Gases & Gas Laws

Charles' Law

Teacher's Guide

Content Overview

From everyday experience you are familiar with the phenomenon that when a gas is heated, its volume increases. On the other hand, as a gas is cooled, its volume decreases. The expression of this relationship, known as Charles' Law, states "At a constant pressure, the volume of a gas is directly proportional to the absolute temperature of the gas." Mathematically, it may be written as

$$V = kT$$

where V represents the volume of the gas, T represents the temperature (in Kelvin) and k is a proportionality constant.

Rules of algebra tell us that an equality of this type when plotted, gives a straight line. Thus, if we plot V versus T, we should get a straight line with a slope of k.

In this experiment a Beral pipet with a clear plastic ruler attached is used as the gas container. A thin-stem Beral pipet is used to introduce a drop of colored water into the stem of the pipet with the ruler just above the point where the stem joins the bulb. This drop of liquid traps room-temperature air in the bulb of the pipet and part of the stem.

Lesson Objectives

At the end of the lesson that students will be able to:

1. predict the effect temperature change will have on a gas
2. have more practice in constructing graphs
3. gain experience with a different type of measurement
4. relate change of length to change of volume in a cylinder
5. gain a greater understanding of Kinetic Molecular Theory

Correlation with 2001 Mississippi Science Framework

Chemistry I

Competency 9. Apply understanding of the interactions of matter and energy. (P)

Competency 10. Analyze the nature and behavior of gaseous, liquid, and solid substances using Kinetic Molecular Theory. (P)

Suggested Teaching Objective:

b. Describe the relationship among volume, temperature, pressure, and moles using ideal gas laws.

Have students determine value at 0°C of gas and calculate the number of moles from graph.

Materials (for each pair of students)

1 Beral microtip pipet from which the microtip and narrowed end have been cut (see drawing)
1 Thin stem Beral plastic transfer pipet
2 Containers for cold and hot water
1 Clear plastic ruler with millimeter markings (use the attached template copied on a transparency to make 24 rulers)
Small amount of colored water (made with 1 drop food coloring in 50 mL water)
1 Thermometer (-10 to 110°C)
1 Sheet graph paper
1 Stirring rod
1 bath container

Estimated Teaching Time: 30-40 minutes

Teaching Procedure

NOTE TO THE TEACHER: Decide whether your students are advanced enough to make up their own data sheets. The design of a data sheet can be given as a homework assignment. High school students need to get the experience of developing a data sheet. This is the type of question students may face in the future on standardized examinations.

Show students the apparatus with a drop of colored liquid in the stem of the Beral pipet with ruler attached. Identify the Beral pipet and the parts of the Beral pipet: the stem, the ruler, and the bulb.

Question: What is holding the liquid up in the stem? Or
Why does the liquid stay in the stem and not drop into the bulb?

[Answer: Air.]

If they do not come up with the correct answer, ask the following questions:
Question: If I squeeze the bulb what will happen?

[Answer: The drop will move up the stem.]

Question: Why?

[Answer: There is less air in the bulb and that pushes the liquid up.]

Question: What effect does a change in volume make on the position of the liquid drop in the stem of the Beral pipet?

[Answer: More volume pushes the liquid up; smaller volume allows the liquid to move closer to the bulb.]

In this experiment you will be determining what effect temperature has on the volume of a gas.

At this point the teacher may choose to let the students proceed with the experiment or this can be made into a hypothesis example by asking the following questions.

Question: What do you think heating the gas will do to the volume of the gas?

[Answer: There are three choices; increase, decrease, or stay the same.]

Question: How would you state this as a hypothesis?

[Answer:

Hypothesis A When a gas is heated its volume increases.
Hypothesis B When a gas is heated its volume decreases.
Hypothesis C When a gas is heated its volume stays the same.]

After the prelab discussion, students can then carry out the experiment.

Prelab Discussion

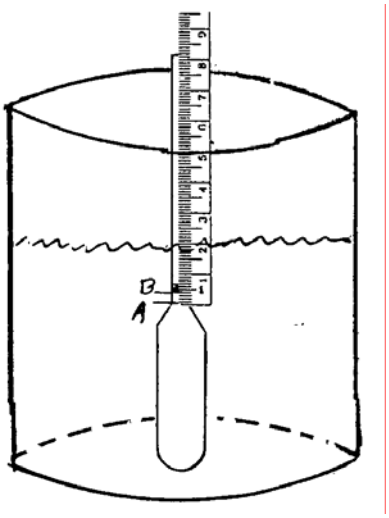
Question: What are some sources of error in this experiment?

[Answers:

1. **Reading the edge of the liquid in the ruler (minimal to none due to ruler being attached to the pipet).**
2. **Not consistently reading either the top or bottom of the liquid.**

Question: Does only the bulb of the pipet need to be under the surface of the water?

[Answer: Not putting the entire portion of the pipet with trapped air in the hot or cold water will not change the temperature of the air in the pipet.]



Question: Why read only the same edge of the liquid?

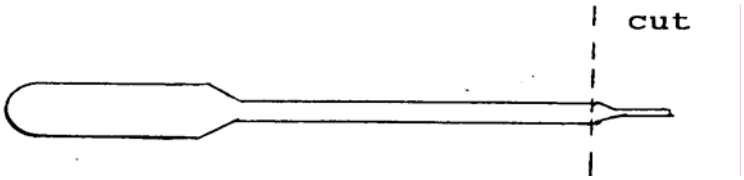
[Answer: If the same edge is not read, a measurement error equal to the length of the liquid is added.]

Question: What if you measure the top of the liquid to begin with and the bottom of the liquid when the temperature in the pipet is changed?

[Answer: There will be an error equal to the length of liquid in the pipet.]

A. <u>Preparation Of The Beral Pipet That Will Be Immersed</u>

Using a pair of scissors cut a Beral microtip pipet as shown below.



B. <u>Preparation Of Colored Water</u>

Add 10 drops of blue, green or red food coloring to 50 mL water. Make sure there is not soap or detergent in the vial or the water.

C. Preparation Of The Transparent Metric Ruler

Using a copier and a blank transparency sheet for copiers, make a copy of the attached metric ruler onto the transparency. This will make 24 rulers. Cut the ruler on one end so that the 0 line is intact and on the other end cut at the 95 mm mark.

D. Attachment Of The Ruler To The pipet Stem

Using a metal file, roughen the surface of the Beral pipet on the side on which the ruler is to be attached.

Attach the clear plastic ruler (from C) to the pipet stem of the cut Beral pipet with super glue (using a thin line of glue across the length of the ruler) so the zero mm mark is at the juncture of the bulb and the stem. (Be sure to wipe all glue off the tip of the glue container before replacing the cap.)

Cut the ruler so the end is flush with the end of the pipet. If it extends beyond the pipet end, it will gradually be pulled loose.

WARNING: Do not use super glue unless you have super glue remover or an organic solvent such as acetone or ethyl acetate. Nail polish remover will work also. Appropriate super glue is Zap-a-Gap (from a hobby store) or Lok-Knot (from a sporting goods store in the fishing section).

E. Determining The Volumes Of The Pipet Bulb And Stem (Optional)

As a special project (or for advanced classes) you may prefer to have your students determine the volume of the pipet bulb in Step 8 for themselves. This may be done by (1) weighing the empty pipet, (2) filling the bulb with water to the juncture with the straight part of the stem, and (3) weighing the pipet and water. The weight of water can be calculated by difference in weight. (Assume the density of water is 1 g/mL.) The stem of the pipet can then be filled, the volume of the stem determined, and the length of the stem measured. By dividing the volume of the stem by the length of the stem, a calibration factor in mL/mm can be determined. As the student measures the distance of the liquid drop in the stem, it is possible to calculate the gas volume by using the calibration factor.

F. Extrapolation Of The Graph To Zero

Although the purpose of this experiment is to validate the direct relationship of volume to temperature, the experience of the authors is that extrapolation of the graphical data to absolute zero does not give an accurate value for absolute zero. This fact does not detract significantly from the value of this experiment.

G. Additional Information

Many experimenters encounter a problem by putting the drop of colored water in the pipet before it is cooled. When the pipet is placed in a cold bath, the air in the bulb contracts and the drop of colored water is sucked into the bulb.

More accurate readings can be obtained by viewing the ruler from the side; i.e., the ruler is almost perpendicular to the eye.

Instead of using glass containers for the water bath, we recommend using the bottom of a 16 oz. or 20 oz. plastic soft drink bottle or a 400-mL beaker as the bath. If

larger containers are used, fairly large amounts of hot water will be needed to raise the bath temperature.

Cold water -- A cooled drinking fountain is an excellent source of cold water. If this is not available, use an ice-water mixture.

Hot water -- If your lab has hot water, it should be adequate for this experiment. If you do not have a hot water tap, devise a safe means of obtaining hot water. A coffee percolator or teapot with a handle is probably safest to avoid hot water burns.

Answers To Questions (on Student Worksheet)

1. Does increase in temperature increase or decrease the volume of a gas? Explain your answer.
   [Answer: Yes, more gas enters the pipet stem as the gas is heated.]

2. Why is 273 added to the temperature in °C?
   [Answer: Absolute temperature measured in Kelvin units is simply Celsius temperature (°C) plus 273.]

3. Why is the stem distance multiplied by 0.01?
   [Answer: Each mm of the stem has a volume of 0.01 milliliters.]

4. Where does the 3.85 come from?
   [Answer: The bulb of the pipet has a volume of 3.85 milliliters.]

5. If all of the air trapped beneath the drop of colored water is not immersed in the bath, will it affect the reading which you take? Explain your answer.
   [Answer: Yes. The portion of air below the surface of the liquid will have the same temperature as the liquid in the bath. The portion of trapped air above the surface of the liquid will be room temperature or close to it.]

6. How can you verify whether your response to question 5 is correct?
   [Answer: Place the entire portion of trapped air in the pipet beneath the surface of the liquid. When the drop of colored liquid doesn't move anymore, record the ruler marking and raise the pipet so the stem is completely out of the water. The colored liquid will move up the stem.]

7. What would you expect to happen if the drop of colored water is added before chilling the bulb?
   [Answer: If the drop of colored liquid is placed in the pipet before immersing it in cold water, the drop of liquid will be sucked into the bulb when the bulb is cooled.]

8. How can you verify whether your response to question 7 is correct?
   [Answer: Carry out the activity suggested in your answer to #7 above.]