Laboratory 14: Ideal Gas Law– Prelab

1 Gas in a chamber

An ideal gas, having an initial temperature equal to 25° C, is pumped into a chamber with fixed volume until the pressure is equal to 1 atmosphere. The chamber is then sealed. The temperature within the chamber is then changed.

a) Which of the variables in $PV = nRT$ remain constant? Which of the variables change?

b) Rearrange $PV = nRT$ so that the variables that change are on one side of the equation, and the variables that remain constant are on the other side of the equation.

c) What is the pressure inside the chamber if the temperature is increased to 50° C?

d) The temperature within the chamber is repeatedly increased. Create a plot of pressure vs. temperature for temperatures equal to 25° C, 50° C, 75° C, 100° C, 125° C, 150° C.

e) Is the relationship of pressure vs. temperature linear?

Laboratory 14: Ideal Gas Law – Activity

The variables that describe the state of an ideal gas obey

$$PV = nRT \tag{1}$$

where P is the pressure of the gas measured in Pa, V its volume measured in units of m^3, n the number of moles, T the temperature measured in Kelvin, and $R = 8.314\,\mathrm{J/mol\,K}$ is the universal gas constant.

The aim of this laboratory is to verify that the general features of the ideal gas law are correct.

1 Experiment: Pressure vs temperature at constant volume

The air inside the sealed flask (plus the connecting tube) represents a gas at constant volume. The pressure and temperature of this gas can be measured with appropriate sensors and this can be done at various temperatures by heating or cooling the gas.

a) The flask and connecting tube will be kept closed while the gas inside it is heated or cooled. During either of the processes, which of the variables in Eq. (1) are constant and which vary?

b) Connect the PASCO pressure sensor to the sealed flask. Open Capstone and connect both the temperature sensor and the absolute pressure sensor. Configure the temperature sensor to measure in Kelvin. Display the temperature and pressure.

c) The temperature of the gas inside the flask can be made to change by immersing the **entire sealed flask** in water, whose initial temperature differs from that of the gas inside the flask. When doing so, it takes a few minutes for the gas, flask and water to reach an equilibrium temperature. At this stage, the temperature of the gas equals that of the water; the water's temperature is easily measured, thus yielding the gas temperature.

   To use this technique, it is essential to ensure that the gas in the flask and the water reach the same temperature. This can be done by monitoring the pressure and temperature over a period of a few minutes. When each levels out, the gas has reached equilibrium.

d) Subject the gas to eight different temperatures, spaced about 10° C apart and ranging from room temperature (about 20° C) to the temperature of water near boiling (about 90° C at this altitude). Measure P and T for each.

e) Using your data, plot a graph of P vs. T, fit a trendline and and print it out. What type of graph does Eq. (1) predict? Does your graph agree with the prediction?

f) Using the equation for the line that best fits the graph of P vs. T determine the temperature at which $P = 0\,\mathrm{Pa}$. This temperature is called **absolute zero.**

2 Experiment: Pressure vs volume at constant temperature

The air inside the syringe represents a gas at constant temperature, provided the plunger is not move extremely rapidly. The pressure of this gas and the volume can easily be measured. The volume of the gas can be varied by moving the plunger in or out and the pressure measured for a variety of volumes.

a) Adjust the plunger on the syringe so that it is roughly midway along the syringe. Connect the PASCO pressure sensor to syringe. Measure the temperature of the air in the room in Kelvin and record the result.

b) The plunger on the syringe can be moved so that the volume changes while the temperature remains approximately constant. Both the volume and the pressure can be recorded. Do this for at least eight different plunger settings, including both expanded and compressed. Record the pressure in units of Pascals and volume in m^3 (i.e. use $1\,\mathrm{ml} = 10^{-6}\,\mathrm{m}^3$).

c) Using your data, plot a graph of P vs. V. Is this a straight line? Does Eq. (1) predict that this should give a straight line?

d) A better way of dealing with this data is to plot P vs. $1/V$. Use your data to compute $1/V$ for each case and plot P vs. $1/V$. What type of line does Eq. (1) predict for this graph? Does this agree with your graph?

e) Fit a trendline to your data. Use the equation of the trendline to determine the volume occupied by the gas in your syringe at a pressure of $90.0\,\mathrm{kPa}$. Use the *slope of your graph and the temperature of the air* to determine the number of moles of gas in the syringe during your experiment. Combine this data to determine the volume occupied by $1\,\mathrm{mol}$ of air at a pressure of $90.0\,\mathrm{kPa}$.

3 Exercises

a) Suppose that in the experiment involving P vs. T, the slope of the graph of P vs. T is $235\,\mathrm{Pa/K}$. Determine the pressure of the gas at $T = 0°\,\mathrm{C}$.

b) The radius of the syringe is approximately $5\,\mathrm{mm}$. Suppose that the pressure of the gas inside the syringe is $2.00 \times 10^5\,\mathrm{Pa}$. Determine the force exerted by the gas on the plunger **and** the force exerted by your hand on the plunger to hold it in equilibrium.

c) Two groups perform the part of the lab involving P vs. V but start with different volumes of air in the syringe. The temperatures of the gases are the same for both groups. Group A attached the pressure sensor when the volume of the syringe is $20\,\mathrm{ml}$ and group B when the volume is $10\,\mathrm{ml}$. Using Eq. (1) determine an expression for the slope of these graphs. Identify which quantities in this expression are different for the two groups and use this to relate the slopes of the graphs of P vs. $1/V$ for the two groups.