



# Hypersonics STEM Curriculum



## Only Three Phases of Matter???

Grade	Time	Subject Area	Key Concepts
5	90 min	Physical Science	phases of matter particles

### Lesson Overview

Prior to this lesson, students should have learned about the three phases of matter: solid, liquid, and gas. In this lesson, students will do a WebQuest to review the three phases of matter and learn about a fourth state of matter, plasma. Students will also explore situations where substances do not behave like a typical substance in that state of matter.

### NGSS Standards

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

5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

### Learning Objectives

By the end of this lesson, students will be able to:

- Explain the difference between a solid, liquid, gas, and plasma at the molecular level.
- Explain how some substances do not behave like a typical substance in that state of matter.

### Essential/Overarching Question

What happens when a fluid does not behave like a fluid?

### Key Vocabulary

**Matter** – any substance that has mass and takes up space (has a volume).

**Solid** – a state of matter where the molecules of a substance are arranged in a manner that their shape and volume are stable, and the material does not flow. Solids have a fixed shape, have closely packed molecules, and have lower internal kinetic energy.

**Liquid** – a state of matter where the molecules of a substance are arranged in a matter that their volume is fixed, and the substance will flow to take the shape of the container they are within. Liquids do not have a fixed shape, have loosely packed molecules, and have a mid-level internal kinetic energy.

**Gas** – a state of matter where the molecules of a substance are arranged in a matter that it does not have a fixed shape nor volume, the substance will flow to fill the container they are

within. Gasses do not have a fixed shape or volume, have freely moving molecules, and have a higher internal kinetic energy.

**Plasma** – a state of matter where a gas has been heated enough that molecular bonds are broken, electrons can escape from the molecules, and ions are created. Like gasses, plasmas do not have a fixed shape or volume, have freely moving ions, and have a high internal kinetic energy.

**Ion** - an atom or molecule with a net electric charge due to the loss or gain of one or more electron(s).

**Melt** – the transition from the solid phase to the liquid phase. Energy is added.

**Freeze** – the transition from the liquid phase to the solid phase. Energy is removed.

**Vaporize** – the transition from the liquid phase to the gas phase. Energy is added.

**Condensation** – the transition from the gas phase to the liquid phase. Energy is removed.

**Deposition** – the transition from the gas phase to the solid phase without going through the liquid phase. Energy is removed.

**Sublimation** – the transition from the solid phase to the gas phase without going through the liquid phase. Energy is added.

**Ionization** – the transition from the gas phase to the plasma phase. Energy (ionization energy) is added, electrons are removed from the molecules/atoms and ions are formed.

**Recombination** – the transition from the plasma phase to the gas phase. Energy is removed as the ions come back together and neutralize.

**Mole** – amount of substance containing the same number of chemical units (atoms, molecules, ions, electrons, etc.) as exactly 12 grams of carbon-12. The number of atoms or other particles in a mole is the same for all substances.

**Fluid** – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

**Flow** – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

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**Viscosity** – the measure of a fluid's resistance to flow or change shape.

**Stress** – the force per unit area within a material that is caused by external forces.

**Non-Newtonian Fluid** – a fluid that does not follow Newton's law of viscosity (constant viscosity independent of stress). A fluid that changes its viscosity when a force is applied, it may become more viscous (more like a solid), or less viscous.

**Speed** – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

**Speed of Sound** – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

**Mach** – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

**Sonic** – speeds equal to the speed of sound (Mach 1).

**Subsonic** – speeds smaller than the speed of sound (less than Mach 1).

**Transonic** – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

**Supersonic** – speeds greater than the speed of sound (Mach 1 and greater).

**Hypersonic** – speeds greater than five times the speed of sound (Mach 5 and greater).

### Science Concepts Overview

Students are typically taught about the three phases of matter (solid, liquid, and gas), but there is a fourth state of matter, plasma. A solid is a substance that has a fixed shape and volume and does not flow. Solids have the least internal kinetic energy and usually have the smallest distance between molecules. A liquid is a substance with a fixed volume but will flow to take the shape of the container it is within. A liquid has a midrange internal kinetic energy and distance between molecules. A gas is a substance with no fixed shape nor volume and will flow to fill the container it is within. Gases have the most internal kinetic energy and the largest distance between molecules. A plasma is gas that has been heated enough that the

valence electrons are able to escape, creating ions. Plasmas have the highest internal kinetic energy.

Substances do not always fall nicely into those definitions. When water transitions from a liquid to a solid, the water molecules arrange themselves in a way that the volume expands due to its polar arrangement, whereas most other substances take up less volume when they freeze. Air interacts with aircrafts differently depending on the speed the aircraft is traveling. Non-Newtonian fluids are further examples of substances that do not behave according to their phase of matter. Oobleck acts like a liquid when it is not under stress and a solid when a force is applied to it.

### Materials List

- Variety of substances that are not easily categorized as a solid, liquid, or gas (modeling clay, silly putty, pudding, melting ice cube, humid air, etc.)
- Devices with access to the internet (one per student)
- Only Three Phases of Matter??? handout (one per student)

### Lesson Preparation

Prior to the lesson, instructors should make copies of the Only Three Phases of Matter??? handout, and ensure that the devices that the students will be using to do the WebQuest are charged and connected to the internet.

If possible, the instructor should provide students with either an electronic copy of the Only Three Phases of Matter??? handout and/or links to the websites through whatever learning platform is used at their school. This will help students more easily and quickly get to the correct resources.

### Safety

There are no additional safety concerns beyond normal classroom procedures for this lesson.

### Procedure

#### **Engage (10 minutes)**

1. Have a variety of substances that are not easily categorized as a solid, liquid, or gas such as modeling clay, silly putty, pudding, melting ice cube, humid air, etc. on the front table for students to observe.
2. Assign groups of students (3-4) a substance to categorize. Have each group share how they categorized the substance and why?

#### **Explore/Explain/Elaborate/Evaluate (80 minutes)**

3. The Only Three Phases of Matter??? handout will take students through the 5E process. In each of the five sections, students will explore different online resources and then explain and elaborate on their understanding of the concepts presented by the resources by answering questions. The handout can be collected and used as an assessment.

- Ideally, students would work individually on this lesson. If there is not a one-to-one student to electronic device ratio, students can work in groups.

### STEM Career Connections

- Aerospace engineering
- Military pilots
- Aircraft design
- Materials science
- Chemist

### Extensions

Students can further *explore* by creating their own oobleck substance and experimenting with its properties (see resources for recipe).

### References & Resources

- FuseSchool - Global Education. (2017, December 18). *Changes of state | Matter | Physics | FuseSchool* [Video]. YouTube. <https://www.youtube.com/watch?v=xYU7RSOZ0U>
- Helmenstine, A. M. (2019, August 18). *List of phase changes between states of matter*. ThoughtCo. <https://www.thoughtco.com/list-of-phase-changes-of-matter-608361>
- Helmenstine, A. M. (2019, November 8). *How oobleck works*. ThoughtCo. <https://www.thoughtco.com/how-oobleck-works-608231>
- Learning Junction. (2020, May 29). *States of matter video for kids | Four states of matter | Bose-Einstein condensates* [Video]. YouTube. <https://www.youtube.com/watch?v=8zrbvbxWgJk>
- MooMooMath and Science. (n.d.). *Phases of matter and the phase changes* [Video]. YouTube. <https://www.youtube.com/watch?v=CMUmQRgJAo0>
- Science Explorers. (2018, August 16). *What is oobleck?*. Science Explorers. <https://www.scienceexplorers.com/what-is-oobleck>
- SciShow. (2019, July 8). *A surprisingly simple secret to supersonic flight* [Video]. YouTube. <https://www.youtube.com/watch?v=kGefMLHJBKA>
- Sharp, T. (2012, July 11). *How to make oobleck*. Live Science. <https://www.livescience.com/21536-oobleck-recipe.html>
- TedEd. (n.d.). *Solid, liquid, gas and ... plasma? - Michael Murillo* [Video]. YouTube. <https://www.youtube.com/watch?v=tJplytSR-ww>
- TestTube 101. (2015, November 11). *Flying at hypersonic speeds* [Video]. YouTube <https://www.youtube.com/watch?v=vL1qAfS0gic>
- TMBGKids. (n.d.). *Why does the sun really shine? (The sun is a miasma of incandescent plasma) - They Might Be Giants* [Video]. YouTube. <https://www.youtube.com/watch?v=r6q3s1MI6NE>
- UNSW Canberra. (2019, August 29). *What is hypersonics?* [Video]. YouTube. <https://www.youtube.com/watch?v=DyIMgPOPJMs>

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Only Three Phases of Matter???

✦ **Objective:** Upon the completion of this activity, you should be able to explain the difference between a solid, liquid, gas, and plasma. You should be able to explain how some materials don't follow the phases of matter rules.

✦ **Instructions:** For each section, use the links to explore different internet resources. Use the information provided in the different resources to answer the questions that follow. You are welcome to reuse resources for other sections and search for other resources as needed.

### ✦ The Three Phases of Matter

FuseSchool - Global Education. (2017, December 18). *Changes of state | Matter | Physics | FuseSchool* [Video]. YouTube. <https://www.youtube.com/watch?v=xYU7RSoOZ0U>

MooMooMath and Science. (n.d.). *Phases of matter and the phase changes* [Video]. YouTube. <https://www.youtube.com/watch?v=CMUmQRgJAo0>

1. In the boxes below, draw a model that show 10 molecules of the same substance as a solid, liquid, and gas. Also label how fast the molecules are moving in each state.

Solid	Liquid	Gas

2. I have 100 moles (molecules or atoms) of a substance in its solid, liquid, and gaseous forms.
  - a. Which form will have the greatest mass?
  - b. Which form will have the greatest distance between molecules?
  - c. Which form will have the greatest amount of energy?
3. Due to its polar properties, water is one of the molecules that behaves differently as it freezes and melts. When I fill an ice cube tray exactly to the top and put it in the freezer, the ice cubes come out overflowing the tray. What does that tell you about the transition from liquid to solid for water? How would the molecules in most materials act when freezing?

★ “Plasma – a fourth state of matter – not gas, not liquid, not solid”

TMBGKids. (n.d.). *Why does the sun really shine? (The sun is a miasma of incandescent plasma) - They Might Be Giants* [Video]. YouTube.

<https://www.youtube.com/watch?v=r6q3s1MI6NE>

TedEd. (n.d.). *Solid, liquid, gas and ... plasma? - Michael Murillo* [Video]. YouTube.

<https://www.youtube.com/watch?v=tJplytSR-ww>

Learning Junction. (2020, May 29). *States of matter video for kids| Four states of matter | Bose-Einstein condensates* [Video]. YouTube.

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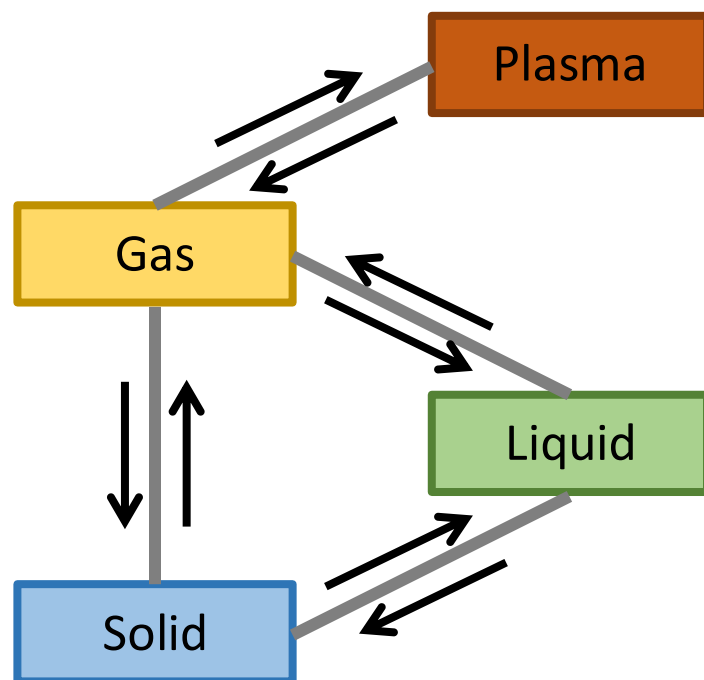
ThoughtCo. <https://www.thoughtco.com/list-of-phase-changes-of-matter-608361>

4. How is plasma different than gas? Explain in words and draw a model that compares the two.

Gas	Plasma

5. What are at least three examples of substances in the plasma state?

6. The diagram to the right shows the four states of matter with arrows indicating the direction of a transition between the two states of matter. For each arrow, label the name of that phase change. For example, when a substance transitions from liquid to solid it is called freezing.



### ✦ Hypersonics – When Fluids Change Their Behavior

UNSW Canberra. (2019, August 29). *What is hypersonics?* [Video]. YouTube.

<https://www.youtube.com/watch?v=DylMgPOPJMs>

TestTube 101. (2015, November 11). *Flying at hypersonic speeds* [Video]. YouTube

<https://www.youtube.com/watch?v=vL1qAfS0gic>

SciShow. (2019, July 8). *A surprisingly simple secret to supersonic flight* [Video]. YouTube.

<https://www.youtube.com/watch?v=kGefMLHJBKA>

7. The videos discuss several different challenges that come with traveling at supersonic and hypersonic speeds. Describe three of those challenges.
  
8. The videos discuss how air does not interact with aircrafts the same way as the aircraft goes from subsonic to supersonic speeds and beyond. Describe two or three of the ways the air changes its interaction.
  
9. One of the videos mentioned that different equations and assumptions were needed to make calculations at different speeds. As a scientist or engineer, how would you handle that issue when working to designing and testing a plane that needs to fly at both subsonic and supersonic speeds?

### ✦ Oobleck – When Liquids Behave Like Solids

Science Explorers. (2018, August 16). *What is oobleck?*. Science Explorers.

<https://www.scienceexplorers.com/what-is-oobleck>

Helmenstine, A. M. (2019, November 8). *How oobleck works*. ThoughtCo.

<https://www.thoughtco.com/how-oobleck-works-608231>

10. Is oobleck a solid or a liquid? What makes you say that?
  
11. How do you define a non-Newtonian fluid?
  
12. Both oobleck and ketchup are non-Newtonian fluids. How is ketchup different from oobleck?



★ **Final Analysis**

13. After working through the different sections, how many phases of matter would you say there are? What makes you say that?
  
14. The one video mentioned two other states of matter that are not observed in normal conditions. What do you think a seventh state of matter could be? What do you think the molecules would look like in your newly discovered state of matter? What causes the molecules to do that?
  
15. When you have objects, like oobleck, that are one phase of matter but can also act like another, how do you categorize them? What makes you say that?