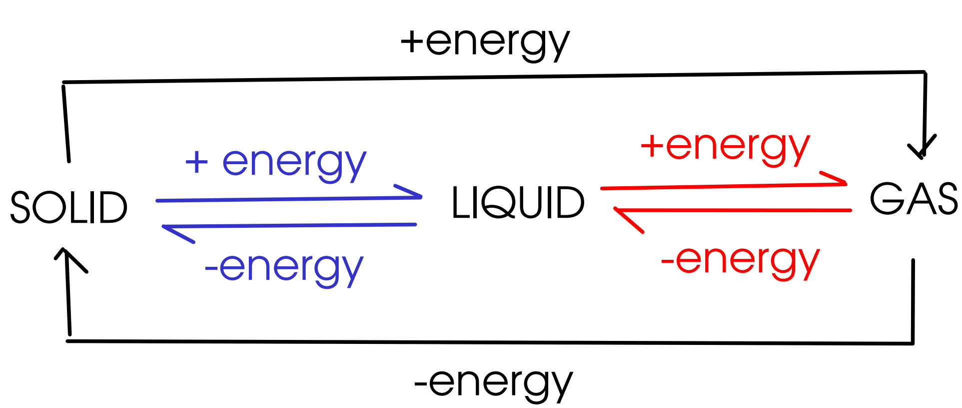
PHASE CHANGES

- To understand solids and liquids at the molecular level, it will help to examine PHASE CHANGES in a little more detail.

A quick review of the phase changes...

Phase change	Description	Energy change
Melting	Solid to liquid	Endothermic
Sublimation	Solid to gas	Endothermic
Vaporization	Liquid to gas	Endothermic
Deposition	Gas to solid	Exothermic
Freezing	Liquid to solid	Exothermic
Condensation	Gas to liquid	Exothermic

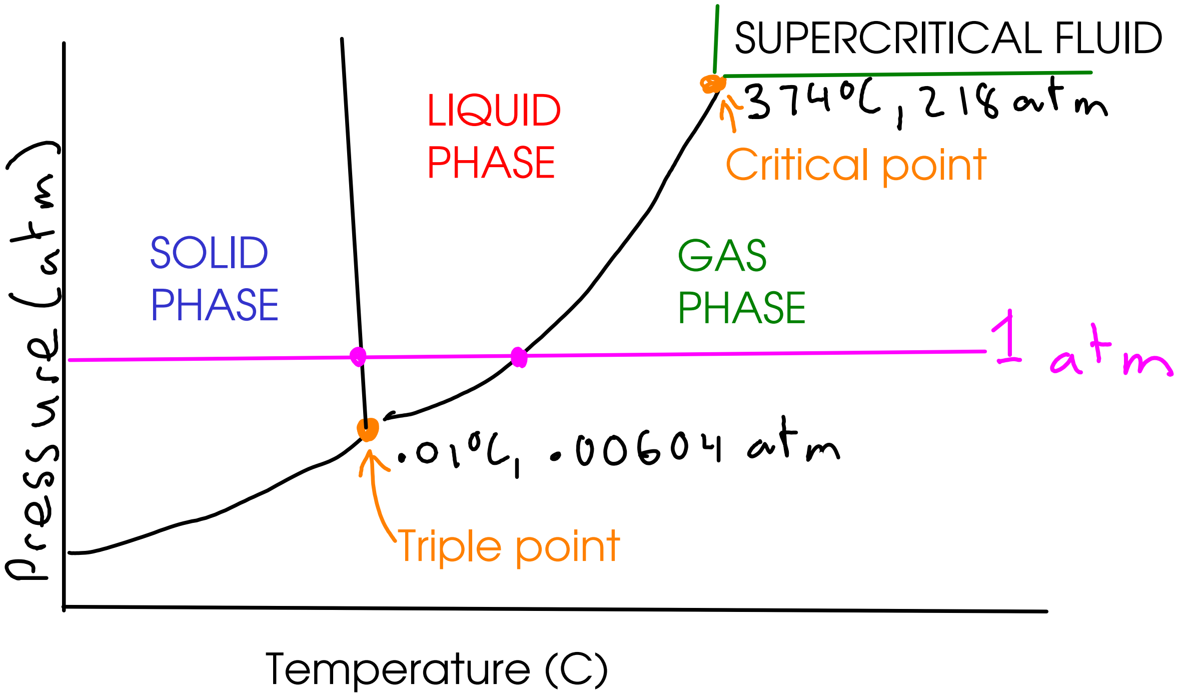


ΔH_{fus} : enthalpy change to melt 1 mol of solid

ΔH_{vap} : enthalpy change to vaporize 1 mol of liquid

PHASE DIAGRAMS

- are a convenient way to show experimental data on when bulk phase changes occur.



SAMPLE PHASE DIAGRAM FOR WATER

See p 439-440 for more!

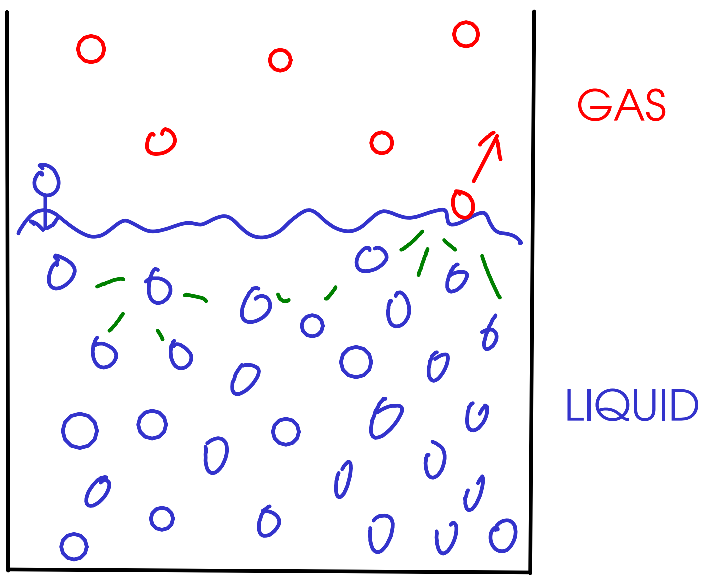
- The curves on the phase diagram represent bulk phase changes.

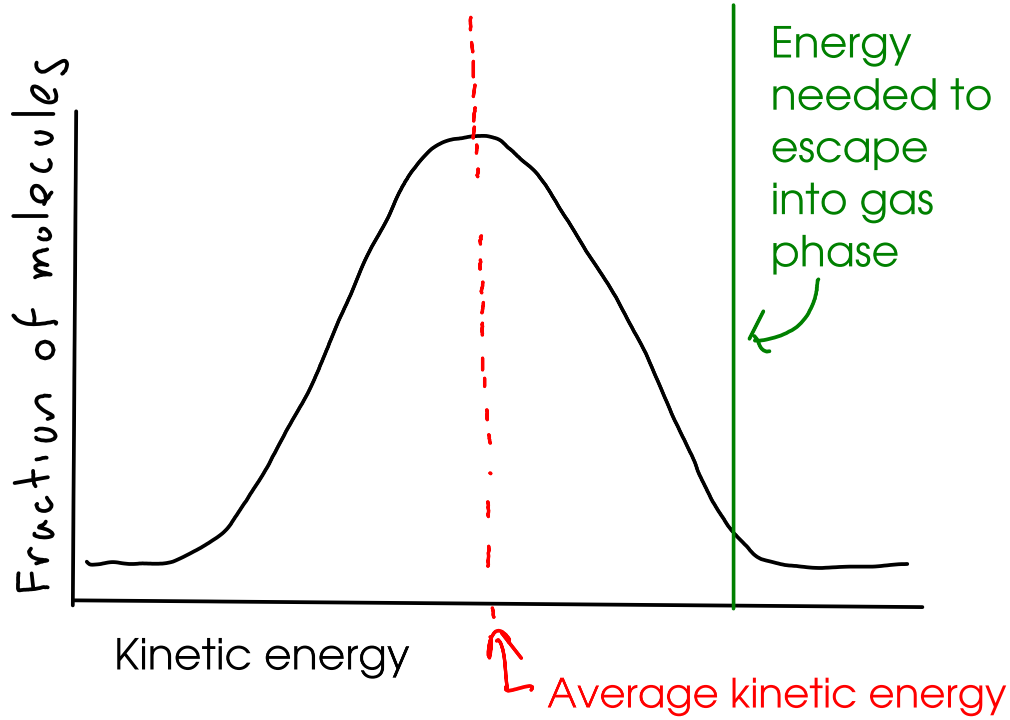
- The TRIPLE POINT is a set of conditions where all six phase changes occur at the same time; in other words all three phases coexist

- The CRITICAL POINT occurs where there stops being a distinction between the gas and liquid states. This occurs at high pressure and high temperature, where the substance has the density of a liquid but the fluidity of a gas. This is called a SUPERCRITICAL FLUID. Supercritical fluids - like supercritical carbon dioxide - are often used as environmentally friendly SOLVENTS.

- The normal boiling point and freezing points are on the curves. The normal melting point is the point on the solid/liquid curve at 1 atm, while the normal boiling point is on the liquid/gas curve at 1 atm!

VAPORIZATION IN MORE DETAIL





- For a molecule to move from the liquid phase to the gas phase, it must acquire enough KINETIC ENERGY (which depends on molecular SPEED) to break away from the INTERMOLECULAR FORCES holding the molecule in the liquid.

- The AVERAGE KINETIC ENERGY of molecules is proportional to the TEMPERATURE. On average, molecules in both the liquid and the solid state move faster at higher temperatures.

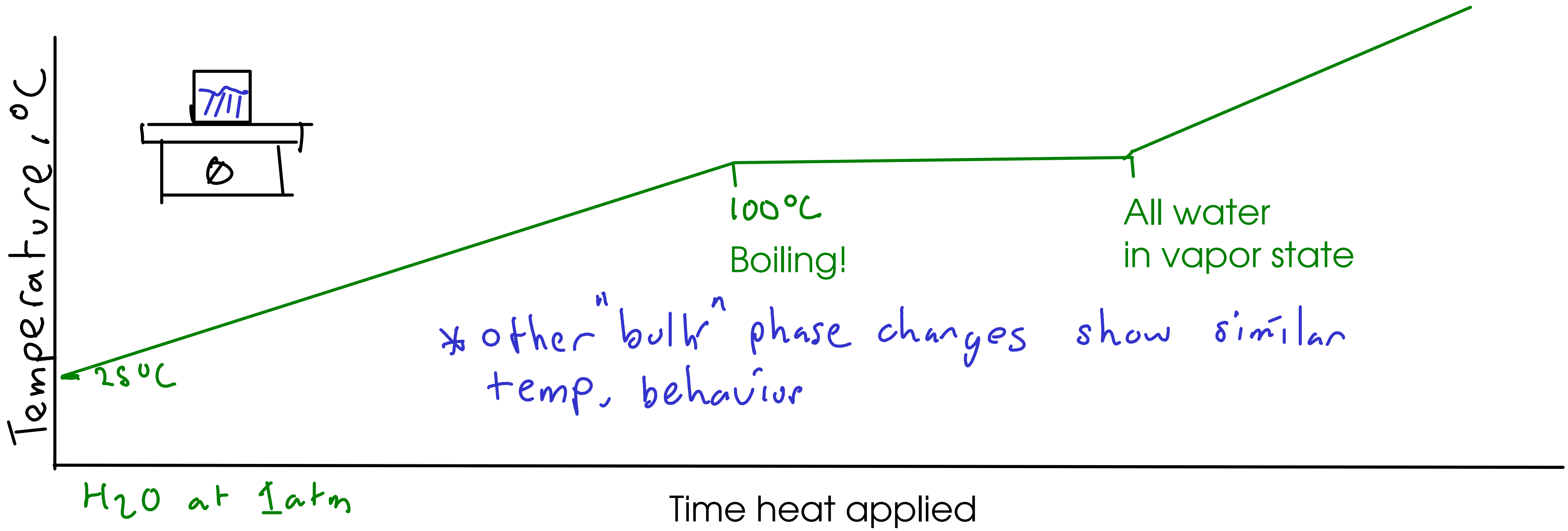
- Even at room temperature, some of the molecules have enough kinetic energy to escape into the gas phase. This accounts for the tendency of volatile liquids to evaporate from open containers even well away from the boiling point.

- As we increase temperature, the gaussian curve above shifts to the right, and a higher fraction of molecules have enough energy to vaporize.

TEMPERATURE PROFILE OF VAPORIZATION

- To increase the rate of vaporization, we can increase the temperature. At the BOILING POINT, the pressure of the vaporizing water is enough to push back against the liquid water and bubbles of vapor form in the liquid: BOILING

- If we look at the temperature changes up to and through the boiling point, we see something interesting...



DURING THE BOILING PROCESS, as long as you have some liquid water remaining, the temperature will remain constant - EVEN AS YOU CONTINUE TO APPLY HEAT!

How do we explain this behavior? ↙ ΔH_{vap}

- The VAPORIZATION itself requires an energy input. What's that energy doing? Breaking water molecules away from one another (breaking apart the water's intermolecular forces).

LIQUIDS

- FLUID, DENSE, INCOMPRESSIBLE

- Posess a few unique properties

(1) SURFACE TENSION

- a measure of the tendency of a liquid to minimize its surface area, or the resistance to the breaking of a liquid surface.

Liquid droplets tend to be spehrical...

... but friction causes falling droplets to take on the traditional "drop" shape.

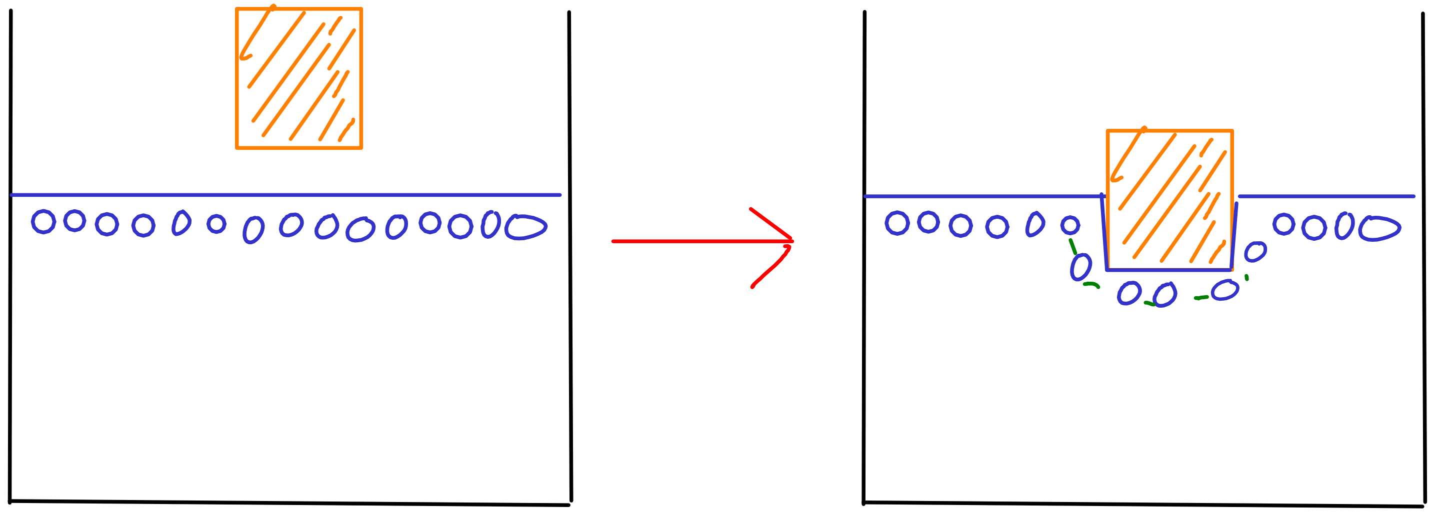
A sphere has the smallest surface area for a given volume.

(2) VISCOSITY (also for gases)

- a measure of a liquids resistance to flow, or "thickness"

SURFACE TENSION

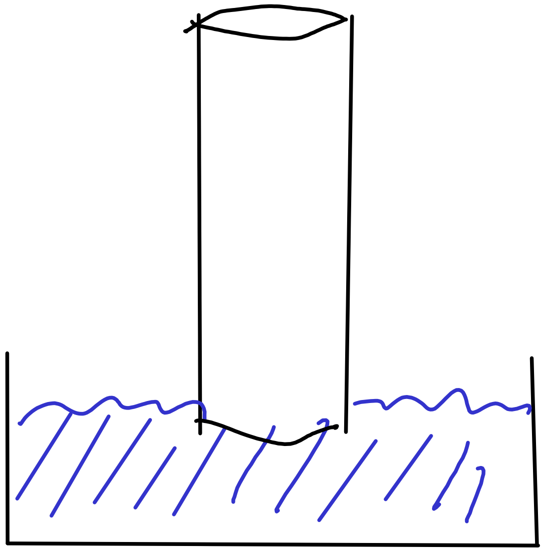
- Surface tension can be explained by looking at liquid molecules as being attracted to each other by INTERMOLECULAR FORCES.

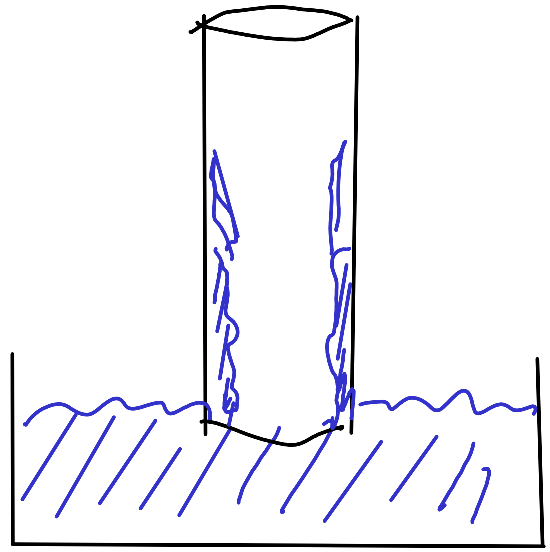


The object increases the surface area of the liquid!

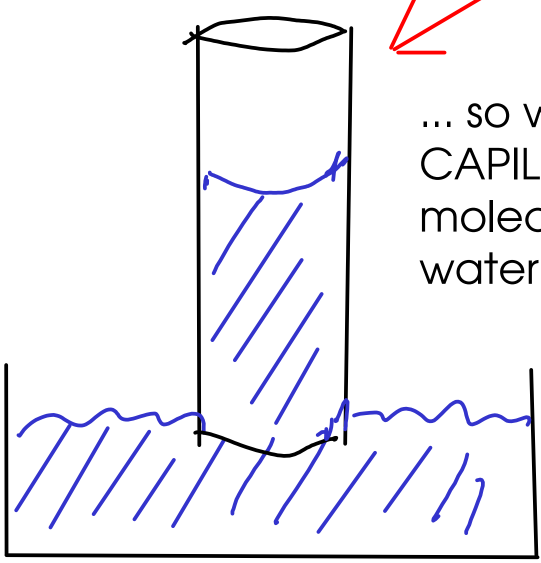
For the object to penetrate the liquid surface, it must push water molecules at the surface apart. Since these water molecules ARE ATTRACTED TO ONE ANOTHER, the liquid will resist!

[39] Surface tension also explains CAPILLARY ACTION, the drawing up of WATER into a glass tube. Water is attracted to glass, and will climb up the surface of a glass tube.





... but this greatly increases the SURFACE AREA of the water, and pulls the water molecules farther from each other.



... so water is PULLED UP THE MIDDLE OF THE CAPILLARY by the attractive forcea between water molecules. This minimizes the surface area of the water and gets water molecules closer to one another.

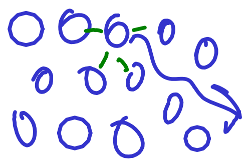
... the water is pulled up AGAINST GRAVITY!

VISCOSITY

- viscosity can also be explained (at least partially) by looking at INTERMOLECULAR FORCES!

- For a liquid to FLOW, its molecules must move past one another. This means that some of the molecules must move farther away from other molecules. Since the molecules in the liquid state are ATTRACTED TO ONE ANOTHER, thst means the flowing will be slowed.

- Viscosity is also determined by STRUCTURE. Liquids with large chains (like oils) which can rotate and tangle in one another will also be viscous.



Molecules have to move past one another to flow, and stronger attractions between molecules make that more difficult!

INTERMOLECULAR FORCES IN LIQUIDS

- "Intermolecular forces" is a generic term. It refers to any number of forces that exist between molecules!

- In liquids, there are three main types of intermolecular force

(1) DIPOLE-DIPOLE INTERACTIONS

- only for polar molecules

(2) LONDON DISPERSION FORCES

- exist in all liquids

(1) and (2): van der Waals forces...

(3) HYDROGEN BONDS

- exist only when hydrogen is directly bonded to a highly electronegative atom.