Lesson 3: Properties of Matter

Wetlands in Butte County, CA; Natural Resources Conservation Service, USDA

Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature is not a measure of heat but of the average motion of molecules of a substance.

Main Lesson Concept:
Matter can exist in three states: solid, liquid and gas. Each state has unique properties.

Note to Teacher: A fourth state of matter, plasma, is beyond the scope of this lesson.

Scientific Question:
What are the similarities and differences between the properties of solids, liquids, and gases?

Objectives	Standards
Students will identify the properties of solids, liquids and gasses and will cite similarities and differences in those properties.	**Meets:** NSES: B (K-4) #1 **Addresses:** NSES: A (5-8) #1

Assessment	Abstract of Lesson
Write-up in Astro Journal.	Students observe samples of solids, liquids and gasses. They then find similarities and differences among the properties. They record their findings and conclusions in their Astro Journals.

Prerequisite Concepts	Major Concepts
• Volume is the amount of space an object takes up. • Shape is a particular form. • Molecules are the smallest individual parts of a substance. • Matter is anything that has mass and volume or anything that takes up space.	• A solid has a definite shape and volume. • A liquid has a definite volume but not a definite shape. • A gas has no definite shape or volume. • Solids, liquids and gases take up space.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore sections
Day 2: Explain, Extend and Evaluate sections

Materials and Equipment:

- Reclosable plastic bags with solids, liquids and gases (one set for each group). Include thick solids such as blocks, and thin solids such as potato chips or crackers, viscous (thicker) liquids such as toothpaste or honey, and less viscous liquids such as water. You may use air as your only gas. All samples should be small enough to fit in a cup.
- Cups (1 or 2 per group)
- Balloons (1 or 2 per group)
- A class set of Astro Journals Lesson 3: Properties of Matter*
- A class set of Astro Journal covers
- A class set of Scientific Inquiry Evaluation Rubric

Preparation:

- Gather materials.
- Make reclosable plastic bags with each object or substance for groups.
- Prepare Astro Journals.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

* A generic Astro Journal and Scientific Rubric are included at the end of Lesson 1. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation

Accommodations

For students who may have special needs:

- Have students give an oral report of their Astro Journal entry.
- Emphasize the visual component of their response.

Advanced Extensions

For students who have mastered this concept:

- Have students research and report on Plasma - the fourth state of matter.
- Have students research and report on why dry ice goes from a solid to a gas?

Note to Teacher: Dry ice is solid CO_2. It cannot exist as a liquid under Earth's normal pressure conditions. Advanced students can, thus, start to investigate that pressure is also a factor in states of matter.

Engage

(approximately 20 minutes)

Water flooding rice fields in central Arkansas; Natural Resources Conservation Service, USDA

1. Review of Part 1.

- Question: In the Astronomy training module, what did you determine to be the essential element for sustaining human life?
- *Answer: Liquid water. (This is the answer you're looking for. Acknowledge other correct responses.)*

2. Going over lesson purpose with students

Since we know we need liquid water to sustain human life, we need to understand a little more about what liquid water is and the conditions that allow us to have liquid water.

3. Bridging to this lesson

- Question: Can water be in another state or form besides liquid?
- *Answer: Yes. As a solid, it's called ice. As a gas, it's called vapor.*

- Question: What states can matter be in?
- *Answer: Solid, liquid or gas.*

Note to Teacher: Plasma is also a state of matter, but is beyond the scope of this lesson.

4. Present Scientific Question for lesson:

What are the similarities and differences among the properties of solids, liquids, and gases?

5. Tell students that they will be observing and testing samples of matter in order to answer that question.

Explore

(approximately 25 minutes)

Icy fog at South Haven Michigan Lighthouse; NOAA

1. Go over ground rules for materials.

Use your standard rules or your knowledge of your class to determine these.

2. Distribute materials.

Have students make initial observations of materials.

3. Have students record their predictions of the answer to the Scientific Question in the Hypothesis/ Prediction section of their Astro Journals.

4. Identify the rules students will be using to find the properties of the three states of matter including taking up space, fixed shape, and fixed volume.

Check to be sure students understand these terms.

5. Data collection: (Teacher Demonstration)

- Hold up a solid and ask students if it is a solid, liquid, or gas. Ask them to record the name of the object and the state of matter on their chart in the Data Collection section of Astro Journal Lesson 4.
- Demonstrate different ways to test the object to see if its shape changes easily. Try bending it, putting your finger through it, putting it in another container, etc. Ask students if the shape is easily changed. Have them record this observation on their Astro Journal chart.
- Demonstrate different ways to test the object to see if it takes up space. Put the object in a container such as a cup. Ask students if the object takes up space. Have them record this observation on their Astro Journal chart.
- Demonstrate different ways to test the object to see if its volume changes easily by pouring it out of the container. Ask students if the amount of space taken up (volume) is the same as when the object is not in the container. Have them record this observation on their Astro Journal chart.

6. Data Collection: (Student Exploration)

- Have students observe the other solids, liquids, and gases with their groups and mark their charts in the same way for each.
- They should also record the test materials in their Materials section.

Explain

(approximately 20 minutes)

Illustration of scientific balloon flying near edge of atmosphere; NASA

1. Review data collection activity (especially if this is a separate class from Engage and Explore sections).

- Question: What are the three states of matter we have been working with?
- *Answer: Solid, liquid, and gas.*

- Question: What rules did we use to test our samples of matter?
- *Answer: We tested whether it has a fixed shape, a fixed volume, and whether it takes up space.*

- Question: What are the similarities and differences among the properties of solids, liquids, and gases? (Scientific Question)

- Elicit some sample responses from people and record key ideas on the board/overhead/chart paper. Question any incorrect or imprecise responses.

  A solid has a definite shape and volume.
  A liquid has a definite volume but not a definite shape.
  A gas has no definite shape or volume.
  Solids, liquids, and gases take up space.

MISCONCEPTION: Students may not really understand or believe that a gas takes up space. To test:

- Question: How do you know that the air is taking up space?
- *Answer: Allow students to share their ideas about this. Answers may include: We can see clouds. When we blow up a balloon, air fills it. Birds and airplanes can glide because of air.*

- Question: How do we know that there is air around us?
- *Answer: We breathe. We can feel the wind blowing, etc.*

- Blow up a balloon.

- Question: What is inside the balloon?
- *Answer: Air.*

- Question: What is causing the balloon to expand and hold its shape?
- *Answer: Air.*

- Question: How does this show us that air takes up space?
- Answer: The air is the only thing in the balloon which could be giving it its expanded shape.

---

2. Go over the rubric for Journal entries with students.

---

3. Students fill in the Results section of the Astro Journal.

Extend/Apply

(approximately 15 minutes)

Gas analysis system monitoring; Savannah River National Laboratory, USDOE

1. Reconnect with lesson purpose.

- Question: What do we know now about liquid water that makes it different from solid water (ice) and gaseous water (steam, vapor, clouds, fog)?
- *Answer: Liquid water has a fixed volume, but not a fixed shape.*

---

2. Have students illustrate and label the three states of water in the Illustrations section of their Astro Journals.

Evaluate

(approximately 10 minutes)

Drinking water source-area monitoring; Government of Cambridge, MA

1. Have students fill out the Conclusion section in their Astro Journals.

Emphasize the importance of referring directly to their testing experience in explaining how they either changed or confirmed their hypothesis.

---

2. Have students share their illustrations.

- Review the characteristics of solids, liquids and gases.
  - A solid has a definite shape and volume.
  - A liquid has a definite volume but not a definite shape.
  - A gas has no definite shape or volume.
- Have students identify drawings completed by their classmates that show the characteristics of each state of matter.
- Have students explain how the drawings clearly illustrate each state.

---

3. Collect Astro Journals and evaluate using the Scientific Inquiry Evaluation Rubric to make sure students are ready for the next lesson.

Note to Teacher: After each lesson, consider posting the main concept of the lesson someplace in your classroom. As you move through the unit, you and your students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 3: Properties of Matter

Name _____ Date _____ Class/Period _____

Scientific Question:
What are the similarities and differences between the properties of solids, liquids, and gases?

1. Hypothesis/Prediction: What do you think are the similarities and differences? Why?

2. Materials: What materials will you use to investigate?

3. Procedure: Check each step off as you complete it.

For each sample:
- Record the type of matter. (Solid, Liquid, or Gas)
- Does it take up space? (Yes or No)
- Does it have a fixed volume? (Yes or No)
- Does it have a fixed shape? (Yes or No)

4. Data Collection: Record and Display your data in a chart, table, picture or graph.

Sample	Solid, Liquid, Gas?	Take up Space?	Fixed volume?	Fixed Shape?

Astro Journal Lesson 3: Properties of Matter

Name _____ Date _____ Class/Period _____

Data Collection (Cont.)

Illustrations:

5. Results: What are the similarities and differences among solids, liquids, and gasses? Describe and illustrate.

6. Conclusions: Compare and contrast your predictions and results. How did testing your hypothesis/prediction change your original ideas?

Lesson 4: Matter and Molecules

Scientific testing of a meltpond in the Arctic; NOAA

Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

Main Lesson Concept:
The properties of matter derive from the bonds between the molecules and the motion of the molecules that make up the matter.

Scientific Question:
Why do the states of matter have the properties that they have?

Objectives	Standards
• Students will explain and illustrate that properties of matter derive from the connections between molecules. • Students will demonstrate their learning on a poster.	**Meets:** 2061: 4D (6-8) #3 NSES: B (9-12) #1 **Addresses:** NSES: A (5-8) #1

Assessment	Abstract of Lesson
Write-up in Astro Journal.	Students will use their bodies to model the connections between molecules in the three states of matter. They then create a poster that illustrates and explains these connections.

Prerequisite Concepts	Major Concepts
• A solid has a definite shape and volume. (Lesson 3) • A liquid has a definite volume but not a definite shape. (Lesson 3) • A gas has no definite shape or volume. (Lesson 3) • An object with a fixed shape will either keep its shape or break into pieces. • A substance with a fixed volume will always take up the same amount of space.	• A molecule is the smallest part of a substance and is composed of one or more smaller parts. • Molecular bonds are the forces that hold molecules together. • Molecular motion is the movement of molecules.

Suggested Timeline (45-minute periods):

Day 1: Engage, Explore, and Explain sections
Day 2: Extend section
Day 3: Evaluate section

Materials and Equipment:

- A class set of Astro Journals Lesson 4: Matter and Molecules*
- Paper and art materials (colored pencils, markers, paints, etc.) for posters
- A class set of Storing and Transporting Matter
- A class set of Molecules and Matter Poster

Preparation:

- Gather materials.
- Duplicate Astro Journals, Storing and Transporting Matter and Molecules and Matter Poster.
- Prepare classroom. (Make sure there's room for the molecular modeling activity in step 3 of Explore.)
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

* A generic Astro Journal and Scientific Rubric are included at the end of Lesson 1. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation

Accommodations

For students who may have special needs:

- Have a partner help write the caption for the poster.
- Have them give an oral report of Storing and Transporting Matter activity

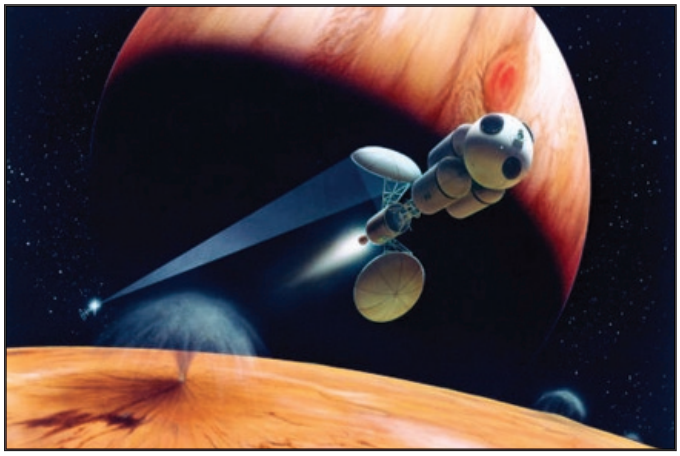
Advanced Extensions

For students who have mastered this concept:

- See Advanced Extensions in Lesson 3.
- Research and report on the relationships among atoms, elements, and molecules.
- Research and report on how molecular bonds work.

Engage

(approximately 10 minutes)



Laser Power Station illustration: Spacecraft drawing energy from local environment; Pat Rawlings, NASA

1. Review states of matter and their properties.

- Question: What are the three states of matter we've been working with and what are their properties?
- *Answer: A solid has a definite shape and volume. A liquid has a definite volume but not a definite shape. A gas has no definite shape or volume. Solids, liquids, and gases take up space.*

---

2. Go over Scientific Question with students.

- Scientific Question: Why do the states of matter have the properties that they have?

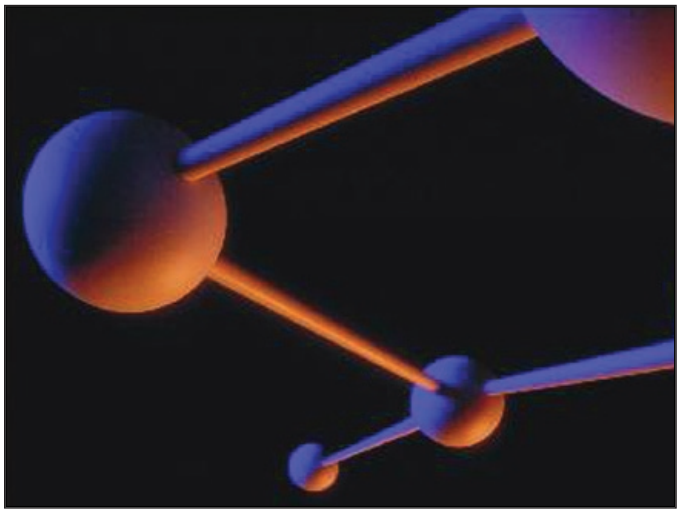
---

3. Record student responses on board/overhead/chart paper.

- Students record their predictions in the Hypothesis/Prediction section of their Astro Journals.

Explore

(approximately 25 minutes)



NIST Program molecule illustration; National Institute of Standards and Technology (NIST)

1. Discussion: Introducing molecules and molecular bonds

- Question: What is the smallest possible unit of a substance?
- *Answer: Molecules. (This is the answer you're looking for.)*

Note to Teacher: Students may respond with "atoms" or "elements." For a substance that is an element, such as gold or lead, an atom is the smallest unit. For all other substances (ones that are made up of more than one element), the molecule is the smallest unit of that substance.

- Question: What holds molecules together?
- *Answer: Molecules are held together by bonds between the molecules called molecular bonds.*

---

2. Check that students understand molecules and molecular bonds.

---

3. Activity: Students will act as "molecules" of a substance in the three states of matter.

Have students first try to figure out the bonds between molecules.

- Question: If a solid has a fixed shape and a fixed volume, what do you think the bonds are like between the molecules, and how could you model this?
- *Answer: The bonds are strong in a solid.*

Note to Teacher: Students should be standing somewhat close together with their hands or wrists linked. They should be vibrating, but not moving around.

Make any corrections to the students' model and explain that even solid matter is made up of atoms and molecules that are moving.

- Question: If a liquid does not have a fixed shape but does have a fixed volume, what do you think the bonds are like between the molecules, and how could you model this?
- *Answer: The bonds between molecules are weaker, allowing the molecules to slide past each other.*

Note to Teacher: Students should now be moving around, but still touching as they pass each other.

Make any corrections to the students' model, and emphasize that the molecular bonds of a liquid are weaker than the bonds of a solid.

- Question: How do the properties of solids and liquids compare with the bonds between those states?
- *Answer: Solids have a fixed shape and have strong bonds between their molecules, which limit movement to vibration. Liquids do not have a fixed shape, and their bonds are weaker allowing the molecules to slide past each other.*

- Question: If a gas does not have a fixed shape or a fixed volume, what do you think the bonds between the molecules are like, and how could you model this?
- *Answer: The bonds are no longer strong enough to hold the molecules together.*

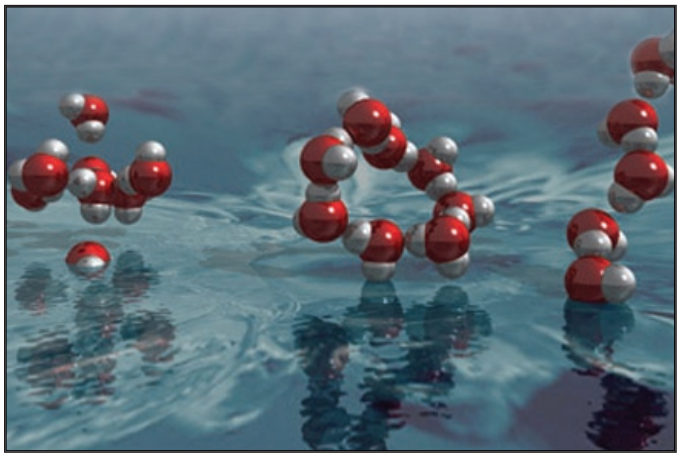
Note to Teacher: The students are moving freely. They should be moving around a little more quickly than when they were liquid, and they should be spread out, rarely encountering each other.

Make any corrections to the students' model and emphasize that the bonds are no longer strong enough to hold the molecules together.

- Question: How do the properties and bonds of a gas compare with the properties and bonds of solids and liquids?
- *Answer: Both solids and liquids have a fixed volume while a gas does not. Both solids and liquids have bonds that are strong enough to keep connections with the molecules. The bonds in a gas are too weak to do so.*

Explain

(approximately 10 minutes)



Water molecule configurations; Advanced Photon Source, USDE

1. Go over the rubric for Journal entries with students.

Note to Teacher: The Astro Journal for this lesson is a little different because the students are not performing an experiment but rather building a model of molecules with teacher direction and assistance.

---

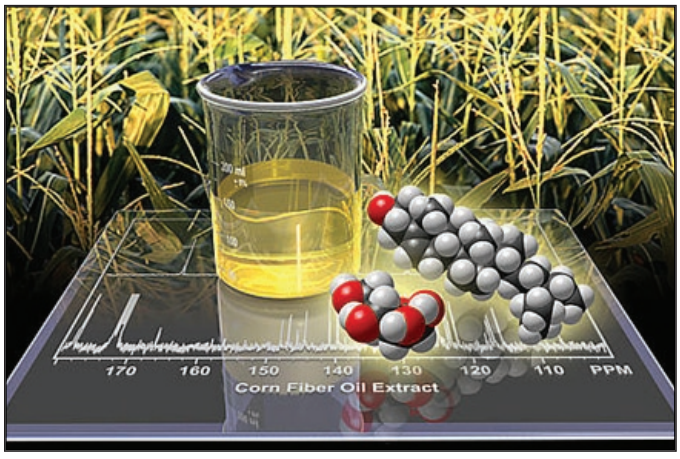
2. Students fill in the Materials and Procedures sections of the Astro Journal.

---

3. Students respond to the Scientific Question in the Results section of the Astro Journal.

Extend/Apply

(approximately 45 minutes)



Pacific Northwest National Laboratory corn molecule illustration, USDOE

1. Review Properties of Matter and Molecules (especially if starting a new class period).

- Question: What are the properties of the states of matter and the molecular bonds that determine them?
- *Answer:*
  - *solid: fixed volume, fixed shape, strong molecular bonds limiting movement to vibration of molecules*
  - *liquid: fixed volume, no fixed shape, weaker molecular bonds allowing molecules to slide past each other*
  - *gas: no fixed shape or volume, extremely weak molecular bonds allowing molecules to move freely*

---

2. Introduce Storing and Transporting Matter activity (student activity sheet and rubric are included with the Lesson 4 Astro Journal.)

- Question: What are some of the liquids that we commonly use?
- *Answer: (Record on the board.) Answers may include: water, milk, juice, soda pop, gasoline, medicines such as cough syrup, etc.*

- Question: What solid items do we commonly use?
- *Answer: (Record on board.) Answers may include: cereal, crackers, vitamins, video tapes, pencils, notebooks, etc.*

- Question: What gases do we commonly use?
- *Answer: (Record on board.) Answers may include: natural gas is often used for heating homes or to power certain appliances. Air conditioning and refrigerators use gas. We might use steam or water vapor to help relieve congestion for a cold.*

- Say: In the following activity, you will apply what you know about how solids, liquids and gases differ to decide how best to store and transport them.

- Highlight the importance of using students' knowledge of matter and molecular bonds to affirm their system for storing and transporting the matter.

---

3. Have students complete the Storing and Transporting Matter activity.

---

4. Have students share and discuss their work.

- Question: What are some considerations you made for storing solids?
- *Answer: Solids have a fixed shape, so it's best if solids can be stacked or contained in rectangular boxes that can be stacked.*

- Question: What considerations did you make for liquids?
- *Answer: Liquids don't have a fixed shape, so they can easily be contained in a stackable container; however, the container must not have any holes for liquid to escape.*

- Question: What considerations did you make for gases?
- *Answer: Gases have no fixed shape or volume, so they must be contained in airtight containers.*

Evaluate

(approximately 45 minutes)

Tanker truck delivering liquid oxygen to kiln burners; EPA

1. Students create a poster that shows the bonds between molecules in the three states of matter.

The assignment is included with the Astro Journal for this lesson. The assignment also includes the evaluation rubric.

- Go over the rubric and expectations with the students. Inform them that they will be self-evaluating their posters when they are done.

Note to Teacher: You may choose to include their self-evaluation as a part of their grade.

---

2. Students create their posters.

---

3. Students fill in the Poster Self-Evaluation section of their Astro Journals.

---

4. Students fill in the Conclusion section of their Astro Journals.

---

5. Students share and discuss their posters.

- Have students look at their classmates' poster and identify good examples of each state of matter.
- Have students explain how the drawings clearly illustrate each state and molecular bonds of each state.

Note to Teacher: After each lesson, consider posting the main concept of the lesson someplace in your classroom. As you move through the unit, you and your students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 4: Matter and Molecules

Name _____ Date _____ Class/Period _____

Scientific Question:
Why do the states of matter have the properties that they have?

1. Hypothesis/Prediction: Why do you think the states of matter have the properties that they have?

2. Materials: What materials were used to model molecular bonds and motion?

3. Procedure: How did the model work?

Astro Journal Lesson 4: Matter and Molecules

Name _____ Date _____ Class/Period _____

4. Data Collection: Record and display your data in a chart, table, picture or graph.

5. Results: Why do the states of matter have the properties that they have?

6. Conclusions: Compare and contrast your predictions and results. How did modeling the molecular bonds and motion change your original ideas?

Activity: Storing and Transporting Matter

Human beings have many uses for matter in all three states. We build things (buildings, tools, and consumer items) out of solids. We consume liquid water, and we use liquid gasoline to power our cars as well as liquid oil to keep the engines running smoothly. Many of our homes are heated with gas (natural gas, propane), and many refrigerators and air conditioning units use some kind of gas as a part of their systems.

For this reason, we need to be able to effectively store and transport matter in all three states. To do so properly, we need to use our knowledge of the properties of the states of matter and of molecular bonds. For example, because of their strong molecular bonds, solids have a fixed shape and a fixed volume. The actual shape of the matter, then, becomes an important factor in designing storage and transportation for it. This is not necessarily the case with gases and liquids.

Assignment:

1. Choose a solid, a liquid, and a gas that humans use on a regular basis.
2. Explain the significance of the substance for humans.
3. Describe and illustrate a system for storing and transporting the matter.
4. Explain how your system deals with the properties of the matter and its molecular bonds. (In other words, how does your system take advantage of the properties and/ or overcome the limitations of the properties?)

Your illustrations will be evaluated using the following rubric:

4 Expectations Exceeded	• Explanations and illustrations are clear and accurate. • Explanation of storage/transport system shows a strong connection to the properties and molecular bonds/movement of the matter.
3 Expectations Met	• Explanations and illustrations are clear and accurate. • Explanation of storage/transport system shows a connection to the properties and molecular bonds/ movement of the matter.
2 Expectations Not Quite Met	• Explanations and illustrations are not completely clear or accurate. • Explanation of storage/transport system shows some connection to the properties and molecular bonds/movement of the matter.
1 Expectations Not Met	• Explanations and illustrations are not clear or accurate. • Explanation of storage/transport system shows little or no connection to the properties and molecular bonds/movement of the matter.

Assignment: Matter and Molecules Poster

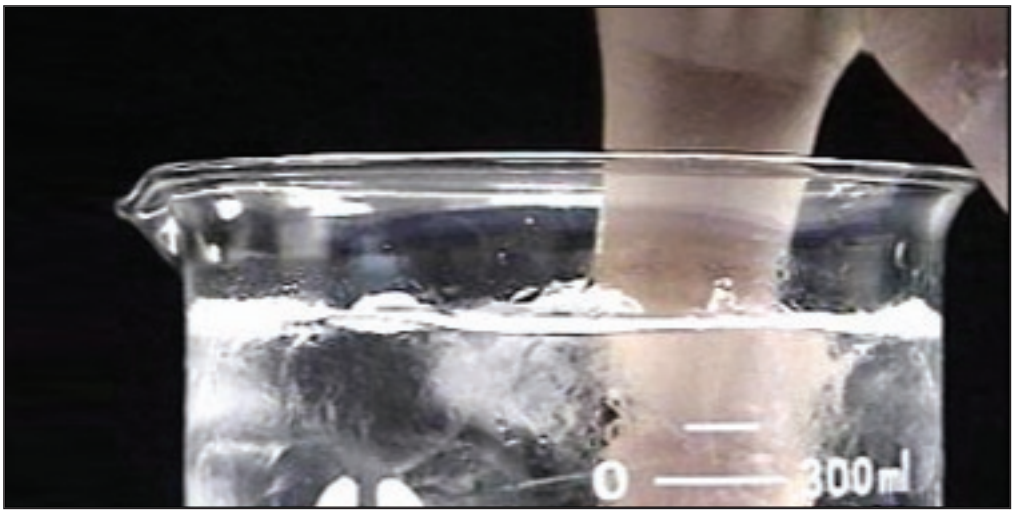
Create a poster that shows the bonds between the molecules and the movement of the molecules in the three states of matter. Your poster should include a caption (or captions) that describe the connections as well as an explanation of the motion. Your poster will be evaluated using the following rubric. Your score will be the number which best describes your work.

4 Expectations Exceeded	• Explanations and illustrations are clear and accurate. • Explanation of storage/transport system shows a strong connection to the properties and molecular bonds/movement of the matter.
3 Expectations Met	• Explanations and illustrations are clear and accurate. • Explanation of storage/transport system shows a connection to the properties and molecular bonds/movement of the matter
2 Expectations Not Quite Met	• Explanations and illustrations are not completely clear or accurate. • Explanation of storage/transport system shows some connection to the properties and molecular bonds/movement of the matter.
1 Expectations Not Met	• Explanations and illustrations are not clear or accurate. • Explanation of storage/transport system shows little or no connection to the properties and molecular bonds/movement of the matter.

Poster Self-Evaluation

Evaluate your performance using the rubric. Give yourself a score and then explain why you think the work deserves that score. Make references to specific parts of your poster when explaining your score.

Lesson 5: Changing States of Matter



Ice water; NASA file photo

Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

Main Lesson Concept:
Matter changes state when temperature changes.

Scientific Question:
What causes matter to change its state and how is this accomplished?

Objectives	Standards
• Students will use an inquiry process to identify temperature as the variable that causes a substance to change from one state to another. • Students will then identify the relationship between temperature and the molecular bonds and movement in a substance. • Students will explain the temperature conditions of a planet necessary for human life.	**Meets:** 2061: 4D (6-8) #3 NSES: B (9-12) #5 NSES: A (5-8) #1 **Addresses:** NCTM: 4, 5, 9

Assessment	Abstract of Lesson
Write-up of inquiry experience in Astro Journal, Test on Part 2: States of Matter.	Students use an inquiry process to determine what causes matter to change state. When they have learned that temperature is the cause, they recreate their physical modeling of molecules and molecular bonds and explore what happens to matter as temperature increases and decreases.

Prerequisite Concepts	Major Concepts
• A solid has a definite shape and volume. A liquid has a definite volume but does not have a definite shape. A gas has no definite shape or volume. (Lesson 3). • Molecular bonds are the forces that hold molecules together. Molecular motion is the movement of molecules. (Lesson 4) • Students should have experience with graphing and applying the correct type of graph for the data that is being represented. A pie chart shows parts of a whole. A line graph shows change over time. A bar chart shows a comparison of amounts.	• Temperature is the variable that causes matter to change state. • Matter tends to expand as temperature increases and to contract when temperature decreases. Water is an exception to this rule.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore – Part 1 sections
Day 2: Explore – Part 2 and Explain sections
Day 3: Extend/Apply and Evaluate – Part 1 sections (30 minutes)
Day 4: Evaluate – Part 2

Materials and Equipment:

- A class set of Astro Journals Lesson 5: Changing States of Matter*
- A class set of Scientific Inquiry Evaluation Rubric
- A class set of States of Matter Test
- Thermometers (approximately 1 for every 3 to 4 students)
- Miscellaneous supplies that students need for the experiments they design (make list after Explore Day 1)
- Chart paper

* A generic Astro Journal and Scientific Rubric are included at the end of Lesson 1. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Preparation:

- Gather materials (e.g., thermometers, miscellaneous supplies).
- Duplicate a class set of Astro Journals, Scientific Inquiry Evaluation Rubric Sheets and States of Matter Test.
- Prepare classroom: (Make sure there's room for the molecular modeling activity in Extend/Apply).
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

Differentiation
Accommodations For students who may have special needs, use a more guided inquiry process.
Advanced Extensions Have students conduct research or an inquiry experiment on the following question: How does pressure affect the molecular bonds and state of matter?

Engage

(approximately 15 minutes)

Restored wetlands in Yolo County, California; Natural Resources Conservation Service, USDA

1. Review Lesson 4.

- Question: What are the properties of the states of matter and the molecular bonds which determine their properties?
- *Answer:*
  - *Solids have a fixed volume, a fixed shape and strong molecular bonds limiting movement to vibration of molecules.*
  - *Liquids have a fixed volume, no fixed shape and weaker molecular bonds allowing molecules to slide past each other.*
  - *Gases have no fixed shape or volume and weak molecular bonds allowing molecules to move freely.*

2. Bridge to this lesson.

- Question: What are the differences between the molecular bonds in solids, liquids, and gases?
- *Answer: Molecular bonds are strongest in solids and weakest in gases.*

- Question: What are the differences between the movement of molecules in solids, liquids, and gases?
- *Answer: The molecules in solids only vibrate. In liquids, the molecules slide past each other. In gases, the molecules spread out freely.*

- Question: How do the strengths of the molecular bonds relate to the movement of the molecules?
- *Answer: As the movement of the molecules increases, the strength of the molecular bonds decreases.*

Note to Teacher: This is true of the bonds between molecules, not the bonds between atoms.

- Question: What could cause the bonds between the molecules to be weaker or stronger?
- *Answer: (The students will probably not be able to answer this. Record their responses if they have some.)*

- The question in another form is the Scientific Question for this lesson.
- Say: We now understand the difference between solids, liquids, and gases, but in order to know what will allow a planet to have the conditions needed for liquid water, we need to understand what causes this change.

3. Introduce Scientific Question and purpose of the lesson.

- Say: The scientific question that we will be exploring is, "What causes matter to change its state and how is this accomplished?"

- Question: Why do we want to know what causes matter to change state?
- *Answer: This will help us to understand the conditions that we need to have liquid water on a planet.*

4. Tell students that they will be conducting experiments and making observations to answer this question.

Explore – Part 1

(approximately 30 minutes)

Scientists taking snow survey readings in Absaroka Mountains, Wyoming; Natural Resources Conservation Service, USDA

1. Elicit some hypotheses from the students.

Go over expectations for hypotheses from the inquiry rubric and model how to revise a hypothesis to improve it (i.e., make it clearer, testable, more specific, etc.).

Note to Teacher: Based on your experience with your class, there are at least 3 ways to proceed from here. Students who would benefit from the opportunity to design their own experiment should do so. If the class is not ready as a whole, you can also do this as a whole-class project in which everyone contributes to one hypothesis and test. You could also work with a group who needs more assistance while allowing those who would benefit to work on their own to do so.

---

2. Put students into groups to refine hypotheses and plan experiments to test them.

Have students record their Hypothesis/Prediction section of their Astro Journals.

---

3. Further model for students how to create a "test" for the hypothesis and demonstrate how the Materials, Procedures, and Data for the test will be recorded in the Astro Journal for this lesson.

Note to Teacher: Make sure that the students are thinking in terms of data—what data they will be collecting, how they will be measuring it, and how it is either going to confirm or refute their hypotheses.

---

4. Give students some time to put together their Materials and Procedures list in order to figure out what data they will be collecting and how they will measure it.

Instruct students to fill out the Procedure section of their Astro Journal.

5. Have students share their hypotheses and experiment plans.

Ask questions to help groups clarify aspects of their plan, but try to avoid giving them the answers.

- Sample Questions:
  - How does this experiment test your hypothesis?
  - What specific data are you collecting?
  - How will this data confirm or refute your hypothesis?
  - How are you going to measure your data?

Note to Teacher: Corrections should be focused on the science process, not the accuracy of the hypothesis. An incorrect hypothesis with a solid experimental plan is fine. A correct hypothesis without a solid experimental plan should be corrected.

6. Ask students for a list of materials they will need to conduct their experiments.

Explore – Part 2

(approximately 25 minutes)

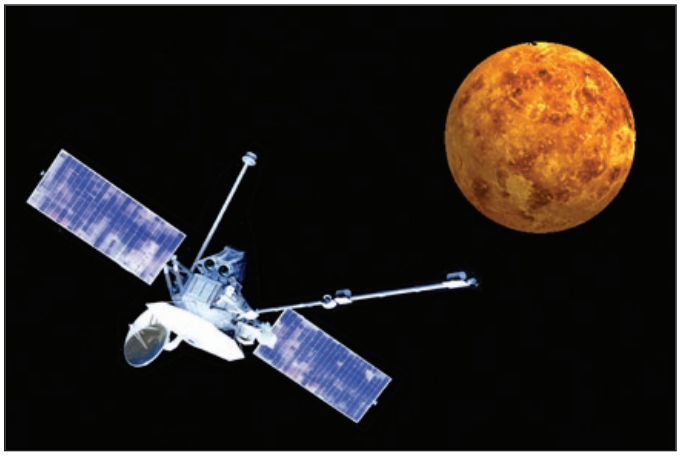


Illustration of Mariner 10 at Venus—photographed without clouds; NAA

1. Have students review their hypotheses and experiment plans and then conduct their experiments.

2. Students perform their experiments and collect their data.

Students record data in the Data section of their Astro Journals.

(Sample Experiment: Many students will identify temperature and heat as the essential factor. One way to test this would be to use ice, water and containers that can be heated. Provide some type of heat source, and thermometers for measuring temperature. The experiment could proceed by measuring the initial temperatures of the samples, and then taking a series of measurements over time as heat is increased. Follow all safety instructions with whatever heat source you and your students use.)

Explain

(approximately 20 minutes)

Lavic Lake, a dry lake bed bordered by a geologically recent lava flow; NASA

1. Instruct students to organize their data into a chart or graph in the Charts and Graphs section of their Astro Journal.

Note to Teacher: You may want or need to do a formal introduction about or review of graphing. Most likely some kind of line graph indicating temperature change over time will be the best way to present the information.

Students may need some assistance in choosing the most appropriate way to graph their data. Sample Questions:

- **How does this graph either support or refute your hypothesis?**
- **Is there any other kind of graph that might better show what the data demonstrates about your hypothesis?**

---

2. Ask some groups to share their hypotheses, data, and what they think their data demonstrates about their hypotheses and what we can learn from each individual experiment and the experiments as a whole.

MISCONCEPTION: Many students may feel that if their hypothesis is not "right" then their experiment is a failure. Emphasize that this is not true. Scientific understanding grows when we eliminate incorrect answers to scientific questions. The success or failure of a hypothesis and experiment is based on the accuracy of the process, not the result. Either way, we learn something.

Extend/Apply

(approximately 15 minutes)

Checking temperature at GLOBE workshop, Rostov, Russia; NASA

1. Have students recreate the molecular bonding modeling that they did in Lesson 4.

- Students begin as a solid (locked tight—vibrating only).
- Say: O.K., now we're raising the temperature. We're turning up the heat. What's happening to the matter?
- *Students should start loosening their connections and moving past each other while continuing to keep contact.*

- Say: Now we're really turning up the heat. The temperature is rising more and more. What's happening to the matter?
- *Students should be moving more quickly and independently.*

- Raise and lower the 'temperature' and have the students adjust their physical model.

---

2. Have students observe what happens to the size of the group of molecules (i.e., the students) as the temperature is raised and lowered.

- Question: As the temperature raises and the matter changes from solid to liquid, then liquid to gas, how does the amount of space that the matter is taking up change?
- *Answer: As the temperature increases, the matter expands and takes up more space.*

- Tell the students that when a substance starts to take up more space, we say it is "expanding".

- Question: As the temperature lowers and the matter changes from gas to liquid, then liquid to solid, how does the amount of space that the matter is taking up change?
- *Answer: As the temperature decreases, the matter contracts and takes up less space.*

- Tell the students that when a substance starts to take up less space, we say it is "contracting."

Note to Teacher: The terms 'expand' and 'contract' will be used in the reading assignment for Lesson 6. Making sure that these concepts are understood will help with that reading.

PROBLEM: There is problem at this point in the lesson, which must be explained. Water is an exception to this tendency. When ice forms, it actually expands (hence experiences such as pipes bursting when frozen in winter and ice cubes rising above the level of the water that was put into the ice tray). There is little way around this since our focus is on water, but the standard requires learning the more general principle. This peculiarity of water derives from the hydrogen bonds in water that form into a special structure that causes the water (ice) to expand. Some students may point this out or you may want to point this out to your students. As the teacher, you're in the best position to know how to introduce this information to your students.

Evaluate – Part 1

(approximately 15 minutes)

Sea ice formed in Arctic Ocean; NASA

1. Have students fill out the Results and Conclusion sections in their Astro Journals.

Emphasize the importance of referring directly to their testing experience and their modeling of molecular bonds.

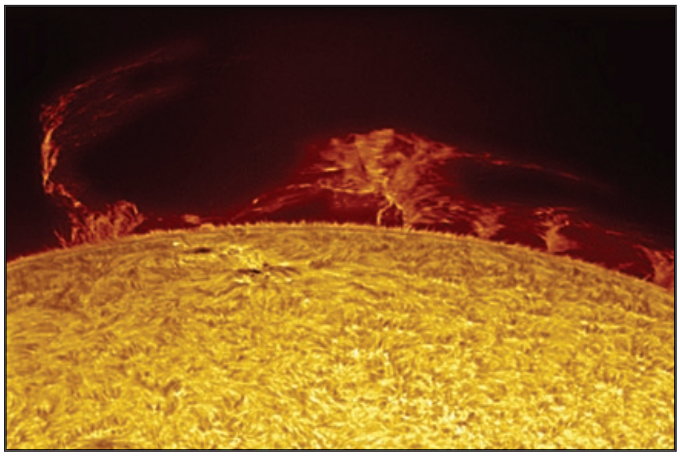
---

2. Discuss the students' results.

- Question: What did you observe causes matter to change its state and how is this accomplished?
- *Answer: Temperature changes states of matter by increasing or decreasing the motion of the molecules and causing changes in the molecular bonds.*

Evaluate – Part 2

(approximately 45 minutes)



Solar prominence as imaged from Earth; NASA

1. Review Lesson 4 and Connect to Lesson 1: Unit Introduction

- Review the requirement for human survival that students explored in Lesson 1:
  - food (plants in particular)
  - water
  - oxygen
  - moderate temperature (average global temperature of less than 50° Celsius.)
  - protection from high levels of radiation
  - other requirements the students found

- Question: If the average temperature of the Earth were lower, what would happen to any liquid water which was present?
- *Answer: The water present would freeze.*

- Question: What would happen to the Earth's ability to support life?
- *Answer: Earth's ability to support life would be reduced, if not eliminated.*

- Question: If the average temperature of the Earth were higher, what would happen to any liquid water?
- *Answer: The liquid water would boil away.*

- Question: What would happen to the Earth's ability to support life?
- *Answer: Earth's ability to support life would be reduced, if not eliminated.*

---

2. Part II Evaluation

- Give the States of Matter test (found at end of Astro Journal).

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 5: Changing States of Matter

Name _____ Date _____ Class/Period _____

Scientific Question:
What causes matter to change its state and how is this accomplished?

1. Hypothesis/Prediction: What do you think causes the change? Why?
2. Materials: What materials will you use to test your hypothesis or prediction?
3. Procedure:

Astro Journal Lesson 5: Changing States of Matter

Name _____ Date _____ Class/Period _____

4. Data Collection: Record and display your data in a chart, table, picture or graph.

5. Results: What causes matter to change its state and how is this accomplished?

6. Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the molecules change your original ideas?

States of Matter Test

Name _____

Directions: Answer the following questions in complete sentences. Make sure to clearly explain your ideas and use specific examples. Include illustrations or other visual information to help with your responses.

1. Explain and illustrate the different states of matter and their properties (such as shape and volume) in terms of the strength of the bonds between molecules and how the molecules move.

Illustrations:

2. Explain and illustrate what happens to bonds between molecules and to the motion of molecules as the temperature increases. Use a solid as the starting point.

Illustrations:

3. What temperature requirements must a planet have in order to support human life?

States of Matter Test — Correction and Scoring Guide

1. Explain and illustrate the different states of matter and their properties (such as shape and volume) in terms of the strength of the bonds between molecules and how the molecules move.	
Solids have strong molecular bonds and little molecular motion. The molecules only vibrate. That's why they retain their shape and volume. Liquids have weaker molecular bonds, which allow for more motion. The molecules can slide past each other. This is why liquids do not retain their shape. The molecules can slide around each other to fit whatever is containing them. However, they do maintain the same volume. Gases have very weak bonds, which allow for great molecular motion. In fact, gas molecules rarely encounter each other. This is why gases do not have a fixed volume or shape. They can spread out until they are contained by something. All three states of matter take up space.	

2. Explain and illustrate what happens to bonds between molecules and to the motion of molecules as the temperature increases. Use a solid as the starting point.	
As the temperature increases, the molecules move faster. For example, as the molecules in a solid warm up, the molecular bonds start to loosen and the molecules start moving faster. As they are able to slide past each other more easily, the solid becomes a liquid. As the temperature keeps increasing, the molecules move faster and faster. Eventually, they are moving fast enough to break free of each other. At this point the liquid becomes a gas.	

3. What temperature requirements must a planet have in order to support human life?
There are many possible answers here. Evaluate the responses according to the strength of the student's reasoning and his or her use of examples. The most important part is that the temperature must be within a range that allows water to be liquid at all times. Too cold will not work, because water will freeze. Too hot will not work, because water will evaporate.

Scoring the Test:
A simple way to score the test is the following. Each question can be worth 5 points for a total of 15 points possible. Assign scores to each question based on accuracy, completion, and use of specific examples. The chart below has a sample table to convert the scores to rubric scores or grades. You may use this or come up with your own scoring system. You may also adjust to include plus or minus grades.

Test Score	Rubric Score	Grade
15, 14, 13	4	A
12, 11, 10	3	B
9, 8, 7	2	C
<7	1	D or F

Prerequisite Concepts	Major Concepts
• Scale is a set of ordered marks on a measuring instrument, usually with numbers in equal or fixed increments. • Molecular bonds are the forces that hold molecules together. (Lesson 4) • Molecular motion is the movement of molecules. (Lesson 4)	• Temperature measures the motion of molecules in a substance. • Thermometers have a liquid inside that expands when heated. • Celsius, Fahrenheit and Kelvin are different temperature scales.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore sections
Day 2: Explain and Evaluate sections

Materials and Equipment:

- A class set of Astro Journals for Lesson 6: Measuring Temperature*
- A class set of Measuring Temperature reading
- Water samples (hot and cold tap water)
- Thermometers (approximately one for every three to four students)

* Digital thermometers will not work for this activity.

Preparation

- Duplicate Astro Journals Lesson 6 and Measuring Temperature Reading.
- Gather materials
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

* A generic Astro Journal and Scientific Rubric are included at the end of Lesson 1. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation

Accommodations

For students who may have special needs:

Provide extra support for the reading assignment (e.g., partner, read aloud, etc.).

Advanced Extensions

For students who have mastered this concept:

- Have students perform conversions between temperature scales.
- Have students explain how the freezing point of water is used to help convert among the Fahrenheit, Celsius, and Kelvin temperature scales.
- Research and Report on how a thermometer is calibrated.

MISCONCEPTIONS (Teacher Background):

There are three related misconceptions about heat and temperature that may appear at various points in this lesson. What they all have in common is that they derive from our experience with temperature. Whatever questions or misconceptions come up, keep students focused on the idea that temperature is measuring the movement of molecules and atoms. The suggested activities below can be done whenever the misconceptions or questions come up during the lesson.

1. Heat is the kinetic energy (or movement) of all molecules in a system. Temperature is the measure of the average kinetic energy (or movement) of the molecules of a system. People tend to think of temperature in terms of "hot" and "cold". The problem with this is that "hot" and "cold" need some reference points in order to have value. The temperature of 101 degrees Fahrenheit (F) may be a "hot" day (to some people), but it would be too "cold" to do most kinds of baking or cooking in an oven. What we as people experience as "hot" and "cold" are actually experiences of heat transfer. Heat tends to transfer from where there is a higher temperature to where there is a lower temperature. On that same 101°F day, the temperature of the air around us is higher than our own temperature (98.6°F) so we experience warmth and call the day, "hot."

   - Questions that can help bring out this misconception are: What is heat? What is temperature? What does it mean to be hot? How could you explain heat in terms of the motion of molecules?
   - For students struggling with this idea, consider the following activity (you'll need warm and cold water – both samples safe to touch). Choose a test object in the classroom that should be at room temperature. Have the student put her or his hand in the cold water and then touch the test object. Because the hand has been cooled, the student should experience the object as "warm." The student should then put his or her hand in the warm water and then touch the test object. Because the hand has been warmed, the student should experience the object as cool. The temperature of the object hasn't changed only the student's perspective on it.
   - Heat transfer can also be modeled physically. Think about billiard balls or marbles. If two balls that are moving at different speeds hit each other, the faster one will slow down and the slower one will speed up. Put students into two groups: one that is "warmer" (moving more quickly) and one that is "cooler" (moving very slowly). Have the two groups mix. As a "warmer" molecule bumps a "cooler" molecule, the warmer one slows down (becomes cooler) while the cooler one speeds up (becomes warmer). Make sure that the students are not too "enthusiastic" when making contact with each other.

2. People sometimes refer to the heat "in" an object, the heat "in" the air or the heat "in" us. This implies that the object is a container for the heat. This is not really true. When heat transfers from one object to another, the movement of the atoms and molecules of the first object slow down (on average) while the movement of the atoms and molecules of the second substance speed up (on average). This transfer will occur until the atoms and molecules in both objects are moving at the same average speed. The heat, then, is not "in" the object but is a quality "of" the object. To demonstrate this understanding, it is more accurate to refer to the heat "of" a substance. This is not to suggest that you mechanically correct students who say "in" as opposed to "of", but rather that you consider that a student who persistently uses "in" might not truly understand what heat is and how it relates to molecular bonds and motion.

3. When we touch an object that has a lower temperature, heat transfers from us to the object and we experience that object as "cold". Because the experience of "cold" is as real as the experience of "hot", people tend to think of "cold" as being a type of energy in the same way that heat is a form of energy. For example, students might think that refrigerators and air conditioners are devices that create cold energy. In truth, these devices work by removing heat energy just as our experience of a "cold" object is the experience of heat from us transferring to the object.

   - For students who don't believe this, have them find a refrigerator or air conditioner and find the part of the device that vents the heat.

Engage

(approximately 15 minutes)

Researchers inspect heat exchanger for advanced heat pump systems; Oak Ridge National Laboratory, USDOE

1. Review Lesson 5.

- Question: What causes matter to change state and how does it do so?
- *Answer: Temperature causes the change by changing the movement of the molecules and the strength of the molecular bonds.*

Note to Teacher: This is true for the molecular bonds between the molecules, not the atomic bonds holding each individual molecule together.

2. Bridge to this lesson.

- Question: So if raising temperature causes molecules and atoms to move more, and lowering temperature causes molecules and atoms to move less, what is temperature really measuring?
- *Answer: The movement of the molecules and atoms. The students may also respond with 'heat'.*

- Question: So what does heat have to do with temperature?
- *Answer: Heat is the energy that causes the molecules and atoms to move. Temperature is the measurement of heat.*

- Question: What about cold? What does it have to do with temperature?
- *Answer: Cold is a word used to describe something that has less heat energy (i.e. less molecular motion) than whatever it is being compared with.*

- Question: Do objects that are 'cold' have any heat in them at all?
- *Answer: Yes, just less than whatever it is being compared with.*

3. Introduce the purpose of the lesson.

- Question: When do we measure temperature and why?
- *Answers may include: We measure heat outside to decide what to wear or to be prepared for ice or snow. We measure the temperature of the refrigerator to make sure that food doesn't go bad. We measure the temperature of the oven so that we can bake food evenly. We measure the temperature of our bodies to see if we have a fever. Measuring temperature allows us to have a common language to compare temperatures accurately such as the temperature of Los Angeles with the temperature of New York.*

- Say: So there are many uses for measuring temperature, since we know that at certain temperatures substances do different things, and we want to be prepared for those changes or we want to control them.

- Question: Thinking about our habitable planet, how might measuring temperature be useful in determining what will make our planet habitable to humans?
- *Answer: By measuring the temperatures that the human body can stand, we can tell what our limits are for temperatures that are too hot or cold. These limits give us a good idea of the temperature range needed for human survival. If we then measure the temperature of a planet or moon, we can tell if its temperature falls in this range.*

- Say: Since measuring temperature is so important in science, we are going to look at how this is done.

4. Introduce the Scientific Question for the lesson:

- What does temperature actually measure and how do we measure it?
- Students record their predictions in the Prediction section of their Astro Journals.

Explore

(approximately 30 minutes)

Mercury thermometer; NASA file photo

1. Engage students in an exploration of how a thermometer works.

- Depending on your class, you may want to give a hint – it involves a small change in the movement and the bonds of the substance in the thermometer (most likely alcohol in a school thermometer).
- Ask students the Exploration question and have a few predict a response orally (How does a thermometer work?).
- Pass out thermometers and samples of hot and cold water to groups.
- Have students use the thermometers in the water samples and closely observe what happens.
- Elicit some sample responses and view some illustrations. If the students are not making the connection to a changing state of matter, give them the hint or ask, Could a change in the motion of molecules and molecular bonds have anything to do with how a thermometer works?
- Students record their observations and create illustrations in the Exploration section of their Astro Journals.
- Have students discuss in their small groups what they wrote and illustrated. Then have a spokesperson from each group share what the group agreed upon as their explanation. Help students to provide reasoning for their explanations.

Note to Teacher: Students should conclude that the water molecules are moving more quickly than the molecules of the substance in the thermometer. The movement of the molecules of the water cause the molecules of the glass to start moving more quickly which causes the molecules of the substance in the thermometer to move more quickly which causes the substance to expand.

Explain

(approximately 30 minutes)

Spring thermometer; NASA file photo

1. **Have students complete the Measuring Temperature reading.**

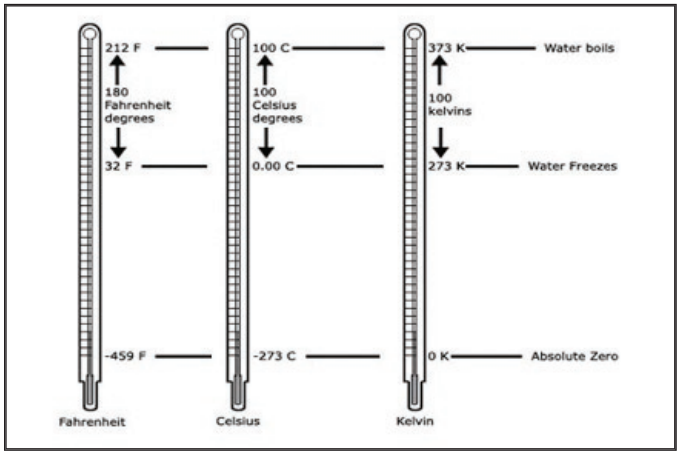
---

2. **Have student complete the questions for the reading in their Astro Journals.**

Discuss with students different temperature scales, when each is useful in science and what they are based upon.

Evaluate

(approximately 10 minutes)



Fahrenheit, Celsius, and Kelvin temperature scales; NASA

1. **Discuss students' results.**

- Question: What does temperature actually measure?
- *Answer: Temperature measures the movement of atoms and molecules in a substance.*

- Question: How do we measure temperature?
- *Answer: We use a thermometer to measure temperature. The liquid inside of the thermometer expands when it becomes hotter and contracts when it becomes cooler. The amount that it expands or contracts is measured with a certain scale: Celsius, Fahrenheit or Kelvin.*

---

2. Have students fill out the Results and Conclusion sections in their Astro Journals.

Emphasize the importance of referring directly to their testing experience in explaining how they either changed or confirmed their hypothesis.

---

3. Discuss student responses to ensure that they have mastered these concepts.

- Question: What does temperature actually measure?
- *Answer: Temperature measures the movement of molecules in a substance.*

- Question: How do we measure temperature?
- *Answer: We use thermometers and the scales of Celsius, Fahrenheit or Kelvin. Thermometers have a liquid inside that expands when heated.*

---

4. Collect Astro Journals and evaluate using the Scientific Inquiry Evaluation Rubric.

Focus on students understanding of temperature as the measurement of the motion of molecules and the use of thermometers and different scales to measure temperature.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 6: Measuring Temperature

Name _____ Date _____ Class/Period _____

Scientific Question:
What does temperature actually measure and how do we measure it?

1. Hypothesis/Prediction: What do you think temperature actually measures and how do we measure it?

2. Materials: What materials will you use to investigate?

3. Exploration: How does a thermometer work? Record your observations and illustrate below.

Astro Journal Lesson 6: Measuring Temperature

Name _____ Date _____ Class/Period _____

4. Questions from reading: Carefully read the questions and respond using complete sentences.

Why is measurement important in science?

What qualities does mercury have that makes it a good substance to use in a thermometer? What do these qualities have to do with molecular motion and bonds?

How did Anders Celsius create his temperature scale?

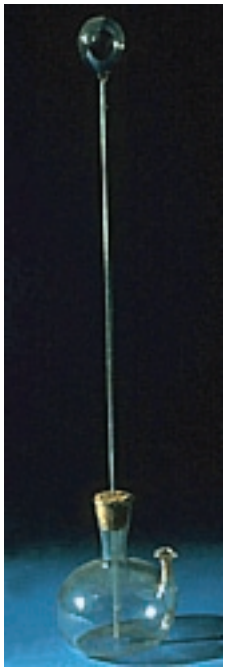
What is absolute zero and what does it have to do with the motion of molecules?

5. Results: What does temperature actually measure? How do we measure temperature?

6. Conclusions: Compare and contrast your predictions and results. How did modeling the molecular bonds and motion change your original ideas?

Measuring Temperature Reading

"When you can measure what you are speaking about and express it in numbers, you know something about it."
Lord William Thomson Kelvin (1824–1907)

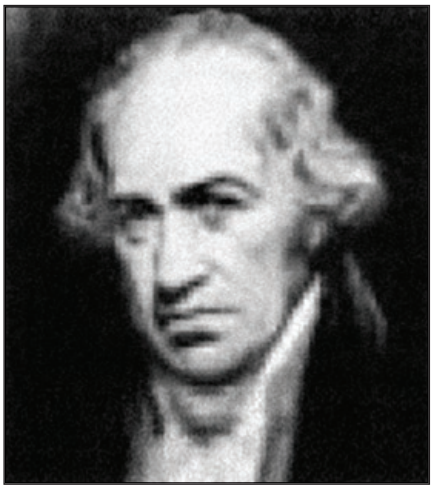


Replica of thermoscope built by Galileo in 1597; California Energy Commission

There are two requirements for taking a measurement of something. The first is a tool for taking a measurement. The second is scale for making sense of the numbers of the measurement. For example, a ruler is often used to measure short lengths. It is the tool for measurement. On the ruler are one or more number scales with equally spaced numbers. These numbers can be compared with numbers from any other ruler that is accurately set to the same scale. Measuring length is far simpler than measuring temperature. While there is evidence of tools for measuring length at various times in human history, tools and scales for measuring temperature do not appear until more recent human history.

Early thermometers, called thermoscopes, first appear in the 1500's. They were crude instruments that were not at all accurate. Most did not even have a number scale associated with them. This made them useless for most practical purposes.

Gabriel Fahrenheit created the first accurate thermometer in 1714, and the Fahrenheit temperature scale followed it in 1724. The thermometer's accuracy was based on its use of mercury, a silver colored substance that remains liquid over a wide range of temperatures but expands or contracts in a standard, predictable way with changes in temperature. To set the scale, Fahrenheit created the coldest temperature that he could. He mixed equal parts of ice, water, and salt, and then used this as the zero point, 0 degrees, of his scale. He intended to make 30 degrees the freezing point of water and 90 degrees the temperature of the human body, but he had to later revise these temperatures to be 32 degrees and 96 degrees. In the final version of the scale, the temperature of the human body became 98.6 degrees.

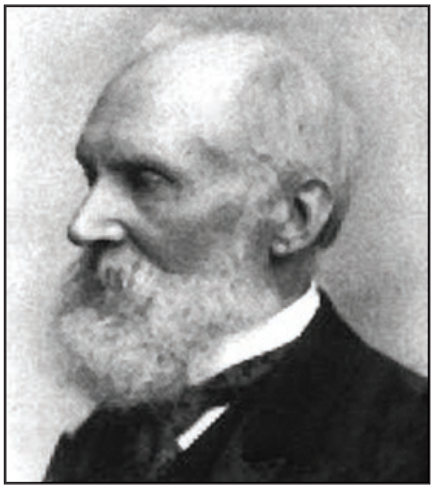


German physicist, Daniel Gabriel Fahrenheit (1686–1736)

Swedish astronomer Anders Celsius (1701–1744)

In 1742, Anders Celsius recommended that the scale on the mercury thermometer be adjusted so that 100 degrees occurred at the freezing point of water and 0 degrees occurred at the boiling point of water. The range between the boiling and freezing points were divided into 100 equal parts. For this reason, the scale was first called the Centigrade scale ('centi' being the prefix for one hundredth). He also made the measurement of those key points more precise. The scale did not become truly popular until after Celsius's death when the measurements for the freezing and boiling points were switched. 0 degrees was set at the freezing point of water, while 100 degrees became the boiling point of water. In 1948, the Centigrade scale became officially known as the Celsius scale in honor of its creator.

The Celsius scale is the most commonly used temperature scale in the world today, but it is not the best scale for every use. Certain formulas used to predict weather do not work if the number for temperature is a negative number. Since the temperature of the air can easily be lower than the freezing point of water, scientists need a different scale. The scale they use is called the Kelvin scale, named for Lord William Thomson Kelvin who created it in the mid-1800's. Kelvin was able to calculate the coldest that anything in the universe could ever be. This became the zero point of his scale. 0 Kelvin is 273 degrees on the Celsius scale. It is also the temperature at which molecules and atoms have the least possible motion. For this reason, 0 Kelvin is also called "absolute zero." There can be nothing colder.



Scottish mathematician and physicist, Lord William Thomson Kelvin (1824–1907)

Scientific Inquiry Evaluation Rubric For Evaluating Astro Journal Entries

Component	Expectations
Hypothesis/Prediction	• Clearly stated • Specific enough to be testable/observable and give a meaningful result • Has basis in solid information or observations and a logical reasoning process
Materials, Procedures, and Data	• Clearly stated • Complete • Accurate and tied directly to hypothesis and Scientific Question
Results	• Clearly stated • Refers directly to Scientific Question and data • Draws a reasonable conclusion from that data
Conclusions	• Clearly stated • States how hypothesis/prediction was confirmed and/or altered • Refers directly to findings, observations, and/or data to explain why thoughts were changed.

Scoring Metrics

4	Expectations Exceeded
3	Expectations Met
2	Expectations Not Quite Met
1	Expectations Not Met