Fountain of Soda

Section **PROPERTIES OF MATTER** *Topic* **SOLUBILITY**

Estimated Time Setup: 5 minutes; Procedure: 5 minutes

OVERVIEW

Students add Mentos® mints to a bottle of diet cola soda pop and watch as an enormous fountain of bubbly soda escapes the bottle.

In this activity, students experience how the bumpy surface of a mint candy creates the perfect place for carbon dioxide gas bubbles from a carbonated beverage to form. As gas bubbles quickly form on the mint's surface they begin to rise and to escape the solution. Bubbles of carbon dioxide rush from the bottom of the bottle where the mint rests, through the opening in the top, pushing the liquid with them and creating a foamy, sticky fountain of soda pop in the process!

INQUIRY QUESTIONS

Getting Started:

- What causes the bubbles that appear in soda drinks?

Learning More:

- How is carbon dioxide dissolved in and released from carbonated drinks?

Diving Deeper:

- How does the structure of a Mentos® mint enable the immediate release of carbon dioxide from a solution?

CONTENT TOPICS

This activity covers the following content topics: carbonation, solubility, solutions, mixtures, polarity, nucleation sites, saturation

This activity can be extended to discuss: factors that affect solubility, rocketry

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-2:** Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.
- **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures.

MATERIALS

For one setup:

- One package of Mentos® mints
- 2-Liter bottle of diet cola soda pop
- 1 Sheet of construction paper
- Index card

ACTIVITY NOTES

This activity is good for:

- Demonstrations
- Large groups

Safety Tips & Reminders:

- This activity is messy! We recommend doing this activity outside in an open area.
- Students should wear protective eyewear and take a few steps back so they don't get sprayed with soda pop.
- Regular soda pop will work, but diet soda pop will have a bigger result.
- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about solubility:

- For "explosive" experiments like this, sometimes the best engagement is the demonstration itself! Perform the activity as a group, then discuss and analyze what occurs in the experiment.
- Provide a cup with a small amount of soda pop and one Mentos® candy to each student or small group. Ask them to drop the candy in and observe what happens. Where are bubbles forming? Where do they go? What do they think will happen if we add many Mentos® to a bottle of soda?
- Search online for videos of this activity! There are lots of exciting and explosive modifications—many of which are fun to watch but might be too risky to try out with your class!

See more ideas for engagement in the Solubility Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #1

This experiment is famous—it is involved in a number of Guinness World Records! In 2009 in the United States, the "Largest Physics Lesson" record was beat by having 5,401 participants conduct hands-on science experiments, including Mentos® and soda! The record for "Most Mentos and Soda Fountains" was broken repeatedly, with the most recent one in 2014 in Mexico, where 4,334 fountains were set off simultaneously!

EXPLORE

Procedure:

1. Open the bottle of soda pop and place it into the center of an open space.
2. Wrap about 10 Mentos® mints in a construction paper tube to hold them in place. They should be stacked neatly so they can easily fall into the opening of the soda pop bottle.
3. Place an index card over the opening of the bottle and the stack of mints on top of the index card, directly over the opening.
4. Quickly pull the index card away to let the mints drop into the bottle, then step away!

Notes

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- What do you see and hear when the bottle of soda pop is opened? Why?
- What are the components of soda pop?
- Draw a step-by-step diagram of what happened in this activity. Why do each of those steps occur?
- What was the appearance of the fountain? What do you think caused it to explode?
- How high did the fountain go? How could you increase or decrease the height?
- What are the components left in the bottle of soda pop in the end?

Notes

EXPLAIN

What's happening in this Activity?

First review the Solubility Background section to gain a deeper understanding of the scientific principles behind this activity.

Solubility is a physical property that describes the ability of a substance (the solute) to dissolve in another substance (the solvent) to create a uniform solution. If a substance can dissolve in another substance, it is said to be **soluble** in that substance. If it does not dissolve, it is **insoluble**.

Carbonated drinks like soda pop are solutions made of carbon dioxide, sweetener, and other compounds dissolved in the water. In these carbonated drinks, water is the **solvent**. Carbon dioxide, sweetener, and the other compounds are **solutes**. Soda exists as a mixture because all of the solutes are **soluble** in water and therefore stay dissolved in the solution.

Several factors can affect solubility, including temperature, pressure, and the amount of solute or solvent in a solution. In general, solid and liquid substances are more soluble in solvents at higher temperatures compared with the same solvents at lower temperatures. (Think of how more sugar can be dissolved in hot water than in cold water.) Gases are more soluble in a solvent when it is at a lower temperature. Gases are also more soluble in solvents at higher pressures.

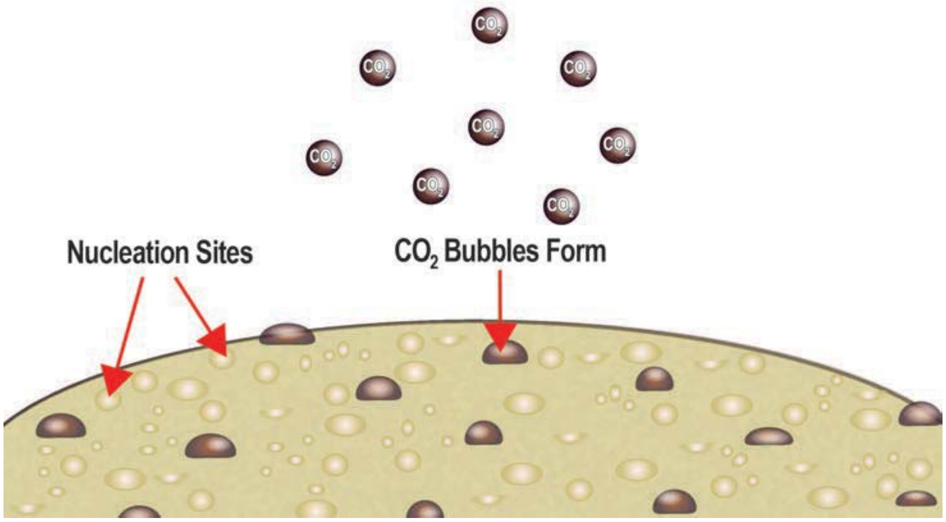
Carbon dioxide (CO_2) is a gas that we exhale each time we breathe. At normal temperature and pressure, carbon dioxide is not very soluble in water. Soda pop bottles are able to keep carbon dioxide dissolved in solution because they are sealed under very high pressure. When you open a can or a bottle of soda, this releases the pressure. The solubility of carbon dioxide decreases as pressure decreases, and carbon dioxide begins to escape when the pressure is lowered. This is why soda pop “hisses” when it is opened—carbon dioxide begins to escape from the solution when the bottle is opened and the pressure is decreased.

Even though carbon dioxide is not very soluble in water under normal conditions, it is still difficult for the dissolved gas to escape after you open a bottle of soda. In order for carbon dioxide gas to come out of the solution, it has to break the strong bonds that exist between water molecules. It is not just about the solubility of the carbon dioxide in water, it is also about carbon dioxide being able to form bubbles of gas in order to escape the solution. Think of how difficult it is to create space in a very crowded room. It takes a very long time for the carbon dioxide gas to escape from soda on its own. When you leave a glass of soda pop out, it does not lose its carbonation and go flat right away—it takes time for the carbon dioxide gas to form bubbles and escape from the solution.

Adding Mentos® mints makes the carbon dioxide gas escape much, much more quickly than when it is left sitting on its own. The surface of each mint is actually a rough surface covered in tiny bumps. These tiny bumps disturb bonds between water molecules. Once the bonds are already disturbed, it is much easier for carbon dioxide bubbles to form. The tiny dents on the surface of each Mentos® mint candy act as nucleation sites. A nucleation site is an imperfection, like a scratch or a speck of dust, where it is easy for a bubble to form.

EXPLAIN continued

Each Mentos® mint is covered in tiny imperfections, or nucleation sites! When a mint is dropped in, bubbles start forming at all of the tiny divots and bumps on the candy's surface.



The Mentos® are also much denser than the soda solution, so they sink to the bottom very quickly. Bubbles form on the Mentos® and move up through the soda pop solution. As a bubble travels up, more carbon dioxide comes out of the solution and attaches to it. All of these bubbles move toward the top of the solution, where there is only one small opening for them to escape. Pressure builds up and the gas forces its way out of the bottle, pushing some liquid out too and creating a fountain!

Diving deeper into solubility and hydrogen bonding, we may wonder why the carbon dioxide may not be very soluble in water under normal conditions, but also takes a long time to escape from the soda pop on its own. There are two main reasons behind what is seen in this activity. First let's discuss the solubility of carbon dioxide in water. The reason why these substances are not very soluble in each other is due to the polarity of their molecules, which describes how charges are distributed throughout a molecule. If a molecule is polar, there are slight positive and negative charges on opposite ends of the molecule. (Think of it like the North and South Poles of the Earth!) This is because electrons are shared unequally throughout the molecule. An example is a water molecule (H_2O) where the oxygen has more electrons than the hydrogen atoms, so the molecule has slight charges on each end: negative near the oxygen, and positive near the hydrogens. Carbon dioxide, CO_2, has a different molecular structure than water, so its charges are distributed throughout the molecule in a different way. The electrons, and therefore charges, in carbon dioxide are evenly distributed throughout the CO_2 molecule. This makes it nonpolar, or not charged. In chemistry, "like dissolves like," meaning that nonpolar solutes can be dissolved by nonpolar solvents, and polar solutes can be dissolved by polar solvents. A nonpolar solute cannot be dissolved by a polar solute, and vice versa. Carbon dioxide is nonpolar and therefore cannot be dissolved by water, which is polar. This is why they are insoluble.

Even though the two substances are not soluble in each other, the carbon dioxide remains in the water solution because of hydrogen bonding. Because of its molecular structure, water molecules are more polar than many other liquid molecules, so they are more attracted to one another than the molecules in most other liquids.

EXPLAIN continued

The strong attraction due to **hydrogen bonding** also gives water molecules the ability to stay connected to other water molecules, which makes it difficult for the carbon dioxide to escape from the solution.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Solutions and mixtures
- Gases in solution
- Solubility of substances
- Factors that affect solubility, including temperature and pressure

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Nucleation sites
- Solubility – dissolving solutes in solvents
- Factors affecting solubility, including polarity of solutes and solvents
- Polarity and molecular structures of molecules
- Hydrogen bonding

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Try the activity again, but using different types of carbonated drinks. Which produces the biggest fountain? Why?
- Set the experiment up alongside a vertical tape measure or mark approximate heights on a nearby wall using tape. Ask students to record the peak height the fountain reached.
- Record the reaction and play it back in slow motion to get a better look at what is happening in this experiment.
- Does the number of Mentos® candies matter? Try the experiment again but this time use one Mentos®, or only a few. Is the reaction bigger or smaller than before? Why might that be the case?
- Some scientists have found that temperature plays a role in the size of the fountain. Try the activity with two identical setups, but with one soda that is cold and another that is room temperature. Do you notice a difference in the explosion? Why might that be the case?
- What happens if different candies or objects are used instead of Mentos®? Try a few and describe the fountain that is produced. Which candy or object works best?
- The activity Dancing Raisins in the Density section is similar to this (but a little less explosive, so it can be done indoors!). Check it out and ask students to note any similarities or differences between the reactions.

EVALUATE

- Ask students to incorporate the step-by-step activity into a funny comic strip or cartoon that describes what is happening in each step as the carbon dioxide is released from the soda pop solution.
- Do students think this is a physical or chemical reaction? Have them defend their point in a written letter or announcement, and share it with the class. Can all the students reach a consensus?
- Many people have made this explosive experiment into a way to power toy cars or model rockets. Have students draw a design and write out a step-by-step procedure to use this reaction to power a device. With adult supervision, students can try building and testing the device. If it needs improvements, make fixes and keep trying until you have a working vehicle.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

With all the power generated in this reaction, some people have taken the experiment a step further to build their own Mentos®-and-soda rockets or powered cars! Though the mess the experiment makes does not allow it to be scalable, it is still a fun, cheap, and easy way to build your own machine (with lots of adult supervision, of course!).

This experiment has inspired a lot of toys, including rocket kits and devices that drop the Mentos® by pulling a trigger. You can find many variations and versions online!

Careers in Chemistry

- This reaction has inspired a lot of scientific research to figure out what exactly is happening in this explosive experiment. Dr. Tonya Coffee at the Appalachian State University published research on what happens and how to make the biggest reaction. Her findings were published in the American Journal of Physics. Another educator, Ander Liljeholm, followed up with his own extension using iron filings and magnets. Researchers from Princeton University then followed up with their own, more dangerous, adaptation: immersion into liquid nitrogen! Researchers at Lander University published a paper on the geyser mechanisms and the factors that affect height. And there are many, many more. Head over to Google Scholar to read more about the scientific research that investigated this activity!

Notes