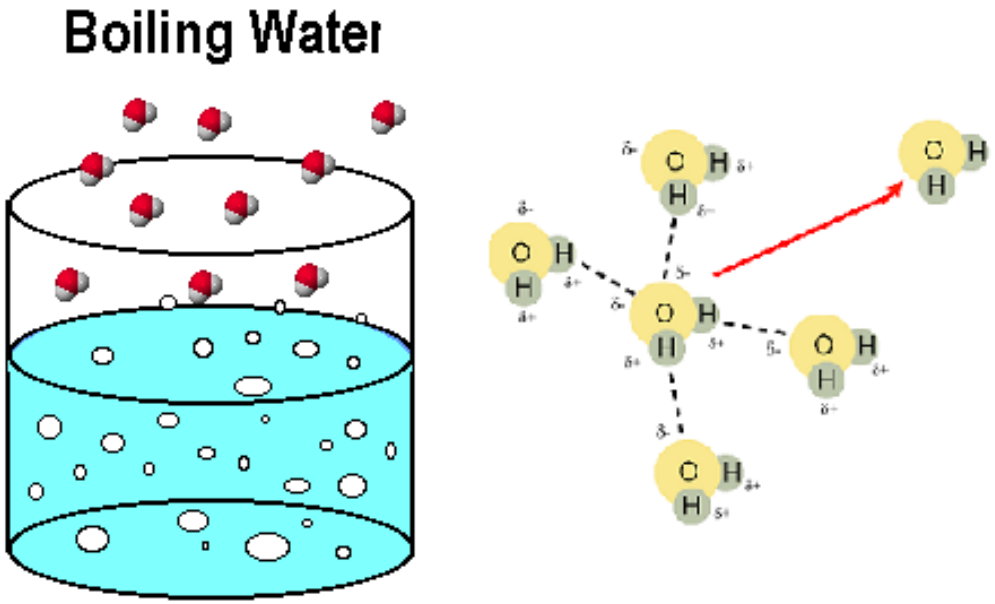
Vapor Pressure curves for various liquids



Vapor Pressure and Boiling

- **The higher the intermolecular forces in a substance, the lower its vapor pressure will be at any given temperature**
- **Volatile liquids have relatively high vapor pressures and hence they also have low boiling temperatures**
- **If the vapor pressure of a liquid is equal to the atmospheric pressure the substance will boil.**

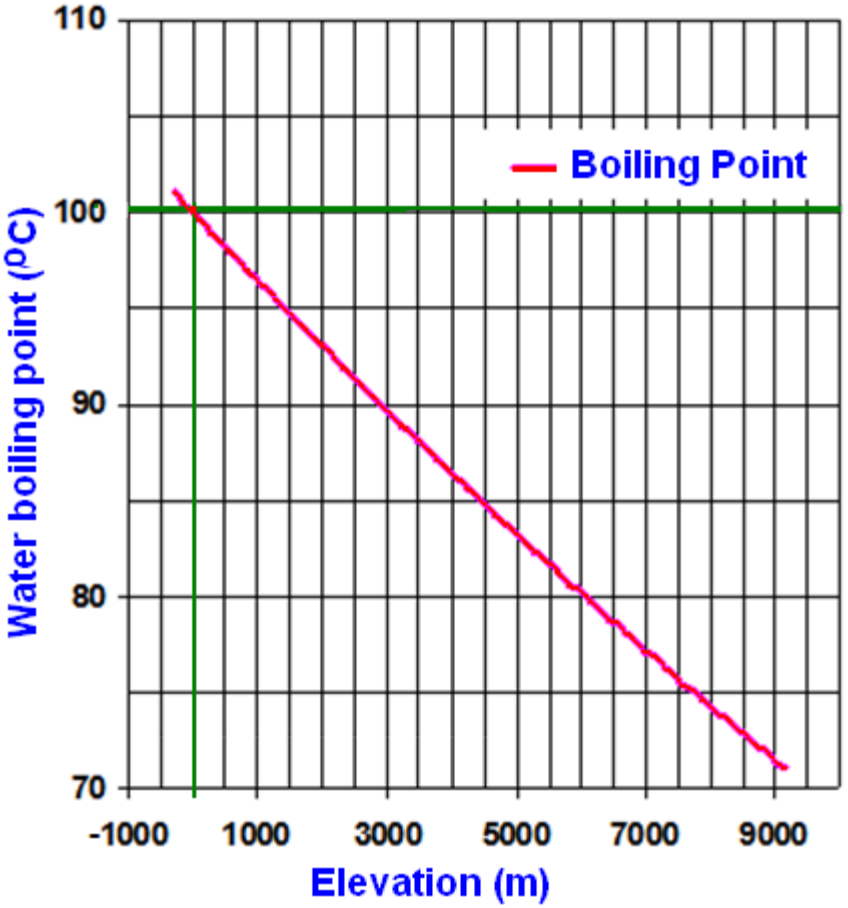
Boiling



At the boiling temperature, bubbles of water vapor form within the liquid. As they escape they cause the churning effect that we know as boiling

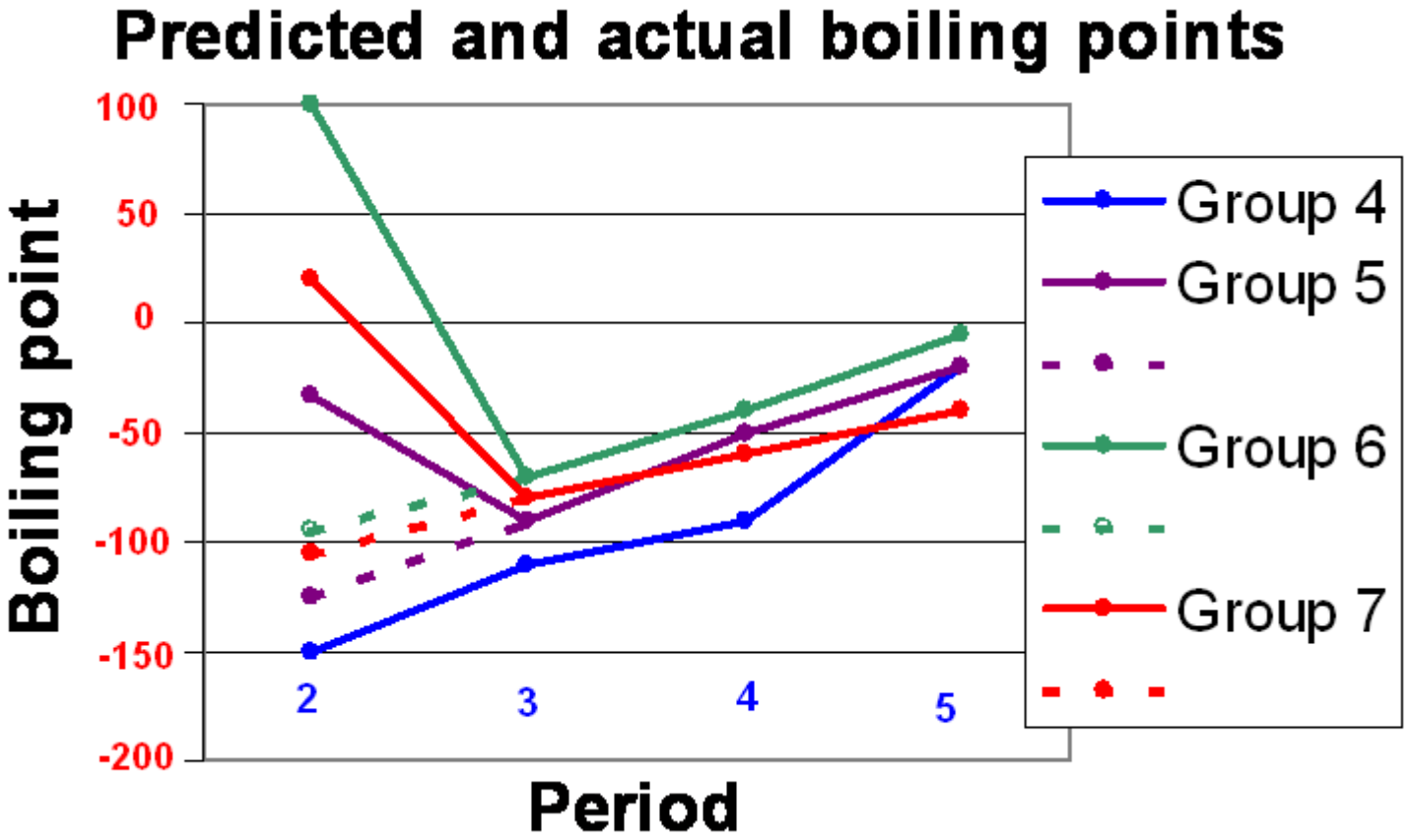
The boiling temperature depends on the pressure above the liquid.

Boiling point of water and elevation



The boiling temperature depends on the pressure above the liquid. Atmospheric pressure decreases with increasing elevation.

Hydrogen bonding & the boiling point



Molecules that undergo significant hydrogen bonding tend to have much higher boiling points than they would otherwise have.

Characteristics of the Liquid State

The most familiar liquid states at room temperature are water, alcohol, benzene, carbon tetrachloride, corn oil, and gasoline.

Two elements, Bromine and Mercury are liquids at room temperature. A third element Gallium has a melting point slightly above room temperature

Glasses, although solids, are often called frozen liquids, because the arrangements of molecules in glasses are very similar to those in liquid states.

Properties of liquids- Viscosity

- **Viscosity of a liquid is a measure of the resistance of a liquid to flow,**
- **Viscosity is measured in N s m^{-2} (SI Units) or *poise* (P) or centipoise (cP).**

  1 P = 0.1 N s m^{-2}

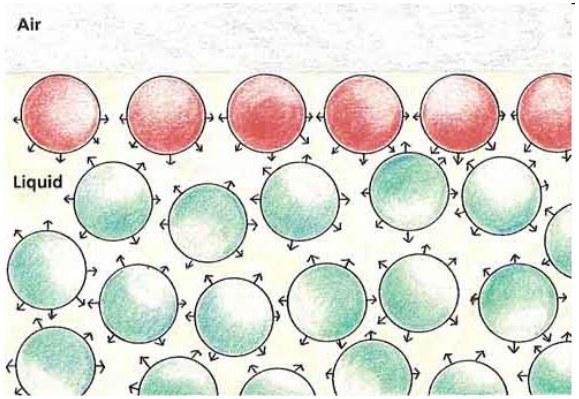
  1 cP = 0.001 N s m^{-2}

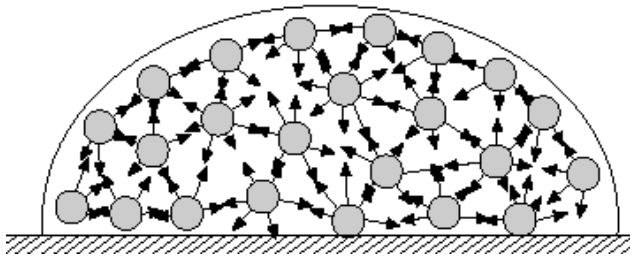
Surface Tension

- **Surface tension** is the energy required to stretch a unit change of the surface area. Thus its units are N * m m^{-2} = N/m.
- There is no direct correlation between viscosity and surface tension. These two properties are independent of each other.
- The surface tension is due to the unbalanced force experience by molecules at the surface of a liquid.
- As a result of surface tension, a drop of liquid tends to form a sphere, because a sphere offers the smallest area for a definite volume.

Surface Tension

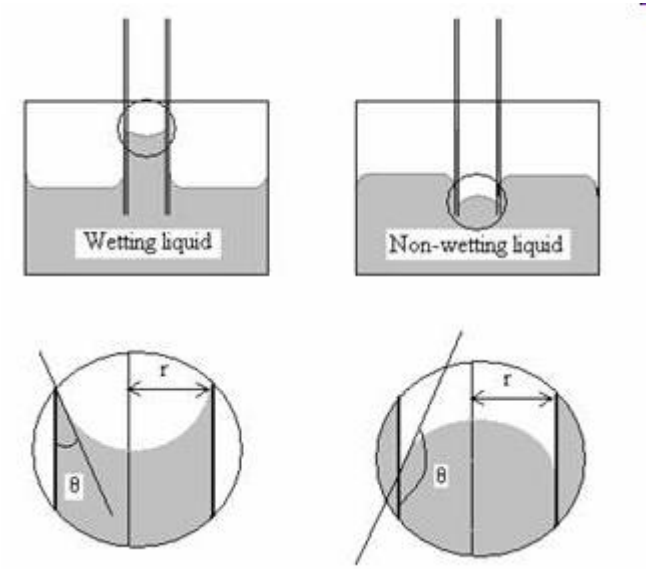
- **Substances with low surface tension have a tendency to form thin films.**
- **When detergent is added to water, it lowers the surface tension.**
- **Blowing soap water with a straw forms bubbles, due to the low surface tension.**



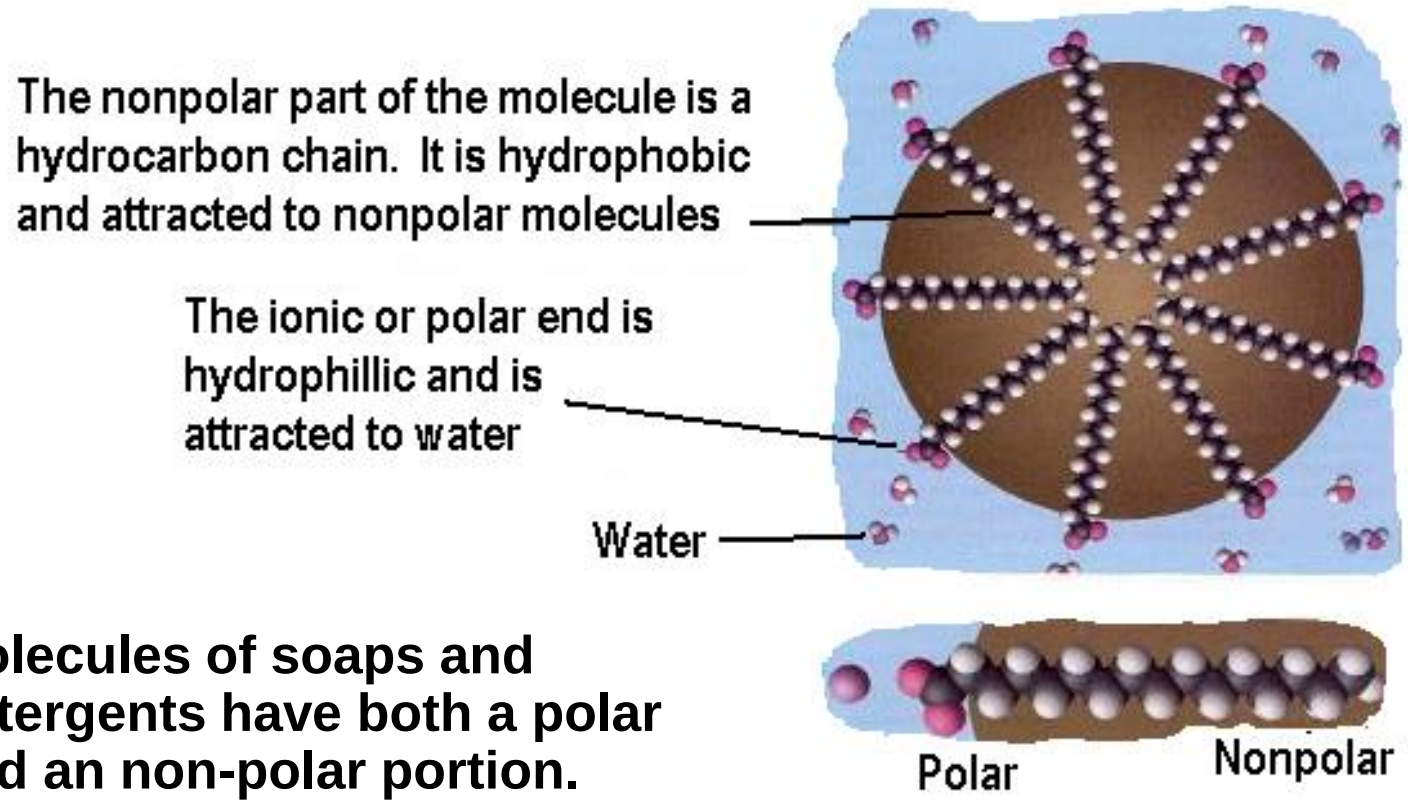


Cohesion and Adhesion

- **Cohesion** is the intermolecular attraction between like molecules,
- **Adhesion** is the intermolecular attraction between unlike molecules.
- Liquids with high surface tensions have strong cohesion forces, and they are poor wetting liquid due to low adhesion forces.
- A **detergent or wetting agent** is a substance that increases the adhesion force between two different materials.



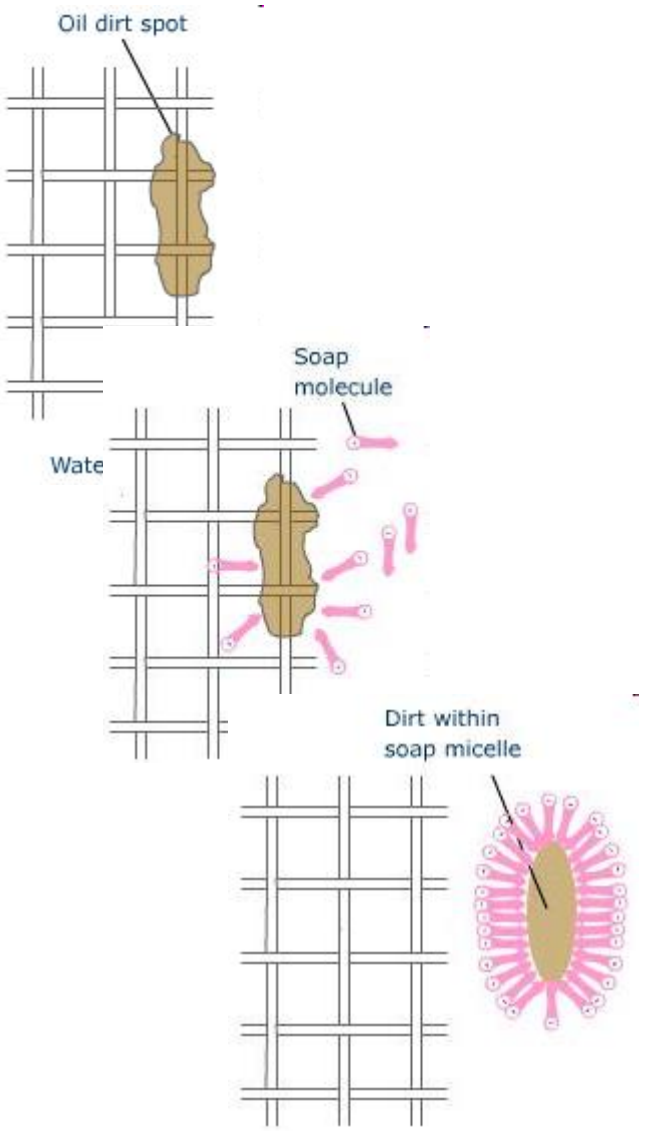
Soaps and Detergents



Molecules of soaps and detergents have both a polar and an non-polar portion.

Soaps and Detergents

- For this reason soaps and detergents are referred to as **wetting agents**.
- The **wetting agent** increases the wetting action of water with the non-polar material.
- By this action, dirt is removed when washed with water.



Capillary Action

- When a small tube is dipped into a liquid, the level in the tube is usually higher or lower than that of the bulk liquid.
- If **adhesion force** between the tube material and the liquid is stronger than the **cohesion force**, the level is higher. Otherwise, the level is lower.
- Such phenomena are called **capillary action.**
- Capillary action is one of the factors responsible for transport of liquid and nutrients in plants, and sometimes in animals.