Name _____

#11 Gas Laws
Quantitative Chemistry

Student Learning Map

Unit EQs: What are the different laws associated with gases?

Key Learnings: Gas laws address the unique properties of gases.

UNIT CONCEPT:

1. Kinetic Molecular Theory	1. 6 Basic Gas Laws	2. Ideal Gas Law
LESSON ESSENTIAL QUESTIONS:		
a. How do pressure, volume, and temperature affect gases? b. What are the postulates of Kinetic Molecular Theory?	a. How do I solve problems with Boyle, Charles, and Gay-Lussac (Amonton's) Laws? b. How was the Combined Gas Law derived? c. How do I solve problems using Avogadro and Dalton's Laws?	a. What is the Ideal Gas Law? b. How do I combine stoichiometry with the Ideal Gas Law?
LESSON ESSENTIAL VOCABULARY:		
Gas Pressure Barometer Atm, torr, mm Hg STP	Partial Pressure	Rate Constant

Date:

1a. Pressure, Volume, and Temperature

EQ: How do pressure, volume, and temperature affect gases?

Gases:

Gases have no definite _____ and no definite _____.

Gas Laws: Variables & Units

Pressure	Volume	Temperature

A. Pressure Conversions:

1. Convert 800. torr to atm.

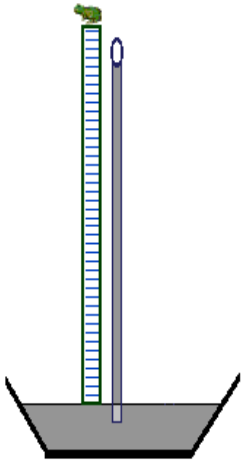
2. Convert 0.45 atm to mm Hg.

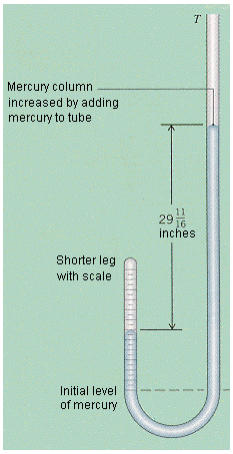
3. Convert 650 mm Hg to atm.

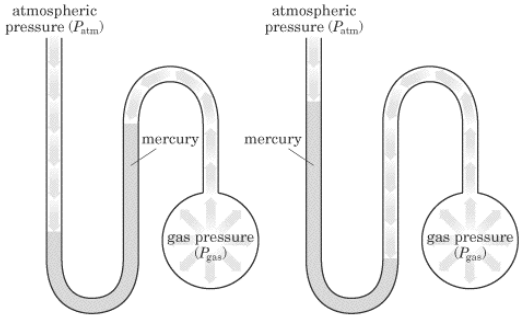
Date:

1a. Pressure, Volume, and Temperature (cont.)

B. Pressure Equipment:







C. Standard Temperature and Pressure

STP

Date:

1b. Kinetic Molecular Theory

EQ: What are the postulates of Kinetic Molecular Theory?

See page 430.

Postulate	Illustration
1. Gases consist of _____ _____.	
2. These particles are so _____, compared with the _____ between them, that the _____ (size) of the individual particles can be assumed to be _____ (zero).	
3. These particles are in constant _____ _____, _____ with the walls of the container. These _____ with the walls cause the _____ exerted by the gas.	
4. The particles are assumed NOT to _____ or _____ each other.	
5. The average _____ of the gas particles is directly proportional to the _____ of the gas.	

Date:

2a. Boyle, Charles, and Gay-Lussac/Amonton

EQ: How do I solve problems with Boyle, Charles, and Gay-Lussac (Amonton's) Laws?

GAS LAWS

Boyle's Law	Charles' Law	Gay-Lussac/Amontons' Law

Problems. Show your work, and use significant figures!

1. A certain gas occupies a volume of 345 mL at 273 K. What is its volume if the temperature is increased to 373 K?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{(345\text{ mL})}{(273\text{ K})} = \frac{V_2}{(373\text{ K})} \rightarrow V_2 = 471\text{ mL}$$

2. A gas in an airtight container contains a heated gas at 1.4 atm and 120°C. When the gas is cooled, the pressure drops to 1.1 atm. What must be the new temperature?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \rightarrow \frac{(1.4\text{ atm})}{(393\text{ K})} = \frac{(1.1\text{ atm})}{T_2} \rightarrow T_2 = 310\text{ K}$$

3. A balloon is inflated to 3.0 L under a pressure of 770 torr. What is the new volume if the pressure increases to 1.5 atm?

$$P_1V_1 = P_2V_2 \rightarrow (1.01\text{ atm})(3.0\text{ L}) = (1.5\text{ atm})V_2 \rightarrow V_2 = 2.0\text{ L}$$

Date:

2a. Boyle, Charles, and Gay-Lussac/Amonton (cont.)

4. A sample of a gas at STP has a volume of 495 mL.

   a. If the pressure on the gas increased to 900. torr, what is the new volume?

   $$P_1V_1 = P_2V_2 \rightarrow (760.\text{ torr})(495\text{ mL}) = (900.\text{ torr})V_2 \rightarrow V_2 = 418\text{ mL}$$

   b. If the temperature on the gas increased to 37°C, what is the new volume?

   $$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{(495\text{ mL})}{(273\text{ K})} = \frac{V_2}{(310.\text{ K})} \rightarrow V_2 = 562\text{ mL}$$

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5. A balloon is inflated to 4300 mL at a temperature of 315 K. For the balloon to deflate to a volume of 4100 mL, to what temperature (in Kelvin) must it be decreased?

   $$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{(4300\text{ mL})}{(315\text{ K})} = \frac{(4100\text{ mL})}{T_2} \rightarrow T_2 = 3\overline{0}0\text{ K}$$

6. A helium tank contains several gallons of helium at a pressure of 15 atm and 25°C. The tank is left to sit outside on a warm summer day (32°C), and the pressure inside increases. What is the new pressure?

   $$\frac{P_1}{T_1} = \frac{P_2}{T_2} \rightarrow \frac{(15\text{ atm})}{(298\text{ K})} = \frac{P_2}{(305\text{ K})} \rightarrow P_2 = 15\text{ atm}$$

7. A sample of carbon dioxide occupies 5.6 L at 760. torr. The pressure changes, and the volume is reduced to 4300 mL. What must be the new pressure?

   $$P_1V_1 = P_2V_2 \rightarrow (760.\text{ torr})(5.6\text{ L}) = P_2(4.3\text{ L}) \rightarrow V_2 = 990\text{ torr}$$

8. Think: Nitrogen gas has a density of 1.18 g/L at 25°C and 1.00 atm. If 28.0 grams of nitrogen is heated to 55°C, and the pressure stays the same, what is the new volume?

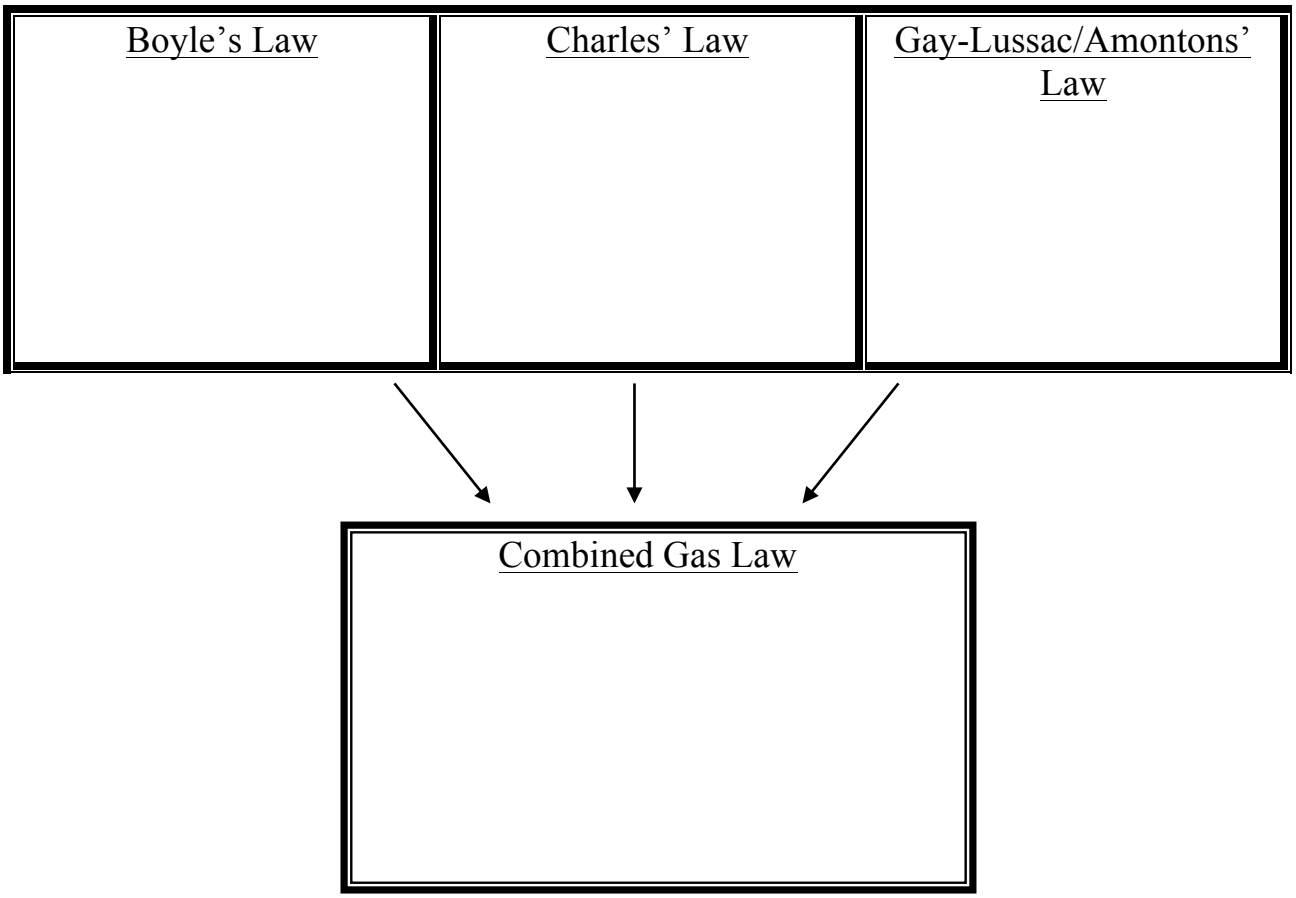
   $$28.0\text{ g N}_2\text{ x}\frac{1\text{ L N}_2}{1.18\text{ g N}_2} = 23.73\text{ L N}_2\text{ (3 sf)}$$

   $$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{(23.73\text{ L})}{(298\text{ K})} = \frac{V_2}{(328\text{ K})} \rightarrow V_2 = 26.1\text{ L}$$

Date:

2b. Combined Gas Law

EQ: How was the Combined Gas Law derived?



Problems. Show your work, and use significant figures!

1. A sample of a gas has a volume of 456 mL and a temperature of 64°C. The pressure exerted on the gas is 1.00 atm. The pressure on the gas changes, and the temperature is decreased to 58°C. If the volume of the gas is now 342 mL, what is the pressure in atm?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow \frac{(1.00\text{ atm})(456\text{ mL})}{(337\text{ K})} = \frac{P_2(342\text{ mL})}{(331\text{ K})} \rightarrow P_2 = 1.31\text{ atm}$$

2. A balloon is filled outside with 4.30 L of helium. The temperature and pressure outside are 31°C and 755 mm Hg, respectively. It is brought inside to an air-conditioned room where the pressure is 760. mm Hg. If the volume of the balloon decreases to 4.18 L, what is the temperature of the room in Celsius?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow \frac{(755\text{ mm Hg})(4.30\text{ L})}{(304\text{ K})} = \frac{(760.\text{ mm Hg})(4.18\text{ L})}{T_2} \rightarrow T_2 = 297\text{ K}$$

°C = 297 K - 273 = 24°C

Date:

2c. Avogadro & Dalton

EQ: How do I solve problems using Avogadro & Dalton's Laws?

A. Volume & Moles

Avogadro's Law

Problems. Show your work, and use significant figures!

1. If 1.00 mol of a gas occupies 22.4 L at STP, how many liters do 2.00 moles occupy?

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \rightarrow \frac{22.41\ \text{L}}{1.00\ \text{mol}} = \frac{V_2}{2.00\ \text{mol}} \rightarrow V_2 = 44.8\ \text{L}$$

2. At a certain temperature and pressure, 0.25 moles of nitrogen occupy 4.5 L. How many moles of nitrogen are present at this same temperature and pressure but at a volume of 3300 mL?

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \rightarrow \frac{4.5\ \text{L}}{0.25\ \text{mol}} = \frac{3.3\ \text{L}}{n_2} \rightarrow n_2 = 0.18\ \text{mol}$$

B. Partial Pressures

Dalton's Law of Partial Pressures

Problems. Show your work, and use significant figures!

1. Scuba tanks contain a mixture of helium and oxygen. If the pressure of helium in a certain tank is 9.8 atm, and the pressure of oxygen is 2.6 atm, what is the total pressure inside the tank?

$$P_{total} = P_1 + P_2 = 9.8\ \text{atm} + 2.6\ \text{atm} = 12.4\ \text{atm}$$

2. A mixture of noble gases (helium, neon, and argon) has a total pressure of 960 torr. If the pressure of helium is 0.75 atm, and the pressure of neon is 250 mm Hg, what must be the pressure of argon? (Be sure to label your units!)

$$P_{total} = P_1 + P_2 + P_3$$

$$960.\ \text{torr} = 570.\ \text{torr} + 250.\ \text{torr} + P_3 \rightarrow P_3 = 140.\ \text{torr (or 0.184 atm)}$$

Date:

2c. Avogadro & Dalton (cont.)

C. Mixed Review

Problems. Show your work, and use significant figures!

1. A 2.2-L container holds 0.10 moles of krypton. What volume would 2.50 moles of krypton occupy?

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \rightarrow \frac{2.2\text{ L}}{0.10\text{ mol}} = \frac{V_2}{2.50\text{ mol}} \rightarrow V_2 = 55\text{ L}$$

2. Atmospheric pressure is 1.00**0** atm at sea level. If the atmosphere is made primarily of nitrogen (0.78**0** atm), oxygen (0.21**0** atm), and argon (0.009 atm), what is the partial pressure of the remaining gases such as carbon dioxide, methane, and ozone?

$$P_{total} = P_1 + P_2 + P_3 + P_4$$

$1.00\text{ atm} = 0.78\text{ atm} + 0.21\text{ atm} + 0.009\text{ atm} + P_4 \rightarrow P_4 = 0.001\text{ atm}$ (ignore sig figs)

Convert the above partial pressures to percentages to determine the percent of each gas in the atmosphere.

N_2 _____ % O_2 _____ % Ar _____ % Remaining _____ %

3. A mixture of hydrogen gas and water vapor has a pressure of 1.03 atm. If the partial pressure of the water vapor is 27 torr, what must be the pressure of the hydrogen gas? Label your answer with units.

$$P_{total} = P_1 + P_2$$

$783\text{ torr} = 27\text{ torr} + P_2 \rightarrow P_2 = 756\text{ torr}$ (or .995 atm)

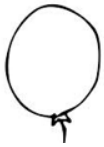
4. If 44 grams of carbon dioxide occupy 22.4 L, how many liters would do 0.22 moles of carbon dioxide occupy?

$$44\text{ g } CO_2 \text{ x } \frac{1\text{ mol } CO_2}{44.0\text{ g } CO_2} = 1.00\text{ mol } CO_2 \text{ (2 sf)}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \rightarrow \frac{22.41\text{ L}}{1.00\text{ mol}} = \frac{V_2}{0.22\text{ mol}} \rightarrow V_2 = 4.9\text{ L}$$

Diagrams:

Draw what happens to the balloon (size!) in each of the following scenarios.



Ext. Pressure Increases	Temperature Increases	Moles Increase	Addition of a Different Gas
Volume Decreases	Volume Increases	Volume Increases	Volume Increases

Date:

3a. The Ideal Gas Law

EQ: What is the Ideal Gas Law?

Ideal Gas Law

Problems. Show your work, and use significant figures!

1. At 32°C, 0.18 moles of helium occupy 2.43 L. Determine the pressure.

$$PV = nRT \rightarrow P = \frac{nRT}{V} = \frac{(0.18\text{ mol})\left(0.0821\ \frac{\text{L}\cdot atm}{\text{mol}\cdot\text{K}}\right)(305\text{ K})}{(2.43\text{ L})} = 1.9\text{ atm}$$

2. How many grams of methane (CH_4) occupy 900. mL at 305 K and 1.20 atm?

$$MVP = mRT \rightarrow m = \frac{MVP}{RT} = \frac{\left(16.04\ \frac{\text{g}}{\text{mol}}\right)(0.900\text{ L})(1.20\text{ atm})}{\left(0.0821\ \frac{\text{L}\cdot atm}{\text{mol}\cdot\text{K}}\right)(305\text{ K})} = 0.692\text{ g}$$

3. At 770 torr, 2.6 moles of a gas occupies 48 liters. Determine the temperature.

$$PV = nRT \rightarrow T = \frac{PV}{nR} = \frac{(770\text{ torr})(48\text{ L})}{(2.6\text{ mol})\left(62.4\ \frac{\text{L}\cdot\text{torr}}{\text{mol}\cdot\text{K}}\right)} = 230\text{ K}$$

4. Complete the following table using the Ideal Gas Law:

Pressure	Volume	Moles	Temperature
1.00 atm	3.52 L	0.144 mol	298 K
2.00 atm	56.6 L	4.55 mol	303 K
3.00 atm	73.1 L	8.32 mol	321 K

Date:

3b. Gas Laws & Stoichiometry

EQ: How do I combine stoichiometry with the Ideal Gas Law?

Demo Equation:

Tools for using Gas Laws & Stoichiometry:

Problems. Show your work, and use significant figures!

1. How many liters of hydrogen gas could be collected at 25°C and 0.98 atm if 15.9 grams of zinc react?

$$Zn + 2HCl \rightarrow 2\ ZnCl_2 + H_2$$

$$15.9\text{ g Zn} \times \frac{1\text{ mol Zn}}{65.39\text{ g Zn}} \times \frac{1\text{ mol } H_2}{1\text{ mole Zn}} = 0.2432\text{ mol } H_2 \text{ (3 sf)}$$

$$PV = nRT \rightarrow V = \frac{nRT}{P} = \frac{(0.2432\text{ mol})\left(0.0821\ \frac{\text{L·atm}}{\text{mol·K}}\right)(298\text{ K})}{(0.98\text{ atm})} = 6.1\text{ L}$$

2. How many grams of potassium would you need to produce 5.0 L of H_2 at STP?

$$2K + 2H_2O \rightarrow H_2 + 2KOH$$

$$5.0\text{ L } H_2 \times \frac{1\text{ mol } H_2}{22.41\text{ L } H_2} \times \frac{2\text{ mol K}}{1\text{ mol } H_2} \times \frac{39.1\text{ g K}}{1\text{ mole K}} = 17\text{ g K}$$

Date:

3b. Gas Laws & Stoichiometry (cont.)

3. A 2.50-gram sample of $NaClO_3$ is heated in order to form oxygen gas and NaCl. What volume of oxygen can be obtained at 373 K and 1.50 atm?

$$2\ NaClO_3 \rightarrow 2\ NaCl + 3\ O_2$$

$$2.50\ g\ NaClO_3 \times \frac{1\ mol\ NaClO_3}{106.4\ g\ NaClO_3} \times \frac{3\ mol\ O_2}{2\ mole\ NaClO_3} = 0.03524\ mol\ O_2\ (3\ sf)$$

$$PV = nRT \rightarrow V = \frac{nRT}{P} = \frac{(0.03524\ mol)\left(0.0821\ \frac{L \cdot atm}{mol \cdot K}\right)(373\ K)}{(1.50\ atm)} = 0.719\ L$$

4. Air bags contain sodium azide (NaN_3) which detonates to form nitrogen gas. How many grams of sodium azide are needed to fill a 70.0 L air bag with nitrogen at 25°C and 780. torr?

$$2NaN_3 \rightarrow 3N_2 + 2Na$$

$$PV = nRT \rightarrow n = \frac{PV}{RT} = \frac{(780.\ torr)(70.0\ L)}{\left(62.4\ \frac{L \cdot torr}{mol \cdot K}\right)(298\ K)} = 2.936\ mol\ (3\ sf)$$

$$2.936\ mol\ N_2 \times \frac{2\ mol\ NaN_3}{3\ mol\ N_2} \times \frac{65.01\ g\ NaN_3}{1\ mole\ NaN_3} = 127\ g\ NaN_3$$

REVIEW