SHORT FILMS ABOUT CHEMISTRY

Untapped Potential

IN THE CLASSROOM

CLASSROOM LESSON PLAN
GRADES 9–12

Overview

This lesson plan contains student activities, teacher notes, and additional resource suggestions that are intended for use with the Chemistry Shorts™ film *Untapped Potential*. The film is freely available for viewing online either at the link above or http://chemistryshorts.org. The activities stand alone, with no additional background material needed. The activities are aimed at grades 9–12. Teachers may adjust or extend discussion of the chemistry involved depending on the students' level. The plan is designed for use as a complete package, although teachers may choose individual activities.

The lesson and materials are suitable for both in-person and virtual classrooms.

Classroom Materials

- Method for viewing Chemistry Shorts™ film *Untapped Potential* (9 min, 53 sec)
- Student Activity handouts (paper or digital copies)

Student Activities with Estimated Times

Pre-class Activity Your Knowledge and Connection to Water	(10–15 min.)
Pre-class Activity Water Chemistry	(5–10 min.)
In-class Activity Scarcity of Water	(5–10 min.)
In-class Activity Chemistry: Transforming the Undrinkable (including watching the film)	(25–30 min.)
After-class Activity Water: Possibilities for the Future	(15–20 min.)

Related Standards

NGSS HS-PS1-1
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

NGSS HS-PS1-2
Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

NGSS HS-ESS3-4
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

NGSS HS-ETS1-1
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

CCSS.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*).

CCSS.ELA-Literacy.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table of chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CCSS.ELA-Literacy.RST.11-12.2
Determine the central idea of conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

CCSS.ELA-Literacy.RST.11-12.7
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Pre-Class Activity Teacher Notes
Your Knowledge and Connection to Water

Question 1, part d
The 2016 *ChemMatters* article "The Flint Water Crisis: What's Really Going On?" is written for a high school audience and relates to one of the problems recently faced with water supply.
https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/2016-2017/december-2016/flint-water-crisis.html

Question 2, parts b and c
Students who live in locations that use a municipal water supply can search online for a municipal water report for their community. One place to start is the U.S. Environmental Protection Agency's Drinking Water Mapping Application.
https://geopub.epa.gov/dwwidgetapp/

Information on a community's wastewater treatment plants can sometimes be found online. Try searching for "waste treatment plant" and your city's name.

This chemistry infographic helps students see the science that takes place between the supply and their tap.
https://www.compoundchem.com/2016/04/21/water-treatment/

Pre-Class Activity Teacher Notes
Water Chemistry

Question 1
Students could share their answers and compile a class summary. Does particular information come up in multiple students' answers? Are there any unusual ideas to highlight?

Watch the video "You Don't Actually Know How Water Works" for more ideas about this everyday chemical with unusual properties.
https://youtu.be/dlHxV0Hpt5I

In-Class Activity Teacher Notes
Water Scarcity

Question 1, part a
Students could compare their predictions for the percentage of accessible freshwater. Was anyone close to the correct percentage?

An interactive demonstration is another way to make the percentages of different types of water on Earth more visible to students. The American Chemical Society offers one using a 1-L bottle of water, which is then separated out into smaller containers, along with salt for part of it, and food coloring for better visibility.
https://www.acs.org/content/dam/acsorg/education/outreach/ccew/educational-resources/2020/all-the-water-in-the-world/2020-ccew-water-in-the-world-demo.pdf

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In-Class Activity Teacher Notes
Chemistry: Transforming the Undrinkable

Question 2, part d
Learn more about how pharmaceuticals make their way into our water supply and the ways chemistry can help. The 2011 *ChemMatters* article "Drugs Down the Drain" is written for a high school audience.
https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/drugs-down-the-drain.pdf

Question 2, part e
At about the 6 minute mark, the film shows an animation of hydrogen peroxide breaking apart and then breaking down organic compounds. It does this through different multi-step mechanisms. They are not presented in this lesson plan due to complexity.

Classes could learn more about 1,4-dioxane.

1,4-dioxane Molecule of the Week resource.
https://www.acs.org/content/acs/en/molecule-of-the-week/archive/d/dioxane.html

Chemical & Engineering News article about 1,4-dioxane.
https://cen.acs.org/environment/pollution/14-Dioxane-Another-forever-chemical/98/i43

Information sheet for citizens concerned about 1,4-dioxane in their local water supply.
https://hicksvillewater.org/wp-content/uploads/2019/04/14D-fact-sheet.pdf

After-Class Activity Teacher Notes
Water: Possibilities for the Future

Question 4
As a follow-up to students' brainstorming, teachers could show the ACS Reactions video that asks and answers this question.
https://youtu.be/w6x54zYuqXk

General Resources
Want to explore chemistry and the environment further? Look for inspiration in this web link round-up of climate, water, and recycling demonstrations, activities, and more.
https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/chemistry-and-the-environment.html

What other ideas are out there? Icebergs? Fog? Evaluate these prospects.
https://theconversation.com/five-unusual-technologies-for-harvesting-water-in-dry-areas-154031

Name ______________________________ Date ______________

Pre-Class Activity
Your Knowledge and Connection to Water

Water. This simple everyday compound is critical to our survival. We count on water being there for us, clean, coming from the tap. Do you think it will continue to? What will it take for that to continue for years to come?

1. The Chemistry Shorts™ film you will watch, *Untapped Potential*, begins with a quote from Benjamin Franklin: "When the well is dry, we know the worth of water."

a. What do you know about wells?

b. Briefly summarize what you think the quote means.

c. The quote was published in *Poor Richard's Almanack* in 1746, over 250 years ago. Do you consider the quote still relevant today? Explain your answer.

Name ______________________________ Date ______________

Pre-Class Activity
Your Knowledge and Connection to Water (continued)

d. What is at least one challenge related to water supply, use, or wastewater that you think the world faces today or might face later in your lifetime?

2. We use water daily. It's such a common occurrence, we may not think about its use that often, where it comes from, or where it goes after we use it.

a. Write your first name in the circle below. On the lines beneath the circle, list several typical ways you personally use water.

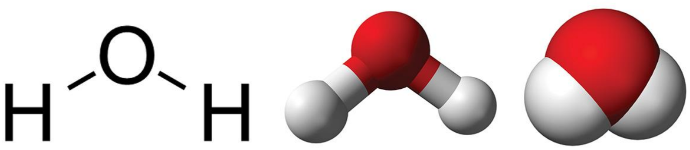
b. Draw a shape to the left of the circle. Write "Supply" in it. Draw an arrow from the shape to the circle. From where does the water you personally use come? Briefly describe what you already know or what you think about it beneath the shape.

c. Draw a shape to the right of the circle. Write "Wastewater" in it. Draw an arrow from the circle to the shape. Where does the water you personally use go afterward? Briefly describe what you already know or what you think about it beneath the shape.

Name ______________________________ Date ________________

Pre-Class Activity
Water Chemistry

1. Different representations of water molecules are shown below. What do you already know about the chemistry of this molecule? Share your thoughts below.



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2. A Lewis dot structure, or electron dot structure, is a way to represent the valence (outer shell) electrons in a molecule. Drawing this type of diagram can help to understand the bonding and arrangement of the molecule.

For example, neon (see below, left) has 8 valence electrons, giving it a full outer shell; it is unlikely to bond with other atoms.

Hydrogen has 1 valence electron (see below, center). To have a full outer shell, it needs 2. One way for it to do this is to form a diatomic molecule, H_2. This allows it to achieve a full shell by sharing electrons, forming covalent bonds. Each atom has one valence electron They are shared as an electron pair in a covalent bond between them; each atom has a full outer shell through this sharing, shown by the circle around each (see below, right).

a. Oxygen has 6 valence electrons. It has more energy levels than hydrogen, so has room for 8 electrons in a full outer shell. Draw a Lewis dot structure for the oxygen atom. Dots (electrons) are paired only when there are no other locations in the diagram to stay unpaired.

O

Name ____________________ Date ____________

Pre-Class Activity
Water Chemistry (continued)

b. In this section, you will draw a Lewis dot structure for water (H_2O). Determine the total number of valence electrons for H_2O and note how many electrons each atom can hold in its outer shell.

Atom	# of valence electrons	# of valence electrons to fill outer shell
H	1	2
H	1	2
O	6	8
Total		

c. The water molecule has covalent bonds, which share electrons between two atoms to fill their outer shells. Draw dots to represent the total valence electrons in the molecule around the atoms so that each has a filled outer shell.

H O H

d. Another arrangement of the atoms is below (H H O). Why is this not a possible arrangement?

H H O

e. Electron pairs that do not participate in bonding between two atoms are called lone electron pairs. How many lone electron pairs does the water molecule have? Circle any lone pairs in your diagram in part b. In what ways do you think they contribute to the chemical properties of water?

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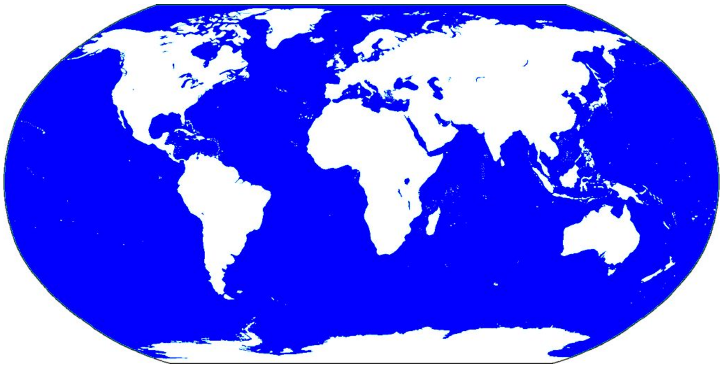
Name ______________________________ Date ________________

In-Class Activity
Scarcity of Water

A world map is shown below, with water blue and land white. While it looks like we have an extensive supply, the amount available for everyday use such as drinking, cooking, and washing, is much smaller. In this activity, you will explore different water sources and their possible use.



1. For the questions on the next page, imagine the bucket below as holding all of the world's water.

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Name ______________________________ Date ______________

In-Class Activity
Scarcity of Water (continued)

a. 100 squares are shown to the right of the bucket, with each square representing 1% of the Earth's water. Predict how many of the squares (you do not need to choose a whole number; fractions may also be used) should be colored in to represent accessible freshwater. Explain your reasoning.

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b. 70% of the water is oceanic saltwater. Choose a crayon or colored pencil and shade squares to represent this.

c. 28% of the water is brackish, or salty water, in locations other than the ocean. Choose a different color and shade squares to represent this.

d. The remaining portion is freshwater, but much of it it is non-accessible. What are some possibilities for why this water is not able to be readily used by humans? Where might it be located?

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e. Only one-tenth of one of the squares is accessible freshwater. How does it compare to your prediction in part a? Choose a color and shade that amount of one square to picture how little is readily available.

Name ______________________ Date ______________

In-Class Activity
Scarcity of Water (continued)

2. The Chemistry Shorts™ film title is *Untapped Potential*.

   a. Discuss how this title relates to the bucket and 100 squares in question

   b. What are water source possibilities that the world could use?

   c. How do you think chemistry could play a role in making these water sources usable by more people around the world?

Name ____________________ Date ____________

In-Class Activity
Chemistry: Transforming the Undrinkable

Chemistry makes it possible to tap into new sources of water that have been previously unusable. The film *Untapped Potential* highlights three different scientists and the methods they have developed to do this using chemistry.

1. As you view the film *Untapped Potential*, use the table below to summarize information the film highlights about the chemistry-based solutions for increasing usable water sources.

Scientist	Solution(s)	Chemistry Involved

Name ______________________________ Date ______________

In-Class Activity
Chemistry: Transforming the Undrinkable (continued)

2. One of the steps that can be used in recycling wastewater is an advanced oxidation process (AOP). This can greatly reduce the concentration of organic contaminants in the water, transforming them into biodegradable compounds that can be further broken down. Hydrogen peroxide (H_2O_2) is one of the chemicals that can be used in AOP.

a. In this section, you will draw the Lewis dot structure for hydrogen peroxide. First, determine the number of valence electrons and how many each can hold in its outer shell.

Atom	# of valence electrons	# of valence electrons to fill outer shell
Total		

b. The molecule has covalent bonds, which share electrons between two atoms to fill their outer shells. Using the basic structure below, draw dots to represent the valence electrons around the atoms so that each has a filled outer shell. This is the Lewis dot structure for hydrogen peroxide.

H O O H

Name ______________________________ Date ______________

In-Class Activity
Chemistry: Transforming the Undrinkable (continued)

c. In AOP, when hydrogen peroxide (H_2O_2) is hit with ultraviolet light, it splits into two identical parts called hydroxyl radicals. Draw a Lewis dot structure of one of these parts.

d. These hydroxyl radicals are incredibly reactive with organic compounds, including things that are present in wastewater as contaminants, such as pesticides, pharmaceuticals, and personal care and cleaning products. Based on the Lewis dot structure you drew above, explain why it is so reactive.

e. One organic contaminant that can be removed using AOP is 1,4-dioxane. This compound is an unintentional impurity in cleaning products like laundry detergent and shampoo, and is a widespread contaminant in drinking water and wastewater. The U.S. Environmental Protection Agency says it is a likely carcinogen.

Various organizations are discussing possible regulations for limiting it in water. If regulations were passed requiring 1,4-dioxane levels to be much lower, what questions would you have about 1,4-dioxane and/or AOP before deciding to use it in a local water treatment plant for drinking water?

Name ______________________________ Date ____________

After-Class Activity
Water: Possibilities for the Future

1. In the Pre-class activity "Your Knowledge and Connection to Water," you created a diagram with shapes and connections that showed a linear water economy, from supply to use to wastewater. The film showed that chemistry can help us connect and lead to different possibilities that are more circular.

   a. Redraw your original diagram from the Pre-class activity "Your Knowledge and Connection to Water" question 2, parts a–c, below. You do not need to include the descriptions you originally added underneath the diagram.

   b. Use the information you summarized in the table of the In-class activity "Chemistry: Transforming the Undrinkable" question 1 to modify your original drawing. Include each of the solutions in your diagram. Some questions to get you thinking about water connections from the film are below:

   - Where does desalination fit in your diagram?
   - Where does wastewater fit in after use? Where does it go back into the cycle?
   - What role can brine play in the cycle?

2. Imagine revisiting the the film *Untapped Potential* 5–10 years from now. What would an updated version include? Provide at least one example of more work that needs to be done between then and now. What are possibilities you picture for the future?

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Name ______________________________ Date ______________

After-Class Activity
Water: Possibilities for the Future (continued)

3. Teenaged researchers have developed exciting innovations over the years that impact our ability to better provide clean water into the future. For example, the Stockholm Junior Water Prize attracts tens of thousands of entries from 15–20 year olds from over three dozen countries. What are some reasons that you think drive these young scientists to engage in this kind of study? Do you have any ideas to better provide clean water?

4. Consider: What do astronauts do with pee in space? Brainstorm your ideas.

a. What are problems you see connected with this situation?

b. What are solutions you imagine for the situation?

SHORT FILMS ABOUT CHEMISTRY

Untapped Potential

IN THE LABORATORY

LAB EXPERIMENT

GRADES 9–12

Overview

This lab experiment complements the Chemistry Shorts™ film *Untapped Potential*. The film is freely available for viewing online either at the link above or http://chemistryshorts.org. The experiment is aimed at grades 9–12 and potentially above. Teachers may adjust or extend discussion of the chemistry involved depending on the students' level.

Materials

- Student Handout
- Experiment materials—shared equipment for class
  - Access to a freezer
  - Method to compare salinity (e.g., conductivity probe, refractometer, multimeter)
  - Digital balances
- Experiment materials per student pair/group
  - Two 250-mL beakers or similar containers
  - Table salt (sodium chloride, NaCl)
  - Tap water
  - Stirring rods or spoons
  - Timer
  - Fork or slotted spoon
  - Small bowl or container

Estimated Times

Solution preparation and measurements	5–10 min.
Freezing solutions, with observations every 15 minutes (depends on freezer)	45-90 min.
Ice collection and melting	10-15 min.
Final conductivity measurements	5-10 min.
Total	**65-125 min.**

Related Standards

NGSS HS-ESS2-5
Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

NGSS HS-ESS3-4
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

NGSS HS-ETS1-1
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Name ______________________________ Date ______________

Freezing: Is It a Desalination Opportunity?

How can we desalinate, or get the salt out of seawater, to make it usable for our everyday water supply? The Chemistry Shorts™ film *Untapped Potential* discusses different ways, including boiling it: "Very, very early on, people realized that if they could boil water, the condensate would be fresh or pure. Thermal desalination is a pretty simple process, but it has very high capital costs and very high energy costs" (starts at 2:32 in film). Is a different phase change another desalination opportunity? Methods for freeze desalination have advanced over the past decade. As saltwater freezes, the salt solute can remain in the liquid, instead of becoming part of the crystalline ice structure. The presence of a solute also lowers the freezing point, the temperature where it changes from a liquid to a solid, known as freezing point depression. Researchers continue to study ways to improve freeze desalination as a possible large-scale desalination alternative. In this experiment, you will investigate the effects of freezing on saltwater as a possible method of desalination.

Materials

- ❏ Digital balance
- ❏ Two 250-mL beakers or similar containers
- ❏ Table salt (sodium chloride, NaCl)
- ❏ Tap water
- ❏ Stirring rods or spoons
- ❏ Method to compare salinity (e.g., conductivity probe, refractometer, multimeter)
- ❏ Access to a freezer
- ❏ Timer
- ❏ Fork or slotted spoon
- ❏ Small bowl or container

Safety

Wear safety goggles. Do not taste or consume any of the solutions. Do not seal or overfill containers you place in the freezer; water expands as it freezes and can damage or overflow containers.

Procedure

1) Prepare a simulated seawater solution. Measure ~7.0 g table salt into a 250-mL beaker or similar container. Add tap water until the overall weight is ~200.0 g. Stir until salt completely dissolves.
2) Prepare a freshwater solution. Add ~200.0 g tap water to a 250-mL beaker or similar container.
3) Measure and record the salinity of both solutions. How do they compare?
4) Place both beakers in a freezer. Observe beaker contents every 15 minutes and record your observations. Continue until a film of ice forms on the surface of both solutions, preferably several millimeters thick. How do the contents compare?
5) Remove beakers from freezer. Set aside freshwater beaker.

Name ______________________________ Date ______________

Freezing: Is It a Desalination Opportunity? (continued)

Procedure

6) Use a fork or slotted spoon to gently scrape around the edge of the ice film in the seawater beaker. Then, scoop out as much as possible into the fork or spoon. Briefly drain any remaining solution from the ice. Place ice in a small bowl or container.
7) Melt ice in the bowl and in the remaining seawater solution.
8) After the ice melts, stir both solutions. Measure and record their salinities.

Questions

1) Compare the salinity results of the simulated seawater and freshwater solutions before freezing in step 3. Why can seawater not be used "as is" for drinking water?

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2) Compare and contrast your observations of the contents of the two beakers during the freezing process.

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3) Describe and discuss the salinity results of the melted seawater ice and remaining seawater solution in step 8.

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4) Based on your observations, is freezing a potential solution for obtaining desalinated water? Explain why/why not.

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Teacher Notes

Sample Observations

Testing showed the following results:

- Step 3 salinity (used Agriculture Solutions salinity refractometer for aquariums, with scale from 0 to 100 parts per thousand, or ppt)
  - Freshwater 0 ppt
  - Simulated seawater 35 ppt
- Step 4 observations

Freezing time (min)	Freshwater	Simulated seawater
15	No visible change	No visible change
30	Ice beginning to form on edge of beaker	No visible change
45	Ice continuing to form	No visible change
60	Ice layer several millimeters thick formed, solid, transparent	Ice layer a few millimeters thick formed, slushy rather than frozen solid, not transparent

- Step 8 salinity
  - Melted seawater ice 31 ppt
  - Remaining seawater solution 37 ppt

Tips

- Recycled plastic water bottles could also be used as freezing containers. Cut off the top portion of the bottle.
- Freezing times will vary, depending on the freezer and its settings. Remind students that the goal is to only partially freeze the contents, not to freeze it solid.
- If a freezer is not available in or near the lab, another option would be for students to take the two solutions and containers to freeze at home. They could make observations and collect the ice from the simulated seawater to place in a third container, then make salinity measurements in the lab. Alternatively, instructors could use dry ice/acetone baths. In testing, an ice/salt bath was not an effective method for freezing.

Teacher Notes (continued)

Background Information

Adding salt as a solute lowers the freezing point of the solution. The container with only tap water freezes more quickly.

The process used in the experiment is sometimes called freeze desalination. The 2022 open access article: Najim, A. A review of advances in freeze desalination and future prospects. *npj Clean Water* 5, 15 (2022)(https://doi.org/10.1038/s41545-022-00158-1) discusses the benefits of the process and how it could become more widely used. The first part of the article describes it, along with factors that can affect the ice:

> "The process produces ice crystal/crystals and concentrated saltwater. Freshwater is obtained by the separation of ice crystal/crystals from the concentrated saltwater and afterwards melting it. …
>
> The … process increases the concentration of an aqueous solution by separating the dissolved solute from ice into the liquid, undergoing crystallization. The solute separation is because the ice crystal lattice has small dimension that rejects solute ions. Additionally, the solute separation mechanism from the ice phase could be due to the insignificant solubility of solute ions in the ice phase compared to water. If the separated solute is not mixed into the liquid, then a high solute concentration layer builds up adjacent to the moving ice-liquid interface. As the layer grows, the solute gets trapped into the ice by the ice-liquid interface. This increases the concentration of the solute into the ice and severely affects its purity. … The growth rate of an ice crystal affects its purity."

The author also mentions that resulting ice is further treated by a process such as washing to further remove remaining salt.

Students could compare the energy costs of desalination of boiling versus freezing. The article states: "Thermodynamically, the latent heat of freezing and vaporization of water is 330 kJ/kg and 2256 kJ/kg, respectively. The FD [freeze desalination] process needs approximately 1/7th of the energy required by the vaporization-based desalination processes." Although freeze desalination requires less energy, there are other factors that need to be addressed in the process (see article mentioned above for a more complete discussion). For example, as the water freezes and crystallizes under certain conditions, the salt/solute can be trapped in the ice, reducing its purity.

The lab could also be extended with a discussion of related real-world examples, such as why freshwater bodies of water freeze before saltwater ones, the way lakes and ponds freeze (https://www.nsta.org/lesson-plan/how-do-lakes-freeze), and the use of salt on winter roads (https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/articlesbytopic/solutions/chemmatters-feb2006-salting-roads.pdf).

Teacher Notes (continued)

Multimeter Measurements

If conductivity probes or refractometers are not available, in testing, a multimeter set to measure resistance gave results that supported the refractometer readings.

To use a multimeter, set it to measure resistance (Ω). In testing, the multimeter automatically selected the best range when taking a reading. Students should confirm the units on the screen for each reading, as the multimeter can switch between units. The range can also be set manually (in testing, using the "range" button).

Submerge most of the metal part of both electrodes in the solution. For consistency, use the same containers and amount of solutions, holding the electrodes the same distance apart (for example, at the sides of the container), measuring for the same amount of time. In testing, 3 sec was used.

A higher salinity shows a lower resistance. Sample measurements are below, with the multimeter's range set to .0 MΩ. Measurements were taken at 3 sec. Electrodes were then wiped, and the next solution measured.

Tap water	Saltwater: 2.0 g NaCl, filled to 100.0 g with tap water	Saltwater: 3.5 g NaCl, filled to 100.0 g with tap water
0.911	0.334	0.104

Chemistry Shorts™ is a film series that communicates the breadth and depth of chemistry's impact on humankind in an approachable manner, sponsored by the Camille and Henry Dreyfus Foundation. These films will celebrate the science and the people who share a passion for the vital role chemistry plays in the biggest issues, including human health, renewable energy, the nature of life, sustainability, new materials, and climate change. Each film incorporates a lesson plan that offers ideas for ways they may be incorporated into the classroom. We welcome your feedback at: chemistryshorts.org.

SHORT FILMS ABOUT CHEMISTRY