

ChemMatters®

Demystifying Everyday Chemistry

Teacher's Guide

October 2023

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October Teacher's Guide Introduction

Lesson Ideas

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

To celebrate 40 years of *ChemMatters*, three of the feature articles (“Gas Laws and Scuba Diving,” “Flatus: Chemistry in the Wind,” and “Radium Girls: Dialing Up Trouble”) are from past issues of *ChemMatters*. At the end of each of these articles, there are notes from the editor about new scientific information and advances since publication. This helps support student understanding of science and engineering practices (Constructing explanations and designing solutions) as well as the nature of science (Scientific knowledge is open to revision in light of new evidence) from the NGSS. Encourage students to read the editor’s notes and consider how these changes may have affected their lives.

This year’s National Chemistry Week theme is “The Healing Power of Chemistry.” The “Pimple Patches” article relates most directly to the theme, but you can challenge students to explain how an understanding of chemistry helped improve people’s lives for each article.

Teaching Ideas for this issue:

1. “Chemistry in Pictures” on page 2 shows a photograph of the green flash. Before reading, ask students if they have ever seen the green flash, and whether there is a scientific explanation for it. Also ask them how one might go about looking for the green flash.
2. “Open for Discussion” on page 4 challenges students to think about the future of AI and how it relates to chemistry. After reading, ask students to make predictions about how AI might affect the future of chemistry in their lifetimes.
3. “Quick Read: Bones” on page 14 describes the chemistry of bones. Some of the information relates to this year’s National Chemistry Week theme: “The Healing Power of Chemistry.”
4. The “Chemistry in Person” column on page 19 describes how two people combined their chemistry knowledge with business acumen to create a successful startup company producing enzymes. Ask students to consider how they might use chemistry in their future careers, even if they are not scientists.
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. 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.

Teacher's Guide

Pimple Patches and What They Offer

October 2023

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This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
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Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Pimples are caused by hormones producing excess oil.
		2. Everyone who gets pimples has acne-prone skin.
		3. Pimple patches are waterproof.
		4. Using a pimple patch more than once is recommended.
		5. Pimple patches can stop a pimple from appearing.
		6. Pimple patches contain a polymer gel that creates a moist environment.
		7. All pimple patches contain medication.
		8. Tea tree oil can be very moisturizing.
		9. Microneedle pimple patches are used for deep, painful pimples.
		10. Wearing a face mask can cause more pimples to form.

Student Reading

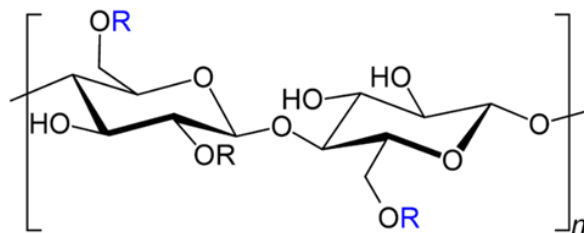
Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What is it that causes a pimple to form?
2. Why do people tend to get acne during puberty?
3. People often use the words “acne” and “pimples” to describe the same thing. What, if any, is the difference between acne and pimples?
4. There are three main reasons that a pimple patch can speed up the healing of a pimple. List these and explain why each speeds healing.
5. A hydrocolloid is a substance that forms a gel when it is mixed with water. These are typically made from different types of hydrophilic (water-loving) polymers.
 - a. What is a polymer?
 - b. What structural feature of hydrophilic polymers allows them to attract water to form the gel?
6. A basic pimple patch can be made using a hydrocolloid, along with a thin outer plastic layer, without containing any medication. Explain the physical process involving the hydrocolloid that helps the pimple to heal.
7. Large organic structures are typically represented using a line structure, rather than a full Lewis structure. The end of each line segment represents a carbon atom, while hydrogen atoms that are attached to the carbons are not shown. Since carbon atoms have four bonding sites, the number of implied hydrogen atoms can be easily determined.
 - a. Using the line structure for salicylic acid, found in the article, draw a complete Lewis structure, including all bonding and nonbonding electrons.
 - b. Using the line structure for niacinamide in the article, determine the molecular formula for the molecule.

8. Below is a diagram showing a section of hydroxymethylcellulose. (“R” is a symbol used in chemical structures to represent a generalized group of atoms or molecules that could be attached at that point.)
- Draw in the lone pairs of electrons that are not shown (ignore the R group).
 - Draw three water molecules in any appropriate part of the diagram to show how water is attracted to the hydroxymethylcellulose.



9. A hydrocolloid is a type of colloid. What is a colloid and how is it different from a solution?
10. A hydrogel is a solid network of hydrophilic polymers that is insoluble and can incorporate water into its pores, thus swelling to a larger size. Both hydrogels and hydrocolloids are composed of polymer molecules and water, but they are used very differently. Explain why a hydrocolloid is better than a hydrogel for use in a pimple patch.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the chemistry of pimple patches.

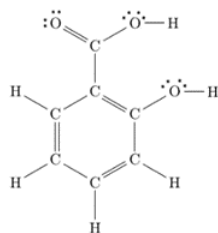
Ingredient	What it is (chemically)	Purpose
Hydrocolloid		
Adhesive		
Salicylic acid		
Hyaluronic acid		
Benzoyl peroxide		
Niacinamide		

Summary: On the back of this sheet, write three interesting facts about pimple patches you learned from the article to share with a friend who is considering using them.

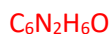
Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What is it that causes a pimple to form?
When there is excess sebum (oils) it stops the dead skin cells from being shed and traps them in the pore. These are also likely to become infected through bacteria.
2. Why do people tend to get acne during puberty?
During puberty, the glands that produce sebum (sebaceous glands) can become overstimulated due to the change in hormones. This produces excess sebum which can get trapped in the pores.
3. People often use the words “acne” and “pimples” to describe the same thing. What, if any, is the difference between acne and pimples?
Acne is the name of the condition. Pimples are a symptom of the condition. Acne causes pimples, but pimples can also be caused by factors not associated with the skin condition.
4. There are three main reasons that a pimple patch can speed up the healing of a pimple. List these and explain why each speeds healing.
The patch prevents you from touching the pimples, which can further irritate or infect them.
The hydrocolloid in the patch draws fluid out of the wound which helps to clean out the pore.
The outer film on the patch prevents the evaporation of water, providing the moist environment needed for healing to occur.
5. A hydrocolloid is a substance that forms a gel when it is mixed with water. These are typically made from different types of hydrophilic (water-loving) polymers.
 - a. What is a polymer?
A chain of repeating smaller units that are bonded end to end to create a molecule that is a continuous long strand.
 - b. What structural feature of hydrophilic polymers allows them to attract water to form the gel?
Multiple hydroxyl (-OH) groups along the polymer chain can attract the water molecules through hydrogen bonding interactions.
6. A basic pimple patch can be made using a hydrocolloid, along with a thin outer plastic layer, without containing any medication. Explain the physical process involving the hydrocolloid that helps the pimple to heal.
Since the hydrocolloid is hydrophilic, it attracts the fluids from the pimple to clear out the pore. A feature of hydrocolloids is that they can attract water and oils which will become trapped as the gel matrix forms, sequestering the fluids away from the pore so it can heal.

7. Large organic structures are typically represented using a line structure, rather than a full Lewis structure. The end of each line segment represents a carbon atom, while hydrogen atoms that are attached to the carbons are not shown. Since carbon atoms have four bonding sites, the number of implied hydrogen atoms can be easily determined.
- Using the line structure for salicylic acid, found in the article, draw a complete Lewis structure, including all bonding and nonbonding electrons.



- Using the line structure for niacinamide in the article, determine the molecular formula for the molecule.



8. Below is a diagram showing a section of hydroxymethylcellulose. (“R” is a symbol used in chemical structures to represent a generalized group of atoms or molecules that could be attached at that point.)

- Draw in the lone pairs of electrons that are not shown (ignore the R group).

There should be 2 pairs of electrons added to each oxygen atom.

- Draw three water molecules in any appropriate part of the diagram to show how water is attracted to the hydroxymethylcellulose.

Water molecules should be drawn such that the H atoms of water are pointing toward an O atom of the polymer chain (or attached with a dashed line) or the O atoms of water are pointing toward the H atoms of the -OH groups (or attached with a dashed line).

9. A hydrocolloid is a type of colloid. What is a colloid and how is it different from a solution?

A colloid has two parts, like a solution, but the parts are dispersed throughout a medium, rather than dissolved. In a solution, water molecules surround each individual solute particle. In a colloid, water molecules are attracted to larger clusters or single macromolecules that cannot dissolve. In a colloid, one substance is dispersed throughout another. In a hydrocolloid, it is hydrophilic polymers that are dispersed throughout water.

10. A hydrogel is a solid network of hydrophilic polymers that is insoluble and can incorporate water into its pores, thus swelling to a larger size. Both hydrogels and hydrocolloids are composed of polymer molecules and water, but they are used very differently. Explain why a hydrocolloid is better than a hydrogel for use in a pimple patch.

Hydrocolloids actively draw water or fluid into the polymer network; as it soaks up oil or fluid from a pimple or wound, it swells. Hydrocolloids are good for wounds that are producing liquids. A Hydrogel doesn't have as much room as a hydrocolloid to draw the water away from the wound because the polymers are in a more rigid, less water loving, network. Hydrogels are best for dry wound applications.

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

❖ Labs and demonstrations

- Royal Society Lab investigation: <https://edu.rsc.org/experiments/investigating-hydrogels-in-nappies-and-hair-gel/689.article>
- AACT-Changing a Monomer to a Polymer: <https://teachchemistry.org/classroom-resources/changing-a-monomer-to-a-polymer>
- Inquiring Minds Want to Know: Growing Plastic Beads
<https://www.canr.msu.edu/resources/inquiring-minds-want-to-know-growing-plastic-beads>

❖ Simulations

- Video: What's the Deal with Acne? <https://www.acs.org/pressroom/reactions/library/whats-the-deal-with-acne.html>

❖ Lessons and lesson plans

- AACT-Molecular Spaghetti
<https://teachchemistry.org/classroom-resources/molecular-spaghetti>
- AACT-Watch the Baby! Superabsorbent Polymer
<https://teachchemistry.org/classroom-resources/watch-the-baby-superabsorbent-polymer>
- ACS Activity- Bandages for Faster Healing
<https://www.acs.org/education/outreach/celebrating-chemistry-editions/2023-ncw/bandages-for-faster-healing.html>

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 or their friends have used pimple patches. Ask students how they think pimple patches work. Their initial ideas can be collected electronically via Jamboard, Padlet, 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 chemistry of chemistry cosmetics.
- After students have read and discussed the article, ask students what information they would like to share with friends and family about pimple patches, and whether they will treat pimples differently based on the information in the article.
- Consider showing the ACS Reactions Video: "What's the Deal With Acne?" (3:56) <https://youtu.be/KrMbwDil1hc?si=godzEJuexeet9q4Z>. Although the video does not describe pimple patches, it does review the causes of pimples and some ways to treat them, including salicylic acid, benzoyl peroxide, and retinoids.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Functional groups
- Molecular structure
- Polymers

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-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- ETS.1.C: Optimizing the Design Solution

Crosscutting Concepts:

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

Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

Nature of Science:

- Science addresses questions about the natural and material world.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

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Demystifying Everyday Chemistry

Teacher's Guide

Gas Laws and Scuba Diving

October 2023

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This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
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Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
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Name: _____

Anticipation Guide

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. The air pressure at the top of a tall building is higher than at the bottom of the building.
		2. Diving 10 meters deep in water doubles the pressure exerted on your body.
		3. Pressure changes in your body when diving are most noticeable in body cavities containing air, such as the lungs, ears, and sinuses.
		4. The regulator of a scuba tank keeps the pressure in a diver’s lungs the same as surface air pressure.
		5. Scuba divers must ascend slowly and breathe regularly when ascending from a deep dive.
		6. Gases are more soluble in liquids at lower pressures.
		7. Formation of nitrogen gas bubbles in the blood can cause many physical problems for divers.
		8. Contamination of the air in scuba tanks is rare if a certified dive shop is used.
		9. Taking a hot shower right after a deep dive is recommended for scuba divers.
		10. Since 1983, scuba divers use scuba computers to track depth of dives and calculate nitrogen absorption.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. List three relationships among gas properties that impact scuba diving.
2. Compare the air pressure at sea level and at the top of a tall mountain.
3. Why might your ears hurt during plane descent?
4. Are pressure changes greater in water or air? Explain.
5. What does it mean to say that two variables are related directly? What does it mean to say that two variables are related inversely? Give an example of each from the article.
6. If the pressure of a gas is doubled, what happens to the volume? Which law applies here?
7. A diver is at a depth of 20 m. How deep would a diver need to dive to double the pressure at 20 m?
8. Explain why vacationing scuba divers should not dive in the morning and then fly home in the afternoon.
9. Explain one way that technology has improved diving safety.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

10. Research decompression sickness (the “bends”). What are the symptoms, causes, and treatment?
11. Research and explain the relationships between oxygen, carbon monoxide, and your blood.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe how an understanding of gas behavior and gas laws can help make scuba diving safer.

Concept	Explanation	Effects on scuba diving
Boyle's Law		
Henry's Law		
Gas solubility and temperature		
Important changes to scuba diving in past 40 years (since publication of the original article)		

Summary: On the back of this sheet, write a short email (3-4 sentences) to a friend about the importance of understanding gas laws when scuba diving.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. List three relationships among gas properties that impact scuba diving.
Three relationships that impact scuba diving include pressure-volume effects, pressure-solubility, and temperature-solubility effects.
2. Compare the air pressure at sea level and at the top of a tall mountain.
Air pressure at sea level is greater than the air pressure at the top of a mountain.
3. Why might your ears hurt during plane descent?
Since the air pressure is lower at higher altitude, the pressure inside your ear is lower than the air pressure outside your ear as you begin to descend in a plane. You may feel pain as the inside and outside pressure equalize.
4. Are pressure changes greater in water or air? Explain.
For a specific depth change, pressure changes are greater in water than air because water (liquid) has a higher density than air (gas).
5. What does it mean to say that two variables are related directly? What does it mean to say that two variables are related inversely? Give an example of each from the article.
When two variables are related directly, they change in the same direction. For example, according to Henry's Law, as the pressure above a liquid increases, the amount of gas that can dissolve increases. When two variables are inversely related, they change in opposite directions. For example, according to Boyle's Law, as pressure increases, volume decreases. This relationship is also shown with temperature and gas solubility; at higher temperatures gases are less soluble.
6. If the pressure of a gas is doubled, what happens to the volume? Which law applies here?
If the pressure of a gas is doubled, the volume is cut in half. This is an example of Boyle's Law.
7. A diver is at a depth of 20 m. How deep would a diver need to dive to double the pressure at 20 m?
According to the graphic, at 20 m, a diver feels 3 atm pressure. To experience a pressure of 6 atm, the diver would be at a depth of 50 m.
8. Explain why vacationing scuba divers should not dive in the morning and then fly home in the afternoon.
As a diver comes to the surface, water pressure decreases causing the solubility of dissolved air to decrease. The gas "comes out of solution" similar to seeing gas bubbles in an open soda bottle. At higher altitudes, the solubility of gas will further decrease, and gas bubbles can form in the blood. This can lead to health issues, some of which can be serious.
9. Explain one way that technology has improved diving safety.
One way that technology has improved diving safety is that diving tables published by the US Navy have been replaced by computers that divers wear. These computers monitor time and depth of a dive. They also provide guidelines for coming to the surface safely.
10. Research decompression sickness (the "bends"). What are the symptoms, causes, and treatment?
Decompression sickness occurs when dissolved gas comes out of solution and forms bubbles in the blood and body tissue. This can occur when divers rise rapidly to the surface of the water. Nitrogen is not used by the body the way oxygen is, so it is often the gas that causes the problem. The quantity of nitrogen gas that comes out of solution is a result of the length of time and depth of the dive. It can be

prevented if divers come to the surface slowly, which allows some of the nitrogen gas to escape. Symptoms include joint pain, itchy skin, dizziness, and fatigue. Doctors treat decompression sickness by putting the diver in a hyperbaric recompression chamber. This process simulates a dive in that gas bubbles can be reabsorbed and oxygen can be given to help injured tissues.

11. Research and explain the relationships between oxygen, carbon monoxide, and your blood.

Oxygen gas is transported throughout the body by binding to a protein known as hemoglobin in the bloodstream. If a person inhales carbon monoxide gas in a contaminated scuba tank, this gas binds to the hemoglobin molecule instead of oxygen. In fact, carbon monoxide binds 200-300 times more than oxygen gas. This is how tissues and cells are deprived of oxygen during carbon monoxide poisoning.

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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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

❖ Labs and demos

- <https://teachchemistry.org/classroom-resources/crush-the-can>
- <https://teachchemistry.org/classroom-resources/exploring-gas-solubility>
- <https://teachchemistry.org/classroom-resources/density-of-gases-and-particle-diagrams>
- <https://teachchemistry.org/classroom-resources/three-station-gas-lab>

❖ Simulations

- https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html
- <https://www.learner.org/series/chemistry-challenges-and-solutions/when-chemicals-meet-water-the-properties-of-solutions/decompression-sickness-and-henrys-law-animation/>
- <https://teachchemistry.org/classroom-resources/gases-animation>

❖ Lessons and lesson plans

- <https://teachchemistry.org/classroom-resources/robert-boyle-video-questions>

❖ Projects and extension activities

- <https://cen.acs.org/physical-chemistry/chemical-bonding/Periodic-Graphics-Gases-scuba-diving/96/i34>

Teaching Strategies

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

- **Composition of Air:** Review the composition of air (approximately 78% N₂, 21% O₂, 1% other gases) before reading the article. Some students may not realize that air is almost 80% nitrogen gas (N₂). See <https://www.noaa.gov/jetstream/atmosphere> for more detailed information.
- **Alternative to Anticipation Guide:** Before reading, ask students if they have snorkeled or been scuba diving. Ask them to describe the differences in the two activities. Ask how an understanding of chemistry might help them be safer scuba divers. Their initial ideas can be collected electronically via Jamboard, Padlet, 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 gases and scuba diving. Ask students how the information will be helpful if they want to become certified scuba divers.
 - As an interesting side note, I once had a student who shared that he wanted to snorkel at a greater depth without diving, so he tried making a snorkel that was a meter long. It didn't work, and this article helped him understand why! ~ Susan Cooper

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Gases
- Gas laws
- Pressure
- Temperature
- Volume
- Solubility

Correlations to Next Generation Science Standards

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

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- ETS.1.C: Optimizing the Design Solution

Crosscutting Concepts:

- Patterns
- Scale, proportion, and quantity
- Systems and system models

Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

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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Flatus: Chemistry in the Wind

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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.

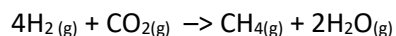
Me	Text	Statement
		1. Flatus is a subject of serious scientific study.
		2. Pilots flying at high altitudes in World War II were not allowed to have dried beans, vegetables in the cabbage family, or carbonated drinks prior to flying.
		3. Most people pass less than 5 milliliters of gas each day.
		4. Vegetarians produce less gas than meat eaters.
		5. People who are lactose intolerant produce less gas than others.
		6. Almost all the gases in flatus are odorless.
		7. Some people produce methane gas, and their stools float in water.
		8. Methane has more global warming capacity than carbon dioxide.
		9. Sulfur-containing compounds give flatus an odor.
		10. All chemical products that relieve gas symptoms contain enzymes.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Define Boyle's Law (You can use your textbook for assistance). What two variables are measured? What one variable is kept constant?
2. On average, approximately how many times does a person have flatulence per day? Is this number different for males and females?
3. What are the most common gases found in the human body digestive system?
4. What gases commonly cause the bad odor of flatulence?
5. Give a brief explanation of these different chemical identifying processes: gas chromatography, infrared spectrometry, and mass spectrometry.
6. What is the enzyme needed to digest dairy products? For people who do not have this enzyme, how do they deal with this issue?
7. Explain why vegetarians produce more flatulence.
8. Explain how Beano and Lactaid work differently than Gas-X.
9. What are farmers trying to do to help limit the amount of methane emitted into the atmosphere?
10. The scientist Amedeo Avogadro stated that the volume of a gas (or a mixture of gases) decreases when the number of moles decrease (and vice-versa). For the following reaction that produces methane, use Avogadro's principle to explain what happens to the volume of the gases.



11. Patients are instructed to not eat or drink before a surgery (typically 12 hours before). Why is this important?
12. According to scientists, methane is approximately 25 times worse for global warming than carbon dioxide. However, carbon dioxide (CO₂) seems to be discussed more in discussions on greenhouse gases. Why do you think this is the case?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

13. Deep Sea divers sometimes experience a painful effect called “the bends”. Research and give a brief explanation of what happens when a diver gets the bends, how to get rid of the bends, and how the name “the bends” was coined.

Graphic Organizer

Name: _____

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

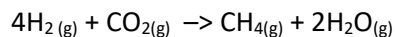
Concept	Connection to the article
Boyle's Law	
Enzymes	
Bacteria	
Flatus gases	
Methane	
Sulfur compounds	
Gas relief	

Summary: On the back of this sheet, write three new things you learned about flatus.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Define Boyle's Law (You can use your textbook for assistance). What two variables are measured? What one variable is kept constant?
Boyle's Law states that the pressure and volume of a gas are indirectly proportional. The two measured variables are pressure and volume. Variables that remain constant are temperature and amount of gas.
2. On average, approximately how many times does a person have flatulence per day? Is this number different for males and females?
The average person passes gas between 5-15 times each day. This number is the same for both men and women.
3. What are the most common gases found in the human body digestive system?
The most common gases found in the human body are nitrogen, oxygen, hydrogen, carbon dioxide and methane.
4. What gases commonly cause the bad odor of flatulence?
The gases that cause the foul odor of flatulence are hydrogen sulfide (the most common one), methanethiol, and methyl sulfide.
5. Give a brief explanation of these different chemical identifying processes: gas chromatography, infrared spectrometry, and mass spectrometry.
Gas chromatography: identifies the different compounds in a complex gas mixture.
Infrared spectrometry: molecules are identified through interacting with infrared radiation.
Mass spectrometry: chemicals are identified by measuring molecular masses.
6. What is the enzyme needed to digest dairy products? For people who do not have this enzyme, how do they deal with this issue?
The enzyme needed to digest dairy products is lactase. Those who are "lactose intolerant" need to take medicines such as Beano, Lactaid, and Gas-X.
7. Explain why vegetarians produce more flatulence.
Vegetarians produce more flatulence because their diet has a larger amount of carbohydrates. These carbohydrates are what produce gas in the digestive system.
8. Explain how Beano and Lactaid work differently than Gas-X.
Beano and Lactaid medicines contain enzymes that will help break down the sugars in the body that produce gases. Gas-X, however, has a special ingredient (simethicone) that lessens the surface tension of bubbles, which prevents them from forming, or breaks the bubbles down.
9. What are farmers trying to do to help limit the amount of methane emitted into the atmosphere?
Methane is a greenhouse gas, so farmers need to limit the amount of this gas produced by cows. Farmers are doing this by finding different feed to give the cows that will limit the amount of methane produced in the cow's digestive system.

10. The scientist Amedeo Avogadro stated that the volume of a gas (or a mixture of gases) decreases when the number of moles decrease (and vice-versa). For the following reaction that produces methane, use Avogadro's principle to explain what happens to the volume of the gases.



In the reaction, there are 5 moles of gas on the reactant side (4 moles of hydrogen and 1 mole of carbon dioxide). These produce three moles of gas (1 mole methane and 2 moles water). The drop in the number of moles will decrease the overall volume of the gases.

11. Patients are instructed to not eat or drink before a surgery (typically 12 hours before). Why is this important?
By not eating before surgery, the body has no food to digest, thus no gases will be produced in the digestive system. This will keep the patient safe from any issues involving releases of gases from the body.
12. According to scientists, methane is approximately 25 times worse for global warming than carbon dioxide. However, carbon dioxide (CO₂) seems to be discussed more in discussions on greenhouse gases. Why do you think this is the case?
(Answers may vary). A common answer would be that gas powered machines (cars, airplanes, etc) produce large amounts of CO₂. So even though methane is worse, carbon dioxide is produced in much larger amounts.

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

❖ Labs and Simulations

- Phet Gas Intro
<https://phet.colorado.edu/en/simulations/gases-intro>
- Phet Gas Properties (more complex)
<https://phet.colorado.edu/en/simulations/gas-properties>
- AACT Gas Law Simulation
<https://teachchemistry.org/classroom-resources/the-gas-laws-simulation>
- Boyle's Law Activity
<https://teachchemistry.org/classroom-resources/boyle-s-law>

❖ Lessons and lesson plans

- AACT Gas Law Unit Plan
<https://teachchemistry.org/classroom-resources/the-gas-laws-unit-plan>
- Robert Boyle Video
<https://teachchemistry.org/classroom-resources/robert-boyle-video>
- Compound Chem Odor infographic
<https://www.compoundchem.com/2014/04/07/the-chemistry-of-body-odours-sweat-halitosis-flatulence-cheesy-feet/>
- YouTube Science of Farts
https://youtu.be/GTvnjaUU6Xk?si=Zgq_KQpnNbXBOiR
- Scientific American article on flatulence
<https://www.scientificamerican.com/article/in-and-out-demonstrating-boyles-law/>

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 ever wondered how science can answer questions about flatulence. Ask students how chemistry might help us understand how to reduce flatulence. Their initial ideas can be collected electronically via Jamboard, Padlet, 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 is helpful in explaining the chemistry of our digestive system.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Gas laws
- Enzymes

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the 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.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- PS.1.B: Chemical Reactions

Crosscutting Concepts:

- Patterns
- Cause and effect
- 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](#).

Teacher's Guide

Radium Girls: Dialing Up Trouble

October 2023

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Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	36
These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You'll find the questions ordered in increasing difficulty.	
<u>Graphic Organizer</u>	38
This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
<u>Answers</u>	39
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	42
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
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Name: _____

Anticipation Guide

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Paint containing pure radium was used to make watch dials glow in the dark.
		2. Radioactivity is a natural process.
		3. Alpha particles can penetrate a piece of paper.
		4. If radium enters the body, it can replace calcium in the bones.
		5. The Radium Girl painters sometimes painted their teeth and faces as a game.
		6. Safety procedures for the painters were in place prior to the 1920s.
		7. Promethium was used as a substitute for radium because it is not radioactive.
		8. Luminescent watch dials today are not radioactive.
		9. Radium is found in all uranium minerals.
		10. Marie Curie knew about the health problems suffered by the Radium Girls.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. List the two components in the powdered base of the paint used by the watch dial painters and the two ingredients the powder was mixed with to produce paint.
2. What type of radiation particles are released when radium salts decompose?
3. Define the term radioactivity.
4. What are the three most common types of radioactive emissions?
5. What is a scintillator?
6. Explain why the watch-dial painters' clothes and bodies would glow in the dark even if they did not directly touch the radium powder.
7. Explain why radium is deposited in bones when it is absorbed in the body.
8. Why is it safer to use promethium than radium when making luminescent objects?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

9. How does using a breathalyzer to measure radon levels help determine someone's level of radium exposure?
10. What unit of measure is named after Marie Curie and what does it measure?
11. List the elements used in the Indiglo Night-light and describe how they emit light.
12. Identify at least three workplace reforms instituted to try and protect the radium girls and explain why each reform was implemented.
13. The article lists some benefits and drawbacks of exposure to radiation. Perform some additional research to identify and analyze two benefits and two drawbacks of radioactivity.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe problems that caused the Radium Girls to suffer.

	Description	Safety Issues
Radium Paint		
Alpha particles		
Radium		
Painting method used by Radium Girls		
Radium Paint Substitutes		
Marie Curie's discoveries		

Summary: On the back of this sheet, write a short summary (20 words or less) of the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. List the two components in the powdered base of the paint used by the watch dial painters and the two ingredients the powder was mixed with to produce paint.
The two components of the powder are radium salts and zinc sulfide. The powder was mixed with glue and water.
2. What type of radiation particles are released when radium salts decompose?
Alpha particles are released when radium salts decompose.
3. Define the term radioactivity.
Radioactivity is the spontaneous emission of particles or electromagnetic radiation of high energy from the nucleus of an atom.
4. What are the three most common types of radioactive emissions?
The three most common types of radioactive emissions are alpha particles, beta particles, and gamma radiation.
5. What is a scintillator?
A scintillator is a material that emits visible light in response to ionizing radiation.
6. Explain why the watch-dial painters' clothes and bodies would glow in the dark even if they did not directly touch the radium powder.
The radium powder would become airborne and land on them.
7. Explain why radium is deposited in bones when it is absorbed in the body.
Radium is deposited in bones as a substitute for calcium because both elements are alkaline earth elements.
8. Why is it safer to use promethium than radium when making luminescent objects?
Promethium is less hazardous because it decomposes into beta particles which are less able to ionize than alpha particles.
9. How does using a breathalyzer to measure radon levels help determine someone's level of radium exposure?
When radium-226 decays, it decays into atoms of radon-222 and helium-4. Because radium breaks down into radon, measuring radon levels can help to determine the amount of radium a worker may have been exposed to.
10. What unit of measure is named after Marie Curie and what does it measure?
The curie is named after Marie Curie and it is used to measure radioactivity.

11. List the elements used in the Indiglo Night-light and describe how they emit light.
The Indiglo Night-light uses ZnS and Cu. An electrical charge is applied to the ZnS and Cu which excites their electrons. When the electrons return to their ground state, energy is released as light.
12. Identify at least three workplace reforms instituted to try and protect the radium girls and explain why each reform was implemented.
One reform was to ban eating in the work area. This would help prevent the workers from ingesting radium.
The workers were required to wear gloves to wash their paint equipment. This would also prevent contact with radium.
Weighing and mixing the paint was performed under a fume hood to reduce the amount of powder that became airborne.
The amount of time a worker was able to be in the painting department was limited to limit exposure.
13. The article lists some benefits and drawbacks of exposure to radiation. Perform some additional research to identify and analyze two benefits and two drawbacks of radioactivity.
Student responses will vary based on their research. Two benefits are that radioactivity can be used to slow or destroy cancer and can sterilize foods. Two drawbacks are that it can cause sickness and death.

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

❖ Simulations

- [Radioactivity Simulation](#) – Students can use this simulation to explore four different radioactive sources and materials that can be used to block radiation.

❖ Lessons and lesson plans

- [Detecting Radiation in our Radioactive World](#) – This resource developed by the American Nuclear Society includes a variety of lesson plans and activities on topics related to radiation including half-life, irradiation, fission, decay chains, radiation types, and waste.
- [Radium Girls](#) - This lesson plan utilizes graphing to help students understand the impacts of radiation exposure.

❖ Projects and extension activities

- [Marie Curie Video Questions](#) – This video resource and accompanying questions from the American Association of Chemistry Teachers website enables students to learn more about Marie Curie and her work.
- [Primary Sources in Science Classrooms](#) - This post includes links to a variety of primary source documents to provide students with historical context about the uses of radium.

Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students how watch dials are made to glow in the dark. Also ask students if they have heard of the Radium Girls and what happened to them. Their initial ideas can be collected electronically via Jamboard, Padlet, 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 radioactivity and how the suffering of the Radium Girls lead to safety regulations in industry.
- After reading, ask students how they might use information from the article to make decisions about the safe use of radioactive substances.
- There are photos of radium watches and clocks as well as quotes from some of the Radium Girls at the National Museum of American History website: <https://americanhistory.si.edu/girlhood/work/radium-girls>

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- History and Safety
- Alpha/Beta/Gamma decay
- 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-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- ETS1.C: Optimizing the Design Solution

Crosscutting Concepts:

- Cause and effect
- Structure and Function

Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

Nature of Science:

- Science is a human endeavor.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).