

## Phase Changes

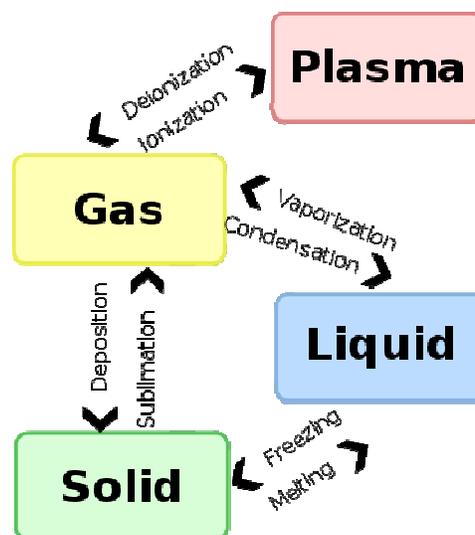
### Endothermic Process

- Heat must be supplied to the system
- Heat is from the surroundings (or external heat source)
- Melting, vaporization, sublimation

## Exothermic Process

- Gives off heat
- The heat is transferred to the surroundings
- Condensation, freezing (solidification), deposition

## Possible Phase Transitions



## Melting

- Heat added to the system goes to increase the kinetic energy of the solid particles
  - The temperature of the substance does not change
- Once a particle has enough energy to change phase it does
- Temperature will not change until all particles have changed phase

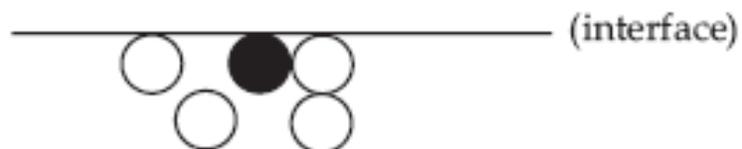
## Melting Point

- The temperature at which the forces holding the crystal lattice together are broken and it becomes a liquid

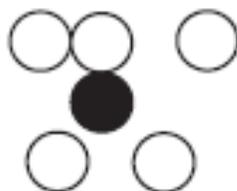
# Vaporization

- The process by which a liquid changes to a gas or vapor
- If the input of heat energy is gradual, the molecules tend to escape from the surface of the liquid
  - The molecules at the surface are attracted to fewer other molecules than those in the interior

Particle at Surface

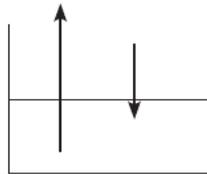


Particle in the Interior

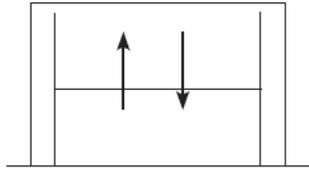


- When vaporization occurs **only** at the surface of a liquid, it is called evaporation
- Even at cold temperatures some molecules have enough energy to escape from the liquid (evaporate)
- As the temperature rises more and more molecules obtain the minimum energy required to escape from the liquid
- The time it takes to evaporate depends on the amount of liquid, the surface area, and the amount of energy available

- At the surface of a liquid two things are happening
  - Evaporation (Vaporization)
    - Particles escaping from the liquid
  - Condensation
    - Particles being “recaptured” by the liquid
- If the liquid is in an open container, the rate of evaporation is usually greater than the rate of condensation
  - More particles will escape and the level of the liquid will drop



- If the liquid is in a closed container, then the rate of evaporation will eventually equal the rate of condensation
  - The level of the liquid will no longer change (if the temperature remains constant)
  - This is called dynamic equilibrium



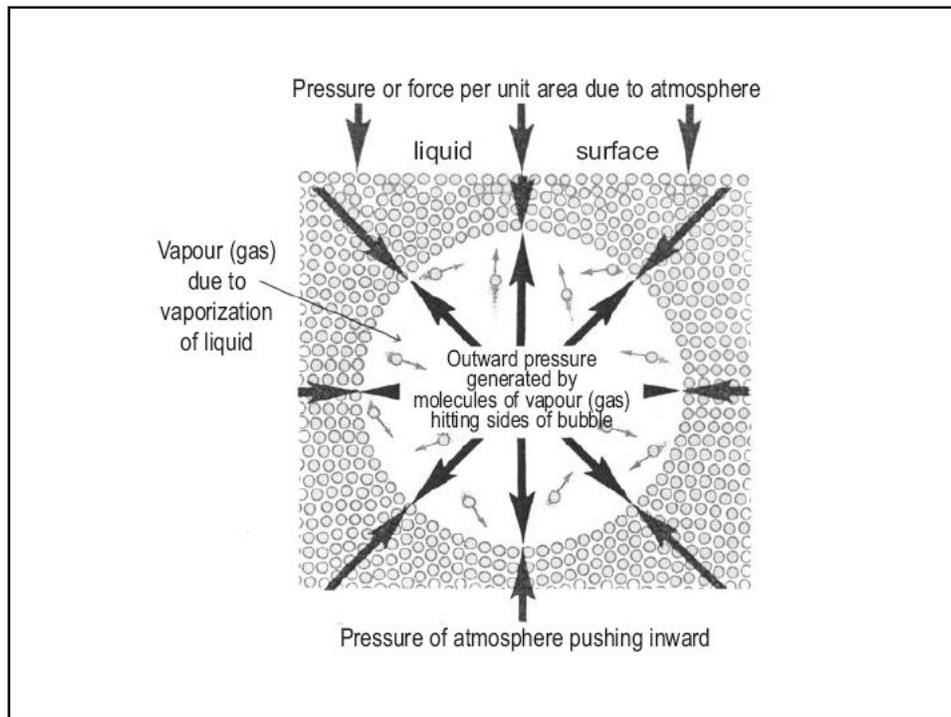
## Vapor Pressure

- The pressure exerted by a vapor over a liquid
  - Occurs because of evaporation

## Boiling Point

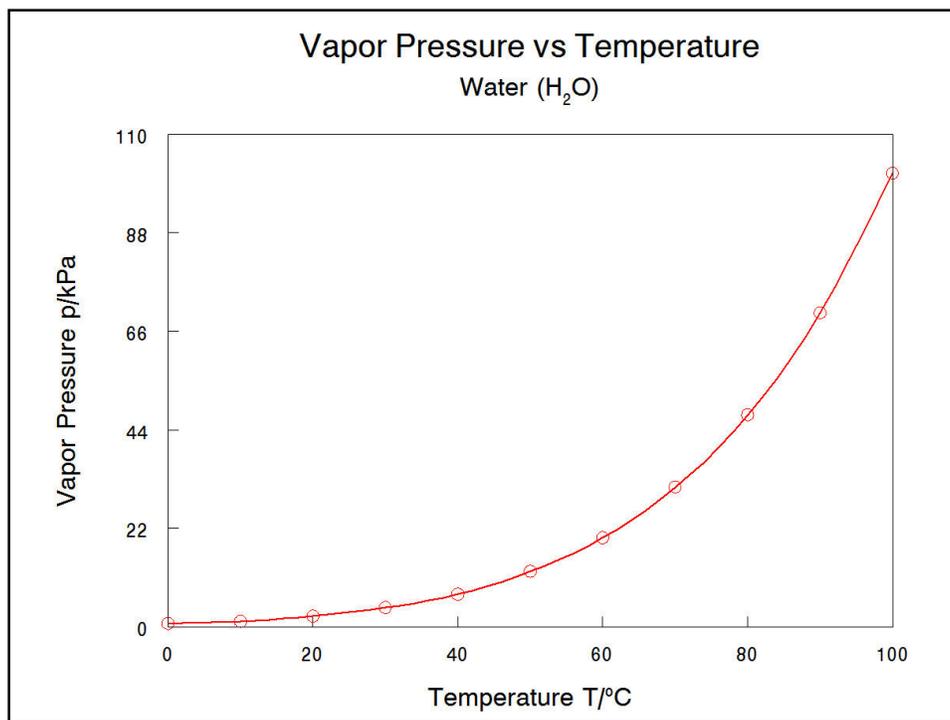
- At low temperatures and low average kinetic energy, only the particles at the surface are able to evaporate into the gaseous state
- As the temperature of the liquid increases, the number of particles having enough energy to overcome the intermolecular forces of attraction increases so that particles within the liquid are also able to change to gaseous particles.

- These gaseous particles form micro-bubbles within the liquid.
- If the vapor pressure of these micro-bubbles is less than the atmospheric pressure above the liquid, then the gas bubbles collapse and the particles within the bubbles return to the liquid state.
- However, if the vapor pressure of these micro-bubbles equals or exceeds the atmospheric pressure above the liquid, then the bubbles become larger and rise to the surface as the pressure on the bubbles becomes less.



- As the temperature of the liquid increases, more micro-bubbles form because more particles have enough energy to change phase.
- The temperature at which the vapor pressure of the liquid equals the atmospheric pressure above the liquid is called the boiling point.
- Normal boiling point occurs when the atmospheric pressure above the liquid is standard pressure (1 atmosphere, 101.3 kilopascals [kPa], or 760 mm of mercury).

- The vapor pressure of a given liquid is inversely proportional to the strength of the intermolecular forces of attraction
- The vapor pressure is also related to the average kinetic energy of the liquid
- If the pressure is low enough, a liquid can be made to boil at any temperature
- We can determine the boiling point at a certain pressure by looking at a vapor pressure vs temperature graph

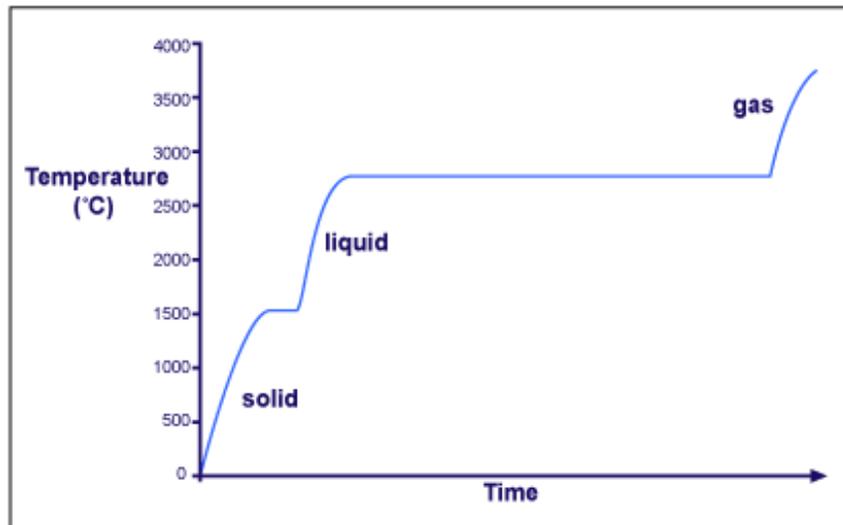


## Sublimation

- The process by which a solid changes directly to a gas without first becoming a liquid
- In this situation the particles gain enough energy to escape directly from the solid phase
- Dry ice (solid  $\text{CO}_2$ ), moth balls, solid air fresheners

- Ice cubes ( $\text{H}_2\text{O}$ ) left in the freezer for a long time will shrink because the ice sublimates
- At extremely low pressures, ice sublimates in a much shorter time period
- This process is used for freeze drying
  - Fresh food is frozen and placed in a container that is attached to a vacuum pump
  - As the pressure is reduced, the ice sublimates and is removed from the container
  - Freeze-dried foods contain no water and therefore can be stored for a long period of time

## Heating Curve



## Condensation

- The process by which a gas or vapor becomes a liquid
- Condensation is the opposite of vaporization
- Energy is released causes the particles to slow down allowing the intermolecular forces to take hold

## Freezing

- The reverse of melting
- Cooling the liquid causes the particles to lose energy and allow the intermolecular forces to take over

## Deposition

- The opposite of sublimation
- Frost and snow flakes

# Cooling Curve

