* Chapter 13

Gas Laws

* 13-1 A Model to Explain Gas Behavior

* The Nature of Gases: Physical Properties of gases:
  * Gases have mass: an empty basketball weighs less than a full one
  * It is easy to compress gas: This is why it is used in air bags and shock absorbers
  * Gases fill their container completely: Balloons get bigger when you blow them up

* Gases can move through each other rapidly and this is known as diffusion. (Explains smells traveling through the air)
* Gases exert pressure: explains why balloons keep their shape

Model of gases (continued)

*Kinetic Molecular Theory

* Gas properties are explained by the *Kinetic Molecular Model* that describes the behavior of the particles that make up a gas.

* all gas consists of small particles, each which has a mass.
* the particles spread apart by relatively large distances.
* the particles are in constant, rapid, random motion.
* Gases exert pressure because their particles frequently collide with the walls of the container in perfectly elastic collisions. (no energy of motion is lost)

Kinetic Molecular Theory

* The kinetic energy of gas particles depends on the temp of the gas.
* Gas particles exert no attractive forces on one another.

Kinetic Molecular Theory

* To study a gas sample and make predictions about its behavior under changed conditions, it is important to be familiar with four measurable variables:
  * n = amount of gas (measured in g or moles)
  * V = volume (measured in mL, L etc.)
  * T = temperature (measured in ^{o}C but converted to K by $^{o}C + 273 = K$)
  * P = pressure …

* 13-2 Measuring Gases

* Pressure (P)

* Why doesn't a balloon burst or deflate?
  * Because the gas in the balloon is pushing on the inside and the atmosphere is pushing on the outside of the balloon
* Gas pressure – determined by units of force per unit area
  * SI unit of pressure = pascal (Pa)
  * Other pressure units include atmospheres (atm), Torricellis (torr), and mm Hg
  * 1 atm = 101.3 kPa = 760 torr = 760 mmHg

Standard pressures

* Atmospheric pressure - pressure of air due to the pull of gravity on gas particles (because they have mass)
* Measured with a barometer
  * U shaped glass tube upside down in pool of mercury. The height of the mercury tells you how much pressure is being exerted on the open reservoir of mercury.

Atmospheric pressure

* Manometer – used to measure the pressure of a gas in a closed container.

* Manometer

* The gas inside a basketball pushes the mercury in a manometer to a height that is 15 mm higher on the closed side. The atmospheric pressure is measured at 750 mmHg.

1st the pressure inside the basketball is LOWER than the atmospheric pressure

2nd because the pressure is LOWER subtract the height of the gas side from the atmospheric pressure

$$750 - 15 = 735 \text{ mmHg}$$

3rd convert to atm

$$735 \text{ mmHg} \times \frac{1\text{atm}}{760 \text{ mmHg}} = 0.97 \text{ atm}$$

*Manometer problems

* WS 13-2 PP do #10 - 15

* **Try some more…**

* 13-3 The Gas Laws

* **Boyle's Law** – The pressure and volume of a sample of gas at constant temperature are inversely proportional to each other or

$$P_1V_1 = P_2V_2$$

Ex. WS13-3 PP #1

* **Charles's Law** – At constant pressure, the volume of a constant amount of gas is directly proportional to its Kelvin temperature.

$$V_1T_2 = V_2T_1 \text{ or } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

* Ex. WS13-3 PP #6

*Charles Law

* Guy Lusaac's Law – at a constant volume and a fixed amount of gas the pressure and Kelvin temperature of a gas will be directly related.

$$P_1T_2 = P_2T_1 \text{ or } \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

*Guy-Lusaac's Law

* Ex. If an aerosol can with a pressure of 1 atm and a temperature of 25 ^oC is thrown into a fire and the pressure increases to 2.5 atm. What is the temperature of the gas at this pressure?

T_1 = 25 ^oC + 273 = 298 K

P_1 = 1 atm

T_2 = X

P_2 = 2.5 atm

$$T_2 = \frac{P_2 T_1}{P_1}$$

$$T_2 = \frac{(2.5\ \text{atm})(298\text{K})}{1\ \text{atm}}$$

T_2 = 745 K or 472 ^oC

* Examples

* A gas measures 25.0 mL at 735 mmHg, what will its volume be at 750 mmHg?
* Answer: 24.5 mL

* A 50.0 mL volume of gas is measured at 20 ^{o}C. What will the volume of the gas be at 40 ^{o}C?
* Answer 53.4 mL

* A flask containing hydrogen gas has a pressure of 22.5 kPa and a temperature of 25 ^{o}C. What will the pressure be if the gas is heated to 38 ^{o}C?
* Answer:23.5 kPa

*Combined Gas Law

* When all but amount of gas changes, the three changing variables are related in the same ways as in Boyle's, Charles', and Guy-Lusaac's laws…so they are *combined* to be the **combined gas law**…

$$P_1V_1T_2 = P_2V_2T_1 \text{ or } \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example

* WS13-4 #2
* V_1 = V_2=
* T_1= T_2=
* P_1= P_2=

* Avogadro's Law – equal volumes of gases at the same temperature and pressure contain an equal number of particles
* Important points
  * All gases show the same physical behavior
  * A gas with a larger volume consist of a greater number of particles.
  * The volume of one mole of a gas is called the **molar volume** (@ STP…standard temperature and pressure)…22.4 L

Avogadro's Law: The Amount-Volume Relationship

* Dalton's Law of Partial Pressures

* The sum of the partial pressures of all the gases in a gas mixture is equal to the total pressure of the gas mixture.
* $P_T = p_a + p_b + p_c + \ldots$
* P_T is the total pressure

* Ex. What is the atmospheric pressure if the partial pressure of N_2, O_2, and Ar are 604.5mmHg, 162.8 mmHg, and 0.5 mmHg

P_T = 604.5 mmHg + 162.8 mmHg + 0.5 mmHg

P_T = 767.8 mm Hg

* Example

* The ideal gas equation describes the physical behavior of an ideal gas in terms of the pressure, volume, temperature, and the number of moles of a gas.
* Ideal gas – a gas that is described by the kinetic-molecular theory
* Real Gas – behave like ideal gases except at low temperatures and high pressures.

13-4 The Ideal Gas Law

* This is a summary of the gas laws from the previous section.
* PV = nRT

  P= gas pressure (must match R)

  V = gas volume (must be in L)

  n= the number of **moles** of gas

  R = ideal gas constant (must match P)

  T = temperature of a gas (must be in K)

The Ideal Gas Equation

* Ex. How many moles of a gas at 100ºC does it take to fill a 1.00-L flask o a pressure of 1.50 atm?

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{(1.5atm)(1.00L)}{(0.0821atm*L/Mol*K)(373K)} = 0.0490\ mol$$

*Example