DEPARTMENT OF BIOLOGY
NE STEM 4U

Diet Coke & Mentos

I. Objective

A portion of this lesson needs to be done outdoors, so be sure the weather is decent. Some key concepts to be learned in this lesson are: The difference between chemical and physical reactions, surface tension, gas formation, and the effects of gas pressure.

II. Required Materials

a. 2-Liter Bottle of Diet Cola per group
b. Club Soda
c. Mint Mentos
d. Construction Paper
e. Tape
f. Golf Balls
g. Clear cups (preferably glass, plastic will suffice)
h. Dish soap
i. Eyedroppers
j. Pennies

III. Other Required Worksheets or Handouts

None

IV. Precaution

Do not stand over the soda once the Mentos have been dropped into it. Conduct this experiment outside in the grass, if possible. Do not drink the Diet Coke or eat the Mentos.

V. Main Concept to be learned

1. Chemical and physical reactions
2. Surface tension
3. Nucleation sites

VI. Vocabulary

a. **Chemical reaction:** a chemical reaction has occurred when a substance's chemical identity has been altered by the reaction.

b. **Physical reaction/change:** a change in the appearance or form of a substance, but the chemical identity is unaltered. (i.e. when water freezes and melts)

c. **Surface Tension:** a contractive tendency of the surface of a liquid that allows it to resist an external force. Surface tension is a result of intermolecular forces.

d. **Nucleation sites:** areas in which gas molecules can congregate and form bubbles.

VII. Background (Science)

Combine Diet Coke and Mentos, and the result is explosive—Diet Coke shoots out of the bottle like a miniature, sticky Old Faithful. The reaction is so intense, you can make a rocket propelled by the resulting geyser. But what's the science behind this reaction?

In June 2008, Dr. Tonya Coffey of Appalachian State University and her physics students published a paper on the phenomenon in the *American Journal of Physics*. They were inspired by a 2006 *MythBusters* episode that, according to the paper, "did a wonderful job of identifying the basic ingredients in this reaction ... [but] did not sufficiently explain why those ingredients affect the explosion, nor did they provide direct proof of the roughness of the Mentos—a tall order for an hour-long television program." Coffey and her students decided to dig deeper.

IT'S ALL ABOUT TEXTURE

Coffey and company discovered that the ingredients in the Mentos and Diet Coke and, more importantly, the structure of the Mentos, allow carbon dioxide bubbles to form extremely rapidly. When this happens fast enough, you get a nice Diet Coke fountain. (It's not just Diet Coke and Mentos that react; other carbonated beverages will also readily respond to the addition of Mentos.)

Each Mentos candy has thousands of small pores on its surface which disrupt the polar attractions between water molecules, creating thousands of ideal nucleation sites for the gas molecules to congregate. In non-science speak, this porous surface creates a lot of bubble growth sites, allowing the carbon dioxide bubbles to rapidly form on the surface of the Mentos. (If you use a smooth surfaced Mentos candy, you won't get nearly same the reaction.) The buoyancy of the bubbles and their growth will eventually cause the bubbles to leave the nucleation site and rise to the surface of the soda. Bubbles will continue to form on the porous surface and the process will repeat, creating a nice, foamy geyser.

In addition to that, the gum arabic and gelatin ingredients of the Mentos, combined with the potassium benzoate, sugar or (potentially) aspartame in diet sodas, also help in this process. In these cases, the ingredients end up lowering the surface tension of the liquid, allowing for even more rapid bubble growth on the porous surface of the Mentos—higher surface tension would make it a more difficult environment for bubbles to form. (Compounds like gum arabic that lower surface tension are called "surfactants").

Diet sodas produce a bigger reaction than non-diet sodas because aspartame lowers the surface tension of the liquid much more than sugar or corn syrup will. You can also increase the effect by adding more surfactants to the soda when you add the Mentos, like adding a mixture of dishwasher soap and water.

SIZE MATTERS

Another factor that contributes to the size of the geyser is how rapidly the object causing the foaming sinks in the soda. The faster it sinks, the faster the reaction can happen, and a faster reaction creates a bigger geyser; a slower reaction may release the same amount of foam overall, but will also create a much smaller geyser. This is another reason Mentos works so much better than other similar confectioneries: The candies are fairly dense objects and tend to sink rapidly in the soda. If you crush the Mentos, so it doesn't sink much at all, you won't get a very dramatic reaction.

The temperature of the soda also factors into geyser size. Gases are less soluble in liquids with a higher temperature, so the warmer your soda is, the bigger your Mentos-induced geyser will be. This is because the gases want to escape the liquid, so when you drop the Mentos in, the reaction happens faster.

WHAT DOESN'T WORK
While caffeine is often cited as something that will increase the explosive reaction with the soda, this is not actually the case, at least not given the relatively small amount of caffeine found in the typical 2-liter bottle of soda generally used for these sorts of Diet Coke and Mentos reactions.

You'll also sometimes read that the acidity of the soda is a major factor in the resulting geyser. This is not the case either. In fact, the level of acidity in the Coke before and after the Mentos geyser does not change, negating the possibility of an acid-based reaction—though you can make such an acid-based reaction using baking soda.

(Information borrowed from http://mentalfloss.com/article/48759/why-do-diet-coke-and-mentos-react)

Many students have heard of this lesson before, but it easy to overlook the science behind the experiment… so we like to begin by asking questions about what is going on inside the coke bottle. A common misconception is that the geyser is formed due to a chemical reaction between the mentos and diet coke. We use this opportunity to distinguish between a chemical and physical reaction or change. A chemical reaction occurs when a substances identity is chemically altered. If we were to analyze a sample of the diet coke before the reaction, and once again after the diet coke has shot out of the bottle, we would find them to be chemically identical. This is because a physical change is occurring, which is simply a change in the visible form of a substance. For instance, when water changes from liquid to solid.

If you'd like to show the kids that an acid-base reaction is not occurring, you could test the diet cokes pH before and after the reaction using litmus paper. All that is occurring is the CO_2 gas is escaping from the liquid faster than it would naturally. A nice connection we like to make with the students is asking them what happens when we leave soda opened for too long…It goes flat because the CO_2 has escaped even if you cannot see it.

There are a few reasons why dropping mentos into diet coke causes the gas to escape at an extremely rapid rate. The primary reason is that each mentos candy has thousands of small pores on its surface. These pores disrupt the attractions between water molecules in the diet coke and this allows for the CO_2 gas molecules to form all over the mentos. The spots where gas can form are called nucleation sites.

In addition, the gum arabic and gelatin ingredients of the Mentos, combined with the potassium benzoate and aspartame in diet soda lower the surface tension of the liquid. This decrease in surface tension allows for even more bubble formation on the porous surface of the Mentos— A higher surface tension would make it more difficult for bubbles to form and even harder for them to escape from the surface of the liquid.

To demonstrate what surface tension is to the students, you can drop water onto a penny and watch a large bubble form. This large bubble is able to form because water has strong intermolecular forces that hold the water molecules together.

VIII. Procedure:

1. Open
2. Administer Quiz/ Play Quiz Game
3. Experiment 1: Surface Tension Penny
    a. Have students guess how many drops of water will fit on the penny. They will surely underestimate.
        i. Hand out pennies and eyedroppers and have each student count each drop of water that fits on the penny.
            1. While their minds are being blown by how many drops they have added, talk about surface tension. Water has really strong intermolecular forces, resulting in a high surface tension.
4. Experiment 2: Nucleation sites
    a. Fill two clear cups with club soda.
    b. Add dish soap to one of the cups and stir very slowly so you don't create a bunch of bubbles.
        i. Drop a golf ball into each cup.
            1. Have the students observe the nucleation sites and gas formation on the golf ball.
            2. In the cup with dish soap, the bubbles form and escape more rapidly than in the cup without dish soap. This is because the soap lowers the surface tension of the water, making the bubbles form and escape more easily.
    c. Now, we compare the nucleation sites on the mentos and the golf ball.
        i. Place two clear cups next to one another.
        ii. Fill with club soda

iii. Add a mentos to one cup and a golf ball to the other.
   1. You will notice, that bubbles form far more rapidly on the mentos when compared to the golf ball. This is because the mentos has many more nucleation sites than the golf ball.

5. Experiment 3: The Geyser
   a. First, we roll construction paper into a funnel shape so the mentos can be dropped into the diet coke bottle quickly and accurately.
   b. Necessary Explanations. Safety first! No hovering over the soda bottles once the Mentos have been dropped. Give the geyser the space it needs, we don't want people being soaked in soda.
   c. Before opening the soda, have the students explain what they think will happen when they drop the mentos into the diet coke and why.
   d. Open the soda, drop at least 7 mentos into the soda using the funnel, and watch science happen.

   e. You can compare warm diet coke to cold diet coke and see which yields a larger geyser. The warm coke will have a larger geyser because gas is less soluble in warm temperatures.

6. Have the students write observations in their scientific journals. Collect the notebooks at the end.
7. Final Quiz/Game
8. All students should participate in cleaning up the room.

IX. References

http://www.stevespanglerscience.com/lab/experiments/homemade-geyser-tube
http://mentalfloss.com/article/48759/why-do-diet-coke-and-mentos-react
Wikipedia