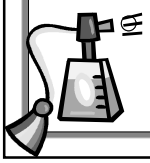
Chapter 13- The States of Matter

- Gases- indefinite volume and shape, low density.
- Liquids- definite volume, indefinite shape, and high density.
- Solids- definite volume and shape, high density
- Solids and liquids have high densities because their molecules are close together.

Kinetic Theory

- **Kinetic theory says that molecules are in constant motion.**
- **Perfume molecules moving across the room are evidence of this.**

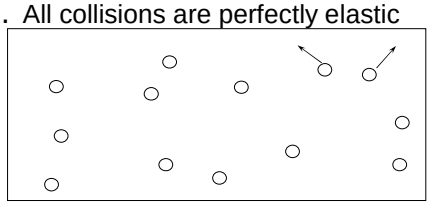


The Kinetic Theory of Gases

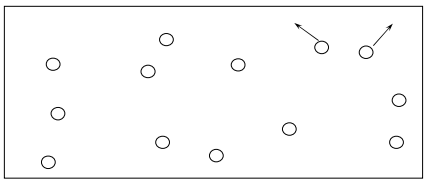
Makes three descriptions of gas particles

1. A gas is composed of particles
   - molecules or atoms
   - Considered to be hard spheres far enough apart that we can ignore their volume.
   - Between the molecules is empty space.

2. The particles are in constant random motion.
   - Move in straight lines until they bounce off each other or the walls.
3. All collisions are perfectly elastic

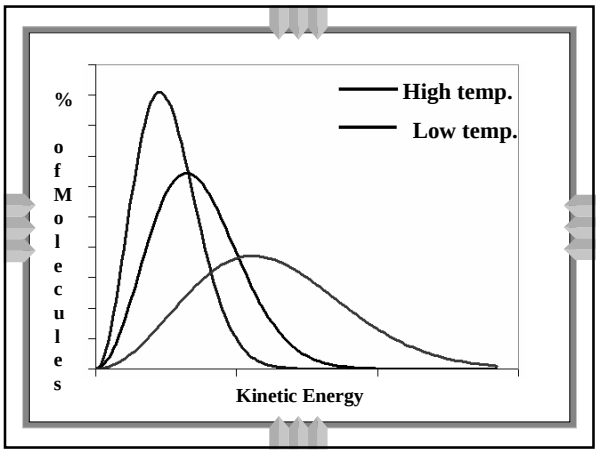


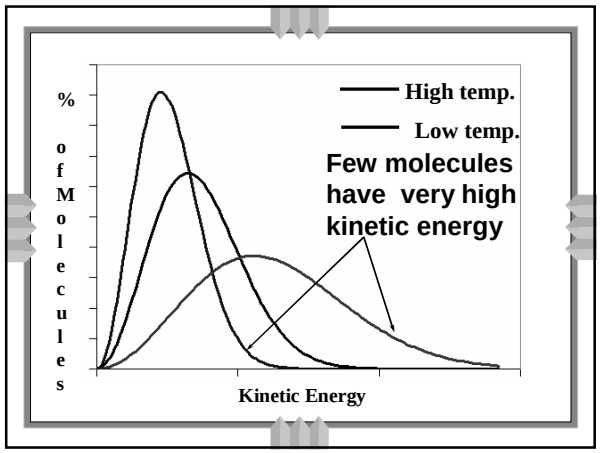
- The Average speed of an oxygen molecule is 1656 km/hr at 20ºC
- The molecules don't travel very far without hitting each other so they move in random directions**.**

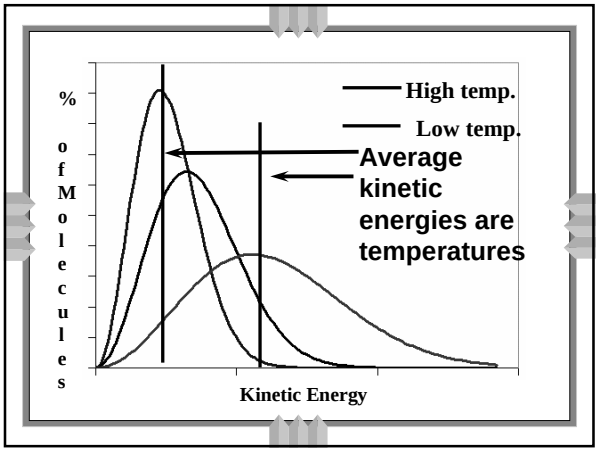


Kinetic Energy and Temperature

- Temperature is a measure of the Average kinetic energy of the molecules of a substance.
- Higher temperature faster molecules.
- At absolute zero (0 K) all molecular motion would stop**.**







Temperature

- The average kinetic energy is directly proportional to the temperature in Kelvin
- If you double the temperature (in Kelvin) you double the average kinetic energy.
- If you change the temperature from 300 K to 600 K the kinetic energy doubles.

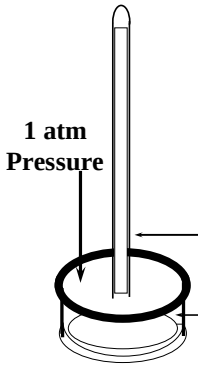
Temperature

- If you change the temperature from 300ºC to 600ºC the Kinetic energy doesn't double.
- 873 K is not twice 573 K

Pressure

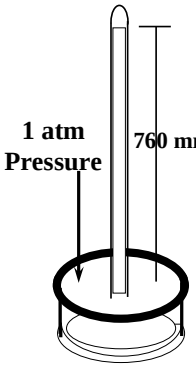
- Pressure is the result of collisions of the molecules with the sides of a container.
- A vacuum is completely empty space - it has no pressure.
- Pressure is measured in units of atmospheres (atm).
- It is measured with a device called a barometer.

Barometer



- At one atmosphere pressure a column of mercury 760 mm high.

Barometer



- At one atmosphere pressure a column of mercury 760 mm high.
- A second unit of pressure is mm Hg
- 1 atm = 760 mm Hg
- Third unit is the Pascal
- 1 atm = 101.3 kPa

Pressure units

- kilopascals – kPa
- 1 atm = 760 mm Hg = 101.3 kPa
- Can make conversion factors from these

Convert

- 1 atm = 760 mm Hg = 101.3 kPa
- 743 mm Hg to atm
- 895 kPa to mm Hg

Same KE – different speed

- Mass affects kinetic energy.
- Less mass, less kinetic energy at the same speed
- The smaller particles must have a greater speed to have the same kinetic energy.
- Same temperature, smaller particles move faster

Liquids

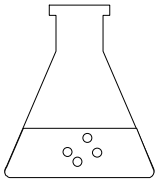
- Particles are in motion.
  - Tends to pull them apart
- Attractive forces between molecules keep them close together.
- These are called intermolecular forces.
  - Inter = between
  - Molecular = molecules

Breaking intermolecular forces.

- **Vaporization - the change from a liquid to a gas below its boiling point.**
- **Evaporation - vaporization of an uncontained liquid (no lid on the bottle).**

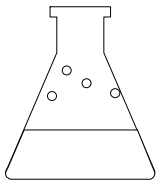
Evaporation

- **Molecules at the surface break away and become gas.**
- **Only those with enough KE escape**
- **Evaporation is a cooling process.**
- **It requires energy.**



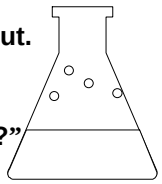
Condensation

- **Change from gas to liquid**
- **Molecules stick together**
- **Releases energy.**



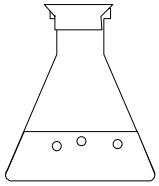
Condensation

- **Achieves a dynamic equilibrium with vaporization in a closed system.**
- **What is a closed system?**
- **A closed system means matter can't go in or out. (put a cork in it)**
- **What the heck is a "dynamic equilibrium?"**



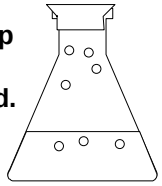
Dynamic equilibrium

- **When first sealed the molecules gradually escape the surface of the liquid**



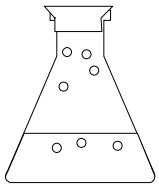
Dynamic equilibrium

- **When first sealed the molecules gradually escape the surface of the liquid**
- **As the molecules build up above the liquid some condense back to a liquid.**



Dynamic equilibrium

- **As time goes by the rate of vaporization remains constant**
- **but the rate of condensation increases because there are more molecules to condense.**
- **Equilibrium is reached when**



Dynamic equilibrium

Rate of Vaporization = Rate of Condensation

- **Molecules are constantly changing phase "Dynamic"**
- **The amount of liquid and vapor remains constant "Equilibrium"**

Vapor Pressure

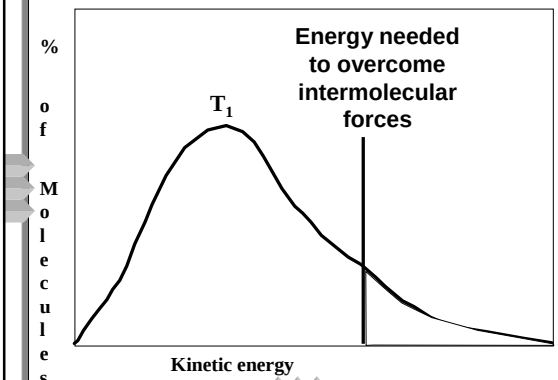
- In a closed container the gas molecules will cause pressure.
- The pressure at equilibrium is called vapor pressure
- Different compounds have different vapor pressures because of different intermolecular forces
- Stronger forces, lower vapor pressure

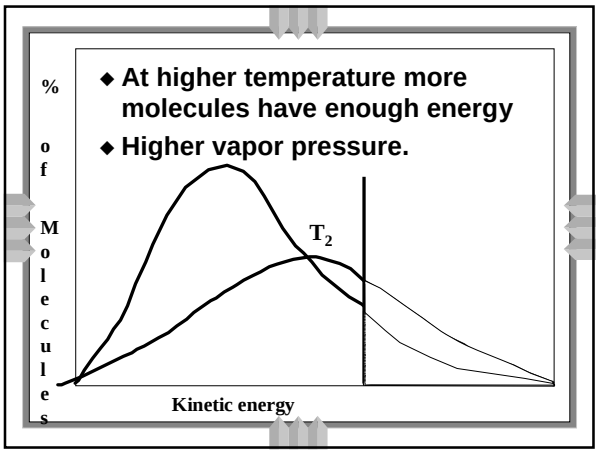
Vapor Pressure

- At higher temperature there are more gas molecules
- More have the energy to escape
- Higher vapor pressure

Vaporization

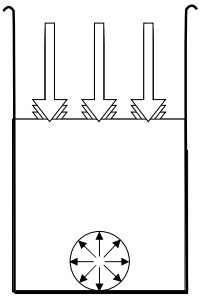
- **Vaporization requires heat.**
- **Energy is required to overcome intermolecular forces**
- **Absorbing heat cools**
- **Highest kinetic energy leaves**
- **Average drops**
- **Why we sweat.**





Boiling

- Making bubbles of gas
- Forces liquid level to rise
- Must push against air pressure on the liquid.



Boiling

- A liquid boils when the vapor pressure = the external pressure
- Temperature is called the boiling point
- Normal Boiling point is the temperature a substance boils at 1 atm pressure.
- The temperature of a liquid can never rise above it's boiling point
- Energy goes into breaking forces, not moving faster.

Changing the Boiling Point

- Lower the pressure (going up into the mountains).
- Lower external pressure requires lower vapor pressure.
- Easier to make bubbles
- Lower vapor pressure means lower boiling point.
- Food cooks slower.

Changing the Boiling Point

- Raise the external pressure (Use a pressure cooker)
- Raises the vapor pressure needed.
- Harder to make bubbles
- Raises the boiling point.
- Food cooks faster.

Different Boiling points

- Different substances boil at different temperatures because they have different intermolecular forces
  - Weak forces- lower boiling point
- Different vapor pressures
  - Low vapor pressure – high boiling point

Solids

- **Intermolecular forces are strong**
- **Molecules still move**
- **Can only vibrate and revolve in place.**
- **Particles are locked in place - don't flow.**
- **Melting point is the temperature where a solid turns into a liquid.**
- **The melting point is the same as the freezing point.**

Solids

- **When heated the particles vibrate more rapidly until they shake themselves free of each other.**
- **As they are heated the temperature doesn't change.**
- **The energy goes into breaking bonds, not increasing motion**
- **Move differently, not faster.**

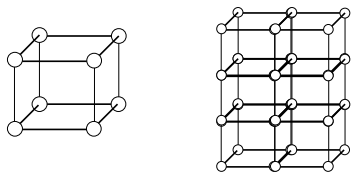
Solids

- **Molecular solids have weak intermolecular forces so a low mp.**
- **Polar molecules higher mp than nonpolar**
- **Hydrogen bonding higher still**
- **Ionic solids have stronger intermolecular forces so even high mp.**

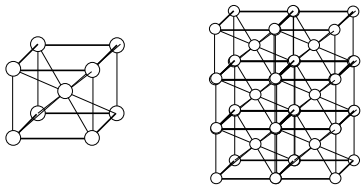
Crystals

- **A regular repeating three dimensional arrangement of atoms in a solid.**
- **Most solids are crystals.**
- **Break at certain angles**

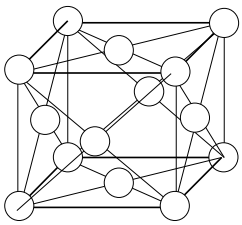
Cubic



Body-Centered Cubic

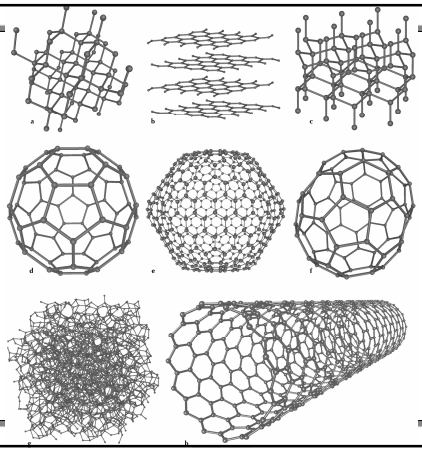


Face-Centered Cubic



Allotropes

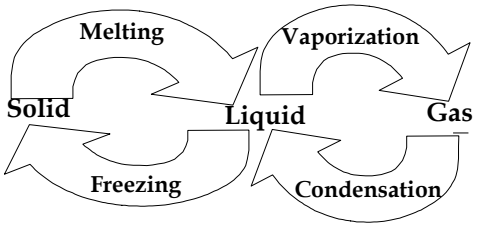
- **When one compound has two or more crystal structures, they are called allotropes.**
- **Graphite, diamond and soot are all carbon**
- **New carbon structures-**
  - Fullerenes- pattern on soccer ball
  - Carbon nanotubes

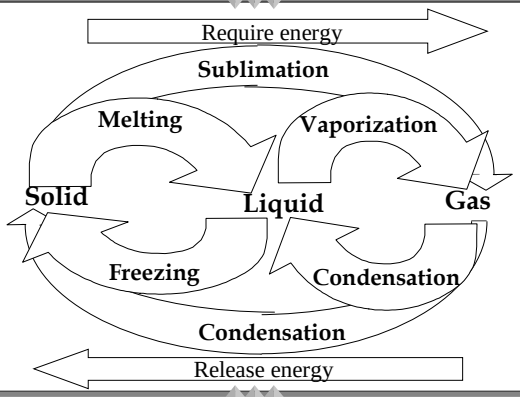


Amorphous solids

- **lack an orderly internal structure.**
- **Think of them as super-cooled liquids.**
- **Glasses are one type.**
- **Rigid but lacking structure**
- **Do not melt- just gradually get softer.**
- **Shatter at random angles**

Phase Changes



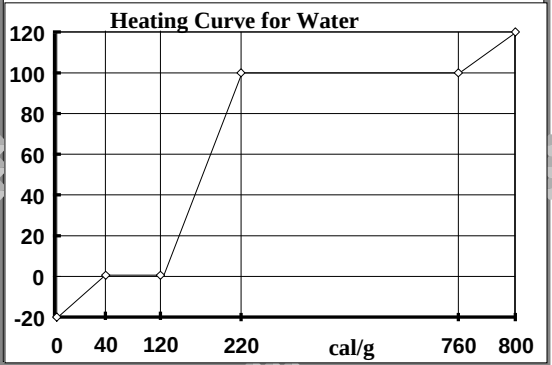


Temperature and Phase Change

- **The temperature doesn't change during a phase change.**
- **If you have a mixture of ice and water, the temperature is 0ºC**
- **At 1 atm, boiling water is 100ºC**
- **You can't get the temperature higher until it boils**

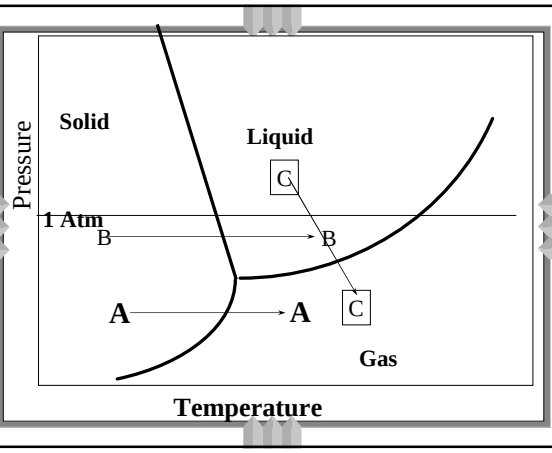
Heating Curve

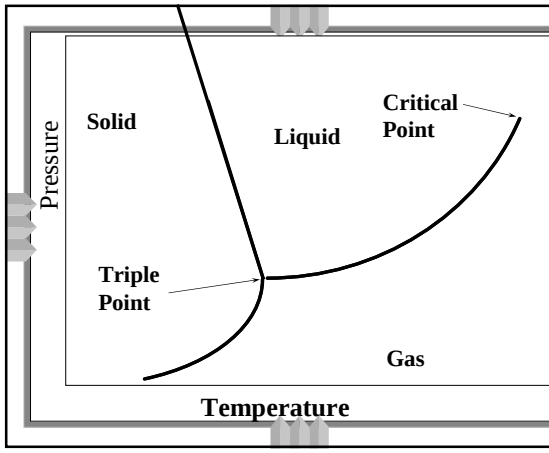
- **A graph of Energy versus temperature.**

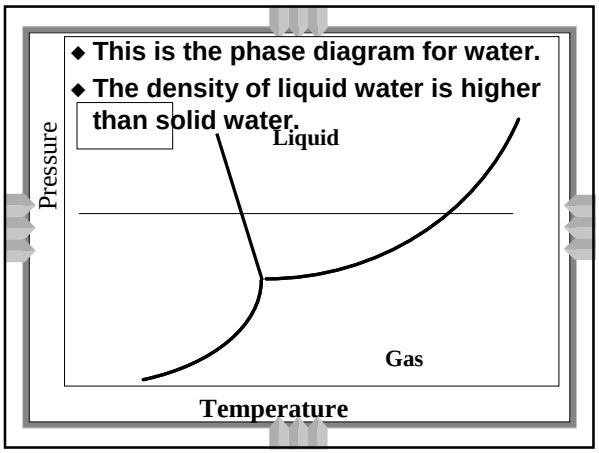


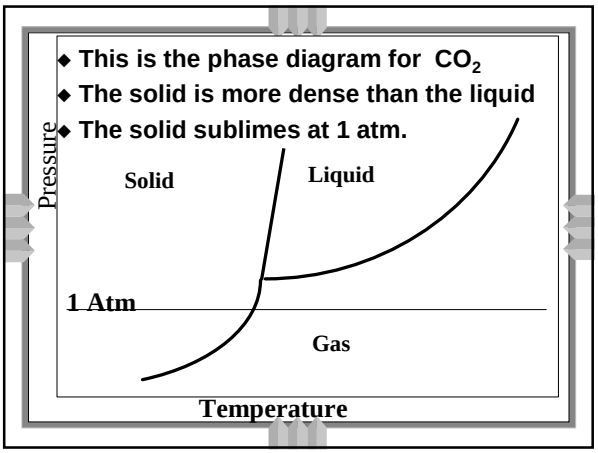
Phase Diagram

- **Graph of Pressure versus temperature for a compound.**
- **Draw lines where the phase changes.**






◆ This is the phase diagram for water.
◆ The density of liquid water is higher than solid water.
Pressure
Liquid
Gas
Temperature


◆ This is the phase diagram for CO_2
◆ The solid is more dense than the liquid
◆ The solid sublimes at 1 atm.
Pressure
Solid
Liquid
1 Atm
Gas
Temperature