Lesson Plan: Salting Roads in Winter

Summary

In this lesson, students investigate how the freezing point of water changes when salt is added. Many students know that water freezes at 0 °C, and many believe that all substances freeze at 0 °C. The investigations in this lesson help students understand why salt is spread on roads in cold and snowy conditions.

Resource Type: Lesson plan
Grade Level: Elementary school

Objectives

By the end of this lesson, students should be able to:
- Measure amounts of water (solvent) and salt (solute) carefully to prepare solutions.
- Describe how the addition of salt affects the freezing point of water.
- Predict what will happen when a saltwater solution is placed in an environment below 0 °C.
- Apply the results of a freezing point depression experiment to understand the purpose of spreading salt on snowy roads in winter.

Chemistry Topics

This lesson supports students’ understanding of the following topics in chemistry:
- States of matter
- Solutions
- Solubility
- Solute/solvent
- Freezing point
- Freezing point depression

Time

Teacher Preparation:

Lesson:
Engage: 10 minutes
Explore Activity 1: 30 minutes
Explain Activity 1: 15 minutes
Explore Activity 2: 25 minutes
Explain Activity 2: 30 minutes

Materials

Explore Activity 1:
For each group
- 2 paper towels
- 2 ice cubes
- Table salt in a small cup
Explore Activity 2:
- Freezer
- Thermometer

For each group:
- 3 clear plastic cups, 8 oz.
- 3 plastic spoons
- Permanent marker
- Measuring cup (¼ or ½ cup)
- Water
- 3 thermometers that can measure below -20 °C
- Measuring spoon (Tablespoon)

Extension materials for each small group:
- Ice melt, sugar, or other solute to test freezing point depression

Safety
- Remind students not to taste or drink the ice, water, or salt solutions that they prepare.

Vocabulary Terms
- Atom
- Molecule
- Solute
- Solution
- Mixture
- Freezing point
- Boiling point
- Freezing point depression

Keywords
water, molecule, states of matter, phase, solute, solvent, freezing point, freezing point depression

Teacher Notes
Logistics and Tips
- To get the most from these lessons, it is important that students discuss their results and how their findings relate to the real-life problems being investigated before they move on to the next experiment.
- This activity can be coupled with Pothole Science, which also examines winter road phenomena.

Science Background

*Freezing Point Depression*
The temperature at which water turns from liquid to solid or from solid to liquid is known as the freezing point or melting point (they happen at the same temperature; freezing happens when thermal energy – heat— is removed from the system, melting happens when thermal energy is added to the system). Pure water at normal atmospheric pressure has a freezing/melting point of 0 °C (or 32 °F). When a solute such as salt is added to water, a solution forms. The solution has a lower freezing point than the solvent. In the case of salt and water, saltwater freezes (and melts) at a lower temperature than fresh water. The lower freezing point occurs because of the interaction between the solute and solvent. In the solution, water molecules interact with other particles as well as with other water molecules, and so they slow down and form a solid at lower temperatures. Roads are salted in winter to melt snow or prevent water from freezing on the road. However, if temperatures are significantly lower than 0 °C, this method won’t prevent roads from freezing.

Lesson

Engage

Begin by asking students what they know about roads in winter: In what ways can driving be dangerous during the winter? What happens to wet roads and sidewalks during the winter? What can happen overnight? Guide them to think about the effects of weather on roads and driving. [Roads get slippery, snowy, and icy.]

Next, discuss what they’ve seen road crews do to keep people safe on slippery roads. Ask them: What do you see people doing to help prevent icy roads? What kind of equipment or vehicles have you seen used? What were they doing? [snow plows scraping snow and slush off roads, trucks spreading salt] After the discussion, show the students the video (2:12) of snow plows on the road: http://www.youtube.com/watch?v=7PwJ2rSKeWM

Students may also have spread salt on sidewalks for the same reason. The question that will be answered next is: What happens when salt is applied to icy roads and why is it used?

Explore Activity 1

Spreading Salt on Icy Roads Model (hands-on)

Experimenting with this model will show students what happens when salt is spread on icy roads and sidewalks: salt lowers the freezing point of water, which causes the ice to melt.

1. Give each group of students two paper towels and ask them to label them “SALT” and “NO SALT.” What do you think will happen if you allow the ice cubes to sit on the table? What will happen if you sprinkle salt onto one of the ice cubes?

2. Give each group two ice cubes of equal size to place on the paper towels.
3. Give each group some table salt and ask them to sprinkle some on the ice cube labeled “SALT.”

4. Ask the students to watch the ice cubes over time and make observations. Which ice cube melted fastest?

![Ice cubes at different stages](image)

Credit: J. Sengbusch

**Explain Activity 1**

Have students use their observations to answer the following question:

*Why do cities and towns spread salt on icy and snowy roads and sidewalks during the winter?*

Students should work together to answer this question, backing up their answer with evidence from the experiment, other observations they have made, and reasoning. Explain to each group that they should be prepared to answer the following additional questions:

- *How does salt affect ice and snow?*
- *At what temperature do snow and ice usually melt?*
- *What does adding salt do to the melting point of ice and snow?*
- *How do you know?*

Groups can present their explanations in the form of a group discussion or a written product.

Once groups have presented, make sure that all students understand the main idea: *Adding salt to ice or snow decreases the melting point of snow and ice: that is, it melts at temperature lower than 0 °C.*

Go on to discuss the application further:

- *How do your results connect with what happens in real life?* [trucks will spread salt on roads and the ice will begin to melt]
- *What happens when cars drive over the salted ice? What do you think it looks like?* [the cars will crush it into smaller pieces; slush]
- *Remember that during winter, the ice and snow may melt during the day. What do you think will happen at night when the temperature falls below freezing again?* The next set of experiments will help answer this question.
**Explore Activity 2**  
**Salted Slushy Roads Model**

This model will demonstrate what happens to salted slushy roads during freezing temperatures and why some cities and towns salt wet roads before an expected freeze.

Hand out the following materials to each group of students: 3 plastic cups, 3 spoons, salt, permanent marker, water, and a measuring cup or measuring spoon. Have the students do the following:

1. Label the three cups using the marker: A: Control, B: Salt 1 and C: Salt 2. Students should also label the bottoms of the cups with the name of their group.
2. Measure 1 Tablespoon of salt into cup B and 2 Tablespoons of salt into cup C.
3. Add $\frac{1}{2}$ cup of water to each cup (A, B, and C) and stir the solute and solvent until the solute (the salt) is dissolved.
4. Once the solutions are prepared, draw a line on the outside of the cup to mark the water level. *Do you think that adding salt will change the way the water freezes? How?*
5. Tape the thermometer to the inside of each cup so that the temperature can be read. Measure and record the starting temperature of the water. (Note: if the number of available thermometers is limited, the same one can be used to measure each sample. We recommend leaving the thermometers in each cup so that the ice or slush temperature can be measured easily later on.)
6. Place the cups with thermometers in the freezer until the next day, along with a thermometer to see what the freezer temperature is.

**Explain Activity 2**

Have students use their observations to answer the following question: *Why do cities and towns spread salt on wet roads and sidewalks before it gets icy out?*

1. Before the class sees the results of their test, review how they set up the experiment.
2. Carefully remove the cups from the freezer and hand them back to the groups. Have the students measure the temperature of the water or slush in each cup if possible. Provide them with the temperature of the freezer.
3. Have the students make observations about the control cup (water only) and salt solutions that were in the freezer overnight. *What happened to the cup containing only water? Cup B? Cup C?* They will likely find that the cup with water froze solid, the mixture in cup B froze some but some liquid remains, cup C...
is slushy; note that the exact results will depend on the temperature of the freezer and the actual percentage of salt in each cup.

4. Remind students that their goal was to determine: *What happens when salt is spread on icy roads and sidewalks and why is it used?* Encourage students to answer the question based on the results of their investigations. In the icy roads model, when salt is placed on ice cubes, they melt faster. This is what would happen if trucks spread salt on icy roads—the ice would begin to melt. Once cars run over the melting ice, the ice would break down into smaller pieces and the salt and water would mix resulting in a salty slush. *Does the resulting salty slush on roads refreeze? What factors determine whether it refreezes or not?* [amount of salt (strength of the solution), temperature]

5. Have students answer the question: *Why do cities and towns spread salt on wet roads and sidewalks before it gets cold out?* Have students to work in small groups to answer the question and back up their response with evidence and reasoning.

As with other activities, students can present their explanations in any form that works well for your class.

**Elaborate**

Students can extend their understanding of expansion with freezing and freezing point depression with additional activities.

- In this investigation, students worked with table salt (typically sodium chloride, NaCl), but the salt spread on roadways may be different. There are a number of different types of salt used to prevent roads, sidewalks, and steps from freezing. It can be hard for a consumer (a buyer) to know what substance works best. Have students design an experiment to test which formula or brand works best. Note that students will need to begin by defining “best.”
- Have students measure the temperature of cups of ice/water from Activity 2 when placed at room temperature over time (after they are taken out of the freezer). Graph results and compare the different concentrations.
- Have students design and carry out an investigation to determine the minimum amount of salt needed to prevent water from freezing at a particular temperature.

**Evaluate**

Assess the quality of the students’ response to tasks you assigned in the Explain sections. Further assessment can be made using any of the following items.

**Discussion Questions**

1. Potholes are holes in roads. Potholes form when water seeps into cracks in the road, freezes, and expands. The expanding water pushes on the materials of the road, cracking the road apart over time. If roads are salted to prevent them from freezing, how do you think salt affects pothole formation? [Students may infer that potholes might not form as easily if the salt prevents the water from freezing. They may also wonder if salt has other affects that can *contribute* to pothole formation.]
Multiple Choice Questions
1. Which is the best definition of the freezing point of water?
   a. The temperature that liquid water turns into ice*
   b. The fact that water does not always turn into ice
   c. The place on a surface where water turns into ice
   d. The place in the water that starts turning to ice first

2. Kim spreads salt on the ice on the sidewalk in front of her house. What is most likely to happen as a result?
   a. The ice will break into pieces.
   b. The ice will stay frozen, even when the air warms up.
   c. The ice will start to melt, even if it is still cold outside.*
   d. The ice will automatically turn into water vapor, without becoming a liquid first.

Constructed Response Questions
1. Keili makes a claim about solids and liquids. She says,

   When a liquid freezes, it turns solid. The temperature that a liquid turns solid is called its freezing point. The freezing point of all liquids is 0 °C. For example, if it is colder than 0 °C outside, all water will turn to ice.

   Critique Keili’s claim. What is correct about what she said? What is incorrect? [Keili is correct that when a liquid freezes, it turns solid, and that the temperature that this happens is called the freezing point. She is not correct in saying that all liquids turn solid at 0 °C. The freezing point of pure water is 0 °C, but the freezing point of saltwater is lower. Some water will turn to ice when at 0 °C, but not all.]

2. Senaya’s parents put a variety of drinks in the freezer to cool off before a party. Senaya notices that some of the drinks have frozen but others are still liquid or partially liquid. Identify two possible explanations for Senaya’s observations.
   [1) The drinks have different freezing points because they are different mixtures of things like water, sugar, salt, (alcohol); 2) Some drinks were in smaller bottles, which freeze faster; 3) The drinks could have started out at different temperatures; 4) The drinks could have been placed in the freezer at different times; 5) Some parts of the freezer could be colder than others.]

Cross-Disciplinary Extensions
Connect to Math
- Have students calculate the percentage of salt by volume in the solutions that they made. Note that they will first need to convert units from Tablespoons to Cups or Cups to Tablespoons.
Connect to Reading
- Have students research the impact of salting roads on the environment and write an essay to communicate their results. *How does the salt affect grass and other plants near the road? Animals? Local streams? Bodies of water father away? Are the benefits of salting roads worth the risks to the environment?*

Connect to Writing
- Have students imagine that the budget for road salt has been cut: the city will no longer buy any road salt. Students can then either
  - Write a short story in which they imagine what a winter in a cold city would be like without road salt
  - Write a persuasive letter to the city council against or in support of this decision

Connect to Social Studies
- Have students research and communicate about the use of salt in their area.
  *What kind of salt is used in your state to clear roads during the winter months? Where does the salt come from? How is it transported to your area?*

Next Generation Science Standards
This lesson supports the following:

Practices of Science and Engineering
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Cross-Cutting Concepts
- Cause and Effect: Mechanism and Explanation
- Systems and System Models
- Energy and Matter: Flows, Cycles, and Conservation
- Stability and Change

Disciplinary Core Ideas, Grades 3-5
Physical science
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model shows that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects. (5-PS1-1)
• The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)

• When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)

Earth science
• Earth’s major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth’s surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. (5-ESS3-1)

Engineering Design
• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

(secondary to 4-PS3-4)