THE GAS LAWS

The kinetic-molecular theory describes the behavior of _____ gases in terms of particles in motion. Real gases do not obey the kinetic molecular theory.

1) Gas particles are much smaller than the distances between them. The gas particles themselves have virtually no (negligible) _____.
2) Gas particles are in constant, _____ motion. Particles move in a straight line until they collide with other particles or with the walls of their container.
3) Gas particles do not attract or _____ each other. Therefore ideal gases would never condense to form liquids.
4) No kinetic energy is _____ when gas particles collide with each other or with the walls of their container. Collisions are perfectly _____.
5) All gases have the same average _____ energy at a given temperature.

Gases are _____ soluble in warm liquids than in cooler liquids. Gases are more soluble when under _____. The vapor pressure of water _____ as the temperature increases. STP stands for standard temperature and pressure. Standard pressure is 1_____ (atmosphere) which is equal to 760 mm Hg, 760 torr, and _____ kPa (kilopascals). Standard temperature is _____ Kelvin.

1) Perform the following pressure conversions.

a) 144 kPa = _____ atm b) 795 mm Hg = _____ atm

c) 669 torr = _____ kPa d) 1.05 atm = _____ mm Hg

Air pressure at higher altitudes, such as on a mountaintop, is slightly _____ than air pressure at sea level. Air pressure is measured using a _____.

Boyle's Law

Boyle's law states that the pressure and _____ of a gas at constant temperature are inversely proportional. Inversely proportional means as one goes up the other goes _____. The P-V graph for Boyle's law results in a _____ because pressure and volume are inversely proportional.

- Sketch the PV graph that represents Boyle's law.

$$P_1 V_1 = P_2 V_2$$

Example: A balloon is filled with 25 L of air at 1.0 atm pressure. If the pressure is changed to 1.5 atm, what is the new volume? (Make sure the pressure and volume units in the question match.)

2) A balloon is filled with 73 L of air at 1.3 atm pressure. What pressure is needed to change the volume to 43 L?

3) A gas is collected in a 242 cm^3 container. The pressure of the gas in the container is measured and determined to be 87.6 kPa. What is the volume of this gas at standard pressure?

4) A gas is collected in a 24.2 L container. The pressure of the gas in the container is determined to be 756 mm Hg. What is the pressure of this gas if the volume increases to 30.0 L?

Charles' Law

Charles' law states that the volume of a gas is directly proportional to the _____ temperature if the pressure is held constant. Directly proportional means that as one goes up, the other goes _____ as well. The V-T graph for Charles' law results in a _____ _____ because pressure and volume are directly proportional.

- Sketch the PV graph that represents Charles' law.

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

In any gas law problem involving temperature, temperature must be in Kelvin.

$$K = °C + 273$$

Example: What is the temperature of a gas that is expanded from 2.5 L at 25 ºC to 4.1 L at constant pressure? (Make sure the volume units in the question match and make sure to convert degrees Celsius to Kelvin.)

5) What is the final volume of a gas that starts at 8.3 L and 17 ºC and is heated to 96 ºC?

6) A 225 cm^3 volume of gas is collected at 57 ºC. What volume would this sample of gas occupy at

standard temperature?

7) A 225 cm^3 volume of gas is collected at 42 ºC. If the volume is decreased to 115 cm^3, what is the new temperature?

Gay-Lussac's Law

Gay-Lusaac' Law states that the _____ of a gas is directly proportional to the Kelvin temperature if the volume is held constant. At higher temperatures, the particles in a gas have greater kinetic _____. They move faster and collide with the walls of the container more often and with greater force, so the pressure _____. The P-T graph results in a straight _____ because pressure and temperature are directly proportional.

- Sketch the P-T graph that represents Gay-Lussac's law.

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

Example: What is the pressure inside a 0.250 L can of deodorant that starts at 25 ºC and 1.2 atm if the temperature is raised to 100 ºC? Volume remains constant. (Make sure the pressure units in the question match and make sure to convert degrees Celsius to Kelvin.)

8) A can of deodorant starts at 43 ºC and 1.2 atm. If the volume remains constant, at what temperature will the can have a pressure of 2.2 atm?

9) A can of shaving cream starts at 25 ºC and 1.30 atm. If the temperature increases to 37 ºC and the volume stays constant, what is the pressure of the can?

10) A 12 ounce can of a soft drink starts at STP. If the volume remains constant, at what temperature will the can have a pressure of 2.20 atm?

The Combined Gas Law

The gas laws may be combined into a single law, called the combined gas law, which relates two sets of conditions of pressure, volume, and temperature by the following equation.

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

Example: A 15 L cylinder of gas at 4.8 atm pressure at 25 ºC is heated to 75 ºC and compressed to

17 atm. What is the new volume?

11) If 6.2 L of gas at 723 mm Hg at 21 ºC is compressed to 2.2 L at 4117 mm Hg, what is the temperature of the gas?

12) A sample of nitrogen monoxide has a volume of 72.6 mL at a temperature of 16 °C and a pressure of 104.1 kPa. What volume will the sample occupy at 24 °C and 99.3 kPa?
13) A balloon is filled to 1.00 L at sea level and a temperature of 27 °C. At an altitude of 7000 m, atmospheric pressure drops to 300. mm Hg and the temperature cools to - 33 °C. What would its volume be when it reached the height of 7000 m?

Avogadro's Law

Avogadro's law states equal volumes of all gases, at the same temperature and pressure, have the same number of _____. For a given mass of an ideal gas, the volume and amount (moles) of the gas are _____ proportional if the temperature and pressure are constant. The molar _____ for a gas is the volume that one mole occupies at 0.00ºC and 1.00 atm. 1 mole = _____ L at STP (standard temperature and pressure).

Example: How many moles are in 63.2 L of a gas at STP?

14) How many moles are in 45.0 L of a gas at STP?

15) How many liters are in 0.636 moles of a gas at STP?

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Example: Consider two samples of nitrogen gas. Sample 1 contains 1.5 mol and has a volume of 36.7 L. Sample 2 has a volume of 16.5 L at the same temperature and pressure. Calculate the number of moles of nitrogen in sample 2.

16) If 0.214 mol of argon gas occupies a volume of 652 mL at a particular temperature and pressure, what volume would 0.375 mol of argon occupy under the same conditions?

17) If 46.2 g of oxygen gas (O_2) occupies a volume of 100. L at a particular temperature and pressure, if the final volume is 10.8 L, how many moles of oxygen gas occupies this volume under the same conditions?

18) A 6.0 L sample at 25 °C and 2.00 atm of pressure contains 0.50 moles of a gas. If an additional 0.25 moles of gas at the same pressure and temperature are added, what is the final total volume of the gas?

Dalton's Law of Partial Pressures

Dalton's law of partial pressures states that the _____ pressure of a mixture of gases is equal to the sum of the pressures of all the gases in the mixture, as shown below.

$$P_t = P_1 + P_2 + P_3 + \ldots \qquad P_t = \text{total pressure}$$

Example: Container 1 has a pressure of 2 atm, container 2 has a pressure of 1 atm, and container 3 has a pressure of 3 atm. Determine the pressure in the fourth container if all of the gas molecules from the 1st three containers are placed in the 4th container.

19) What is the total pressure in a balloon filled with air if the pressure of the oxygen is 170 mm Hg and the pressure of nitrogen is 620 mm Hg?

20) In a second balloon the total pressure is 1.30 **atm**. What is the pressure of oxygen (in mm Hg) if the pressure of nitrogen is 720. mm Hg?

21) A container has a total pressure of 846 **torr** and contains carbon dioxide gas and nitrogen gas. What is the pressure of carbon dioxide (in kPa) if the pressure of nitrogen is 50. kPa?

It is common to synthesize gases and collect them by displacing a volume of _____.

$$P_t = P_{water} + P_{gas}$$

22) Hydrogen was collected over water at 21°C on a day when the atmospheric pressure is 748 torr. The volume of the gas sample collected was 300. mL. The vapor pressure of water at 21°C is 18.65 torr. Determine the partial pressure of the dry gas.

23) A sample of oxygen gas is saturated with water vapor at 27ºC. The total pressure of the mixture is 772 mm Hg and the vapor pressure of water is 26.7 mm Hg at 27ºC. What is the partial pressure of the oxygen gas?

The Ideal Gas Law

_____ gases do not really exist, but assuming that all gases are ideal makes the math easier and is a close approximation. Real gases behave more ideally at _____ temperature and _____ pressure. At high temperature, the gas molecules move more _____, so attractive forces are negligible. At low pressure, the molecules are farther _____ so attractive forces are negligible.

$$P\,V = n\,R\,T$$

Pressure times volume equals the number of _____ (n) times the ideal gas constant

(R) times the temperature in Kelvin. Volume must be in _____. If given milliliters divide the number by _____ to convert it to liters.

➢ R = 0.0821 (L **atm**)/(mol K) or R = 8.314 (L **kPa**)/(mol K) or R = 62.4 (L **mm Hg**)/(mol K)

The constant you choose depends on the unit for pressure!

Example: How many moles of air are there in a 2.0 L bottle at 19 ºC and 747 mm Hg?

Example: What is the pressure in atm exerted by 1.8 g of H_2 gas exerted in a 4.3 L balloon at 27 ºC?
24) Sulfur hexafluoride (SF_6) is a colorless, odorless and very unreactive gas. Calculate the pressure (in atm) exerted by 1.82 moles of the gas in a steel vessel of volume 5.43 L at 69.5 ºC.

25) Calculate the volume (in liters) occupied by 7.40 g of CO_2 at STP.

26) A sample of nitrogen gas kept in a container of volume 2.30 L and at a temperature of 32 ºC exerts a pressure of 476 kPa. Calculate the number of moles of gas present.

27) Calculate the volume of 0.0520 moles of a gas at STP.

28) How many moles of nitrogen gas (N_2) can occupy 1.00 L at STP?

Proportionality

$$P V = n R T$$

Variables on the same side of the equals sign are _____ proportional. This means as one goes up the other must go down. Variables on opposite sides of the equals sign are directly proportional. This means as one goes up the other must go _____.

29) How are pressure and temperature related?

30) If pressure increases, what happens to volume if temperature and number of moles stay constant?

31) If number of moles decreases, what happens to volume if temperature and pressure stay constant?

32) How are moles and temperature related?