*Fifth Edition*

# YOU BE THE CHEMIST™

## ACTIVITY GUIDES

Hands-on Science
for Grade K-8 Students

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Background

# Properties of Matter: States of Matter

*Activity Guides:*

THE MOVING MOLECULE STOMP | THE AIR AROUND YOU | MELTING ICE WITH SALT | SOLID OR LIQUID?

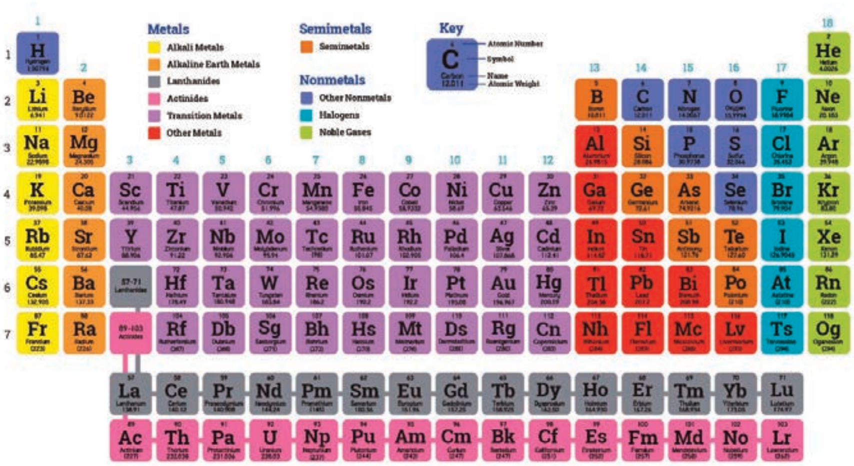
## The Basics of Matter

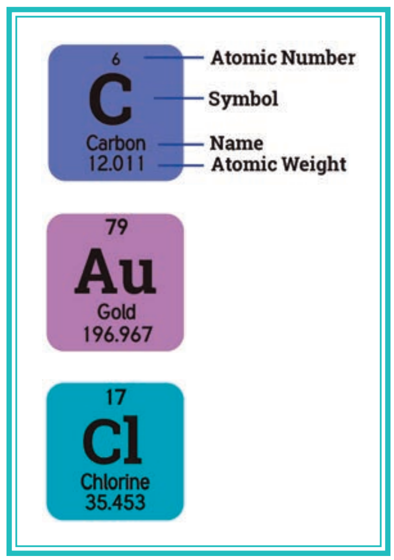
Chemistry is the study of matter, its properties, and the changes it undergoes. **Matter** is anything that has mass and takes up space. Matter exists in many different shapes, sizes, and forms. Air, water, and dirt are all examples of matter, but they have very different properties that distinguish them from one another.

## Elements, Compounds, & Mixtures

All matter is made up of 118 different building blocks called elements, each of which is unique. **Elements** are the simplest chemical substances, and cannot be broken down further through physical or chemical means. Think of the 26 letters in the English alphabet. This guide is made of various combinations of those 26 letters, just as is a book, a magazine, a text message, or a street sign. Similarly, all the matter in the universe is made of some combination of the 118 different elements on the periodic table.

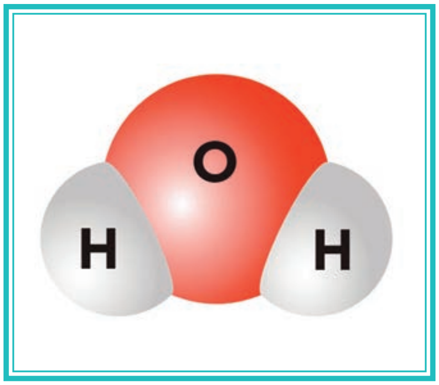
Some of the elements occur commonly in nature, while others are very rare. Each element has a unique name, such as hydrogen, carbon, or sodium, and also a one- or two-letter symbol: C is carbon, Au is gold, Cl is chlorine. The periodic table (below) shows all of the elements known today.



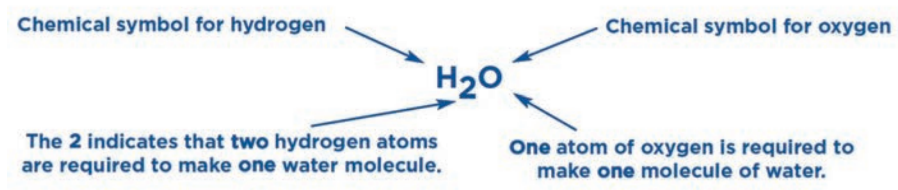




An **atom** is the smallest particle of an element that retains the element's chemical properties. For example, if a chemist could cut a sheet of aluminum metal foil into smaller and smaller pieces until the pieces could no longer be divided, but still retained the properties of aluminum, only individual aluminum atoms would remain. All matter is made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.

**Compounds** are made up of two or more elements that are chemically combined in a defined ratio. For example, water is a compound that is made up of two elements – oxygen and hydrogen – in a 2:1 ratio. As shown in the image on the next page, two hydrogen atoms (gray) and one oxygen (red) atom join together to form water.



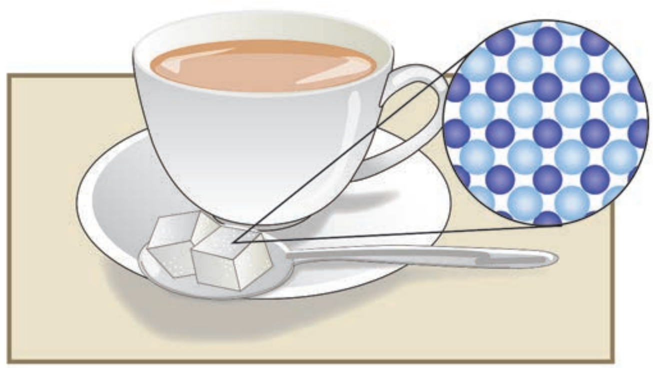

A compound's **chemical formula** shows what elements are in the compound and in what ratio they combine. The formula for water is $H_2O$.




Every substance has characteristic chemical and physical properties that can be used to identify it. Most matter can be described as either as a pure substance or a mixture.

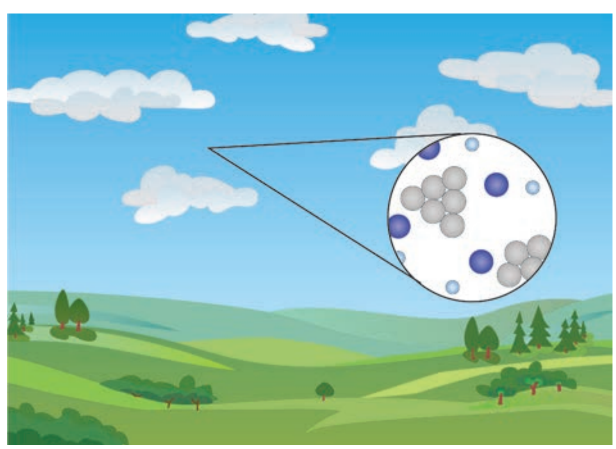
- **Pure substances** are uniform substances made up of only one type of particle, either an element or a compound. They cannot be broken down by physical means.

  For example, iron is a pure substance because every particle is the same type of atom: iron. 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. In the image below, we can see that sugar crystals from the sugar cubes have the kind of same molecules throughout.



- **Mixtures** are made up of two or more substances that are combined physically, but not chemically. From the foods we eat to sand at the beach, most of the matter around us are mixtures.

  In the image below, we can see that air is a mixture composed of many elements and compounds, including nitrogen ($N_2$), oxygen ($O_2$), argon (Ar), carbon dioxide ($CO_2$), water vapor ($H_2O$), and small traces of other gases.



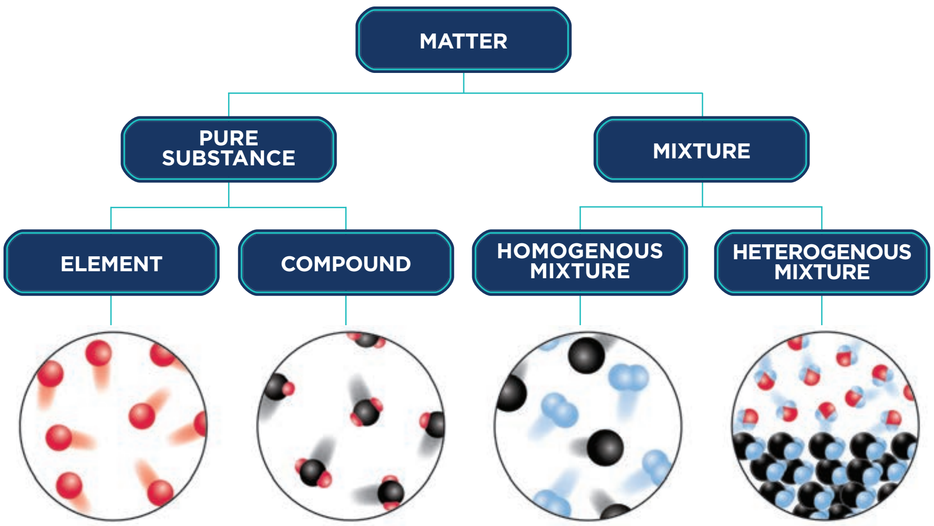
Mixtures can be split into two categories:

- **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.

Homogenous vs Heterogenous Mixture

The diagram below shows how matter around us is categorized.




## Physical & Chemical Properties of Matter

Matter can be identified by its chemical and physical properties. **Physical properties** are properties of a substance that can be observed or measured without changing the substance's chemical makeup, or chemical composition. Measuring physical properties will never change the identity of a substance. For example, color is a physical property. You can observe and identify the color of an object without changing its identity.

**Chemical properties** describe a substance's ability to change into another substance and to undergo chemical reactions. Chemical properties cannot be observed without changing the identity of a substance. For example, flammability is a chemical property. To see if a piece of paper is flammable, it has to be burned. This changes the chemical makeup of the piece of paper—it is no longer a piece of paper after it is burned.

These are some examples of physical and chemical properties of matter:

- **Physical properties:** color, smell, boiling point, texture, hardness, viscosity, area, length, volume, mass, density, pressure, solubility

- **Chemical properties:** flammability, toxicity, oxidation states, chemical stability, reactivity other substances

Every pure substance has characteristic chemical and physical properties that it can be identified by. When multiple pure substances are combined to create a mixture, each of those pure substances retains their own physical and chemical properties. Sugar in a cup of coffee has the same properties as pure sugar.

Scientists can use each substance's unique physical and chemical properties to identify and classify different kinds of matter. For example, vinegar and water are both clear liquids, but they have different properties. If both vinegar and water were heated, the water would boil and evaporate before the vinegar because the liquids have different boiling points. The physical property of smell could also be used to determine which sample is vinegar, since it has a different smell than water. Chemical properties, like flammability, could also be used to distinguish between the two samples.

The unique physical and chemical properties of a substance also lead to certain uses. For example, aluminum is used to build spaceships because it is lightweight but still strong. These are physical properties. Calcium carbonate is used in antacid medications that treat heartburn because it neutralizes excess acid in the body. This is a chemical property.

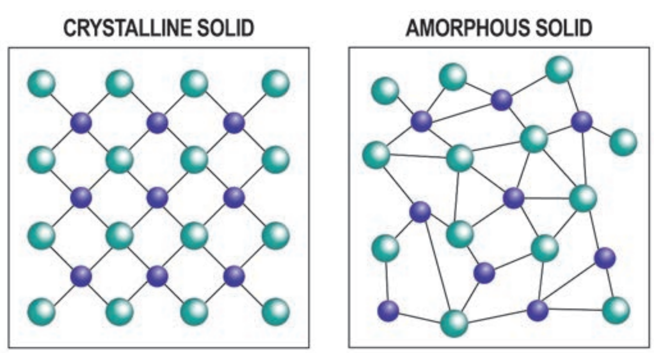
## States of Matter

Matter is commonly described and categorized by an important physical property: its **state**. There are three major states of matter: solid, liquid and gas.

**Solids** have definite volume and definite shape. For example, the shape and volume of a pencil or a ruler will remain the same, regardless of what container is used to hold them. Particles in a solid are locked in place, although they vibrate slightly, and are more tightly packed together than those in liquids or gases.

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.

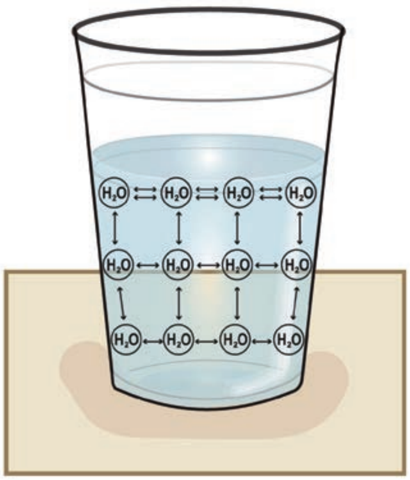
**Liquids** have a definite volume, but no definite shape. A liquid will take the shape of whatever container it is in, but its volume will not change. Particles in a liquid are in constant random motion and move more than those in solids. Even though they move more than solid particles, liquid particles still tend to remain close together.

Liquids have unique characteristics that can describe them.

- **Viscosity** describes a liquid's thickness and ability to flow. For example, water has a lower viscosity than honey. You can see this because water flows much more easily and quickly than honey.

- **Surface tension** is a property of liquids that describes the attraction of liquid molecules at the surface. This strong attraction brings the molecules closer together at the surface and creates a kind of surface "film." Surface tension means that it is harder to move through the surface of a liquid than it is to move through the liquid under the surface.

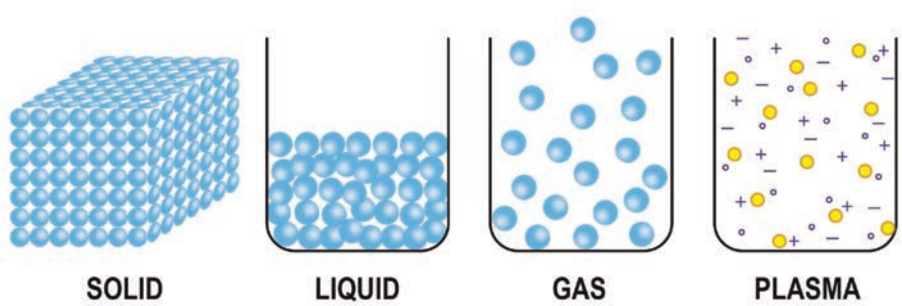
Viscosity Examples




**Gases** have no definite volume and no definite shape. A gas will fill the shape of its container, and will change in volume depending on that container as well. Gas particles have weaker attractions between them than solid or liquid particles, which allow them to move quickly in random directions and over larger distances.

Gases and liquids are considered fluids. A **fluid** is a substance that doesn't have a fixed shape, so its shape changes when force or pressure is applied. For example, you can change the shape of an inflated balloon easily by pushing on it. The same is true for a balloon filled with water.

There is also a fourth state of matter known as plasma. **Plasmas** are ionized gases. Some electrons in plasma are free, which means they are not bound to an atom or molecule. Plasma is the most abundant phase of matter in the universe.



Temperature is measured using a thermometer. Pressure is measured using a tool called a barometer.

## Phase Changes

As heat is added or removed, matter may undergo a change of state, called a **phase change**. Phase changes are physical changes, and are a result of the temperature and/or pressure of a substance changing. Temperature is measured using a thermometer. Pressure is measured using a tool called a barometer.

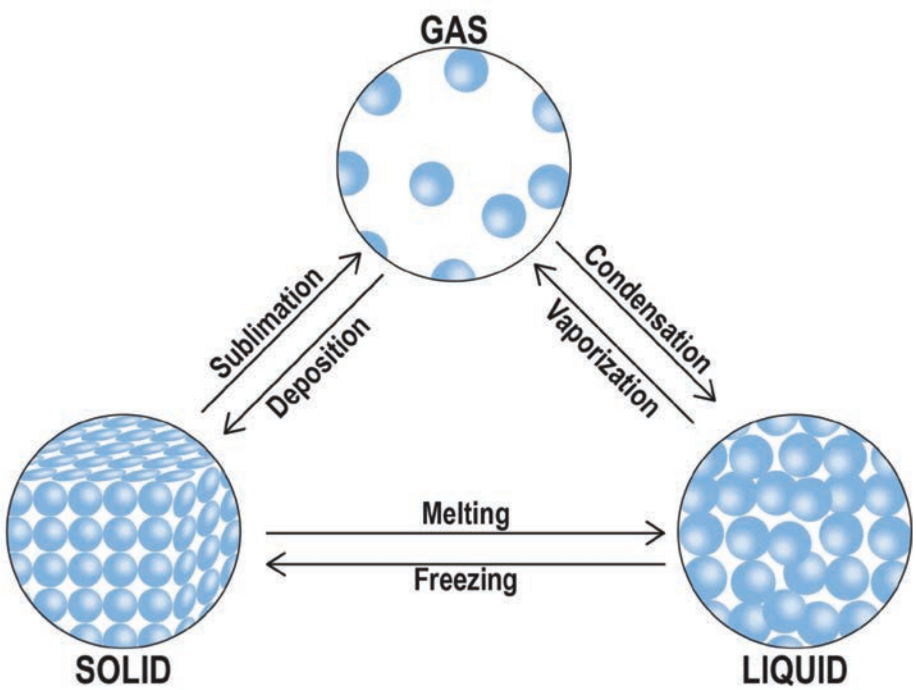
Matter can change states if energy is added or removed. **Energy** is defined as the capacity to do work or produce heat. Energy can take many different forms, including light, sound, electricity, chemical bonds, mechanical motion, and thermal energy. For example, during melting energy is added as heat, so the solid particles gain energy and change into the liquid phase.

**Temperature** is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around. At higher temperatures, the average kinetic energy of particles is higher, so particles in the substance are moving around at a faster rate than at lower temperatures.

Whether a substance is a solid, liquid, or gas depends on its temperature. At -10°C, water is found as ice, a solid. However, when the temperature of ice is increased enough, the ice melts and turn to into liquid water.

The phase changes between solids, liquids, and gases are outlined below.

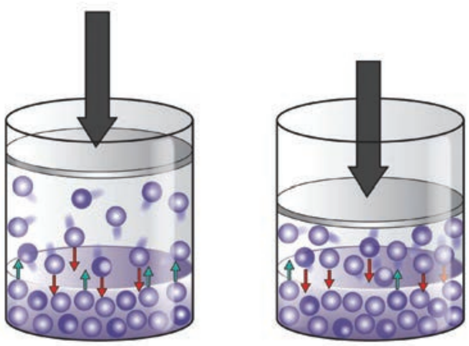
- **Melting:** a change in state from a solid to a liquid
- **Freezing:** a change in state from a liquid to a solid
- **Vaporization:** a change in state from a liquid to a gas
- **Condensation:** a change in state from a gas to a liquid
- **Sublimation:** a change in state from a solid to a gas.
- **Deposition:** a change in state from a gas to a solid.



You can see the relationship between energy (due to the increase and decrease in temperature) and the movement of the particles at each phase. For example, as the water increases in temperature, the particles begin to move at a faster rate, and over a longer distance, and eventually evaporate to become a gas.

Remember that when matter changes state because it gains or loses energy, its molecule's speed changes but its chemical makeup remains the same. For example, water is still H2O both before and after it freezes.

Phase changes are most commonly caused by temperature changes, but they can also be caused by changes in pressure. This is because adjusting the pressure changes how spread out, or how tightly packed together, the molecules are within a substance. In the image below, we can see that increasing the pressure causes the particles to become more compact. As the pressure increases on a gas, it eventually changes state to become a liquid.



Let's try some experiments so can you can experience properties of matter in action!

# ENGAGE YOUR STUDENTS

## Before beginning any of these activities, use the following ideas to engage your students in learning about states of matter:

- To show how tightly packed particles are in a solid vs. liquid vs. gas, use tape to draw a square on the floor. Based on how big your square is, have a few students walk around in the circle—there should be enough space for them to be spread out. This is a gas. Then double the number of students in the square, so they can still walk around but are more cramped. This is a liquid. Then add more students so there is no longer room to walk around, but the students can still spin around or move in place. This is a solid.
- Give individual students or groups of students three or more balloons. Have them blow up the first balloon and fill it with gas. Tell them to use the sink to fill up the second balloon with water. Then say that they have to fill the third balloon with a solid. You can provide small objects to each group, like erasers, paperclips, and pencils, or larger objects, like chalkboard erasers and textbooks. Which balloon was hardest to fill? Why? Can they blow up a balloon so it takes up more space than a textbook? If so, why is it difficult for a textbook fit inside a balloon?
- Present your students with examples of matter in different states, focusing on the differences between the three primary states: solid, liquid, and gas. Next, show a single substance at different states of matter. For example, show water as ice, water, and water vapor. Ask students to discuss the differences between the three states of matter, and see if they can conclude why water could exist in three different states. Explain that these changes occur because of changes in energy.

# Moving Molecule Stomp

*Section* **PROPERTIES OF MATTER** *Topic* **STATES OF MATTER**

**Estimated Time** Setup: 5 minutes; Procedure: 15-20 minutes

## OVERVIEW

Explore the differences between the motion of particles in solids, liquids, and gases by using students as models.

This activity demonstrates the physical differences in the solid, liquid, and gaseous states of matter by using students to represent the movement of particles in each state. The different states have unique characteristics depending on the movement of their particles. Students will see that as particles gain energy and move at a faster rate, matter can change between different states.

## MATERIALS

**For setup:**

- Space for students to move around freely

**Optional materials:**

- Ice
- Water
- Beakers
- Hot plate & pan

## INQUIRY QUESTIONS

**Getting Started:**

- What makes something a solid, liquid, or a gas?

**Learning More:**

- Why does matter exist in different phases?

**Diving Deeper:**

- What factors can affect phase changes between states of matter?

### CONTENT TOPICS

**This activity covers the following content topics:** states of matter, energy, phase changes

**This activity can be extended to discuss the following:** conversion of energy, energy transfer, phase change diagrams, crystalline solids, amorphous 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-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

### ACTIVITY NOTES

**This activity is good for:**

- Demonstration
- Whole class activity
- Concept introduction

**Safety Tips & Reminders:**

- You will need plenty of space for students to move around. If space is limited, try doing this activity with a smaller group or as a demonstration.
- Remind students to be safe as they move throughout the space.
- Review the Safety First section in the Resource Guide for additional information.

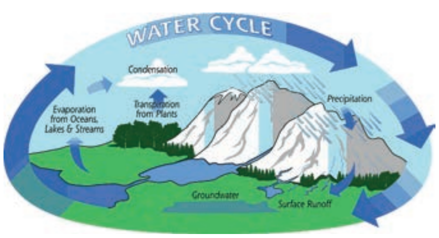
*Fun Fact* **#1**

**Though we usually think of there being only 3 states of matter, there is actually a fourth! Plasma is similar to the gaseous state, however the particles have electrostatic charges. It makes up the sun and stars and is the most common state of matter in the universe as a whole.**

# ENGAGE

Use the following ideas to engage your students in learning about states of matter:

- Present your students with examples of matter in different states, focusing on the differences between the three primary states: solid, liquid, and gas. Next, show a single substance at different states of matter. For example, show water as ice, water, and water vapor. Ask students to discuss the differences between the three states of matter, and see if they can conclude why water could exist in three different states. Explain that these changes occur because of changes in energy.
- Use the water cycle to demonstrate matter changing between different states. Why is matter able to change from one state to another? Water can turn from a liquid (rivers, oceans, rain), to a gas (water vapor forming clouds), to a solid (snow and ice) in nature. Why do these changes occur?




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

### *Fun Fact* #2

**It is possible to turn a gas into a liquid by compressing it (making the container that holds it smaller). The opposite is also possible. Propane tanks are filled with liquid propane, but when the propane is released, it becomes a gas again because the pressure has decreased and the particles are free to move around.**

# EXPLORE

## Procedure:

**Solids**

1. Have the students stand closely in one part of the room.
2. Instruct students to softly and slightly sway without moving their feet.
3. Ask students what state of matter they represent.
   - At this point, they represent particles in a solid: close together, tightly packed, and relatively motionless.

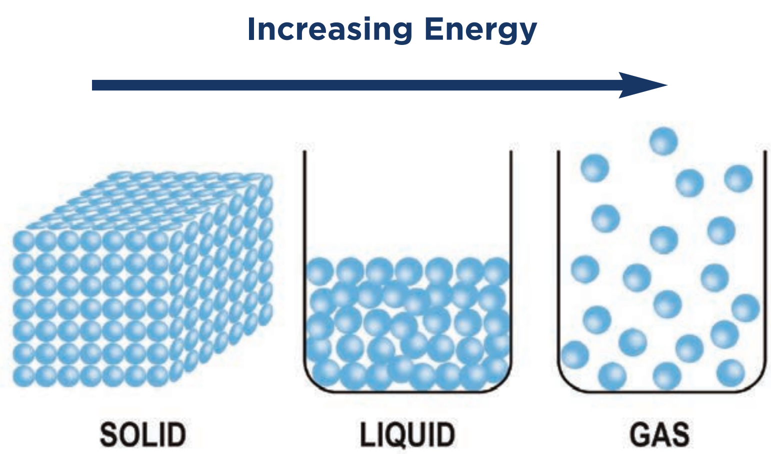
**Liquids**

4. Ask the group what would happen if the particles had more energy and they were able to increase their movement.
   - Supplying the particles with more energy will change them to the next state of matter – liquid. Tell students they have been energized so they can start moving their feet, but stay together in the same area. Have them start walking slowly. They are allowed to move past one another, but they must always have at least one student within arm's length.
5. Ask students what state of matter they represent.
   - At this point, they represent particles in a liquid: they have more energy and are not as tightly packed because they can move around. Like particles of a liquid, they are still connected to each other and contained in their container or area.

**Gases**

6. Instruct students that they have even more energy than before. Ask the group how they would feel with more energy: energetic, like running around.
7. Tell students to move around the entire room, now walking at a normal speed.
8. Ask students what state of matter they represent.
   - At this point, they represent particles in a gas: the particles are free to quickly move anywhere they want because they have so much energy.

**Remind students to be careful as they move about the room and demonstrate the movement of particles. They should be reminded not to run, and to slide past one another gently.**



# DATA COLLECTION & ANALYSIS

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

- What do particles in a solid look like? What about particles in a liquid or gas? Draw the arrangement of particles in each state of matter.
- Describe the properties of each state: solid, liquid, gas
- Which state of matter has the most energy? Which has the least?
- What is required for a substance to change states? Explain.

## *Fun Fact* #3

**Coconut oil can be found as both a solid and a liquid in your cupboard. This is because it has a melting point of 24 °C (76 °F), while room temperature is taken to be an average of 23 °C (74.3 F). If the room gets too warm coconut oil will turn from a white solid to a clear liquid.**

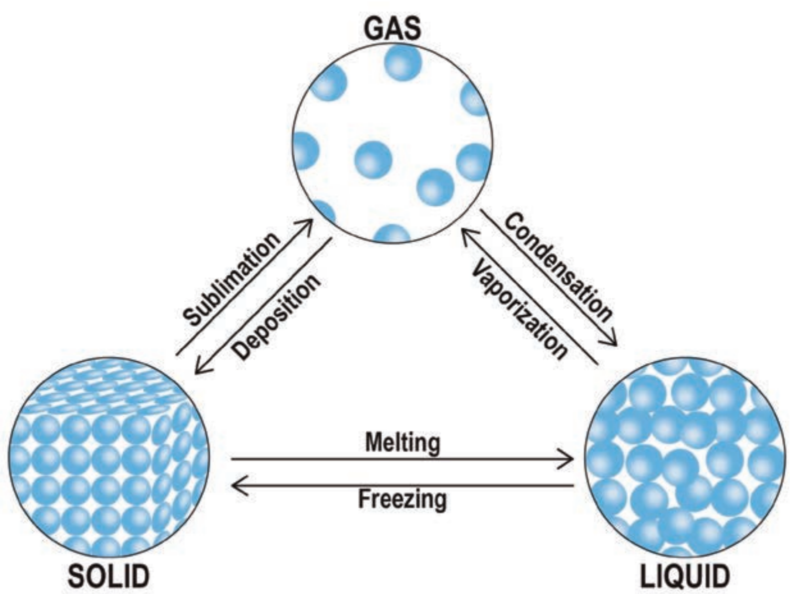
# EXPLAIN

## What's happening in this Activity?

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

**Matter** exists in one of three major states: **liquid**, **solid**, or **gas**. **Solids** have definite volume and definite shape. Particles in a solid are locked in place, although they vibrate slightly, and are more tightly packed together than those in liquids or gases. **Liquids** have a definite volume, but no definite shape. A liquid will take the shape of whatever container it is in, but its volume will not change. Particles in a liquid are in constant random motion and move more than those in solids. **Gases** have no definite volume and no definite shape. A gas will fill the shape of its container, and will change in volume depending on that container as well. Gas particles have weaker attractions between them than solid or liquid particles, which allow them to move quickly in random directions and over larger distances.

Matter can undergo a change of state, or a **phase change**, when energy (often in the form of heat) is added or removed from the substance. An increase or decrease in energy causes the particles in a substance to move faster or slower. This changes the way they are bonded together and structured, which is part of what defines each state of matter.




All matter is made up of tiny particles that are always in motion. Even though we can't see these tiny particles, we can demonstrate the differences between particles in gases, liquids, and solids using other objects. In this activity, students represent the movement of particles in a substance. As they move around the room with different amounts of energy, they represent particles in different states of matter.

When students start out, they are packed tightly together. They can move in place, but cannot pick up their feet and move past one another. This is true of **solid** particles. Particles in a solid vibrate in place but are locked in position. Students' increased ability to move shows that they are gaining energy. The more energy a particle has, the more it can move and overcome the attractions between particles in a substance.

In the next part of the activity, students are able to walk short distances, but still remain together in a clump. **Liquid** particles can move more than solid particles, and can even move past one another. However, they are still somewhat bound by the attraction between particles and cannot move long distances. In the final stage of the experiment, students

# EXPLAIN continued

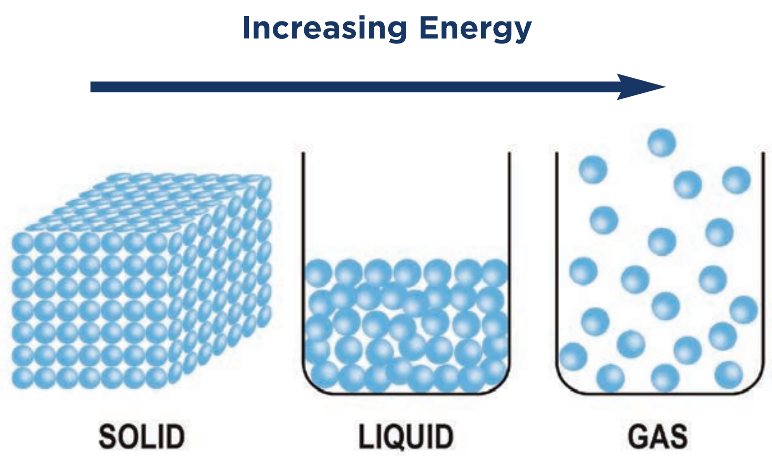
can move totally independently of one another, and can walk long distances around each other. There is also more space between students because they are more spread out. This is true of gas particles. **Gas** particles move more than either solid or liquid particles, and are much more spread out.

Although matter on Earth is typically categorized by the three major states of matter, there is also a fourth state of matter called **plasma**. **Plasmas** are ionized gases. Some electrons in plasma are free, which means they are not bound to an atom or molecule. Plasma is the most abundant phase of matter in the universe. Plasma can't be described just by how much energy its particles have and how tightly packed they are—it is more complicated, and difficult to demonstrate with students.

Diving deeper into phase changes, we can look at how matter may undergo a change of state, called a **phase change** when energy is added or removed. Phase changes are physical changes, and are a result of the temperature and/or pressure of a substance changing. Matter can change states if energy is added or removed. **Energy** is defined as the capacity to do work or produce heat. Energy can take many different forms, including light, sound, electricity, chemical bonds, mechanical motion, and thermal energy. For example, during melting, energy is added as heat, so the solid particles gain energy and change into the liquid phase.

**Temperature** is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around. At higher temperatures, the average kinetic energy of particles is higher, so particles in the substance are moving around at a faster rate than at lower temperatures.

You can see the relationship between energy (due to the increase and decrease in temperature) and the movement of the particles at each phase. For example, as the water increases in temperature, the particles begin to move at a faster rate, and over a longer distance, and eventually evaporate to become a gas.




Remember that when matter changes state because it gains or loses energy, its molecule's speed changes but its chemical makeup remains the same. For example, water is still $H_2O$ both before and after it freezes.

## Notes

# 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:**

- Matter is made up of particles too small to be seen. These particles are always in motion.
- Matter can exist in different phases.
- Particles in matter of different phases have different amounts of energy.
- Matter can change between different states of matter because of changes in energy.

### DIVING DEEPER

**For more advanced students, emphasize the following concepts:**

- Temperature is a measure of the average kinetic energy found in particles of a substance
- Changes of state due to variation in temperature and pressure can be predicted through models
- Substances have unique temperatures at which they change state, and can be identified by these properties (boiling point, melting point).
- Phase changes are physical changes and not chemical changes.

# 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 do this activity from their seats. Students can sit still and hold their arms close to their chest to represent a solid. Students can spread out their arms and move them lightly to represent solids. A gas can be represented by having students spread out their arms as far as possible and moving their fingertips.
- Do this activity with balloons! Use clear trash bags and balloons to demonstrate the different states of matter. Have students stuff different amounts of balloons into three different trash bags to represent particles in the solid, liquid, and gas state.
- Explore how pressure can affect the phase in which you find certain types of matter. Show a video showing how compressing a gas can turn it into a liquid for easier storage (example – propane tanks). Ask your students to analyze and discuss why pressure can affect phase changes.
- Give each student a bag with a few ice cubes in it. Have a competition to see who can melt it the most in ten minutes. After ten minutes, measure the amount of water in each student's bag. What worked best? Why? Where did the heat come from? Discuss how their bodies produce this energy. At the end of the activity, you can place some water in a beaker on a hot plate and heat it until water vapor rises from the beaker. Tell the students that they are watching a liquid changing to a gas.

**Instruct students to put the ice down on their desk if their hands get too cold or start to ache. Have paper towels, cups, and/or plates available for students.**

**Instruct students to put the ice down on their desk if their hands get too cold or start to ache. Have paper towels, cups, and/or plates available for students.**

# EVALUATE

- As a take-home assignment, have students categorize household items into each state. Students can also try to identify something in their home that can change into all 3 states. Is there anything that is hard to categorize? Why?
- As a project, have students create a model that shows the three different states of matter. They can use any crafts you provide to develop their solid, liquid, and gas models.
- Have students apply their new learning to a real-world chemistry connection. Other than the water cycle, what are some examples of phase changes in our lives? Have students come up with or research some examples of phase changes in our lives, and explain what changes occur as the states change from one to another.

# CHEMISTRY IN ACTION

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

## Real-World Applications

Matter is all around you in different states. The change of $H_2O$ (water) from one state to another can be seen commonly on Earth. On cold winter days, ponds and lakes freeze into solid sheets of ice. Likewise, on hot summer days, puddles of water on the ground evaporate and disappear more quickly. If the temperature drops in the evening after a long, hot summer day, condensation often occurs. As warmer air gets closer to the surface of Earth, it comes in contact with the ground. When the water vapor in the air touches the cool surface of Earth, the water vapor condenses into liquid water, leaving water droplets on the ground.

When a substance goes directly from a solid to a gaseous state it is called sublimation. A common example of sublimation is $CO_2$ (carbon dioxide), or dry ice. At room temperature, the dry ice sublimes into a milky white gas which is often used as a prop to create the appearance of smoke. Deposition is a change directly from gas to solid. Sublimation and deposition are much less common than melting and freezing.

## Careers in Chemistry

- Chemists can use gas chromatography (GC) to identify volatile substances (substances that evaporate easily at room temperatures). A liquid that is often a mixture is injected into a gas chromatography machine and evaporated into a gas. As a gas, the different kinds of molecules found in the liquid sample can be separated and identified more easily, so chemists can use this to identify the different components in their sample. For example, food chemists can use this process to identify what molecules cause certain flavors and aroma in food.

# Notes

# The Air Around You

*Section* **PROPERTIES OF MATTER** *Topic* **STATES OF MATTER**

**Estimated Time** Setup: 5 minutes; Procedure: 5-10 minutes

## OVERVIEW

Students place an inverted cup containing a paper towel into a bowl of water to show that air takes up space.

This activity demonstrates the presence of gas, a state of matter that can be difficult to see, by providing a method to show that air (a mixture of gases) takes up space. In this activity, a paper towel is lodged in the bottom of a cup. The cup is inverted and placed into a bowl of water until it is submerged. Since air takes up space and prevents the water from entering the cup, the paper towel remains dry even when the cup is submerged in water.

## INQUIRY QUESTIONS

**Getting Started:**
- How can we see that all matter takes up space?

**Learning More:**
- How can we observe and measure properties of matter?

**Diving Deeper:**
- Can we develop a model to show that air takes up space?

### CONTENT TOPICS

**This activity covers the following content topics:** states of matter, properties of matter, physical properties

**This activity can be extended to discuss the following:** displacement, volume, surface tension, gas pressure, contact forces, particles interactions, kinetic energy

### 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-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

## MATERIALS

**For one setup:**
- Clear glass or plastic cup
- Bowl or container, deep enough to submerge cup
- Bounty® paper towels
- Tape
- Water

### ACTIVITY NOTES

**This activity is good for:**
- Demonstration
- Small or large groups
- Concept introduction

**Safety Tips & Reminders:**
- This activity can be messy with younger students. Have plenty of paper towels and a clear space.
- Review the Safety First section in the Resource Guide for additional information.

# ENGAGE

Use the following ideas to engage your students in learning about states of matter:

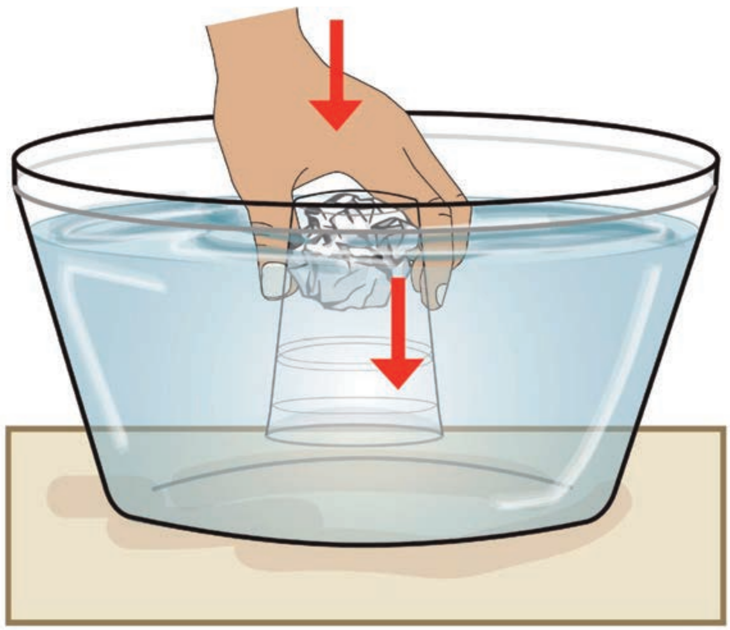
- Challenge your students to put a paper towel in a bowl of water without getting the paper towel wet. Provide them with all the materials for this experiment and pose the question as a mystery problem.
- Use a balloon to show the air pressure inside of a plastic bottle. Put an un-inflated balloon inside of a plastic bottle so that the opening to the balloon is around the mouth of the bottle. Have students try blowing up the balloon inside the bottle. Why can't they do it? How can they change the setup so that the balloon will inflate? Use a nail or other sharp object to poke a hole in the bottom of the plastic bottle. Do they think the balloon will be able to inflate now? Why?

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

# EXPLORE

## Procedure:

1. Crumple a Bounty® paper towel into a ball and push it to the bottom of the cup until it stays in place. The paper towel should not fall out when the cup is inverted. Tape it to the cup if necessary.
2. Fill a deep bowl with enough water to submerge the cup.
3. Turn the cup upside down and push it straight down into the bowl of water, but be sure to not let the cup touch the bottom. Hold the cup still while it is submerged in the water for a few seconds.
4. Pull the cup straight out of the water and feel the paper towel. Record your observations.



### *Fun Fact* #1

**The earth is wrapped in a layer of gas called the atmosphere. Gravity keeps the atmosphere from dissipating into space. The atmosphere remains connected to the earth by gravity, so it does not float off into space.**

# Notes

# DATA COLLECTION & ANALYSIS

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

- What happens when you push the cup down in the water? What does the water do?
- Why can we fully submerge a cup in water and still have a dry paper towel?
- When you pull the cup out of the water, is the paper towel wet? Why or why not?
- If there is not any water in the cup, is the cup empty?
- If you place the cup into the water at an angle, will the result stay the same? What do you notice is different when you do this? Is it easier or more difficult to push the cup down at an angle? Why?
- In what other ways or situations can it be seen that air takes up space? What other proof is there that air is a type of matter and takes up space?

### *Fun Fact* #2

**Wind energy is an abundant source of energy in many parts of the U.S. It is used mainly to generate electricity. Wind is a type of renewable energy, meaning it does not use up the earth's resources.**

# EXPLAIN

## What's happening in this Activity?

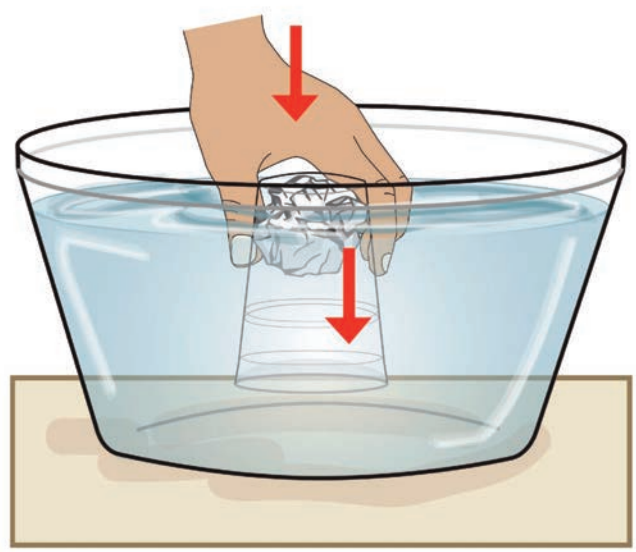
First review the States of Matter Background section to gain a deeper understanding of the scientific principles behind this activity.

All matter takes up space. For many types of matter we can see this, but for others we can't. Solids, liquids, and gases are all states of matter, and therefore all take up space. It is easy to see a solid or liquid taking up space, but it can be difficult to see a gas taking space.

However, there are other ways we can observe the presence of a gas. For example, we may not be able to see the air around us, but we can feel it in different situations, such as a gust of wind or a balloon expanding as it is blown up. This expansion occurs because the gases you exhale are taking up space within the balloon, pushing the sides of the balloon outward.

In this experiment, a paper towel is lodged in the bottom of a cup. Then the cup is inverted and placed straight down into a bowl of water. In order for air to occupy space in the bowl, the water that was already there needs to move out of the way. The cup and the air inside it displace some of the water in the bowl, causing the water level to rise. Air in the cup takes up space and prevents the water from entering the cup. The air remains in the space surrounding the paper towel, keeping the paper towel dry.

Water can only enter the cup (and get the paper towel wet) if air escapes. Because air is matter and takes up space, it prevents water from filling up the cup.



Diving deeper in the concepts at play in this activity, we can also see **displacement** in action. **Displacement** occurs when an object takes up space in a fluid (a liquid or gas) and pushes the fluid that was there out of the way. As the cup and air moves into the space where the water used to be, the water is forced out of the way—or displaced—and the volume of the system (water and cup and air) increases. The amount of water that is moved, or displaced, is equal to the object's volume. Think about when you get into a full bathtub, or when you pour a box of pasta into boiling water. The water level rises when objects are added.

# 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:**

- Matter has mass and takes up space
- Matter exists in different phases and is made up of particles too small to be seen.
- Each state of matter of a substance has unique physical properties.
- Air is a gas and takes up space
- Volume measures the amount of space an object occupies

### DIVING DEEPER

**For more advanced students, emphasize the following concepts:**

- Displacement is the act of moving something out of its original position or of one substance taking the place of another.
- There are various ways to calculate volume based on the state and shape of the substance, including displacement and mathematical formulas

# 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.

- Conduct the experiment as described. Then after completing Step 4, place the cup back in the water, but this time, tilt the cup. When the cup is tilted, air can escape from the cup, and water can displace the air. The amount of water that displaces the air can be controlled by how much you tilt the cup in the water. Tilting the cup about 45 degrees should cause the water to enter halfway, pushing out half of the air.
- After the paper towel is lodged in the bottom of the cup, pose the experiment as a challenge to determine what volume of water the cup can hold without getting the paper towel wet. Provide students with a large measuring cup to hold the water instead of a bowl. See if students can figure out that they need to invert the cup and record how much the water in the measuring cup rises.
- Tie in the experiment with pressure and changes in pressure. How deep would you have to submerge the cup before the paper towel gets wet? How many miles below sea level? How would the pressure change?
- Perform the experiment as described but take the explanation further to focus more on displacement and volume. Because air has mass, the air inside of the cup takes up space. This space can be determined by calculating the volume of the cup. **Volume** is a measure of the amount of space an object occupies. There are various ways to calculate volume based on the state and shape of the substance. The approximate volume of the gas inside a glass can be calculated by the equation: $V = h\pi r2$. In this equation, h is the height of the glass, r is the radius of the bottom of the glass, and π is a constant multiplier. This is the equation for the volume of a cylinder.

# EVALUATE

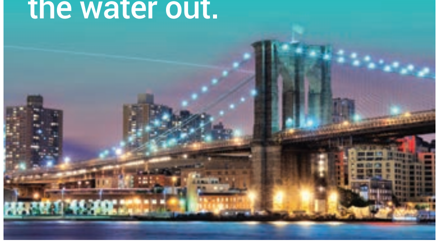
- Have the students draw a diagram showing all of the forces acting on the air in the cup and on the water when the cup is inverted. Have them write down conclusions they can make about the relative strengths of the different forces.
- Have each student find a method of measuring air pressure, either current or from the past. How does each method work?
- Are there any other ways we can determine if gas takes up space? Challenge students to develop a different model to show that gases are a state of matter and therefore take up space.

# CHEMISTRY IN ACTION

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

## Real-World Applications

The idea of inverting a container and submerging it underwater was used to build the Brooklyn Bridge. The large containers, called caissons, were inverted and submerged in the Hudson (the river the Brooklyn Bridge crosses) allowing workers to dig on the bottom of the river and keep the water out.



Wind is simply movement of air on a large scale caused by differences in air pressure within our atmosphere. While most of the time we can't even feel the air, wind can lift the roof off a building, blow down trees, and push us around. The movement of air also makes the temperature feel cooler. This is often referred to as wind-chill. The movement of the air increases the amount of heat lost from your body. The wind-chill factor is similar to using a fan to help cool you down or blowing on a hot cup of tea.

**Air pressure** varies with altitude. At higher elevations, the air pressure is lower than at sea level. When you fly in a plane or travel up a mountain, your ears may "pop." As you travel higher in the atmosphere, outside air pressure decreases. As a result, the air pressure exerted by the air trapped in your inner ear is no longer balanced with the air pressure outside. The trapped air will begin to push outward toward the lower pressure area, which can cause discomfort. The pressure can equalize when some air from your inner ear escapes through the Eustachian tubes, the small channel in each ear that connects the inner ear to the throat. When they open, you feel the pressure release—the "pop." You can hear this change because it is happening in your ear. However, before the pop, you may notice that your hearing ability decreases. The buildup of pressure inside your ear makes it more difficult to transmit sound.

The atmosphere has a clear layer of a gas called ozone ($O_3$) which protects us from many of the sun's harmful rays.

## Careers in Chemistry

- Atmospheric scientists study air pressure and other properties of the atmosphere to analyze climate patterns. Scientists can use a variety of instruments to measure air pressure changes and patterns to understand climate and weather patterns, and even predict short or long-term weather forecasts.

## Notes

# Melting Ice with Salt

*Section* **PROPERTIES OF MATTER** *Topic* **STATES OF MATTER**

**Estimated Time** Setup: 5 minutes; Procedure: 30 minutes

## OVERVIEW

Students explore the physical changes of melting and freezing and the effect that salt has on the freezing point of water.

What effect does salt have on the freezing point of water? Water changes states from solid to liquid (melting) or liquid to solid (freezing) at a certain temperature, but adding salt lowers the temperature at which water freezes.

## INQUIRY QUESTIONS

**Getting Started:**
- Do pure substances freeze and melt at the same temperatures?

**Learning More:**
- Can we change the temperature at which ice melts?

**Diving Deeper:**
- What effect does salt have on the freezing point of water?

### CONTENT TOPICS

**This activity covers the following content topics:** states of matter, properties of matter, physical changes (freezing, melting), elements and compounds, mixtures (solutions), transfer of energy

**This activity can be extended to discuss the following:** hydrogen bonding, ionic and covalent bonding, crystalline structure, solutions, nonvolatile solute

### NGSS CONNECTIONS

**This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:**
- **2-PS1-4:** Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.
- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

## MATERIALS

**For one setup:**
- 1 tablespoon
- 1 metric ruler
- 2 clear cups
- 2 cups of ice
- Salt (1 tablespoon)

**Optional Materials:**
- Beaker or graduated cylinder wide enough to hold ice

### ACTIVITY NOTES

**This activity is good for:**
- Demonstration
- Small groups

**Safety Tips & Reminders:**
- If possible, observe the changes every 5 minutes.
- Review the Safety First section in the Resource Guide for additional information.

### *Fun Fact* #1

**Salts aren't limited to what we put on food and the roads. They are any non-water product of a neutralization reaction between an acid and a base, meaning that there are hundreds of types in a variety of colors.**

# ENGAGE

Use the following ideas to engage your students in learning about states of matter:

- Pose a challenge to your students to see who can melt a cup or bag of ice the fastest using materials in the room.
- Show a video or picture of preparations for snowstorms where roads and walkways are treated.
- Set up the activity as a demonstration. Add salt to one cup prior to the start, and have students discuss what they think is happening and why one ice is melting faster in one cup than the other.

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

# EXPLORE

## Procedure:

1. Fill 2 clear cups halfway with equal amounts of ice
2. Add 1 tablespoon of salt to one cup, but do not add any salt to the other.
3. Observe the two cups every five minutes for 30 minutes. Observe how much water is collecting at the bottom of the cups.
4. Measure the depth of the water in each cup using a metric ruler.

## *Fun Fact* #2

**In Florida the temperature rarely drops below freezing. When it does, however, it threatens Florida's orange crops. To protect the oranges from a freeze, farmers may spray the crops with water. As the water freezes it releases heat. The heat is transferred to the orange, thereby keeping them warmer and protecting the crop.**

## DATA COLLECTION & ANALYSIS

- Research & record the temperatures at which pure water changes states from liquid to solid (freezing point).
- Record your observations after 5 minutes of when salt is added to the cup. Does the ice in each cup look different? What changes are happening?What does the salt do to the ice?
- Use the table below to measure and record the amount of collected in each cup.

| TIME | AMOUNT OF WATER (CM) IN THE CUP | AMOUNT OF WATER (CM) IN THE CUP |
|---|---|---|
| 5 MINUTES | | |
| 10 MINUTES | | |
| 15 MINUTES | | |
| 20 MINUTES | | |
| 25 MINUTES | | |
| 30 MINUTES | | |

- Does the ice melt faster in the regular cup or in the cup with salt? Why?
- What are some examples of how salt can be used in freezing temperatures?
- Salt is also placed in water when water is boiled at high altitudes. Why?

## Notes

# EXPLAIN

### What's happening in this Activity?

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

Matter can be in different states: solid, liquid, gas, or plasma. Matter may change from one state to another and back again depending on a variety of factors, including temperature or pressure. A change in the state of matter is a **physical change** because it is a change in form but does not change the chemical makeup of the material. For example, water vapor (gas), water (liquid), or ice (solid) all have the chemical formula H2O. As energy is added to a substance it will eventually change from a solid to a liquid to a gas, and as energy is removed from a substance it will eventually change from a gas to a liquid and finally to a solid.

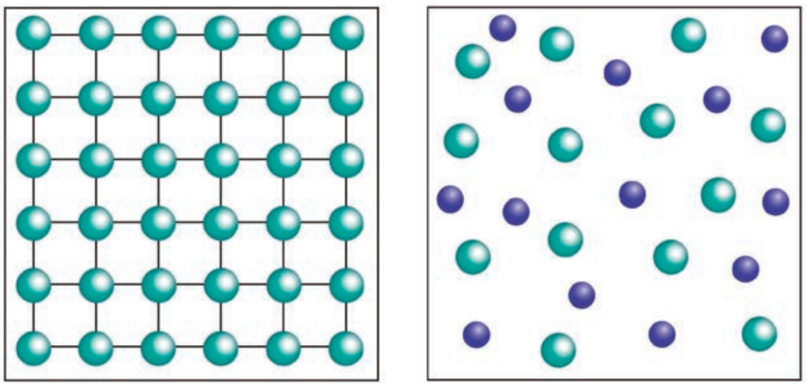
When matter changes state from a liquid to a solid that is called **freezing**. The temperature at which this happens is the **freezing point**. For water the freezing point is 0 °C (32 °F), which means that if liquid water is cooled to 0 °C or below it will turn into solid ice. Conversely, when solid ice is heated to 0 °C or higher it will **melt** into liquid water again. The freezing point is also the **melting point**: the temperature at which the solid substance turns to liquid. Each substance has a unique freezing and melting point, and also a unique boiling point (when liquid turns to gas).

Although each substance has a unique and identifiable freezing and melting point, this point cab be altered by changing the conditions of the substance. For example, the freezing

# EXPLAIN continued

point of water can be lowered by adding salt to the water. With the salt added, the water will no longer freeze or stay frozen at 0 °C.

If an impurity or different substance is added to a substance, it can change its freezing and melting point or the boiling point. In this example, the addition of salt lowers the freezing point of ice, causing the ice melts faster. Water freezes in a specific pattern (making ice a **crystalline solid**), so the addition of salt disrupts the formation of ice and makes it more difficult for the water to freeze in that pattern.



Although salt does lower the freezing point of water, it can only lower it by a certain amount depending on how much salt is added. An increase of salt should further lower the freezing point of water. Additionally, this is only effective to a certain extent. If the temperature is much lower than the freezing point of water, the ice will not melt even with salt present.

Taking a closer look at the differences in melting and freezing points when salt is added to the ice, there is also another factor at play that changes the rate at which the ice melts. Adding salt to ice disrupts the **intramolecular forces**, or interactions between molecules in a substance, and disrupts how the water molecules in ice interact with one another. Because these forces are disrupted when salt is added, the interactions between water molecules are changed, making the freezing and melting point different compared to the freezing/melting point of pure ice and water.

## 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:**

- Matter exists in different forms and can be classified as a solid, liquid, gas, or plasma.
- Matter has observable properties.
- Heating or cooling matter can cause physical changes, such as melting or freezing.

### DIVING DEEPER

**For more advanced students, emphasize the following concepts:**

- Water molecules freeze to form a crystalline solid.
- The formation of ice can be disrupted with the addition of impurities disrupts that pattern, affecting the rate at which it freezes.
- Melting and freezing points are affected by various factors, including pressure and impurities.

# 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.

- Replicate the experiment and adjust the variables: amount of ice, amount of solvent, temperature, material of cup, type of solute (i.e. sand, sugar), amount of surface area of ice (i.e. crushed vs. cubed). Students should record their observations and determine which variables change the freezing point and which solute is most effective at lowering the freezing point.
- Put thermometers into cups with various frozen solvents (i.e. water, juice, soda) and ask students to record the temperature every minute, then note at which temperature the solid turned to liquid (freezing point). Try adding a solute to each sample and see if it melts faster.
- Introduce a hypothetical impending snow storm and have teams of students create disaster management plans using materials in the classroom, then have them test their hypotheses using models.
- Show or demonstrate the process of making ice cream using ice and salt to cool the liquid ice cream mixture. Use the concepts in this activity to discuss why salt is added in the process of making ice cream. You can research a recipe and try making ice cream with your students.

# CHEMISTRY IN ACTION

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

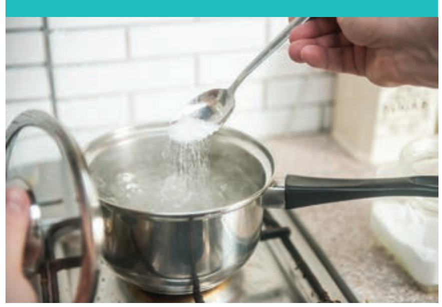
## Real-World Applications

Salt is added to roads and walkways to prevent water from freezing and to melt ice or snow on the road. What environmental impacts might this have for nearby plants and animals?

If freezing and boiling points are known, they can be used to test how pure a substance is. If a sample changes states at a different temperature than expected, it has impurities.

One of the reasons why the ocean does not freeze in winter is because it has a high salt content, whereas freshwater lakes and streams will freeze. Due to runoff from human activity sometimes freshwater systems are polluted. What effect might this have on the ecosystem if the freezing point of the water changes?

At high altitudes there is less air pressure and water will have a lower boiling point. Salt is sometimes added to raise the boiling point so food cooks properly.



## Careers in Chemistry

- Pharmaceutical chemists can test if the medicine they synthesize (create in the laboratory) is pure by testing its melting point and comparing it to the true known value of the substance they are developing. If the sample they produce contains impurities, the melting point will be lower than the expected value, and will help scientists determine whether the sample is pure.

# EVALUATE

- As a take-home assignment, have students categorize household items into each state. Students can also try to identify something in their home that can change into all 3 states.
- As a project, have students create a model that shows the three different states of matter. They can use any crafts you provide to develop their solid, liquid, and gas models.
- Have students apply their new learning to a real world chemistry connection. Other than the water cycle, what are some examples of phase changes in our lives? Have students come up with or research some examples of phase changes in our lives, and explain what changes occur as the states change from one to another.

### *Fun Fact* #3

Antarctica is home to approximately 85% of the world's ice, and 80% of earth's fresh water. That translates to about

**27 million billion**

tons of ice!

# Solid or Liquid?

*Section* **PROPERTIES OF MATTER** *Topic* **STATES OF MATTER**

**Estimated Time** Setup: 5 minutes; Procedure: 15 minutes

## OVERVIEW

Mix cornstarch and water to demonstrate the properties of a non-Newtonian fluid to learn that some substances can exhibit properties of multiple states of matter.

Does matter always fit into one of the states of matter? Students experiment with a non-Newtonian fluid made from cornstarch and water. This activity addresses the basic states of matter, and demonstrates obstacles that can arise when classifying matter.

## MATERIALS

**For one setup:**

- 16-oz Box of cornstarch
- 1 Large bowl or cake pan
- 1 Large spoon
- Water
- Plastic bag for disposal

**For one setup:**

- Gloves
- Spoons

## INQUIRY QUESTIONS

**Getting Started:**

- What are the states of matter?

**Learning More:**

- Does matter always fit into one of the states of matter?

**Diving Deeper:**

- What is a non-Newtonian fluid and how are its properties classified as a state of matter?

### CONTENT TOPICS

**This activity covers the following content topics:** states of matter, properties of matter (viscosity), mixtures, forces

**This activity can be extended to discuss the following:** viscosity, sheer stress and forces

### 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-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **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:**

- Demonstration
- Large group activity

**Safety Tips & Reminders:**

- This activity can be messy, especially with younger students! Have water and paper towels available if you will have students touching with the mixture with their hands.
- To reduce water, you can do the activity as a demonstration.
- For a tidier alternative, have students use spoons and/or gloves to touch the mixture and test its properties.
- DO not pour the mixture down the drain when disposing of it. The cornstarch and water will eventually separate and the thick cornstarch can clog the pipes. Pour the mixture into a plastic bag and throw it away in a trash can. You can also choose to let the mixture sit until it separates. Then, carefully pour off some of the water, and pour the rest of the mixture into a plastic bag and throw it away.
- Review the Safety First section in the Resource Guide for additional information.

# ENGAGE

Use the following ideas to engage your students in learning about states of matter:

- Use a video of a non-Newtonian fluid in real life to discuss the properties of these fluids. One example is quicksand, which becomes more viscous when force is applied (i.e. flows less easily when force is applied). Another more common example is ketchup – consider its resistance to flow when you first attempt to pour it from a (non-squeezable) container, compared with its ease of flow (i.e. often more of it would come out than you intended!) after hitting the end of the container.
- Before the activity, have the mixture prepared, along with a pan of water for comparison. Pour both of the fluids into separate containers to show that they both behave similarly. Stick your fingers in both to demonstrate the fluid properties. Now ask the students what will happen if you smack each of the fluids. Surprise your students by smacking the cornstarch mixture, and they will be shocked that there is no splatter. Then, let them handle the water and cornstarch mixture. See if they can figure it out what is occurring.
- Start a discussion about a crowded hallway. Is it more difficult to move through a crowded hallway with other people moving in different directions? What methods do they use to move through the crowd? Do they run or walk slowly? Point out that it is usually easiest to get through a crowd slowly to find a path between all of the people. If you ran straight into the crowd, you would most likely slam into another person and not move very far. Then explain that the particles in the cornstarch mixture act like a large crowd of people in a hallway. Slowly pressing your hand into the mixture allows the particles to move out of the way. However, smacking the mixture doesn't allow the particles to slide past one another out of the way, making it more like hitting a wall.

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

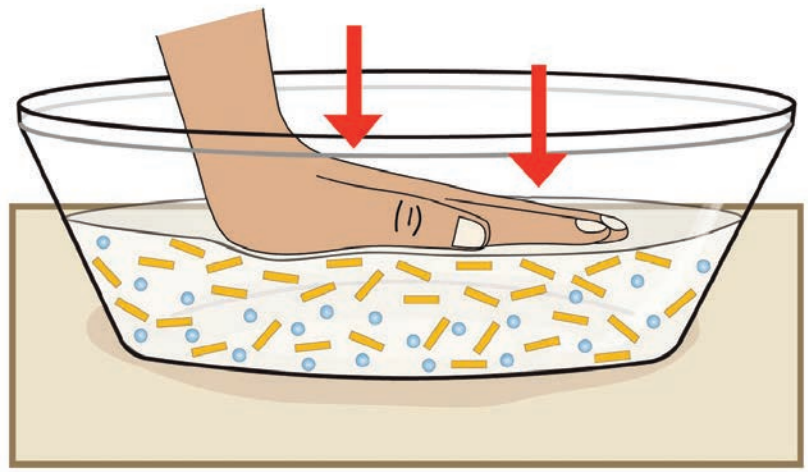
# EXPLORE

## Procedure:

1. Mix cornstarch and water in a cake pan, using about a quarter of the box of cornstarch at a time, until you have a uniform consistency. If the mixture causes significant splashing, add more corn starch. If the mixture is grainy, add more water.

   **It may be easier to mix the cornstarch and water and get a uniform consistency if you use your hands. Gloves can be worn to protect your hands and minimize the mess.**

2. Allow students to test the properties of the fluid.
   - Students can hit the mixture and observe its response. It should not splash.
   - Students can also scoop up some of the mixture in their hands and observe what occurs when they open their hands or when they apply pressure.

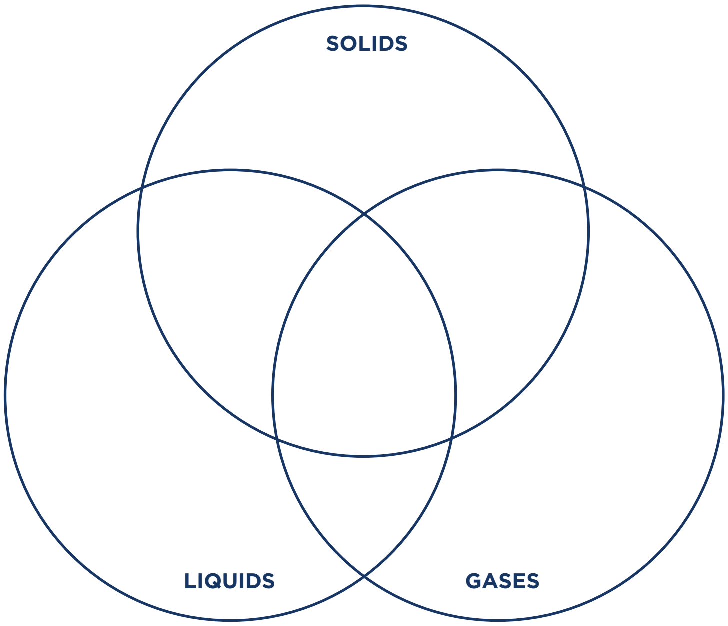


# Notes

## DATA COLLECTION & ANALYSIS

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

- Compare the properties of solids, liquids, and gases using the diagram below.




- What is the state of matter of the cornstarch? Of the water? In what state of matter is the cornstarch mixture?
- What occurs when you smack the mixture? What about when you apply less force and run your fingers or a spoon slowly through it?
- Do you think the mixture is a solid, liquid, or gas? Why?
- How can the viscosity of a Newtonian fluid change? Provide an example.
- Humans have a non-Newtonian fluid that runs throughout their bodies. What do you think it is and why?

## Notes

## EXPLAIN

### What's happening in this Activity?

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

**Matter** exists in one of three major states: **liquid**, **solid**, or **gas**. **Solids** have definite volume and definite shape. Particles in a solid are locked in place, although they vibrate slightly, and are more tightly packed together than those in liquids or gases. **Liquids** have a definite volume, but no definite shape. A liquid will take the shape of whatever container it is in, but its volume will not change. Particles in a liquid are in constant random motion and move more than those in solids. **Gases** have no definite volume and no definite shape. A gas will fill the shape of its container, and will change in volume depending on that container as well. Gas particles have weaker attractions between them than solid or liquid particles, which allow them to move quickly in random directions and over larger distances.

There are different ways to classify matter and sometimes it can prove challenging. Some types of matter can't be categorized simply as a solid, liquid, or gas. The cornstarch mixture in this experiment is a **fluid**, a substance made up of particles that flow or move freely. A fluid can also easily change shape when force is applied. Fluids can be classified in one of two ways:

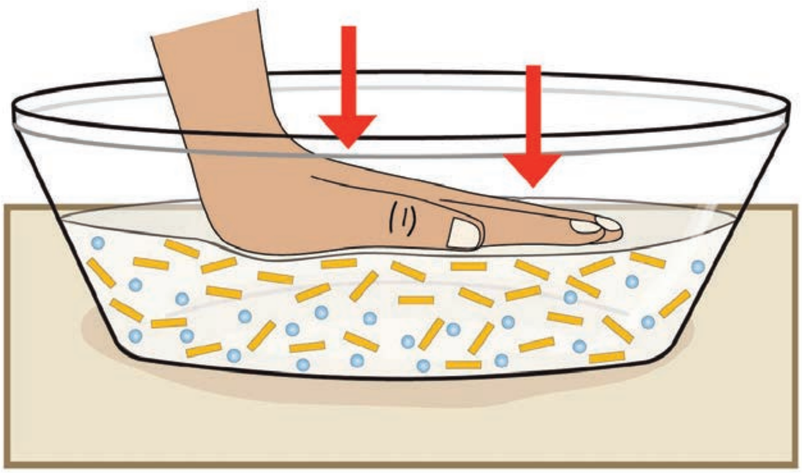
- **Newtonian fluids:** fluids which flow and act in their usual manner no matter what forces are applied.
- **Non-Newtonian fluids:** fluids which flow and act differently based on the force that's applied.

### *Fun Fact #1*

**If a pool is filled with the n on-Newtonian cornstarch mixture from this lesson, a person can actually run across it.**

# EXPLAIN continued

The cornstarch mixture will act as a fluid under normal conditions, but if a force is applied, the mixture seems to behave almost like solid, making it a non-Newtonian fluid. If a constant force is applied to the mixture, eventually the pressure will equalize, and the mixture will act like a liquid again. While liquids flow at a consistent rate, non-Newtonian fluids do not. The viscosity, or measure of a fluid's resistance to force, of the mixture changes when pressure is applied to the mixture.



Diving deeper into the molecular level of what's occurring in this activity, the cornstarch particles in the mixture are actually suspended in the solution, instead of mixed homogenously with the water. This property of the mixture is responsible for the unique properties that it exhibits.

## 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:**<br>• Matter can exists as a solid, liquid, or gas<br>• Difficulties with identifying all matter as solid, liquid, or gas | **For more advanced students, emphasize the following concepts:**<br>• Each state of matter also has its own properties due to how molecules move in each state<br>• Fluids have unique properties, such as viscosity.<br>• Differences between Newtonian and non-Newtonian fluids. |

# 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.

- What factors can affect the viscosity of a non-Newtonian fluid? If we change the temperature of the water, will that have an effect on the properties of the fluid?
- Put thermometers into cups with various frozen solvents (i.e. water, juice, soda) and ask students to record the temperature every minute, then note at which temperature the solid turned to liquid (freezing point). Try adding a solute to each sample and see if it melts faster.
- Introduce a hypothetical impending snow storm and have teams of students create disaster management plans using materials in the classroom, then have them test their hypotheses using models.

### Fun Fact #2

**A common name for non-Newtonian substances is oobleck, coming from the Doctor Seuss book Bartholomew and the Oobleck, where a green substance rained down from the sky and caused trouble in the kingdom.**

# CHEMISTRY IN ACTION

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

## Real-World Applications

Non-Newtonian fluids like the cornstarch mixture and gravy become more resistant to flow as a force is applied. When you smack the cornstarch mixture, it behaves similar to a solid. Likewise, stirring gravy more quickly, causes the gravy to thicken. Other non-Newtonian fluids, like ketchup become less resistant when a force is applied. If you stir or shake a bottle of ketchup, it becomes easier to pour it out of the container.

**Quicksand** is a non-Newtonian fluid that behaves like ketchup. It will become less viscous (flow more easily) when force is applied. Moving your legs slowly in the quicksand will apply a steady force. This force reduces the resistance of the quicksand and creates a space between your legs and the sand where the water can flow and loosen the sand. Therefore, you can get out by slowly and progressively moving toward solid ground. **The belief that moving in quicksand will make a person sink completely is a myth.** Struggling will cause you to sink some as the quicksand liquefies, but it will not cause you to sink completely in over your head. People are less dense than quicksand, so they will only sink up to about their waist. **However, quicksand can still be dangerous.** It is often found near the ocean or sea, so a person caught in quicksand can drown if he or she does not get out in time. Likewise, panicking and moving too quickly can create other problems. If you stop moving, the quicksand will behave like a solid, trapping you inside. If someone tugs on you quickly, you could get seriously injured.

## Careers in Chemistry

- Scientists can use non-Newtonian fluids and their unique properties for a variety of purposes. For example, in **Poland**, scientists are using non-Newtonian fluids to create bulletproof armor. The fluid they are using is called Shear Thickening Fluid. In theory, the fluid would thicken when the bullet hit, and absorb its shock.

# EVALUATE

- As a take-home assignment, have students categorize household items into each state and into examples of Newtonian and non-Newtonian fluids. Students can try to identify
- As a project, have student create a model that shows the three different states of matter. They can use any crafts you provide to develop their solid, liquid, and gas models.
- Have students apply their new learning to a real world chemistry connection. Other than the water cycle, what are some examples of phase changes in our lives? Have students come up with or research some examples

### Fun Fact #3

**Isaac Newton's mother originally wanted him to be a farmer and made him drop out of school to do so. However, his former principle eventually convinced her to let him return.**