How Cold Can You Go? (Activity)

Subject Area(s): water cycle, physical properties, temperature, phase equilibrium

Associated Unit: Properties of Water (Grade 4, NYC PS)

Associated Lesson: How Cold Can You Go? (Lesson Plan)

Activity Title: How Cold Can You Go? (Activity)

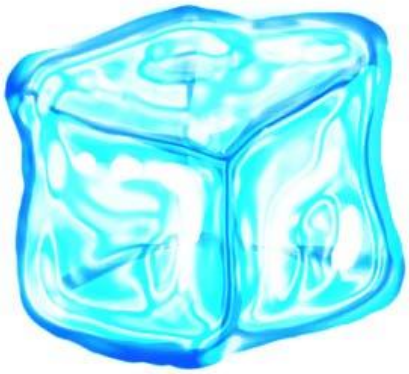

Image 1
ADA Description: A Stylized Image of a Single Ice Cube
Caption: Ice Cube
Image file name: icecube.jpg
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Grade Level: 4 (3-5)

Activity Dependency: None

Time Required: 45 minutes

Group Size: 4

Expendable Cost per Group: US $5

Summary

Students will use a mechatronic temperature sensor to learn about the lower temperature limit at which liquid water can exist—specifically, that even if placed in contact with a material much colder than 32 degrees Fahrenheit, liquid water will not get colder than 32 degrees Fahrenheit.

Students also see an example of how materials can be modified (engineered) to change their equilibrium properties. Students will learn this principle by observing that, when mixed with salt, liquid water's lower temperature limit can be dropped.

Students will be motivated to understand the importance of material temperature limitations, and the utility of being able to modify this, by seeing the effect of lowered temperature on ice cream mix—students who bring ice cream mix to temperatures lower than 32 degrees Fahrenheit using the salt mixture will get the icy, thick consistency they'd expect from ice cream, whereas students who use the salt free liquid water will not be able to get their ice cream mix to freeze, and will see that their ice cream mix remains a soupy liquid—albeit a colder soupy liquid.

Engineering Connection

The engineering connection of this lesson is two-fold: (1) the active use of mechatronic sensors, as well as (2) learning about how material properties can be useful, or changed to be more useful.

(1) Sensors—students will need to learn how to use temperature sensors in order to measure changes in water temperature.

(2) Material Property Utility & Modification—students will also learn that when attempting to get a material colder than it currently is, the material properties must be considered, and tested to determine if it is appropriate for the task at hand. Students will also learn that materials can be modified to change their properties to be specific to a given task.

Engineering Category

(#1) relates science concept to engineering

Keywords

water cycle, mechatronics, sensors, water, ice, temperature, physical properties, material properties, phase equilibrium, ice cream, baggies

Educational Standards (New York City Public Schools)

State science: PS 3.1, 3.2, 2.1, 4.1
State math: 4.M.2, 4.S.2, 4.S.3

Pre-Requisite Knowledge

A working familiarity with water, and students who have an intuitive understanding that cold materials can cool down warmer materials by contact.

Learning Objectives

After this lesson, students should be able to:

- Understand that mechatronic sensors can be used to detect temperature, and use mechatronic temperature sensors to measure temperature.
- Understand that some materials, for example water, can only be cooled to a lower temperature limit and still remain in liquid form, even when given the opportunity to equilibrate with much colder materials
- Understand that material properties can be modified by changing the material composition
- Understand that material properties can make materials useful for different tasks, and that material property modification can be used to make a material useful for a specific task

Materials List

Each group needs:

- a mechatronic temperature sensor (BASIC Stamp)
- a clear plastic watertight container (glass beakers, or dollar store vases, etc.)
- water supply (sink, or 1 liter sized container of water, etc.)
- A 1 liter (approximate) container of crushed ice
- 2 quart-sized plastic baggies (in [#1]: ¼ cup ice cream mix, in [#2] baggie #1 & 5 marbles)
- ice cream mix (makes 17 single bag [1/4 cup] servings):
    - 2 cups half & half

    - 2 cups heavy cream
    - ¼ cup powdered sugar
    - 1 teaspoon vanilla extract
- 1 Ruler
- 5 marbles
- 1 wooden stirring spoon
- 4 sets of paper & pencil (1 per student)
- 4 plastic spoons (1 per student)

Depending on the Group:

"Lots of Salt" Groups: 1 plastic baggie containing 1.5 cups of salt

"Some Salt" Groups: 1 plastic baggie containing ¼ cups of salt

"No Salt" Groups: Nothing extra

To share with the entire class:

- Either a whiteboard, or a blackboard, or an overhead projector

Introduction / Motivation

Discussion & Lecture with Students—Pt. 1, The Freezing Temperature of Water

There's nothing like a glass of ice cold water on a hot day. Have you ever wondered how ice makes water cold? Is it just that the ice is melting, making cold water, or is the room temperature water being cooled down just by contact with the ice?

Today, we're going to learn about how cold water can get. Does anyone know what temperature water freezes? Raise your hand if you have an idea or guess. (Call on students with guesses—if no guesses are made, ask for a random guess).

Pure water always freezes at the same temperature, 32 degrees Fahrenheit. If you have water that's above 32 degrees Fahrenheit, it will be liquid. If you cool water to below 32 degrees Fahrenheit, even by just a single degree, it will become the solid we know as ice.

Checking for understanding:

With what I just said, if we have a bucket of water at 31 degrees Fahrenheit, by raising your hand, who can tell me if the water will be liquid or solid? (Ask for guesses, and explain whether right or wrong & why). Ans: **solid** ice, because 31 is a lower temp. than 32

Again, with what I just said, if we have a bucket of water at 28 degrees Fahrenheit, who can tell me if the water will be liquid or solid? Ans: **solid** ice**,** because 28 is a lower temp. than 32

What about if the water is at….. negative 73 Fahrenheit?! Ans: **solid** ice, because -73 is a much lower temp. than 32

Alright… now, what about if the water is at… 33 Fahrenheit?

Ans: **liquid** water, because 33 is a higher temp. than 32.

58 Fahrenheit?
Ans: **liquid** water, because 58 is a higher temp. than 32.
So, who can tell me at what temperature water freezes?
Ans: **32 degrees Fahrenheit!**

So, to recap, if you have water above 32 degrees Fahrenheit, it will be liquid, but if you cool water to below 32 degrees Fahrenheit, even just a little bit, it will turn into ice. Do we all feel okay with that?

Discussion & Lecture with Students—Pt. 2, How to cool materials, & how cold they can get
If I wanted to cool this piece of tin foil down, by raising hands, who could give me an idea of how could I do it? (Take suggestions) Could I cool tinfoil down by putting it in cold water? (Take answers, and correct: Ans: yes) If the water was at 40 degrees Fahrenheit, how cold could the piece of tinfoil get? (Take answers, and correct Ans: 40 degrees, since the tinfoil could get just as cold as the water, and the water wouldn't cool down from the tinfoil) If the water was at 35 degrees Fahrenheit, how cold could the piece of tinfoil get? (Take answers, and correct Ans: 35 degrees, same reason) What about if we put the piece of tinfoil on a piece of ice at 31 Fahrenheit? Would the tinfoil turn to ice? Or would it just become colder? (Take answers, and correct Ans: 31 Fahrenheit, & wouldn't turn to ice, since it's already solid) What about tinfoil on a piece of ice at 10 degrees Fahrenheit? (Take answers, and correct Ans: 10 Fahrenheit, & wouldn't turn to ice, since it's already solid)
So, to recap, we can cool a material like tinfoil by putting it against a large amount of a material at a lower temperature.

What about if we wanted to cool down water? Who could give me an idea of how I could do it? (Take suggestions) Could I cool water down by putting ice in it? (Take suggestions, Ans: yes) If I put ice cubes that were 20 degrees Fahrenheit in a glass of liquid water, how cold could I get the liquid water? (Take suggestions, & correct, Ans: 32 degrees Fahrenheit) Could I get liquid water colder than 32 degrees Fahrenheit? (Take suggestions, & correct, Ans: no, only 32 degrees Fahrenheit)

So, to recap, we can only get liquid water as cold as zero degrees Fahrenheit, but not colder while it's still liquid, because water colder than 32 Fahrenheit becomes ice.

Discussion & Lecture with Students—Pt. 3, How to change the limit of low temperature
I don't think you guys would believe me if I now told you that there was a way to get water colder than 32 degrees Fahrenheit, but there is! You can get liquid water colder than 32 degrees Fahrenheit by changing the properties of water! Changing the properties of water is pretty easy—you can change regular water into salt water, and salt water has different properties. If you have water that's mixed with a LOT of salt, it can freeze at 15 degrees Fahrenheit instead of 32 Fahrenheit. Cool, right?

What could you use water below 32 degrees Fahrenheit for? How about an instant freezer! If you have water at 15 degrees Fahrenheit, you could cool down a piece of tinfoil to 15 degrees Fahrenheit, right? What about if you put… a bag of ice cream mix in the 15 degree Fahrenheit water? It would also freeze! You could make ice cream! And that's what we're going today!

Vocabulary / Definitions

Word	Definition
phase	A state of matter that a material exists in, such as liquid phase, solid phase, or gaseous phase. Matter can exist in different phases depending on the environmental conditions of temperature, confinement volume, and pressure.
equilibrium	A stable state in which perturbation is required for a change to occur. For example, ice and water are in equilibrium at 32 degrees Fahrenheit, meaning that if both ice and water are at 32 degrees Fahrenheit, neither the amount of water nor the amount of ice will change unless a temperature change occurs.
temperature sink/reservoir	A large amount of a material at a known temperature, which is assumed to have negligible change in temperature due to contact from materials at a different temperature from that of the temperature sink/reservoir.
mechatronic sensor	A type of electrical sensor which can measure temperature by converting an electrical reading to a digital display.

Procedure

Background

Most of the background information for this experiment is intuitive, and a review of the lesson plan before beginning the activity would be useful. Focus should however be paid to the BASIC Stamp mechatronic temperature sensor, as it is unlikely a teacher would be familiar with this.

Before the Activity

Assign Students into Groups

- Assign each into a group of 4 students
- Assign each group into one of 3 categories: (1) Salt Free, (2) Some Salt, (3) Lots of Salt
- Assign each student in a group one of the following roles:
    - Temperature Measurer
        - Temperature measurers use the mechatronic temperature sensor by:
            - Making sure that the temperature probe is within the water
            - Reading off the temperature and telling the
    - Time Measurer
        - Time measurers use either a clock on the wall to determine time by:
            - Calling out the time at which to start
            - Calling out when one minute intervals have passed from the start time
    - Recorder (Time & Temperature)
        - Recorders use a pencil and paper to:
            - Make a list with spots for times & temperatures
            - Record the temperature told by the Temperature Measurer when the Time Measurer calls out an interval

- Prodder/Stirrer
  - Prodders use a wooden spoon to:
    - Keep the ice in motion
    - Keep the ice cream mix submerged and in motion

Assemble Materials for each Group onto Group Desks

- On each group desk, place one set of all materials listed on the Materials section

Prepare a Form on Either an Overhead Projector, Blackboard, or Whiteboard

- Create a form which has the following structure:

Time [min.]	Temperature [°F]		Group
0	0	1	Salt Free
	4	0	Some Salt
	1	2	Lots of Salt!
2			
4			
6			
8			
10			

With the Students

- Complete the Introduction/Overview Section Discussion
- Complete the Pre-Activity Section Assessment with the Students
- Provide each Group with the Supplies Mentioned in the Materials Section
- Instruct the Groups to Follow the Complete the Following Procedure
  (*with variability in the "*Addition of Salt*" step according to their group type*)

PROCEDURE:

1. Fill beaker with six inches of shaved ice [*Prodder*]
2. Pour water into beaker until water line visibly reaches two inches high [*Prodder*]

3. Insert temperature probe to the bottom of the beaker, and have the recorder write down both the start time & temperature [*Temperature Keeper*]

ADDITION OF SALT [*Prodder*]

- No Salt—do not add any salt at this step, and continue stirring
- Some Salt—add all of the "*1/4 cup salt*" bag, & continue stirring
- Lots of Salt—add all of the "*2 cups salt*" bag, & continue stirring

4. Call out the time every one minute, and call special notice to the 3 & 8 minute marks [*Time Keeper*]
5. After the minute marks have been called, call out the temperature according to the temperature probe [*Temperature Keeper*]
6. Record the temperature have been called by the *Time Keeper*, record the temperature as called out by the *Temperature Keeper* [*Recorder*]
7. When the 5 minute mark has been called by the *Time Keeper*, insert the ice cream mix baggie as low as possible into the beaker [*Prodder*]
8. Use the wooden spoon to keep the ice cream bag in motion near the bottom of the beaker [*Prodder*]
9. After the 10 minute mark has been called by the *Time Keeper*, remove the ice cream mix baggie from beaker, and place on a paper towel [*Prodder*]
10. Have each person feel the bag on the paper towel, and record five words which describe what the bag feels like [*Recorder*]

Figure 2

ADA Description: A Cone of Vanilla ice Cream

Caption: Figure #2

Image file name: ice-cream.jpg

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Attachments

None

Safety Issues

None

Troubleshooting Tips

- For the students in "Lots of Salt" groups:
    - If the ice cream mix has not solidified after 5-10 minutes, add additional salt to the salt/ice/water solution

Investigating Questions

- How cold can water get and still remain liquid?
- What can be done to change the lowest temperature water can be while liquid?
- How is the modification of material properties useful?

Assessment

Pre-Lesson Assessment

Call-out Question & Answer Session

During the initial introduction of the lesson, students will be asked a variety of questions relating to temperature limits of water, temperature transfer, and how temperature properties of materials can be modified. An example text of of possible questions integrated with introductory content can be found in the "Introduction/Motivation" section of this TeachEngineering Lesson.

Post-Introduction Assessment

Real-Time Compilation of Group Temperatures

As students are actively engaged in measuring the water/salt/ice mixture temperature, as well as keeping the ice cream mixture in motion, one student will be responsible for relaying the temperature of the group's mixture to the instructor along with the time at which it was recorded. The instructor will tabulate this information on a chalkboard/whiteboard/overhead projector so this information can be used in the post-activity analysis and discussion. This will serve as a check that students are collecting reasonable data, and can determine for themselves what data makes sense.

Lesson Summary Assessments

Eat Ice Cream

Students will enjoy 3 different cups of ice creams, one with a spoonful of each of the environmental set ups. This way they will taste the ice creams that were allowed to form, and understand for themselves the different freezing points of the liquid waters.

Call-out Question & Answer Session

While students are eating their 3 different ice creams, students will be asked a variety of questions relating to the lab they just performed, and the questions and answers will be written on the chalkboard/whiteboard/overhead projector. An example text of of possible questions integrated with introductory content can be found in the "Introduction/Motivation" section of this TeachEngineering Lesson

Diagram Drawing

Students will draw the before and after set-ups of their ice/water/salt/ice-cream mixtures, and label temperatures on the.

Activity Extensions

None

Activity Scaling

- For lower grades, omit the investigation of the salt-free water/ice system, and focus on the use of salt and ice to make ice cream. Although this removes a large amount of the learning material, the students become excited about science, and gain familiarity with using mechatronic sensors to measure temperature.

- For upper grades, include thermodynamic explanation of the phases of water. Make use of a phase diagram for water as a function of temperature and pressure. Discuss vocabulary such as phase changes, equilibrium, etc. Include the chemical explanation for the reason why salt is able to cause the freezing point of water to depress.

Additional Multimedia Support

None

References

Ice Cream Recipe:

[1] Recipies.com, "Ice Cream in a Bag," accessed 06/22/10
http://images.allrecipes.com/site/allrecipes/pdfs/icecream_in_a_bag.pdf

Lower Temperature Limit of Water Given Salt Saturation:

[2] NOAA's JetStream - Online School for Weather, "Learning Lesson: We all Scream for Ice Cream," accessed 06/23/10
http://www.srh.noaa.gov/jetstream/ocean/ll_scream.htm

Other

None

Redirect URL

None

Contributors

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None

Supporting Program

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