Name ___________________________________Chem 161, Section: _______**Group Number:** ______

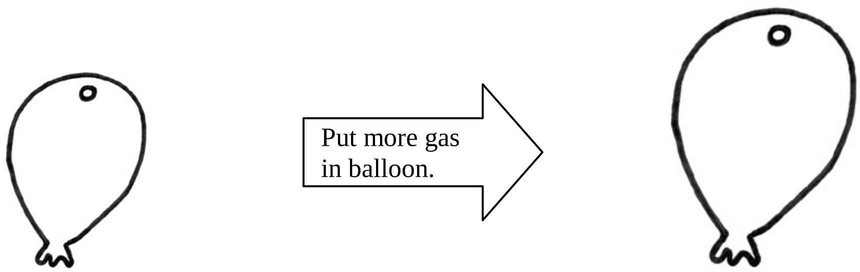
ALE 22. The Ideal Gas Law

(Reference: Chapter 5 in *Silberberg 5th edition*)

How do we relate all of the variables of a gas together?

The Model: Avogadro's Hypothesis

Avogadro's Hypothesis: Relationship between the volume and the number of moles of an ideal gas.
Condition: the pressure and the temperature of the gas are constants.



Balloon filled with 1 mole of a gas at atmospheric pressure and at room temperature. It has a volume of 24 L.

Balloon filled with 2 moles of a gas at atmospheric pressure and at room temperature. It has a volume of 48 L.

Key Question

1. Suppose you have n_1 moles of a gas at STP and n_2 moles of the gas also at STP. If you wanted to relate the volumes of the two gases, which of the following two equations would you use? (*Circle your choice*.)

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

   Briefly explain your choice. (Is volume directly proportional or inversely proportional to the number of moles of gas?)

The Model: Three Two-Variable Gas Laws

The individual gas laws (The "*a*", "*b*", and "*c*" in the equations are constants.):

$\boldsymbol{V} = a \cdot \boldsymbol{n}$	$\boldsymbol{V} = \frac{b}{\boldsymbol{P}}$	$\boldsymbol{V} = c \cdot \boldsymbol{T}$
Avogadro's Hypothesis (constant P, T)	**Boyle's Law** (constant n, T)	**Charles' Law** (constant n, P)

Key Questions

2. When *V* is in the numerator on one side of the equation and *T*, or *P*, or *n* is on the other side of the equation:
   a. *T* is in the numerator / denominator on the other side of the equation. (Circle your answer)
   b. *P* is in the numerator / denominator on the other side of the equation. (Circle your answer)
   c. *n* is in the numerator / denominator on the other side of the equation. (Circle your answer)

3. Charles' Law, Boyle's Law, and Avogadro's Hypothesis are often combined as one equation, which is called the ***Ideal Gas Law***. Combine the three equations in the Model, keeping **V** on one side and putting **T, P**, and **n** on the other within the dashed box. [*Hint*: Keep your answers to Questions 2a-c in mind as you combine the gas laws together. Since a constant times another constant is a constant, *a* and *b* and *c* have been combined as ***R*** (which is called the "gas constant"). Verify the Ideal Gas Law with either your instructor or with your textbook before your proceed.]

The Ideal Gas Law: **V =** ***R*** [ ]

4a. Algebraically rearrange the Ideal Gas Law (answer to Question 3) to solve for ***R***.

b. When 1 mole of an ideal gas is at STP, it has a volume of 22.414 L. Use this information to calculate the value (including units) of ***R*** to four significant figures. *Circle your answer*.

Exercises

A. A 1.0-L sealed glass flask is found attached to a pressure gauge and in a constant temperature bath. The transparent flask appears to be empty, but is labeled "0.0426 mol air". The pressure gauge indicates that the pressure inside the flask is 1.17 atm. What is the temperature of the bath in °C? *Circle your answer*.

B. A helium-filled balloon has a volume of 4.50 L when the temperature is 22.5 °C and the barometric pressure is 747.3 mmHg.

① The balloon's volume is neither increasing nor decreasing, so what is the pressure of the helium inside the balloon? *Explain your reasoning*.

② Calculate how many moles of helium are there inside the balloon? *Circle your answer*.

C. A 4.0-gram chunk of "dry ice" (solid CO_2, which exists as a gas at room temperature and atmospheric pressure) is placed in a 2.0-L plastic soda bottle and the bottle is capped. In time, heat from the room (the temperature of which is 21.9 °C) transfers to the bottle, and all of the dry ice sublimes (*i.e.*, the solid CO_2 becomes gaseous). What is the "extra pressure" inside the plastic bottle above the 1 atm it started at when the solid CO_2 was placed in it and the bottle sealed? (The bottle was not evacuated of air, so the 4.0-g of CO_2 is accompanied by ~1 atm of air pressure.) *Circle your answer*.

Key Questions

5a. Complete the equation relating the number of moles (n) of a substance with the mass (m) and the molar mass (M) of that substance. (Take Note! M = molar mass; M = molarity)

n =

b. Complete the Ideal Gas Law (See Question 3.) solved for P, putting everything else on the right-hand side.

P =

c. Now, substitute for *n* in the Ideal Gas Law the expression that is equivalent to *n* that you put as an answer to Question 6a.

P =

d. What is the definition of density? Make one final algebraic substitution, replacing what is equal to density in the equation in Question 6c by the symbol *d*.

P =

Exercise

D. ① Calculate the density of H_2O vapor at 1.00 atm and 100.0 °C in g/L. *Circle your answer*.

② 1.00 mL of water at 25 °C is heated to 100 °C, at which point it boils at an atmospheric pressure of 1 atm and is vaporized. What is the difference in volume (in mL) when this happens? (At 25 °C, liquid water has a density of 0.997 g/mL.) *Circle your answer*.

Key Question

6. Why is it dangerous to heat a liquid in a closed container? (Look back at Exercise D!)

Exercises

E. A 75.0 g sample of dinitrogen monoxide is confined in a 3.10 L flask. What is the pressure of the gas in atm at 115 ^{o}C? *Show your work and circle your answer*.

F. The density of a noble gas is 2.71 g/L at 3.00 atm and 0.00 ^{o}C (3 sig figs for the temperature). Identify the gas. *Show your work and circle your answer*.