

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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**National Science Education Standard—Physical Science
Structure and Properties of Matter**

Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

Teacher Materials

Learning Sequence Item:

1022

Understanding the Behavior of Gases

May 1996

Adapted by: Jessie M. Jones and Dorothy L. Gabel

Solids, Liquids, and Gases: Empirical Laws and the Kinetic Theory. Students should use the combined gas law to determine changes in volume, pressure, and temperature when two variables are held constant (*Chemistry, A Framework for High School Science Education*, p. 60).

Contents

Matrix

Suggested Sequence of Events

Lab Activities

1. Don't Flick the Bic
2. Waiting to Exhale
3. Defacing Marble

Assessments

1. Temperature and Pressure
2. Correcting Gas Volume
3. Gas Collection

1022

Solids, Liquids, and Gases: Empirical Laws and the Kinetic Theory. Students should use the combined gas law to determine changes in volume, pressure, and temperature when two variables are held constant (*Chemistry, A Framework for High School Science Education*, p. 60).

Learning Sequence

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>Don't Flick the Bic Activity 1</p> <p>Waiting to Exhale Activity 2</p> <p>Defacing Marble Activity 3</p> <p>Temperature and Pressure Assessment 1</p> <p>Correcting Gas Volume Assessment 2</p> <p>Gas Collection Assessment 3</p>			

Suggested Sequence of Events

Event #1

Lab Activity

1. Don't Flick the Bic (1 hour)

Event #2

Lab Activity

2. Waiting to Exhale (50 minutes)

Alternative or additional activity

3. Defacing Marble (45 minutes)

Event #3

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Kefauner, E.M., "Ashy, Gassy Light Snow," *Science World*, Scholastic Inc., Vol 48, No. 4, Oct. 18, 1991, p. 5.

Kendrick, Karolyn, "Kuwait's Blazing Oil Fields," *Science World*, Scholastic Inc., Vol. 49, No. 5, Sept. 6, 1991, pp. 7-11.

Orlando, Louise, "Swirling, Whirling Air," *Science World*, Scholastic Inc., Vol. 47, No. 9, Jan. 25, 1991, pp. 8-9.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Don't Flick the Bic**What is the volume of a gas if the pressure and temperature change simultaneously?****Overview:**

In practice, both the pressure and temperature of a constant mass of a gas will change if the volume is changed. In this activity, students will dispense butane gas from a lighter and collect the insoluble gas by the *displacement of water* method. They first collect the gas under one set of conditions—pressure, temperature and volume (V_1 , P_1 , T_1)—and then determine property changes under a second set of conditions—(V_2 , P_2 , T_2). *Caution: Butane is a flammable, toxic hydrocarbon. No flames are allowed in the classroom during this activity—and students should follow instructions exactly when releasing the butane from the lighter.*

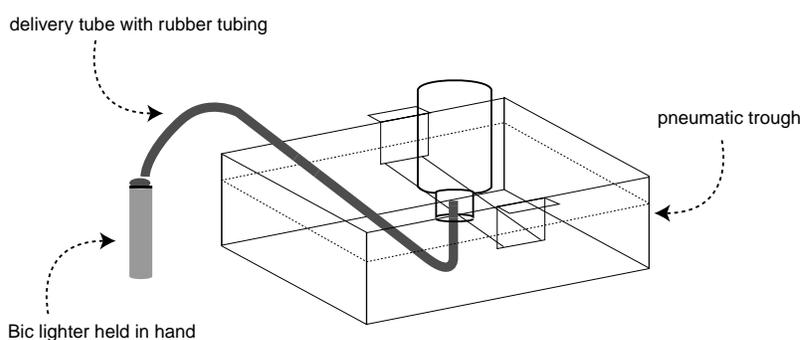
Materials:**Per lab group:**

butane lighter
barometer
delivery tube, 20 cm
Erlenmeyer flask, 250 mL
glass plate
pneumatic trough
thermometer
graduated cylinder

Procedure:

Students construct a data table to record measurements of the volume of the flask (mL), the volume of water in the flask after the gas is released (mL), the temperature of the water ($^{\circ}\text{C}$), barometric pressure (mmHg), and the vapor pressure of the water (mmHg). To determine the “true” volume of the 250 mL flask, students completely fill the flask with water. They pour the water into the graduated cylinder and measure the total quantity of water that was in the flask. Next, they refill the flask and cover the top with a glass plate before carefully inverting it in the trough filled with water. *Students should use care so as not to get any air bubbles in the flask.*

Students hold the free end of the “butane lighter-delivery tube assembly” beneath the mouth of the inverted flask. Before they press the release button of the lighter, instruct them to make sure the bubbles



go into the flask in order for them to collect approximately 250 mL of gas.

Students remove the tubing from the lighter, then raise or lower the flask until the water levels inside and outside are equal. This technique is used to equalize the pressure inside the flask with atmospheric pressure. They measure the temperature of the water in the flask. Students dispose of the toxic gas by putting the glass plate over the top of the inverted flask, turning it upright and releasing it in the hood.

Now that the gas has been released, students should measure the volume of water remaining in the flask. The difference between the total amount of water in the flask and the amount of water remaining after the gas is released is volume taken up by the gas. They should record this volume in a data table along with the barometric pressure, the temperature of the water and the vapor pressure of water (see Tables 1 and 2).

Since the butane gas was not collected under standard conditions (STP), it is necessary to convert the laboratory volume of the gas to STP by correcting for temperature and pressure. Students make the correction by multiplying the original volume, V_1 , by both a temperature ratio and a pressure ratio. They combine the gas laws (Boyle's and Charles' laws, give $V_1 P_1 T_2 = V_2 P_2 T_1$). Students must use the data given to determine the second volume:

$$V_2 = \frac{V_1 P_1 T_1}{P_2 T_1}$$

With this type of approach, they can

Table 1. Vapor Pressure of Water

Temp. C	Pressure mmHg	Temp. C	Pressure mmHg	Temp. C	Pressure mmHg
0	4.60	24	22.40	42	61.50
2.5	5.50	25	23.80	43	64.80
5	6.50	26	25.20	44	68.30
7.5	7.80	27	26.70	45	71.90
10	9.20	28	28.30	46	75.60
11	9.80	29	30.00	47	79.60
12	10.50	30	31.80	48	83.70
13	11.20	31	33.70	49	88.00
14	12.00	32	35.70	50	92.50
15	12.80	33	37.70	60	149.40
16	13.60	34	39.90	65	187.50
17	14.50	35	42.20	70	233.70
18	15.50	36	44.60	75	289.10
19	16.50	37	47.10	80	355.10
20	17.50	38	49.70	85	433.60
21	18.60	39	52.40	90	525.80
22	19.80	40	55.30	95	633.90
23	21.10	41	58.30	100	760.00

Table 2. Vapor Pressure of Water

Temperature C	Pressure kPa	Temperature C	Pressure kPa
0	0.61	23	2.81
1	0.65	24	2.99
2	0.71	25	3.17
3	0.76	26	3.36
4	0.81	27	3.56
5	0.87	28	3.77
6	0.93	29	4.00
7	1.00	30	4.24
8	1.07	35	5.63
9	1.15	40	7.37
10	1.23	45	9.59
11	1.31	50	12.30
12	1.3:	55	15.73
13	1.49	60	19.86
14	1.60	65	25.00
15	1.71	70	31.16
16	1.81	75	38.54
17	1.43	80	47.34
18	2.07	85	57.81
19	2.20	90	70.00
20	2.33	95	84.51
21	2.49	100	100.10
22	2.64	105	120.80

develop a mental picture of the relationship by reasoning through each gas law rather than memorizing a formula and plugging numbers into it. They make the following calculations:

- the volume of gas collected; and
- correct barometric pressure for the vapor pressure of water.

When the collection of butane gas is finished, water vapor is present in the flask along with the butane collected (refer to Dalton's Law of Partial Pressure). Therefore,

$$P_g = P_T - P_{H_2O}$$

(See Tables 1 and 2.)

$$\begin{aligned} P_g &= 755 \text{ mmHg} - 23.8 \text{ mmHg} \\ &= 731 \text{ mmHg} \end{aligned}$$

c. Gas laws are based on the Kelvin temperature scale because it gives a direct relationship between temperature and pressure. The relationship makes it easier to work with gases. Therefore, the temperature of the water in Kelvin = $25^\circ\text{C} + 273 = 298 \text{ K}$.

d. Students convert the volume of gas to STP by correcting for pressure and temperature where standard pressure is 760 mmHg and standard temperature is 273 K.

$$V_2 = \frac{230.0 \text{ mL} \left| \frac{273 \text{ K}}{298 \text{ K}} \right| \frac{731 \text{ mmHg}}{760 \text{ mmHg}}}{1} = 203 \text{ mL}$$

Note:

$$\begin{aligned} V_1 &= 230.0 \text{ mL} \\ P_1 &= 731 \text{ mmHg} \\ T_1 &= 298 \text{ K} \\ P_2 &= 760 \text{ mmHg} \\ T_2 &= 273 \text{ K} \\ V_2 &= ? \end{aligned}$$

Provide a brief review of Boyle's law and Charles' law to the students that reminds them of the relationship between pressure and volume and between temperature and volume. As students complete the calculation of V_2 , draw a chart (see below) on the chalkboard and have them put their results on this chart.

Have students review the chart and draw conclusions about the change of a constant mass of butane from one set of conditions of pressure, absolute temperature, and volume (V_1, P_1, T_1) to a second set of conditions (V_2, P_2, T_2).

Sample Table for Chalkboard

Group	Original Vol. V_1	Original Temp. T_1	Original Press P_1	P_2	T_2	V_2
1	230.0 mL	298 K	755 mmHg	760 mmHg	273 K	203 mL
2						

Background:

In this activity, the combined gas law should be introduced as a two-step procedure, with the second step being a correction of the result of the first step. In most experiments, both the pressure and the temperature of a constant mass of gas would change if the volume were changed. Since they are almost always carried out at temperatures and pressures other than standard, certain corrections must be made in order to determine the volume of the dry gas at STP (standard temperature, pressure or standard conditions). These corrections involve the use of Dalton's law of partial pressure and the combined gas laws of Boyle and Charles.

According to Boyle's law, the volume of a fixed amount of dry gas is inversely proportional to the pressure, if the temperature is held constant.

Additionally, a sample of the gas butane is obtained by bubbling it through water and collecting it by the displacement of water method. To use this method, the gas must be practically insoluble in water, but water vapor will be present in the gas sample. Since there is a mixture of gases, each will exert a pressure. John Dalton was the first to form a hypothesis about partial pressures. He concluded that the total pressure of a gas collected over water is the sum of the pressure exerted by the gas and the pressure exerted by water vapor. This is called Dalton's Law of Partial Pressure ($P_{\text{Total}} = P_{\text{gas}} + P_{\text{H}_2\text{O}}$).

More than 100 years after Robert Boyle stated his principle, Jacques Charles observed a sensitivity of volume to temperature of a gas. He found that to a large extent, gases expand on heating and contract on cooling. Thus, he stated that the volume of a gas varies directly proportional to its temperature, provided pressure remains constant.

The gas, butane, is used as a fuel in disposable lighters, in fuel canisters for camping stoves and lanterns, and in the manufacture of synthetic rubber. It is a hydrocarbon that occurs in petroleum and is separated from it by fractional distillation.

Listed below are the answers to Questions 3 and 4 (see Student Materials) for this activity:

Question 3:

$$V_2 = \frac{895 \text{ mL} \mid 543 \text{ mm} \mid 273 \text{ K}}{760 \text{ mm} \mid 292 \text{ K}} = 598 \text{ mL}$$

Question 4:

$$V_2 = \frac{149 \text{ cm}^3 \mid 110 \text{ kPa} \mid 273 \text{ K}}{101.3 \text{ kPa} \mid 333 \text{ K}} = 133 \text{ cm}^3$$

A sample data table follows:

Group #	Original Vol., V_1	Original Temp., T_1	Original Press, P_1	P_2	T_2	V_2
1	230.0 mL	298 K	755 mmHg	760 mmHg	273 K	203 mL
2						

Variations:

This activity could be extended to determine the molar mass of butane by calculating the mass of butane, using the experimental data and previously learned equations. However, moles in SS&C are not the forms of instruction until Grade 11.

Calculate the mass of the butane gas collected by finding the difference between the initial mass of the lighter and the final mass of the lighter after the gas has been released into the flask. Convert the volume of the gas to liters, calculate the density of butane gas in g/L at STP, and calculate the molar mass of butane in g/mol. Then calculate the percent error. Example:

Initial mass of lighter	21.80 g	
Final mass of lighter	21.30 g	
Mass of gas in liters	0.50 g	
Volume of gas in liters	$\frac{203 \text{ mL}}{1000 \text{ mL}} \times \frac{1.00 \text{ L}}{1000 \text{ mL}}$	= 0.203 L
Density of butane gas at STP	$\frac{.50 \text{ g}}{0.203 \text{ L}}$	= 2.5 g/L
Molar mass of butane	$\frac{2.50 \text{ g}}{\text{L}} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$	= 56 g/mol
Percent error	$58 \text{ g} - 56 \text{ g} = 2 \text{ g}$, then	
	$\frac{2 \text{ g}}{58 \text{ g}}$	= 3.4%

Adapted from:

Smoot, R. C., R. G. Smith and J. Price, *Chemistry—A Modern Course*, Columbus, Ohio: Glencoe (Merrill), 1990.

Tzimopoulos, N., H. Metcalf, J. Williams and J. Catska, *Modern Chemistry Laboratory Experiments*, New York: Holt, Rineholt and Winston, 1990.

Science as Inquiry

Waiting to Exhale**How do pressure and temperature relate to the volume of a gas produced when a solid decomposes?****Overview:**

Students will decompose copper (II) carbonate basic [$\text{CuCO}_3 \cdot \text{Cu(OH)}_2 (\text{s})$] and collect the CO_2 gas produced at room conditions by the *displacement of water* method. Corrections, involving the use of Dalton's law of partial pressure and the combined gas laws of Boyle and Charles must be made in order to determine the volume of the dry gas, CO_2 , at STP. Requires some equipment preparation time before attempting.

Materials:**Per lab group:**

balance
burner
copper (II) carbonate basic
 $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$, 2.20 g
2 collecting bottles, 250 mL
2 glass plates
graduated cylinder, 100 mL
2 glass tubing bends
ring stand
Tables 1 and 2 from Activity 1

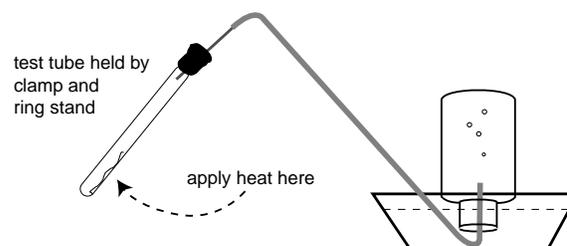
pneumatic trough
rubber stopper, one-hole
safety glasses
spatula (micro)
test tube, 18 x 150 mm
tubing, delivery
thermometer
utility clamp

Procedure:

Have students assemble ring stand, glass tubing bends, stopper and delivery tube, and set up the collection apparatus, complete with water in the trough.

They add 2.20 g of copper (II) carbonate basic, $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$ to a clean, dry test tube and clamp the test tube at an angle to the ring stand—with the solid spread along the side of the tube. Then they measure the total volume of two collecting bottles by filling them with water, carefully pouring the water into a graduated cylinder, and then measuring it. They create a data table and record this information on it.

Students refill the two collecting bottles with water, cover each with a glass plate. They invert one bottle and place it in the water filled trough over the delivery tube—removing the glass plate. None of the water in the bottle should escape—there should be no air bubbles in the bottle. Holding the burner in one hand, students heat the contents of the test tube gently by moving the flame back and forth beneath the tube.



When the first bottle is filled with gas, students slide the glass plate back under the mouth of the first bottle, remove it from the water, and place it upright on the table. They immediately invert the second bottle, and place it in the water filled trough over the delivery tube as before. However, this time, they heat the tube until no more gas is produced—turning off the burner and removing the delivery tube immediately as this occurs. *Caution: If the delivery tube remains in the water after the burner is turned off, water will be sucked back into the hot generator tube causing it to crack.*

Students cover the mouth of the second bottle (still inverted) with the glass plate and remove it from the trough. Using the graduated cylinder, they measure the volume of water remaining in the second collecting bottle and record this volume in the data table, along with the temperature, barometric pressure and vapor pressure of the water of the second bottle. See sample data table.

After the collection of CO₂, students calculate the volume of CO₂ gas (V₁) collected, the pressure exerted by dry CO₂ gas (P₁), and the volume (V₂) of the CO₂ gas at STP. Example:

$$V_1 = 500.0 \text{ mL} - 240.0 \text{ mL} = 260.0 \text{ mL}$$

$$P_1 = P_{\text{barometric}} - P_{\text{H}_2\text{O}}$$

$$= 763 \text{ mmHg} - 18.6 \text{ mmHg} = 744 \text{ mmHg}$$

$$V_2 = \frac{V_1 \left| \begin{array}{c} P_1 T_2 \\ P_2 T_1 \end{array} \right.}{P_2 T_1} = \frac{260.0 \text{ mL} \left| \begin{array}{c} 744 \text{ mmHg} \\ 760 \text{ mmHg} \end{array} \right. \left| \begin{array}{c} 273 \text{ K} \\ 294 \text{ K} \end{array} \right.}{760 \text{ mmHg} \left| \begin{array}{c} 273 \text{ K} \\ 294 \text{ K} \end{array} \right.} = 236 \text{ mL}$$

Data Table

Total volume of collecting bottles	500 mL
Volume of water remaining in bottle	240 mL
Temperature of water, T1	21°C = 294 K
Barometric pressure	763 mmHg
Vapor pressure of water	18.6 mmHg

V ₁	P ₁	P ₂	T ₁	T ₂	V ₂
260 mL	744 mmHg	760 mmHg	294 K	27 K	23.6 mL

Background:

Before the lab begins, prepare a class quantity of glass tubing bends. These bends are part of the delivery tube system.

This activity is based on the decomposition of copper (II) carbonate basic. The balanced equation for the reaction is:



The gas collected is carbon dioxide, CO₂. Carbon dioxide gas is a by-product of several chemical

processes. It is collected, compressed, and sold as a liquid in steel cylinders, and is used for refrigeration, carbonating beverages, and producing other chemicals.

After this activity, review with students the combined gas laws, Dalton's Law of Partial Pressure, and how to obtain vapor pressure of water from the Vapor Pressure Water Table. Discuss the reasoning used in determining the volume of carbon dioxide at STP. It would be appropriate for students to solve combined gas law problems commonly found in most chemistry texts.

Also ask the students:

1) What happens to the gaseous water produced when $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$ decomposes? (This water is absorbed in the liquid water in the collecting bottles.)

2) What are some possible sources of error in this activity? (Some gas may be lost while transferring the delivery tube from the first bottle to the second bottle; some water may leak from the bottles while being placed in the trough; some CO_2 gas may be lost through leaks in the delivery apparatus; some water may be lost from the partially filled bottle while being removed from the trough; there may be errors in measuring the volume.)

Regarding the caution: (*If the delivery tube remains in the water after the burner is turned off, water will be sucked back into the hot generator tube causing it to crack.*) Keep in mind that the CO_2 gas is collected by the water displacement method. Water will be sucked back into the tube because as the generator tube begins to cool, the gas occupying the tube also cools and contracts (Charles' Law). As the gas contracts, the space vacated by the gas is filled with water from the trough.

Listed below are the answers to Question 4 (see Student Materials) for this activity:

$$V_2 = \frac{980 \text{ cm}^3 \mid 98.8 \text{ kPa} \mid 291 \text{ K}}{94.3 \text{ kPa} \mid 301 \text{ K}} = 993 \text{ cm}^3$$

Variations:

None.

Adapted from:

Wagner, Maxine, *Laboratory Manual for Chemistry*, Cebco Standard Publishing, 1983.

an alternative activity for Event 2

Teacher Sheet

Science as Inquiry

Defacing Marble

What is the volume, at STP, of the gas produced by treating marble chips with hydrochloric acid (HCl) and collecting it under room conditions?

Overview:

Students determine the volume of a gas under room conditions. They then correct the volume for a pressure change while the temperature is held constant, and correct the volume for the temperature change while the pressure is held constant. This can be done at the same time because the two changes do not have any effect on each other.

Materials:**Per lab group:**

2 bottles, wide mouth, 250 mL

bottle, wide mouth, 125 mL

delivery tube

graduated cylinder

hydrochloric acid, 6M (50 mL HCl + 50 mL H₂O), 100 mL

marble chips, 2.0 g

pail (can be used instead of pneumatic trough)

thistle tube (may be used instead of test tube)

rubber stopper, 2-hole (may be used instead of delivery tube)

barometer (or 1 per class)

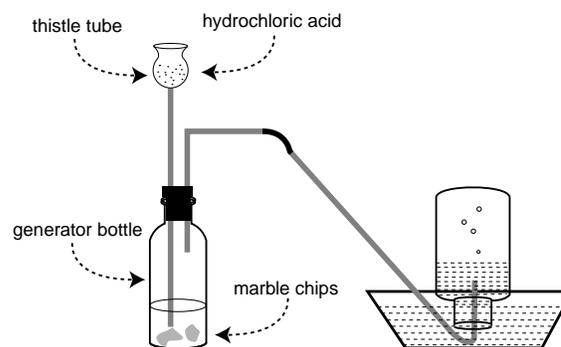
Tables 1 and 2 from Activity 1

Procedure:

In the prelab discussion, use a sample set of data to show the calculations that will be used in this activity. Also, review the techniques of collecting a gas by water displacement. Stress the importance of using full bottles of water at the start of the reaction. Review the proper methods of inserting glass tubing in rubber stoppers and delivery tubing.

Instruct students to stop heating and remove the delivery tube as soon as the gas is no longer being evolved. Safety precautions for working around open flames and for heating chemical reagents should be followed. Further, this activity may be conducted as a teacher demonstration.

Students measure the volume of CO₂ gas produced in a reaction between marble chips and hydrochloric acid. They measure the total volume of two collecting bottles and record this in a data table. They



then prepare the two bottles for the collection of gas by displacement of water. After the first collecting bottle is filled with gas, students *immediately* (to prevent gas leakage) remove and replace the first bottle with the second bottle. When no more gas is produced, students cover the second bottle with a glass plate and remove it from the pail. Using a graduated cylinder, students measure the volume of water remaining

Sample Data Table

Total volume of collecting bottles	500.0 mL
Volume of water remaining in bottle	240.0 mL
Temperature of water, T_1	21°C = 294 K
Barometric pressure	763 mmHg
Vapor pressure of water	18.6 mmHg

in the second bottle. They record this volume in the data table. Then they also measure and record the temperature of the water in the second bottle, the barometric pressure, and the vapor pressure of the water.

Students calculate the volume of CO₂ gas (V_1) collected, the pressure exerted by dry CO₂ gas and the volume (V_2) of the CO₂ gas at STP.

Students use the data observed and make the following calculations:
The volume of CO₂ gas:

$$(V_1) = 500.0 \text{ mL} - 233 \text{ mL} = 267 \text{ mL}$$

The pressure exerted by dry CO₂ gas:

$$\begin{aligned} P_1 &= P_{\text{barometer}} - P_{\text{H}_2\text{O}} \\ P_1 &= 757 \text{ mm} - 21.2 \text{ mm} \\ P_1 &= 736 \text{ mmHg} \end{aligned}$$

The volume (V_2) of the CO₂ gas at STP:

$$V_2 = \frac{(736 \text{ mmHg})(267 \text{ mL})(273 \text{ K})}{(760 \text{ mmHg})(296 \text{ K})}$$

$$V_2 = 239 \text{ mL}$$

Background:

This lab is a simple alternative for the other two labs in this unit. However, the same precautions must be observed. Special care must be taken when using hydrochloric acid. Do not get any on the hands. Use gloves when handling acids.

Refer to the procedures and background information given in the previous two labs in this unit.

Variations:

This activity could be shortened and used to test the properties of carbon dioxide gas. To do this, students discard the first bottle of gas collected as impure, and then collect three bottles of carbon dioxide. They cover the bottles and set them upright on the table and test for action in limewater, in blue litmus solution, for color, odor, solubility, combustibility and whether CO_2 is lighter or heavier than air.

Adapted from:
Unknown.

Science as Inquiry

Temperature and Pressure**Item:**

A kernel of popcorn contains a thick shell and a small amount of moisture. As it is heated a gas forms. What happens inside the kernel until it pops?

- A. Pressure decreases.
- B. Pressure increases.
- C. Pressure fluctuates.
- D. Pressure remains constant.

Justification:

What is the relationship between pressure and temperature?

Answer:

B. Guy Lussac's law shows a direct relationship exists between temperature and pressure ($P = KT$).

Science as Inquiry

Correcting Gas Volume**Item:**

A sample of washing soda is treated with hydrochloric acid. The gas formed is collected by the displacement of water method. The maximum amount of water in the collecting container was 530 mL. After the gas was released the amount of water left in the container was 485 mL at a temperature of 23°C. The atmospheric pressure in the classroom was 750 mmHg. How can a determination of the gas volume at STP be made? What is its value?

Answer:

The gas volume at STP may be determined by finding the difference between 530 mL and 485 mL to give the volume of the gas. Then change Celsius temperature to Kelvin and find the vapor pressure of water at that temperature. Find the difference between barometric pressure and vapor pressure of water to give the pressure of the gas (P_1). Finally, the correction is made by multiplying the original volume (V_1) by both the temperature ratio and the pressure ratio. Use the Combined Gas Law to find (V_2).

$$V_1 = 530 \text{ mL} - 485 \text{ mL} = 45 \text{ mL}$$

$$P_1 = 750 \text{ mmHg} - 21.1 \text{ mmHg} = 729 \text{ mmHg}$$

$$T_1 = 23 \text{ C} + 273 = 296 \text{ K}$$

$$P_2 = 760 \text{ mmHg}$$

$$T_2 = 273 \text{ K}$$

$$V_2 = \frac{45 \text{ mL}}{1} \times \frac{273 \text{ K}}{296 \text{ K}} \times \frac{729 \text{ mmHg}}{760 \text{ mmHg}} = 40 \text{ mL}$$

Science as Inquiry

Gas Collection**Item:**

Performance Assessment.

Materials. Alka-Seltzer tablet, test tube, distilled water, wide mouth bottle, pail or pneumatic trough, utility clamp, ring stand, delivery tube, 1-hole rubber stopper.

Procedure. Assemble the apparatus so that the gas evolves when the tablet is dropped into the test tube containing 10 mL of water. When the reaction stops, turn the bottle upright, then find the volume of the water displaced. What does this represent? Explain how this is done.

Answer:

The gas is collected by the water displacement method. The volume of the water displaced is the difference between the total volume of the bottle and the amount of water remaining in the bottle after the reaction ceases. This difference represents the volume of the gas (V_1).

Consumables		
Item	Quantity (per lab group)	Activity
butane lighter	1	1
copper (II) carbonate	2.20 g	2
hydrochloric acid	100 mL	3*
marble chips	2.0 g	3*
water	2000 mL	1, 2, 3*

Nonconsumables		
Item	Quantity (per lab group)	Activity
balance, digital or pan	1	2, 3*
barometer	1	1, 2, 3*
bottle, 250 mL	2	1, 2, 3*
bunsen burner	1	2
cylinder, graduated	1	1, 2, 3*
delivery tube	1	1, 2, 3*
glass plate	2	1, 2, 3*
glass tubing, bends	1	1, 2, 3*
pail	1	3*
pneumatic trough	1	1, 2, 3*
ring stand	1	2
rubber stopper, 1-hole	1	2
rubber stopper, 2-hole	1	3*
safety glasses	1	1, 2, 3*
spatula, micro	1	2, 3*
test tube, 18 x 150 mm	1	2
thistle tube	1	3*
utility clamp	1	3*

*indicates alternative or additional activity

Key to activities:

1. Don't Flick the Bic
2. Waiting to Exhale
3. Defacing Marble

Activity Sources

Smoot, R. C., R. G. Smith and J. Price, *Chemistry—A Modern Course*, Columbus, Ohio: Glencoe (Merrill), 1990.

Tzimopoulos, N., H. Metcalf, J. Williams and J. Catska, *Modern Chemistry Laboratory Experiments*, New York: Holt, Rineholt and Winston, 1990.

Wagner, Maxine, *Laboratory Manual for Chemistry*, Cecco Standard Publishing, 1983.