

## Student Worksheet for Chemical Gas Laws

Attempt to work the following practice problems after working through the sample problems in the videos. Answers are given on the last page(s).

### Relevant Equations

#### Gas Laws

Boyle's Law:  $P_1V_1 = P_2V_2$

Charles' Law:  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Ideal Gas Law:  $PV = nRT$

Graham's Law:  $\frac{r_1}{r_2} = \frac{\sqrt{MM_2}}{\sqrt{MM_1}}$

Avogadro's Law:  $\frac{V_1}{n_1} = \frac{V_2}{n_2}$

#### Moles and Rates

Molar Mass:  $\Sigma$  Atomic Weights in Molecule

Moles: Amount Given  $\div$  MM

Mole Fraction ( $X_i$ ): # moles of a gas  $\div$   $\Sigma$  moles

K= Kelvin =  $^{\circ}\text{C} + 273$

STP= 273K and 1 atm

Partial Pressures:  $P_{\text{Total}} = \Sigma$  Partial Pressures

$$P_{\text{Partial}} = X_i (P_{\text{Total}})$$

Where n= number of moles, P= Pressure, V= Volume (L), T= Temperature (K), MM= Molar Mass, r= rate, STP= Standard Temperature and Pressure, and R= Gas Constant\*

\* NOTE: The R value used depends on the units of Pressure according to the following table:

Unit of Pressure	Gas Constant (R)
atm	0.0826 L <b>atm</b> K <sup>-1</sup> mol <sup>-1</sup>
barr (b)	8.34 L <b>b</b> K <sup>-1</sup> mol <sup>-1</sup>
Torr	62.4 L <b>Torr</b> K <sup>-1</sup> mol <sup>-1</sup>

#### Tips for solving Gas Law problems.

- 1) Be careful of your units of Pressure. The R value depends on it.
- 2) You will not always use every piece of data given.
- 3) In all cases, you will only be solving for 1 variable.
- 4) Identify what you are solving for, and then find the equation that you are given all other variables for.

1. If a gas occupies 25.2 liters at a pressure of 2 atm. What is the volume when the pressure is decreased to 0.5 atm?
2. A sample of air has a volume of 675.0mL at 106°C. At what temperature will its volume be at 700mL?
3. How many moles of CO<sub>2</sub> gas are contained in a 5L container at STP?
4. What is the volume in liters of 2.00 grams of Cl<sub>2</sub> at 150 K and 100 atm?
5. How does the Kinetic Molecular Theory explain the transformations of kinetic and potential energies? HINT: Remember that heat is a form of energy.

6. If a sample of gas has an effusion rate that Gas A is 1.5 times Gas B, and Gas B has a molar mass of 7 g/mol, what is the molar mass of Gas A?

7. How many moles of a gas occupy 78.0 L at 600 barr and 25.0 °C?

8. A 12.2 L metal tank at STP contains three gases: oxygen, helium, and nitrogen. If the partial pressures of the three gases in the tank are 72.0 atm of O<sub>2</sub>, 6.0 atm of N<sub>2</sub>, and 27.0 atm of He, how many moles of each gas are present inside of the tank?

9. If a steel container holds 3.00 moles of hydrogen gas and 4.50 moles of helium gas, and the total pressure is 7.00 atm., what is the partial pressure of each of the gases?

10. During a winter visit to Michigan, you decide to buy a Helium balloon for a friend's birthday. The temperature inside the store is  $60\text{ }^{\circ}\text{C}$ . The balloon has 249 moles of He and a volume of 0.5L. After arriving to your car, where it is  $-6.6\text{ }^{\circ}\text{C}$ , what is the new volume of the balloon and what is the explanation of what has happened to your balloon?

11. You are impatient with the balloon in #10, so you decide to inflate it faster by adding 50 moles of He. When the gas returns to  $60\text{ }^{\circ}\text{C}$ , what is the final volume of the balloon? If the balloon has a maximum volume of 0.55L, will it pop before giving it to your friend?

12. What is the MM of 52.7 g of a gas that exerts 3.15 Torr of pressure in a 1.5 L container at 275K?

13. The volume of a gas solution that exerts 45 barr at 1 liter is decreased to 750 mL. What is the new pressure exerted by the gas in barrs?

14. You have decided to cook a pasta dinner for your family. After turning the stove on to warm the water, you notice that the pot lid begins to bounce (increasing the volume of the gas). If the pot's (initial volume) was 10.5L at room temperature (23°C), what was the new volume when the lid "jumper" after the temperature was raised to 101°C.

15. How many moles of any gas in a 1.75 liter container exerts 28 Torr of pressure at 273K?

1. If a gas occupies 25.2 liters at a pressure of 2 atm. What is the volume when the pressure is decreased to 0.5 atm?

$$P_1 V_1 = P_2 V_2 \quad \text{You are solving for } V_2.$$

$$V_2 = (P_1 V_1) / P_2$$

$$= (2 * 25.2) / 0.5$$

$$= 100.8 \text{ L}$$

2. A sample of air has a volume of 675.0 mL at 106°C. At what temperature will its volume be at 700 mL?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{Solving for } T_2$$

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

$$= \frac{0.7 * 379}{0.675}$$

$$= 393.04 \text{ K}$$

3. How many moles of CO<sub>2</sub> gas are contained in a 5L container at STP?

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$= \frac{(1 * 5)}{(0.0826 * 273)}$$

$$= 0.22 \text{ moles CO}_2$$

4. What is the volume in liters of 2.00 grams of Cl<sub>2</sub> at 150 K and 100 atm?

First convert grams to moles.

$$\text{Moles} = \frac{2g}{70.9g/mol} = 0.03 \text{ moles Cl}_2$$

Now use the Ideal Gas Law: PV=nRT to solve for V

$$V = \frac{nRT}{P}$$

$$= \frac{(0.03 * 0.0826 * 150)}{100}$$

$$= 3.7 * 10^{-3} \text{ L or } 3.7 \text{ mL}$$

5. How does the Kinetic Molecular Theory explain the transformations of kinetic and potential energies? HINT: Remember that heat is a form of energy.

When heat energy is added to a system, the heat energy is transformed to kinetic energy. The kinetic energy is then transformed to potential energy. Think of it as a group of people are confined to a small space or room. This room catches on fire/heat is added. When that happens, people start running and try to get away from the fire/heat. As the people run, the potential to run into each other increases as a result of kinetic/moving energy increasing. Molecules behave the same way. Chemically, this increased movement of the molecules makes it more likely that two molecules will interact, just as the fire makes it more likely that two people will interact.

6. If a sample of gas has an effusion rate that Gas A is 1.5 times Gas B, and Gas B has a molar mass of 7 g/mol, what is the molar mass of Gas A?

$$\frac{\text{rate 1}}{\text{rate 2}} = \frac{\sqrt{MM2}}{\sqrt{MM1}}$$

$$\frac{1.5}{1} = \frac{\sqrt{X}}{\sqrt{7}}$$

$$\sqrt{X} = 1.5\sqrt{7} \text{ Note that anything multiplied by 1 equals the same.}$$

$$\sqrt{X} = 3.97 \text{ g/mol}$$

Square both sides to find X.

$$X = \text{MM of Gas A} = 15.75 \text{ g/mol}$$

7. How many moles of a gas occupy 78.0 L at 600 barr and 25.0 °C?

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$= \frac{600 \cdot 78}{8.34 \cdot 298}$$

$$= 18.83 \text{ moles of gas}$$

8. A 12.2 L metal tank at Standard T contains three gases: oxygen, helium, and nitrogen. If the partial pressures of the three gases in the tank are 72.0 atm of O<sub>2</sub>, 6.0 atm of N<sub>2</sub>, and 27.0 atm of He, how many moles of each gas are present inside of the tank?

For this problem, you are given pressures, but need moles. Thus, you must first find the partial pressures of each gas, and then use the Ideal Gas Law to solve for n (number of moles). The former begins with the mole fraction of each gas.

$$P_{O_2} = 72/105 = 0.686$$

$$P_{N_2} = 6/105 = 0.057$$

$$P_{He} = 27/105 = 0.257$$

Now that you have the pressure for each gas, plug the P value into  $PV=nRT$  to solve for n. In all cases,  $n = \frac{PV}{RT}$

$$\text{Oxygen: } \frac{0.686 \cdot 12.2}{0.0826 \cdot 273} = \frac{8.37}{22.55} = 0.37 \text{ moles of Oxygen}$$

$$\text{Nitrogen: } \frac{0.057 \cdot 12.2}{0.0826 \cdot 273} = \frac{0.70}{22.55} = 0.03 \text{ moles of Nitrogen}$$

$$\text{Helium: } \frac{0.257 \cdot 12.2}{0.0826 \cdot 273} = \frac{3.13}{22.55} = 0.14 \text{ moles of Helium}$$

Hopefully, you noticed that the equation is the same and only the value of P changes.

9. If a steel container holds 3.00 moles of hydrogen gas and 4.50 moles of helium gas, and the total pressure is 7.00 atm., what is the partial pressure of each of the gases?

$$P_{\text{partial}} = X_i(P_{\text{Total}})$$

$$P_H = \left(\frac{3}{7.5}\right) \cdot 7 = 2.8 \text{ atm of H}$$

$$P_{He} = \frac{4.5}{7.5} \cdot 7 = 4.2 \text{ atm of He}$$

To check your work, the partial pressures should sum to the total pressure. In this case, 2.8 atm + 4.2 atm = the total pressure of 7 atm.

10. During a winter visit to Michigan, you decide to buy a Helium balloon for a friend's birthday. The temperature inside the store is 60 °C. The balloon has 249 moles of He and a volume of 0.5L. After arriving to your car, where it is -6.6°C, what is the new volume of the balloon and what is the explanation of what has happened to your balloon?

Solving for V<sub>2</sub>.

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



$$\begin{aligned}
 V_2 &= \frac{V_1 T_2}{T_1} \\
 &= \frac{0.5 \times 266.34}{333} \\
 &= \frac{133.17}{333} \\
 &= 0.40 \text{ L}
 \end{aligned}$$

This question extends from #5. As the temperature decreases, the gas molecules crowd closer together, just like people get closer together to stay warm when it's cold. As the molecules move less because they are clustered, there are fewer collisions with the balloon container. This causes the balloon to be less expanded because fewer molecules are pushing on it outwardly. Inevitably, the balloon will attempt to "hug" the molecules inside that are as close to each other as possible, and in the center. This leads to natural deflation/less volume.

11. You are impatient with the balloon in #10, so you decide to inflate it faster by adding 50 moles of He. When the gas returns to 60 °C, what is the final volume of the balloon? If the balloon has a maximum volume of 0.55L, will it pop before giving it to your friend?

Solving for  $V_2$

$$\begin{aligned}
 \frac{V_1}{n_1} &= \frac{V_2}{n_2} \\
 V_2 &= \frac{V_1 n_2}{n_1} \\
 &= \frac{0.5 \times (249 + 50)}{249} = \frac{149.5}{249} \\
 &= 0.60 \text{ L of Volume}
 \end{aligned}$$

Yes, the balloon will explode because after you added 50 moles of air and the increased temperature has increased the volume of the balloon, the 0.60 L volume exceeds the 0.55 L maximum capacity of the balloon.

12. What is the MM of 52.7 g of a gas that exerts 3.15 Torr of pressure in a 1.5 L container at 275K?

$$PV = nRT$$

Molar mass is not a factor in the Ideal Gas Law, but moles are, and are calculated as

$\frac{\text{Amount Given}}{\text{Molar Mass}}$ . Using the two formulas, solve for  $n$ , and then for MM.

$$\begin{aligned}
 n &= \frac{PV}{RT} \\
 &= \frac{3.15 \times 1.5}{62.4 \times 275}
 \end{aligned}$$

$$= \frac{4.73}{17160} = 0.00028 \text{ moles of gas or } 2.8 \times 10^{-4} \text{ moles of gas}$$

Solving for MM:

$$\text{Moles} = \frac{\text{Amount Given}}{\text{Molar Mass}}$$

Manipulation of the equation:

$$\text{Moles} * \text{Molar Mass} = \text{Amount Given}$$

$$\begin{aligned} \text{Molar Mass} &= \frac{\text{Amount Given}}{\text{Moles}} \\ &= \frac{52.7}{0.00028} = \boxed{188,214.29 \text{ g/mol}} \end{aligned}$$

13. The volume of a gas solution that exerts 45 barr at 1 liter is decreased to 750 mL. What is the new pressure exerted by the gas in barrs?

Using Boyle's Law to solve for  $P_2 = \frac{P_1 V_1}{V_2}$

$$P_2 = \frac{(45 * 1)}{0.75}$$

$$P_2 = \boxed{60 \text{ barrs of pressure}}$$

14. You have decided to cook a pasta dinner for your family. After turning the stove on to warm the water, you notice that the pot lid begins to bounce (increasing the volume of the gas). If the pot's (initial volume) was 10.5L at room temperature (23°C), what was the new volume when the lid "jumper" after the temperature was raised to 101°C.

Using Charles' Law to solve for  $V_2$

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

$$V_2 = \frac{(10.5 * 298)}{374}$$

$$V_2 = \boxed{8.37L}$$

Note that the temperature is given in °C, so convert to K by adding the °C to 273 before using the formulas.

15. How many moles of any gas in a 1.75 liter container exerts 28 Torr of pressure at 273K?

Using the Ideal Gas Law,  $PV = nRT$

$$n = \frac{PV}{RT}$$

$$n = \frac{(28 * 1.75)}{(273 * 62.4)}$$

$$n = \boxed{0.0029 \text{ or } 2.9 * 10^{-3} \text{ moles of gas}}$$

Remember that the Ideal Gas Law "assumes" that all gasses behave the same/Ideally. The other gas Laws that evaluate the different variables of the IGL and the special properties of individual gasses account for how untrue this is. For the *Ideal* Gas Law, all gasses are treated the same. ☺