Lab: Ideal Gas Law

Summary
In this lab, students use the reaction of an antacid tablet with water to inflate a balloon. They then use the ideal gas law to determine the number of moles of gas produced by the reaction.

Resource Type: Lab
Grade Level: High school

Objectives
By the end of this lesson, students should be able to
- use the ideal gas law to calculate the number of moles in a sample of gas.
- calculate the mass of a known volume of gas.

Chemistry Topics
This lesson supports students’ understanding of
- Gas laws

Time
Teacher Preparation: 15 minutes
Lesson: 40-80 minutes

Materials
For each group:
- Antacid tablets (up to three per group)
- Balloon
- 10- mL graduated cylinder
- Stopwatch
- Length of string
- Meter stick
- Thermometer

Safety
- Always wear safety goggles when working with chemicals in a laboratory setting.
- Students with latex allergies should not handle balloons.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- Students should wash their hands thoroughly before leaving the lab.

Teacher Notes
- Even if students have a difficult time tying the balloon, make sure they have pinched off the opening as soon as the reaction begins.
- You can either have students look up the barometric pressure from the weather report, use a barometer, or use the accepted value for atmospheric pressure if resources are unavailable.
Verify the antacid tablets you use have the same quantity of sodium bicarbonate per tablet (1,916 mg is listed in the student procedure).

Extension: Students can consider the volume of water they used, would changing the amount of water affect the results of the experiment?

FOR THE STUDENT

Student Activity Sheet: Ideal Gas Laws

Lesson

Purpose

1. Measure and record pressure, volume, and temperature data for a gas sample.
2. Use the ideal gas law to determine the amount of gas in a sample.
3. Compare an amount of gas produced with the predicted amount.

Safety

If you have a latex allergy, do not touch the balloons and tell your teacher immediately.

Materials

- Antacid tablets (your teacher will pass out a specific amount to each group)
- Balloon
- 10-mL graduated cylinder
- Stopwatch
- String
- Meter stick
- Thermometer

Procedure

1. Blow up the balloon a little bit, then let the air out—this makes it easier for the balloon to inflate later. Record the number of antacid tablets given to you by your teacher in data table two. Break the tablet(s) into pieces small enough to fit into the balloon and push them inside.
2. With the balloon still deflated, use the graduated cylinder to add 10 mL of water to the balloon, then quickly close and tie the balloon. It is critical to work quickly when tying the balloon!
3. Shake the balloon to mix the contents. Allow the contents to reach room temperature and then start the stopwatch. Gently swirl the contents every so often.
4. Measure and record the circumference of the balloon in data table one every two minutes until the size of the balloon no longer changes. To measure, wrap the string around the balloon and note how fare the string wrapped around the balloon. Use the meter stick to measure the length of the string that wrapped around the balloon. When the circumference does not change between measurements, you may stop the timer, and stop measuring.
5. When you have time, check the weather online for the current pressure and in the classroom. Use a thermometer to determine the temperature of the
classroom. Record these values in data table two. Convert the temperature
to K, and record this in data table two as well.

Data

<table>
<thead>
<tr>
<th>Data Table 1 – Circumference of Balloon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
</tr>
<tr>
<td>Circ. (cm)</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Data Table 2 – Gas Sample Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tablets</td>
</tr>
<tr>
<td>Pressure (kPa)</td>
</tr>
<tr>
<td>Temperature (°C)</td>
</tr>
<tr>
<td>Temperature (K)</td>
</tr>
<tr>
<td>Volume (cm³)</td>
</tr>
<tr>
<td>Volume (L)</td>
</tr>
</tbody>
</table>

Calculations
1. Use the maximum circumference to calculate the volume of the balloon.
   Since the balloon is nearly spherical, use the formula for a sphere:
   \[ V = \frac{4}{3} \pi r^3 \]
   where \( r = \frac{\text{circumference}}{2\pi} \)
2. Convert this volume from \( \text{cm}^3 \) to \( \text{L} \) and record this value in data table two.
3. Assume that the balloon is at the same temperature and pressure as the
   room. Use the ideal gas law to calculate how many moles of gas are in the
   balloon. Record it in the data table below.
4. Given the following equation for the reaction that took place in the balloon,
   what is the identity of the gas in the balloon?
   \[ \text{H}_3\text{C}_6\text{H}_5\text{O}_7(aq) + 3 \text{NaHCO}_3(aq) \rightarrow 3 \text{H}_2\text{O}(l) + 3 \text{CO}_2(g) + \text{Na}_3\text{C}_6\text{H}_5\text{O}_7(aq) \]
   \( \text{citric acid} + \text{baking soda} \rightarrow \text{water} + \text{carbon dioxide} + \text{sodium citrate} \)
5. Use the number of moles of gas you calculated in the balloon to determine
   the mass of that gas in the balloon; this is stoichiometry! Record it in the
   data table below.
6. The box the tablets came in claims that there are 1,916 mg of \( \text{NaHCO}_3 \) in
   each tablet. Given that amount of \( \text{NaHCO}_3 \) and the number of tablets,
   calculate what mass of that gas \textit{should} be produced if each tablet completely
   reacted; this is also stoichiometry! Record it in the data table below.
7. Calculate the percent yield:
   \[ \% \text{ yield} = \frac{\text{theoretical}}{\text{actual}} \times 100\% \]
   Record it in the


<table>
<thead>
<tr>
<th>Gas amount (mol)</th>
<th>Actual mass of gas (g) – from PV=nRT</th>
<th>Theoretical mass of gas (g) – from stoichiometry</th>
<th>Percent yield</th>
</tr>
</thead>
</table>

**Conclusion**

1. On the board, record in the data table:
   a. How many tablets you had.
   b. The maximum volume, in L.
   c. The actual mass of gas.
   d. Your percent error.

2. Compare your results with those of the other groups. For example, a group with two tablets *should* have twice the volume and mass of gas as a group with one tablet. Describe how the results compare between groups and propose explanations for any discrepancies.