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Experiment 12: Gas Laws

Objectives

a. To describe, use, and understand the properties, measurements, and units of:
   i. gas pressures
   ii. gas volumes
   iii. temperature
   iv. gas quantities

b. To observe and apply:
   i. Ideal Gas Law
   ii. Boyle's Law
   iii. Charles' Law
   iv. Avogadro's Law

Introduction
The gas phase has neither a fixed shape nor a fixed volume. Gases are compressible, have low densities, and spontaneously mix when brought into contact with other gases. The kinetic molecular theory of gases is used to describe a gas on the molecular level. A gas contains particles that are very far apart from each other and move in continuous random motion. Gases are described by their pressure (P), volume (V), temperature (T) and number of moles (n). These properties are inter-related; the value of any one property is determined by the values of the other three. This means, for instance, that if you create a box of gas with a given pressure, volume, and number of moles of particles, then you cannot set the temperature to be any value you may want: the temperature is defined by the other three variables, already. Historically, these four properties were investigated by determining the relationship between two of these properties, while holding the other two properties constant. These "mini" gas laws are summarized below:

"Mini" Gas Laws

Charles's Law $V \propto T$ (n, P constant) $V_1T_1= V_2T_2$
Boyle's Law $V \propto 1/P$ (n, T constant) $P_1V_1 = P_2V_2$
Avogadro's Law $V \propto n$ (P, T constant) $V_1n_1= V_2n_2$
Combined Law $V \propto TP$ (n constant) $P_1V_1T_1= P_2V_2T_2$

Note that the Kelvin temperature scale *must* be used in these calculations. The overall equation relating all four properties is called the **ideal gas law**, seen here in Equation IG.1: $PV = nRT$ (Equation IG.1)

The gas constant, R, has different values when used with different units of pressure and volume. When using the units of atmospheres and liters, R = 0.08206 L·atm/mol·K.

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Procedure:

Creating the baseline:

1. Acquire the materials.
2. Take the syringe and pull the plunger out to the 10mL mark and screw the stopcock on the end.
3. Record the room temperature.

This is the baseline that the entire set of experiments will reference.

Charles' Law:

1. To observe Charles' Law, we will observe the changes in volume with different temperatures. To do this, take the syringe and screw the stopcock on the end. With the stopcock closed, the pressure inside the syringe is held constant, and the volume can change with respect to the temperature.
2. Go to the hot water bath and note down the temperature.
3. Place the syringe in the hot water bath by the little flanges on sides of the syringe, leaving the plunger free to move. Fully cover the air chamber below the waterline.
4. The volume will change, note down the reading on the syringe.
5. Go to the cold water bath and note down the temperature.
6. Place the syringe in the cold water bath by the little flanges on the sides of the syringe, leaving the plunger free to move. Fully cover the air chamber below the waterline.
7. Draw a plot of the relationship between the temperature and the volume.

Boyles' Law

1. To observe Boyles' Law, we will observe the changes in pressure with different volumes. To do this, take the syringe at 10 mL and screw the end to the pressure sensor. This is the baseline pressure.
2. Push the plunger in to 5mL and note down the new pressure.
3. Pull the plunger out to 15mL and note down the new pressure again.
4. Draw a plot of the relationship between the volume and the pressure.

Combined Laws

1. Finally, put the two laws together into the combined law: $P_1V_1T_1= P_2V_2T_2$. In this case, add the line of tubing to the end of the syringe to connect it to the pressure sensor without getting the sensor wet. Check to make sure the sensor is working properly with the tubing by moving the plunger on the syringe.
2. Go to the hot-water bath and note down the temperature, pressure, and the volume.
3. Place the syringe in the hot-water bath by the little flanges on sides of the syringe, leaving the plunger free to move. Fully cover the air chamber below the waterline.
4. The volume will change, note down the reading on the syringe.
5. Go to the cold-water bath and note down the temperature, pressure, and the volume.
6. Place the syringe in the cold-water bath by the little flanges on the sides of the syringe, leaving the plunger free to move. Fully cover the air chamber below the waterline.

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Data

Baseline measurements

Volume: ______10 mL Temperature: __________°C ___________K

Boyle's Law

Hot Water Bath

Volume: ________mL Temperature: __________°C ___________K

Cold Water Bath

Volume: ________mL Temperature: __________°C ___________K

Draw a graph with volume on the x-axis and temperature on the y-axis. Plot the data on this graph and give an estimated fit line.

Is the slope positive or negative?

Is the volume directly proportional to the temperature or inversely proportional?

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Charles' Law

Volume: _______15 mL Pressure: ___________

Volume: ________5 mL Pressure: ___________

Draw a graph with volume on the x-axis and temperature on the y-axis. Plot the data on this graph and give an estimated fit line.

Is the slope positive or negative?

Is the volume directly proportional to the temperature or inversely proportional?

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Combined Laws

Hot Water Bath

Volume: ________mL Temperature: ______°C__________K

Pressure: ______________

Cold Water Bath

Volume: ________mL Temperature: ______°C__________K

Pressure: ______________

Calculating the number of moles of molecules via the Ideal Gas Law.

Hot Water Bath

Volume: ________mL Temperature: ______°C__________K

Pressure: ______________

Number of molecules using PV=nRT: n: ___________________mol

Cold Water Bath

Volume: ________mL Temperature: ______°C__________K

Pressure: ______________

Number of molecules using PV=nRT: n: ___________________mol

Baseline

Volume: ________mL Temperature: ______°C__________K

Pressure: ______________

Number of molecules using PV=nRT: n: ___________________mol

Average number of molecules

Number of molecules using PV=nRT: n: ___________________mol

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Conclusions