

## ChemQuest 36

# Gases and Moles

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Hour: \_\_\_\_\_

## Information: The Gas Constant

We previously examined the fact that  $\frac{PV}{T}$  is a constant as long as the number of moles of a gas remains unchanged.

This means that any time you measure a gas, the pressure times the volume divided by the temperature (in Kelvin) will always equal the same number unless the amount of gas in the container changes. We are now going to explore how the pressure, volume and temperature depend on the number of moles of gas that are present.

Table 1: Experimental Data for Three Different Samples of Gas That Contain the Same Amount of Gas (# of moles of gas is constant)

Gas	# of moles of Gas in container (mol)	Volume of Container (L)	Temperature of Gas (K)	Pressure of Gas (kPa)
A	0.3008	14.0	672.0	120.0
B	0.3008	16.0	1280	200.0
C	0.3008	10.0	340.0	85.0

Table 2: Experimental Data for Three Different Samples of Gases That Contain Different Amounts of Gas (# of moles of gas is not constant)

Gas	# of moles of Gas in container	Volume of Container (L)	Temperature of Gas (K)	Pressure of Gas (kPa)
D	3.3485	40.0	230.0	160.0
E	0.7306	22.5	315	85
F	0.85950	16.0	280	125

## Critical Thinking Questions

1. Prove that  $\frac{PV}{T}$  is a constant for the data in Table 1, but not a constant for the data in Table 2.

$$P_A V_A / T_A = P_B V_B / T_B = 2.5; \text{ but in Table 2, } P_D V_D / T_D \text{ does not equal } P_E V_E / T_E$$

2. Why is  $\frac{PV}{T}$  a constant in Table 1, but not in Table 2?

The number of moles of gas is not constant in Table 2.

3. Which of the following is a constant for Table 1 and Table 2? (Note that “n” means **number** of moles of gas in the container.)

A)  $\frac{PT}{nV}$

B)  $\frac{PTn}{V}$

C)  $(n^2)PV+T$

D)  $\frac{PV}{nT}$

4. Consider your answer to question 3. Compute the numerical value of the constant by putting values into the equation indicated by your answer to question 3. This constant is given a special name, “The Ideal Gas Constant” and it has the symbol “R”.

$$\frac{PV}{nT} = 8.31 = R$$

5. Which of the following equations is true? The equation is known as the “Ideal Gas Law”.

A)  $PT = nRV$

B)  $PV = nRT$

C)  $TV = nRP$

$$\frac{PV}{nT} = R \rightarrow PV = nRT$$

6. At 215 kPa of pressure and a temperature of 318 K, 2.35 mol of a gas has what volume? (Use the ideal gas law and the ideal gas constant, R, to calculate V. Your answer should be 28.9 L.)

$$PV = nRT \rightarrow (215)V = (2.35)(8.31)(318) \rightarrow V = 28.88 \text{ L}$$

7. What is the temperature of a gas if 4.11 mol of a gas has a pressure of 315 kPa and a volume of 12.5 L?

$$PV = nRT \rightarrow (315)(12.5) = (4.11)(8.31)T \rightarrow T = 115.3 \text{ K}$$

8. 23.5 g of CO<sub>2</sub> gas is at a temperature of 45°C and a pressure of 125 kPa. What is the volume of the container? (Hint: change grams to moles and 45°C to Kelvin.)

$$23.5\text{g} \div 44.0\text{g/mol} = 0.534 \text{ mol}; T = 45^\circ\text{C} + 273 = 318\text{K}$$

$$PV = nRT \rightarrow (125)V = (0.534)(8.31)(318) \rightarrow V = 11.3 \text{ L}$$

### Information: Molar Volume

Molar volume: the volume of one mole of a gas. Depending on the temperature and pressure a mole of gas may have different volumes. Whenever we are speaking of molar volume, we can assume that we are talking about one mole of the gas. Thus, whenever we need to calculate the molar volume,  $n=1$ .

## Critical Thinking Questions

9. What is the molar volume of oxygen gas if the gas has a pressure of 120 kPa and a temperature of 38°C? Use the ideal gas law (from question 5) with  $n=1$  for one mole of gas and solve for  $V$ ; remember to use Kelvin temperature and that  $R$  always equals 8.31.

$$PV = nRT \rightarrow (120)V = (1)(8.31)(311) \rightarrow V = 21.5 \text{ L}$$

10. Prove that if two different gases are at the same pressure and temperature, each gas has the same molar volume.

In question 9 we looked at oxygen gas at 120 kPa and 38°C (311 K). Now, I'll pick another gas—nitrogen—at 120 kPa and 38°C.

$$PV = nRT \rightarrow (120)V = (1)(8.31)(311) \rightarrow V = 21.5 \text{ L}$$

11. What is the molar volume of any gas at STP? Recall that STP is standard temperature (273 K) and standard pressure (101.325 kPa).

$$PV = nRT \rightarrow (101.325)V = (1)(8.31)(273) \rightarrow V = 22.4 \text{ L}$$

12. Why do you think all gases have the same molar volume at STP?

As we found in question 10, the molar volume of a gas depends on the temperature and pressure and not the identity of the gas.

## Information: Using the Ideal Gas Law to Calculate Molar Mass

You should know that to find the number of moles ( $n$ ) of a substance, you take the mass ( $m$ ) of the substance and divide it by its molar mass ( $M$ ) according to the following equation:

$$\# \text{ of moles} = \frac{\text{mass}}{\text{Molar mass}} \Rightarrow n = \frac{m}{M}$$

Now consider the Ideal Gas Law,  $PV=nRT$ . Since  $n=m/M$  we can replace  $n$  with  $m/M$  in the ideal gas law to get:

$$PV = \frac{m}{M} RT$$

By rearranging it a bit, we can get a more useful form of the equation:  $MPV = mRT$ .

This equation can then be used when you are dealing with grams and molar mass instead of moles.

### Critical Thinking Questions

13. If 128g of a certain gas in a container with a volume of 21.5 L has a pressure of 132 kPa and a temperature of 45°C, what is the molar mass of the gas?

$$MPV = mRT \rightarrow M(132)(21.5) = (128)(8.31)(318) \rightarrow M = 119.2 \text{ g/mol}$$

14. How many grams of CO<sub>2</sub> are in a 5.0 L container if the pressure in the container is 101 kPa and the temperature is 280 K?

$$MPV = mRT \rightarrow (44.0)(101)(5.0) = m(8.31)(280) \rightarrow 9.55 \text{ g}$$

15. If 4.0 L of a gas were produced at STP and the mass of the gas was found to be 12.8g, then what is the molar mass of the gas?

$$MPV = mRT \rightarrow M(101.325)(4.0) = (12.8)(8.31)(273) \rightarrow 71.6 \text{ g/mol}$$