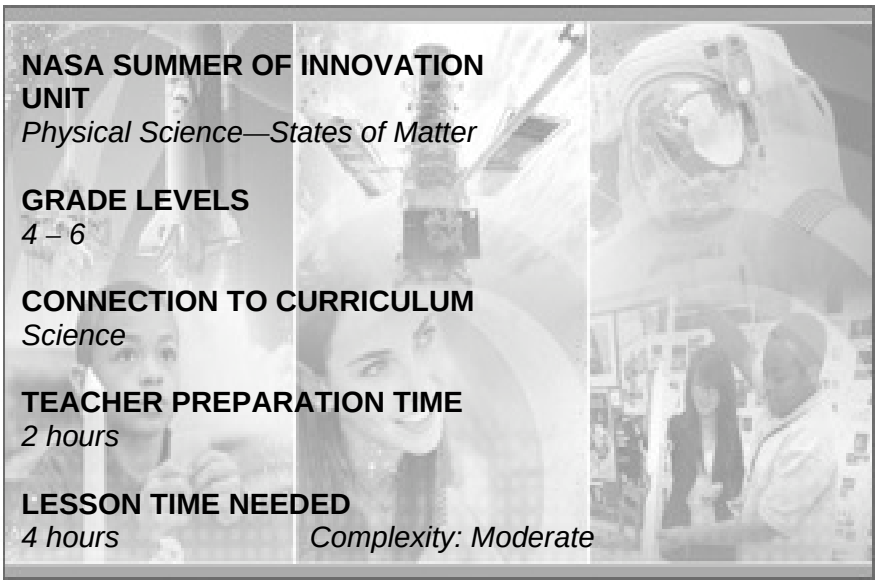
STATES OF MATTER



NASA SUMMER OF INNOVATION UNIT
Physical Science—States of Matter

GRADE LEVELS
4 – 6

CONNECTION TO CURRICULUM
Science

TEACHER PREPARATION TIME
2 hours

LESSON TIME NEEDED
4 hours *Complexity: Moderate*

LESSON DESCRIPTION
This lesson explores the states of matter and their properties.

OBJECTIVES
Students will

- Simulate the movement of atoms and molecules in solids, liquids, and gases
- Demonstrate the properties of liquids including density and buoyancy
- Investigate how the density of a solid behaves in varying densities of liquids
- Construct a rocket powered by pressurized gas created from a chemical reaction between a solid and a liquid

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science and Technology

- Abilities of technological design
- Understanding science and technology

Physical Science

- Position and movement of objects
- Properties and changes in properties of matter
- Transfer of energy

MANAGEMENT
For the first activity you may need to enhance prior knowledge about matter and energy from a supplemental handout called “Diagramming Atoms and Molecules in Motion.” At the middle school level, this information about the invisible world of the atom is often presented as a story which we ask them to accept without much ready evidence. Since so many middle school students have not had science experience at the concrete operational level, they are poorly equipped to work at an abstract level. However, in this activity students can begin to see evidence that supports the abstract information you are sharing with them. They can take notes on the first two descriptions as you present on the overhead.

Emphasize the spacing of the particles, rather than the number. Say, “In liquids the molecules are farther apart,” rather than, “In liquids there are fewer molecules.” Although students may be uncomfortable thinking about things they cannot see, they should be reminded that the scientists who first developed these theories couldn't see atoms or molecules either. They may not have acted out the states of matter with fellow scientists, but they definitely engaged in imagination exercises similar to those presented here.

For the second activity where students create a liquid rainbow, students should never taste any chemical in the laboratory setting. If the students cannot guess correctly, then tell them they will learn the "secret ingredient" after the next step of the demonstration. Also, presenting the liquids as different colors eliminates the potential for students to pour the chemicals back into the dispensing container thereby contaminating a larger quantity. Tell them that all of the liquids used in this activity are colorless and that you have added color for safety and that the color has no effect on the results of the lab. Remind students to never put the pipet or any substance in a lab in their mouths.

The third activity is suggested as a demonstration. Prepare these solutions before students arrive in the class so they are not aware that there is a difference among solutions.

For the fourth activity where the students build rockets, it may be helpful to make samples of rockets in various stages of completion available for students to study. This will help some students visualize the construction steps. Be sure to use white film canisters where the lid snaps inside the canister.

CONTENT RESEARCH

Matter commonly exists on Earth in three forms: solid, liquid, and gas. These three forms are called the three states of matter. Matter is usually found in only one form at ordinary Earth temperatures. The main difference between material in the solid state, the liquid state, and the gas state is how fast its molecules are moving. As a solid, the molecules are tightly packed and cannot move very much. As a liquid, the molecules have more space and can move about more. Gas molecules are moving very fast and are even farther apart.

Water is unusual because it can be readily found on Earth in all three states. Although it is obvious that water *vapor* (not *steam*—which is tiny liquid drops of water suspended in air) expands from its liquid volume, it may not be as obvious, and is definitely not the expected result, that ice also expands from its liquid volume. If you have ever filled ice cube trays right to the rim, you may have noted that the resulting cubes stick up over the top of the tray. The expansion of liquid water into ice allows ice to float. This unique property of water is thought to be a factor that allows life to exist on our planet.

Density is a property of matter that can be introduced by thinking in terms of the relationship between weight and volume. How can two objects that are the same size have different weights? The answer has to do with their density. An object's density is determined by comparing its mass to its volume. If you compare a rock and a cork that are the same size having equal volume, which would be heavier? The rock is, because it has more mass. Thus the rock is denser than the cork because it has more mass in the same volume.

Liquids have density too. Unlike the densities of solids, which remain relatively constant, the densities of many fluids can be easily changed. Do objects float the same way in fresh water as they do in salt water? If you have the same amount of each, saltwater weighs more than fresh water. Salt water is described as being denser than fresh water. In the case of ocean water, heating, cooling, and salinity all influence density.

Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Circulation in the ocean depends in part on differences in density of the water. Water with more salt is denser (heavier) and sinks while fresh water is less dense and "floats" on the surface. When solutions of two different densities meet, the lower density (less dense) solution will move on top of the higher density (more dense) solution.

The relationship between density of fluid, weight of an object, and buoyancy is a basic concept in understanding the behavior of seawater. These buoyancy differences can result in the separation of water into layers (stratification) within an estuary or ocean. Stratification can be disrupted by tidal mixing, heating and cooling of surface waters, and/or by wind generated water movement, such as waves and currents. This action results in vertical mixing. Density-driven currents are an important feature in coastal waters, affecting the physical, chemical, and biological dynamics in the ocean. Many marine organisms use density currents for migration, reproduction, and feeding.

As seen from space, Earth has been described as a "blue marble," dominated by sapphire oceans and swirls of white clouds. Continents appear as widely spread outposts, covering less than one-third of the planet's surface. Earth is dominated by water in all its states of matter: liquid seas, vaporous clouds, and solid ice. The interplay among these forms is depicted as a "water cycle." Ocean circulation—including currents and eddies—transports this energy as heat from the tropics to the poles. Evaporation at the sea surface releases energy into the atmosphere as water vapor. Over time, water returns to the oceans and land through the precipitation of rain or snow. This global cycling of water and energy helps to make Earth's overall climate hospitable to human and other life forms.

Yet the ties among the water cycle, ocean circulation, and climate are poorly understood. Interestingly, global measurement of sea surface salinity (SSS), the principal surface tracer of fresh water input to and output from the ocean and a direct contributor to seawater density, provides a clear way resolve these relationships. By tracking SSS over time we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, evaporation, and precipitation over the oceans. Global SSS data taken by NASA's Aquarius satellite mission scheduled to launch in 2011 will allow us to create unprecedented computer models that bridge ocean-atmosphere-land-ice systems, with the goal of predicting future climate conditions.

Key Concepts:

- Matter is made up of particles too small to be seen.
- The three states of matter are solid, liquid, and gas.
- Solids, liquids and gases can be characterized by their properties (including volume, shape, and the movement and spacing of particles).
- Different densities of water, or solutions, will stratify to form layers.
- An object can both sink and float depending on its relative density to the surrounding fluid.
- A mixture can be made by combining solids, liquids, or gases that can be separated again.
- When some substances are mixed together, they chemically combine to form a new substance that cannot easily be separated.

Misconceptions:

- Temperature determines states of matter.
- Gases contain fewer molecules than do liquids or solids.
- An object floats because it has air in it.
- Thick liquid is denser than thinner, less viscous liquids.
- All liquids mix.
- Objects float in water because they are lighter than water.
- Objects sink in water because they are heavier than water.
- Mass, volume, weight, heaviness, size, and density may be perceived as equivalent.
- Wood floats and metal sinks.
- All objects containing air float.
- Liquids of high viscosity are also liquids with high density.
- An object that appears to be on top of the solution is not floating but is held up by the solutions "skin."
- Objects that are completely submerged but freely suspended, such as fish or submarines, are not buoyant.

LESSON ACTIVITIES

Activity 1: Heat As The Agent of Change: Atoms and Molecules in Motion

Students study heat and its effects on space flight. Module from Genesis mission education
http://genesismission.jpl.nasa.gov/educate/scimodule/heat/index.html

Activity 2: Liquid Rainbow

Students use salt and food colorings to generate different density water and create a density rainbow
http://aquarius.nasa.gov/liquid_rainbow.html

Activity 3: Potato Float
Students will float an object in varying density solutions.
http://aquarius.nasa.gov/potato_float.html

Activity 4: 3-2-1 Pop!
Students construct a rocket powered by the pressure generated from an effervescing antacid tablet.
3-2-1 Pop!

ADDITIONAL RESOURCES
This demonstration reintroduces three of the states of matter (solid, liquid, and gas), and introduces the fourth state of matter, plasma, and its connection to the Sun. It also provides an overview of the IBEX mission to explore the boundary of the solar system.
http://teachspacescience.org/graphics/pdf/10001138.pdf

This kinesthetic science demonstration introduces four states of matter: solid, liquid, gas, and plasma, and how the addition of energy can transform matter from one state to another.
http://teachspacescience.org/graphics/pdf/10001139.pdf

Construct models of greenhouse gas molecules using gummy drops.
http://spaceplace.nasa.gov/en/kids/tes/gumdrops/index.shtml

Briefing of the NASA AQUARIUS/SAC-D mission designed to investigate sea surface salinity from space.
Sea Surface Salinity From Space

Lithograph and background information on the NASA AQUARIUS/SAC-D mission designed to investigate sea surface salinity from space.
http://aquarius.nasa.gov/pdfs/aq_sacd_litho_final.pdf

DISCUSSION QUESTIONS

- Define the following terms: solid, liquid, and gas.
  Gas: The state of matter without a set shape or volume.
  Liquid: The state of matter with a set volume but no set shape.
  Solid: The state of matter with a set volume and a set shape.

- Give an example of each of the three states of matter that was not discussed in class. *Answers will vary. Example: Water is liquid. Ice is solid. Water vapor is gaseous.*

- You get to be a molecule in a solid, a liquid, or a gas. Which would you rather be? Why? *Answers will vary. Example: I would rather be a gas because the particles have a lot of energy.*

- Why do some objects float or sink relative to other objects? *An object can both sink and float depending on its relative density to the surrounding fluid.*

- How is salt water different from fresh water? *If you have the same amount of each, saltwater weighs more than fresh water. Salt water is described as being denser than fresh water.*

MATERIALS
Activity 1: Atoms and Molecules in Motion
- Floor space for student simulation masking tape
- Copies of student text: "Atoms and Molecules in Motion: States of Matter"
- Student copies of: "Diagramming Atoms and Molecules in Motion" handout
- An overhead transparency of: "Diagramming Atoms and Molecules in Motion" handout

Activity 2: Liquid Rainbow
- Four large containers (e.g., pitchers or milk jugs)
- Food coloring (four colors)
- Transparent drinking straws
- Pickling salt (preferred)
- Five vials or test tubes per student group (four for solutions and one for waste)

Activity 3: Potato Float
- Three tall beakers
- Water
- Salt
- Spoon
- Knife
- Potato
- Balance
- Objects with varying densities
- Ruler
- Graduated cylinders

Activity 4: 3-2-1 Pop
- Heavy paper
- Plastic 35-mm film canister
- Student sheets
- Cellophane tape
- Scissors
- Effervescing antacid tablet
- Paper towels
- Water
- Eye protection

- Would the Earth be different if the oceans contained fresh water? *Yes. Salinity influences the density of ocean water along with heating and cooling. Circulation in the ocean depends in part on differences in density of the water.*

- What will happen if four liquids, each a different color and density, are poured together? *These buoyancy differences can result in the separation of water into layers (stratification).*

- What is density a measure of? *An object's density is determined by comparing its mass to its volume.*

- Why is density important to life in the ocean? *Many marine organisms use density currents for migration, reproduction, and feeding.*

- How does temperature affect the density of water? *An increase in the temperature of water decreases its density. Conversely, a decrease in the temperature of water increases its density.*

- What is the relationship between sea surface temperature, ocean circulation, and climate change? *Surface winds drive currents in the upper ocean. Deep below the surface, however, ocean circulation is primarily driven by changes in seawater density, which is determined by salinity and temperature. Density-controlled circulation is key to transporting heat in the ocean and maintaining Earth's climate. In Earth's "water cycle," water circulates from the ocean to the atmosphere to the land and back again to the ocean. Water moves as a gas (water vapor), liquid (rain), and solid (snow and ice) through the cycle. Exchanges between the ocean and atmosphere are a major component, with approximately 86% of global evaporation and 78% of global precipitation occurring over the ocean.*

- How can studying the density of sea surface water help us make climate predictions? *Data from Aquarius will allow scientists to see how freshwater moves between the ocean and the atmosphere as a result of rainfall, evaporation, ice melt, and river runoff. These data will improve global "water cycle budget" estimates over the ocean, where the majority of global precipitation and evaporation occurs. Accurate data will also be used to improve computer models to better resolve how climate, ocean circulation, and the water cycle are connected and thereby improve climate prediction.*

ASSESSMENT ACTIVITIES

The student activity sheet for the first activity can be found at http://genesismission.jpl.nasa.gov/educate/scimodule/heat/index.html in the left column under the heading "Atoms and Molecules in Motion." Also, the aforementioned handout "Diagramming Atoms and Molecules in Motion" may be used as a formative assessment.

For the Liquid Rainbow activity and the Potato Float demonstration in the third activity, the assessment falls in a whole and/or collaborative group discussions with regard to questions about density, salinity, mass, and volume. Sample topics in the lesson write-ups found at http://aquarius.nasa.gov/potato_float.html and are

- How can knowing the density of solutions be useful in daily life?
- Why is density important to life in the ocean?
- Name examples of high-salinity water and low-to-no-salinity water.
- What happens when rain falls on the ocean?
- How will NASA's Aquarius Mission help us monitor how ocean salinity affects climate change?

For the fourth activity on rocketry, students are expected to explain how the states of matter of substances used interact to power the rocket.

ENRICHMENT
Consider using the following activities to enrich the concepts taught in this lesson:

- Use the Crystallization Model to demonstrate how atoms in a solid arrange themselves. http://www.nasa.gov/pdf/315954main_Microgravity_Crystallization_Model.pdf

- Use this Gravity-Driven Fluid Flow activity to study gravity-driven fluid flow that is caused by differences in solution density. http://www.nasa.gov/pdf/315955main_Microgravity_Gravity_Driven.pdf

- This is a videoconferencing module from the Digital Learning Network on the states of matter. http://www.nasa.gov/pdf/467716main_StatesofMatterTeacherGuide_July 6th, 2010.pdf

www.nasa.gov