Charles's Law

INTRODUCTION

Charles's law gives the relation between the volume and temperature of a gas at constant pressure. It states that the volume of a given mass of gas is directly proportional to the absolute temperature when pressure is constant. Mathematically we may state this in either of two ways:

$V = kT$ (P constant) or $V_1/T_1 = V_2/T_2$ (P constant)

In this experiment the student will heat the air inside a flask to the boiling temperature of water. Then he will cool the flask by placing it in a cold water bath. As the air inside the flask cools, its volume will decrease, and water will be drawn into the flask. The volume of this water is the difference between the initial and final air volumes.

One correction must be made. The water drawn into the flask has a vapor pressure (about 20 mm). Therefore, the air in the flask at the end of the experiment will be mixed with water vapor. The pressure of air:

$$P_{air} = P_{atm} - P_{H_2O}$$

Now we can use Boyle's law to calculate the volume the air would occupy if $P_{air} = P_{atm}$. Let's call this volume V_2. Then

$$P_{atm} V_2 = (P_{atm} - P_{H_2O})(V_1 - V_{H_2O})$$

where V_{H_2O} is the volume of water drawn into the flask and V_1 is the volume of the flask.

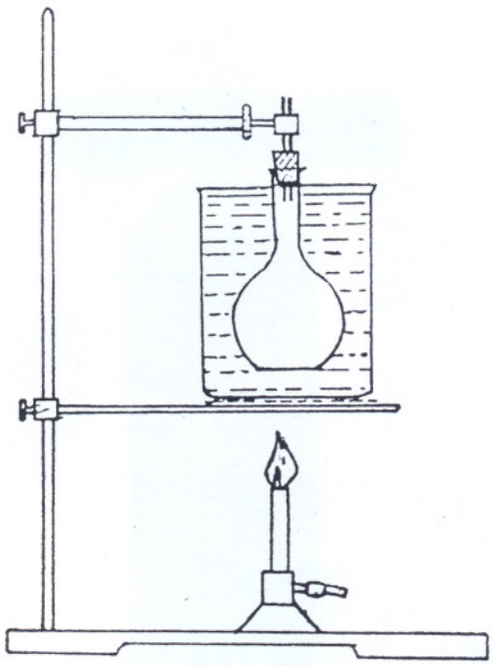
Now it should be possible to compare V_1/T_1 (the volume and temperature of the air at the boiling temperature of water) with V_2/T_2 (where T_2 is room temperature). Since in both cases $P = P_{atm}$, if Charles's law is obeyed, we will find that

$$V_1/T_1 = V_2/T_2$$

PROCEDURE

Take a clean 250 mL flask and make sure it contains no moisture by passing it back and forth through a (**luminous**) bunsen burner flame, until it is completely dry. (You have to hold the flask in your **hand** and heat the area that contains moisture). Take a one-holed rubber stopper that fits the flask and insert a 7-8 cm length of fire-polished glass tubing so that one end is even with the bottom of the stopper. Fit the stopper **firmly** into the flask and mark with a pencil where it comes in contact with the

flask. Place the flask in a 1000 mL beaker and set up apparatus as shown below. The flask should be almost completely immersed in water.



Gently boil the water for about 10 minutes. Record the temperature of the boiling water (T_1) and the atmospheric pressure (P_{atm}). Turn the burner off and cover the open end of the glass tube with your finger. Loosen the clamp and, keeping your finger over the glass tube, turn the flask upside down and immerse it in a room temperature water bath. Remove your finger and keep the flask completely submerged for 10 minutes. At the end of this time, raise the inverted flask until the water levels inside and outside are the same. Cover the end of the glass tube with your finger, remove the flask from the bath, and restore it to an upright position. Record the temperature of the water bath (T_2). Pour the water from the flask into a graduated cylinder and record its volume (V_{H_2O}).

Fill the flask with water and place the rubber stopper in its original position (using the pencil mark). The glass tube should be completely filled with water, and no air bubbles should be trapped around the bottom of the stopper. Dry the outside of the stopper, then remove the stopper and carefully drain the contents of the glass tube into the flask. Pour the water from the flask into a graduated cylinder and record its volume (V_1).

From the appendix of your textbook obtain the vapor pressure of water (P_{H_2O}) at room temperature T_2.

CALCULATIONS

Remember to convert T_1 and T_2 to the absolute temperature scale. Now calculate V_2, as shown in the introductory discussion. Calculate and compare V_1/T_1 and V_2/T_2.

QUESTIONS

1- Assuming your values of V_1, T_1, and T_2 were correct, what is the theoretical value of V_2 ? (Calculate from Charles's law). Calculate your percent error.

$$\% \text{ error} = \frac{\text{difference between } V_2 \text{ (theoretically) and } V_2 \text{ (experimentally)}}{V_2 \text{ (theoretically)}} \times 100$$

2- How would the experimental results be affected if the flask contained moisture at the beginning of the experiment ?

3- Why was it necessary to match the water levels inside and outside the cooled flask before removing it from the water bath ?

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Date:

Temperature of the Boiling water (T_1) : .....

Atmospheric Pressure (P_{atm}) : .....

Temperature of Water Bath (T_2) : .....

Volume of Water in the Flask (V_{H_2O}) : .....

Vapor Pressure of Water at Room Temperature (P_{H_2O}) : .....

Volume of the Flask (V_1) : .....

Name of the student:

Submitted to :