Ideal Gas Law

Objectives

These lab activities will focus on the concepts of the Ideal Gas Law to describe the relationship between pressure, volume, the number of atoms or molecules in a gas, and the temperature of a gas. You should read all the steps in each part before you start. Work in your assigned groups and maintain a collaborative and communicative team.

For the following activities, you will use a physics simulation program. Visit: https://uglabs.physics.ucr.edu/ for lab downloads and links.

Introduction

The Ideal Gas Law is an idealization because it assumes an “ideal” gas. An ideal gas consists of atoms that do not interact and that occupy zero volume – it is an idealized hypothetical model for studying the physics and chemistry of gases, but it turns out to work pretty well to model real gases as well. A real gas consists of atoms or molecules (or both) that have finite volume and interact by forces of attraction or repulsion due to the presence of charges.

A gas is a physical state of matter in which there is a massive separation between atoms and molecules, as compared to other states like liquids and solids. Gases will expand to fill their container to maintain the separation between atoms/molecules. This results in the gases exerting force on the walls of their containers by means of continual collisions with the surface (think about what happens when you blow up a balloon). The force exerted per unit area of the container is termed pressure. If the volume of a container holding a gas sample is increased, the molecules may be expected to spend a larger portion of their time...
traveling through the interior. Therefore, they will strike the walls of the container less frequently, so the pressure should decrease. Decreasing the volume of the container should have the opposite effect on pressure.

Molecules of a gas at a high temperature have higher kinetic energy than molecules of the same gas at a lower temperature. Hence the molecules of a high temperature gas move at higher speeds than molecules of the same gas at a lower temperature. Molecules moving at high speed will exert more force on the walls of the container than the same molecules moving at lower speeds, thus a high temperature gas has a higher pressure than the same gas at a lower temperature.

The behavior of a gas depends on several properties: pressure $P$, volume $V$, temperature $T$, and the amount of gas $n$. These variables are related to each other by an equation of state called the Ideal Gas Law:

$$PV = nRT$$

where, $R$ is the Universal Gas Constant, $R = 8.31 \text{ J/(mol} \cdot \text{K})$

Most gases near room temperature and pressure (~20 °C and 101 kPa) can be approximated as an “Ideal Gas.” An Ideal Gas must consist of an extremely large number of particles. It is convenient to express the amount of gas in a given volume in the term of moles, $n$. One mole of a material contains $6.02 \times 10^{23}$ particles. This number is known as Avogadro’s number $N_A$:
Simulated Experimental Apparatus:
The apparatus (shown below) is a sealed beaker, plunger, a pressure sensor, and a temperature sensor. Make sure the device is reset by clicking Free For All and lowering the plunger to 2500mL.

![Figure 1: Ideal Gas Law Apparatus]

1. Temperature Change Experiments

1.1: Start an Excel document and label the first tab “Part I,” here you will be making a table of initial and final state measurements. Ensure that the system is at room temperature ~27°C. Set Pressure as constant.

1.2: While you perform these steps, you should begin to record data in your spreadsheet. Slowly raise temperature to 400°C (or until the plunger can go no further) in 50°C steps. Record the value of volume, temperature, and pressure at each step.

1.3: Take special note of your first and last data points. $P_i$ is the initial pressure of the gas before you increase temperature and while the gas was at $T_i$, the initial temperature. $P_f$ and $T_f$ are pressure and temperature at the final volume.

1.4: You now have six useful variable values: initial volume, initial pressure, initial temperature, final volume, final pressure, and final temperature. In
Ideal Gas Law

your notebook, calculate the number of initial moles \( (n_i) \) and the number of final moles \( (n_f) \). Remember to use SI units during your calculations.

Q1: Do your initial and final number of moles value agree with one another (i.e. did the total amount of gas change from before-to-after the experiment)?

Q2: Do the values agree within experimental uncertainty?

2. Volume Change Experiments

2.1: Create another tab labeled “Part II” where we will evaluate a plot of pressure. Reset the device by clicking Free For All and raising the plunger to 4000mL. Ensure that the system is at room temperature ~27°C. Set Temperature as constant.

2.2: While you perform these steps, you should begin to record data in your spreadsheet. Slowly lower the plunger to 500mL in 500mL steps. Record the value of volume, temperature, and pressure at each step. Do this until the plunger can go no further.

2.3: Calculate the inverse of the pressure (Inverse Pressure = 1/P) in a new column. Plot this data over Volume. In the Volume vs. 1/P graph, apply a linear fit. Try to be mindful of units when performing this step.

2.4: Use the slope of your linear fit, the room temperature, and the Ideal Gas Law to calculate the number of moles in the beaker. Remember to use SI units in your calculations.

Q4: Does your value of moles calculated in step 2.1 agree with the initial and final mole values you calculated in your initial experiment in Part I? Why or why not?

2.5: Repeat steps 2.1 – 2.4, but this time with an initial volume of 5000mL and taking it down to 1000mL. Proceed to calculate the inverse of pressure
Ideal Gas Law

(Inverse Pressure = 1/P) in a new column. Plot this data over Volume. In the Volume vs. 1/P graph apply a linear fit.

Q5: Did the number of moles increase the amount you expected with this new initial volume compared to the old initial volume?

Write a short summary discussing today’s activities. In it, please discuss:

- Why is the ideal gas law an important relation? What is an “ideal gas”?
- In what physical systems can the ideal gas law be assumed to be valid? In what physical systems will the ideal gas law be invalid? Why?
- Discuss the importance of the universal gas constant. Where else might this constant be useful? Why? (Hint: Think about energy)
1. Consider 3.0 moles of an ideal gas, which undergoes the process shown in the PV diagram below. Make sure you are mindful of units when you are performing this problem.

(a) What is the temperature of the gas (in Kelvin) at point A? What is the temperature (in Kelvin) of the gas at point B?

(b) On the PV diagram, place at least three more points that have the same temperature as point A.