Rocket Science: Unleashing Gas Laws with Alka-Seltzer

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Introduction

Physics is the study of understanding how the world around us behaves by exploring cause-and-effect relationships between different physical quantities. We test these relationships by turning them into mathematical models that we can compare to real-world measurements and use to predict future results.

In this experiment, we'll examine the relationship between the amount of Alka-Seltzer used and the reaction time of launching a canister. Does adding more Alka-Seltzer consistently reduce the reaction time? If so, it suggests a linear relationship between the amount of Alka-Seltzer and the reaction time. To test this idea, we'll measure reaction times for different amounts of Alka-Seltzer and plot the data on a graph. This will help us determine whether our hypothesis holds and allow us to develop a mathematical model that describes the system's behavior.

In real-world experiments, things rarely go exactly as we expect. Just like the reaction time of a canister launch might not change linearly with how much Alka-Seltzer we add, the data we collect in the lab often doesn't fit exactly on a specific curve. This happens because many factors influence the outcome, and when we focus on just one relationship—like the amount of Alka-Seltzer and the reaction time—we're simplifying a more complex system. This is what makes physics a science of approximation. Our mathematical models aim to describe nature, but they can only do so approximately.

Prediction:

Before diving into the experiment, take a moment to make a prediction. What do you think will happen when you vary the amount of Alka-Seltzer? How will this affect the reaction time of the canister launch? What would happen if you used hot water instead of cold water? What would happen if you increased the surface area of the Alka-Seltzer. Write down your prediction and explain why you think this will occur.

Experiment:

Today's lab journal will be graded but, as long as it is submitted on time, the grade will not count in your final lab grade. Throughout these instructions you will see references to sections of the *Introduction to Laboratory Practices* (ILP) document; refer to that document for the details.

Now, carry out the experiment as outlined below. Pay close attention to how different amounts of Alka-Seltzer affect the reaction. Record your observations and data carefully.

Part 1: Dissolution Rate Investigation

Whole Tablet Dissolution in cold water:

- Measure 50 ml of room temperature water into a beaker.
- Measure the temperature of the water.
- Measure the mass of a whole Alka-Seltzer tablet.
- Drop a whole Alka-Seltzer tablet into the water and start the stopwatch on your phone.
- Record the time it takes for the tablet to dissolve completely.
- Repeat this process twice to obtain an average dissolution time.

Create a table in your lab notebook with the following columns:

- Trial Number
- Tablet Form (Whole or Powdered)
- Mass of Tablet
- Water Temperature
- Dissolution Time (seconds)
- Average Dissolution Time (seconds)

Whole Tablet Dissolution in warm water:

- Measure 50 ml of room temperature water into a beaker.
- Use hot water in the front of the room.
- Measure the temperature of the water.
- Be cautious when using the hot water to avoid burns.
- Measure the mass of a whole Alka-Seltzer tablet. Be sure that the mass is almost the same as the one above.
- Drop a whole Alka-Seltzer tablet into the water and start the stopwatch.
- Record the time it takes for the tablet to dissolve completely.
- Repeat this process twice to obtain an average dissolution time.
- Fill in the information on the table you created above.

Powdered Tablet Dissolution:

- Measure 50 mL of room-temperature water into a beaker.
- Measure the temperature of the water.
- Calculate the average mass of the whole Alka-Seltzer tablet based on your previous measurements.
- Weigh out the same average mass of Alka-Seltzer, but this time in its powdered form.
- Add the powdered Alka-Seltzer to the water and immediately start the stopwatch.
- Record the time it takes for the powder to fully dissolve.
- Repeat this process twice to calculate an average dissolution time.

In the future, you'll need to identify potential sources of error. To help you get started, consider the following points.

Sources of Error:

While performing this experiment, consider any potential sources of error that might affect your results. Here are some questions to guide you:

> ***Measurement Accuracy***: Were the measurements of the Alka-Seltzer powder and water precise? Could there be any inaccuracies in measuring the powder or the water volume?
>
> ***Timing Consistency***: Did you start and stop the stopwatch accurately each time? Were there any delays in recording the time? How about your reaction time?

Powder Consistency: Was the powdered Alka-Seltzer evenly distributed when added to the water? Could clumping or uneven mixing affect dissolution rates?

Temperature Variations: Was the water temperature consistent throughout the experiment? Did any changes in room temperature or water temperature affect the results?

Why Identifying Sources of Error is Important:

Understanding and identifying sources of error is crucial in any scientific experiment because it helps us evaluate the reliability and accuracy of our results. By recognizing potential errors, we can:

Improve Accuracy: Addressing these errors allows us to refine our methods and improve the precision of our measurements.

Assess Reliability: Knowing the sources of error helps us determine how reliable our data is and whether our conclusions are valid.

Enhance Experiment: Identifying and analyzing errors deepens our understanding of experimental techniques and the scientific process.

Reflecting on these sources of error ensures that we not only get more accurate results but also gain valuable insights into how to conduct experiments more effectively.

Analysis Questions:

- How does the dissolution time change with increased temperature? Compare the cold, room temperature, and warm water results.
- Is there a noticeable difference in how quickly the tablet dissolves when crushed into a powder versus a whole tablet in warm water? Why might this be the case?
- Which factors (temperature, surface area) seem to have a greater effect on dissolution speed? Do they work together, or does one dominate?
- How might changing the volume of water affect the dissolution rate of Alka-Seltzer? Specifically, would a larger or smaller volume of water influence how quickly the tablet dissolves? Perform a quick test to investigate this and explain your findings.

Part 2: Dissolution Rate Investigation

Safety Precautions:

- **Handle Film Canisters with Care:** The canisters can launch with considerable force, so always handle them gently.
- **Work in an Open Area:** If the weather permits, we will conduct this experiment outdoors to avoid any potential mess or accidents.
- **Avoid Angling the Canister:** Ensure that the canister is placed upright and not angled to prevent accidental injury to people nearby.
- **Stand Back:** Keep a safe distance from the canister once you have placed it on aluminum tray. After you have placed it on the tray, don't open it without talking to your instructor first.
- **Use an Aluminum Tray:** Place the inverted canister on an aluminum tray to contain any potential mess and to protect surfaces.
- **Wear Safety Goggles:** To protect your eyes from any debris, everyone involved should wear safety goggles.
- **Be Prepared for Launches:** Always expect the canister to launch suddenly and be prepared to step back immediately after closing the lid and inverting the canister.

Experiment Procedure:

1. **Reaction Time for Whole Tablets:**
   - Measure 10 ml of room temperature water into a graduated cylinder.
   - Measure the mass of a quarter of the Alka-Seltzer tablet.
   - Add a quarter of an Alka-Seltzer tablet, and quickly close the lid. Make sure lid is closed well.
   - Place the inverted canister on an aluminum tray.
   - Start the stopwatch as soon as you close the lid and invert the canister.
   - Record the time from when you close the lid until the canister launches.
   - Repeat the steps one more time to calculate an average reaction time for this amount of Alka-Seltzer (quarter tablet). Have a different lab partner conduct the repeat.
2. **Testing Different Amounts:**
   - Repeat the experiment using different amounts of Alka-Seltzer (e.g., half tablet, whole tablet, 1.5 tablets).
   - For each variation, record the reaction time from the moment you close the lid until the canister launches.
   - After completing all trials, calculate the average reaction time for each amount of Alka-Seltzer used.

Create a table in your lab notebook with the following columns:
- Amount of Alka-Seltzer Tablet (fraction of a tablet)
- Mass of Alka-Seltzer Tablet
- Trial Number
- Launch Time (seconds)
- Average Launch Time (seconds)

In the future, you'll need to identify potential sources of error and propose ways to improve the experiment. To help you get started, consider the following points:

Sources of Error and Experiment Improvement:

Sources of Error:
- **Canister Variability:** The film canisters might have slight differences in their sealing or launch mechanism, which could affect the results.
- **Timing Accuracy:** Timing the reaction from closing the lid to the launch can be challenging. What could you do to make sure your timing measurements are as accurate as possible?
- **Water Temperature Consistency:** Variations in water temperature might affect the dissolution rate. How could you control for or account for any changes in water temperature?
- **Alka-Seltzer Powder Distribution:** If the tablet isn't crushed evenly, it could dissolve unevenly. How can you make sure that the powder is distributed consistently?

Improving the Experiment:
- **Use More Trials:** Increasing the number of trials can help account for variability and improve the reliability of your results. How many trials would you include to get a more accurate average reaction time?
- **Control Environmental Factors:** Ensuring consistent environmental conditions, such as temperature and humidity, can improve the accuracy of your results. What measures could you take to control these factors in your experiment?
- **Calibrate Timing Equipment:** Using more precise timing methods, such as electronic timers or automated systems, could reduce human error in recording the reaction time. What tools or methods could you use to enhance timing accuracy?

Graph the Data in Excel

X-Axis: Mass of Alka-Seltzer tablet (in grams)
Y-Axis: Average launch time (in seconds)

Instructions for Creating the Graph in Excel

Enter Your Data
- *Open a new spreadsheet in Excel.*
- *Input your data as follows:*
- ***Column A:** Mass of Alka-Seltzer tablet (in grams)*
- ***Column B:** Corresponding average launch time (in seconds)*

Select the Data
- *Highlight the data in both columns (include headers if used).*

Insert the Chart
- *Go to the "Insert" tab in the Excel toolbar.*
- *Click on "Scatter" in the "Charts" group.*
- *Choose "Scatter with Markers" to plot the data points.*

Add a Chart Title:
- *Click on the chart title and enter a descriptive title, such as "Launch Time vs. Amount of Alka-Seltzer."*

Label the Axes:
- *Right-click on the X-axis and select "Add Axis Titles." Label the X-axis as "Mass of Alka-Seltzer Tablet (grams)."*
- *Do the same for the Y-axis and label it "Average Launch Time (seconds)."*

Adjust the Scale (if needed):
- *Right-click the Y-axis (or X-axis) and select "Format Axis" to modify the scale if necessary, ensuring all data points are clearly visible.*

Trend Analysis and Further Questions:

1. **Identify Trends:**
   - Examine the graph to identify any general trends in how reaction time changes with different amounts of Alka-Seltzer.
   - How does the reaction time vary as you increase or decrease the amount of Alka-Seltzer? Is there a noticeable pattern?

2. **Discuss Deviations and Outliers:**
   - Are there any deviations or outliers in your data? If so, what might have caused these anomalies?
   - Consider potential experimental errors or inconsistencies that could affect your results.

3. **Relate to Gas Laws:**
   - Reflect on how the amount of Alka-Seltzer affects gas production and pressure buildup.

4. **Impact of Reaction Time on Data Collection:**
   - Assess whether the reaction time of your own observations could influence your data collection.
   - How might your timing affect the results, and what strategies could be used to minimize this impact?

5. **Effect of Water Temperature:**
   - Predict what might happen if hot water were used instead of room temperature water.
   - How do you think the temperature change would affect the dissolution rate of Alka-Seltzer?

Part 3: Conclusions and Key Points

Research and discuss how Boyle's Law, Charles's Law, and the Kinetic Theory of Gases relate to the experimental results. Discuss any discrepancies between expected and observed results and propose possible explanations. Yes, you can look up definitions online.

Hints:

What is Boyle's Law?

Application to the Experiment: Gas Production and Canister Launch

Discussion: Compare your observations of reaction time with the expected results from Boyle's Law.

What is Charle's Law?

Application to the Experiment: Temperature and Dissolution Rate

Discussion: Analyze how heating the water affected the dissolution rate and relate it to Charles's Law.

What is the Kinetic Theory of Gases?

Application to the Experiment: Temperature Effects on Gas Production

Discussion: Consider how the kinetic theory explains the increase in reaction speed with warmer temperatures.

Please clean up your work area when you have completed your experiment. Return the setup to the condition you found it when you entered the lab. Be sure to read through the "Laboratory Etiquette" section of the *Laboratory Syllabus* before leaving. And be sure to re-read the *Introduction to Laboratory Practices*, as well as the sample lab journals, before next week's lab.