CHANGING SPEEDS, CHANGING STATES

INSTRUCTIONS

Overview:

Using a computer simulator, students make observations about the speed of molecules in water in three states: solid, liquid and gas. Additionally, students conduct an investigation to see how much energy it takes for water to change phase from ice to liquid compared to bringing just melted water to a near boil.

Objectives:

The student will:

- identify heat transfer as a means for state of matter changes;
- describe the speed of molecules indicates temperature; and
- explain melting.

Targeted Alaska Grade Level Expectations:

Science

[8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[8] SB3.1 The student demonstrates an understanding of the interactions between matter and energy and the effects of these interactions on systems by exploring changes of state with increase or decrease of particle speed associated with heat transfer. (L)

[8] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather.

Vocabulary:

boiling point - the temperature at which a liquid changes to a vapor or gas. As the temperature of a liquid rises, the pressure of escaping vapor also rises, and at the boiling point the pressure of the escaping vapor is equal to that exerted on the liquid by the surrounding air, or atmospheric pressure, causing bubbles to form. Typically boiling points are measured at sea level. At higher altitudes, where atmospheric pressure is lower, boiling points are lower. The boiling point of water at sea level is 212˚F (100˚C); that of mercury is 673.84˚F (356.58˚C).

boil - to change from a liquid to a gaseous state, producing bubbles of gas that rise to the surface of the liquid, agitating it as they rise, usually occurring when a liquid is heated to its boiling point.

condensation point - the temperature at which a material changes from a gas to a liquid; the same as the boiling point.

condensation - the change of a gas or vapor to a liquid, either by cooling (to the condensation point) or by being subjected to increased pressure. When water vapor cools in the atmosphere, for example, it condenses into tiny drops of water, which form clouds.

evaporation - the process by which water is converted from its liquid for to its vapor form and thus transferred from land and water masses to the atmosphere

freezing point - the temperature at which a liquid becomes a solid. For a given substance, the freezing point of its liquid form is the same as the melting point of its solid form. The freezing point of water is 32˚F (0˚C); that of liquid nitrogen is -347.75˚F (-209.89˚C).

freezing - to change from a liquid to a solid state by cooling or being cooled to the freezing point.

gas: One of the three basic forms of matter, composed of molecules in constant random motion. Unlike a solid, a gas has no fixed shape and will take on the shape of the space available. Unlike a liquid, it has no fixed volume and will expand to fill the space available.

heat - a form of energy produced by the motion of molecules. The heat of a substance is the total energy produced by the motion of its molecules.

heat of fusion - heat absorbed by a unit mass of a solid at its melting point in order to convert the solid into a liquid at the same temperature; "the heat of fusion is equal to the heat of solidification"

Kelvin - unit of absolute temperature having the same value as one Celsius degree. It is used in the Kelvin scale.

Kelvin scale - scale of temperature beginning at absolute zero (-273.15˚C). Each degree, or kelvin, has the same value as one degree on the Celsius scale. On the Kelvin scale water freezes at 273.15 K and boils at 373.15 K.

latent heat - the quantity of heat absorbed or released by a substance undergoing a change of state, such as ice changing to liquid water or liquid water changing to ice, at constant temperature and pressure. The latent heat absorbed by air when water vapor condenses is ultimately the source of the power of thunderstorms and hurricanes. Also called heat of transformation.

liquid - one of the three basic forms of matter, composed of molecules that can move short distances. Unlike a solid, a liquid has no fixed shape, but instead has a characteristic readiness to flow and therefore takes on the shape of any container. Unlike a gas, a liquid usually has a volume that remains mostly constant, changing only slightly under pressure or with temperature changes.

matter - something that occupies space, has mass, and can exist ordinarily as a solid, liquid, or gas.

melting point - the temperature at which a solid becomes a liquid. For a given substance, the melting point of its solid form is the same as the freezing point of its liquid form. The melting point of ice is 32˚F (0˚C); that of iron is 2,797˚F (1,535˚C).

melting - to change from a solid to a liquid state by heating or being heated to the melting point.

molecule - a group of two or more atoms linked together by sharing electrons in a chemical bond.

plasma - state of matter consisting of a gaseous mixture of positive ions and electrons. Plasma is a distinct phase of matter, separate from the traditional solids, liquids, and gases. It is a collection of charged particles that respond strongly and collectively to electromagnetic fields, taking the form of gas-like clouds or ion beams. Since the particles in plasma are electrically charged (generally by being stripped of electrons), it is frequently described as an "ionized gas." Plasma was first identified (as "radiant mattter") by Sir William Crookes in 1879. Sir J.J. Thomson identified the nature of the matter in 1897. It was Irving Langmuir who assigned the term "plasma" in 1928. It is odd to consider that plasma is actually the most common phase of matter, especially since it was the last one discovered. Flame, lightning, interstellar nebulae, stars, and even the empty vastness of space are all examples of the plasma state of matter.

solid state - the state in which a substance has no tendency to flow under moderate stress; resist forces (such as compression) that tend to deform it; and retains a definite size and shape.

state of matter (phases of matter) - one of the principal conditions in which matter exists. Matter is traditionally divided into three states-solid, liquid, and gas. Ice, liquid water, and steam, for example, are three states of matter of the same substance. [The electrically neutral condition known as plasma is often considered a fourth state of matter.]

Whole Picture:

Matter consists of everything in the universe which has mass and can be identified in one of the states of matter. The four states of matter are solid, liquid, gas and plasma. Solids consist of molecules that have fixed positions with very little movement. The molecules do not flow and are tightly packed in a usually regular pattern. Liquids consist of molecules that assume the shape of the container they are in and can move around one another but cannot expand. The molecules flow easily and are close together but do not have a pattern. Gases consist of molecules that expand to fill the container they are in and move very rapidly. The molecules flow very easily and have lots of space between them without a regular pattern. The difference between the states of matter is the motion of their molecules. See the definition for plasma, above.

Matter can change form from one state to another through a state of matter change. These changes are caused by the process of melting, boiling, condensation, and freezing. The heat that is added/removed is an energy source that enables the matter to change forms. The process of melting involves adding heat energy to speed up the molecules in a solid to change it to a liquid. The process of boiling involves adding heat energy to speed up the molecules in a liquid to change it to a gas. The process of condensation involves removing heat to slow down the molecules in a gas to change it to a liquid. The process of freezing involves removing heat to slow down the molecules in a liquid to change it to a solid.

The points where states change from one to another have specific temperatures based on the type of substance. The melting point is the temperature at which the substance changes from solid to liquid. The boiling point is the temperature at which the substance changes from liquid to gas. The condensation point is the temperature at which the substance changes from gas to liquid. The freezing point is the temperature at which the substance changes from liquid to solid. The terms melting point and freezing point can be used synonymously, as can boiling point and condensation point, because they occur at the same temperature point for a substance, transitioning in opposite directions.

Temperature is a measurement of the effect that heat has on a substance, such as speeding or slowing molecules, thereby increasing or decreasing the average kinetic energy (energy of motion). There are three different scales for measuring this kinetic energy: Fahrenheit, Celsius and Kelvin. Fahrenheit is the most commonly used unit in the United States, however Celsius is used in the rest of the world and in science, while Kelvin scales are used almost exclusively in science. Celsius scale is based on the freezing and boiling points for pure water. The Kelvin scale provides a direct measurement of the energy of motion due to heat within a substance and provides a scale where "absolute 0" is the absence of all energy, therefore deriving no negative numbers.

Latent heat, the heat of fusion, and heat of transformation are terms that refer to the amount of energy required to change the state of a substance. Heat of fusion refers specifically to the amount of heat energy required to change the state of a substance from solid to liquid and can be calculated mathematically using a formula. More energy is required to change the state of a substance from solid to liquid, than to raise the temperature from near freezing to boiling. The substance absorbs heat until it reaches its melting point. The melting point is a point of transition that requires extra energy; this extra energy is the heat of fusion.

Materials:

- Computers (one per student)
- A cup of ice
- Measuring cup (one per group)
- 250 milliliter beakers (one per group)
- Hot plate/Bunsen burner with stand (one per group)
- Thermometer (one per group) (-20˚C to 150˚C range)
- Stop watch (one per group)
- Hot mitt/tongs (one per group)
- Safety goggles (one pair per student)
- STUDENT INFORMATION SHEET: "Spring Breakup Milder in Recent Years"
- MULTIMEDIA: "States of Matter Simulator" (http://phet.colorado.edu/en/simulation/states-of-matter)
- STUDENT WORKSHEET: "Simulating Phase Changes with Heat"
- STUDENT LAB: "Melting"

NOTE: Please follow safety procedures and make sure a fire extinguisher is handy.

Activity Preparation:

1. Gather all supplies for the lesson. Ice and water are needed for the lab; store them in a cooler until needed.
2. The simulation software needs to be downloaded from the Internet and will be saved in the Downloads folder on your computer as a .jar file. Download the data to the computers before beginning the lesson to save time.
   a. Go to http://phet.colorado.edu/en/simulation/states-of-matter.
   b. Click the Download button.

   c. An options window will pop up, click OK.
   d. It will download the file to your computer into the Downloads folder. Launch the software by double clicking on the file.
   e. If for some reason it doesn't launch, you can also click the Run Now! tab and hit OK. Then the program should open automatically.
   f. Leave the program open until you are ready to teach the lesson, or open it from the Downloads folder.

3. For instructions on how to use the PhET States of Matter simulator, access the "PhET Tips for Teachers" pdf file, go to http://phet.colorado.edu/en/simulation/states-of-matter, look for "Tips for Teachers," and click on the "teacher's guide" pdf link. The guide includes tips for using the controls.

Activity Procedure:

1. Conduct a five-minute review session of the states of matter and the difference in particle motion. Begin by asking students guiding questions. If students cannot recall information, explain there are three traditional states of matter: solid, liquid, and gas. Solids have closely packed molecules that cannot move very much and therefore they do not change shape. Liquids have molecules that are able to flow past one another, cannot expand, and they take the shape of the container they are in. Gases have molecules that can move quickly, can expand, and fill the container they are in. Define plasma, but tell students today's lesson will focus on exploring the three traditional states of matter, solid, liquid, and gas.
2. Discuss vocabulary words and/or the whole picture with students to give them background information for the lesson.
3. Hand out the STUDENT WORKSHEET: "Simulating Phase Changes with Heat." Ask students to open the MULTIMEDIA: "States of Matter Simulator." Students should complete the worksheets individually.

   NOTE: If necessary, pair up students or connect a computer to a projector, and project the simulator to complete the worksheet in pairs or as a class.

4. When students have completed the worksheet, pass out the STUDENT LAB: "Melting." Divide class into groups of 2-4 students to complete the investigation. Provide all needed supplies to students. Students will be using hotplates. Refresh students on proper lab safety for use of hotplates and ensure all students are following safe lab procedure. Aid students in proper set-up and safety and explain expectations for cleanup.
5. Direct students to conduct the investigation and to complete the data analysis and conclusion. Discuss their results. Explain why it took more heat to make the ice melt than to heat cold water to near boiling. Explain the concept of latent heat (heat absorbed or radiated during a change of phase at a constant temperature and pressure) and the latent heat of fusion (the amount of heat required to convert a solid into a liquid without an increase in temperature). Even though there is heat applied to the beaker full of ice for a comparatively long time, the substance remains frozen and at freezing temperature until it reaches the melting point.
6. Hand out the STUDENT INFORMATION SHEET: "Spring Breakup Milder in Recent Years" for students to read to answer the final question on the lab handout. Direct students to complete their lab questions.
7. Wrap up the lesson by discussing how the information students have discovered can help people understand what happens during spring ice breakup in Alaska.

Answers:

STUDENT WORKSHEET: "Simulating Phase Changes with Heat"

1. b. Speed of the water molecules.
2. Answers will vary, but should reflect that adding heat speeds the molecules up.
3. Answers will vary, but should reflect that removing heat slows the molecules down.
4. Temperature should be between 260-280 K.

5. Liquid
6. Melting
7. d. Melting point (a is right too, but d is better choice)
8. Temperature should be between 390-420 K. (This is not the actual boiling point of water, just an easier place to identify the phase change.)
9. Gas
10. Boiling
11. b. Boiling point (c is right too, but b is better choice)
12. a. Higher
13. Answers will vary, but should reflect understanding that as heat is added, molecules speed up and the substance changes phases as a result.

STUDENT LAB: "Melting"

1. Students may answer a or b to predict the results of the investigation. Table 1 and Table 2. Answers will vary, but should reflect temperatures and times.
2. Answers will vary, but should be approximately between 1 and 10 degrees Celsius.
3. Answers will vary, but should be approximately between 90 and100 degrees Celsius.
4. Answers will vary, but should give a unit of time and be less than the answer to question 5.
5. Answers will vary, but should give a unit of time and be more than the answer to question 6.
6. a. melting the ice
7. Answers will vary, but should confirm or correct the answer to the prediction. If necessary, explain the concept of latent heat and why it takes more energy to change phase than to increase temperature.
8. In the students own words, a definition for phase change should describe the concept that the speed of molecules indicates temperature, and that heat transfer will cause phase change by speeding up or slowing down the molecules in a substance. A complete answer will include descriptions of solid, liquid and gas.
9. d. Molecules getting slower, changing the liquid to a solid.
10. c. Sun.
11. Student paragraphs should discuss phase change during ice breakup in Alaska's spring. Paragraphs should refer to the article "Spring breakup milder in recent years."

SPRING BREAKUP MILDER IN RECENT YEARS

Alaska Science Forum
March 31, 2005
Article #1744
by Ned Rozell

Spring breakup just ain't what it used to be, according to a long-time hydrologist at the Alaska-Pacific River Forecast Center in Anchorage.

Larry Rundquist has helped forecast the transition of Alaska's rivers from solid ice to liquid water for the past 18 years. The change can be damaging for villages as large pulses of snowmelt hit river channels or huge chunks of ice form dams that back rivers up, but the past few breakups have been mild ones.

"For the first decade that I worked here, we had watches or warnings for flooding going on at several locations every day for two or three weeks as the Yukon and Kuskokwim rivers were going out," Rundquist said. "It was a given we'd have flooding somewhere. The only question was how much damage would be done to villages."

"In the last decade, there's almost been a complete reversal," he said. "The number of threats due to ice jamming and snowmelt have reduced to the point where during one year we put out no flood (warnings or watches) and several years we've put out just a handful."

The month of May is when most river breakups occur in Alaska, according to the forecast center, which lists some average dates on the web. The Yukon at Eagle breaks up around May 6, while at the river's mouth at Alakanuk the average date is May 23. For those betting on the Nenana Ice Classic, the average date for the Tanana River breakup is May 2.

In a forecast issued in late March 2005, the hydrologists predicted an average spring flood potential for most Alaska rivers and a below-average potential for the Kenai Peninsula. Thick ice on the upper Yukon near Eagle and heavy snowpack in many areas of Alaska are ingredients that lead to spring floods, but the forecasters are predicting an average breakup because computer model projections call for a warm spring. April and May weather is the most important factor in determining the severity of river breakup, Rundquist said.

An example of what Rundquist calls a "bad extreme" is a cold April followed by a very warm May, which occurred in Fairbanks in 1992. A cold early spring didn't allow much snow to melt and the snowpack increased until mid-May. In late May, temperatures rose into the 70s, and much of the water stored in the snowpack of the upper Chena River basin became liquid in a few days, prompting the engineers at the Chena River Lakes Flood Control Project to divert much of the Chena's flow through the massive flood channel toward the Tanana. Spring 1992 was the only time Chena water has reached the Tanana through the channel.

An ice jam in the lower Yukon backed the river into the village of Russian Mission in 1989. Floodwaters remained in the village for one week, when the only way in or out was by helicopter. Photo by Larry Rundquist, Alaska-Pacific River Forecast Center.

In the milder breakup extreme, which has lately been more typical, warm and sunny Aprils have bled out the snowpack over a longer time frame.

"We call them 'thermal breakups' or 'mushouts' because the ice gets rotten and mushy before it begins to move and has very little threat of jamming," Rundquist said.

Dramatic breakups, where huge rafts of ice converge to create dams, have not been as prevalent as when Rundquist flew in a Cessna over Russian Mission on the Yukon River in spring of 1989. That year, a dam created by jammed ice backed the river into the village for one week.

The river forecasting team has flown the Yukon and Kuskokwim drainages less frequently in the past several years because breakup has been gentler.

"We've definitely been in a different regime the last five to 10 years," Rundquist said. "I don't know if it's global warming or what, but we've seen pretty nice spring weather for several years now. But people on the rivers shouldn't let their guard down. There will very likely be some flooding this year in some flood-prone villages."

For the most current forecast of the spring flood potential in Alaska, go to http://aprfc.arh.noaa.gov/

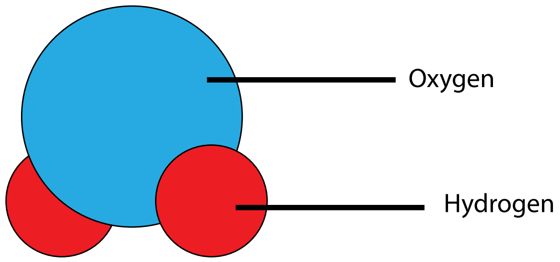
NAME: ______________________________

SIMULATING PHASE CHANGES WITH HEAT

Directions: : Follow the instructions below to find the answers to the questions.

Open the "States of Matter" simulator downloaded onto the computer. On the right side, under the Molecules choices, select Water.

This is what one water molecule looks like:



Below the Molecules section, there are three choices under Change State. Select Solid and observe what the molecules do. Then, select Liquid and observe what the molecules do. Lastly, select Gas and observe what the molecules do.

1. The difference between the three phases of water is: (circle one)

   A. Shape of the water molecules.

   B. Speed of the water molecules.

   C. Number of water molecules.

   D. Color of the water molecules.

At the top of the Simulator window, there are three tabs. Select Phase Changes. On the right side, under the Molecules section select Water again. Below the container in the Simulator window, there is a gauge for Heat Control. Click your mouse on the slider pointing at 0, but do not move it yet. Use the up/down arrows on your keyboard to Add/Remove heat. Hit the up arrow on the keyboard five times. Observe the speed of the molecules for approximately two minutes.

2. What happens to the water molecules as heat is applied to the ice?

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Click your mouse on the slider in the Heat Control box once. This should reset the heat to 0. Then hit the down arrow on the keyboard five times. Observe what happens to the speed of the molecules for approximately two minutes.

3. What happened to the water molecules as heat was removed?

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On the bottom right of the window, click Reset All. A question will pop up asking "Reset all settings?" Click Yes. Reselect Water. There is a colorful graph in the right panel showing Pressure on the y-axis and Temperature on the x-axis. Click your mouse on the slider pointing at 0 in the Heat Control box. Hit the up arrow five times as before. Watch the graph in the right panel and when the red dot moves to the first black dot labeled "triple point" hit the pause button at the bottom of the window. The temperature of the water molecules is listed right above the thermometer. It is listed in Kelvins (K), which is a measure of temperature.

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SIMULATING PHASE CHANGES WITH HEAT

4. Fill in the table.

Tempearture at triple point	

5. Based on what the water molecules look like, what phase are they in now? ________________________

6. What is this process called? ________________________

7. What is this point called? (circle one)

   A. Freezing point
   B. Boiling point
   C. Condensation point
   D. Melting point

Press the play button and watch the graph in the right panel and when the red dot hits a place on the black line right above the g in gas hit the pause button at the bottom of the window.

8. Fill in the table.

Tempearture at mid point	

9. Based on what the water molecules look like, what phase are they in now? ________________________

10. What is this process called? ________________________

11. What is this point called?

   A. Freezing point
   B. Boiling point
   C. Condensation point
   D. Melting point

Results:

12. When the water was in its gas state, was the temperature higher or lower than when it was in its solid state? (circle one)

   a. Higher
   b. Lower

13. Explain what you learned about how adding heat affects the phases of matter.

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MELTING

Testable Question:

Which requires more heat energy? Melting ice? Or raising the temperature of melted ice water to near boiling?

Prediction ***(circle one)*****:**

a. More heat energy is required to melt ice than to raise its temperature to near boiling.

b. More heat energy is required to raise the temperature of melted ice water than to melt the ice in the first place.

Investigation:

Materials:

- 1 cup of ice
- Measuring cup
- 250 ml beaker
- Hotplate
- Thermometer
- Stopwatch
- Goggles
- STUDENT WORKSHEET: "Simulating Phase Changes with Heat"

Procedure:

1. Collect all supplies except for the ice. Wait until step 7 to get it.
2. Put your goggles on, turn on the hotplate on, and adjust the heat setting to high. (Once the hotplate is on, do not touch the surface! It will be very hot!)
3. Place the ice in the beaker. Measure the temperature of the ice, and list it in Table 1.
4. Place the beaker on the hotplate and begin heating the ice. Use the stopwatch to track the amount of time it takes to melt the ice completely. Start the stopwatch when you place the beaker on the hotplate. Stop it when the ice has melted completely, and measure the temperature of the water. Note the time it took for the water to melt completely in Table 2 and note the temperature of the just-melted water in Table 1.
5. Start the stopwatch again to time how long it takes to heat the water to almost boiling. Stop it when the water is nearly boiling. Measure the temperature. Record the temperature in Table 1. Note the time it took in Table 2.
6. Turn off the hotplate, and remove the beaker of water using tongs or hot mitts to let it cool. Clean up all lab materials as teacher instructs.
7. Answer all questions on lab handout.

Data:

Table 1: Temperature Degrees Celsius

Temperature of the ice before applying heat	
Water at its coldest (just melted)	
Near Boiling Temperature	

Table 2: Time

Temperature of the ice before applying heat	
Water at its coldest (just melted)	
Near Boiling Temperature	

NAME: ______________________________

MELTING

Analysis of Data:

1. How many degrees difference was there between the ice and the melted ice water at its coldest? ___________
2. How many degrees difference was there between the water at its coldest and the water near boiling? _______
3. How long did it take to melt the ice? ____________________________
4. How long did it take to raise the temperature of the cold water to near boiling? _________________________
5. Which took more time and heat energy *(circle one)*:
   a. melting the ice or
   b. heating the water to near boiling?

Conclusion:

6. Was your prediction correct? Why or why not?.____

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Further Questions:

7. Write a definition for phase change. Include the words molecules and temperature. ____________________

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8. What does freezing mean?
   A. Molecules getting faster, changing the solid to a liquid.
   B. Molecules getting faster, changing the liquid to a gas.
   C. Molecules getting slower, changing the solid to a liquid.
   D. Molecules getting slower, changing the liquid to a solid.

9. During spring ice break-up in Alaska, what is the heat source causing the phase change?
   A. Wind
   B. Volcanoes
   C. Sun
   D. None

10. Read the article "Spring Breakup Milder in Recent Years" by Ned Rozell. Write a paragraph or two in reaction to the article. Explain how the information you learned from the investigation or phase change simulator helps you understand what happens during spring ice break-up in Alaska. The article states that the weather in April and May determine the nature of the ice breakup for any given year. Why does a cold April and warm May mean more flooding potential? Why does a warm April and warm May mean less flooding potential?

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