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.

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..

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

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.

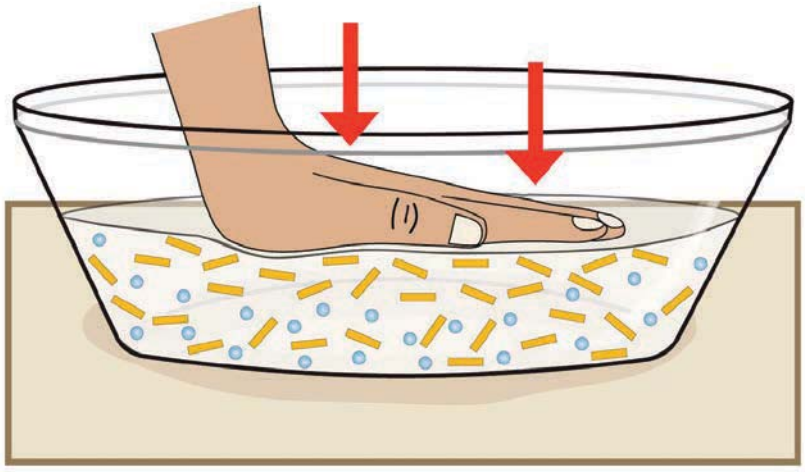
EXPLORE

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.

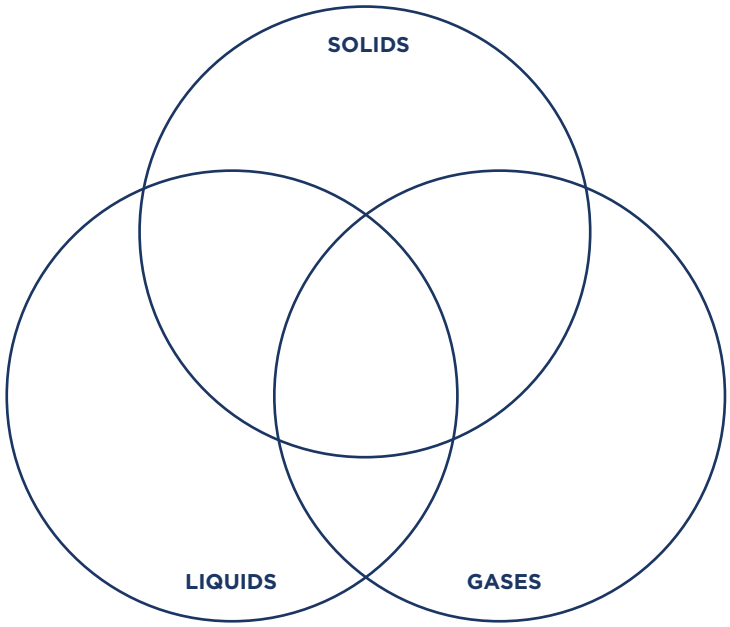


Notes

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:

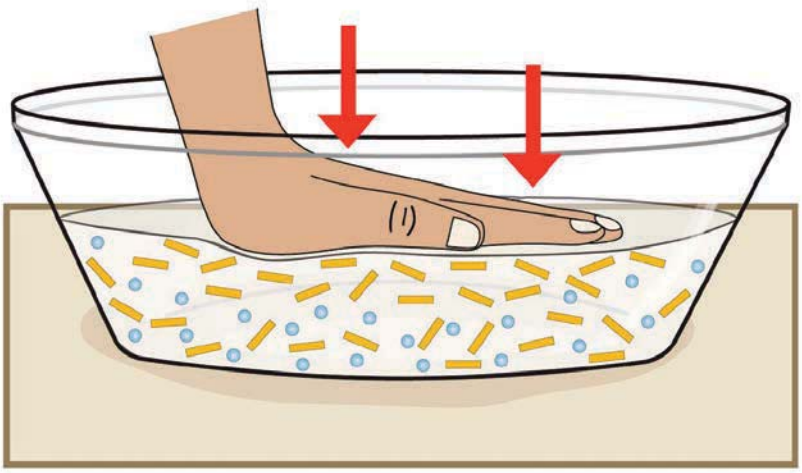
- **Newtonian fluids:** fluids which flow and act in their usual manner no matter what forces are applied.
- **Non-Newtonian fluids:** fluids which flow and act differently based on the force that's applied.

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: • Matter can exists as a solid, liquid, or gas • Difficulties with identifying all matter as solid, liquid, or gas	**For more advanced students, emphasize the following concepts:** • Each state of matter also has its own properties due to how molecules move in each state • Fluids have unique properties, such as viscosity. • 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

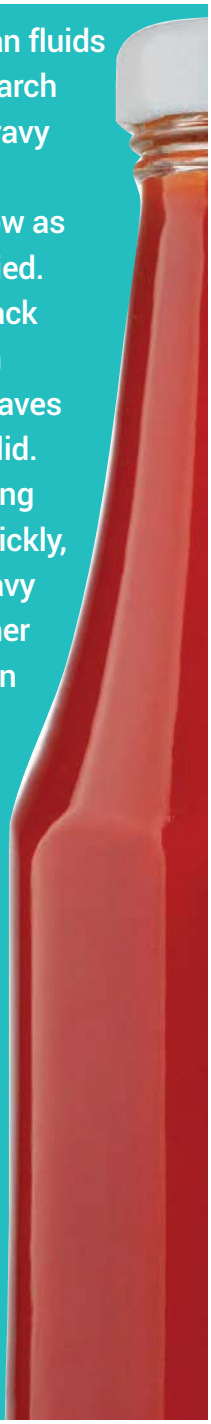
A common name for non-Newtonian substances is oobleck, coming from the Doctor Seuss book Bartholomew and the Oobleck, where a green substance rained down from the sky and caused trouble in the kingdom.

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.