

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

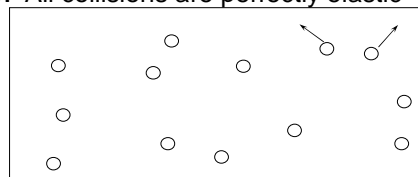
Makes three descriptions of gas particles

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.

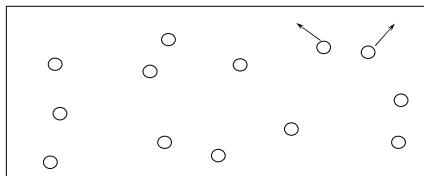
2. The particles are in constant random motion.

- ◆ Move in straight lines until they bounce off each other or the walls.

3. All collisions are perfectly elastic

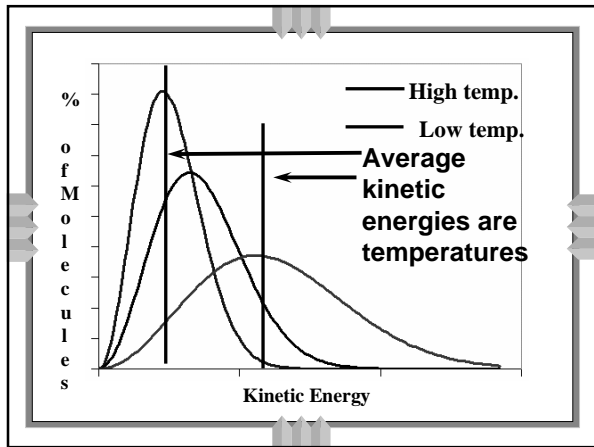
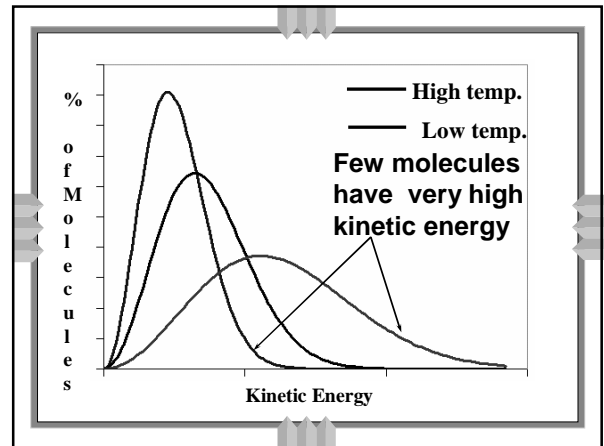
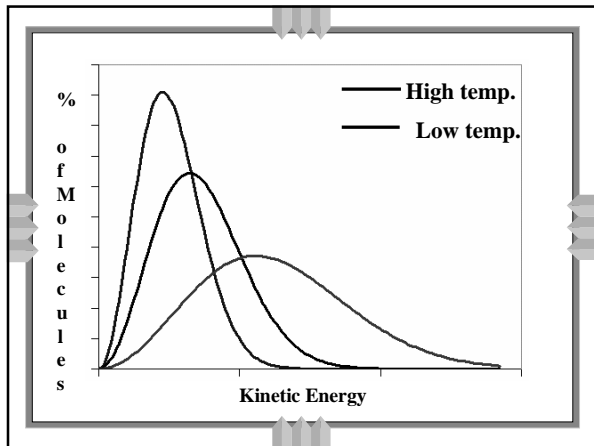


- ◆ The Average speed of an oxygen molecule is 1656 km/hr at 20°C
- ◆ The molecules don't travel very far without hitting each other so they move in random directions.



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

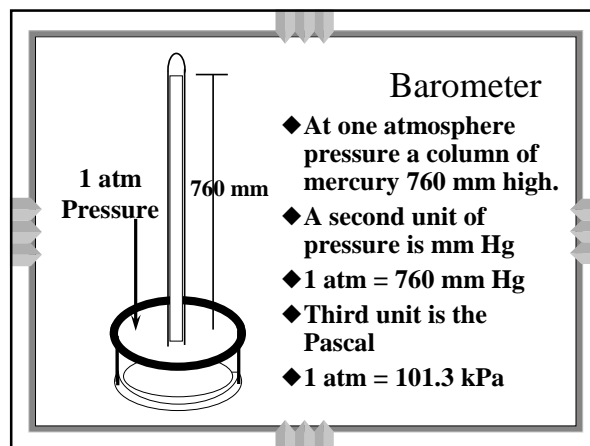
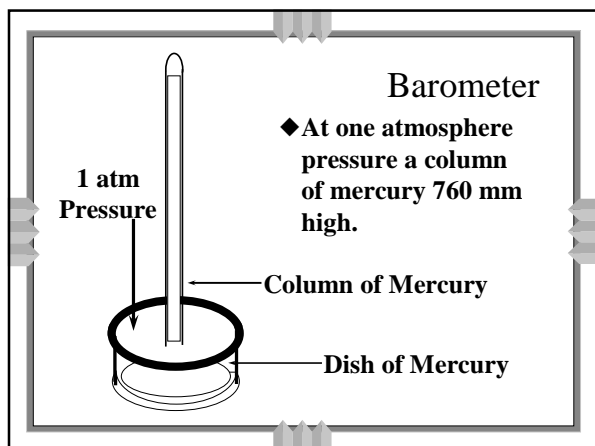
- ◆ The average kinetic energy is directly proportional to the temperature in Kelvin
- ◆ If you double the temperature (in Kelvin) you double the average kinetic energy.
- ◆ If you change the temperature from 300 K to 600 K the kinetic energy doubles.

Temperature

- ◆ If you change the temperature from 300°C to 600°C 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.



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

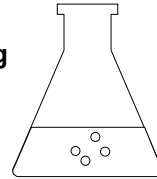
- ◆ Particles are in motion.
 - Tends to pull them apart
- ◆ Attractive forces between molecules keep them close together.
- ◆ These are called intermolecular forces.
 - Inter = between
 - Molecular = molecules

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).

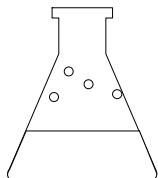
Evaporation

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



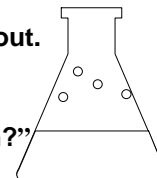
Condensation

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



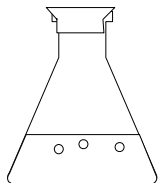
Condensation

- 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?"



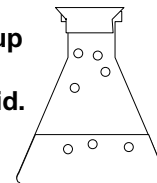
Dynamic equilibrium

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



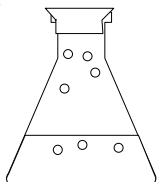
Dynamic equilibrium

- 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

$$\text{Rate of Vaporization} = \text{Rate of Condensation}$$

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

Vapor Pressure

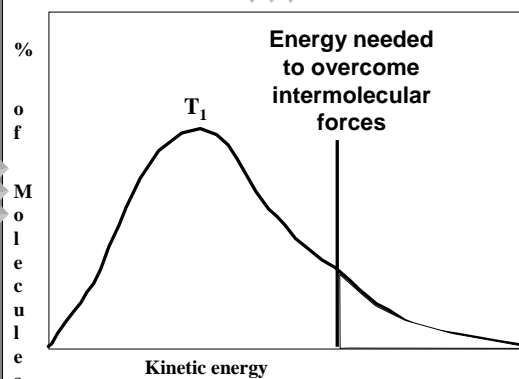
- ◆ In a closed container the gas molecules will cause pressure.
- ◆ The pressure at equilibrium is called vapor pressure
- ◆ Different compounds have different vapor pressures because of different intermolecular forces
- ◆ Stronger forces, lower vapor pressure

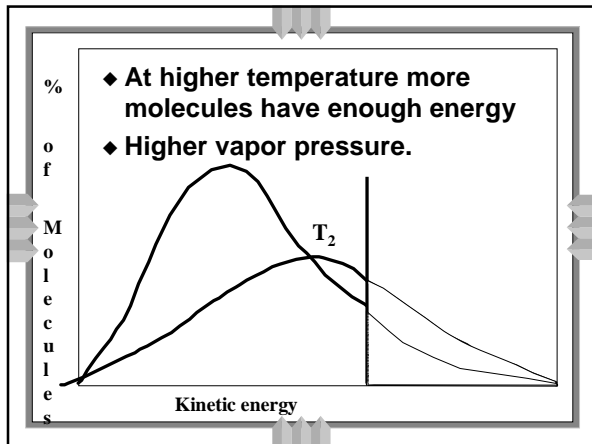
Vapor Pressure

- ◆ 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.

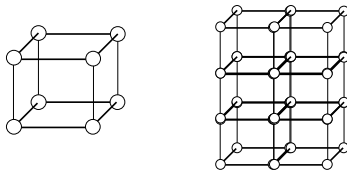
Solids

- ◆ 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.

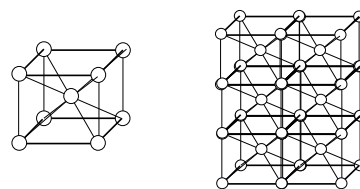
Crystals

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

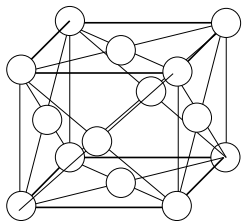
Cubic



Body-Centered Cubic

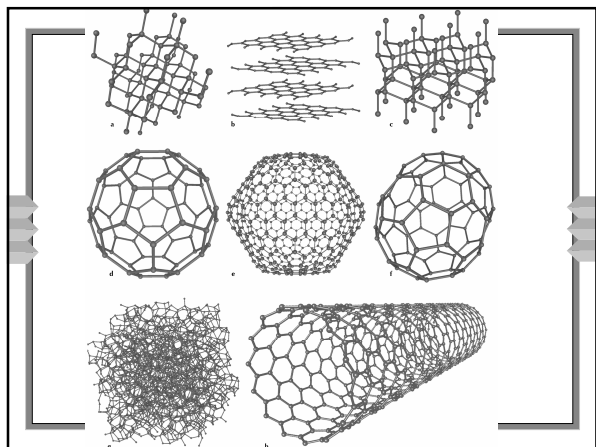


Face-Centered Cubic



Allotropes

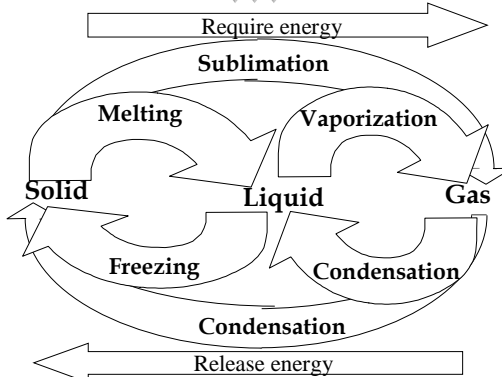
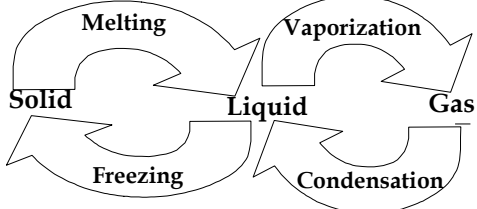
- ◆ When one compound has two or more crystal structures, they are called allotropes.
- ◆ Graphite, diamond and soot are all carbon
- ◆ New carbon structures-
 - Fullerenes- pattern on soccer ball
 - Carbon nanotubes



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

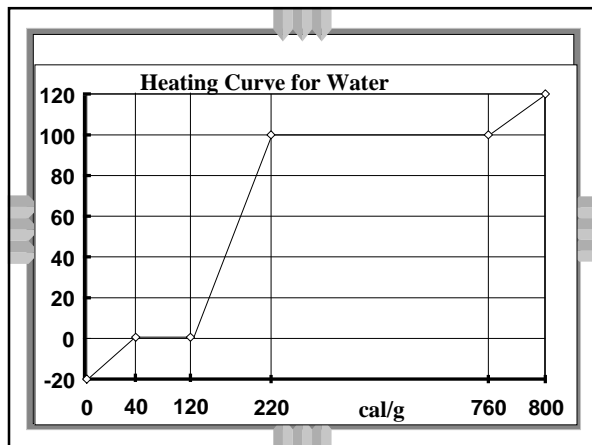


Temperature and Phase Change

- ◆ The temperature doesn't change during a phase change.
- ◆ If you have a mixture of ice and water, the temperature is 0°C
- ◆ At 1 atm, boiling water is 100°C
- ◆ 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.

