



**Tools and Resources**

***“‘Beeting’ Icy Roads”***

December 2018/January 2019

<http://www.acs.org/chemmatters>

**Teacher’s Guide:**



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# Connections to Chemistry Concepts

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| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Solubility** | The study of the solubility of ionic and molecular compounds can be enriched by including the information in the article that directly relates this concept to the daily lives of those who experience snow in winter and/or travel to ski resorts over icy roads. |
| **Chemical bonding** | Predicting the effectiveness of a solute, used to prepare a solution designed to prevent road icing—based on the number of particles the solute will donate to a solution—presents an opportunity to add relevance to the study of covalent and ionic chemical bonding. |
| **Colligative properties** | The study of colligative properties can help direct student focus to the particle level for understanding how the number of solute particles in a solution affects the melting of ice and snow. This article provides a useful, everyday (in the winter) application of colligative properties. |
| **Freezing point** | Once students recognize freezing point as a characteristic of a pure substance, using water as an example in articles such as this one provides evidence that characteristics change as the purity of a substance changes. |
| **Freezing point depression** | The information in this article can add relevance, meaning and importance to the world of students when they study freezing point depression. Rather than just a bunch of calculations, they can understand how chemical engineers use this information to reduce icy roadways. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5:** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + **ELA-Literacy.RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + **ELA-Literacy.RST.11-12.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
  + **ELA-Literacy.WHST.9-10.2F:** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + **ELA-Literacy.WHST.11-12.1E:** Provide a concluding statement or section that follows from or supports the argument presented.

## Vocabulary

* **Vocabulary** and **concepts** that are reinforced in this issue:
  + Structural formulas
  + Crystalline structure
  + Environmental impacts of personal and societal decisions
  + Electromagnetic radiation
  + Colligative properties
  + Gas laws
* Consider asking students to read “Open for Discussion: A Slippery Slope” on page 4 to learn about concerns regarding using artificial snow prior to reading the article “What’s Artificial Snow, and How Is It Made?”
* Students from warmer climates may be unaware of the use of salt to melt ice on roadways. Ask them if they have ever traveled to cold climates and if they had trouble walking on icy sidewalks, or if they have seen this problem in movies or television. Show students the ACS Reactions video referenced on page 14 AFTER they have read the article to help them understand why salt is used to deice roads and how it works.
* Two of the articles relate to personal health (UV eye protection and cupping). Ask students how the articles might impact their decisions regarding their health and why.
* Two of the articles relate to environmental impacts of our decisions (artificial snow and salting roads). Ask students how the information from the articles might help them make decisions in the future, and factors they might consider as citizens asked to provide input on related projects.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles, and what they would like to explore further.
* Ask students if they have questions about some of the issues discussed in the articles.

# Possible Student Misconceptions

1. **“Sand and salt are both used to treat icy roads. I didn’t know sand melts ice just like salt.”** Actually, sand doesn’t melt ice; it is used to improve traction on icy roads. Sand crystals increase friction between automobile tires and road surfaces to prevent slipping. On the other hand, salt lowers the freezing point of water, thus melting ice.
2. **“I’m not from snow country, but I’ve heard that when salt is spread on snow and ice, it melts them quickly so cars can drive on the roads again.”** Actually when salt is spread on top of snow, each salt grain just melts the ice crystals around it. This forms little pools of salty water that begin to melt the ice around them. This process works, but it is actually slow. When the salt is spread before the snow falls, as soon as snow hits, the salt begins to melt the surface snow above it and vehicles driving over this accelerate the process by churning the mess and making it easier for snow plows to push the melting ice and snow off the road.
3. **“I’ve heard that sometimes it’s just too cold to snow.”** There is a maximum amount of water that air can hold at a particular temperature, and colder air has less capacity to hold moisture than warm air. However, there will be enough moisture in the air for snow until the temperature reaches below –40 oC. At this point the moisture content will be so low that snow can rarely occur. So a place where it’s just too cold to snow will be extremely cold!!
4. **“After our snow season, it looks like the concrete on our driveway is flaking away. The road salt must have damaged the concrete.”** Usually, road salt will not harmconcrete driveways. However, damage can occur if the concrete has not been properly mixed, installed and “finished”. Chemical additives (admixtures) should be added to cement just before or during mixing. These reduce water in the mixture, slow the rate of setting (especially in hot climates), inhibit corrosion, and add millions of microscopic bubbles (air pockets) in the concrete surface to increase cohesion and prevent damage during freeze-thaw cycles by allowing ice crystals to form and expand without breaking the surface. The flaking of the surface concrete is called spalling.
5. **“I understand the dangers of deicers increasing the salinity of lakes and streams, but I live in a wooded area far from any major waterways, so this is probably not a problem here.”** Salt left on the roads is a problem even in locations far from bodies of water. Animals such as moose and deer need salt during the winter to supplement their diet. Unfortunately, in winter they are often attracted to salty roads and highways that they use as “salt licks.” Here they may be hit by motorized vehicles causing severe damage to vehicles and possible death to animals.

# Anticipating Student Questions

1. **“Why doesn’t the salt that they put on our roads in the winter look white like table salt?”** Road salt (halite) is the natural, unrefined form of table salt, sodium chloride (NaCl). When mined, the salt contains natural mineral impurities that give it a brownish or gray color. To prepare table salt, halite is crushed after mining and impurities are removed.
2. **“Sea salt is used to cook. What is it?”** Food-grade sea salt is less refined than table salt. It has about the same nutritional value as table salt and is usually white. It can be recovered from ocean water or salt water lakes by evaporation. Highly refined table salt has trace minerals removed. Table salt is often “iodized” with small amounts of potassium iodide or sodium iodide to prevent iodine deficiency. Iodized salt can interfere with chemistry experiments, so you should use the non-iodized version in classroom experiments.
3. **“What is brackish water, where does it from and why is it a concern?”** Brackish wateris water that contains more salt than fresh water. It forms where seawater mixes with freshwater in locations such as estuaries, marshes, and swamps. Concerns include the inability of many plants and animals to survive in an extremely salty environment. In addition, these water areas are prime breeding grounds for mosquitoes.
4. **“Why do they pre-salt, or brine, our roads before the snow actually falls?”**Pre-salting means spreading a layer of salt or liquid deicer directly on the road, so when the snow falls it doesn’t freeze the road surface. The salt makes the snow slushy, vehicles tires mush it around, and the snowplow can push the whole mess off the road.
5. **“What kind of deicer is least harmful to grasses and plants?”** Unfortunately, this question can’t be answered easily because tests show that the toxicity of deicers depends upon the plant. For example, calcium magnesium acetate deicers are more harmful to the duckweed plants than sodium chloride. However, the opposite is true for barley plants.
6. **“The pH, as well as the salinity, of streams and rivers is increasing in the U.S. NaCl is a neutral salt, so how does it increase the pH?”** Research shows that both salinization and alkalinization (change in pH to make the solution more basic) are increasing in U.S. streams and rivers, due in varying degrees to each of these:

* Deicers increase salinity.
* Agricultural runoff often contains lime (calcium hydroxide), which is alkaline.
* Urbanization leads to an increased use of basic (alkaline) concrete that also contains lime, which leaches into groundwater when freshly poured.
* The widespread use and disposal of salts of bases such as ammonium hydroxide (ammonia cleaner) and carbonates such as sodium bicarbonate (baking soda) contribute to the alkalinity of our environment.

(<http://www.pnas.org/content/pnas/early/2018/01/03/1711234115.full.pdf>)

1. **“How do some little bugs keep from freezing in icy winters?**

Some bugs make their own antifreeze, often an alcohol (a solute), that mixes with their body fluids, thus lowering the liquid’s freezing point.

(<https://indianapublicmedia.org/amomentofscience/bug-antifreeze/>)

# Activities

**Labs and demos**

**“How does Salt ‘Melt’ Ice?” lab (90 min):** This lab activity is designed to help students understand why salt is used to clear snow; they also investigate which type of salt is best.

(Access is restricted to AACT members, but the article will be available for free until February 1, 2019 at <https://teachchemistry.org/classroom-resources/how-does-salt-melt-ice>.)

**“Molar Mass of a Molecular Compound by Freezing-Point Depression: A ‘Green’ Chemistry Activity” lab (90 min):** This Honors- or AP-level laboratory activity has replaced usual organic solutes (such as benzophenone and naphthalene) with glucose for a safer, greener process. The Teacher Preparation page shows sample calculations; teachers are given permission to duplicate materials for classroom use. (<https://www.carolina.com/teacher-resources/Interactive/molar-mass-by-freezing-point-depression/tr10799.tr>) This URL contains a link to the student worksheet.

**Simulations**

**“Salty Roads” simulation:** Students can add NaCl or CaCl2 to water and watch the animation as particles dissolve; students can choose solution concentrations and, as dissolving occurs, the temperature drops and the final freezing point depression (color coded by solute) is shown on a freezing point vs salt concentration graph. (Free CK-12 Foundation access requires sign-up with name, e-address and password; <https://interactives.ck12.org/simulations/chemistry/freezing-point/app/index.html>)

**Media**

**“Boiling Point Elevation and Freezing Point Depression” video (13:59):** This Khan Academy video uses particle-level diagrams to show how the addition of a solute (like road salt) to a pure substance (such as water) interferes with both the boiling point and the freezing point; the video begins with the boiling point elevated with the addition of a solute, then the video shows how the freezing point is lowered when salt is applied to snowy roads. The calculations of boiling point elevation and freezing point depression are shown as the explanation is developed. (<https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/mixtures-and-solutions/v/boiling-point-elevation-and-freezing-point-supression>)

**“The Effects of Salinity and Temperature on Dissolved Oxygen” YouTube video (8:17):** Aerated beakers at different salinities and temperatures are measured by a dissolved oxygen meter, data is collected and graphed. This video produced by the Ocean Research and Conservation Association (ORCA) shows the types of fish that can survive in the tested situations on the data graph. (<https://www.youtube.com/watch?v=ibaD-9KwSDM>)

**Lessons and lesson plans**

**“Alternative Deicers: An Application of Freezing Point Depression” (2 lab periods + outside research):** This lesson involves student research, an on-line simulation to learn about concentration and the van't Hoff factor, a chemistry lab (experimental design), a summary of findings, and a written proposal to be sent to the mayor for an alternative deicer. (<https://serc.carleton.edu/bioregion/examples/59182.html>)

**“Ecology Disrupted: Human impacts demonstrate ecological principles” lesson plan—Middle and High School Level— (6 lessons):** The American Museum of Natural History has produced a set of five 45-minute lessons (“Salting Winter Roads”, “Salt and Living Things”, “Water in Our Daily Lives: Coming and Going”, “Investigating and Graphing Salinity Data”, “[Presenting and Making Meaning from Salinity Data: Graphing and Drawing Conclusions](https://www.amnh.org/explore/curriculum-collections/ecology-disrupted/winter-roads/lesson-plans/representing-and-making-meaning-from-data)”), and a sixth, 90-minute lesson (“[Ecology Disrupted: Unexpected Consequences Of Human Daily Life On Abiotic and Biotic Ecosystem Components](https://www.amnh.org/explore/curriculum-collections/ecology-disrupted/winter-roads/lesson-plans/ecology-disrupted)”). Click on links for extensive teacher materials.

(<https://www.amnh.org/explore/curriculum-collections/ecology-disrupted/winter-roads/lesson-plans>)

**Projects and extension activities**

**“An Alternative to Road Salt” (A Science Fair Project):** The effectiveness of beet juice and a solution of beet juice and rock salt are compared to only rock salt in melting ice. Data includes time for each variable to melt ice plus conductivity measurements of each. This was designed as a middle school project. However, by adding more alternatives it can easily be adapted for use in the high school classroom.

(<https://www.education.com/science-fair/article/salting-icy-roads-alternative/>)

**“Effect of Salt Concentration on Plants” (2 class lab periods + observations of changes in plant material, as necessary):** This very well-written student laboratory exercise, with its ample student and teacher materials and a bit of lab design included, deals with the standard osmosis lab, which you could use to correlate (or ask students to correlate) with the effects of the runoff from salted roads on plant growth. (Access is restricted to AACT members, but the article will be available for free until February 1, 2019 at <https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/summer.html>.)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles published from the magazine’s inception in October 1983 through April 2013; all**

**available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get 30 Years of *ChemMatters* Magazine!” (the icon on the right of the screen).**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



“Salting Roads: The Solution for Winter Driving” emphasizes salting roads to save lives; the article explains freezing-point depression and the phase diagram for sodium chloride; it is suggested that corrosion is a small price to pay for the reduction in deadly winter vehicle accidents; the long term environmental effects of salinization of natural fresh and salt water were not addressed. (Kimbrough, D. Salting Roads: The Solution for Winter Driving. *ChemMatters*. 2006, *24* (1), pp 14–16)

Sprayed-on deicers save planes and their passengers; efforts to prevent environmental pollution from airline deicers are included such as collecting and recycling the anti-freeze running off plane wings are included in the article. (Banks, P. Weighting in the Wings *ChemMatters*. 1992, *15* (4), pp 10–12)

# Web Resources for More Information

**Salting roads—history**

This publication discusses the history of the use of salt for deicing roads and the effects on the health of humans, plants, and animals, due to changes in the salinity of wetlands and ground water. Graphs and cost/benefit analyses are used to illustrate the problem; possible solutions and alternatives are discussed.

(<https://www.caryinstitute.org/sites/default/files/public/reprints/report_road_salt_2010.pdf>)

This article discusses the early use of salt and cinders to add traction to slick roads. Graphs and cost/benefit analyses are used to illustrate the problem; possible alternatives are discussed.

(<https://www.vox.com/2015/1/13/7531833/road-salt-environment-alternatives>)

**Salting roads—problems**

Toxic effects of high chloride level in waterways are described in this article citing EPA data.

(<https://www.wired.com/2015/03/road-salt-polluting-rivers/>)

“Hidden Dangers of Road Salt” contains many links to journal articles that feature data from their original studies showing the harmful effects of increased levels of chloride from road salt to both aquatic and terrestrial animals, including trout, frogs and butterflies; it includes evidence photos showing normal animals next to those living in waters of high salt content.

(<https://www.smithsonianmag.com/science-nature/road-salt-can-disrupt-ecosystems-and-endanger-humans-180963393/>)

**Drinking water standards**

EPA national drinking water regulations include safe sodium and chloride concentrations, as well as risk values for cancer causing contaminants.

(<https://www.medicalnewstoday.com/articles/263371.php>)

This is an interactive map showing national unsafe drinking water areas and state actions taken for ensuring safety at school drinking fountains.

(<http://www.drinkingwateralliance.org/new-map>)

**Environmental problems**

This report investigates data for salt alternative, including cost and quantity. Results show alternatives work, and harm can be reversed if introduced.

(<https://mcspolicycenter.umaine.edu/wp-content/uploads/sites/122/2016/09/Winter-Road-Maint-Final.pdf>)

Chloride ions are not filtered out by the soil, are very soluble, and cannot be removed from the environment by natural means; the article is divided into seven topics, and road salt toxicity is explained.

(<https://www.des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/impacts.htm>)

**Salinity**

The study shows that high chloride levels in streams that flow from suburban and urban areas of Baltimore than in streams fed by water from forests and agricultural areas. Data is shown in graphical format.

(<http://www.pnas.org/content/102/38/13517.full>)

Short video and graphs describe results of studies on the variations and causes of ocean salinity. The salinity of surface water is affected by the climate—dilution from rain and concentration from water evaporation.

(<https://www.sciencelearn.org.nz/resources/686-ocean-salinity>)

**Alternatives**

**This article discusses the environmental problems in lakes of using both road salt and organic waste for deicing. In the future, solar panels to melt snow may replace asphalt on roads.**

(<http://theconversation.com/road-salt-is-bad-for-the-environment-so-why-do-we-keep-using-it-87860>)

This article discusses the pros and cons of using six alternatives to rock salt for deicing: beet juice, organic waste, fracking waste-water, cheese brine, pickle brine, and potato juice.

(<https://montrealgazette.com/news/local-news/a-look-at-the-alternatives-to-rock-salt-for-de-icing-roads>)