Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science for Grade K-8 Students

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Properties of Matter: Solubility

Background

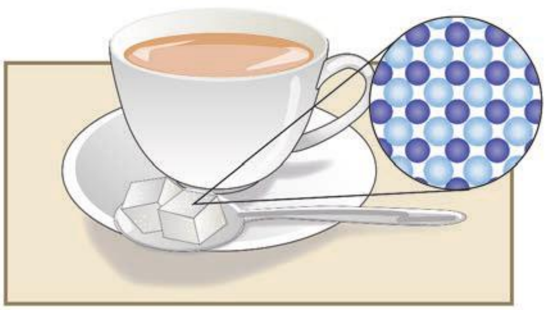
Activity Guides:

CRYSTAL ART | T-SHIRT TIE-DYE | WACKY WAXY WATERCOLORS | FOUNTAIN OF SODA

Pure Substances & Mixtures

Matter can exist as a pure substance or as a mixture. **Pure substances** are made up of one type of element or compound that cannot be broken down into its different parts by physical means. Pure substances have characteristic chemical and physical properties that can be used to identify them. For example, solid iron is an example of a pure substance because it is composed of a single element: iron (Fe). Sugar ($C_{12}H_{22}O_{11}$), table salt (NaCl), and baking soda ($NaHCO_3$) are also examples of pure substances because they are made up of one type of compound. Each is composed of specific elements in a distinct molecular arrangement that yields a single compound.

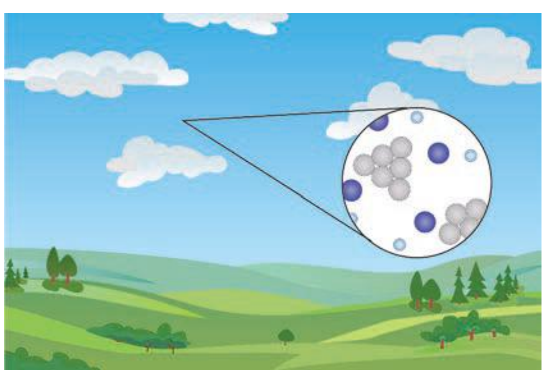
In the image below, we can see that sugar crystals from the sugar cubes have the kind of same molecules throughout.



The circles in the image represent Sugar ($C_{12}H_{22}O_{11}$) molecules that make up sugar.

Mixtures are made up of two or more substances that are combined physically, but not chemically, and therefore can be broken down into their different parts by physical means. From the foods we eat to sand at the beach, most of the matter around us are mixtures.

The image below shows a zoomed-in view of air in a field. In this image, we can see that different types of molecules and substances are found in this sample of air. The different colored circles each represent a different type of atom or molecule found in air. Because it's a mixture, we can distinguish between the different types of substances that make up air.



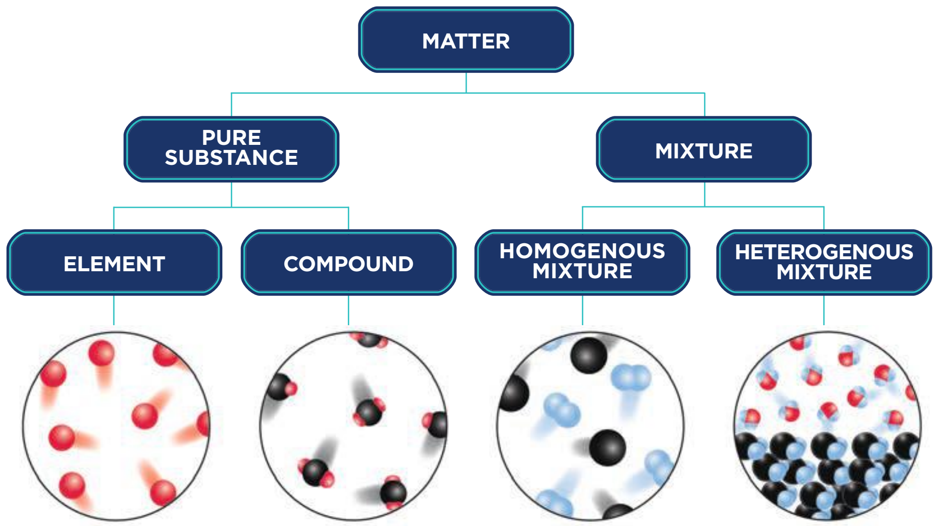
In the image above, we can see that air is a mixture composed of different types of elements and compounds. Air is composed of nitrogen (N_2), oxygen (O_2), argon (Ar), carbon dioxide (CO2), water vapor (H_2O), and small traces of other gases.

Mixtures can also be split into two categories:

- **Homogeneous mixtures** have the same appearance and composition throughout. Examples of homogeneous mixtures include apple juice and coffee. A sample taken from one the top of the mixture would be the same as a sample from the bottom.

- In **heterogeneous mixtures**, the components are not evenly mixed or uniformly distributed. Examples of heterogeneous mixtures include a bowl of cereal with milk, a salad, and many other types of food. Samples taken from the top and the bottom of a heterogeneous mixture might not be the same. Some heterogeneous mixtures are easy to recognize, such as pizza or a sandwich, where you can clearly see the different ingredients that make up the whole. Other times it can be harder to tell that a mixture is heterogeneous. For example, while milk appears to be a uniform liquid, it is actually heterogeneous because the fat in the milk is distributed unevenly throughout.

The diagram below shows how matter around us is categorized.



Solubility

A **solution** is a type of homogeneous mixture in which one or more substances (known as **solutes**) are dissolved into another substance (known as a **solvent**). For example, in salt water the salt is the solute because it is dissolved, and the water is the solvent because it does the dissolving.

Solubility is a physical property that describes the ability of a solute to dissolve in a solvent and create a uniform solution. A substance that dissolves in another substance is **soluble** in that substance. If a substance does not dissolve in another substance, it is **insoluble**. For example, salt is **soluble** in water, but butter is **insoluble** in water.

Several factors can affect solubility, including temperature, pressure, and the amount of solute or solvent in a solution. In general, substances are more soluble at higher temperatures (think of sugar dissolving in cold or hot water), and gases are more soluble at higher pressures.

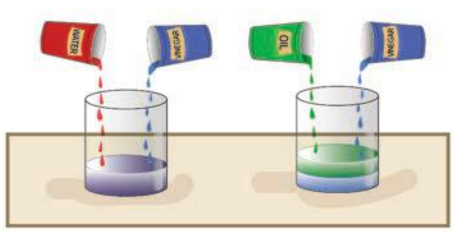
An important concept directly related to solubility is saturation. **Saturation** is the state in which no more of a solute can be dissolved into a solvent. As solute is added to a solvent, the ability for more solute to go into the solution decreases until the **saturation point** is reached. The saturation point is when no more solute can dissolve in the solvent. You might have seen this when adding sugar or powdered drink mixes to water: at first, the solute dissolves easily in the water, but at a certain point the solute no longer dissolves and instead sits at the bottom of the cup.

Whether a solute is soluble in a solvent depends on the chemical makeup of both the solute and the solvent, and therefore on the physical and chemical properties of the substances. Substances that have similar chemical compositions are more likely to dissolve in one another than substances with different chemical makeups. If a solute and a solvent have similar chemical compositions, they are more likely to dissolve in one another compared to a solute and solvent that have different compositions.

Further study of atomic structure reveals that solubility is dependent on the **polarity** in a molecule. Polarity means that the molecule has partial negative and positive charges. These slight charges are caused by varying electron density throughout the molecule, which means that charge is unequally distributed. The general rule with polarity and solubility is that "like dissolves like":

- polar solute + polar solvent = soluble
- nonpolar solute + nonpolar solvent = soluble
- nonpolar solute + polar solvent = not soluble
- polar solute + nonpolar solvent = not soluble

For example, water is a polar substance and oil is nonpolar. Water and oil are not soluble in one another. As a result, they don't mix and instead separate into different layers when added together. Vinegar is also a polar substance, as shown in the example below, and can therefore dissolve in water.



Vinegar is soluble in water and they will mix evenly to form a homogenous mixture. However, vinegar is insoluble in oil, so those liquids do not mix. Instead, oil and vinegar form distinct layers when put together.

There are some substances or compounds that have both polar and nonpolar portions of their structures. For example, isopropyl alcohol (rubbing alcohol) has both polar and nonpolar areas, so it can dissolve both polar and nonpolar substances equally.

Let's try some activities so you can experience solubility in action!

ENGAGE YOUR STUDENTS

Before beginning any of these activities, use the following ideas to engage your students about solubility:

- Show students the "Raccoon Cotton Candy" video, which is one of our favorites! The video can be found here or by searching on YouTube. The video is a fun example of a raccoon learning about solubility the hard way!
- Explore the effect of temperature on solubility. Ask students to drop sugar cubes into pure water at different temperatures, and to plot the temperature versus the time it took for the sugar cubes to completely dissolve. What do they notice about the relationship between temperature and solubility?
- There are two PhET simulations where students can explore solubility: Salts & Solubility and Sugar and Salt Solutions. Students can take time to play within the simulations and record their observations.
- Students can explore solubility by testing a series of solutes with a series of solvents. Some examples of solutes are table salt, baking soda, sand, sugar, and Epsom salt. Examples of solvents are water, rubbing alcohol, club soda, and cooking oil. Ask students to take notes or plot whether the solute was soluble, somewhat soluble, or insoluble in each solvent.
- Perform a demonstration with samples of water and sugar, asking the students to predict what will dissolve faster. At the front of the room, hand one student a cup of warm water, and another student a cup of cold water. Drop a sugar cube in each cup and ask them to report to the class when the sugar cube is fully dissolved. Next, use two new cups of water at the same temperature. Drop a sugar cube into one cup, and an equal amount of granulated sugar into the other cup. Ask the students to report out the results. Finally, use room temperature water and sugar cubes in both cups, but give one student a spoon to stir the solution. Ask both students to report out the results to the class. As a class, discuss which variables might have affected solubility and why.

Crystal Art

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

Estimated Time Setup: 5 minutes; Procedure: 30 minutes

OVERVIEW

Students mix a variety of solid crystals into water, then use the solutions to paint on black paper and watch solid crystals form again.

In this activity, students learn about the solubility of solids and the process of crystallization. Students dissolve a series of crystalline solids into water, then use the solutions to create designs on black paper. As the water evaporates they see their designs appear as clusters of crystals, each with a different appearance particular to the original crystalline solid used.

INQUIRY QUESTIONS

Getting Started:

- Is dissolving a solid in a solution a physical or chemical change?

Learning More:

- How can we use properties of solids to distinguish different solids from one another?

Diving Deeper:

- How are crystals formed and separated from a solution?

CONTENT TOPICS

This activity covers the following content topics: properties of matter, physical changes, solubility, saturation, phase changes (evaporation, crystallization), states of matter, crystalline and amorphous solids

This activity can be extended to discuss: molecular structures of crystalline solids, categories of crystalline solids

NGSS CONNECTIONS

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

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **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:

- 3 Clear plastic cups
- 3 Cotton swabs
- 3 Teaspoons
- Table salt
- Epsom salt
- Sugar
- Warm water
- Black construction paper
- Masking tape
- Pen or marker

Optional materials:

- Hand lens

ACTIVITY NOTES

This activity is good for:

- Individuals
- Small groups
- Concept introduction

Safety Tips & Reminders:

- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- This activity uses warm water in plastic cups. Be sure that the water is not too hot or it could melt the cups and injure students.
- 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:

- Start by handing out samples of each crystalline solid. Ask students to compare and contrast the physical properties they observe. Can they guess the identity of each solid sample? Which might dissolve best in water? Why?
- Prepare a demonstration where it is a mystery which solution was used to make each design. Ask students to predict which is which by examining the solid crystals. After performing the activity, ask them to determine if their predictions were correct based on comparisons with their own results.
- Brainstorm a list of substances that are soluble in water. Based on their experiences, can students order them from most to least soluble? Where do they think salt, sugar, and Epsom salt will fall on this continuum?
- Pass around different water samples: some with varying amounts of dissolved crystals in them, some without. Ask students whether they can determine if there are things dissolved in the water by sight alone. How can they test whether their predictions are accurate?

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.

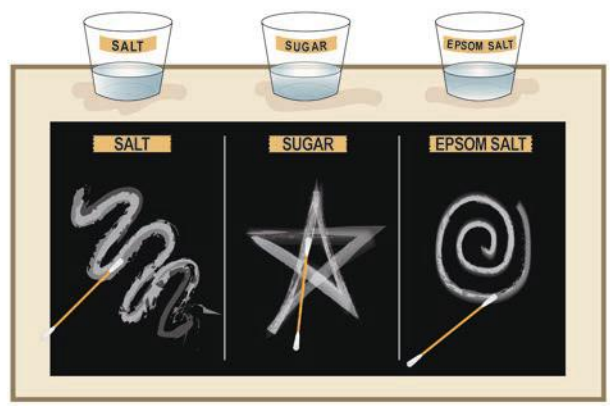
Fun Fact #1

Epsom salt has a variety of uses: crop fertilizer, pain reliever, sunburn treatment, facewash, hair product, aid for splinter removal, and more!

EXPLORE

Procedure:

1. Divide a piece of black construction paper into three equal sections. Using the masking tape and pen, label the sections “salt,” “sugar,” and “Epsom salt.”
2. Label the three plastic cups “salt,” “sugar,” and “Epsom salt.”
3. Fill ¼ of each cup with warm water and place on the corresponding labeled sections of the paper.
4. Add one level teaspoon of salt into the cup labeled “salt” and stir until all the crystals dissolve. Continue to add teaspoons of salt until no additional salt can be dissolved. (You will see crystals in the water even after stirring.)
5. Repeat step 4 with the sugar and Epsom salt in their corresponding cups.
6. Dip one end of a clean cotton swab into the salt solution, and use it to paint a design into the salt section of the paper. Using new cotton swabs, do the same with the sugar and Epsom salt solutions.
7. Allow water to evaporate (about 30+ minutes) and examine the designs.



Notes

DATA COLLECTION & ANALYSIS

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

- Record the number of teaspoons needed to completely saturate each solution.

SUBSTANCE	NUMBER OF TEASPOONS
SALT **Sodium chloride ($NaCl$)**	
SUGAR **Sucrose ($C_{12}H_{22}O_{11}$)**	
EPSOM SALT **Magnesium sulfate (MgO_4S)**	

- Which substance has the highest saturation point (dissolves the most in water)?
- Which substance has the lowest saturation point (dissolves the least in water)?
- What happens when you first draw on the paper with the cotton swabs? Are crystals visible? Why or why not?
- What happens after the liquid evaporates? Are crystals visible? Why or why not?
- What does each crystal look like? Compare the original solid crystals to what appears on the paper and draw a close-up of the "before" and "after" of each crystal sample. What are the similarities and differences? Compare and discuss with a peer.

EXPLAIN

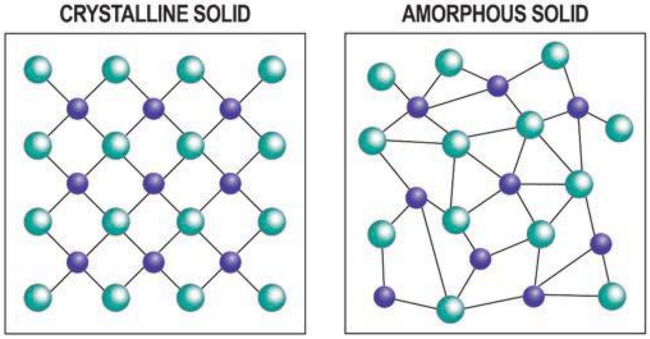
What's happening in this Activity?

First review the Solubility Background section to gain a deeper understanding of the scientific principles behind this activity. You can also review the States of Matter Background section for a review of states of matter and phase changes.

Matter is commonly described and categorized by an important physical property: its **state**. There are three major states of matter: solid, liquid and gas. There are many different ways to categorize matter in each of the states. For example, there are two main types of solids: amorphous solids and crystalline solids.

- **Crystalline solids** are made up of atoms or molecules that are organized in specific repeating patterns, which form crystals. Examples include ice, sugar, salt, and diamonds.
- **Amorphous solids** are made up of atoms or molecules that are locked in place, but are not arranged in a specific repeating pattern or structure. Examples include cotton candy, glass, rubber, and plastic.

CRYSTALLINE SOLID AMORPHOUS SOLID



Notes

EXPLAIN continued

The same compound can take different shapes a solid. For example, sugar is found as a crystalline solid as sugar cubes or as granulated sugar. However, sugar is also the main ingredient of cotton candy. Cotton candy is made by melting down sugar, then solidifying it in a different form. Although sugar cubes and cotton candy are both created from sugar ($C_{12}H_{22}O_{11}$), it exhibits different properties as each type of solid.

Salt, sugar, and Epsom salt are all crystalline solids, and have molecules arranged in specific repeating patterns. In this activity, a type of mixture called a **solution** is created by dissolving different crystalline solids in water. **Solubility** is a physical property that describes the ability of one substance (the solute) to dissolve in another substance (the solvent) to create a uniform solution. A substance that dissolves in another substance is **soluble** in that substance. If a substance does not dissolve in another substance, it is **insoluble**.

In this case, the solutes are sugar, salt, and Epsom salt because they are being dissolved in the solution. The solvent is water because it is the substance doing the dissolving. As more of each solute is added to the water, the solution reaches its saturation point. The **saturation point** of a solution is when no more solute can be dissolved in a solvent. Each solution becomes saturated when no more of each solute (salt, sugar, or Epsom salt) can be dissolved in the water.

Dissolving a solute in a solvent is a physical change. Even though the solutes (salt, sugar, Epsom salt) dissolve in water and the solutions may appear to have formed just one type of substance, both components of the solution maintain their properties. We can't see the crystals when they are dissolved in the water so it may appear to be a pure substance. However, when the solution is used to draw on the black construction paper and the water evaporates, we can see that the solute crystals from the solution remain. Water naturally evaporates over time, but the crystalline solids have very high boiling points, and therefore remain on the paper even after water has evaporated.

Because salt, sugar, and Epsom salt are crystalline solids, they re-form into their regular, crystalline structure, and leave distinct patterns on the paper.

Diving deeper into solubility, there are 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.

Fun Fact #2

Table salt may be inexpensive today, but it used to be so valuable that it was a form of payment! Roman soldiers were given an allowance to buy salt, and the Latin word for salt, sal, is where our modern word "salary" comes from!

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	DIVING DEEPER
For younger students, emphasize the following concepts: • States of matter – solids, liquids, gases • Types of solids – crystalline and amorphous • Solutions and mixtures	**For more advanced students, emphasize the following concepts:** • Molecular differences between crystalline and amorphous solids • Variation of saturation point by solute and solvent type • Factors affecting solubility

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.

- Explore how the temperature of the water affects solubility. Try steps 2–5 of the activity again, but with cold water, room temperature water, warm water, and hot water. (Use hot water only if you have a glass; the plastic will melt with hot water!) Add each solid into the cups slowly and record how many teaspoons of each solid can dissolve at each temperature. How does the temperature of the water affect the saturation point? Why might this be the case?
- Explore how motion affects solubility. Repeat steps 2–5, but this time do not stir. How long does it take each teaspoon of crystalline solid to dissolve?
- Explore how surface area affects solubility. Repeat steps 2–5, but this time use powdered sugar, granulated sugar, and a sugar cube in three separate cups. Which one takes longest to dissolve? Why? When you draw with each solution, do you think the designs will look the same? Try it out!
- Explore how concentration affects recrystallization. Repeat the activity, using different concentrations of salt. (In other words, use the same amount of water every time, but vary the amount of salt with the final cup as fully saturated.) Do the crystal drawings look different depending on how much salt was dissolved? Why?
- If you live in a place that gets snow in the winter and your community puts salt on the roads and walkways, see if there are similar patterns outside after the snow has melted and the ground is dry.
- Have students graph or plot the solubility of each solute on a graph that shows grams of solute (y-axis) and liters of solvent (x-axis). There will have to be measurement of the solvent at the start and slow addition of solute solvent to ensure the data is accurate. Are there trends or commonalities in the data? Try it again, but this time with water at a different temperature, or with a different amount of solvent. Does this change the graph?

EVALUATE

- There are many examples of crystalline solids in nature. Ask students to research an example (e.g., ice, minerals, different types of rocks) and present their findings to the class. What does it look like at a molecular and macro level? Where can you find it? What makes it unique? What are some uses?
- Have students look up the molecular structures of Epsom salt, sugar, and table salt. Draw the molecular structures for one molecule and a group of molecules in a crystal. Do these structures relate to the appearance of these substances?
- Discuss factors that affect the solubility of solutes in a solvent. Challenge students to devise a method to create an image with the largest quantity of crystals remaining on the paper. What solute would be best to use and what solvent (and at what temperature!) will be best for accomplishing this?

CHEMISTRY IN ACTION

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

Real-World Applications

The maple syrup you buy at the store is a supersaturated solution. That means that the solvent (water) contains more of the solute (sugar) than is normally possible. To achieve this, manufacturers create solutions of sugar water, and then boil off water until the solution reaches the ideal consistency.

Rock candy is created by dissolving sugar in hot water (where it is more soluble!) and creating a saturated solution. When the temperature of the hot water and sugar solution decreases, sugar crystals begin to form and separate from the solution, creating rock candy!

Careers in Chemistry

- Chemists can create medications by understanding the solubility of different solvents and solutes. If a certain ingredient that is vital to the medication is not easily dissolved in the human body, scientists can dissolve it in a solvent to create a medication that can easily be absorbed into the bloodstream.

T-Shirt Tie-Dye

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

Estimated Time Setup: 5 minutes; Procedure: 15 minutes

OVERVIEW

Students draw colorful designs on fabric and transform them into a permanent tie-dye pattern using rubbing alcohol.

In this activity, students explore that some solutes are only soluble in specific solvents. In this case, students draw designs on a T-shirt using permanent marker, which is not soluble in water. But when rubbing alcohol is added to the design, the ink easily dissolves and spreads throughout the fabric. Once the shirt is dry, the permanent tie-dye design of the markers will remain on the shirt even after washing!

INQUIRY QUESTIONS

Getting Started:
- What happens if a dye is absorbed by a solid?

Learning More:
- How can we dissolve "permanent" dyes?

Diving Deeper:
- On a molecular level, what factors determine solubility?

CONTENT TOPICS

This activity covers the following content topics: properties of matter, solubility, mixtures, absorption, polarity, diffusion

This activity can be extended to discuss: chromatography, separation techniques

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:
- White T-shirt or fabric swatches (10 x 10 cm or larger)
- Permanent markers of assorted colors
- Isopropyl rubbing alcohol (70% or stronger)
- Cup with at least an 8-cm wide opening
- Eye dropper or pipette
- Rubber band
- Cup of water

Optional materials:
- Bounty® paper towels

ACTIVITY NOTES

This activity is good for:
- Individuals
- Advanced students

Safety Tips & Reminders:
- Permanent marker can easily stain clothing or skin. We recommend using gloves and an apron or lab coat for this activity and putting a plastic tablecloth or newspaper over the work area.
- The T-shirt pieces will take some time to dry; do not remove them from the cups until they are completely dry.
- Rubbing alcohol is poisonous if swallowed, flammable, and emits fumes once opened—which is why we recommend using pipettes and not having open containers! Be sure to do this activity in a well-ventilated area and with adult supervision.
- If you don't want to use a whole T-shirt, you can use white fabric squares to demonstrate this activity.
- 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:

- Show a video of the tie-dying process. Students can take notes on how it is done, what is done to create different patterns, the chemistry of the dyes, and how they might preserve the colors on the fabrics.
- Start with a problem: You accidentally got permanent marker on your clothing! How can it be removed or made less noticeable? Students can try different solvents and see what works best.
- Hand out fabric squares with spots of permanent marker already drawn in the middle. Layer the different permanent marker colors on these spots beforehand, and see if students can guess which colors are present. They can test their predictions in the activity as the colors move and spread.

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**

If you ever have a dried-out permanent marker, it can be revived by dipping the tip in alcohol!

EXPLORE

Procedure:

1. Place a single layer of T-shirt or fabric square over the mouth of the cup.
2. Stretch the fabric so it is taut and secure it to the cup with a rubber band over the opening.
3. Using the permanent markers, draw designs onto the fabric over the opening.
4. Using the eye dropper or pipette, place 5–10 drops of water on the design. Observe and record what happens.
5. Repeat steps 1–3 with a new area of the shirt or a new fabric square. This time, use the eye dropper to place 5–10 drops of alcohol at a time on the new design. Observe and record what happens.

Notes

DATA COLLECTION & ANALYSIS

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

- What happens when a marker is used to draw on a T-shirt or fabric square?
- Make a prediction: What will happen if water is added to the design? What about alcohol?
- What happens to the ink designs when you add drops of water?
- What happens to the ink designs when you add drops of alcohol?
- Did the water and alcohol cause similar or different changes? Why do you think they behaved that way?

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.

Permanent markers—also known as "waterproof markers"—contain dyes composed of a variety of compounds that form a permanent surface layer when writing. Unlike regular markers, which can be removed from clothing and skin with soap and water, permanent markers are only removable with certain organic solvents and cleaners.

When you touch the tip of a marker to a T-shirt, you will see the marker "bleed" into the fabric. If you look closely, you can watch as it spreads thread-by-thread from the tip of the marker to the surrounding area of the fabric. This process is called **absorption**, which is when atoms or molecules are taken in by another substance; the latter substance can be a solid, liquid, or gas. The absorbed substance is spread throughout the absorbing matter, like when a kitchen sponge soaks up water. In the activity, the dye in permanent markers was absorbed by the T-shirt, but the colors only spread a limited distance at first.

Solubility is a physical property that describes the ability of one substance (the solute) to dissolve in another substance (the solvent) to create a uniform solution. A substance that dissolves in another substance is **soluble** in that substance. If a substance does not dissolve in another substance, it is **insoluble**. For example, salt is **soluble** in water, but butter is **insoluble** in water.

The dye in permanent markers is soluble in certain solvents, like rubbing alcohol. When rubbing alcohol is added, the dye dissolves within the alcohol. As the T-shirt absorbs the alcohol and it travels though the shirt material, the dye from the permanent marker moves a farther distance as well. This is because the dye is dissolved in the alcohol, which pulls the dye throughout the shirt as it spreads. When the alcohol evaporates, the dye remains spread throughout the T-shirt. The T-shirt can then be washed without changing the pattern because the dye from the permanent marker is still not soluble in water.

On the other hand, washable markers are soluble in water, meaning that they dissolve in water. If you tried to tie-dye a T-shirt with washable markers, the colorful design would be washed away once the shirt was washed. The dye in permanent markers like the ones used in this activity is insoluble in water. This is why you did not see any change when you dropped water on the first design: the water moves through the cloth, but the dye stays in place.

Diving deeper into solubility, we may wonder why some dyes are soluble in water and some are only soluble in alcohol. The reason for this is based on **polarity**, 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. Rubbing alcohol—isopropyl alcohol or ethanol—has a different molecular structure than water, so its charges are distributed throughout the molecule in a different way. Although isopropyl alcohol is polar, it is not as polar as water.

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. Washable marker ink is polar, so it can be dissolved by water, which is also polar. Permanent marker ink is dissolved by a solvent that is closer to its polarity than water is, such as alcohol.

EXPLAIN continued

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
- Process of absorption – one substance is taken in by another
- Basics of solubility

DIVING DEEPER

For more advanced students, emphasize the following concepts:

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

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.

- If you do not wish to do a T-shirt tie-dye experiment, you can simply use a Bounty® paper towel to achieve the same results and teach the same lesson. Simply lay the paper towel on a surface that will not be ruined by the ink and make a design. Then, add the alcohol and observe. Likewise, smaller pieces of cloth can be used to create bandanas or wrist bands.
- Want the fabric to dry faster? Set up a fan station in the room or have students put their designs next to the windowsill.
- What do you think would happen if you used washable markers instead of permanent markers, and why? Try it out, using both alcohol and water for solvents.
- Test how different colors respond to the alcohol. Set up the experiment in different parts of the shirt or various fabric squares and try one color in each: draw the same design, let it dry, and then add the same amount of alcohol to each example. Do the colors move differently? Why do you think that happens?
- Try the experiment again using different types of solutes (markers). Which markers can be absorbed by water only? Alcohol only? Both alcohol and water? Neither alcohol nor water? Why?
- As the colors spread, did any separate into more than one color? Look closely at the different edges. If so, what colors? Why do you think this happens?
- Why do some dyes separate into different colors? Check out the Mysterious Mixtures Activity Guide and learn more about this process!

Notes

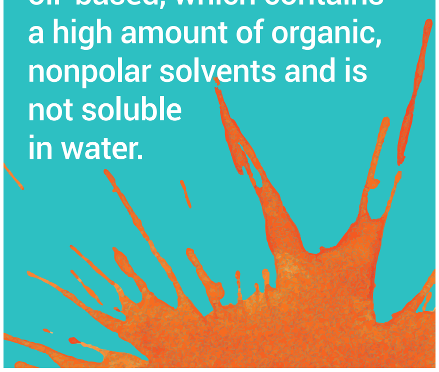
CHEMISTRY IN ACTION

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

Real-World Applications

Have you ever accidentally drawn on a whiteboard with a permanent marker instead of a dry erase marker? You can remove the permanent marker by simply coloring on top of it with a dry erase marker! Some of the components from the dry erase markers dissolve the components from the permanent marker, making it easy to remove the permanent marker drawings from the board.

There are many different types of paint. In the past, the most common type of paint used in art was oil-based, which contains a high amount of organic, nonpolar solvents and is not soluble in water.



Careers in Chemistry

- Chemists can develop paints and dyes with various properties by changing their composition. Water-based paints and dyes are easily washable and removable. On the other hand, oil-based paints and dyes can have water-resistant qualities that can be useful for painting buildings, walls, and everyday objects to make them water-proof.

EVALUATE

- There are lots of other "hacks" on how to remove permanent marker from a variety of surfaces. Students can look up each technique and present the science of the removal to the class, along with a demonstration!
- Ask students to research different common clothing dyes. Where do they come from? How are they applied to materials? How do we ensure they don't come off after each wash? How can detergents effectively remove dirt without removing dyes?

Fun Fact #2

The smell of rubbing alcohol might bring back some memories of the doctor's office: it is used to clean the skin before an injection or taking blood. This is because it kills bacteria on contact, making it safe to do an injection without pushing bacteria into the bloodstream. Because of its disinfectant properties, rubbing alcohol is used in a number of cleaning products.

Notes

Wacky Waxy Watercolors

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

Estimated Time Setup: 5 minutes; Procedure: 10 minutes

OVERVIEW

Students draw designs with wax on paper and paint over them with watercolors to watch the interaction between wax and water.

In this activity, students explore whether waxy substances are soluble in water. They draw a design on paper using wax crayons or candles, then paint over their design with watercolors, and notice that the watercolors appear to roll off or be repelled by the wax. The watercolors are only absorbed by portions of the paper without wax, creating fun designs in the process.

MATERIALS

For one setup:

- White paper
- White wax crayons or candles
- Watercolor paints
- Paintbrushes
- Water
- Cups

INQUIRY QUESTIONS

Getting Started:

- What are the physical properties of waxes?

Learning More:

- How does solubility explain why wax and water don't mix?

Diving Deeper:

- How does the molecular structure of wax molecules explain why they are insoluble in water?

ACTIVITY NOTES

This activity is good for:

- Individuals
- Small groups
- Concept introduction

Safety Tips & Reminders:

- Be sure to do this activity over a waterproof or protected surface and let each paper dry completely before moving it.
- Review the Safety First section in the Resource Guide for additional information.

CONTENT TOPICS

This activity covers the following content topics: solubility, properties of matter, polarity, crystalline versus amorphous solids

This activity can be extended to discuss: colloids, sols, waxy material production in plants and animals, human use of waxy products

NGSS CONNECTIONS

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

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **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.

ENGAGE

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

- Start the activity by telling students that you have a secret message to share with them. Can they find a way to reveal the secret message? You can distribute different parts of the message to different groups, and after the messages are revealed they can be fit together!
- Brainstorm a list of substances that are soluble in water. Based on their experiences, can students order them from most to least soluble? What causes these distinctions between substances? Why do they interact differently with water?

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

Paraffin comes from the Latin words for parum, which means "barely," and affins, which means "lacking reactivity." The name comes from the fact that paraffin is unreactive in nature.!

EXPLORE

Procedure:

1. Pressing firmly, use the crayon or candle to draw designs or a message on a white piece of paper.
2. Wet the paintbrush in a cup of water and then in a watercolor.
3. Lightly paint the entire sheet of paper. Observe and record what happens.

Notes

DATA COLLECTION & ANALYSIS

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

- Look closely: What do you see after writing with the wax on the paper?
- What happens when the watercolors touch the wax? Why do you think this happens?
- What about on the parts of the paper without the wax? Why do you think this happens?

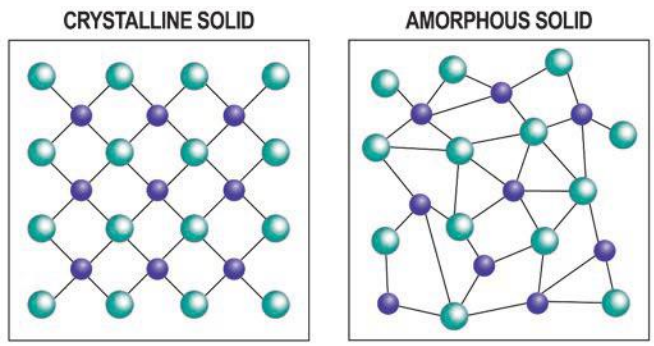
EXPLAIN

What's happening in this Activity?

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

Matter is commonly described and categorized by an important physical property: its **state**. There are three major states of matter: solid, liquid and gas. There are many different ways to categorize matter in each of the states. For example, there are two main types of solids: amorphous solids and crystalline solids.

- **Crystalline solids** are made up of atoms or molecules that are organized in specific repeating patterns, which form crystals. Examples include ice, sugar, salt, and diamonds.
- **Amorphous solids** are made up of atoms or molecules that are locked in place, but are not arranged in a specific repeating pattern or structure. Examples include cotton candy, glass, rubber, and plastic.



The same compound can take different shapes a solid. For example, sugar is found as a crystalline solid as sugar cubes or as granulated sugar. However, sugar is also the main ingredient of cotton candy. Cotton candy is made by melting down sugar, then solidifying it in a different form. Although sugar cubes and cotton candy are both created from sugar ($C_{12}H_{22}O_{11}$), it exhibits different properties as each type of solid.

Waxes are amorphous solids, and have molecules that are not arranged in a specific pattern. Both crayons and candles are made of Paraffin wax, a type of wax that is a white or colorless soft solid obtained from crude oil and is composed of a mixture of hydrocarbon molecules (i.e. molecules containing hydrogen and carbon atoms). Waxes tend to have similar **physical properties** because they are composed of hydrocarbon molecules: they have low melting points and melt at moderate temperatures, can be buffed or polished under slight pressure to produce a glossy appearance, and are **hydrophobic**—meaning they repel water.

Crayons and candles both exhibit these properties of waxes. For example, if you place water on a wax candle—or on a wax drawing—you might notice that the water forms a "bead" or droplet which sits on the surface of the candle or rolls off. Wax and water do not mix, and are **insoluble** in one another.

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

In this activity, the crayons or candles are not soluble in water, but the dyes in watercolor paints are soluble in water and easily mix to form a colorful solution. Because the dyes in

EXPLAIN continued

the watercolor paints mix with the water, they can be transferred and applied to the paper. However, when the water and dye solutions move over the wax, the wax does not mix with the water, causing the water roll off the area from the wax and preventing the paint form being applied to the paper underneath.

As the water evaporates from the watercolor paint mixture, the paint is left behind on the paper where the water was absorbed. In the places where the wax form the candle or crayon was used to draw on the paper, none of the watercolor paint mixture was absorbed by the paper, and remains colorless.

Diving deeper into solubility, we may wonder why dyes are soluble in water but waxes are not. The reason for this is based on polarity, 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. Conversely, paraffin ($C_{20}H_{42}$ or $C_{30}H_{62}$) has charges evenly distributed throughout. 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. Paraffin wax is nonpolar and therefore cannot be dissolved by water, which is polar. This is why they are insoluble.

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	DIVING DEEPER
For younger students, emphasize the following concepts: • States of matter - solids, liquids, gases • Types of solids – crystalline and amorphous • Solutions and mixtures • Basics of solubility	**For more advanced students, emphasize the following concepts:** • Molecular differences between crystalline and amorphous solids • Solubility – dissolving solutes in solvents • Factors affecting solubility, including polarity of solutes and solvents • Polarity and molecular structures of molecules

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.

- Have students write secret messages to one another, and use the watercolor paint to reveal the work!
- Repeat the procedure using a white colored pencil or pastel instead of a crayon or candle. Ask students to compare and contrast the results.
- There are many types of waxes students might have encountered with physical properties that make them especially useful. Ask students to find other waxy substances in the classroom, at home, or through research. Describe their physical properties, uses, and some fun facts.
- For some added science art, sprinkle salt on the picture while it is still wet. You will see the salt particles dissolve in water and repel the color pigments, which creates an interesting effect in the picture.
- There are dozens of techniques to make interesting designs using watercolors, many of which can be used in the classroom! Research and see if students can figure out the science behind each technique.
- Do this activity in conjunction with a book the students are reading. Can they make a wax picture to depict a certain part of the story?
- Try the activity with colored and fluorescent crayons to create more vibrant designs.

CHEMISTRY IN ACTION

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

Real-World Applications

Many products are covered in a waxy coating to make them waterproof or look shiny while on display. Next time you go to your local grocery store, take a close look at some of the produce. Apples, plums, pears, and many other fruits produce their own wax to help keep moisture in, retain firmness, protect the fruit, and slow the natural degradation. Sometimes food-grade wax is added to fruits and vegetables (think of a cucumber!) so they have a longer shelf life. This wax is edible and safe for human consumption.

Some animals and plants produce waxes: bees create beeswax, and sheep create lanolin wax in their wool. Waxes can also be derived from plants. An example of this is carnauba wax, which comes from the Brazilian palm. This wax creates a glossy finish and is used in car and surfboard waxes, shoe polish, dental floss, food products (think of the glossy coating on your favorite sweets!), cosmetics, and paper coatings.

Careers in Chemistry

- Chemists use hydrophobic materials for a variety of purposes! Hydrophobic coatings, which repel water, are often used on ships and large vessels to make them more fuel efficient. As large ships sail through water, the hydrophobic coatings allow the water to glide off the surface off the ship, increasing its fuel efficiency.

EVALUATE

- Ask students to journal throughout their day: Where do they notice waxy coatings on things? Why might that be? Can students find examples at home, at school, and outside? They can report their findings in small groups the next day.
- Students can write or draw out the takeaways from the activity in wax, then pass to a partner to reveal with watercolor and add comments as a form of peer evaluation.

Fun Fact #2

Watercolor is one of the oldest painting techniques. Starting in 15,000 BCE, artists made cave paintings by mixing natural pigments with animal fat or spit. Today, the pigments are dissolved in water and dried into a powder or disc.

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!

MATERIALS

For one setup:

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

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.

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.

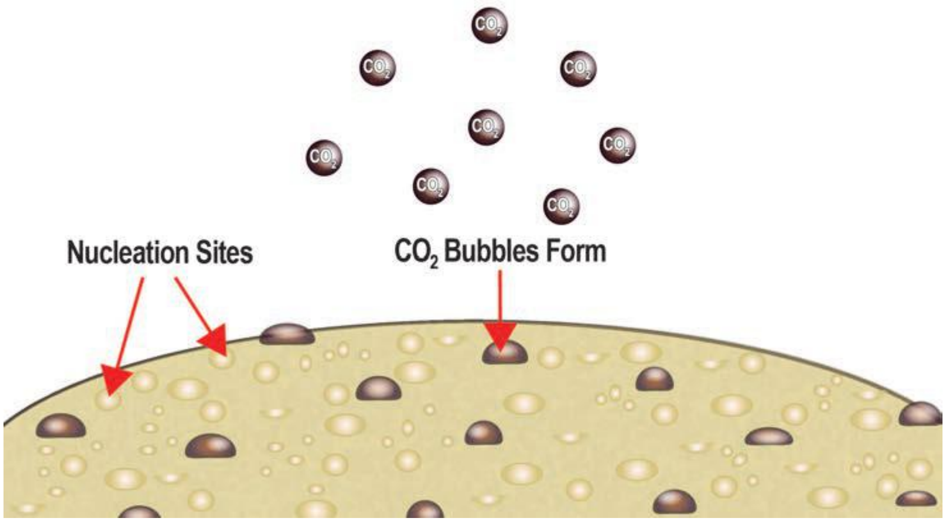
Carbon dioxide (CO_2) is a gas that we exhale each time we breathe. At normal temperature and pressure, carbon dioxide is not very soluble in water. Soda pop bottles are able to keep carbon dioxide dissolved in solution because they are sealed under very high pressure. When you open a can or a bottle 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