# Introductory Chemistry Lab: Gases

**Outcomes**

As a result of today's laboratory, you will have:

- Investigated the relationship between the temperature and volume of a gas.
- Investigated the relationship between the pressure and volume of a gas.
- Used the Ideal Gas Model to explain the relationships among temperature, pressure and volume of gas.

**Prelab**

Prepare a Title (can use the lab handout for this), Purpose (a concise statement) and a Procedure (short "to do" list … see "Writing a Procedure" in the lab handouts folder). **The data/calculations/results are entered directly into Table 1 (The Lab Hand-In) and stapled to the lab report.**

**Purpose:**

To determine how the volume of a gas changes when temperature or pressure changes.

**Background Information**

Gases are fluids with indefinite volumes and shapes, meaning they assume both the volume and the shape of their container. Gases are highly compressible and much lower in density than liquids and solids. Gas particles are thought to be in constant random motion, widely spaced apart, and moving independently of one another.

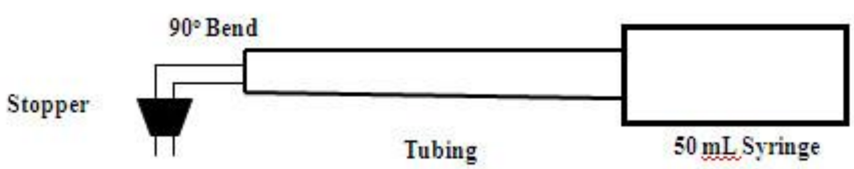
There are four variables that describe the behavior of a gas: the number of gas particles, the volume occupied by the moving gas molecules, the temperature of the gas, and the pressure exerted by the gas. The temperature of a gas is a reflection of the average kinetic energy ($KE = \frac{1}{2} mv^2$), the energy of motion, of the gas molecules. As the temperature of a gas increases, the kinetic energy (speed of motion) increases. This increase in kinetic energy is seen as an increase in pressure (force of impact per unit area) in rigid containers and an expansion of volume in flexible containers. Likewise, increasing the number of gas molecules in a container (more collisions with container walls) will increase pressure. To make the experimental data easier to interpret, a fixed amount of gas is used and one of the remaining three variables (pressure, volume, or temperature) is held constant.

**Procedure   Work in groups of 4**

Wear safety goggles until instructor advises that it is OK to remove.

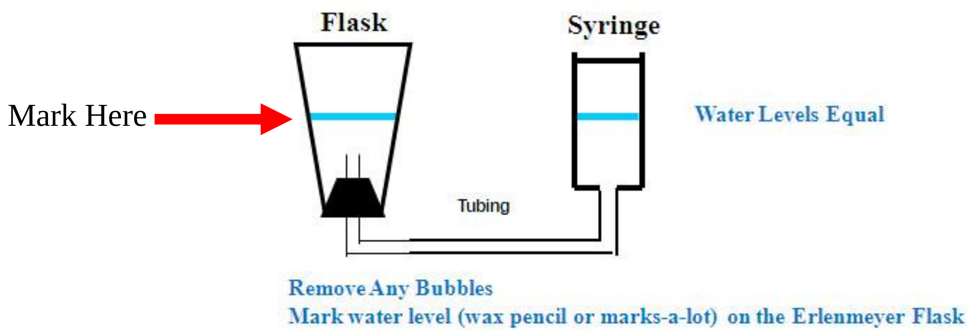
*Part I Setting Up*

1. Fill a 2 L beaker with hot tap water and heat on a hot plate to ~60 °C.
2. Fill a 250-mL Erlenmeyer flask with about 200 mL of deionized water.
3. Check volume assembly: rubber stopper, 90° glass bend, rubber tubing, and 50 mL syringe, to make a flexible "U".




Tubing: forms a flexible "U" (See below)

4. Cap the hole in the rubber stopper with your finger and fill the 50 mL syringe with deionized water. Then remove your finger and let the water drain from the syringe through the tubing and out the hole in the stopper. When approximately 10 mL - 15 mL of water remain in the syringe, insert the stopper into the Erlenmeyer flask and invert it - **all in the same motion**. Keep the Erlenmeyer flask inverted at **all times**, until the apparatus is to be disassembled.



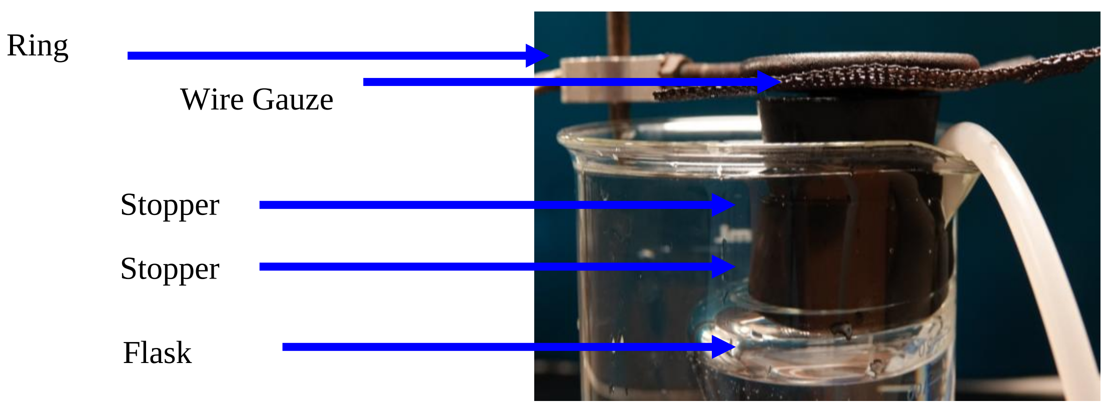

5. Remove any air bubbles that may be trapped in the rubber tubing by squeezing the tubing along its length **after** raising the syringe and lowering the flask as much as the tubing will permit.

6. Hold the syringe and the flask next to each other with their water levels at the same height as your eye. Mark the water level of the flask with a Sharpie. With the water levels still all at the same height, read the level of the water in the syringe. **Record the volume (nearest 0.1 mL) in the Table 1 as the initial syringe volume.**

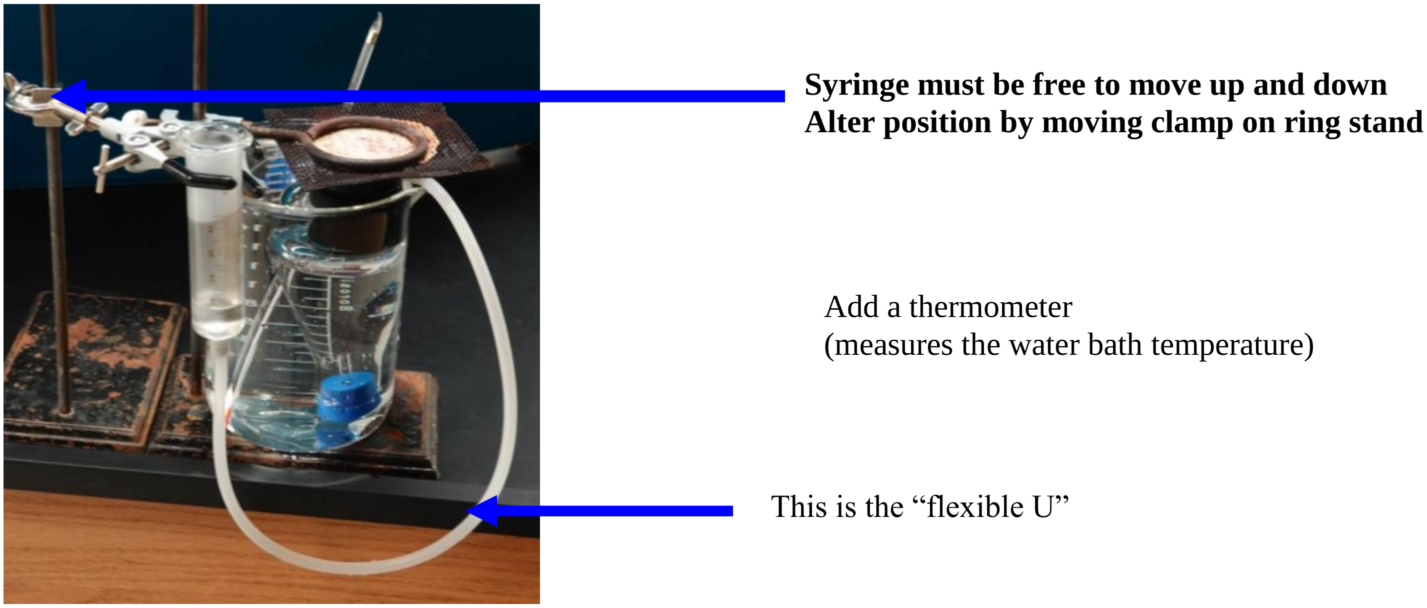
7. Place the inverted Erlenmeyer flask in a 2000 mL beaker. Keep the tubing unkinked.

***Part II: Determine the Volume Changes with Change in Temperature***

1. Set the beaker on a ring stand. To keep the flask from floating later in the experiment, place 2 large rubber stoppers on the top of the flask. Then, place wire gauze on the rubber stopper. Hold in place with a small iron ring. The ring/stopper/wire gauze combo holds the flask in place when beaker is filled with water



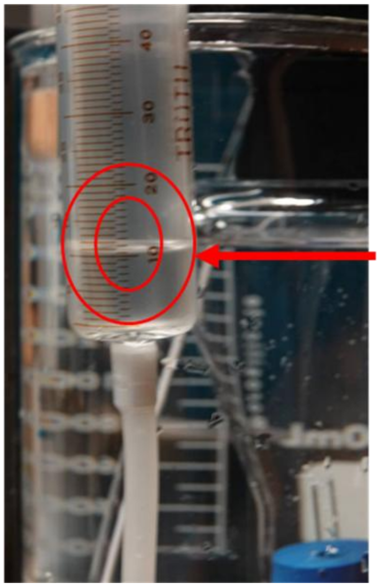
Use a second ring stand and 3-fingered clamp to hold the syringe. This allows the syringe to be freely moved up and down so the water level in the syringe can be set equal to the water-gas interface in the Erlenmeyer flask. **The syringe will have to be moved at each data point.**




2. Pour the 60 °C water into the 2 L beaker. The flask must be **completely covered** by the hot water. **(Make sure you have initial reading before adding the hot water)**
3. While stirring with a glass rod, add ice to drop the temperature of the water bath to 50 $^{o}$C.

4. **When the thermometer reads 50.0 °C, the syringe should be adjusted so that its water level in the syringe is at the same height as the water level in the flask**. ***Your eye should also be at this same level.*** With the water levels still at the same height, read the level of the water in the syringe. Record the volume and temperature in the data table.

5. Repeat Step 3 above four more times for the temperatures ~ 40.0, 30.0, 20.0, and 10.0 °C.



CRITICAL
At each data point:
Clamp holding the syringe is moved up and down to set level of water in syringe = level of water/gas interface in flask

Sight through the syringe to confirm alignment

**Most common source of bad data:**

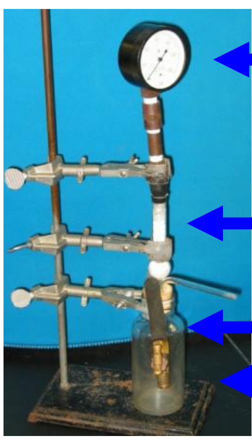
**Not setting syringe level = water level**

**What's Happening?**

The volume of trapped gas (in the flask) is changing with temperature
This change in volume is measured by the volume change in the syringe. So,
*Total gas volume in the flask is the trapped gas (measured later) plus syringe volume change.*

***Part III: Determine the Volume Change with Change in Pressure***

This is the Vacuum Gauge Apparatus as furnished



**Vacuum Gauge (mmHg)**

**Drierite (Desiccant-keeps water out of gauge)**

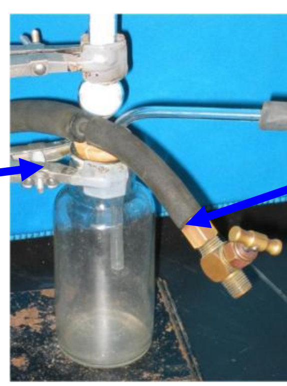
**Safety Flask (keeps water out of gauge & vacuum Line)**

**Needle Valve (open to air for changing pressure)**

The T-Connector connects vacuum line, safety bottle, and the air bleed valve

To syringe

To vacuum



Air Bleed Valve

1. Keep the cold water in the 2000 mL beaker.

2. Connect the vacuum gauge apparatus to the top of the syringe using a pre-assembled short piece of vacuum tubing with a rubber stopper and a right angle piece of glass tubing. Use a second piece of vacuum tubing to connect the safety bottle to the lab bench vacuum outlet.

3. Turn the needle valve on the vacuum gauge apparatus completely counterclockwise. Then **carefully** open the vacuum valve at the laboratory bench until the needle on the vacuum gauge just begins to move. **All adjustments to the vacuum should now be done with the needle valve.**

4. Close the needle valve (slowly turn clockwise) until a reading of 50 mm of Hg is obtained on the vacuum gauge. Then adjust the syringe so that its water level, your eye, and the water level in the flask are all superimposed**.** Record the level of the water in the syringe in Table 1 as the syringe reading for the vacuum of 50 mm of Hg.

5. Repeat Step 3 for the vacuum gauge readings of 100, 150, 200 mm of Hg.

6. Record the barometric pressure reading in Table 1.

**What's Happening?**

The volume of trapped gas (in the flask) is changing with pressure
This change in trapped gas volume is measured with the change in volume within the syringe

So, Total gas volume is the trapped gas (measured later) plus syringe volume change.

The barometric pressure is the pressure of the gas (air) that surrounds the apparatus.
The vacuum gauge indicates the decrease in pressure within the apparatus
So, pressure on the trapped gas volume = barometric pressure – vacuum gauge pressure.

***Part IV: Measure the Volume of Trapped Gas***

1. Disconnect the vacuum and disassemble the apparatus.

2. Empty the flask to the Sharpie mark made in Setting Up: Step 6 (page 2).

3. Measure the water with a 50 mL graduated cylinder. Record this volume in the data table.

***Part V. Barometric Pressure***

Measure the barometric pressure. This is the pressure surrounding the apparatus. To read the barometer:
1. Blue horizontal arrow (Temperature) on slider is aligned with the tip of the blue liquid in the thermometer.
2. Barometric pressure is indicated on the slider by the position of the tip of the red liquid.

**Data / Calculations / Results**

**The Hand-in is a combination data / calculation / results table.**

**Fill out the Hand-In page data and calculation tables and staple to your lab report. (Another download, Filling-In Tables, has detailed instructions for filling out the tables of the Hand-In)**

**Results**

For Part II, plot (using a full page of graph paper on Blackboard) your data using Temperature ($^{o}$C) on the x-axis and Total Gas Volume (mL) on the y-axis. Draw the "Best-line" fit on the graph.

**Table 2: Mathematical Relationships**

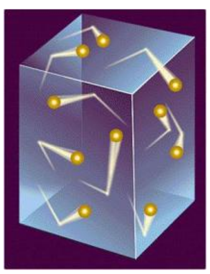
If the V / T (Part II) values are constant, then Volume and Temperature have a direct proportional relationship and Charles' Law is validated. If your P x V (Part III) values are constant, then Pressure and Volume have an inverse relationship and Boyle's Law is validated.

| **Quantity** | **Within Experimental Error, are these values constant? (Yes/No)** |
|---|---|
| V/T (Part II) | Yes |
| P x V (Part III) | Yes |

**Conclusion**

Based on your results, describe the volume-temperature at constant pressure relationship you observed in Part II and the pressure-volume at constant temperature relationship you observed in Part III.

**Questions**



Kinetic Theory of Gases States:

Pressure is the force (sum of all the molecular collisions between gas molecules and container walls) per unit area.

Temperature is the average kinetic energy (how fast gas molecules are moving) of the gas molecules inside a container

1. Use the concept of moving molecules (Kinetic Theory) to explain:

   a. Increase in pressure at constant volume in a rigid container when temperature increases.

   b. Increase in volume at constant pressure in a flexible container when temperature increases.

   c. Decrease in volume at constant temperature in a flexible container when outside pressure increases.

   d. Increase in pressure at constant volume and temperature when more molecules are added to the container.

2. Why is there a warning label on aerosol cans advising you not to incinerate these cans?

3. If a gas filled balloon filled has a volume of 1 Liter at ten feet underwater, would you predict the volume of the balloon to be greater than, less than, or the same as 1 Liter when it is brought up to the surface? Why?

4. Which of the following gas relationships is NOT correct? Explain your choice.

a. If the temperature increases from 100 K to 200 K, the volume of the gas increases from 1.5 L to 3.0 L

b. If the pressure decreases from 400 torr to 200 torr, the volume of the gas increases from 3 L to 6 L.

c. If the temperature increases from 50 °C to 100 °C, the pressure of the gas increases from 1 atm to 2 atm.