Name: SOLUTIONS
Hour: ________ Date: 5/9/2014

Today's task: Investigate the Gas Laws. These laws are mathematical expressions that describe the various behaviors of gases when conditions are changed. Next week, we'll bring all of these laws together into the "Ideal Gas Law." For now, we'll look at pairs of variables, such as volume and pressure, and how changing one variable of a gas affects the other.

Bellwork:
Some of your classmates were able to boil water at 80°C in lab yesterday. By pulling back on a partially-filled syringe, how did they change the atmospheric pressure inside the syringe? How did this lead to the water boiling?

By pulling back the syringe, more room was made for the air molecules present inside the syringe (no more were able to get in due to cap stopper). Because pressure is the measure of molecules hitting the container, more room for air molecules to move will ↓ atmospheric pressure in syringe. Thus the warm water had enough KE to boil (vapor pressure of water = atmospheric pressure) at 80°C under these conditions.

Units of Gas Variables

Temperature: °C and K

Standard temp: 0°C = 273 K

Pressure: atmospheres (atm); kiloPascals (kPa); millimeters Mercury (mm Hg)

Standard press: 1 atm = 101.3 kPa

Volume of gases: Liters*

The Gas Laws

* $1\ dm^3 = 1\ L$
$1\ cm^3 = 1\ mL = \frac{1}{1000}\ L$

Using what we know about the relationships between conditions which affect gas behavior, fill out the chart below:

Variables that affect motion of gas particles	Thinking it through: As one goes up, the other goes…	Relationships between variables	Mathematical equation
P vs. V	P ↑ V ↓	Inversely proportional	$P_1V_1 = P_2V_2$
P vs. T	P ↑ T ↑	directly proportional	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
V vs. T	V ↑ T ↑	directly proportional	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
n vs. V	n ↑ V ↑	directly proportional	$\frac{V_1}{n_1} = \frac{V_2}{n_2}$

Marshmallow

Boyle's Law: Pressure vs. Volume

Example problem: For a basketball with a volume of 2.42 L, the pressure of the gas inside is determined to have a pressure of 87.6 kPa, what happens to the volume of this gas if the pressure is raised to 101.3 kPa ("standard pressure")?

Reasoning: In order to increase the gas pressure in the container, we must decrease the volume of the container such that the gas particles are forced to hit the container walls more often. *Thus, we expect the new volume to have a value smaller than 0.242 L.*

$$P_1V_1 = P_2V_2$$

$P_1 = 87.6$ kPa
$V_1 = 2.42$ L
$P_2 = 101.3$ kPa
$V_2 = ?$

$$(87.6kPa)(2.42L) = (101.3kPa)(V_2)$$

$$\frac{(87.6\cancel{kPa})(2.42L)}{(101.3\cancel{kPa})} = (V_2) = 2.09\ L$$

Problems to complete:

1) If a gas occupies 2.5 L at standard pressure, what volume will it occupy if the pressure is decreased to 92.9 kPa?
Will the volume increase or decrease? P ↓ ∴ V ↑ Answer: 87 L

$V_1 = 2.5$ L
$P_1 = 101.3$ kPa
$V_2 = ?$
$P_2 = 92.9$ kPa

$$V_2 = \frac{(2.5L)(101.3\cancel{kPa})}{(92.9\cancel{kPa})} = 87\ L$$

2) A gas is collected in a 9.5 L container and under a pressure of 4.5 atm. In order to get the volume of this gas to 22.4 L, what does the pressure of the container to be changed to?
Will the pressure increase or decrease? V ↑ P ↓ Answer: 1.9 atm

$V_1 = 9.5$ L
$P_1 = 4.5$ atm
$V_2 = 22.4$ L
$P_2 = ?$

$$P_2 = \frac{(9.5\cancel{L})(4.5\ atm)}{(22.4\cancel{L})} = 1.9\ atm$$

3) If 1.0 L of gas at 2.0 atms is brought to 4.0 atms, what is the resulting volume given temperature is held constant?
Will the volume increase or decrease? P ↑ V ↓ Answer: 0.5

$V_1 = 1.0$ L
$P_1 = 2.0$ atm
$V_2 = ?$
$P_2 = 4.0$ atm

$$V_2 = \frac{(1.0L)(2.0\ atm)}{(4.0\ atm)} = \boxed{0.5\ L}$$

Egg, flash   Helium balloon

Gay Lussac's Law: Pressure vs. Temperature

Example problem: A student has a helium balloon which is at standard pressure (101.3 kPa). However, it's not s inflated as she wants it to be, so she heats it over a hot plate from 25°C to 50°C. What will the new internal pressure of the balloon be, assuming the volume of the balloon removes the same?

Reasoning: The new pressure of the gas should be larger than the original volume, because increasing the temperature causes the gas molecules to move faster and thus they will hit sides of the balloon more often. Thus, we expect to have a higher pressure than 101.3kPa.

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

$P_1 = 101.3$ kPa
$T_1 = 25 + 273$ K $= 298$ K
$P_2 = ?$
$T_2 = 50 + 273$ K $= 323$ K

$$\frac{(101.3\ kPa)}{298\ K} = \frac{P_2}{323\ K}$$

$$\frac{(101.3\ kPa)(323K)}{(298\ K)} = (P_2) = 110\ kPa$$

Problems to complete:

4) If a gas is cooled from 323.0 K to 273.15 K and the volume is kept constant, what final pressure would result if the initial pressure was 1.12 atm?
Will the pressure increase or decrease? T ↓ P ↓   Answer: 0.947 atm

$T_1 = 323.0$ K
$T_2 = 273.15$ K
$P_1 = 1.12$ atm
$P_2 = ?$

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

$P_2 = \frac{P_1 T_2}{T_1} = \frac{(1.12\ atm)(273.15\ K)}{(323.0\ K)} = 0.947$ a

5) If a gas in a cooled container is pressurized from 15.0 atm to 16.0 atm and its final temperature was 300 K, what was the initial temperature of the gas?
Will the temperature increase or decrease? P_2 ↑ T ↑$_2$ Answer: 280 K
(∴ T_1 will be lower than 300 K)

$P_1 = 15.0$ atm
$T_1 = ?$
$P_2 = 16.0$ atm
$T_2 = 300$ K

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

$T_1 = \frac{P_1 T_2}{P_2} = \frac{(15\ atm)(300\ K)}{(16\ atm)} =$

6) A sample of oxygen gas initially at 0.97atm is cooled from 21°C to -68°C at a constant volume. What is its final pressure (in atm)?
Will the pressure increase or decrease? T ↓ P ↓   Answer: 0.68 atm

$P_1 = 0.97$ atm
$T_1 = 21 + 273 = 294$ K
$P_2 = ?$
$T_2 = -68 + 273 = 205$ K

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

$P_2 = \frac{P_1 T_2}{T_1} = \frac{(0.97\ atm)(205\ K)}{(294\ K)}$

~~Helium balloon~~ Can crusher

Charles' Law: Volume vs. Temperature

Example problem: A student fills a balloon with 7.12 L of air at room temperature (25°C) and then places it in Mr. Erickson's freezer and is allowed to cool to -10°C. What will the new volume of the balloon be, assuming that the pressure?

Reasoning: The new volume of the gas should be smaller than the original volume, because decreasing the temperature causes the gas molecules to move more slowly *and thus they will fill the balloon less. Thus, we expect to have a smaller volume than 7.12 L.*

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

Problems to complete:

7) A 7.12 L volume of gas is collected at 715°C. What volume would this sample occupy at standard temperature (0°C) if the pressure stays constant?
Will the volume increase or decrease? T↓ V↓ Answer: 1.97 L ✓

$V_1 = 7.12\ L$
$T_1 = 715 + 273 = 988\ K$
$V_2 = ?$
$T_2 = 273 + 0 = 273\ K$

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

$V_2 = \frac{V_1 T_2}{T_1} = \frac{(7.12\ L)(273\ K)}{(988\ K)} = 1.97$

8) A gas occupies a volume of 4.50 L at 27°C. At what temperature would the volume be 6.00 L if the pressure stays constant?
Will the temperature increase or decrease? V↑ T↑ Answer: 400 K ✓

$V_1 = 4.50\ L$
$T_1 = 27 + 273 = 300\ K$
$V_2 = 6.00\ L$
$T_2 = ?$

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

$T_2 = \frac{V_2 T_1}{V_1} = \frac{(6.00\ L)(300\ K)}{(4.50\ L)}$

9) If a 25.0 L balloon at 25.0 degrees Celsius is heated to 100.0 degrees Celsius, what is the resulting ? volume given pressure is held constant?
Will the volume increase or decrease? T↑ V↑ Answer: 31.3 L ✓

$V_1 = 25.0\ L$
$T_1 = 25 + 273 = 298\ K$
$V_2 = ?$
$T_2 = 100 + 273 = 373\ K$

$V_2 = \frac{V_1 T_2}{T_1} = \frac{(25.0\ L)(373\ K)}{298\ K} = 31.3\ L$