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LAB: IDEAL GAS LAW

AP PHYSICS II

Driving Question | Objective

What are the relationships between a) volume and temperature of a gas at constant pressure b) pressure and volume of a gas at constant temperature and c) pressure and temperature of a gas at constant volume? Perform an experiment whose data will help determine each of these relationships.

Materials and Equipment

- Beaker
- Water
- Hot plate
- Volume collector
- Tubing
- Cylinder
- Temperature probe
- PASCO Absolute Pressure Sensor
- PASCO Temperature Sensor
- Hot hands

Background

The ideal gas law is an equation that relates to the pressure, temperature, and volume of a gas and is used to estimate what will occur to it under varying conditions. The law is used for ideal gases: which have particles that do not attract or repel one another, particles that take up no space/have no volume, and have no intermolecular attractive forces between the collisions of molecules. Since no gas is truly ideal, the law is merely an approximation of the behavior of a real gas.

This equation is a combination of Boyle's Law ($p_1*v_1=p_2*v_2$), Charles law ($k = V/T$), Avogadro's law ($v_1/n_2=v_2/n_2$) and Gay-Lussac's law ($P/T = k$) and was first stated by Benoit Paul Emile Clapeyron, a French engineer, in 1834.

In this activity we will be exploring the relationship between the different components of the ideal gas law: pressure, temperature, and volume; as well as how these components affect each other when changed.

Safety

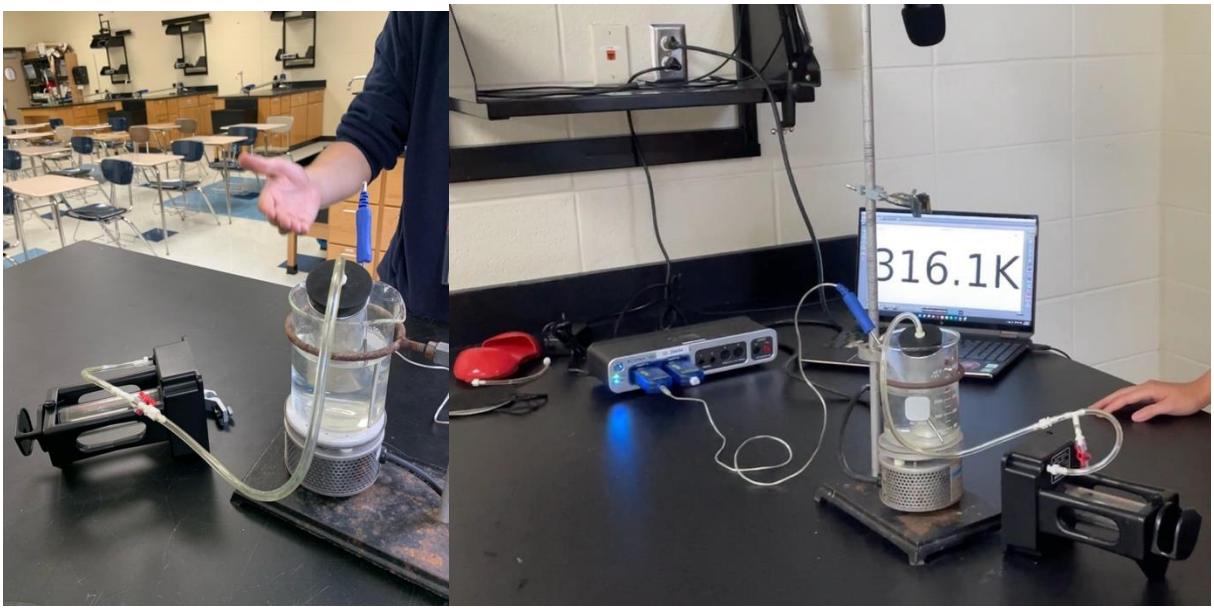
Follow these important safety precautions in addition to regular classroom procedures:

- Make arrangements to avoid the workstation from getting water on any of the sensors
- Use hot hands when dealing with anything that has come into contact with the hot plate

Procedure

SET UP: VOLUME AND TEMPERATURE

1. Fill the beaker approximately halfway with water and place it on the hot plate.
2. Connect the volume collector to the tubing with the valve. First, attach the tubing with the valve to the volume collector. Close the valve by making it perpendicular to the tubing. Twist the tubing at the connection slightly until it makes a clicking noise, meaning that it is secure.
3. Connect the tubing with the valve to the tubing without the valve. Make sure the screw is twisted tight.
4. Connect the tubing without the valve to the cylinder. This is the same connection as step 2, so it should also make a click noise when it is secured.
5. Place the volume collector horizontally on the table.
6. Place the temperature sensor and cylinder in the water and connect the temperature sensor to the PASCO interface.
7. Connect the USB to your laptop and create a new file to measure temperature in Kelvin.



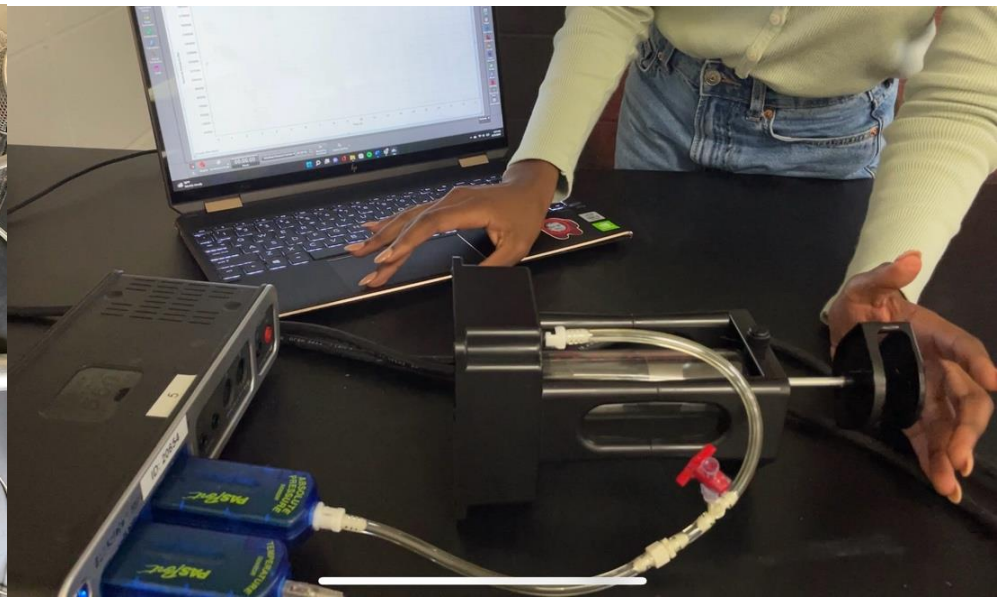
Your set up should look like the photos above.

COLLECT DATA

1. Measure the diameter of the volume collector. The markings on the volume collector measure length, not volume, so volume should be calculated using the volume of a cylinder formula V = Ah where A = πr^2. Use the displacement lengths on the volume collector to calculate volume.
2. Heat up the hot plate.
3. Record the temperature *T* and the volume *V* in the table.
4. Repeat step 4 until you have recorded the volume at 5 different temperatures. Use the data table in the Data Analysis section to organize your data.
5. Empty the water in the beaker and let the hot plate cool.

SET UP: PRESSURE AND VOLUME

1. Connect the volume collector to the tubing with the valve. First, attach the tubing with the valve to the volume collector. Close the valve by making it perpendicular to the tubing. Twist the tubing at the connection slightly until it makes a clicking noise, meaning that it is secure.
2. Connect the tubing with the valve to the absolute pressure sensor.
3. Place the volume collector horizontally on the table.
4. Connect the absolute pressure sensor to the PASCO interface.
8. Connect the USB to your laptop and create a new file to measure change in absolute pressure over time.



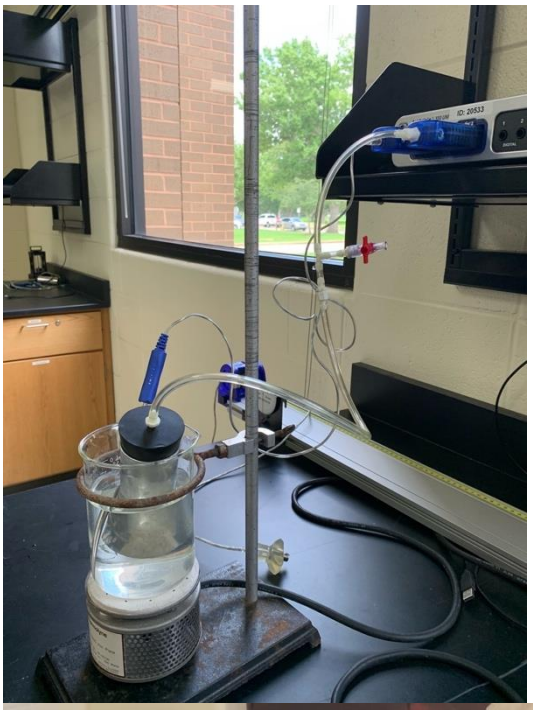
Your set up should look like the photos above.

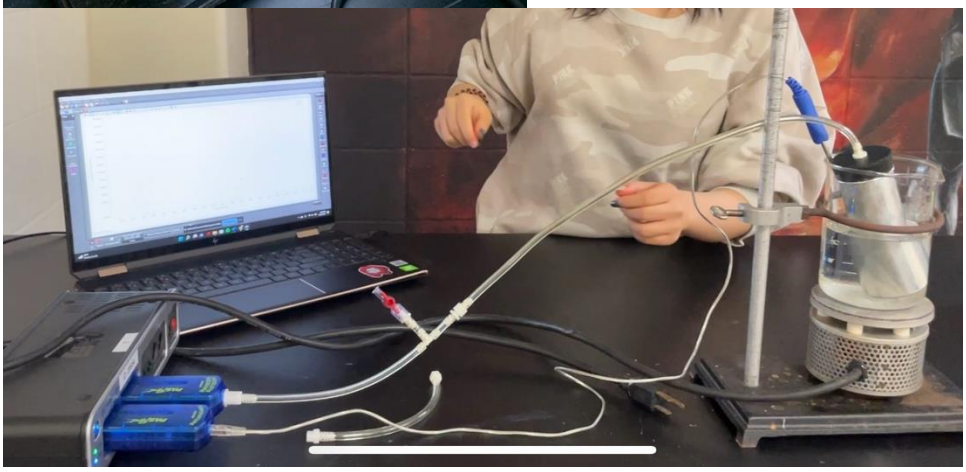
COLLECT DATA

1. Measure the diameter of the volume collector. The markings on the volume collector measure length, not volume, so volume should be calculated using the volume of a cylinder formula $V = Ah$ where $A = \pi r^2$. Use the displacement lengths on the volume collector to calculate volume.
2. Make sure the valve is open, then pull the syringe up to 50 mm.
3. Quickly push down to 40 mm, then release. Find the maximum pressure on the graph.
4. Repeat step 3 until you have recorded the pressure at 5 different volumes. Use the data table in the Data Analysis section to organize your data.

SET UP: PRESSURE AND TEMPERATURE

1. Fill in the beaker approximately 250 ml with water and place it on the hot plate.
2. Connect the cylinder with the pressure sensor with the valve tube and close the valve by making it perpendicular to the tubing. Screw a side of the valve tube into the opening of tube of the cylinder and ensure that it is tight.
3. Then, twist the tubing at the connection side with the pressure sensor slightly until it makes a clicking noise, meaning that it is secure.
4. Make sure the temperature is connected to the temperature sensor.
5. Place both the cylinder and the temperature probe into the beaker on the hot plate.
6. Connect the temperature sensor and the pressure sensor to the PASCO interface.
7. Connect the USB to your laptop and create a new file to measure the change in absolute pressure in relation to the change in temperature.





Your set up should look like the photos above.

COLLECT DATA

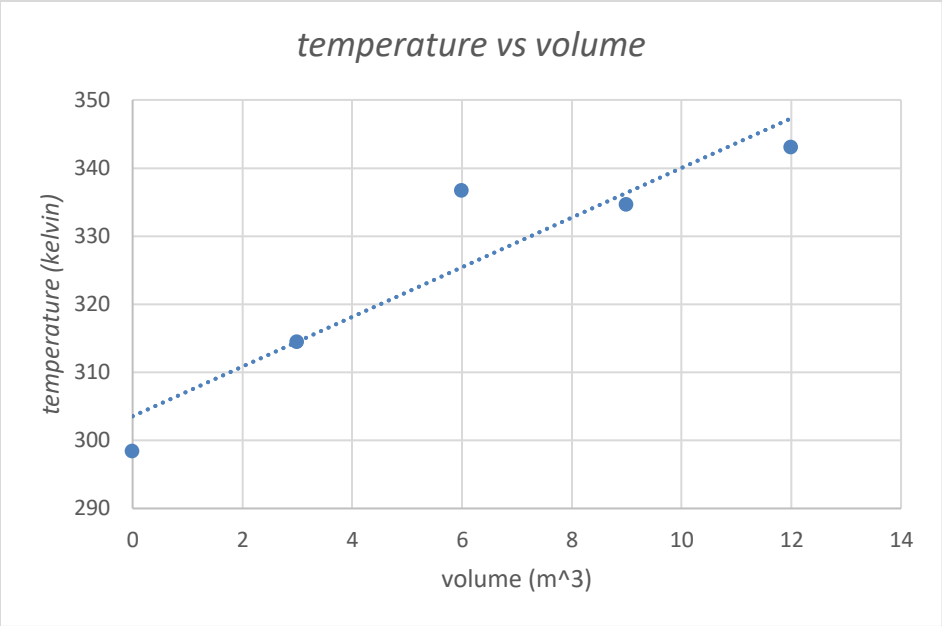
1. Heat up the hot plate.
2. Record the temperature *T* and the pressure P in the table at five different temperatures.
3. Repeat step 2 until you have recorded the pressure at 5 different temperatures. Use the data table in the Data Analysis section to organize your data.
4. Empty the water in the beaker and let the hot plate cool.

Data Analysis

Graph 1: Volume collected in Volume Collector vs. Temperature of Water in Beaker

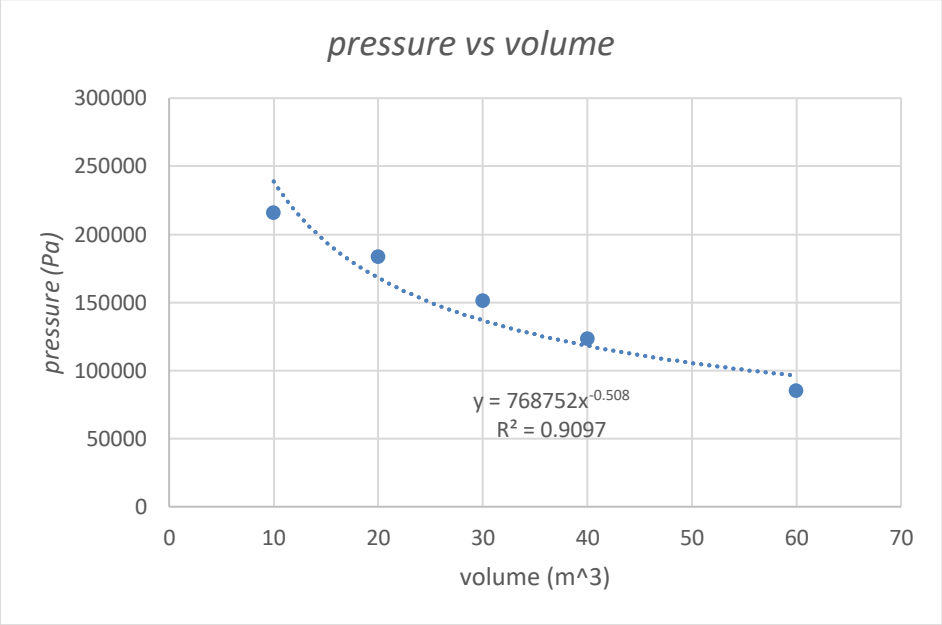
volume (m^3)	temperature (kelvin)
0	298.4
3	314.4
6	336.7
9	334.6
12	343.0

Diameter: 4.4 cm



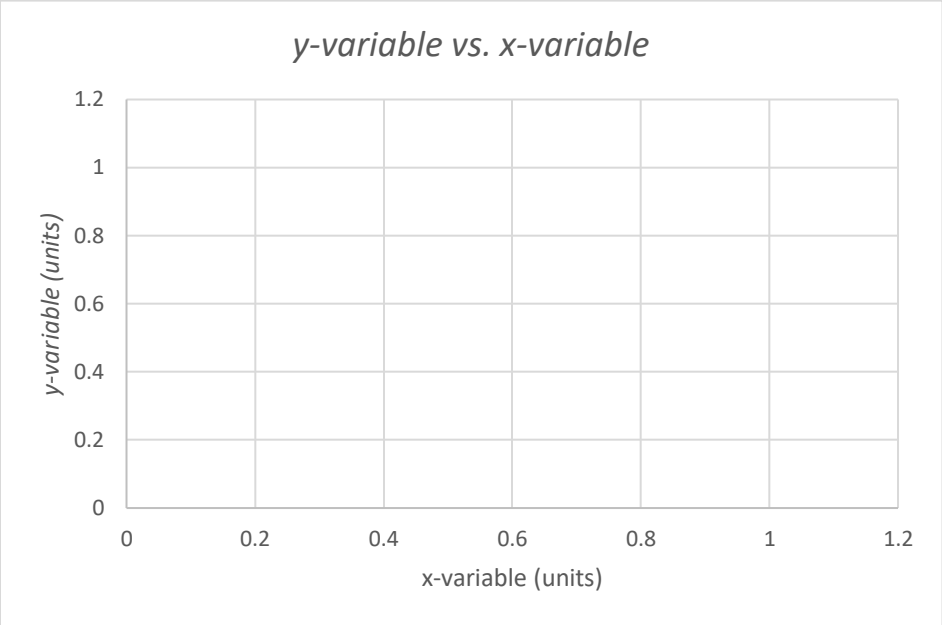
Graph 2: Pressure in cylinder vs. Volume collected in Volume Collector

volume (mm)	pressure (Pa)
40	123137.6
30	151306.4
60	84748.1
20	183168.3
10	215912.3



Graph 3 : Pressure in cylinder vs. Temperature of water in beaker

pressure (Pa)	temperature (kelvin)



Our group did not complete this portion of the lab due to the leakage of air in the pipe.

Analysis Questions

1. What type of relationship exists between the pressure and volume of a gas? What important values exist on the Pressure vs. Volume graph (y-intercept, x-intercept, etc.)?

Pressure and volume are inversely related. As volume increases, pressure decreases. The y-intercept represents the pressure at zero volume. The x-intercept represents the volume necessary for pressure to equal zero. Both quantities do not exist in the world.

2. Would the relationships we found in the lab change if we collected our temperature readings using Celsius or Fahrenheit instead of Kelvin? If so, what would cause this difference? Explain using ph

No, the relationships would not be different, because the temperature would change at the same rate regardless of the unit. The graph would look the same except for a downward shift representing the conversion factor.

3. In the pressure vs. temperature experiment, how would the reading of the pressure collector be affected if the cylinder was placed in an ice bath? Why?

N/a; There was an issue with the leaking pressure sensor.

4. Using the equation generated by your data, what would be the volume when the temperature is at 320 K? Is this an interpolation or extrapolation of your data? Show the calculation.

Temperature cannot be calculated because there was an issue with the leaking pressure sensor. This calculation would be an interpolation because 320 K is between recorded data points.