ChemMatters®
Demystifying Everyday Chemistry

Teacher's Guide

April 2025

April Teacher's Guide Introduction

Lesson Ideas

The April 2025 issue of *ChemMatters* connects to the theme for this year's Chemists Celebrate Earth Week (CCEW)-- Glaciers: Hot Topic, Cool Chemistry. You can find more information at https://www.acs.org/education/ccew.html.

For all of the articles, encourage students to think about how science is done, how we know what we know, and how chemistry connects to their lives.

Notes regarding this issue:

- Two of the articles ("The Frozen Past" on page 5 and "Fire and Ice" on page 8) are closely related and linked through the sidebar "Tracking Solar Events Using Isotopes." Reading the articles sequentially will support student understanding of the link between ice cores and atmospheric events.
- Consider discussing the differences among glaciers, ice sheets, and icebergs prior to reading. Although all are made of water ice (H_2O), understanding how their differences contribute to evidence regarding climate change over millions of years is important.
- This issue provides a good opportunity to highlight the differences between observations and inferences as students learn how we know what we know about changes in Earth's climate, past solar flares, and details about Otzi the Iceman's life.
- The abbreviations CE (Common Era) and BCE (Before Common Era) are used throughout this issue. If students are unfamiliar with these terms, remind them that CE and BCE, preferred in scientific writing, are the nonreligious equivalents of AD and BC.

Teaching Ideas for this issue:

1. "Chemistry in Pictures" on page 2 shows a beautiful photograph of an aurora, along with a brief summary of how auroras are formed. Challenge students to look for the connections between auroras and glaciers as they read this issue.
2. "Open for Discussion" on page 4 includes information about the importance and location of Earth's water resources. Encourage students to consider the effects of melting glaciers and ice sheets on our water resources.
3. "Quick Read: How to Melt an Iceberg" on page 18 describes the chemistry behind an interesting experiment. For added student engagement, ask students to do the activity BEFORE reading the description or watching the video they can access via the QR code at the top of the page. The article has excellent examples of density, buoyancy, and convection.
4. The "Chemistry in Person" column on page 23 describes how a geochemist uses volcanic ash found in Antarctic ice cores to help solve puzzles related to climate change.

5. Assign a team of students to read each feature article, then present what they learned in a podcast, PowerPoint or similar presentation, poster or brochure, or some other engaging format.
    - Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
    - Be sure to ask students to include information providing evidence for the claims made in the article.
6. Alternatively, students can create concept maps about the important chemistry concepts in the article they choose.

5E Lesson Ideas for individual articles:

Engage	Provide the Anticipation Guide or ask a thoughtful question (see the individual Teacher's Guide for each article) to engage students in the reading. Students should record their initial ideas individually, in pen, so they can't be erased or forgotten. Students can then discuss their initial ideas in small groups or as a whole class.
Explore	Students read the article to discover more about the concepts in the article. During this phase, students will revisit their beginning ideas and record how the information in the article supports or refutes their initial ideas, providing evidence from the article.
Explain	Students answer questions and/or complete the graphic organizer provided for each article, then discuss their learning with their classmates. Students should recognize the evidence for the claims made in the articles, and how the evidence supports the claims.
Elaborate	Students can pose questions for further study. For some articles, there are related ACS Reactions videos students can watch to learn more about the concepts presented. See the individual Teacher's Guide for each article to learn more.
Evaluate	Students write a short summary of what they learned that describes how it connects to their lives. Students may also present their learning to their classmates or others. Here is a template for an exit slip: ● I used to think… ● But now I know… ● And this is how I learned it…

ChemMatters®
Demystifying Everyday Chemistry

Teacher's Guide

The Frozen Past

April 2025

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Anticipation Guide

Name: _____

Directions: ***Before reading the article*****,** in the first column, write "A" or "D," indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Ice cores are formed from snow that may have fallen millions of years ago.
		2. Most ice core samples are about 25 cm in diameter.
		3. Ice cores usually come from icebergs.
		4. Scientists use ice cores to study ancient climates.
		5. Scientists look at isotopes of oxygen in water molecules to make inferences about atmospheric temperatures long ago.
		6. Today's global atmospheric CO_2 is very close to the global level of CO_2 during past warm periods.
		7. Melting glaciers can wash out chemical information in ice layers below the glacier.
		8. The rate of glacier loss is accelerating.
		9. Plasma jet particles from solar flares take more than three days to reach Earth.
		10. Solar flares can change the ratio of radioactive isotopes in Earth's atmosphere.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Ice cores are long tubes of ice that are drilled out of glaciers and ice sheets for scientists to study. Why do these cores have layers?

2. Glaciers and ice sheets are both formed from the same process. Scientists call them glaciers when they are more localized and ice sheets when they span a large area. How much area will the ice cover if it is large enough to call an ice sheet?

3. Drilling for ice cores always takes a lot of special equipment and planning. Why is it more difficult to collect ice cores from glaciers at higher elevations than from ice sheets that have a smaller elevation range?

4. How does snow form in the atmosphere?

5. What are isotopes?

6. Which isotope of hydrogen is radioactive?

7. The amount of mass, in atomic mass units (amu), contained in a proton and in a neutron can both round to 1 amu. What is the rounded mass, in amu of each of the following:

    a. Water containing one oxygen-16 and two hydrogen-1 atoms

    b. Water containing one oxygen-17 and two hydrogen-1 atoms

    c. Water containing one oxygen-17, one hydrogen-1 atom, and one hydrogen-3 atom

    Use the average atomic masses on the periodic table to make a claim about which kind of water molecule from a, b, and c above is the most prevalent in nature.

8. Differences in the ratio of different isotopes within the ice cores can also occur with stable isotopes. Even though the oxygen-18 isotope is stable, there are other reasons that water molecules containing this isotope might be more prevalent or less prevalent in the atmosphere, and therefore in different layers of an ice core, from year to year. Explain one of these reasons that relates to atmospheric temperature.

9. If glaciers are shrinking, what does this say about changes in the rate of snowfall or the amount of melting from year to year?

10. Why are scientists rushing to collect ice cores from glaciers and ice sheets that are shrinking?

11. Why is the Ice Memory Foundation planning to store ice cores in an ice cave in East Antarctica, rather than storing them in a lab?

12. What isotopes in ice cores help scientists to verify the ages of the layers by comparing them to other evidence related to solar flares?

13. Ice core layers can provide evidence of a lot of geological events and climate changes. Explain what this evidence can show scientists for any one thing not already discussed in these questions.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe ice cores and what information we can learn from ice cores.

Where are they collected?		
How big are they?		
What are they made of?		
How were they formed?		
Importance of measuring isotopes in ice cores		
Levels of CO_2 in the past		
Levels of CO2 in September 2024		
Importance of Antarctic snow cave		

Summary: On the back of this sheet, write three interesting facts about ice cores that you learned from the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Ice cores are long tubes of ice that are drilled out of glaciers and ice sheets for scientists to study. Why do these cores have layers?
   Each year, the accumulated snow slowly melts. Whatever snow remains after the melting season will compact under its weight. When new snow falls the next year, it forms on top of a mostly compacted ice layer from previous years. Over time, the snow from any given year gets deeper and deeper as ice and continues to get compressed with the weight of each new snowfall. This leaves layers, as the different layers have been compacted for different amounts of time. The layers are not the same year-by-year, like tree rings they show annual differences in total snowfall and other dissolved materials, but they can be compared to other evidence to confirm timelines.

2. Glaciers and ice sheets are both formed from the same process. Scientists call them glaciers when they are more localized and ice sheets when they span a large area. How much area will the ice cover if it is large enough to call an ice sheet?
   Ice sheets cover at least 50,000 km^2 of land.

3. Drilling for ice cores always takes a lot of special equipment and planning. Why is it more difficult to collect ice cores from glaciers at higher elevations than from ice sheets that have a smaller elevation range?
   At higher elevations, there may not be large flat areas or easy ways to bring a truck from high to low altitudes. This means that the ice cores will be collected up high, where it is very cold, and will have to be kept from melting as they are transferred down to the lower elevations where it is warmer. Scientists need to get the heavy ice cores into a freezer truck before it starts to melt and mix the layers together.

4. How does snow form in the atmosphere?
   Molecules of water vapor will run into tiny particles in the air, causing them to accumulate and freeze together. When enough water molecules freeze around each other, the density of the frozen crystal becomes heavier than the air and falls as snow.

5. What are isotopes?
   Isotopes are atoms of a given element, with a specific number of protons, that have different numbers of neutrons. With the same number of protons and different numbers of neutrons, they will have different atomic weights while still being the same element. Atoms of some elements only come in one form, but others may contain from 2 to over 30 different isotopes. Some isotopes are stable and others are radioactive.

6. Which isotope of hydrogen is radioactive?
   Hydrogen-3 which is called tritium.

7. The amount of mass, in atomic mass units (amu), contained in a proton and in a neutron can both round to 1 amu. What is the rounded mass, in amu of each of the following:

    a. Water containing one oxygen-16 and two hydrogen-1 atoms
    18 amu
    b. Water containing one oxygen-17 and two hydrogen-1 atoms
    20 amu
    c. Water containing one oxygen-17, one hydrogen-1 atom, and one hydrogen-3 atom
    21 amu

    Use the average atomic masses on the periodic table to make a claim about which kind of water molecule from a, b, and c above is the most prevalent in nature.
    Using average masses, the H_2O molecules would have an average mass of 18.015 amu. Since this average mass is closest to the water molecule with one and two atoms, the molecule described in (a), with a mass of 18 amu, is likely to be the most prevalent in nature because it is closest to the average mass and there are no H_2O molecules possible with a mass lower than 18, as these are the lightest isotopes of both oxygen and hydrogen.

8. Differences in the ratio of different isotopes within the ice cores can also occur with stable isotopes. Even though the oxygen-18 isotope is stable, there are other reasons that water molecules containing this isotope might be more prevalent or less prevalent in the atmosphere, and therefore in different layers of an ice core, from year to year. Explain one of these reasons that relates to atmospheric temperature.
    Water molecules with oxygen-18 are heavier than water molecules with oxygen-16. The heavier molecules take more energy to evaporate into the atmosphere. This means that scientists can use the proportion of oxygen-18 to oxygen-16 in the ice core layers to determine when the atmosphere was warmer or colder. If it is warmer, there would be a more than average amount of oxygen-18 compared to oxygen-16 and the opposite would be true when it is cooler.

9. If glaciers are shrinking, what does this say about changes in the rate of snowfall or the amount of melting from year to year?
    This means that the rate of snowfall outpaced the rate of melting to form the glaciers, but that melting is starting to outpace the snowfall.

10. Why are scientists rushing to collect ice cores from glaciers and ice sheets that are shrinking?
    They want to preserve the history that is embedded in the layers of the ice cores so they will have them available for future studies.

11. Why is the Ice Memory Foundation planning to store ice cores in an ice cave in East Antarctica, rather than storing them in a lab?
    The site is known to have a stable low temperature. Freezers in a lab can fail for a number of different reasons, so the natural storage site gives the ice cores a better chance of surviving for future scientists.

12. What isotopes in ice cores help scientists to verify the ages of the layers by comparing them to other evidence related to solar flares?
    Beryllium-10, and chlorine-36

13. Ice core layers can provide evidence of a lot of geological events and climate changes. Explain what this evidence can show scientists for any one thing not already discussed in these questions.
    There are many answers from the article, such as the history of volcanic eruptions, changes in atmospheric CO_2, dust storms, and fires.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Additional Resources

❖ Recommended Activities

- ➢ AACT Radioactive Decay and Seafloor Data
- ➢ AACT Simulation Activity: Half-Life Investigation
- ➢ AACT Using Stable Isotopes to Determine Material Origin
- ➢ AACT Marie Curie Video and Questions
- ➢ AACT Lise Meitner Video and Questions
- ➢ AACT Building a Nuclide
- ➢ AACT Physical, Chemical, and Nuclear Changes
- ➢ PhET Simulation w/ suggested resources Build a Nucleus
- ➢ PhET Simulation w/ suggested resources Isotopes and Atomic Mass
- ➢ ACS Chemistry Basics Video What Are Isotopes?

❖ Information for Teachers

- ➢ ACS Chemical landmarks Willard Libby and Radiocarbon Dating

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students what they know about ice cores, where they are found, and why scientists study them. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students what they learned about the importance of studying ice cores.
- **Note:** This article (“the Frozen Past”) and the next one, “Fire and Ice,” are closely related through the study of ice cores. The sidebar “Tracking Solar Events Using Isotopes” links the two articles with a discussion of the science of solar flares.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Isotopes
- Radioactive isotopes
- Radiation
- Alpha/beta/gamma decay

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- PS3.D: Energy in Chemical Processes
- ESS2.A: Earth Materials and Systems

Crosscutting Concepts:

- Cause and effect
- Energy and matter
- Stability and change

Science and Engineering Practices:

- Analyzing and interpreting data

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

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Teacher's Guide

Fire & Ice

April 2025

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Anticipation Guide

Name: _____

Directions: ***Before reading the article*****,** in the first column, write "A" or "D," indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Buried snow forms layers of ice with atmospheric gases from long ago trapped inside.
		2. Evidence from glacial ice, tree rings and sometimes historical documents help scientists create timelines of Earth's past climate.
		3. Auroras are produced when enormous solar flares strike Earth's atmosphere.
		4. Unstable isotopes are radioactive.
		5. Carbon-14 is found in tree rings and ice cores.
		6. Beryllium-10 is found in ice cores but not tree rings.
		7. Gamma ray bursts from the sun are fairly common, occurring once about every 1000 years.
		8. Gamma ray bursts can create ^{14}C, ^{10}Be, and ^{36}Cl.
		9. Volcanic eruptions can temporarily change Earth's climate.
		10. Ice cores to study Earth's past climate are collected from both Antarctica and Greenland.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Ice cores are long tubes of ice that are drilled out of glaciers and ice sheets for scientists to study. Why do these cores have layers?

2. Why do scientists compare ice core data to data from tree rings and written historical documents?

3. What are isotopes?

4. What is the difference between stable isotopes and radioactive isotopes?

5. Why can solar flares change the types of isotopes that are in the atmosphere?

6. When studying natural phenomena, scientists look for patterns because patterns can indicate that there is some kind of order to what they are studying. What patterns allowed scientists to classify Miyake events as solar flares?

7. How are Miyake events now used to help scientists adjust and verify timelines of ice cores from various locations?

8. Using the graphs on page 10, describe what is meant by a “spike” as related to a certain isotope.

9. How did scientists conclude that large volcanic eruptions in the past had effects on the climate?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe what we have learned from ice cores by linking claims in the article to evidence found by scientists.

	Claims	Evidence
Ice Core Layer		
Solar Flare		
Miyake Events		
Extreme Volcanic Eruptions		

Summary: On the back of this sheet, write a short email to a friend describing what we can learn from studying ice cores.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Ice cores are long tubes of ice that are drilled out of glaciers and ice sheets for scientists to study. Why do these cores have layers?
   Each year, the accumulated snow slowly melts. Whatever snow remains after the melting season will compact under its weight. When new snow falls the next year, it forms on top of a mostly compacted ice layer from previous years. Over time, the snow from any given year gets deeper and deeper as ice and continues to get compressed with the weight of each new snowfall. This leaves layers, as the different layers have been compacted for different amounts of time. The layers are not perfect year-by-year, but can be compared to other evidence to confirm timelines.

2. Why do scientists compare ice core data to data from tree rings and written historical documents?
   Scientists can compare different types of data to gain multiple types of evidence to support a given conclusion. They can also compare them to help line up the apparent historical timelines with more precision than only one method would allow.

3. What are isotopes?
   Isotopes are atoms of a given element, with a specific number of protons, that have different numbers of neutrons. With the same number of protons and different numbers of neutrons, they will have different atomic weights while still being the same element. Atoms of some elements only come in one form, but others may contain from 2 to over 30 different isotopes. Some isotopes are stable and others are radioactive.

4. What is the difference between stable isotopes and radioactive isotopes?

   Stable isotopes remain in their original form, and do not decay into other species over time. Radioactive isotopes decay to form other elements, so that portions of the original isotope sample will no longer exist in the same form.

5. Why can solar flares change the types of isotopes that are in the atmosphere?
   The intense energy of a solar flare can cause particles to collide at energies that are high enough to induce nuclear reactions. Even stable isotopes can transform into other elements when they collide with a particle of high enough energy to interact with the nuclear particles.

6. When studying natural phenomena, scientists look for patterns because patterns can indicate that there is some kind of order to what they are studying. What patterns allowed scientists to classify Miyake events as solar flares?
   Tree ring data and ice core data showed matching rises and falls in amounts of two different isotopes from the atmosphere over thousands of years. This led to scientists beginning to regularly compare the two types of data. Eventually, the presence of beryllium-10 in ice cores discounted the working theory

and led to conclusions that the variations in both sets of data were due to extreme solar flares and not due to gamma rays.

7. How are Miyake events now used to help scientists adjust and verify timelines of ice cores from various locations?
   The layers that accumulated during years when a Miyake event (extreme solar flare) happened have characteristic spikes in the amounts of certain isotopes. When comparing ice cores from different locations, scientists can find the layers that signify Miyake events and line them up from core to core to mark layers that formed in the same year.

8. Using the graphs on page 10, describe what is meant by a "spike" as related to a certain isotope.
   When the amount of a certain isotope being detected rises significantly more than any other rise or fall, this is called a spike in the data.

9. How did scientists conclude that large volcanic eruptions in the past had effects on the climate?
   After lining up the ice core data from various places by Miyake events, they were able to show that volcanic eruptions in certain years were followed by decades of colder than normal temperatures. This also corresponded to historical records about civilizations that existed at those times.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Additional Resources

❖ Recommended Activities

- ➢ AACT Radioactive Decay and Seafloor Data
- ➢ AACT Simulation Activity: Half-Life Investigation
- ➢ AACT Using Stable Isotopes to Determine Material Origin
- ➢ AACT Marie Curie Video and Questions
- ➢ AACT Lise Meitner Video and Questions
- ➢ AACT Building a Nuclide
- ➢ AACT Physical, Chemical, and Nuclear Changes
- ➢ PhET Simulation w/ suggested resources Build a Nucleus
- ➢ PhET Simulation w/ suggested resources Isotopes and Atomic Mass
- ➢ ACS Chemistry Basics Video What Are Isotopes?

❖ Information for Teachers

- ➢ ACS Chemical landmarks Willard Libby and Radiocarbon Dating

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students how scientists study atmospheric events from the distant past. Ask how ice cores might be helpful when learning about past climates. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about how the chemistry of ice cores can inform a deeper understanding of Earth's past.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Alpha/beta/gamma decay
- Half-lives
- Radioactive isotopes
- Radiation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- PS1.C: Nuclear Processes
- ESS2.A: Earth Materials and Systems

Crosscutting Concepts:

- Patterns
- Structure and function
- Stability and change

Science and Engineering Practices:

- Obtaining, evaluating, and communicating information

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.
- Science is a human endeavor.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

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Teacher's Guide

Freshwater Threat: Salt

April 2025

Table of Contents

Anticipation Guide

Name: _____

Directions: ***Before reading the article*****,** in the first column, write "A" or "D," indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. About 5% of Earth's water is available for human use.
		2. Droughts contribute to saltwater intrusion of ocean water into rivers.
		3. Laundry detergents add salt to surface water.
		4. More than 95% of salt in seawater is NaCl.
		5. All salts are soluble in water.
		6. The allowable amount of salt in drinking water is tightly regulated by the EPA.
		7. Salt water can damage lead water pipes.
		8. Evaporation-based desalination has been used around the world, and by sailors.
		9. Reverse osmosis desalination plants use more energy than evaporation-based desalination.
		10. Globally, desalination plants supply only 1% of the world's water needs.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What are examples of activities that add salt to water?
2. What is the chemistry definition of a salt?
3. Why is it OK for people to have a small amount of salt in water or food?
4. Describe reverse osmosis and why it can be used to desalinate water.
5. What are other needs for fresh water, in addition to drinking water?
6. What are some other metal ions (and their symbols) found in sea water?
7. Describe the process of salt dissolving in water.
8. How is the remaining salt disposed of after desalination?
9. Why do plants need a proper balance of sodium and calcium in the water they consume?
10. Lead chloride is considered “insoluble” in water. Explain how chloride ions can “leach” ions of lead from city water pipes (Similar to the Flint water crisis).
11. How do other countries desalinate through evaporation? Why is this process not effective both economically and environmentally?
12. State some ways you could help preserve fresh water in your neighborhood or community.
13. Research the Flint water crisis. Briefly explain how the water became so contaminated. What are some proposed solutions that could fix the problem?

Graphic Organizer

Name: _____

Directions: As you read, use information from the article to complete the graphic organizer below to describe the problems and possible solutions to obtaining fresh water.

Sources of salt contamination	
Types of salt contamination	
Problems with salt contamination	
Evaporation desalination	Description:
	Drawbacks:
Reverse osmosis desalination	Description:
	Drawbacks:

Summary: Write a short summary of the article (18 words or less).

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What are examples of activities that add salt to water?
   Adding road salt, doing laundry, fertilizers on grass and plants.

2. What is the chemistry definition of a salt?
   A salt is a chemical compound that has positive and negative charged particles.

3. Why is it OK for people to have a small amount of salt in water or food?
   Sodium is an important ion for heart health.

4. Describe reverse osmosis and why it can be used to desalinate water.
   Reverse osmosis involves adding pressure to a saltwater solution to force it through a filter, which only water can flow through. The salt remains behind, producing desalinated water.

5. What are other needs for fresh water, in addition to drinking water?
   Cooling infrastructures and machines, cooling data centers, supporting global trade.

6. What are some other metal ions (and their symbols) found in sea water?
   Potassium (K^+), Magnesium (Mg^{2+}), and Calcium (Ca^{2+}).

7. Describe the process of salt dissolving in water.
   The water molecules penetrate the bonds between the positive and negative ions in the salt. The water molecules then surround each ion as the salt dissolves and combines with the water molecules.

8. How is the remaining salt disposed of after desalination?
   If the desalination plant is near the coasts, the excess brine can be dumped into the ocean, which is already salty. If the plant is inland, the company would most likely either bury it deep underground or evaporate any excess water and place the leftover salts into the landfill.

9. Why do plants need a proper balance of sodium and calcium in the water they consume?
   The correct ratio is needed for development and proper growth of crops and plants. If the ratio is off, the plants may not grow to full size or not grow at all.

10. Lead chloride is considered “insoluble” in water. Explain how chloride ions can “leach” ions of lead from city water pipes (Similar to the Flint water crisis).
    Leaching means that lead ions are being pulled off the pipes. The chlorine bonds with the lead, which causes the lead to come off the pipes and mixes with the water. The water is then contaminated with the lead ions.

11. How do other countries desalinate through evaporation? Why is this process not effective both economically and environmentally?
    Many of these desalination plants will use the heat from the atmosphere, or through the burning of fossil fuels, to evaporate the pure water from the salt. The water is then condensed into desalinated water. This process is a very expensive process and uses up a lot of unrenewable natural resources.

12. State some ways you could help preserve fresh water in your neighborhood or community.
    Answers may vary but should include conserving water when washing clothes and dishes, limiting the amount of detergent, or even finding more environmentally friendly detergent, and not using salt to melt ice on the driveways.

13. Research the Flint water crisis. Briefly explain how the water became so contaminated. What are some proposed solutions that could fix the problem?
    Typically, the water pipes are coated with phosphates that prevent the chlorine from bonding with the lead ions. In order to solve the problems and get clean water, officials are having the lead and steel pipes replaced with newer and better protected materials. Also, more water filters have been installed.

    At the moment, the water in Flint is better, but still not at normal levels.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

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2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Additional Resources

- **Lessons and lesson plans**
  - https://www.compoundchem.com/2016/01/25/flint-water/
  - https://teachchemistry.org/classroom-resources/investigating-sea-water

- **Projects and extension activities**
  - https://teachchemistry.org/classroom-resources/solubility-animation
  - https://teachchemistry.org/classroom-resources/would-you-drink-it
  - https://teachchemistry.org/classroom-resources/corrosion-and-precipitation

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students how much of the Earth's water is available for human use. Ask them what problems there are with using salt water for our everyday needs. Their initial ideas can be collected electronically via digital whiteboards or similar technology.
  - As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students how a knowledge of chemistry can help them make decisions about responsible water use and how to obtain more fresh water.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Salts
- Ions
- Separating mixtures
- Distillation
- Solutions
- Conservation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

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

Disciplinary Core Ideas:

- PS.1.A: Structure and properties of matter
- ETS.1.B: Developing possible solutions

Crosscutting Concepts:

- Energy and matter
- Structure and function
- Systems and system models

Science and Engineering Practices:

- Obtaining, evaluating, and communicating information

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

ChemMatters®
Demystifying Everyday Chemistry

Teacher's Guide

The Colors of Climate Change

April 2025

Table of Contents

Anticipation Guide

Name: _____

Directions: ***Before reading the article*****,** in the first column, write "A" or "D," indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Color from satellite data indicates that less than one-quarter of the ocean is experiencing climate change.
		2. A greenish shift in ocean color indicates more green organisms like phytoplankton.
		3. More sunlight is absorbed by ice than by blue water.
		4. Phytoplankton thrive when melting glaciers release micro- and macronutrients.
		5. Phytoplankton capture carbon, but too much phytoplankton is harmful.
		6. Some color changes observed in the oceans are due to non biological factors.
		7. Salinity does not affect how water absorbs, reflects, and scatters light.
		8. Lakes with dissolved tannins warm more quickly, meaning less dissolved oxygen available for fish.
		9. Color change will occur when the balance of predator and prey is upset.
		10. A new satellite launched in 2024 is more sensitive to light wavelengths than earlier satellites.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. How are color shifts in the ocean related to chemistry?
2. Explain why you feel warmer wearing a black shirt in the summer and cooler in a white shirt.
3. Explain the method used to measure how Earth reflects the Sun's radiation.
4. What happens to the value of albedo when sea ice melts?
5. What is the cause of the green color shift that Kelsey Bisson and her team studied?
6. Describe benefits and a drawback of ocean phytoplankton.
7. Explain the cause of the orange color that has developed in some Alaskan rivers.
8. What is the cause and effect of browning lakes in the Adirondack area of New York?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

9. Research the Great Calcite Belt and its involvement in the carbon cycle.

10. Research the Great Oxidation Event, a time period over two billion years ago, that resulted in huge changes in Earth's chemistry. Create a poster that shows information about the proliferation of cyanobacteria that is largely responsible for this change, along with a timeline of the events.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the color changing chemistry of the oceans.

	Color change observed	Explanation
Melting glaciers		
Albedo		
Phytoplankton		
HABs (harmful algal blooms)		
Tannins		
Melting permafrost		

Summary: How does the information in the article relate to you, now or in the future? Answer in 1 or 2 sentences.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. How are color shifts in the ocean related to chemistry?
   Color shifts happen when chemical changes occur in the ocean. Color changes occur when substances absorb light of specific wavelengths. Scientists can detect the presence of different substances in the ocean when they observe color changes, such as those detected by the Aqua satellite.

2. Explain why you feel warmer wearing a black shirt in the summer and cooler in a white shirt.
   Black cloth absorbs all the visible wavelengths of sunlight whereas white cloth reflects all the visible wavelengths of light. The black material will feel warmer, because wavelength is related to energy by E = *hc*/l where h is Planck's constant, c is the speed of light and l is wavelength of light. Energy can be transferred as heat.

3. Explain the method used to measure how Earth reflects the Sun's radiation.
   Albedo is the fraction of sunlight that an object reflects. It is a unitless quantity that indicates how reflective a substance is. For example, an albedo of 1 means the object is 100% reflective and an albedo of 0.5 means the object is 50% reflective. Albedo is measured either by using satellite imagery or an instrument called a pyranometer. Sunlight is measured directly, then the light reflected from the object is measured, the ratio of the two measurements is the albedo.

4. What happens to the value of albedo when sea ice melts?
   The Aqua satellite detects sea ice as white and very reflective. When ice melts, the satellite detects dark water. The water absorbs more light than ice, reducing the albedo value.

5. What is the cause of the green color shift that Kelsey Bisson and her team studied?
   Bisson and her team proposed that the green color is a result of an increase in phytoplankton, which proliferated as a result of nutrients released during glacial melting. Specifically, the green color is chlorophyll, which is produced when the phytoplankton photosynthesize.

6. Describe benefits and a drawback of ocean phytoplankton.
   Phytoplankton provide food for other organisms, produce oxygen, and recycle nutrients. However, too many phytoplankton can result in a harmful algal bloom. The chemicals released are toxic to fish, mammals, and birds.

7. Explain the cause of the orange color that has developed in some Alaskan rivers.
   As the Arctic warms, frozen ground melts quickly, releasing sediment and minerals into the water. Scientists determined that the amount of zinc, iron, and manganese are one to two orders of magnitude greater than in clear rivers. These minerals cause the rusty-orange color.

8. What is the cause and effect of browning lakes in the Adirondack area of New York?
   Chemical compounds called tannins are responsible for the brown color that is developing in some Adirondack lakes. These compounds come from the landscape and dissolve in the water.

However, since darker colors absorb more light, the lakes heat up. Tannins react with dissolved oxygen in the water, reducing the amount of oxygen available to fish. As a result, the lake environment is no longer able to provide a home for certain fish.

9. Research the Great Calcite Belt and its involvement in the carbon cycle.
   Answers will vary, but should include that the Great Calcite Belt is an area of the ocean around Antarctica. Some marine organisms produce shells made of white calcium carbonate which are deposited on the ocean floor. To synthesize calcium carbonate ($CaCO_3$), carbon is removed from the atmosphere, reducing the amount of carbon dioxide, thus, helping to offset climate change.

10. Research the Great Oxidation Event, a time period over two billion years ago, that resulted in huge changes in Earth's chemistry. Create a poster that shows information about the proliferation of cyanobacteria that is largely responsible for this change, along with a timeline of the events.
    Answers will vary, but the poster should describe the emergence of cyanobacteria (2.7 billion years ago) which use water as fuel to produce oxygen in large quantities. Eventually, Earth's atmosphere became oxygen-rich, which resulted in the rise of aerobic organisms.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Additional Resources

❖ Projects and extension activities

➢ **Great Plankton Sink Off**
In this activity, students study images of phytoplankton and zooplankton. Then, the students use various materials to design and create plankton that will sink slowly in a tub of water.
https://naturalhistory.si.edu/sites/default/files/media/file/greatplanktonsinkoff.pdf

➢ **Harmful Algal Bloom**
In this lesson, students will learn about a real-life harmful algal bloom and create their own cyst map and graphs using authentic data from the Gulf of Maine.

Teacher materials including answer-key maps:
https://pubmed.ncbi.nlm.nih.gov/31929658/

Student handout:
https://northeasthab.whoi.edu/wp-content/uploads/sites/34/2020/05/Curran-Richlen-Supplemental-Info.pdf?_gl=1*14vi1og*_ga*MTIxNDM2MzU0OC4xNzQxNTYxMjM2*_ga_HLKFZX9JZK*MTc0MTU2MTIzNi4xLjEuMTc0MTU2MzA2NS4wLjAuMA..*_gcl_au*MjQxNjM5NTIxLjE3NDE1NjEyMzY.

Note: This is designed for middle school students, but it can be used by high school students.

➢ **Article**
Read more about the orange Alaskan rivers:
https://www.scientificamerican.com/article/why-are-alaskas-rivers-turning-orange/

➢ **Video**
Students watch a short video that explains how the instruments on the Aqua satellite capture images that scientists use to better understand how oceans and land are changing.
https://www.youtube.com/watch?v=1jqFxZI_2XY&list=UUAY-SMFNfynqz1bdoaV8BeQ&index=2

➢ **Website**
This site provides students with a wealth of information on the Aqua Satellite Project including tracking, news, and links to a podcast.
https://aqua.nasa.gov/

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students how observing ocean colors from satellite data might inform our understanding of ocean ecosystems. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about changes in the ocean that are related to colors.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Solutions
- Mixtures
- Physical properties

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedback loops that cause changes to other Earth systems.

Disciplinary Core Ideas:

- LS2.A: Interdependent Relationships in Ecosystems
- ESS2.A: Earth Materials and Systems

Crosscutting Concepts:

- Cause and effect
- Systems and system models
- Energy and matter

Science and Engineering Practices:

- Obtaining, evaluating, and communicating information

Nature of Science:

- Science is a human endeavor.

See how *ChemMatters* correlates to the **Common Core State Standards** online.

ChemMatters®
Demystifying Everyday Chemistry

Teacher's Guide

Ötzi the Iceman

April 2025

Table of Contents

Anticipation Guide

Name: _____

Directions: ***Before reading the article*****,** in the first column, write "A" or "D," indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Ötzi the Iceman was perfectly preserved by freeze drying.
		2. Ötzi's remains were buried in Italy, near where he was found.
		3. Ötzi was found with an ax and a knife with steel blades.
		4. Ötzi probably died from freezing to death.
		5. Scientists used DNA analysis to determine Ötzi's ancestry, but new evidence caused them to change their ideas.
		6. Ötzi probably had Lyme disease.
		7. Ötzi's tattoos are elaborate designs depicting hunting scenes.
		8. Once an organism dies, carbon-14 in the body remains the same.
		9. The discovery of Ötzi's remains has advanced the science of glacial archaeology.
		10. More mummified prehistoric remains have been found in Europe and Canada since Ötzi's discovery.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What role does radiocarbon dating play in determining Ötzi's age?
2. How does DNA sequencing help scientists study Ötzi?
3. What is the polymerase chain reaction (PCR) and how is it used in analyzing Ötzi's DNA?
4. How did gel electrophoresis contribute to the study of Ötzi's DNA?
5. What chemical evidence indicated that Ötzi died quickly from his wounds?
6. What is the significance of isotopes in analyzing Ötzi's remains?
7. How did scientists determine Ötzi's last meals using chemistry?
8. What chemical process allowed Ötzi's body to be naturally preserved?
9. What evidence suggests that Ötzi suffered from Lyme disease?
10. What role did mass spectrometry play in studying Ötzi?
11. How did pollen analysis help reconstruct Ötzi's last movements?
12. What does the presence of charcoal in Ötzi's intestines suggest about his diet?
13. What are the chemical properties of copper that made Ötzi's ax an important artifact?
14. How did scientists determine Ötzi's tattoos were made with carbon-based ink?
15. How did the discovery of *Helicobacter pylori* in Ötzi's stomach contribute to medical chemistry?

Graphic Organizer

Name: _____

Directions: As you read, use information from the article to complete the graphic organizer below to describe what scientists and archaeologists have learned about the Iceman.

Question	Claim	Evidence
When did he die?		
How old was he when he died?		
How did he die?		
What were his last meals?		
Where did he eat his last meals?		
What diseases did he have?		
Who were his ancestors?		
What was the meaning of his tattoos?		
How did the discovery of his remains advance the science of glacial archaeology?		

Summary: On the back of this sheet, write three interesting details you learned about Ötzi the Iceman. In a sentence, explain why these details are interesting to you.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What role does radiocarbon dating play in determining Ötzi's age?
   Radiocarbon dating measures the decay of carbon-14 isotopes in organic material. Since carbon-14 decays at a predictable rate with a half-life of 5,730 years, scientists can determine how long ago Ötzi died by analyzing the ratio of carbon-14 to carbon-12 in his remains.

2. How does DNA sequencing help scientists study Ötzi?
   DNA sequencing determines the order of nitrogenous bases (A, T, C, G) in Ötzi's DNA, revealing information about his ancestry, physical traits, health conditions, and even what he ate before he died.

3. What is the polymerase chain reaction (PCR) and how is it used in analyzing Ötzi's DNA?
   PCR is a technique that amplifies DNA by making multiple copies of a specific genetic sequence. Scientists use PCR to increase the amount of Ötzi's ancient DNA, making it easier to analyze for genetic markers and pathogen identification.

4. How did gel electrophoresis contribute to the study of Ötzi's DNA?
   Gel electrophoresis separates DNA fragments based on size using an electric current. By running Ötzi's DNA through a gel, scientists could analyze different DNA sequences to identify species he consumed and potential genetic diseases.

5. What chemical evidence indicated that Ötzi died quickly from his wounds?
   Scientists found fibrin, a blood-clotting protein, around his wound. Fibrin appears rapidly after an injury but degrades quickly, suggesting that Ötzi did not survive long after being shot with the arrow.

6. What is the significance of isotopes in analyzing Ötzi's remains?
   Isotopes of elements like carbon, oxygen, and nitrogen can provide insights into Ötzi's diet, climate, and even migration patterns. For example, carbon isotopes helped date his remains, while oxygen isotopes in his teeth indicated where he grew up.

7. How did scientists determine Ötzi's last meals using chemistry?
   Scientists analyzed the stomach contents using DNA sequencing and protein analysis. They identified meat from ibex and deer, as well as grains, indicating a well-rounded diet before his death.

8. What chemical process allowed Ötzi's body to be naturally preserved?
   Ötzi was freeze-dried by the cold temperatures of the Alps, which prevented bacterial decomposition. Unlike Egyptian mummies, which were preserved using salt and resin, Ötzi's preservation resulted from natural dehydration and freezing.

9. What evidence suggests that Ötzi suffered from Lyme disease?
   DNA analysis of Ötzi's remains revealed the presence of *Borrelia burgdorferi*, the bacterium responsible for Lyme disease, making him the earliest known human with the infection.

10. What role did mass spectrometry play in studying Ötzi?
    Mass spectrometry helped identify proteins, lipids, and other biomolecules in Ötzi's tissues. This allowed scientists to determine his health conditions, diet, and even the presence of ancient bacteria in his body.

11. How did pollen analysis help reconstruct Ötzi's last movements?
    Scientists used chemical analysis to identify pollen grains in Ötzi's digestive system. The presence of different types of pollen indicated that he moved through multiple altitudes before his death.

12. What does the presence of charcoal in Ötzi's intestines suggest about his diet?
    Traces of charcoal suggest that Ötzi cooked his food, likely over an open fire. This indicates knowledge of fire use and food preparation during the Copper Age.

13. What are the chemical properties of copper that made Ötzi's ax an important artifact?
    Copper is a relatively soft metal with high malleability and corrosion resistance. Ötzi's copper axe demonstrated early metal smelting and technological advancement in tool-making during the Copper Age.

14. How did scientists determine Ötzi's tattoos were made with carbon-based ink?
    Chemical analysis of Ötzi's tattoos showed they were created using soot or charcoal, both rich in carbon. This suggests early use of tattooing for medicinal or ritualistic purposes.

15. How did the discovery of *Helicobacter pylori* in Ötzi's stomach contribute to medical chemistry?
    The identification of *H. pylori* in Ötzi's stomach provided insights into the ancient evolution of this bacterium, which is linked to stomach ulcers and gastric cancer. This finding helps scientists understand how infectious diseases evolved over time.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
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Additional Resources and Teaching Strategies

Additional Resources

❖ Labs and demonstrations

➢ **Radiocarbon Dating Simulation Lab**
Link: https://serc.carleton.edu/sp/mnstep/activities/34884.html
Description: In this hands-on lab, students simulate radiocarbon dating using M&Ms or dice to model the radioactive decay of carbon-14. This experiment helps students understand half-life, decay rates, and how scientists determined Ötzi's age.

❖ Projects and extension activities

➢ **"The Iceman: Uncovering the Life and Times of a Prehistoric Man Found in an Alpine Glacier" by Brenda Fowler**
This book provides an in-depth historical and scientific analysis of Ötzi's discovery, including forensic investigations, radiocarbon dating, and the impact of his find on archaeology and anthropology.

➢ **National Geographic's Ötzi the Iceman Interactive Feature**
LInk:
https://www.nationalgeographic.com/premium/article/otzi-the-iceman-what-we-know-3-decades-after-his-discovery
This interactive article explores the scientific discoveries surrounding Ötzi, with detailed explanations on DNA sequencing, isotopic analysis, and forensic chemistry.

➢ **PBS NOVA - "Iceman Murder Mystery" (Documentary & Article)**
Link: https://www.pbs.org/wgbh/nova/video/iceman-reborn/
This high school-friendly NOVA documentary explores Ötzi's discovery, forensic analysis, and the chemistry of his preservation. The website also has short articles, interactive features, and teacher resources.

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students if they have heard of the perfectly preserved iceman found in the Italian Alps. Ask what they think we can learn from his remains. Their initial ideas can be collected electronically via digital whiteboards or similar technology.
    - As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students how a knowledge of chemistry helped answer questions about the life of a person who lived more than 5000 years ago. Ask them why the discovery matters to us today.
- **Note**: This article provides a good opportunity for students to think about and discuss how science is done, especially how changing explanations for phenomena when new evidence is found is a strength of science.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Radiocarbon dating
- Half-life
- Instrumentation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-8. Develop models to illustrate the changes in composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Disciplinary Core Ideas:

- PS1.A: Structure and properties of matter
- PS1.C: Nuclear processes
- LS3.A: Inheritance of traits

Crosscutting Concepts:

- Patterns
- Cause and effect
- Structure and function
- Stability and change

Science and Engineering Practices:

- Analyzing and interpreting data

Nature of Science:

- Science is a human endeavor.

See how *ChemMatters* correlates to the **Common Core State Standards** online.