Phase Changes
(Four Class Periods)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Physical Science

Grade Level: Middle School (7-8)

Materials

- 600 ml glass beaker (for each group)
- 200 ml ice (for each group)
- Assortment of glass beakers
- Sand
- Food coloring
- Ziploc bags
- Salt
- Coffee Filters
- Liquid Gallium (order on Amazon)
- Rubber bands
- Insulated foam
- Reflective coatings
- Strong metals
- Biodegradable materials

STANDARDS

Next Generation Science Standards

- **MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- **MS-PS1-3.** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- **MS-PS1-1**. Develop models to describe the atomic composition of simple molecules and extended structures.

Mathematics Standards | Common Core State Standards

- MP.2 Reason abstractly and quantitatively. (MS-PS1-1)
- MP.4 Model with mathematics. (MS-PS1-1)
- 6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-1)
- 6.NS.C.5 Understand that positive and negative numbers are used together to describe

quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS1-4)

- 8.EE.A.3 Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. (MS-PS1-1)

English Language Arts Standards | Common Core State

- RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions (MS-PS1-3)
- RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-1),(MS-PS1-4)
- WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-PS1-3)

LESSON OBJECTIVE(S)

Students will be able to:

- Plan and conduct an investigation to test a hypothesis
- Collect and display data - a phase change diagram for ice
- Communicate molecular motion changes during phase changes
- Research properties of materials
- Design and build container for an extreme environment
- Test designs for success, analyze and communicate results

CAREER CONNECTION(S)

Mentor Background: Dr. Brendan Hanrahan - received his B.S. degree in Ceramic and Materials Engineering from Clemson University in 2006, and the M.S. and Ph.D. degrees in Materials Science and Engineering from the University of Maryland in 2009 and 2013, respectively. For his Ph.D., Brendan determined the fundamental materials properties dictating the performance of micro ball-bearing platforms, which could serve as enabling technologies for future microsystems.

STEM Careers: Materials Engineer, Materials Scientist, Mechanical Engineer, FerroElectric Scientist, Clean Room Technician, Nanoscientist

ENGAGEMENT

Duration: One to two class periods.

Brief Description: Students will observe a beaker filled with ice and water, make and record observations, then create a hypothesis about where the water comes from that is formed *outside* of the beaker. Students will create their own procedure using the list of materials available, to provide evidence that supports or refutes their hypothesis. Students will perform their procedures and share their findings.

Procedures:

*The teacher will need to prep the beakers before the students enter the classroom. Teacher places a glass beaker that is filled with ice and water at each group. **Condensation Beaker Slideshow**

Students enter the class and retrieve their notebooks, or Student Handout, and pencils. Teacher prompts the students to observe the beakers on the desks, to look at the beakers and to also touch the beakers. After a few minutes of open exploration, the teacher will have students fill in box 1 of their handout.

In Box #1: Write down what you notice and feel.

Allow time for students to record their thoughts, then have students discuss what they wrote with their partner. The teacher will now lead a whole class discussion allowing time for students to share out what they noticed and felt, or what their partner noticed and felt. (The goal of this is to elicit the response that they noticed and felt water on the *outside* of the beaker). After eliciting the target response, the teacher asks the entire class "Who noticed that there was water on the outside of the beaker?" Then ask "How do you think it got there?" Allow time for students to think quietly to themselves, then have them fill in box 2 of the worksheet.

In Box #2: Using the picture of a beaker, create a visual representation of what you observed, and provide a written explanation for *where you think* the water on the outside of the beaker is coming from. (Encourage students to fully explain the phenomena observed. If a student uses the term "condensation" prompt them to explain in detail what that means, to diagram that process).

Allow time for students to record their thoughts independently. As students work, the teacher is observing and prompting students to include more details, more diagrams, more explanation. Have students share their thoughts and drawings with their partners. The teacher will now lead a class discussion about the ideas students have that explain where the water comes from that ends up on the *outside* of the beaker.

The teacher will now challenge the students to create a procedure that will provide evidence that supports their hypothesis of where the water on the outside of the beaker comes from. . The teacher will show the class the materials that are available to them (plastic bags, sand, salt, assorted beakers, food coloring, paper towels, assorted cups,water, ice, etc). Students will work in their groups to create a procedure that provides evidence that supports their ideas of where the water comes from (the water

formed on the *outside* of the beaker). Give students time to discuss, and then fill out box #3 of their worksheets.

In Box #3: Create a procedure, using only the available supplies, that will help you to determine where the water on the *outside of the beaker* is coming from.

The teacher observes student work, and uses questions, prompts, and cues to elicit greater detail. The teacher will read through the procedures from each group, and then allow each team access to the materials to begin carrying out their procedures. Students carry out their procedures. Students then fill in box #4 of their worksheets.

In box #4: Draw a picture of what you did and what your results were. Describe how this gives you evidence to determine where *the water on the outside of the beaker* came from.

The teacher observes students working, then leads a class discussion about what each group tried and what they were able to conclude from their experiment.

EXPLORATION

Brief Description: Students will perform the Heat of Vaporization lab, collect data Data Table and then create a phase change diagram for water.

Procedures:

The teacher will quickly review the results from the 'engage' activity by showing the slides **(Heat of Vaporization Lab).** The teacher will explain that the water from outside of the beaker is the result of a phase change, the water molecules in the air (gas phase) touch the outside of the beaker, lose heat energy (get cold), and undergo a phase change, becoming liquid water.

The teacher then explains that today the students will use ice again, and find out what is necessary for a phase change.

*This lab uses hotplates, make certain that your students have been trained to use hotplates and know the first aid protocols if an accident occurs.

Each group will need a hotplate, 600 ml beaker filled with 200 ml of ice, goggles for all students, a timer, and thermometers.

Students retrieve the materials, put on goggles, take the initial temperature of their ice, place the beaker on the hotplate, and turn on the hotplate to medium or high. Students will take the temperature of the ice inside of the beaker every 30 seconds for about 20 minutes. The goal is to allow enough time for the ice to melt, and then for the water in the beaker to begin to boil. The teacher will observe students as they work to ensure that proper behaviors are being followed and that all students are recording the data.

Once the data is collected, students will put away their equipment.

Students will now need graph paper and colored pencils. The teacher will lead the students in setting up their graph paper x and y axis. The x axis needs to be time, and the y axis needs to be temperature. Students will label their axis, then begin to plot their points on the graph. The teacher will need to observe, and provide small group instruction as needed. When students finish plotting their points, they should then connect the dots to create a line. Students also need to indicate on their graphs the time that all of the ice melted, and the time that the water began to boil.

Teacher will lead a class discussion about the graph results. Students will either turn in graphs or glue into notebooks.

EXPLANATION

Brief Description: Students will engage in active note-taking and processing of information.

Procedures:
*Students will need to reference the graph that they created in the "Explore" phase.

The teacher will use direct instruction and videos to engage students in active note-taking and processing of new information.

Students will watch a short video and then add information to their notes. The information added to their notes will be:
A diagram of the phase of matter (drawing of the molecules)
Describe the force of attraction of the bonds between molecules
Describe the shape of the phase
Describe the volume of the phase
Describe the movement of the molecules

Teacher will play THIS VIDEO: STATES OF MATTER while students fill in the information in their worksheet. The Teacher may need to play the video and pause after each phase of matter is explained to provide time for the students to write down information in their worksheet.

After showing the video, and taking notes, students will be given time to discuss the notes with their groups. The teacher will then ask the class "What is necessary for a phase change to occur?" Students will be given time to think independently, then to discuss ideas with their partner and group. The teacher will then lead a brief class discussion. Students will then be given time to fill in the bottom section of their worksheet.

Students will then be asked to review the graph they created in the "Explore" Heat of Vaporization Lab. The teacher will ask the class "What happens when the line is horizontal?" Students will be given time to discuss with partners and groups. The teacher will then lead a brief class discussion.

The students will watch THIS VIDEO: PHASE DIAGRAMS to learn about phase diagrams.

Students will make notes on their graphs that explain that when the line is horizontal, the heat energy is being used to break the bonds between the molecules - which is why the temperature is not increasing.

Students will either turn in their graphs or glue them in their notebooks.

To complete this phase of the lesson, the teacher will show the slides and explain that each material has its own melting point and heat of vaporization. Students will then watch THIS VIDEO: GALLIUM to learn about Gallium, and its unique melting point. While watching the video, the teacher passes out samples of gallium for students to explore. Follow all safety guidelines if allowing students to handle the gallium directly.

ELABORATE

Brief Description:

In this phase, students will explore the properties of materials and their reactions to extreme environmental conditions such as heat, cold, and pressure with the goal of designing a container that can safely transport important samples from Mars. The project culminates in testing their containers to observe and analyze how well they perform under simulated extreme conditions.

Procedures:

Teacher will discuss the project and objectives with students. Show Google Slides presentation to engage students and explain their tasks. Teacher will explain that students have been tasked with creating a container to carry important samples from the surface of Mars, back to Earth for study. Remind students to take into consideration all the extreme conditions their container might encounter in space flight, or on the surface of Mars.

Teacher will place students into groups and advise them of the five materials they may choose from for their build (gallium, iron, aluminum, steel, copper). Teacher will further explain that students will be conducting research on the available materials prior to beginning the building phase of their project and remind them to recall their prior knowledge of phase changes from the Heat of Vaporization lab and their notes to assist them in choosing the most appropriate material.

Teacher will provide each student with a research recording sheet to document their findings. Remind students that they should use reputable sources in their research and create a detailed record of their findings.

Students will spend one class period collecting research and documenting their findings as well as justifications for why they believe one material will outperform the others. Teacher should check in with each group and as guiding questions to elicit deeper scientific thinking. Teacher will discuss with

students how temperature can cause materials to expand or contract which can affect their strength and integrity. Humidity can cause corrosion, degradation and mold growth. Pressure changes can have an impact on sealed containers, and light exposure can degrade certain materials. Solicit input from students on real life experiences related to temperature, humidity, pressure, and light.

After students have completed the research phase and are ready to begin their draft design, teacher should post a list of available materials to be used to simulate environmental conditions their container might encounter. See below:

Materials:

- Various materials for container construction (e.g., plastic, aluminum foil, gallium, etc.)
- Hot plate or heat source
- Ice or freezer
- Pressure chamber (optional, can be simulated in discussion)
- Safety goggles and gloves
- Thermometers (digital or traditional)

Day 1: Understanding Materials and Extreme Conditions

Introduction (15 minutes):

Begin by discussing with students the concept of extreme environmental conditions (e.g., extreme heat, extreme cold, high pressure) and why it's important to design containers that can withstand such conditions. Ask students to recall prior knowledge of extreme environmental conditions they are familiar with or have experienced.

Activity 1: Material Research (30 minutes): Teacher will provide students with a list of materials they can choose from, including gallium. Each student or group selects three materials from the list (gallium, iron, aluminum, steel, copper) to research. Instruct students to use reliable sources (books, websites) to gather information about their chosen material, focusing on its physical properties and how it reacts to temperature changes and pressure. Teacher will ask students to predict and record how they think their chosen material will change its state (solid, liquid, gas) in extreme conditions. Encourage them to justify their predictions based on their research.

Discussion (15 minutes): Facilitate a class discussion where students share their findings about their chosen materials. Guide them to think about how each material might behave in extreme heat, extreme cold, and high-pressure environments.

- What extreme conditions do you expect to encounter on the journey to space, and on Mars?
- How could changes in pressure, heat and humidity impact your chosen material?
- What are the potential pitfalls to your chosen material?

Activity 2: Predicting Material Behavior (30 minutes): Ask students to predict and record how they think their chosen material will change its state (solid, liquid, gas) in extreme conditions. Encourage them to justify their predictions based on their research.

EVALUATION

Brief Description: Students will use knowledge gained from previous parts of the unit and their research to construct their container. Students will work in their groups to develop a working prototype they can test using either simulated conditions or the provided supplies.
After building their container, students will be given 30 minutes to test its viability and make any changes they believe would result in a better build. Teacher will end with a class discussion regarding the results obtained and possible solutions to problems they may have encountered.

Procedures:

Day 2: Designing and Testing the Container

Introduction (10 minutes):

Teacher will facilitate class discussion regarding the previous day's assignment. Have students provide feedback on how they conducted their research and any surprising findings. Teacher should have students engage in group discussions to determine which available materials might best mitigate the potential environmental impacts and how they believe their container should be designed.

Teacher will instruct students to sketch a draft of their container and make a list of items they might need in order to build and test their device. Students should be instructed to gain teacher approval of sketch design prior to beginning their build.

Once all teams have been granted a building permit, teacher will explain to students their design should protect their collected specimens and provide easy access for scientists on the ground while maintaining its environmental controls.

Container Design (40 minutes)

Students will spend approximately 45 minutes working on their build and determining what tests they would like to perform to test their design. Teacher will facilitate materials collection and monitor

students progress and teamwork throughout the build process.

Testing the Container (30 minutes)

Once students have completed their container, they will conduct tests to determine the container's viability. Teacher may instruct students they will have an additional 15 minutes to make any modifications they feel would be beneficial prior to a final test.

Conclusion and Discussion (20 minutes):

Teacher will advise students when time is up and tell them it is time for the grand reveal! Each team will present their container design, explain its features, and demonstrate its effectiveness in protecting the specimen. Judges (school admin) will evaluate the containers based on creativity, scientific accuracy, and practicality.

Teacher will facilitate group presentations, culminating in a whole class discussion that allows students to reflect on the challenges faced and lessons learned during the mission. Discuss how understanding the changes in matter due to environmental conditions helped improve your container designs. Ask students to consider how these principles could be applied to future scientific explorations and engineering projects.

Teacher will Ask students to reflect on what jobs/fields might conduct some of the same research they completed. Discuss implications of this type of research on their lives and the products they use today.

Teacher should have students reflect on the importance of teamwork and ways in which their team could have performed more efficiently. Discuss any roadblocks and ask students to brainstorm ways in which they could improve.

Bonus Activity (Optional: If additional time is available, teacher may have teams exchange containers and test them under unexpected extreme conditions devised by other groups. This encourages adaptability and innovative thinking in problem-solving.

Assessment:

- Evaluate students based on their research notes, predictions, container designs, and participation in the testing and discussion phases.

- Use a rubric that assesses their understanding of material properties, their ability to apply that knowledge to design a container, and their analysis of how their chosen material behaves in extreme conditions.

EXTENSIONS

- Have students research real-world examples where materials are designed to withstand extreme conditions (e.g., spacecraft, Arctic research equipment).
- Explore other materials not included in the initial list and discuss their potential uses in extreme environments.

REFERENCES

- https://teacherdashboard.ai/rubrics/edit/669f11ec11ae7aef457d8740
- https://thecorestandards.org/read-the-standards/
- https://www.nextgenscience.org/