Dr. Skip's Corner: K-12 Teaching Adventures @ OSU Engineering

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THE FIZZ FACTOR – WHICH SODA HAS THE MOST *POP*?

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I'm sure we've all experienced the *fizz factor* at some points in our lives, whether it be opening a soda can and having it spill out all over the table (not fun) or purposely shaking-up a soda and spraying a friend (FUN!). We probably all have our own personal ideas on which sodas make the most fizz….and so do the kids! There are various ways to figure this out.

Experiment #1: Visual Product Testing (Qualitative)
A very qualitative experiment is to buy a bunch of different sodas, shake them up, open them….and see which sprays the most. That's one experiment that every kid loves!

Experiment #2: Balloon Expansion (Quantitative?)
The "classic" experiment is to place a balloon over the soda bottle, shake it up, and measure the diameter (or volume) of the balloon. Most people think this is a very *quantitative* experiment because you can get a number out of this. But is it a "good" experiment? Maybe, but is it always easy to blow up a balloon the first time? Remember what you always do before trying to blow-up a balloon….stretch it out. And is the first time a balloon is blown-up the same as the second, third, fourth…etc? Probably not. And what happens when you blow-up a balloon? Isn't it more difficult to blow it up at the beginning and end then in the middle? So, the ballon inflation experiment may be good, but it may lead to inaccuracies. The Ashbrook kids decided to do a different experiment….***volume displacement***.

Volume Displacement – The FIZZ FACTOR!
In this experiment you connect a tube to the top of a bottle filled with soda, and place the tube in an inverted cylinder filled with water that sits in a tub filled with water. Shake the soda bottle and bubble the gas released into the inverted cylinder, which displaces the liquid in the cylinder. It's an old and reliable technique, which is very easy to do in your kitchen at home! Here's what you need to do this simple experiment.

Materials
In order to complete this investigation you will need the following supplies for each group:

- SODA (any types and brands you want to test)
- 500 ml spray bottle (an any bottle you can easily attach tubing to)
- 3/16 in. i.d. Tygon tubing (or any rubber tubing that fits on a bottle)
- 1000 ml graduated cylinder (plastic) – or another suitable container
- Plastic tub
- Stopwatch
- Water

Experimental Procedure

1. Fill the 1000 ml graduated cylinder with water. Fill up the tub with water about 2-3 in. deep. Place a hand over the graduated cylinder, invert, and place carefully in the water bath. Record the height of the water in the graduated cylinder.
2. Connect one end of the tubing to the spout on the spray bottle lid. Slide the other end into the upside-down 1000 ml graduated cylinder, making sure to not let the water out. Record the height of the liquid column (initial volume of liquid).
3. In the empty plastic spray bottle pour 250ml (approx. 8 oz) of the SODA to be tested and screw the lid on tightly (we don't want leaks or spillage!).

4. Shake, shake, shake….be sure to hold the tube in the cylinder so it doesn't pop out! Watch the gas (what gas is it?) bubble through and displace the liquid in the graduated cylinder. Go ahead and SHAKE some more until you think all of the gas is gone from the soda (no more bubbles coming out).
5. When the gas release is complete, record the height of the water in the graduated cylinder (final height).
6. Now calculate and record the volume of gas released.

Volume of gas released = initial height (volume) – final height (volume)
NOTE: If you don't have a graduated cylinder available, you can use any container. Just mark the liquid level before and after the experiment. Then, after the test pour some liquid into the container and measure the volume between the lines using a measuring cup or something similar.

7. Rinse the spray bottle with water
8. Repeat steps 1-6 a minimum of three (3) times for each SODA.

Data Analysis

Some *typical data* on the *FIZZ FACTOR* from the Ashbrook 3rd Grade Class is provided below. The kids chose the sodas and they did the measurements. This is real experimental data!

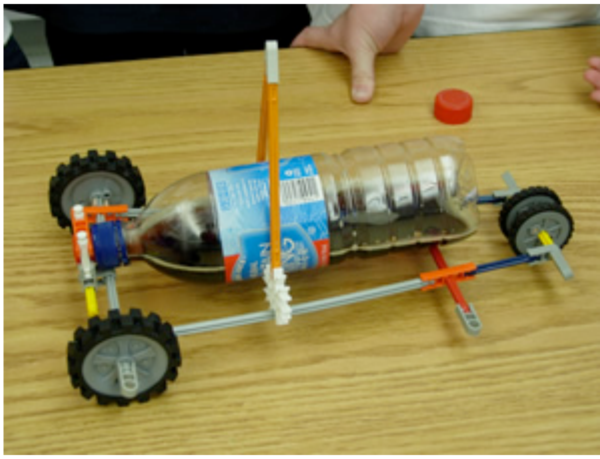
SODA	GROUP Fizz#1 (Volume in milliliters)					GROUP FIZZ #2 (Volume in ml)				
	Run #1	***Run #2***	***Run #3***	***Total***	***Rank***	***Run#1***	***Run#2***	***Run #3***	***Total***	***Rank***
Sprite						350	400	400	1160	1
Sierra Mist	320	380	400	1100	1	330	280	400	1010	2
Mountain Dew	380	270	200	850	3	310	130 (?)	300	740	4
BigK Lem-lime						250	230	230	710	5
Pepsi	150	160	190	500	6	260	370	310	940	3
Coke	190	210	310	710	4					
BigK Cola	180	270	490 (?)	940	2					
Mug Root Beer	190	160	180	530	5	160	120	190	470	6

You can see that there is pretty good reproducibility (with a few exceptions) between runs for the same group and even between groups. When we look at the rankings, they both come out with the surprising result (at least for me it was a surprise!), that the “clear sodas” such as Sprite and Sierra Mist have more *fizz* (CO_2 gas) than the colas….and root beer is about the lowest in *fizz factor*. This experiment also lends itself nicely to making plots of the data (bar graphs are nice) and for the more advanced grades, discussing standard deviations and error in measurements.

Powering a Car with Soda

If you want to take this experiment to the next levelof excitement, you can then have the kids construct a car and use soda to power it (see below for examples).

Which soda would you choose as your fuel?




Kitchen Chemistry: Stoichiometry, Gas, and the Reaction Powered Car
by Abbie Kimerling and Dr. Skip Rochefort

Objective

This is a “real” chemistry/engineering experiment suitable for any K-12 grade level.

The goal is to introduce the scheme of powering a small car with a chemical reaction, by first understanding how much gas is produced by a reaction. During this lab we’ll also explore the concept of stoichiometry and limiting reagents in a reaction.

Materials

In order to complete this investigation you will need the following supplies for each group:

- 5% acetic acid vinegar
- Baking soda
- 500 ml spray bottle
- 3/16 in. i.d. Tygon tubing
- 1000 ml graduated cylinder (plastic)
- 50 ml graduated cylinder (plastic)
- Plastic tub
- Stopwatch
- Water

Background – Kitchen Chemistry: The Baking Soda and Vinegar Reaction

$$Vinegar(liquid) + BakingSoda(solid) \Rightarrow Water(liquid) + CarbonDioxide(gas) + SodiumAcetate(aq.)$$

$$[AceticAcid + Water] + SodiumBicarbonate \Rightarrow Water + CarbonDioxide + SodiumAcetate$$

$$[CH_3COOH(aq.) + H_2O(l)] + NaHCO_3(s) \Rightarrow H_2O(l) + CO_2(g) + NaCH_3COO(aq.)$$

The above equations are all representations of the same reaction. It is important to note that for a complete reaction the molar ratio of acetic acid to sodium bicarbonate must be kept constant. Baking soda is 100% sodium bicarbonate, but vinegar is only 5% (by volume) acetic acid.

The carbon dioxide produced can be used to power a small car. Before we can use this reaction to power a car, we need to find out how much carbon dioxide is produced.

Pre-Experiment Calculations

Based on the stoichiometry given above and starting with 50ml of vinegar (5 vol%), calculate the mass of baking soda required for complete conversion of the acetic acid. How many moles and what volume of CO2 gas would be produced?

Show this calculation to the instructor before proceeding to the Experiment.

Experimental Procedure

1. Fill the 1000 ml graduate cylinder with water. Fill up the tub with water about 2-3 in. deep. Place a hand over the graduated cylinder, invert, and place carefully in the water bath. Record the height of the water in the graduated cylinder.
2. Connect one end of the tubing to the spout on the spray bottle lid. Slide the other end into the upside-down 1000 ml graduated cylinder, making sure to not let the water out.
3. In the empty plastic spray bottle pour 50 ml of 5% acetic acid vinegar. **Start with ~1 g baking soda for the first trial. Calculate how much CO2 gas you would expect to produce with his amount of baking soda.** Weigh the baking soda in a Kimwipe and wrap up into a little pouch.
4. When ready, add the pouch to the spray bottle and **immediately** screw the lid on. (It is good to practice this with out the reactants once or twice.) Time the reaction with the provided stopwatch.
5. Gently shake the bottle to encourage mixing. The reaction produces gas that will travel through the tubing and into the graduated cylinder, displacing the water in the cylinder. When the reaction is complete, record the height of the water in the graduated cylinder.
6. Rinse the spray bottle with water in between experiments to remove any unreacted acetic acid or baking soda (throw away the wet Kimwipe).
7. Repeat steps 1-6 a few times with different amounts of baking soda all the way past the stoichiometric balance (baking soda as the limiting reactant) to check if this concept (or your interpretation of it) is correct.

Additional Experimental step after you have gone through various amounts of baking soda.

8. Choose a mass of baking soda for which you have reasonable data. Try adding just plain water (say 25 ml) to your reaction mixture and see if it has any effect on the gas production (would you expect it to?).

***Real Engineering* -- Design, Build and Run a Reaction Powered Car**
If time permits, we would encourage you to design and build a simple car with a sport water bottle (valve cap) as the "reaction chamber" and to run your reaction to see if you can propel the car forward. This is a great way to look at the transition from the **chemistry** to the **engineering** in this project.

Car – build using the K'Nex kit provided.

Reaction Vessel – see instructor for a choice of reaction vessels.

Discussion Questions

1. How much gas did you produce? Calculate how much carbon dioxide the reaction should produce and compare that to your experimental results. How/when did you potentially lose gas?
2. At what mass of baking soda did the reaction no longer progress while the vinegar volume was held constant at 50 ml? How does this compare with your calculations of baking soda as the limiting reactant? Explain your results.
3. How did the car run (if you got to this)?