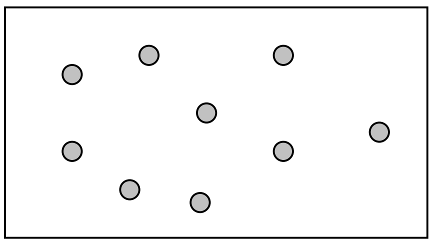
ChemQuest 35

Intro. to Gases

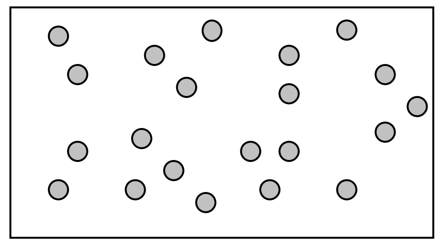
Name: ______________________________
Date: ________________
Hour: _____

Information: Gas Pressure

Figure 1: Two containers of gas molecules



Container 1



Container 2

Gas molecules move randomly in their containers, colliding with the walls of their containers causing "gas pressure." Pressure can be defined as the force pushing on an area. It can be described with the equation:

$$P = \frac{F}{A}$$ where P is pressure (in kPa), F is force (in N) and A is area (in m^2).

The more molecules collide with the wall and the faster the molecules are going when they strike the wall, the greater the force on the wall and therefore, the higher the pressure.

Critical Thinking Questions

1. Use the pressure equation to explain why it would be more likely for an ice skater to fall through the ice on a lake than it would be for someone walking across the lake with regular shoes on.
   The blade of an ice skate has a much smaller surface area than the sole of a shoe. With a smaller area (A), the pressure (P) on the ice is larger.

2. Which container in Figure 1 has the highest pressure? Explain.
   Container 2, because there are more gas molecules just like a tire filled with more air.

3. If I heated container 1 and did not heat container 2, could I get the pressure in container 1 to equal container 2? Explain.
   Yes, increasing the temperature increases pressure by speeding up gas molecules.

4. If container 2 was made of an elastic material and if I expanded container 2, could I make the two containers have equal gas pressures? Explain.
   Yes, increasing volume decreases pressure giving both containers an equal number of molecules per volume.

Information: Gas Laws

Observe the following experimental data concerning a container of gas. The pressure, volume and temperature of a gas are all related. The table of data was obtained by making measurements of the pressure, volume and temperature of a sample of a gas. Several different kinds of gases were used and all had identical results. The variable that was not changed was the amount of gas present. The number of moles of gas always remained the same during these trials.

Table 1: Experimental Data for Gases

Trial	**Pressure (P)** Units: kPa	**Volume (V)** Units: L	**Temperature (T)** Units: K
A	120	3.2	324.3
B	135	2.5	285.0
C	195	2.3	378.7
D	150	2.0	254.4
E	135	4.2	480.8
F	100	3.0	254.4
G	225	3.2	608.0
H	262	2.8	620.4

Critical Thinking Questions

5. Verify that this equation is true when the volume is unchanged: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
   (Hint: You must use two sets of data where the volume does not change like in trials A and G. Note: the subscript 1 refers to the pressure and temperature for the first trial you select and the subscript 2 refers to the pressure and temperature for the second trial you select.)

   $$\frac{P_A}{T_A} = \frac{P_G}{T_G} \rightarrow \frac{120}{324.3} = \frac{225}{608.0} = 0.370$$

6. Scientists often look for relationships between variables. If you wanted to see how the volume and pressure are related you would need to compare data from different trials when the temperature does not change. Why?
   Temperature would affect volume and pressure.

7. Find two sets of data in the table that have constant temperature. Which of the following mathematical relationships is true (there may be more than one) when the temperature remains unchanged? This relationship is known as "Boyle's Law", named after the person who first discovered it.

   a) $\frac{P_1}{V_1} = \frac{P_2}{V_2}$ b) $(P_1)(V_1) = (P_2)(V_2)$ c) $P_1 + V_1 = P_2 + V_2$ d) $\frac{P_1}{P_2} = \frac{V_1}{V_2}$

   B is the correct choice. Using data from trials D and F, we see:
   $(P_D)(V_D) = (P_F)(V_F) \rightarrow (150)(2.0) = (100)(3.0) = 300$

8. At constant pressure, which of the following equations is/are true? This relationship is known as "Charles' Law", named after the person who first discovered it.
   a) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ b) $(T_1)(V_1) = (T_2)(V_2)$ c) $P_1 + V_1 = P_2 - V_2$ d) $\frac{V_1}{V_2} = \frac{T_1}{T_2}$

   Substituting data from trials B and E you will see that a is correct.

9. Complete the following. You may want to consider the equations from questions 5, 7 and 8.

   a) At constant volume, as the temperature increases, the pressure always ___increases______.

   b) At constant temperature, as the volume increases, the pressure always ___decreases______.

   c) At constant pressure, as the temperature increases, the volume always ___increases______.

10. If the volume is not constant, is the statement you completed in 9a always true? Justify your answer by citing experimental data from the data table.
    No, in trial A, the temperature is greater, but the pressure is lower than in trial B.

11. If the temperature or pressure is not constant are your statements in 9b and 9c correct? Justify your answer.
    No. In trial C, the volume is greater, but the pressure is higher than in trial D. In trial C, the temperature is greater, but the volume is lower than in trial B.

12. Would the equations you discovered still be true if the temperature was measured in degrees Celsius (°C) instead of Kelvin (K)? Recall that K = °C + 273 or °C = K – 273.
    No, if you changed all the temperatures to °C, none of the equations would work.

13. Which of the following quantities is a constant?
    a) $\frac{PV}{T}$ b) PV + T c) $\frac{PT}{V}$

    For each trial, if you multiply the pressure and volume and then divide by the temperature you get approximately 1.18.

14. Based on your answer to question 13, verify that this equation is true: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ This equation is called the "Combined Gas Law". Notice that it contains all of the equations combined into one!
    Again, the pressure times the volume divided by the Kelvin temperature equals 1.18 for every trial in the table.

15. What needs to remain constant in order for equation 14 to be true? (You may need to refer to the information section.)
    The number of moles of gas in the container must be the same. If the moles changes we probably would not get (P)(V)/T to equal 1.18.

16. Prove that when the temperature remains constant, the combined gas law becomes Boyle's Law.
If the temperature is constant, then $T_2 = T_1$ and we can write:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_1} \rightarrow \text{multiplying both sides by } T_1 \rightarrow P_1V_1 = P_2V_2$$

17. Prove that when the pressure remains constant, the combined gas law becomes Charles's Law.
If pressure is constant, then $P_2 = P_1$ and we can write:

$$\frac{P_1V_1}{T_1} = \frac{P_1V_2}{T_2} \rightarrow \text{dividing both sides by } P_1 \rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

18. You have discovered several new mathematical relationships among gases. Now is your chance to practice using these equations!

a) At constant temperature, the volume of a gas expands from 4.0 L to 8.0 L. If the initial pressure was 120 kPa, what is the final pressure?

$P_1V_1 = P_2V_2 \rightarrow (120)(4.0) = P_2\,(8.0) \rightarrow P_2 = 60$ kPa

b) At constant pressure, a gas is heated from 250 K to 500 K. After heating, the volume of the gas was 12.0 L. What was the initial volume of the gas? Notice: as the temperature doubled, what happened to the volume?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{V_1}{250} = \frac{12.0}{500} \rightarrow V_1 = 6.0 \text{ L}$$

c) The volume of a gas was originally 2.5 L; its pressure was 104 kPa and its temperature was 270K. The volume of the gas expanded to 5.3 L and its pressure decreased to 95 kPa. What is the temperature of the gas?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow \frac{(104)(2.5)}{270} = \frac{(95)(5.3)}{T_2} \rightarrow T_2 = 522.9 \text{ kPa}$$

19. At constant temperature, if you increase the volume by a factor of two (doubling the volume), the pressure ____decreases_____ (increases or decreases) by a factor of ______2_______ (what number). (Refer to 18a for a hint.)