# 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<br>Your Knowledge and Connection to Water | (10–15 min.) |
| Pre-class Activity<br>Water Chemistry | (5–10 min.) |
| In-class Activity<br>Scarcity of Water | (5–10 min.) |
| In-class Activity<br>Chemistry: Transforming the Undrinkable<br>(including watching the film) | (25–30 min.) |
| After-class Activity<br>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/

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## 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/dIHxV0Hpt5I

## 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.

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## 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.

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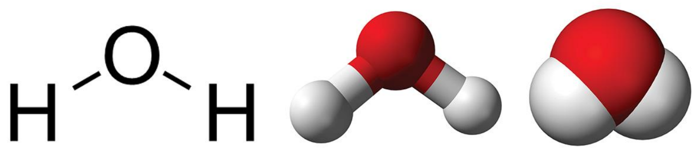
## Pre-Class Activity
## Water Chemistry

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

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**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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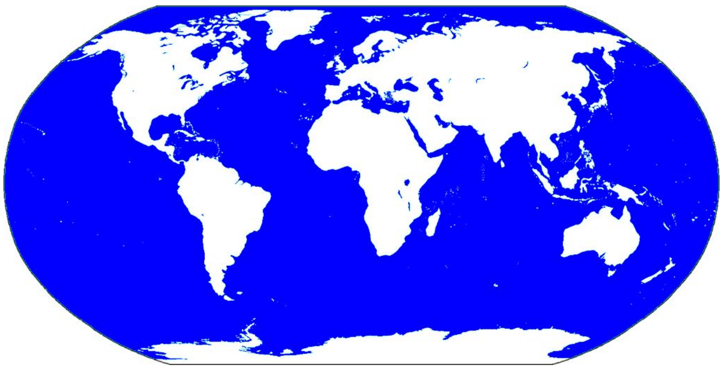
## In-Class Activity
## Scarcity of Water

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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## 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.

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## 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 1.

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?

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## 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

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**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.

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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?

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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?

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