7-0

States of Matter

- Solid
- Liquid
- Gas
- Most (all) things can exist in all three states

7-1

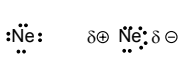
The Kinetic Molecular Theory (KMT)

1. All particles are in continuous, random motion.
2. Particles move in straight lines, and change direction only when they collide with something.
3. Collisions between particles are elastic.
4. As the temperature increases, so does the kinetic energy of the particles.
5. The distance between particles increases as the temperature increases.
6. Particles in a gas occupy an insignificant amount of the total volume.

7-2

Forces between Molecules
I. London Forces

- <u>all</u> particles have London forces

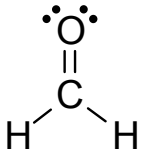


- larger particles have larger London forces
- <u>only</u> force between noble gases and nonpolar compounds
- about 1/1000 as strong as a covalent bond

7-3

Forces between Molecules
II. Dipole-Dipole Interactions

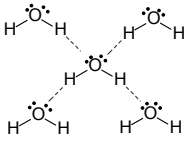
- different from London forces only in permanence
- somewhat stronger than London forces because permanent
- occurs in all *polar* molecules
- weaker than ionic bond because only δ^+ or δ^-



7-4

Forces between Molecules
III. Hydrogen Bonds

- rare
- occur between one H which is covalently bonded to an N, O, or F atom and a second N, O, or F atom
- strongest of three intermolecular forces



7-5

Sample Test Questions

1. What intermolecular forces occur between molecules of Cl_2 gas?
2. What is the <u>strongest</u> intermolecular force which occur between between NH_3 molecules?

7-6

The KMT Explains What State a Molecule Will Exist In

- forces between molecules
- molecules kinetic energies

We can predict whether a chemical will exist as a solid, a liquid, or a gas.

7-7

Sample Test Questions

1. Which molecule would you expect to have a higher melting point, Br_2 or I_2? Explain your answer.
2. Which molecule would you expect to have a higher melting point, HF or HCl? Explain your answer.

7-8

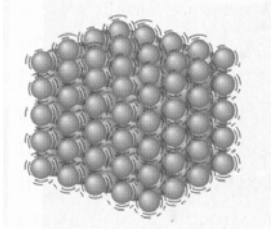
The KMT Explains Properties of States

- By thinking about the space between molecules, we can explain many physical properties of solids, liquids, and gases.

7-9

The KMT and the Properties of Solids

1. Movement is restricted to vibration and rotation about a fixed space.
2. The volume of a given mass (number of particles) is small (high density)- because atoms are tightly packed.
3. Cannot be compressed - particles are close together already and cannot be compressed further.
4. Not fluid - particles are too close together to move past each other.

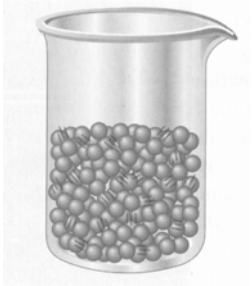


Similar to Fig. 6.1 Blei & Odian

7-10

The KMT and the Properties of Liquids

1. Particles can move, but do not go far before a collision occurs.
2. Because of the extra space, liquids usually have a density less than that of the corresponding solid.
3. Liquids are slightly compressible because there is some extra space between particles.
4. Liquids are fluid because there is more space between them and they can thus move past one another.

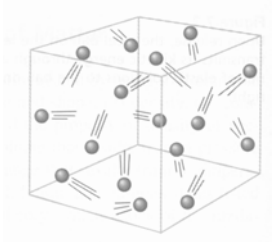


Similar to Fig. 6.1 Blei & Odian

7-11

The KMT and the Properties of Gases

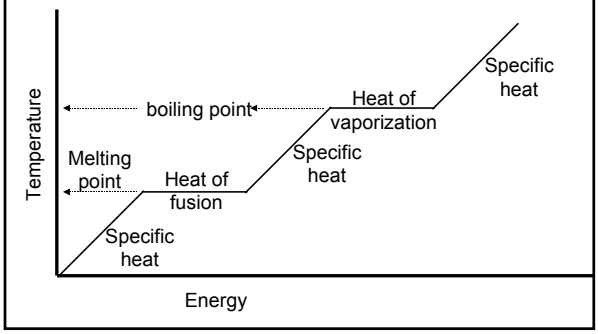
1. Travel quite a ways before a collision occurs.
2. Density very low, because a given number of particles spreads out to such a high volume.
3. Gas molecules are a long ways apart. Therefore, we can compress them into a much smaller space.
4. Gases can mix, because the particles are a long ways apart and easily go past one another.



Similar to Fig. 6.1 Blei & Odian

7-12

The Temperature-Energy Diagram and Changes in Physical State



7-13

Heat

Melting point- the temperature at which a solid is converted to a liquid.

Boiling point- the temperature at which a liquid is converted to a gas.

Sublimation- process of going from a solid to a gas directly.

7-14

Evaporation/Condensation

Vaporization- the process of conversion from a liquid into a gas.

Condensation- the process of conversion from a gas into a liquid.

Vapor Pressure- the pressure at the point at which

$$(l) \longrightarrow (g) = (g) \longrightarrow (l)$$

The weaker the interactions between molecules, the higher the vapor pressure.

7-15

So What is the Difference Between Boiling and Evaporating?

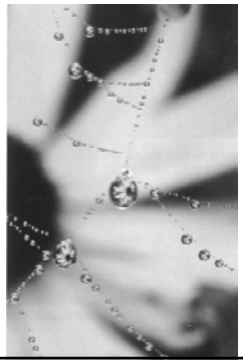
Liquid goes to gas in solution, not just at the surface of the liquid

Boiling point- the temperature at which the vapor pressure equals the atmospheric pressure.

7-16

Properties of Water

- Liquid instead of a gas at room temp because of hydrogen bonding. (H_2S)
- The density of ice is less than water. This is an exception to the general rule.
- Water has a very high specific heat. This is because as you heat water, H bonds break instead of causing a temperature increase.
- High heat of vaporization.
- Excellent solvent.
- High surface tension. (Fig. Popular Photography)



7-17

Solutions

Solution- homogenous mixture of pure substances, of which the concentration can be varied.

Solvent- the chemical species of a solution present in greater amount.

Solute- the chemical species of a solution present in lesser amount.

Solubility- how much solute will dissolve in a solvent.

7-18

Solutions Continued

Solubility- in order to be soluble, the forces of attraction between solute and solvent must be greater than between solute-solute or solvent-solvent.

Miscibility- is the term used to describe a liquid being soluble in a liquid.

7-19

Solubility as a Function of Temperature

7-20

Solubility of Air in Water

7-21

Solubility of Gas in Liquid

Increasing temp decreases sol of gas in solvent.

7-22

Properties of Gases

1. Gases mix with each other (form solutions).
2. Temperature, pressure and volume are interrelated.
   a. Gases exert pressure.
   b. Gases are compressible.

7-23

Gas Laws: Boyle's Law

Boyle's Law- At constant temperature, the volume of a fixed amount of gas is inversely proportional to pressure.

7-24

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$$V \propto \frac{1}{P} \qquad V = \kappa \frac{1}{P}$$

7-25

Gas Laws: Boyle's Law

Boyle's Law- At constant temperature, the volume of a fixed amount of gas is inversely proportional to pressure.

$$V \propto \frac{1}{P} \qquad V = \kappa \frac{1}{P}$$

Volume for gases are typically measured in liters. Pressure units are often mm Hg, sometimes atm.

7-26

Gas Laws: Charles' Law

Charles' Law- At constant pressure, the volume of a fixed amount of gas is directly proportional to temperature.

$$V \propto T \qquad V = \kappa T$$

Temperature is in Kelvins!

7-27

Gas Laws: Gay-Lussac's Law

Gay-Lussac's Law- At constant volume, the pressure of a fixed amount of gas is directly proportional to temperature.

$$P \propto T \qquad P = \kappa T$$

7-28

Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Where P= pressure,V=volume, and T=temp (K)

7-29

Practice Problems

If a sample of gas is heated, what will happen to the volume? (assume the container will shrink or swell)

If a closed can of soup is heated up, what will happen to the pressure?

What is the new pressure if 400 mL gas at 700 mm Hg is compressed to 200 mL at const temp?

If the temp of 1 L gas changes from 20°C to 30°C what is the final vol (pressure const).

A gas occupies 1.08 L at -10°C & 450 mm Hg. What volume will it occupy at 30°C & 800 mm Hg?

7-30

Gas Laws: Dalton's Law of Partial Pressures

The total pressure of a gas mixture equals the sum of the partial pressures of each gas in the mixture

$P_t = P_1 + P_2 + ... + P_n$

7-31

Practice Problems

A gas mixture with 80.0% He and 20.0% O_2 has a total pressure of 800 mm Hg. What is the partial pressure of O_2?

What is the total pressure of a mixture of He and N_2 if their partial pressures are 160 and 800 mm Hg?

7-32

Practice Problems

A sample of gas has a volume of 125 mL at 0.60 atm. What is the new volume if the pressure decreases to 0.20 atm at constant temp?

What is the new pressure if 400 mL gas at 700 mm Hg is compressed to 200 mL at const temp?

7-33

Practice Problems

If the temp of 1.00 L gas changes from 20°C to 30°C what is the final vol (pressure const).

7-34

Practice Problems

A gas mixture with 80.0% He and 20.0% O_2 has a total pressure of 800 mm Hg. What is the partial pressure of O_2?

What is the total pressure of a mixture of He and N_2 if their partial pressures are 160 and 800 mm Hg?