

Can You Change the Rate of a Chemical Reaction by Changing the Particle Size of the Reactants?

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Experimental Procedure

Setting Up the Gas Collection Apparatus

1. Remove the small red cap from one of the squeeze bottles. Then connect the tubing to the tip opening, as shown in Figure 2. Make sure that you have a tight fit.



Figure 2. Tube connected to the bottle opening.

2. You will be collecting carbon dioxide from the Alka-Seltzer® chemical reaction by displacing water trapped in an inverted graduated cylinder. Here's how to set it up:
 - a. Fill your plastic dishpan (or bucket) about one-third full with water.
 - b. Fill the 250-mL graduated cylinder with water.
 - i. If your dishpan is deep enough, fill the graduated cylinder by tipping it on its side inside the dishpan. Allow any bubbles to escape by tilting the

- cylinder up slightly, while keeping it under water. Keeping the opening of the cylinder under water, turn it upside down and attach it to the side of the dishpan with packing tape (or have your helper hold it in place).
- ii. If your dishpan is not deep enough, fill the graduated cylinder completely using the faucet and cover the top tightly with plastic wrap. Quickly invert the cylinder and place the opening in the dishpan, beneath the surface of the water. Remove the plastic wrap. Attach the cylinder to the side of the tub with packing tape (or have your helper hold it in place).
- c. The graduated cylinder should now be upside down, full of water and with its opening under the surface of the water in the dishpan. Place the free end of the tubing from the plastic bottle inside the graduated cylinder. Your apparatus is now ready to trap carbon dioxide from the Alka-Seltzer® chemical reaction (see Figure 3).



Figure 3. Picture of the inverted graduated cylinder gas collection apparatus.

- d. You can test your gas collection apparatus by removing the tube from the bottle top and blowing gently into the tube. The bubbles you create should be

captured inside the cylinder. (You will need to reconnect the tube to the bottle and re-fill the cylinder before starting your experiment.)

Running the Experiment

- In this experiment, you will be measuring the reaction rate for the production of carbon dioxide gas from a single Alka-Seltzer® tablet.
 - You will measure the volume of gas produced at 10-second time intervals after the reaction begins.
 - You will investigate how the reaction rate changes as you vary the particle size of the reactants.
- You can use the same plastic bottle for repeated trials, so it is convenient to mark the desired water level.
 - Fill the bottle with about 120 ml (4 oz.) water.
 - You do want to use the same amount of water for each trial. Use a permanent marker to mark the water level on the outside of the bottle.
- For measuring the reaction rate, you will use the same volume of water at the same starting temperature. You will use four different particle sizes for the Alka-Seltzer® tablets:
 - A whole tablet
 - A tablet broken in half
 - A tablet broken in quarters
 - A tablet ground into powder. To do this, fold a single tablet to be ground inside a clean piece of paper. Place the folded paper on a piece of scrap wood, and use the the back of a large metal spoon to firmly pound the tablet about ten times. Stop immediately if the paper shows signs of tearing: you don't want to lose any of the powder.
- Here is how to measure the reaction rate:
 - Fill the bottle with water up to the level of your marker line.
 - Measure the temperature of the water, and record it in your lab notebook.
 - Remove the thermometer.
 - Have your helper get ready with the stop watch, while you get ready with an Alka-Seltzer® tablet. Hold the tablet in one hand and the bottle cap (with tubing attached) in the other hand.
 - Have your helper count one-two-three. On three, the helper starts timing and you drop the tablet (or tablet pieces) into the water.
 - Quickly cap the bottle tightly using the cap with the tubing attached. You will immediately see bubbles of CO₂ streaming out from the tablet.
 - Using the hand that you *don't* use for writing, swirl the bottle gently, keeping the bottom of the bottle flat on the table top.
 - Every ten seconds, your helper should call out "Time!" You should immediately read the carbon dioxide volume in the graduated cylinder and write it down in your lab notebook. Prepare a table to keep your data organized.

| Particle Size (whole/halves/quarters /powder) | Trial # | Volume of CO ₂ after reaction begins (times in seconds) | | | | | | | | | | | |
|---|------------|--|----|----|----|----|----|----|----|----|-----|-----|-----|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| | | | | | | | | | | | | | |

- Continue recording the volume of gas at 10-second intervals until the volume is no longer changing. At this point, the reaction is complete.
- Tip: be careful when opening the packets and handling the Alka-Seltzer® tablets. The tablets are thin and brittle, so they break easily. Remember that you need to have three whole tablets for this experiment.

5. For each of the four particle sizes, you should repeat the experiment three times, for a total of 12 trials.

Analyzing Your Data

1. For each particle size, calculate the average volume of gas at each time point for the four trials (see the table below)

| Particle Size (whole/halves/quarters/powder) | Trial # | Volume of CO ₂ after reaction begins (times in seconds) | | | | | | | | | | | |
|---|---------|--|----|----|----|----|----|----|----|----|-----|-----|-----|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| whole tablet | 1 | | | | | | | | | | | | |
| whole tablet | 2 | | | | | | | | | | | | |
| whole tablet | 3 | | | | | | | | | | | | |
| Average | - | | | | | | | | | | | | |

2. Make a graph of the volume of CO₂, in mL, (y-axis) vs. time after the reaction begins, in seconds (x-axis).
 - a. You can include the data from all four particle sizes on one graph.
 - b. Use a different symbol and color for each particle size.
 - c. Remember to include a legend that identifies the particle size associated with each symbol.
3. More advanced students should also calculate the **standard deviation** (<http://www.sciencebuddies.org/science-fair-projects/science-fair/variance-and-standard-deviation>) of the reaction times for each particle size.
 - a. Use the standard deviation to add error bars to your graph.
 - b. For example, say that the average volume for two half-tablets 30 seconds after the reaction began was 45 mL, and the standard deviation was 5.2 mL (these are made-up numbers). You would graph the symbol for the data point at 45 mL, and then draw short vertical bars above and below the symbol. Each vertical bar would have a length equivalent to 5.2 mL.
 - c. Error bars give your audience a measure of the **variance** (<http://www.sciencebuddies.org/science-fair-projects/science-fair/variance-and-standard-deviation>) in your data.
4. How does reaction rate change with particle size?