Gases and Atmospheric Chemistry

UNIT 2: GASES

All important vocabulary is in Italics and bold.

- Identify the abundances of the naturally occurring gases in the atmosphere.

- Examine the historical development of the measurement of pressure.
  Include: Evangelista Torricelli, Blaise Pascal

- Describe the various units used to measure pressure.
  *Include: **atmospheres** (atm), **kilopascals** (kPa), **millimetres of mercury** (mmHg)*

- Experiment to develop the relationship between the pressure and volume of a gas using visual, numeric, and graphical representations.
  *Include: **Boyle's Law***

- Experiment to develop the relationship between the volume and temperature of a gas using visual, numeric, and graphical representations.
  *Include: **Charles' Law**, **Absolute zero**, **Kelvin temperature scale**, **ideal gas***

- Develop the relationship between the pressure and temperature of a gas using visual, numeric, and graphical representations.
  *Include: **Gay-Lussac's Law**, Combined Gas Law, **partial pressure***

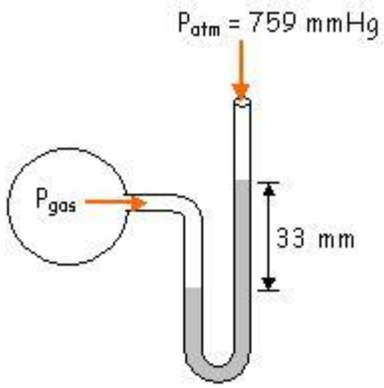
- Solve quantitative problems involving the relationships among the pressure, temperature, and volume of a gas using dimensional analysis.
  *Include: Amadeo Avogadro, **Ideal Gas Law** and the **mole***

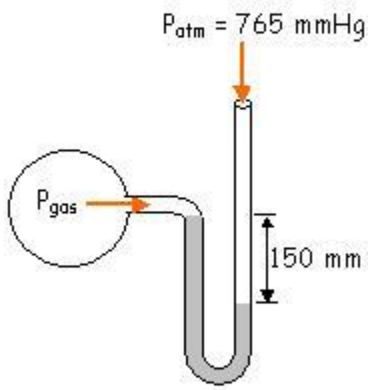
Additional KEY Terms

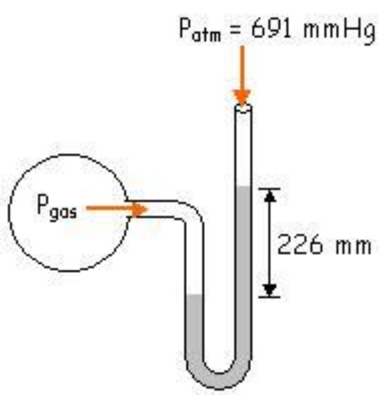
Barometer	Inverse relationship
Direct relationship	Molar volume
Molar mass	

Answer the following questions on Manometers and pressure units:

1. Find the pressure, in mmHg, kilopascals and atmospheres of the gas in each of the following manometers:

a. 

b. 

c. 

2. A gas container is fitted with a manometer. The level of the mercury is 15.0 mm lower on the open side. Using a laboratory barometer, you find that atmospheric pressure is 750.0 mm Hg. What is the pressure, in atmospheres, of the gas in the container?

3. A soccer ball is attached to an open-ended manometer. The mercury level in the manometer is 10.0 mm higher on the side attached to the ball than on the side open to the atmosphere. Atmospheric pressure has already been determined to be 770.0 mm Hg. What is the gas pressure, in kPa, inside the ball?

Complete the following activity: This assignment will be worth 10 marks.
Submit: a data document and graph with questions.

Introduction:

The relationship between gas pressure and its volume (**with a constant temperature)** was first described by Robert Boyle in 1662 and is commonly called **Boyle's Law**.

GO TO THE FOLLOWING WEBSITE:
http://content.blackgold.ca/ict/Division4/Science/Div.%204/Boyles%20Law/boyleslaw.htm

On the website is a Flash simulation of a syringe and a pressure gauge. This simulation uses a moveable syringe with a maximum volume of 30 mL. The pressure is measured in psi (pounds per square inch).

Remember from our discussion of units of pressure - 14.7 psi = 101.3 kPa
The starting volume of 30.0 mL is at standard pressure, 1 atm or 14.7 psi.

We will examine how pressure changes as the volume in the syringe is decreased.

Procedure:

1. Choose ANY ONE of the four available gasses (*make sure all your data and graphs note this gas*)
2. Start collecting data for your chosen gas by dragging the plunger to continuous, incremental volumes. The pressure will read on the gauge and be recorded in the accompanying table.
3. Collect the pressure values for **8** distinctly different volumes.
4. Draw a graph of pressure vs. volume (pressure on y-axis and volume on the x-axis). Include a title and labels (including units) on the axis

    **put pressure into kPa units and volume in mL.

Questions:

1. How does the pressure change when the volume of the gas was decreased? Is this a direct or inverse relationship?
2. Using the graph of your data , determine the value for the following questions:
    a. If the volume is doubled from 10.0 mL to 20.0 mL, what does your data show happens to the pressure? Show the pressure values from your graph.
    b. If the volume is halved from 30.0 mL to 15.0 mL, what does your data show happens to the pressure? Show the pressure values from your graph.
    c. If the volume is tripled from 7.0 mL to 21.0 mL, what does your data show happens to the pressure? Show the pressure values from your graph.
3. If this relationship is direct, then pressure divided by volume will equal a constant value ($k = P/V$). If the relationship is inverse, then pressure multiplied by volume will equal a constant value ($k = P \cdot V$).

    Based on your answer to Question #1, choose the correct formula and calculate k for the pressure-volume pairs in your data table (divide or multiply the P and V values). If you choose correctly, the calculated values should be similar. Show the answers in a separate column of the table.

Answer the following questions. Remember that showing all your work is good practice.

1. Gas is placed into a syringe until the pressure is 45.0 kPa. What is the new pressure if

   a) the volume in the syringe is doubled?
   b) the volume in the syringe is tripled?
   c) the volume is one third its original volume?

2. 100.0 mL of gas is placed into a syringe. What is the new volume if

   a) the pressure is doubled?
   b) the pressure is tripled?
   c) the pressure is one quarter the original pressure?

3. Change the following from the initial conditions to the new conditions:

   a) 100.0 mL oxygen gas at 10.50 kPa is changed to 9.91 kPa
   b) 25.0 mL nitrogen at 0.990 atm is changed to 0.751 atm
   c) 1.40 atm of carbon dioxide in 1.32 L is changed to 0.705 L
   d) 525 mL neon at 49.3 kPa is changed to 845 mL
   e) 0.150 L carbon monoxide at 635 mmHg is changed to 895 mmHg

Complete the following activity: This assignment will be worth 10 marks.
Hand-in a data table of temperature (^{0}C) and volume (mL), quick graph and ***ALL*** questions.

Introduction:

The relationship between gas volume and its temperature (**while keeping the pressure constant**) was first described by Jacques Charles around 1787 and is commonly called **Charles's Law**.

GO TO THE FOLLOWING WEBSITE:
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/charles_law.html

On the website is a simulation plunger that measures the volume of the gas at a constant pressure. When the temperature is changed, the volume of the gas will change by pushing out or drawing in the plunger.

The volume is measured as cm^3 *which is the same as* mL.

The temperature (given in Kelvin) must be converted in to degrees Celsius. The following conversion is given:

Temperature in Kelvin = Temperature in Celsius + 273

OR

$T_K = T_C + 273$ $\qquad$ $T_C = T_K - 273$

Method of Evaluation:

Directions:

Follow the directions below and answer the questions.

5. Drop the temperature to very low (approx. 100K), and ***wait*** until the gas equalizes – yellow light on.
6. Start collecting data for the gas by increasing the temperature (try to move up in even increments). Select "show data table."
7. Collect the volume values for at **8** distinctly different temperatures.
8. Record the data yourself, converting into units of (^{0}C) and (mL)
9. Generate a ***quick*** (but neat) ***sketch*** of a graph that shows the relation ship of volume vs. temperature using the *"Show Plot"* button in the Data Table.
10.

Questions:

1. Based upon the data is this a direct or inverse relationship?

Answer the following questions. Remember that showing all your work is good practice.

1. Calculate the change in temperature, in degrees Celsius, when the volume of 1.00 L of a gas, at 25.0°C, is doubled to 2.00 L.

2. Calculate the volume of 100.0 mL gas if its temperature is doubled from 20.0°C to 40.0°C.

3. You get a balloon at the circus with a volume of 2.50 L at room temperature (25.0°C). You then step outside on a cold winter day (–25.0°C). If the pressure remains constant, what is the balloon's new volume?

4. 20.0 mL of a gas at 285 K increases in volume to 32.0 mL. What is the new temperature of the gas?

5. Find the new volume if the following changes occur at a constant pressure:

    a. 225 mL of oxygen at 273 K warmed to 300 K.
    b. 3.00 L of nitrogen cooled from 90.0°C to –45.0°C.

6. Find the new temperature in degrees Celsius when the following changes occur at a constant pressure:

    a. 5.00 L of air at 45.0°C expands to 22.0 L.
    b. 100.0 mL of helium at 300.0 K compresses to 80.0 mL

7. Would it be possible for a sample gas to have a volume of zero? Explain.

ANSWER KEY

1. 323°C 2. 107 mL 3. 2.08 L 4. 456 K 5a) 257 mL b) 1.9 L
6a) 1130°C b) –33.0°C

Answer the following questions. Remember that showing all your work is good practice.

1. A gas in a rigid container has a pressure of 1.00 atm at 25.0°C. What is the pressure of the gas at 50.0°C?

2. A gas in a rigid container has a pressure of 695 torr at 20.0°C. What is the pressure of the gas at – 20.0°C?

3. Water vapour in a pressure cooker is at standard pressure at 30.0°C. What is the temperature, in degrees Celsius, when the pressure is 151 kPa?

4. The air pressure in a SCUBA tank is 175 atm at room temperature, 22.0°C. What is the pressure in the tank while diving in water at a temperature of 6.0°C?

5. You fill your tires on a cool morning (10.0°C) to a pressure of 205. kPa. If you take a long driving trip where the tire temperature reaches 85.0°C, what is the pressure in the tire while you are driving?

6. Instead of filling the tires on your car when they are cold, you fill them after driving for a period of time. You stop at a gas station and fill your tires to 205 kPa when the tire temperature is 45.0°C. A cold snap hits and the temperature dips to –30.0°C. What is the pressure in the tires?

7. An air compressor is filled to a pressure of 3.2 atm at 26.0°C. If the air is suddenly released from the compressor and the pressure drops to 2.6 atm, what is the temperature, in degrees Celsisus of the air remaining in the compressor?

ANSWER KEY

1. 1.08 atm **2. 600 torr** **3. 179°C** **4. 170 atm**

5. 259 kPa **6. 157 kPa** **7. –30°C**

Dalton's Law Worksheet

1) A metal tank contains three gases: oxygen, helium, and nitrogen. If the partial pressures of the three gases in the tank are 35 atm of O_2, 5 atm of N_2, and 25 atm of He, what is the total pressure inside of the tank?

2) Blast furnaces give off many unpleasant and unhealthy gases. If the total air pressure is 0.99 atm, the partial pressure of carbon dioxide is 0.05 atm, and the partial pressure of hydrogen sulfide is 0.02 atm, what is the partial pressure of the remaining air?

3) If the air from problem 2 contains 22% oxygen, what is the partial pressure of oxygen near a blast furnace?

4) Three flasks are connected to each other, separated only by a three-way stopcock.

- Flask 1 has a volume of 3.000 liters and holds helium gas at a pressure of 3.500 atmospheres
- Flask 2 has a volume of 2.000 liters and holds nitrogen gas at a pressure of 2.000 atmospheres
- Flask 3 has a volume of 1.800 liters and holds oxygen gas at a pressure of 4.000 atmospheres If the stopcock separating the flasks were to be opened, what would the partial pressure of each gas in the apparatus be?

5) What would the total pressure in the apparatus be?

Answer the following questions. Remember that showing all your work is good practice

1. In a laboratory experiment, 85.3 mL of a gas are collected at 24.0°C and 733 mm Hg pressure. Find the volume STP (**s**tandard **t**emperature and **p**ressure: 0.0°C and 101.3 kPa).

2. A flexible container has a maximum volume of 15.0 L. If the container is filled to 8.0 L at a pressure of 1.8 atm and temperature of 17.0°C at what temperature will the container have a maximum volume at a pressure of 2.9 atm?

3. If I have 17 L of gas at a temperature of 27°C and a pressure of 88.89 atm, what will be the pressure of the gas if I raise the temperature to 67°C and decrease the volume to 12 L?

4. A gas that has a volume of 28 L, a temperature of 45°C, and an unknown pressure has its volume increased to 34 L and its temperature decreased to 35°C. If the pressure after the change is 2.0 atm, what was the original pressure of the gas?

5. A sample of argon has a volume of 205 mL when its temperature is –44.0°C and its pressure is 712 mm of Hg. What would be the volume of the argon at 755 mmHg and –15.0°C?

6. A student collects a 325 mL sample of hydrogen at 36.0°C and 103.2 kPa. What volume would the hydrogen occupy at 91.9 kPa and 18.0°C?

7. A toy balloon has an internal pressure of 1.05 atm and a volume of 5.0 L at 20.0°C. The balloon is released and reaches the upper atmosphere where the volume of the balloon becomes 21.0 L and the pressure is 0.21 atm. What is the temperature at this altitude?

8. A gas collected on a day when the pressure was 101 kPa and the temperature was 8.0°C has a volume of 942 mL. If the volume on another day changed to 837 mL when the temperature was 33°C, what was the pressure on that day?

ANSWER KEY

1. 76 mL 2. 880 K 3. 140 atm 4. 2.5 atm 5. 218 mL

6. 344 mL 7. 250 K 8. 120 kPa

ANSWER QUESTIONS ON THE IDEAL GAS LAW:

1. If I have 4 moles of a gas at a pressure of 5.6 atm and a volume of 12 litres, what is the temperature?

2. If I have an unknown quantity of gas at a pressure of 1.2 atm, a volume of 31 litres, and a temperature of $87^{o}C$, how many moles of gas do I have?

3. If I contain 3 moles of gas in a container with a volume of 60 litres, and at a temperature of 400 K, what is the pressure inside the container?

4. If I have 7.7 moles of hydrogen gas at a pressure of 0.09 atm, and at a temperature of $56^{o}C$, what is the volume of the container that the gas is in? How much would this gas weight in grams?

5. If I have 0.5 grams of oxygen gas at a temperature of $67^{o}C$, and a volume of 88.89 litres, what is the pressure of the gas?

6. If I have an unknown quantity of nitrogen gas at a pressure of 0.5 atm, a volume of 25 litres, and a temperature of 300 K, how many grams of nitrogen gas do I have?

7. Small children are occasionally injured when they try to inhale helium from a compressed helium tank. If a small child tries to transfer the contents of a 5.0 L tank of helium at a pressure of 125 atm and a temperature of $20^{o}C$ into its lungs, how many moles of gas will it inhale? How much will it weight?

8. After the child has exhaled all of this gas, it becomes sick. If its temperature rises to $42^{0}C$ and it can hold 0.15 moles of air in its lungs at a pressure of 1.15 atm, what is the new volume of the child's lungs

9. What is the pressure inside a 25 L container that holds 1.86 g of carbon dioxide gas at a temperature of 250^0C?

10. If 4 moles of ammonia gas at a pressure of 5.4 atm has a volume of 120 litres, what is the temperature? How many grams is this?

11. If I initially have a gas with a pressure of 84 kPa and a temperature of 35^oC and I heat it an additional 230 degrees, what will the new pressure be? (assume the volume of the container is constant)

12. My car (if I had one), has an internal volume of 2600 L. If the sun heats my car from a temperature of 20 degrees to a temperature of 55 degrees, what will the pressure inside my car be? Assume the pressure was initially 760 mmHg.

13. How many moles of gas are in my car?

14. A toy balloon filled with air has an internal pressure of 1.25 atm and a volume of 2.50 L. If I take the balloon to the bottom of the ocean where the pressure is 95 atmospheres, what will the new volume of the balloon be? How many moles of gas does the balloon hold? (assume T = 285 K)

ANSWER:

1)	**205 K**	**7)**	**26 mol, 104 g**	**13)**	**110 moles**
2)	**1.3 moles**	**8)**	**3.3 L**	**14)**	**0.033 L, 0.13 moles**
3)	**1.64 atm**	**9)**	**7.4 kPa**		
4)	**2000 L, 15 g**	**10)**	**2000 K , 70 g**		
5)	**0.5 kPa**	**11)**	**48 kPa**		
6)	**14 g**	**12)**	**850 mmHg**		

Gases Unit Review

Use Boyles' Law to answer the following questions:

1. Part of the reason that conventional explosives cause so much damage is that their detonation produces a strong shock wave that can knock things down. A thermonuclear device contains 0.050 liters of gas under intense pressure. When the bomb casing is destroyed by the explosion, the gas is exposed to an atmospheric pressure of 1.00 atm. This causes the gas to expand rapidly producing the shock wave as it reaches a volume of 2.0×10^5 L. What is the original pressure of the gas in explosive?

2. Divers get "the bends" if they come up too fast because gas in their blood expands, forming bubbles in their blood which can clog arteries. If a diver has 0.05 L of gas in his blood under a pressure of 250 atm, then rises instantaneously to a depth where his blood has a pressure of 50.0 atm, what will the volume of gas in his blood be?

Use Charles' Law to answer the following questions:

3. On hot days, you may have noticed that potato chip bags seem to "inflate", even though they have not been opened. If I have a 250 mL bag at a temperature of 19 ^{0}C, and I leave it in my car which has a temperature of 60^0 C, what will the new volume of the bag be?

4. A soda bottle is flexible enough that the volume of the bottle can change even without opening it. You place an empty soda bottle (volume of 2.0 L) at room temperature (25 ^{0}C) in the freezer. The next day it has a new volume of 1.81 L. What is the temperature of your freezer?

Use Gay-Lussac's Law to answer the following questions:

5. The pressure in an automobile tire will cause it to explode if the pressure exceeds 2.0 atm. It is initially 1.88 atm at 25.0° C. Will the tire explode if the temperature warms up to 37.0°C?

6. A rigid plastic container holds 1.00 L methane gas at 660 mmHg pressure when the temperature is 22.0°C. When the temperature is increased the pressure rises by 50.5 mmHg. What was the final temperature?

Use the Combined Gas Law to answer the following questions:

7. A sample of air in a syringe exerts a pressure of 1.02 atm at a temperature of 22.0°C. The syringe is placed in a boiling water bath at 100.0°C. The pressure of the air is increased to 1.23 atm by pushing the plunger in, which reduces the volume to 0.224 mL. What was the original volume of the air?

8. I have 7.41 L of gas held at a temperature of 115 K in a container with a pressure of 60.0 atm. If by increasing the temperature and decreasing the pressure to 30.0 atm causes the volume of the gas to be 29.0 liters, how much did I raise the temperature?

Use the Ideal Gas Law to answer the following questions:

9. If I have 2.4 moles of gas held at a temperature of 97 ^{0}C and in a container with a volume of 45 liters, what is the pressure of the gas?

10. If I have an unknown quantity of gas held at a temperature of 1195 K in a container with a volume of 25 liters and a pressure of 560 atm, how many moles of gas do I have? If the gas was oxygen, what would its mass be?

ANSWER:

1) 4.0 x 10^{6} atm 2) 0.25 L 3) 285 mL 4) -3.3^{o}C 5) 2.1 kPA ~ Yes.

6) 45^{o}C 7) 0.214 mL 8) 110 K increase 9) 160 kPa 10) 143 moles, 4600 g