Chem I Name ________________________

Date _________________ Per ______

Worksheet # C50: Silent Lecture: Intro to Gas Laws

Today we will be looking into the properties of gases: how they behave, and how they are affected by changes in pressure, temperature, and volume. As you work through this packet, answering the questions as you go, think about encounters you've had with gases, such as with bicycle pumps, balloons, altitude changes, and the like. When dealing with problems with gases, remember to use your experience and common sense. Also, feel free to write notes to yourself in the margin as you go - especially questions or summaries to help you remember what you're reading.

First, the Kinetic Molecular Theory.

• Gases are defined on the basis of the kinetic molecular theory. This theory makes several assumptions about gases. The first assumption is that gases are made up of individual molecules that are in constant rapid motion. The molecules possess kinetic energy (energy of motion) and bounce into each other and the walls of the gas container. Molecules bump into the wall at the top of the container as often as they bump into the bottom.

The kinetic molecular theory also assumes that the molecules of a gas are much farther apart then molecules of a solid or liquid. Because of this they are completely free to move about.

1) What is kinetic energy? __________________________________

2) Which do you expect would contain more molecules, a liter of a gas such as oxygen or a liter of a liquid such as water?

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• The constantly moving gas molecules possess kinetic energy (energy of motion). All gases at the same temperature are assumed to have the same average kinetic energy because temperature is simply a measure of average kinetic energy. Heating a gas results in an increase in the temperature of the gas and an increase in the average kinetic energy of the gas molecules.

3) Which gas at room temperature has more kinetic energy: a gas made of small molecules such as H_2, or a gas made of big molecules such as I_2?

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4) If the average kinetic energy of sample A of a gas is greater than sample B of that gas, which gas sample (A or B) would you expect to have a higher temperature (all other conditions being equal)?

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• The kinetic molecular theory assumes that the rapidly moving gas molecules collide with each other and the walls of the gas container without any loss of kinetic energy. The collision of the gas molecules with the walls of the gas container results in what we call pressure.

5) A balloon is kept inflated because of pressure caused by ___________________________

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• Like volume, pressure is measured with many different possible units: atmospheres (1.00 atm is the average air pressure at sea level and 25ºC), torr (1.00 atm = 760. torr), mm Hg (1.00 atm = 760.mm Hg), kPa (1.00 atm = = 101.305 kPa), and psi (1.00 atm = 14.7 psi). Each of these different measures of pressure are useful in different situations.

6) Figure it out: 1 torr = ____ mm Hg

• Another assumption of the kinetic molecular theory is that the gas molecules themselves have no volume, thus leaving only the space between molecules as the volume occupied by a gas. The size of the actual molecules themselves is totally unimportant when it comes to volume, as the space between them is so huge.

7) According to the kinetic molecular theory, all the volume of an ideal gas can be attributed to

____(Note: this assumption only works for "ideal gases", or gases at moderate temperatures and pressures. You can deal with what happens with more extreme conditions in later classes.)

• Gases can be more readily compressed than liquids or solids. Since gas molecules are relatively far apart, an external force or pressure can readily push the molecules closer together.

If a certain volume (such as a liter) of gas is compressed to half that volume, what happens to the number of molecules of the gas during the compression? Do they increase, decrease, or

stay the same? ___________________________________

• When a gas is compressed, the same number of gas molecules occupies a smaller volume than before compression. That is , the gas container is smaller but contains the same number of molecules. We have defined pressure as the collision of gas molecules with the wall of the gas container. When a gas is compressed would you expect an increase, decrease, or no change in the number of collisions of gas molecules per square unit (such as a square centimeter) of container

wall? _____________ Why? ____

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• Pressure is often measured as the relative number of collisions on a given area of the gas container. Would you expect the pressure of a compressed gas to be greater than, less than, or the same as that of the gas before compression?

____________________________ So, at constant temperature, when the volume of a gas is decreased by compression, the pressure on a given area of the inside wall of the container is

___________________ (increased, decreased, unchanged), and when the pressure of a gas

increases, the volume of the gas is probably being________________ (increased,decreased).

This is known as Boyle's Law, and mathematically it is written:

$$P_1V_1 = P_2V_2$$

where 1 is before the change and 2 is after the change. This formula shows an inversely proportional relationship. As one (like P) goes up, the other (like V) goes down.

• Here's a typical Boyle's Law kind of problem: 6.00 liters of a gas are at 1.00 atm of pressure. Assuming the temperature stays the same, what will the new volume of the gas be if the pressure is increased to 2.50 atm?

$P_1V_1 = P_2V_2$ P_1= 1.00 atm V_1 = 6.00 L P_2= 2.50 atm V_2= X

1.00 atm• 6.00 L = 2.50atm• X

X = 2.40 L, so V_2= 2.40 L

8) Try this: 4.58 liters of a gas are at 1.93 atm of pressure. Assuming that the temperature stays the same, what will be the new volume of the gas if the pressure is decreased to 1.09 atm? Show your set-up and circle your answer, please.)

• But what if the temperature <u>doesn't</u> stay the same? A guy named Charles figured out that if you increase the temperature of a gas and let the pressure stay the same (such as in an expandable container), the volume of the gas will also increase. This is known as Charles' Law, and mathematically it is written

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

This formula shows a directly proportional relationship, which means that as one (like T) goes up, the other (like V) also goes up. This is common sense: if you hold a balloon over a fire, it gets bigger, right? (Before it pops, that is!)

• There's only one hitch to this formula: it won't work with negative numbers! And even when ºC and ºF (which can both be negative) are positive, the proportions don't work out right. The only kind of temperature scale that works with Charles' Law is the absolute temperature scale, or degrees Kelvin.

degrees Kelvin = ºC + 273 or, if you prefer, ºC = degrees K - 273 (same thing)

For some reason you don't write the little circle (º) when writing degrees Kelvin. It's just K.

Zero degrees Kelvin is known as absolute zero, (-273ºC). Theoretically, that's the temperature at which all motion stops. Nobody's been able to achieve this temperature yet, but at various labs around the world they're working on it!

• Here's a typical Charles' Law kind of problem: 6.00 liters of a gas are at 20.°C (which is room temperature). Assuming the pressure stays the same, what will be the new volume of the gas if the temperature is increased to 37°C (which is body temperature)?

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $V_1 = 6.00\text{L}$ $T_1 = 20.°\text{C} + 273 = 293\text{ K}$ $V_2 = X$ $T_2 = 37°\text{C} + 273 = 310.\text{ K}$

$$\frac{6.00\text{L}}{293\text{K}} = \frac{X}{310.\text{K}}$$

$X = 6.35$ L, so $V_2 = 6.35$ L

9) Try this: 4.58 liters of a gas are at 15°C. Assuming that the pressure stays the same, what will be the new volume of the gas if the temperature is increased to 45°C? (Show your set-up, please, and don't forget to change °C to K!)

That's it for today! Here are a few Boyle's and Charles' Law problems to make sure it all sticks. Show all your set-ups and circle your answers.

10) A sample of oxygen gas occupies a volume of 250. mL at 740. torr pressure. What volume will it occupy at 800. torr pressure?

11) A sample of nitrogen occupies a volume of 250. mL at 25°C. What volume will it occupy at 95 °C?

12) A sample of carbon dioxide occupies a volume of 3.50 liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.75 liters?

13) Chlorine gas is at a temperature of 40.°C when it occupies a volume of 2.3 liters. To what temperature should it be raised to occupy a volume of 6.5 liters? (Answer in °C)