

EXPERIMENT 16: Charles' Law of Gases V vs T

Materials:

Thermometer	Bunsen burner	Ring stand	Clamps
600ml beakers (2)	Closed-tip syringe	Ice Water	

Objectives

1. To put to work the model to verify Charles' law,
2. To describe and explain Charles' law

INTRODUCTION

Charles' Law relating the volume of a gas at constant pressure to its temperature is summarized in this formula:
 $V/T = k$

where T is the absolute temperature (in degrees Kelvin, K), V is the volume and k is a constant for a particular mass and pressure of the gas. The law implies that the volume of a gas will approach zero as the temperature approaches zero on the absolute scale. Of course, this does not really happen because the gas would liquefy and finally solidify if the temperature is low enough. Charles' Law only applies to the gaseous state.

The quantitative relationship between the volume and the absolute temperature of a gas is summarized in Charles' law. This law states: at constant pressure, the volume of a particular sample of gas is directly proportional to the absolute temperature. Charles' law may be expressed mathematically:

$$V = kT = k (\text{constant pressure})T$$

where V is volume, T is Kelvin temperature, and k is a proportionality constant. dependent on the number of moles and the pressure of the gas.

If the volume of the same sample of gas is measured at two temperatures, $V_1/T_1 = k$ and $V_2/T_2 = k$, and we may say that

where V_1 and T_1 , represent one set of conditions and V_2 and T_2 a different set of conditions, with pressure the same at both conditions.

The properties of some materials become very interesting as the temperature approaches absolute zero. For example, helium becomes superfluid, in other words, its viscosity becomes zero, and it also perfectly wets all the surfaces containing it so that it can appear able to flow uphill. Some metals and other substances lose their resistance to electrical currents and become superconducting.

In this **experiment**, you will try to confirm Charles' Law and also estimate absolute zero in degrees Celsius ($^{\circ}\text{C}$).

Procedure

Method I

1. Obtain a closed-tip syringe and record the exact volume of air in the syringe and the room temperature.
2. Add approximately 400ml of water to each of the beakers. Insert the syringe into the water to test the water depth. You want the water to completely cover the barrel of the syringe to at least 30cc.
3. Allow the water in one beaker to reach room temperature while you set up and heat the water in the second beaker to boiling.
4. Clamp the syringe, thermometer, and the water bath to the ring stand as shown in the picture (see Fig. 1). Be sure there is sufficient water in the beaker to completely submerge the air contained in the syringe. Heat the water to a gentle boil by using a Bunsen burner. Allow about 2 minutes for the syringe and air to attain the same temperature as that of the water and then record the temperature of the water and volume of the air in the syringe.
5. Turn off the Bunsen burner and carefully move the thermometer and the syringe to the other 600ml beaker containing water at room temperature. Allow about 5 minutes for the syringe of air to attain the same temperature as water. Record the temperature of water bath and the volume of the air in the syringe.
6. Add a few small pieces of ice to the room-temperature beaker to lower the temperature of the water to approximately 10-15°C. Allow time for the temperature of the water to stabilize and the air in the syringe to attain the same temperature. Record the temperature of the water bath and the volume of the air in the syringe.
7. Pour off half of the 10 -15°C water from the beaker and add more ice. Allow about 5 minutes for the syringe of the air to attain the same temperature as the ice/water bath and then record the temperature of the water bath and the volume of the air in the syringe.

Method II

Dry a 125 mL Erlenmeyer flask by gently heating the entire outer surface with a hot plate using hot water bath . Care must be used in heating to avoid breaking the flask. If the flask is wet, first wipe the inner and outer surfaces with a towel to remove nearly all the water. Then, holding the flask with a test tube holder, gently heat the entire flask. Avoid placing the flask directly in the hot plate. Allow to cool. While the flask is cooling select a l-hole rubber stopper to fit the flask and insert a 6 cm piece of glass tubing into the stopper so that the end of the tubing is flush with the bottom of the stopper.

Attach a 3 cm piece of rubber tubing to the glass tubing . Insert the stopper into the flask and mark (wax pencil) the distance that it is inserted. Clamp the flask so that it is submerged as far as possible in water contained in a 400 mL beaker (without the flask touching the bottom of the beaker).

Heat the water to boiling. Keep the flask in the gently boiling water for at least 8 minutes to allow the air in the flask to attain the temperature of the boiling water. Add water as needed to maintain the water level in the beaker. Read and record the temperature of the boiling water.

While the flask is still in the boiling water, seal it by clamping the rubber tubing tightly with a screw clamp. Remove the flask from the hot water and submerge it in a pan of cold water, keeping the top down at all times to avoid losing air. Remove the screw clamp, letting the cold water flow into the flask. Keep the flask totally submerged for about 6 minutes to allow the flask and contents to attain the temperature of the water. Read and record the temperature of the water in the pan.

In order to equalize the pressure inside the flask with that of the atmosphere, bring the water level in the flask to the same level as the water in the pan by raising or lowering the flask (see Figure 19.3). With the water levels equal, pinch the rubber tubing to close the flask. Remove the flask from the water and set it down on the laboratory bench.

Using a graduated cylinder carefully measure and record the volume of liquid in the flask. Repeat the entire experiment. Use the same flask and flame dry again; make sure that the rubber stopper assembly is thoroughly dried inside and outside.

After the second trial fill the flask to the brim with water and insert the stopper assembly to the mark, letting the glass and rubber fill to the top and overflow. Measure the volume of water in the flask. Since this volume is the total volume of the flask, record it as the volume of air at the higher temperature. Because the same flask is used in both trials, it is necessary to make this measurement only once.

Note – To equalize the pressure in the flask, the water level inside the flask is adjusted to the level of the water in the pan by raising or lowering the flask.

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REPORT SHEET

Name _____

Instructor _____

Unknown # _____

Date _____

Method I - DATA

Initial Temperature: _____

Initial Volume: _____

Water Bath	Temperature	Volume
Boiling Water		
Room Temperature		
10 – 15 °C		
Ice Bath		

Plot your volume-temperature data points on a graph with temperature on the x-axis and volume on the y-axis. Draw the best straight line you can through the data points. Extend this line to zero volume and record your estimate equivalent of the absolute zero temperature.

Open the end of the syringe and set the plunger at the 30-ml mark. Close the end of the syringe. Heat a 600-ml of water to boiling, if you have not already done so.

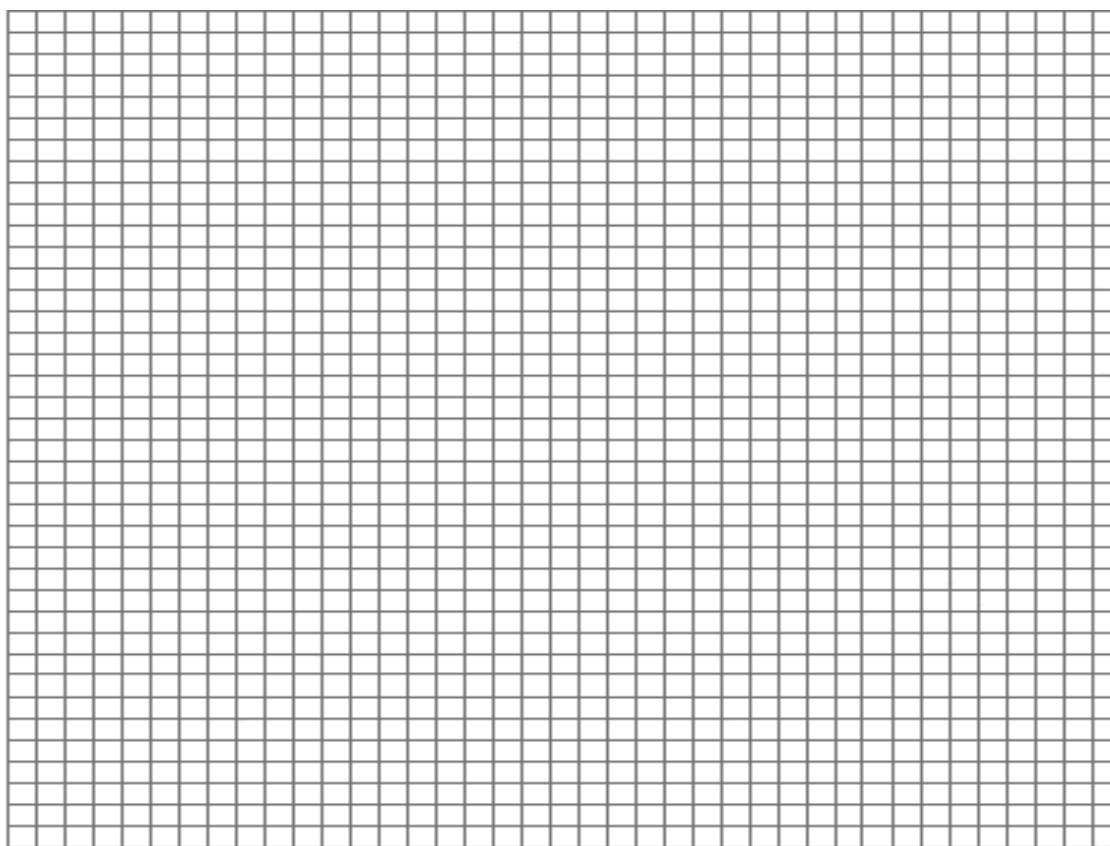
Keep the syringe on the ringstand and place the beaker of hot water under it. Adjust the height of the clamp holding the syringe so that the syringe is as far down in the beaker as possible. Wait about 2 minutes for the air in the syringe to come to the same temperature as the water.

Record the water temperature and the volume on the syringe on your data sheet. Raise the clamp and syringe out of the water. Replace the beaker of hot water with a beaker of hot tap water (or add ice to the boiling water).

Lower the syringe into the water and wait 2 minutes for equilibration to occur. Record the temperature and the volume on the syringe.

Remove the clamp and syringe from the water. Replace the beaker of warm water with cold water.

Wait 2 minutes and then record the temperature and the volume on the syringe. Pour off about half of the water and fill the beaker with ice. Place the syringe in the water and record the temperature and volume as before.



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Pre-Laboratory Questions and Exercises

Due before lab begins. Answer in the space provided.

1. Charles' Law deals with what quantities?
 - a. pressure/temperature
 - b. pressure/volume
 - c. volume/temperature
 - d. volume/temperature/pressure

2. A 125 mL sample of dry air at 230 °C is cooled to 100°C at constant pressure. What volume will the dry air occupy at 100 °C?

3. When the temperature of a gas decreases, does the volume increase or decrease?

4. 3.50 liters of a gas at 727.0 K will occupy how many liters at 153.0 K?

5. I have made a thermometer which measures temperature by the compressing and expanding of gas in a piston. I have measured that at 1000 °C the volume of the piston is 20 L. What is the temperature outside if the piston has a volume of 15 L? What would be appropriate clothing for the weather?

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Post-Laboratory Questions and Exercises

Due after completing the lab. Answer in the space provided.

1. A 250 mL container of a gas is at 150°C. At what temperature will the gas occupy a volume of 125 mL, the pressure remaining constant.
2. 600.0 mL of air is at 20.0 °C. What is the volume at 60.0 °C?
3. Carbon dioxide is usually formed when gasoline is burned. If 30.0 L of CO₂ is produced at a temperature of 1.00 x 10³ °C and allowed to reach room temperature (25.0 °C) without any pressure changes, what is the new volume of the carbon dioxide?
4. Solve the Charles' Law equation for V₂.
5. If the Kelvin temperature of a gas is doubled, the volume of the gas will increase by _____.