National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA's REAL WORLD:
Abiotic Conditions

Educational Product	
Educators & Students	Grades 6-8

EG-2010-004-LaRC

ABIOTIC CONDITIONS

National Standards:

National Science Education Standards (NSES)

Science as Inquiry

Understanding about scientific inquiry

Physical Science

Properties of objects and materials

Transfer of energy

National Council of Teachers of Mathematics (NCTM)

Measurement

Apply appropriate techniques, tools, and formulas to determine measurements

Understand measurable attributes of objects and the units, systems and processes of measurement

Data Analysis and Probability

Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them

International Society for Technology in Education: National Educational Technology Standards (ISTE/NETS)

Digital Citizenship

Exhibit a positive attitude toward using technology that supports collaboration, learning and productivity

Grade Level:
6 - 8

Subjects:
Physical Science, General Mathematics

Teacher Preparation Time:
45 minutes

Lesson Duration:
Two 55-minute class meetings

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Lesson Overview:

During the ENGAGE section of the lesson, students are challenged to lift an ice cube floating in water using only a piece of string and salt. This introduces students to the concept of water's phase changes. In the EXPLORE and EXPLAIN sections, students investigate the freezing point of distilled water and solutions. Students EXTEND their thinking as they modify and perform a self-designed experiment based upon the experiment completed during the EXPLORE and EXPLAIN sections. Several assessment tools are included to EVALUATE student understanding. This lesson is developed using a 5E model of learning.

Icons flag four areas of interest or opportunities for teachers.

- **Technology Icon** highlights opportunities to use technology to enhance the lesson.
- **Modification Icon** denotes opportunities to differentiate the lesson.
- **Resources Icon** relates this lesson to other NASA educator resources that may supplement or extend the lesson.
- **Connections Icon** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **Check for Understanding Icon** suggests quick, formative assessment opportunities.

Essential Questions

- What are abiotic conditions and how do they affect life on Earth?
- What can scientists learn about Earth through the study of ice?
- How does the study of ice relate to space exploration?

Instructional Objectives

Students will

- use problem solving skills to lift an ice cube floating in water using only a piece of string and salt;
- learn more about water's phase changes through experimentation;
- observe and measure temperature accurately;
- record time and temperature data;
- construct and interpret line graphs based on data collected;

Materials List

ENGAGE

Per student

- Student Guide

Per group of two students

- a clear plastic cup half-filled with water
- a 20 cm piece of twine or string
- an ice cube
- 15 mL (1 t) salt in a small cup

EXPLORE

Per group of four students

- 600 mL beaker
- about 300 mL room temperature tap water
- ice
- 150 g of salt
- balance
- stirring rod
- long, red liquid or digital laboratory Celsius thermometer
- timer or watch with seconds

EXPLAIN

Per group of four students

- ice bath made during the EXPLORE activity
- 3 test tubes
- four long, red liquid or digital laboratory Celsius thermometer
- 10 mL of distilled water
- 10 mL of salt solution
- 10 mL of isopropyl alcohol solution
- timer or watch with seconds

- investigate the effects of adding solutes to water on the freezing point of water; and
- design an experiment to test another aspect of the study of water's phase changes.

5E INQUIRY LESSON DEVELOPMENT

ENGAGE (25 minutes)

1. Divide the students into groups of two. Have the materials for the activity in a location accessible to students.

2. Challenge students to remove the ice cube from the cup of water using only the materials provided. *(This challenge can be mastered by placing the string on the ice, sprinkling salt on the string and ice. Students should wait about a minute and then lift the ice by lifting the string.)*.

3. **(CHECK FOR UNDERSTANDING)** Use these questions to guide a class discussion about what students have observed.
   - Why does the ice float? *(Based on student responses, guide students to the understanding that ice is less dense than water causing it to float.)*
   - What happened when you added salt on top of the ice cube? *(Salt lowers the freezing point of the ice, causing the ice cube to melt. The string resting on top of the ice cube is now lying in a thin layer of water. As the salt solution drips off the ice cube and into the glass of water, the freezing point of the water increases and the water freezes the string to the ice cube. This makes it possible to lift the ice cube out of the water.)*
   - Why does table salt melt ice? *(Salt is the compound sodium chloride, or NaCl. When salt comes in contact with ice, it breaks apart into its two ions, Na + and Cl -. These ions disrupt the hydrogen bonds that form between ice molecules, lowering the temperature of ice.)*
   - What phase changes are you observing? *(Ice is melting, going from a solid to liquid, and then freezing, going from a liquid to solid. If the mixture sits long enough, it may be inferred that some water may evaporate to the air, going from a liquid to gas.)*
   - Where might you see this happening in the real world? *(Answers may vary but may include: Salt is sometimes used to melt ice and snow on roads and walkways.)*
   - What are some examples of phase changes for water in nature? *(Ice and snow are examples of water as a solid. Lakes and oceans are examples of water as a liquid. Humidity, steam, or water vapor are examples of water as a gas.)*

4. The History of Winter, sponsored by NASA Goddard Space Flight Center, places teachers in the role of scientists, working side-by-side with professional scientists and technologists. Learning by doing, teachers gain a first-hand understanding of the study of snow and ice as indicators of climate change. The NASA eClips™ video segment *Real World: History of Winter - Abiotic Conditions (7:25)* looks at the tools and practice of scientists studying snow and ice. This segment can be found

on the NASA eClips page of the NASA web site. The video may be streamed or downloaded from the nasa.gov web site; a captioned version is also available at the nasa.gov site.
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms="abiotic"&category=0000

(MODIFICATION) This video may be streamed from the NASA eClips You Tube™ channel. http://www.youtube.com/watch?v=6fk15NgtKmY

(CHECK FOR UNDERSTANDING) Discuss some of the tools and resources showcased in the NASA eClips video segment. *(Some of the tools discussed in the segment include: thermochrons, snow boards and snow tube.)*

Ask students to consider why scientists study ice. *(Studying ice on Earth helps scientists learn more about ice formation on other planets and moons. Scientists can also learn more about Earth's water supply and global climate changes.)*

5. **(RESOURCES)** The following sites offer more information about the History of Winter and NASA's study of ice and snow.

History of Winter
http://education.gsfc.nasa.gov/how/

Cassini Mission
http://www.nasa.gov/mission_pages/cassini/media/cassini-20090612.html

Goddard Institute for Space Studies
http://www.giss.nasa.gov/research/briefs/gornitz_09/

Ice on Mars
http://science.nasa.gov/headlines/y2002/28may_marsice.htm

The Cosmic Ice Laboratory
http://www-691.gsfc.nasa.gov/cosmic.ice.lab/

LCROSS and other ice on the moon missions
http://lcross.arc.nasa.gov/education.htm
http://nssdc.gsfc.nasa.gov/planetary/ice/ice_moon.html

NASA Cryosphere Project
http://www.nasa.gov/vision/earth/environment/cryosphere.html

National Snow and Ice Data Center
http://nsidc.org/cryosphere/

EXPLORE (25 minutes)

The EXPLORE and EXPLAIN activities must be conducted during the same class period. In the EXPLORE and EXPLAIN activities, students study the difference in the freezing point of distilled water as compared to the freezing point of solutions. The freezing point of a solution is always lower than the freezing point of the pure solvent. This phenomenon is most easily observed in seawater. Due to the salt content, sea water remains a liquid at temperatures below 0°C, the freezing point of distilled water.

The EXPLORE activity demonstrates this property to students.
Procedure:

1. Divide students into groups of four and ask them to complete the EXPLORE activity following the directions beginning on page 3 and 4 in the Student Guide. You may want to assign tasks for each group member to make sure they are all engaged.

   SAFETY NOTE: *Remind students that they should never taste anything in a lab and that they should wash their hands when they are finished. Students should wear safety goggles during this activity.*

2. **(TECHNOLOGY)** If available, allow students to use temperature probes connected to data collection devices such as hand-held data collection units or graphing calculators to collect the temperature data.

3. **(CHECK FOR UNDERSTANDING)** Check to be sure students understand how to read liquid volume and temperature measurements. Practice may be needed to improve proficiency.

4. Students will use the ice bath made in the EXPLORE activity for the EXPLAIN activity. Be sure to use ice cubes for this activity and not crushed ice. Crushed ice will melt too quickly.

5. The initial temperature of the ice bath should be near 0°C. This temperature will drop as salt and more ice are added.

6. Ask students to share their temperature data with the class. The temperature of the mixture after salt is added should be around -5°C. Lead students to understand that adding salt to the ice and water lowers the freezing point of water.

7. **(CHECK FOR UNDERSTANDING)** Ask students the following questions:
   a. How do the results of this activity compare with observations from the ENGAGE activity? *(Adding salt, in both cases, lowers the freezing temperature of water.)*
   b. What other materials are sometimes spread on roadways in wintery conditions? *(Sand and cinders are sometimes used on frozen roadways in some locations.)*

c. Do the other materials have the same effect on roads as salt? *(Sand and cinders give cars traction on ice, but they do not melt ice. Sand and cinders do not dissolve in water.)*
d. How would you decide which material to use? *(One way to decide which material to use on frozen surfaces is to find out the predicted temperature for the day. If it is too cold, the salt will not melt the ice and it would be better to use sand or cinders).*

8. **(CONNECTIONS)** As water changes state, it gains or loses energy. Discuss with students that on a molecular level, the more energy a substance has, the faster the molecules in that substance move.

EXPLAIN (30 minutes)

In the EXPLAIN activity, students compare the freezing points of two different solutions to distilled water. One solution, sodium chloride, is a solution made from an ionic compound while the other, isopropyl alcohol, is made from a covalent compound. When a covalent compound is dissolved, the molecules stay intact. However, when ionic compounds dissolve they split up into their component ions. This means that an ionic solution has more particles in it than a covalent solution of the same concentration. Because it has more particles, the ionic solution will lower freezing point than the covalent solution. Both solutions in the EXPLAIN activity are the same concentration, so the salt solution should have a lower freezing point than the isopropyl alcohol solution.

1. Before class, prepare the salt and alcohol solutions.
   a. To prepare the salt solution, measure 800 mL of water into a container. Add 58 g of sodium chloride and stir until it dissolves. Add an additional 200 mL of water and stir thoroughly. Store solution in a container with a cap.

   b. To prepare the isopropyl alcohol solution, measure 800 mL of water into a container. Add 86 mL of 70% isopropyl alcohol. Add an additional 125 mL of water and stir thoroughly. Store solution in a container with a cap.
   NOTE: 70% isopropyl alcohol can be purchased from a pharmacy.

(MODIFICATION) If time permits, allow the students to make their own solutions.

The solutions created for this activity have a concentration of 1 mole of solute per kilogram of solvent (1 mol/kg). A mole is a unit describing a set number of molecules, 6.02×10^{23} molecules. Concentration for liquid solutions refers to the number of units of a substance in a given volume of liquid. In other words, concentration describes how much of something is in solutions.

2. Divide students into groups of four and ask them to complete the EXPLAIN activity beginning on page 4 in the Student Guide.

3. Make sure students continue to monitor the temperature of the ice bath. If the temperature rises above -4°C, students need to add more ice and salt.

4. **(MODIFICATION)** If not enough thermometers are available for each group to have four, assign specific solutions to each group and ask groups to share data with one another.

5. **(TECHNOLOGY)** If available, allow students to use a temperature probe connected to a data collection device to collect the temperature data.

6. When students graph the data collected, they should notice that as the distilled water freezes the temperature remains constant. The solutions will not maintain a constant temperature while they freeze although the rate of change in the temperature will decrease while the solution freezes.
   See Figures1 and 2.

(TECHNOLOGY) Students may use spreadsheet or graphing software to graph the data collected.

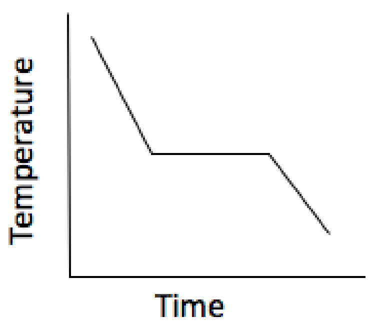

Figure 1. Freezing of distilled water.

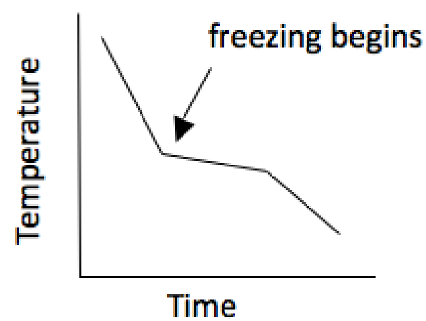

Figure 2. Freezing of a solution.

At first, the temperatures of the liquids drop, until freezing begins. As the distilled water freezes, the temperature holds steady marking the liquid's latent heat. Latent heat is heat energy released when a substance changes from one state to another. Once the phase change is completed, the temperature will drop again.

As the solutions freeze, only the water is changing state. The dissolved solute stays in solution. As less liquid water remains, the concentration of the unfrozen solution increases, lowering the freezing point further. The freezing point of the solution is defined as the temperature at which the solution first starts freezing.

EXTEND (20 minutes)

1. Ask students to make some predictions about the freezing point of other solutions.

2. Challenge students to modify the experimental design of the EXPLAIN activity to test some of these solutions. Students will work as a team to develop their own experimental design.

3. Discuss the importance of maintaining key experimental design elements. *(Be sure students include these elements as they design their own experiments: making a hypothesis, running both a control and experimental test, recording data, taking appropriate measurement and analyzing data).*

4. Build time into the pacing of this activity to gather any additional materials needed for students to conduct their experiments. *(Materials will vary, but may include materials to make other solutions, such as powdered drink mix, Epsom salt, potassium chloride, or seawater.)*

5. **(CONNECTIONS)** Ask students to share the results of their experiments. Discuss any real-world applications relating to their observations. *(For example, students may choose to add powdered drink mix to water for one experimental test. By doing this, they may be able to determine the temperature needed to make popsicles.)*

6. **(CONNECTIONS)** Have students research careers related to studying the cryosphere such as meteorology, geology, and climatology.
   Information can be found at NASA Careers in Earth Science page
   http://kids.earth.nasa.gov/archive/career/

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EVALUATE (10 minutes)

1. Use questions, discussions, student data tables and graphs to check for student understanding and application of knowledge.

2. Ask students to summarize their learning by answering the following journal questions:
   a. Scientists use experimental design to guide discovery. Evaluate the experimental design of your EXPLAIN and EXTEND experiment using these questions:
      1. What were the control, independent and dependent variables in these activities?
         (For the EXPLAIN activity, the independent variables were the solutions used; dependent variable was the freezing temperature; control was distilled water. Answers should be similar for the EXTEND but may vary depending upon the question studied.)
      2. How does graphing data help scientists interpret the data?
         (Graphing data allows scientists to see trends and patterns in the data more easily than looking at individual data points.)

   b. What can scientists learn about Earth through the study of ice?
      (By studying ice, scientists learn about the habitability of different areas of Earth. An area's abiotic conditions determine what living things may survive. The freezing and melting of ice gives scientists an indication of what non-living components may be present but not readily seen within the liquid. For example, if liquid water exists in conditions below 0°C, there must be something dissolved in the water.)

   c. How does the study of ice relate to space exploration?
      (Studying ice on Earth can help scientists determine the abiotic conditions that exist on other bodies in space.)

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ABIOTIC CONDITIONS

Essential Questions

- What are abiotic conditions and how do they affect life on Earth?
- What can scientists learn about Earth through the study of ice?
- How does the study of ice relate to space exploration?

Background

NASA's Cryospheric Sciences Program studies water in its frozen state on Earth. Derived from the term kryos, meaning frost or ice cold, Earth's **cryosphere** includes snow, sea ice, lake ice, glaciers, **permafrost**, ice caps, and ice sheets.

Figure 1. A comet
Image credit: NASA
Goddard Space Flight Center

One of the unique **abiotic** properties of Earth is that water can be found in three states of matter. In fact, Earth is the only planet in the solar system where ice, liquid water, and water vapor exist at the same time. Abiotic factors directly affect the kind of living things found in different places. Other abiotic factors include such things as air currents, **temperature**, moisture, light, climate, and soil type.

Figure 2. Plumes of tiny ice particles spew from Saturn's moon Enceladus.
Image credit: NASA JPL Space Science Institute.

By studying changes in Earth's abiotic properties, scientists learn more about how those changes impact life on Earth. Understanding Earth's cryosphere offers insight into the past, present and future behavior of the Earth as a whole. Polar and sub-polar regions are most sensitive to changes in climate. These areas are remote and therefore difficult to study. Areas of the cryosphere shrink and expand over time. NASA satellite observations help scientists monitor changes in global and regional climate by observing these changes. Scientists use the satellite data to better understand weather and climate patterns over the last several decades. NASA data and analyses will ultimately enable more accurate climate models and prediction.

By studying Earth's ice and the harsh conditions of winter, NASA scientists gain an understanding about ice found in other places of the solar system. Ice on Earth is the frozen form of water. Ice in space may be frozen water, frozen carbon dioxide, or frozen ammonia. Ice is present in the frozen oceans of Jupiter's moon Europa, the particles in Saturn's rings, and the spectacular tails of passing comets.

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Resources

NASA's History of Winter
http://education.gsfc.nasa.gov/how/

Climate Variability and Change
http://nasascience.nasa.gov/earth-science/climate-variability-and-change

NASA Arctic Robot Study
http://www.nasa.gov/topics/earth/features/arctic_robots.html

Vocabulary

abiotic – Abiotic describes conditions and factors that are the nonliving elements of an ecosystem. Examples of abiotic factors include climate, air currents, temperature, moisture, light, and soil type.

constraint – A **constraint** is any limit or restriction given to solve a problem or used to guide the design process.

criteria – Criteria are rules guiding ways to solve a problem or used to guide the design process. The singular form of criteria is criterion.

cryosphere – The **cryosphere** is the part of Earth's system that includes water in its frozen state. Earth's cryosphere includes snow, sea ice, lake ice, glaciers, permafrost, ice caps, and ice sheets.

freezing point – The **freezing point** of a liquid is the temperature at which the liquid changes state from a liquid to a solid.

latent heat – Latent heat is heat energy that is released or absorbed by a substance when it changes from one phase to another.

melting point – The **melting point** of a solid is the temperature at which the solid changes state from a solid to a liquid.

permafrost – Permafrost is any soil or rock that is frozen throughout the year.

phase – Phase describes the physical state of matter. The four common phases of matter are solid, liquid, gas, and plasma.

phase change – A **phase change** occurs when matter changes from one state to another. This is any combination of changing from a solid to a liquid to a gas.

solution – A **solution** is a mixture in which the components are evenly mixed so that every part of the mixture is the same as any other.

states of matter - **States of matter** are the distinct forms of matter. Three common states of matter are solid, liquid, and gas.

temperature – Temperature is a measure of the average heat or thermal energy of the particles in a substance.

A. ENGAGE

Challenge

1. You and your partner need the following materials:
- a clear plastic cup half filled with water and one ice cube
- a 20 cm piece of string
- 15 mL (1 t) salt in a small cup

2. Engineers often work in teams to solve challenges. Time and materials may be **constraints** and **criteria** engineers must consider when coming up with a solution. Using only the materials gathered, work with your partner to solve this challenge of removing the ice cube from the water using only the string and the salt. You may not use the cup holding the salt.

3. Share the procedure you developed and your results with the class.

B. EXPLORE

Changes in temperature cause water to change from one state or **phase** to another. These changes are called **phase changes**. Water freezes, or changes from a solid to a liquid at zero degrees Celsius, or 0°C (32°F). This temperature is both the freezing point and melting point of water. It is called the **freezing point** if the water is changing from a liquid to solid and the **melting point** if water is changing from solid to liquid.

Liquid water has more energy than frozen water. When water freezes, or goes through a phase change, some of water's energy is lost. The amount of energy lost is called the **latent heat** of freezing. The latent heat of freezing is a physical characteristic of a substance. When water freezes, 334 joules of energy are given off for each gram of water that freezes.

1. Gather these materials for your team:

600 mL beaker	about 300 mL room temperature tap water
balance	ice
stirring rod	150 g of salt
Celsius thermometer	timer or watch with seconds

SAFETY NOTE: *Goggles should be worn during this activity. Never taste anything in a lab setting even if you think you know what the substance is.*

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2. Follow this procedure to create an ice bath that you will use during the EXPLORE activity.
   a. Fill the 600 mL beaker to the 200 mL mark with ice.

   b. Add 100 mL of water to the beaker with ice. Stir the mixture and place the thermometer in the beaker. After one minute, record the temperature in Table 1.

   c. Remove the thermometer.

   d. Measure 75 g of salt and add it to the beaker. Stir the mixture.

   e. Add enough ice to bring the level of the water to the 400 mL mark on the beaker. Add another 100 mL of water to the beaker, bringing the mixture's volume to 500 mL. Add another 75 g of salt and stir the mixture. Wait until the salt dissolves.

   f. Place the thermometer in the beaker and then record the temperature of the mixture in Table 1.

Table 1: Creating the Ice Bath

Temperature 1 – without salt	
Temperature 2 – with salt	

C. EXPLAIN

1. Gather these materials for your team:

ice bath made during the EXPLORE activity	10 mL of salt solution
three test tubes	10 mL of isopropyl alcohol solution
four Celsius thermometers	10 mL of distilled water
timer or watch with seconds	

2. Many temperatures need to be read quickly and accurately. To help with this, assign these tasks to team members:
   a. Task One: Read and record the temperature of the ice bath.

b. Task Two: Read the temperature and make observations of the distilled water. Record these data in Table 2.
c. Task Three: Read the temperature and make observations of the salt solution. Record these data in Table 2.
d. Task Four: Read the temperature and make observations of the alcohol solution. Record these data in Table 2.

3. Follow this procedure:
    a. Add 10 mL of distilled water to one test tube, 10 mL of salt **solution** to the second test tube, and 10 mL of alcohol solution to the third test tube. Place a thermometer in each test tube and record the initial temperature, or 0 minute reading, in Table 2. Include observations of the liquids in Table 2.

    b. Place the test tubes in the ice bath.

    c. Place the fourth thermometer in the ice bath to monitor the temperature of the bath.

    d. Record the temperature of each liquid every minute for 8 minutes. Observe and record observations describing the liquid when your record the temperature in Table 2. Note when the liquid begins to freeze. The material will look slushy and begin to solidify.

    e. Record the temperature of the ice bath every minute for 8 minutes. The temperature should remain below -4°C.

4. Once all data is collected and recorded, create a graph of the temperature changes for each test tube. Temperature, the dependent variable you measure when collecting the data, will be recorded on the y-axis. Time, the independent variable you control, will be recorded on the x-axis. Be sure to label each axis and include the appropriate unit.

5. Analyze the graphs to answer these questions.
    a. What similarities and differences do you notice on the graphs?

b. According to your graph, what is the freezing point of distilled water? How do you know?

c. Examine the graphs of each solution. When did each solution begin to freeze? Support your answer with observations.

6. Why would understanding the graphs be important in real life situations related to snow and ice?

7. What are some possible sources of error that could cause your data to be different than your classmates' data?

Table 2. Temperatures and Observations of Ice Bath and Solutions

Ice Bath (˚C)	Time (min)	Distilled Water		Salt Solution		Alcohol Solution	
		Temp. (˚C)	Observations	Temp. (˚C)	Observations	Temp. (˚C)	Observations
	0						
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						

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C. EXTEND

1. After a scientist completes an experiment, new questions often arise.
   a. What questions do you have after completing the EXPLORE and EXPLAIN activities?

   b. What predictions can you make about the freezing point of other solutions?

2. Working as a team, design your own experiment to test another solution. Be sure you consider:
   a. **Key Question:** (What do you wonder about the freezing point of another solution?)
   b. **Hypothesis:** (What do you think will happen?)
   c. **Procedure:** (Do you have a control and experimental test?)
   d. **Data Collection:** (How are you going to organize your data?)
   e. **Data Analysis:** (How will you interpret your data?)

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answerkey

B. EXPLORE

Table 1: Creating the Ice Bath

Temperature 1 – without salt	*Answers will vary but should be near room temperature.*
Temperature 2 – with salt	*Answers will vary but will be less than the first temperature reading*

Table 2. Temperatures and Observations of Ice Bath and Solutions

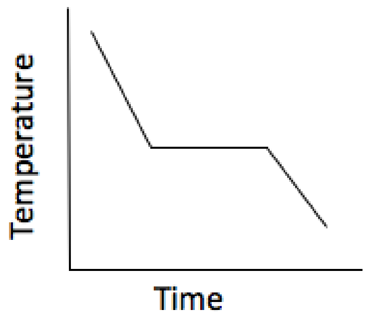
Answers will vary. Example observations are listed below.

Ice Bath (˚C)	Time (min)	Distilled Water		Salt Solution		Alcohol Solution	
		Temp. (˚C)	Observations	Temp. (˚C)	Observations	Temp. (˚C)	Observations
	0	*23*	*liquid*	*23*	*liquid*	*23*	*liquid*
	1	*10*	*liquid*	*11*	*liquid*	*11*	*liquid*
	2	*0*	*slushy*	*1*	*liquid*	*0*	*slushy*
	3	*0*	*slushy*	*0*	*slushy*	*0*	*slushy*
	4	*0*	*slushy/ solid*	*-1*	*solid*	*-1*	*solid*
	5	*-1*	*solid*	*-3*	*solid*	*-2*	*solid*
	6	*-3*	*solid*	*-3*	*solid*	*-4*	*solid*
	7	*-5*	*solid*	*-4*	*solid*	*-5*	*solid*
	8	*-5*	*solid*	*-5*	*solid*	*-5*	*solid*

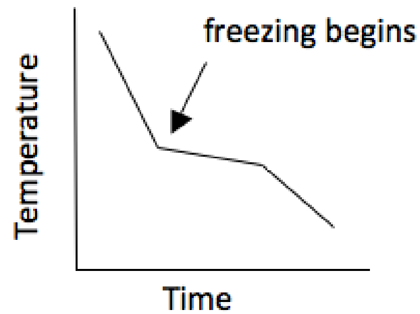
answerkey

4. Once all data is collected and recorded, create a graph of the temperature changes for each test tube. Temperature will be recorded on the y-axis. Time will be recorded on the x-axis. Be sure to label each axis and include the appropriate unit.

Answers will vary, but will resemble the graphs below.



Freezing of distilled water



Freezing of a solution

5. Analyze the graphs to answer these questions.

   a. What similarities and differences do you notice on the graphs?
   Answers will vary but may include: all graphs show quick initial cooling; temperature change slows near 0℃; distilled water shows no temperature change for several readings while solutions continue to change temperature; all graphs stop at the same temperature.

   b. According to your graph, what is the freezing point of distilled water? How do you know?
   The freezing point of distilled water is 0°C. At this temperature the graph is constant for a period of time.

   c. Examine the graphs of each solution. When did each solution begin to freeze? Support your answer with observations
   The salt solution will begin to freeze at -3°C and the alcohol solution will begin to freeze at -2°C. At these temperatures, the solutions became slushy.

6. Why would understanding the graphs be important in real life situations related to snow and ice?
Answers will vary. Possible answers could include being able to predict the temperature that water in a river or lake would freeze, predicting weather conditions, knowing what temperature your freezer would need to be set to in order to make popsicles with different amounts of sugar in them.

7. What are some possible sources of error that could cause your data to be different than your classmates' data?
The major source of error is in measuring the quantities to make the solutions. Students may also list measuring errors such as reading the scale of the thermometer incorrectly.

C. EXTEND

1. After a scientist completes an experiment, new questions often arise.
   a. What questions do you have after completing the EXPLORE and EXPLAIN activities?
   Answers will vary but may include:
   - *How does varying the concentration of a solution affect its freezing point?*
   - *What is the freezing point for seawater?*

   b. What predictions can you make about the freezing point of other solutions?
   Based upon observations from the EXPLORE and EXPLAIN activities, solutions should have lower freezing points than distilled water. Students may predict that the greater the concentration, the lower the freezing point.
2. Working as a team, design your own experiment to test another solution. Be sure you consider:
   a. **Key Question:** (What do you wonder about the freezing point of another solution?)
      a. ***Example:*** *How does doubling the concentration of the salt solution affect its freezing point?*

   b. **Hypothesis:** (What do you think will happen?)
      a. *Based upon the results of the EXPLORE activity, if the concentration of a solution increases, then the freezing point of the solution will decrease.*

   c. **Procedure:** (Do you have a control and experimental test?)
      a. *Follow the procedure outlined in the EXPLORE activity to create an ice bath.*
      b. *You may follow the procedure outlined in the EXPLAIN activity, except when it comes to the solutions to test. One test tube will hold 10 mL distilled water as the control. One test tube will hold 10 mL of the original salt solution. One test tube will hold 10 mL of a salt solution with twice the concentration.*

   d. **Data Collection:** (How are you going to organize your data?)

Ice Bath (˚C)	**Time** (min)	**Distilled Water**		**Salt Solution**		**Alcohol Solution**	
		Temp. (˚C)	**Observations**	**Temp. (˚C)**	**Observations**	**Temp. (˚C)**	**Observations**
	0						
	1						

   e. **Data Analysis:** (How will you interpret your data?)
      a. *Answers will vary, but graphs were helpful in the original experiment and are one tool to interpret data.*

answerkey