Chapter 13

GAS LAWS

Before we begin discussing the gas laws, it is important to review the nature of gases. Most gases act like *ideal* gases in the absence of very high pressure and very low temperature. Characteristics include:

1. **expansion** – no definite shape or volume.
2. **fluidity** – particles glide past one another
3. **low density** – particles are far apart, large volume compared to little mass.
4. **Compressibility** – by making the particles come closer together, the volume of a gas can be compressed greatly.
5. **Diffusion** – spontaneous movement and mixing of two substances due to the KE of the particles. Examples:

****Real gases differ from ideal:**

1. they occupy space and have some mass.
2. They exert some attractive forces on each other.

Ideal gases act like they have NO mass and have NO attractive forces on each other! The kinetic theory holds true for noble gases and diatomic molecules. The **MORE POLAR** a molecule, the less like an ideal gas (remember that polar means unequal sharing electrons).

Gas laws are designed to demonstrate the behavior of a gas in regards to temperature and pressure. Gases are generally compaired based on what happens to their volume when their conditions change. Until now we have only dealt with gases at STP (see below for STP values). We will now learn how to adjust for change. The changes may occur in the amount of gas (number of moles), volume, temperature and/or pressure.

STP values: Temperature: 273K or 0°C
Pressure: 1 atm or 101.3 kPa or 760 mmHg or 760 torr
**For gas problems, temperature must be in Kelvin.

Boyle's Law: at a constant temperature, pressure and volume are inversely proportional. If one goes up, the other goes down.

$$P_1 \times V_1 = P_2 \times V_2$$

- For example: At STP a gas occupies 4L, if the pressure was lowered to 560 mmHg what would the new volume be?
  (760 mmHg)(4 L) = (560 mmHg)(V_2)
  3040 L mmHg = (560 mmHg)(V_2)
  5. L = V_2

Practice: Complete the following.

1. 100.0 cm^3 oxygen at 10.50 kPa changes to 9.91 kPa, what is the new volume?

2. 150.0 ml sulfur dioxide at 748 mmHg changes to 798 mmHg, what is the new volume?

Charles' Law: at a constant pressure, temperature and volume are directly proportional. If one goes up, they both go up.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- For example: If a gas occupies 620 ml at 288K, when the temperature is raised to 463K the new volume will be:

  $\frac{(0.62\ L)}{288K} = \frac{(V_2)}{463K}$ → $0.0022\ L/K = \frac{(V_2)}{463K}$ → $1.0\ L = V_2$

Practice: Complete the following.

1. 75.0 cm^3 hydrogen at 27.0°C changed to –10.0°C, what is the new volume?

2. 150.0 ml nitrogen at 20.0°C changed to standard temperature, what is the new volume?

3. A gas occupies a volume of 0.560 L at a temperature of 120°C. To what temperature must the gas be lowered to occupy 0.400 L?

Combined Gas Law: pressure and temperature both affect volume.

$$\frac{V_1 \times P_1}{T_1} = \frac{V_2 \times P_2}{T_2}$$

- For example: A gas at STP has a volume of 52.3 cm^3, what will the volume be at 4 atm and 340 K?

  $\frac{(0.0523\ L)(1\ atm)}{273K} = \frac{(V_2)(4\ atm)}{340K}$

  $0.000192\ L\ atm/K = (V_2)(0.0118\ atm/K)$

  $0.0163\ L = V_2$

Practice: Complete the following.

1. 500.0 ml hydrogen at 20.0°C and 120 kPa changed to STP, what is the new volume?

2. 140 L chlorine at 15°C and 110.0 kPa to 40.0°C and 94.5 kPa, what is the new volume?

3. 100 cm^3 at STP is changed to 20.0°C at 820 mmHg, what is the new volume?

4. A sample of gas occupies 50.0 L at 27.0°C and 380 mmHg is changed to STP, what is the new volume?

5. Convert the following to STP: 1000 ml at 30.0°C and 7 atm.

6. A gas was collected at 27.0°C and a pressure of 80.0 kPa measures 500 ml. Calculate the volume in mL at –3.00°C and 75.0 kPa.

Boyle's Law	Charles' Law	Guy-Lassac's Law	Combined Gas Law
For a given mass of gas at constant temperature, the volume of a gas varies inversely with pressure	The volume of a fixed mass of gas is directly proportional to its Kelvin temperature if the pressure is kept constant.	The pressure of a gas is directly proportional to the Kelvin temperature if the volume is kept constant.	Combines Boyle's, Charles', and the Temperature-Pressure relationship into one equation. Each of these laws can be derived from this law.
$PV = k$ $P_1V_1 = P_2V_2$	$\frac{V}{T} = k$ $V_1T_2 = V_2T_1$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P}{T} = k$ $P_1T_2 = P_2T_1$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{PV}{T} = k$ $V_1P_1T_2 = V_2P_2T_1$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Dalton's Law	Ideal Gas Law	Graham's Law
At constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of the pressures exerted by each gas,	The Ideal Gas Law relates the pressure, temperature, volume, and mass of a gas through the gas constant "R".	The rate of effusion/diffusion of two gases (A and B) are inversely proportional to the square roots of their formula masses. [*It can be a ratio of molecular speeds, effusion /diffusion times, distance traveled by molecules, or amount of gas effused*]
$P_{total} = P_1 + P_2 + P_3 + \ldots P_n$	$PV = nRT$	$\frac{Rate_A}{Rate_B} = \frac{\sqrt{molar\ mass_B}}{\sqrt{molar\ mass_A}}$

Abbreviations	Standard Conditions
atm = atmosphere mm Hg = millimeters of mercury torr = another name for mm Hg Pa = Pascal kPa = kilopascal K = Kelvin °C = degrees Celsius	0°C = 273 K 1.00 atm = 760.0 mm Hg = 76 cm Hg =101.325 kPa = 101, 325 Pa = 29.9 in Hg

Conversions	Gas Law's Equation Symbols
K = °C + 273 $F^\circ = 1.8C^\circ + 32$ $C^\circ = \frac{F^\circ - 32}{1.8}$ 1 cm^3 (cubic centimeter) = 1 mL (milliliter) 1 dm^3 (cubic decimeter) = 1 L (liter) = 1000 mL	Subscript (1) = old condition or initial condition Subscript (2) = new condition or final condition Temperature must be in Kelvins n = number of moles = grams/Molar mass R = 8.31 L-kPa/ mol-K = 0.0821 L-atm/mol-K = 62.4 L-Torr/mol-K You must have a common set of units in the problem

Name: ______________________ Period: ___ Date: ________________________

Homework: Boyle's Law, Charles' Law and Combined Gas Laws

Match each example to the property that it illustrates.

___ 1. A tire inflates when you pump air in.
___ 2. An air hockey puck floats on the table.
___ 3. A balloon regains its shape after pressure is released.
___ 4. A balloon filled with air weighs more than an empty balloon.
___ 5. The odor of sulfur gas permeates a room.

a. compressibility
b. has mass
c. fills container
d. exerts pressure
e. diffuses through other gases

Complete the following fill in the blank.

6. The volume of gas depends on ____________________ and _________________.
7. ____________________ is the spontaneous movement and mixing of particles.
8. The collisions between particles in an ideal gas are _________________.
9. If the temperature of a gas increases, and the pressure remains the same, the volume will ___________________.
10. Because gas particles are far apart, a large volume of gas has a low ____________.

Complete the following word problems.(complete on separate sheet of paper)

11. Some oxygen occupies 250 mL when its pressure is 720 mm. How many milliliters will it occupy when its pressure is 750 mm?
12. A gas collected when the pressure is 800mm has a volume of 380 mL. What volume, in milliliters, will the gas occupy at standard pressure?
13. A gas has a volume of 100mL when the pressure is 735 mm. How many milliliters will the gas occupy at 700mm pressure?
14. A gas has a volume of 240.0 mL at 70.0 cm pressure. What pressure, in centimeters of mercury, is needed to reduce the volume to 60.0 mL?
15. Convert the following temepratures to Kelvin scale: (a) 20° C; (b) 85 ° C; (c) –15° C; (d) –190 ° C.
16. Given 90.0mL of hydrogen gas collected when the temperature is 27°C, how many milliliters will the hydrogen occupy at 42 °C?

17. A gas has a volume of 180mL when its temperature is 43° C. What change in Celsius temperature reduces its volume to 135mL?

18. A gas measures 500mL at a temperature of –23° C. What will be its volume in milliliters at 23° C?

19. A sample of gas occupies 50.0 L at 27° C. What will be the volume of the gas in liters at standard temperature?

20. Convert to standard conditions: 2280 mL of gas measured at 30° C and 808 mm pressure.

21. Convert to standard conditions: 1000mL of gas at –23° C and 700 mm pressure.

22. Convert to standard conditions: 1520mL of gas at –33° C and 720 mm pressure.

23. A gas collected when the temperature is 27° C and the pressure is 80.0 cm measures 500mL. Calculate the volume in milliliters at –3° C and 75.0 cm pressure.

24. Given 100mL of gas measured at 17° C and 380 mm pressure, what volume, in milliliters, will the gas occupy at 307 °C and 500 mm pressure?

25. Hydrogen, 35.0mL, when collected the temperature was 25° C and the barometric pressure was 740.0mmHg. Convert the volume of hydrogen to STP.

26. A gas collected at a temperature of 20° C and a barometer reading of 715 mm. Convert the volume of gas to STP.