

# ChemMatters™

Demystifying Everyday Chemistry

## Teacher's Guide

**April 2023**

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# April Teacher's Guide Introduction

## Lesson Ideas

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

### Teaching Ideas for this issue:

1. "Chemistry in Pictures" on page 2 shows an interesting image of dyes coloring a biofilm being developed by a doctoral student studying a microbial colony. It might be interesting to show students the image without the caption and ask them what they think it might be.
2. "Open for Discussion" on page 4 has information about climate change, including the differences between climate and weather as well as the effects of climate change. The article concludes by encouraging the reader to consider possible solutions to the problems caused by climate change. This information relates well to other articles in this issue, especially "From Pond Scum to Product."
3. "Quick Read: Fireworks!" on page 14 describes the chemistry of fireworks and how they are made. In addition to learning more about chemistry, students could use the information to impress their families and friends on the Fourth of July.
4. The Chemistry in Person column on page 19 relates very well to "From Pond Scum to Product" on page 5. As students read the article, they should look for how Beth Zotter became interested in her career, what she has learned from her research, what is special about the product, and the challenges faced by her company.
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:

<b>Engage</b>	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.
<b>Explore</b>	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.
<b>Explain</b>	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.
<b>Elaborate</b>	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 in the article. See the individual Teacher's Guide for each article to learn more.
<b>Evaluate</b>	Students write a short summary of what they learned, describing how it connects to their lives. Students may also present their learning to their classmates or others.

## Teacher's Guide

### From Pond Scum to Product

*April 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. Algae photosynthesize more efficiently than plants, so they capture more CO <sub>2</sub> from the atmosphere than plants.
		2. The carbon cycle includes carbon found in living things but not nonliving things.
		3. The oldest algal fossils are more than a billion years old.
		4. Alginates are copolymers found in food thickeners, cosmetics, and other products.
		5. The taste of umami comes from a common amino acid.
		6. Most chemically reactive nitrogen is found in the atmosphere.
		7. Jet fuel can be made from algae.
		8. Algal oils are very similar to palm oil.
		9. Most of the world’s plastic comes from algae.
		10. Algae has the potential to produce medicines to combat viruses, bacteria, and cancer.

# Student Reading Comprehension Questions

Name: \_\_\_\_\_

**Directions:** Use the article to answer the questions below.

1. State some similarities and differences between algae and other types of plants.
2. What are the five basic tastes? Which is the one discovered last?
3. What is the definition of “umami”? What is the main chemical that produces the umami taste?
4. State some reasons why nitrogen is such an important element in our lives.
5. Why do some scientists define algae as a kind of Neosporin?
6. Explain how scientists can more effectively print 3D cells using algae versus plastics.
7. What is the difference between a polymer and a copolymer? Give and describe an example of a common polymer. How would this be different from a copolymer?
8. What are some ways algae can lower excess CO<sub>2</sub> levels? What are some other ways algae can help the environment?
9. Why is nitrogen in the air not chemically reactive? (Hint: look at the structure of the N<sub>2</sub> molecule).

# Student Reading Comprehension Questions, cont.

## Questions for Further Learning

*Write your answers on another piece of paper if needed.*

10. Research and explain what happens to  $\text{CO}_2$  when it is dissolved in water. How would an increase in acidity affect the dissolved  $\text{CO}_2$ ?
11. Research MSG (Monosodium glutamate). What is it used for? Why was MSG considered bad for your health.

# Graphic Organizer

Name: \_\_\_\_\_

**Directions:** As you read, complete the graphic organizer below to describe current and future products made from algae, and the people working on the projects. Try to list at least 4 products for each component of algae. Add horizontal lines as needed.

Component	Products	Advantages	Chemistry involved	Person(s) or group(s) involved <i>(if mentioned)</i>
Alginate				
Algal Protein				
Algal Oil				

**Summary:** On the back of this sheet, write a short email (3-4 sentences) to a friend describing what you learned about the importance of developing products from algae.



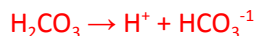
# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. State some similarities and differences between algae and other types of plants.  
Algae are similar to plants because they conduct photosynthesis to get their energy. However, algae do not have roots or stems, so photosynthesis is much more efficient.
2. What are the five basic tastes? Which is the one discovered last?  
The five basic tastes are salt, sour, sweet, bitter, and umami (Umami was discovered last).
3. What is the definition of “umami”? What is the main chemical that produces the umami taste?  
Umami is a Japanese word translated to “deliciousness”. The taste has a rich and savory feel to it. The main chemical that contributes to umami was glutamic acid (an amino acid).
4. State some reasons why nitrogen is such an important element in our lives.  
One of the main reasons why nitrogen is so important is that the element is in amino acids, which we need to create protein to survive. (“amine =  $\text{NH}_3^+$  group on the molecular chain).
5. Why do some scientists define algae as a kind of Neosporin?  
Neosporin is used on cuts and scratches to prevent bacteria from getting into the bloodstream. Studies have shown that compounds from algae have similar properties needed to kill the bacteria.
6. Explain how scientists can more effectively print 3D cells using algae versus plastics.  
Scientists want to create human tissue, but it needs to be in 3D. 3D printing is typically done at high temperatures. However, the human tissue cells can also grow on the compound alginate at much lower, and more favorable temperatures.
7. What is the difference between a polymer and a copolymer? Give and describe an example of a common polymer. How would this be different from a copolymer?  
Polymers and copolymers are both long chains of bonded monomers. A polymer is a long chain that consists of many of the same monomer. An example of this is your basic plastics found around your home and school. A copolymer consists of 2 different monomers bonded together in a long chain. Alginate, from algae (as seen in the article) is a common copolymer. These types of compounds create a gummy type of compound, which in some cases can be edible.
8. What are some ways algae can lower excess  $\text{CO}_2$  levels? What are some other ways algae can help the environment?  
There are a few ways algae can help in the reduction (or “capture”) of  $\text{CO}_2$ . First, the structure of algae is great in absorbing large amounts of the  $\text{CO}_2$ . This is because Algae does not have roots or trunks/branches like other plants. Thus, the algae does not have areas where  $\text{CO}_2$  cannot be absorbed. Also, algae oils can replace palm oils, which would lead to less deforestation. Also, the algae can be converted into more environmentally friendly plastics, which captures permanently the  $\text{CO}_2$ , thus minimizing the amount that goes into the atmosphere.
9. Why is nitrogen in the air not chemically reactive? (Hint: look at the structure of the  $\text{N}_2$  molecule).  
If you look at a picture of the structure of the  $\text{N}_2$  molecule, you will see that the two N atoms are

connected by a triple bond. A very large amount of energy is needed to break these triple bonds, which means the  $N_2$  molecule is very non-reactive. The nitrogen we use in our lives are part of nitrogen-based compounds or ions.

10. Research and explain what happens to  $CO_2$  when it is dissolved in water. How would an increase in acidity affect the dissolved  $CO_2$ ?

When  $CO_2$  is dissolved in water, it reacts with water to make the weak carbonic acid, which breaks down into hydrogen ions and bicarbonate ions. (see reactions below).



If the acidity of the oceans/lakes increases, this means more hydrogen ions are present, thus not as much  $CO_2$  can dissolve in the water. The excess  $CO_2$  remains in the atmosphere, causing the greenhouse gas effect, and disrupts the natural carbon cycle. (Good resource: <https://www.ucsusa.org/resources/co2-and-ocean-acidification>).

11. Research MSG (Monosodium glutamate). What is it used for? Why was MSG considered bad for your health?

Monosodium glutamate (MSG) is a flavor enhancer that is added to foods to make them more tasty and appealing. MSG is commonly added to certain foods (like canned or processed foods) that may need some extra flavor. For a time, there were claims that MSG had adverse health effects, such as headaches and nausea, as well as other symptoms. However, there was very little evidence of this being true, and the FDA still considers MSG to be safe.

(<https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/expert-answers/monosodium-glutamate/faq-20058196>).

# 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 demos

- [The Algae-in-a-Bottle Experiment: A High-Impact Learning Activity \(carleton.edu\)](https://carleton.edu)
- <https://teachchemistry.org/periodical/issues/march-2023/algae-trivia>
- <https://teachchemistry.org/classroom-resources/ingenious-is-the-answer-to-overfishing-algae-video-questions>
- <https://teachchemistry.org/classroom-resources/ideal-gas-law-using-carbon-dioxide>
- <https://teachchemistry.org/classroom-resources/clean-air-chemistry>

### ❖ Lessons and lesson plans

- [Ocean Acidification: “The Other Carbon Dioxide Problem” – Compound Interest \(compoundchem.com\)](https://compoundchem.com)
- [RealTimeChem Week: Turning Carbon Dioxide into Useful Plastics – Compound Interest \(compoundchem.com\)](https://compoundchem.com)
- [The Secrets of the Coke and Mentos Fountain – Compound Interest \(compoundchem.com\)](https://compoundchem.com)
- [A Brief Guide to Atmospheric Pollutants – Compound Interest \(compoundchem.com\)](https://compoundchem.com)

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students where algae might be found and what products are made from algae. Ask them why algae may become more important in the future. 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 importance of developing products from algae.
- This article fits well with the theme for Chemists Celebrate Earth Week: The Curious Chemistry of Amazing Algae (April 16-22, 2023). Go to <https://www.acs.org/education/outreach/ccew.html> to find more information about integrating the chemistry of algae into your curriculum.
- Beth Zotter, one of the people featured in this article, is profiled in the Chemistry in Person column on page 19. Students can find out more about how she became interested in developing the products made by her company.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Polymers
- Molecular structure

## Correlations to Next Generation Science Standards

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

**HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

**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
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- ETS1.B: Developing Possible Solutions

### Crosscutting Concepts:

- Scale, proportion, and quantity
- Systems and system models
- Energy and matter

### 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](#).

## Teacher's Guide

### The Chemistry That Keeps Trains Moving

*April 2023*

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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 first steam locomotive was built in the United States.
		2. Boyle’s Law helps explain how a steam engine works.
		3. Corrosion of steam engine boilers can be reduced by keeping the water in the boiler slightly acidic.
		4. Almost all commercial trains in the U.S. today have internal combustion engines.
		5. Rail ties in the U.S. are usually made of oak.
		6. Rails are joined together using an intensely exothermic thermite reaction.
		7. Expansion gaps are needed to prevent buckling of the train tracks.
		8. In very hot climates, rails may be painted white to reduce their temperature.
		9. Maglev trains can go very fast because they use more efficient fuels than other trains.
		10. Trains produce much less CO <sub>2</sub> per passenger than cars or airplanes.

# Student Reading Comprehension Questions

Name: \_\_\_\_\_

**Directions:** Use the article to answer the questions below.

1. How many times greater is the volume of water in steam form than liquid form?
2. Why were laws passed to ban the use of steam engines?
3. What is the function of the wooden ties that rails are attached to?
4. Create a graph that compares the CO<sub>2</sub> production of airplanes, automobiles, and trains.
5. List three factors that can impact the amount of load a locomotive can haul.
6. What is the function of the boiler of a steam engine and how does its structure impact the function?
7. What is boiler scale and what are three problems it can cause in a steam engine?
8. Explain why using alkaline water in a boiler can prevent corrosion.
9. Explain the function of an expansion joint between sections of rail.



# Student Reading Comprehension Questions, cont.

## Questions for Further Learning

*Write your answers on another piece of paper if needed.*

10. List the reactants that make up thermite and explain why they are finely ground prior to being used in a reaction.
11. Explain what can happen to railroad rails under extreme temperatures.
12. The article notes that some countries are experimenting with railroad ties made from different types of materials. Select concrete, steel, or plastic and research its use as a railroad tie. Create an infographic that describes the chemical composition of the material you selected and include at least two benefits and two drawbacks of the material.
13. Create an infographic that describes at least three science aspects of trains. These aspects could include Boyle's Law, neutralization reactions, solubility, the impact of surface area on chemical reactions, and magnetic forces.

# Graphic Organizer

Name: \_\_\_\_\_

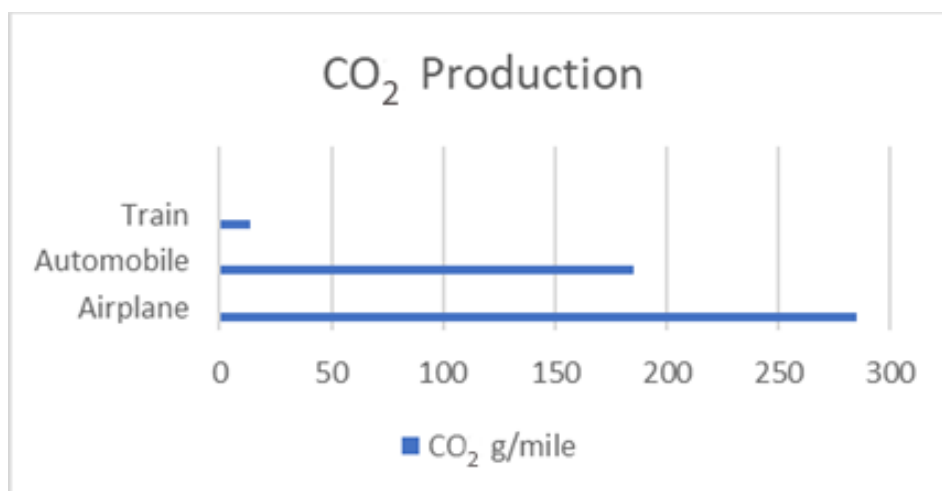
**Directions:** As you read, complete the graphic organizer below to describe the chemistry of train travel.

Component	Chemistry	Safety problems and solutions
Steam Engine		
Steam Engine Boilers		
Diesel-electric engine		
Rail ties		
Metal rails		
Future Trains		

**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. How many times greater is the volume of water in steam form than liquid form?  
The volume of water is 1,600 times greater in steam than in liquid.
2. Why were laws passed to ban the use of steam engines?  
Laws to ban the use of steam engines were passed because the smoke produced by burning coal or wood for the boilers caused pollution in densely populated areas.
3. What is the function of the wooden ties that rails are attached to?  
The wooden ties serve to stabilize the rails and transfer the load to a bed of gravel beneath the tie.
4. Create a graph that compares the CO<sub>2</sub> production of airplanes, automobiles, and trains.



5. List three factors that can impact the amount of load a locomotive can haul.  
The function of the boiler of a steam engine is to turn water into steam. A boiler is made of metal to contain the high pressure created by the steam.
6. What is the function of the boiler of a steam engine and how does its structure impact the function?  
Boiler scale is the buildup of precipitates as water in a boiler evaporates. Boiler scale can decrease engine efficiency, clog pipes, lead to overheating and can cause explosions.
7. What is boiler scale and what are three problems it can cause in a steam engine?  
Carbonic acid can cause corrosion in a boiler. Using alkaline water in a boiler can neutralize carbonic acid.
8. Explain why using alkaline water in a boiler can prevent corrosion.  
Three factors that impact the amount of load a locomotive can haul include the horsepower of the locomotive, the steepness of the route, and the traction of the wheels on the rails.
9. Explain the function of an expansion joint between sections of rail.  
Expansion joints are used to create a gap in the rail which prevents the rails from buckling when the temperature of the rails increases.

10. List the reactants that make up thermite and explain why they are finely ground prior to being used in a reaction.

The reactants that make up thermite are aluminum and iron oxide. They are finely ground to increase surface area to make it easier for them to react.

11. Explain what can happen to railroad rails under extreme temperatures.

Rails expand in extreme heat and can buckle. Extreme cold can cause the rails to contract, resulting in tensile stresses.

12. The article notes that some countries are experimenting with railroad ties made from different types of materials. Select concrete, steel, or plastic and research its use as a railroad tie. Create an infographic that describes the chemical composition of the material you selected and include at least two benefits and two drawbacks of the material.

Student responses will vary and should include an explanation of the material selected as well as two benefits and two drawbacks of the material.

13. Create an infographic that describes at least three science aspects of trains. These aspects could include Boyle's Law, neutralization reactions, solubility, the impact of surface area on chemical reactions, and magnetic forces.

Student responses will vary and should include at least three science connections.

# 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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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

- [Simulation Activity: Gas Laws](#) - This lesson plan aligns with the AACT Gas Laws Simulation and provides students with the opportunity to understand the indirect relationship between pressure and volume.

### ❖ Simulations

- [Gas Laws Simulation](#) - Students can use this simulation to learn more about Boyle's Law, Charles' Law, Gay-Lussac's Law.
- [Gas Properties - Ideal Gas Law](#) - Using this simulation, students will explore relationships between pressure, temperature, and volume as they relate to ideal gas laws.

### ❖ Labs

- [Boyle's Law](#) - In this hands-on lab, students use lab materials to calculate the pressure of a gas.

## 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 traveled on a train and if they know how the train was powered. In addition to passenger trains, some of them may have traveled on trains at theme parks which may operate differently. Ask them how chemistry can help solve safety issues related to train travel. 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 importance of chemistry in designing trains.
- After reading, ask students how they might use information from the article to make decisions about future travel.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical change
- Physical properties
- Gas laws
- Pressure
- Temperature

## 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-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

### Disciplinary Core Ideas:

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

### Crosscutting Concepts:

- Scale, proportion, and quantity
- Systems and system models
- Structure and function

### 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](#).

## Teacher's Guide

### The Ingredients in Your Cosmetics: What Do They Do?

*April 2023*

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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.

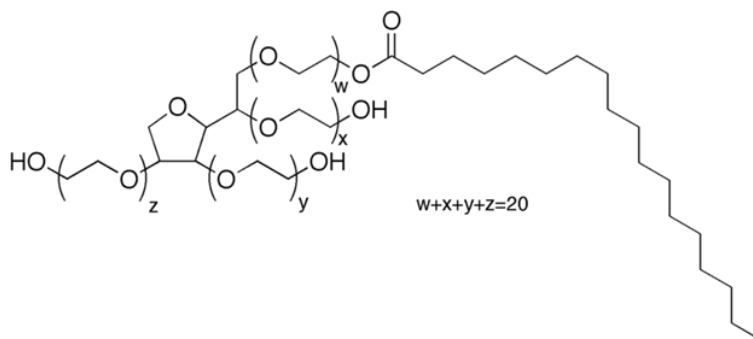
Me	Text	Statement
		1. The names of chemicals in cosmetics are standardized.
		2. Ingredients in cosmetics are listed in order of decreasing concentration.
		3. Usually the solvent in a cosmetic is listed last.
		4. The most common solvent in cosmetics is alcohol.
		5. Emulsifiers are used to make cosmetics homogeneous.
		6. Preservatives are rarely used in cosmetics.
		7. Cosmetics must list an expiration date.
		8. The FDA requires that cosmetics labels include directions and warnings.
		9. Nitrocellulose, a chemical widely used in nail polish, is highly flammable.
		10. The cosmetics industry employs many chemists.

# Student Reading Comprehension Questions

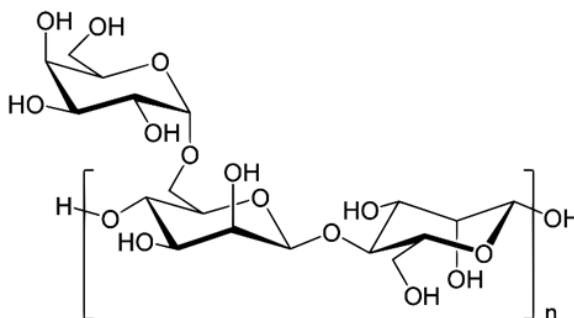
Name: \_\_\_\_\_

**Directions:** Use the article to answer the questions below.

1. On a cosmetic label, how can you determine which ingredient makes up most of the product?
2. What is the role of a solvent in cosmetics? Compare this to the definition of solvent in chemistry.
3. Emulsifiers are molecules that can interact with two different types of molecules that can't interact with each other. A single emulsifier molecule contains regions of bonded atoms that are different from each other. The different regions can interact with different kinds of substances. The molecule pictured below shows a typical structure for polysorbates, which are common emulsifiers in cosmetics. Circle the part of this molecule that would be able to interact with water and explain why the other part would not interact with water.



4. In the emulsifier image in the article, water is shown in light blue and oil is shown in yellow. Notice the shape that is drawn to represent the emulsifier molecules that surround the droplets. Use the above picture to explain why the shape is a good model for emulsifiers.
5. For an emulsion of water in oil, describe the intermolecular forces and explain the process involved in enabling the water to be dispersed throughout the oil without separating.
6. Guar gum (molecular structure pictured below) is a common thickening agent, particularly in water based cosmetics. Draw a few water molecules surrounding the image and refer to your drawing to explain why guar gum increases the viscosity (reduces the flow) of a water-based formulation.



7. List two minerals that are used to give color to cosmetics, and identify the color for each.
8. What is the difference between a wax and an oil? Why are both used in creating lipstick?
9. All cosmetics contain mixtures of different substances, called formulations. Compare and contrast the following types of mixtures: solution, colloid, emulsion
10. Some people add a small amount of nail polish remover to a bottle of nail polish when the polish has gotten too thick. Explain why the nail polish remover doesn't ruin the nail polish.
11. Identify four different things that people with a degree in chemistry can do when working in the cosmetics industry.

# Student Reading Comprehension Questions, cont.

## Questions for Further Learning

*Write your answers on another piece of paper if needed.*

12. Three types of ingredients used in skin lotions are humectants, emollients, and occlusives. Each has different benefits. Research these ingredients and make a claim for which you would want in your own lotion.

# Graphic Organizer

Name: \_\_\_\_\_

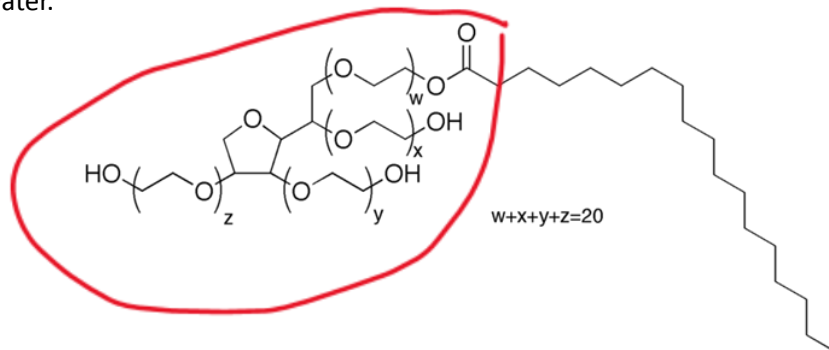
**Directions:** As you read, complete the graphic organizer below to describe the chemistry of cosmetics.

Ingredient	Purpose	Chemicals used
Solvent		
Emulsifiers		
Preservatives		
Thickeners		
Skin Conditioners		
Colorants		
Fragrances		

**Summary:** On the back of this sheet, write three interesting facts about cosmetics you learned from the article to share with a friend.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

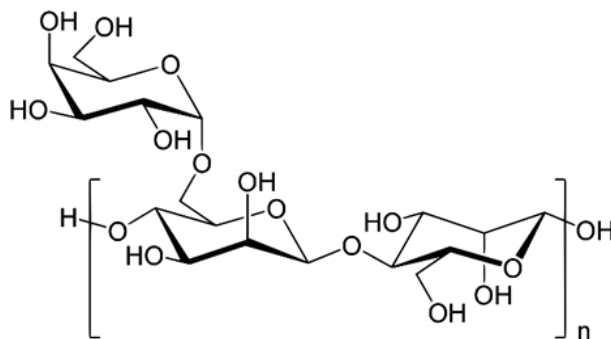
1. On a cosmetic label, how can you determine which ingredient makes up most of the product?  
The ingredients are listed in order of decreasing % weight, so the first ingredient has the highest percentage.
2. What is the role of a solvent in cosmetics? Compare this to the definition of solvent in chemistry.  
A solvent in cosmetics is the ingredient that dissolves the other ingredients, allowing them to mix together and flow. This is the same as the definition in chemistry.
3. Emulsifiers are molecules that can interact with two different types of molecules that can't interact with each other. A single emulsifier molecule contains regions of bonded atoms that are different from each other. The different regions can interact with different kinds of substances. The molecule pictured below shows a typical structure for polysorbates, which are common emulsifiers in cosmetics. Circle the part of this molecule that would be able to interact with water and explain why the other part would not interact with water.



The other part of this molecule will not mix together with water because it is nonpolar. The nonpolar portion of the molecule will interact with other nonpolar regions or molecules. Water is highly polar and will be attracted to areas of a molecule where it can participate in hydrogen bonding or dipole-dipole interactions, as are prevalent in the circled portion.

4. In the emulsifier image in the article, water is shown in light blue and oil is shown in yellow. Notice the shape that is drawn to represent the emulsifier molecules that surround the droplets. Use the above picture to explain why the shape is a good model for emulsifiers.  
There is an area of the molecule containing many oxygen atoms and -OH groups that can interact with water molecules. This area is grouped together and is represented by an oval in the image. The other portion of the molecule is a long nonpolar carbon chain. The squiggly "tail" attached to the oval in the image represents the carbon chain. These are commonly referred to as the "polar head" and "nonpolar tail" of the molecule.
5. For an emulsion of water in oil, describe the intermolecular forces and explain the process involved in enabling the water to be dispersed throughout the oil without separating.  
The polar heads of the emulsifier molecules will surround small water droplets, stopping the droplets from coalescing together. Since the polar heads are attached to a nonpolar tail, the nonpolar tails stick outward and can attract to the nonpolar oil molecules. This arrangement allows many water droplets to be spread throughout the oil, as they are protected from joining by the emulsifier molecules.

6. Guar gum (molecular structure pictured below) is a common thickening agent, particularly in water based cosmetics. Draw a few water molecules surrounding the image and refer to your drawing to explain why guar gum increases the viscosity (reduces the flow) of a water-based formulation.



(Water molecules should be drawn showing hydrogen bonding or dipole-dipole interactions in appropriate locations.) There are many areas throughout the guar gum molecule where hydrogen bonding can take place with water. Water's small molecules can slip past each other easily when in liquid form, but when many molecules are stuck to a larger guar gum molecule, they are not able to move past each other as easily, thus the viscosity is increased.

7. List two minerals that are used to give color to cosmetics, and identify the color for each.  
Any of: iron(III) oxide (red, orange, yellow, or black); chromium(III) oxide (green); titanium(IV) oxide (white)
8. What is the difference between a wax and an oil? Why are both used in creating lipstick?  
Waxes have stronger intermolecular forces and are solid at room temperature. Oils are liquid at room temperature. The wax provides the structure so lipstick stays on the lips. The oil allows it to spread onto the lips easier and gives it a shine.
9. All cosmetics contain mixtures of different substances, called formulations. Compare and contrast the following types of mixtures: solution, colloid, emulsion  
Solutions are mixtures at the molecular level. A solute is separated into its smallest particles, each surrounded by solvent molecules. A colloid contains larger particles, which can be large molecules or aggregates of small particles, surrounded by solvent molecules. Emulsions are mixtures of two immiscible liquids, but stabilized by a third substance such that droplets of one liquid are dispersed throughout the other.
10. Some people add a small amount of nail polish remover to a bottle of nail polish when the polish has gotten too thick. Explain why the nail polish remover doesn't ruin the nail polish.  
The solvent in nail polish is similar to the nail polish remover. The solvent allows the other parts of the nail polish to flow so they can be painted onto a nail. This solvent evaporates, leaving behind a film of the other ingredients. Therefore, the nail polish remover won't ruin nail polish, but if you use too much of it, the polish will be too runny to stay on the nail.
11. Identify four different things that people with a degree in chemistry can do when working in the cosmetics industry.  
Work with colors, work with skincare, work with fragrance, work with safety and compliance, work in marketing.

## 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 demos

- AACT Lab: What Type of Mixture is Paint?  
<https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>

### ❖ Simulations

- AACT Simulation Intermolecular Forces  
<https://teachchemistry.org/classroom-resources/intermolecular-forces-2020>
- AACT Simulation Comparing Attractive Forces  
<https://teachchemistry.org/classroom-resources/comparing-attractive-forces-simulation>

### ❖ Lessons and lesson plans

- AACT Lesson: The Evolution of Materials Science in Everyday Products  
<https://teachchemistry.org/classroom-resources/the-evolution-of-materials-science-in-everyday-products>

### ❖ Projects and extension activities

- ACS Science of Personal Care Products  
<https://www.acs.org/education/students/highschool/chemistryclubs/activities/personal-care-products.html>

## Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students what cosmetic products they use and what purpose they serve. Students may not realize that cosmetic products include hair products, moisturizers, deodorants, and fragrances in addition to makeup. Ask students if they read the labels on their cosmetic products and why. Ask them what information can be found on the labels. 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 cosmetics.
- After students have read and discussed the article, ask students what information they would like to share with friends and family about cosmetic products, and whether they will choose cosmetics differently based on the information in the article.
- This article could be used early in the year when talking about basic matter. It can jumpstart a lesson on the differences between various types of mixtures.
- This article could be used during a unit on intermolecular forces and could use more molecular structures to analyze the various interactions.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Chemical change
- Mixtures
- Solutions
- Solute/solvent

## 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](#).

## Teacher's Guide

### Chemistry and the Sandy Seashore

*April 2023*

#### Table of Contents

<a href="#"><u><i>Anticipation Guide</i></u></a>	<b>36</b>
Activate students' prior knowledge and engage them before they read the article.	
<a href="#"><u><i>Reading Comprehension Questions</i></u></a>	<b>37</b>
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.	
<a href="#"><u><i>Graphic Organizer</i></u></a>	<b>39</b>
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.	
<a href="#"><u><i>Answers</i></u></a>	<b>40</b>
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<a href="#"><u><i>Additional Resources</i></u></a>	<b>43</b>
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<a href="#"><u><i>Chemistry Concepts and Standards</i></u></a>	<b>44</b>

# 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. Sea breezes are a result of land heating up faster than water during the day.
		2. Many compounds containing sulfur have an unpleasant smell.
		3. In the hydrological cycle, water evaporates from plants as well as bodies of water.
		4. The only salt in seawater is sodium chloride.
		5. Fish maintain their bodies at a higher level of salt content than the water in which they live.
		6. White sand is formed from limestone and fragments of coral and mollusk shells.
		7. The salts in ocean water help hold sandcastles together.
		8. The Turing principle explains both patterns in ripples of sand and patterns in colors of seashells.
		9. The ocean is becoming more acidic, weakening the ability of mollusks to build their shells.
		10. Increased sea surface temperatures help corals grow.

# Student Reading Comprehension Questions

Name: \_\_\_\_\_

**Directions:** Use the article to answer the questions below.

1. A gentle sea breeze is something that brings joy and nostalgia to beach lovers each summer. What science phenomena is responsible for the breeze we enjoy?
2. The smell of the ocean is very distinct. What chemicals contribute to the cabbage-like smell of the ocean?
3. Briefly explain the natural water cycle, also known as the hydrological cycle.
4. How do fish adapt to changing levels of salinity as they migrate through the oceans? What is the average amount of salt in one liter of ocean water?
5. What are the primary components of tropical and continental seaboard sand?
6. If you have ever walked on the beach on a windy day, you might have noticed ripples forming in the sand. What causes these ripples and what factors influence the size and spacing of the ripples.
7. What are morphogens and how do they influence colors and patterns on seashells and animal skins?
8. Many sea creatures live in shells made out of primarily calcium carbonate. Natural ocean acidification is caused by carbon dioxide in the atmosphere reacting with water to produce carbonic acid ( $\text{H}_2\text{CO}_3$ ). In what ways have humans accelerated ocean acidification and what are the consequences of lowering the pH level of the ocean?
9. Ocean temperatures have gradually increased over the past few decades. This has negatively impacted many marine species and habitats, particularly coral reefs. How have humans contributed to increasing ocean temperatures and what are the consequences of declining coral reef habitats?
10. Consider the following scenario:

*You walk out of the forest and onto a long stretch of white sand.... the sand is very soft powder... imagine taking off your shoes, and walking through the hot, white sand toward the water....as you approach the water the sand cools and your feet start to feel better (less hot).*

Explain the scenario based on the principles of specific heat capacity and thermochemistry.

# Student Reading Comprehension Questions, cont.

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## Questions for Further Learning

*Write your answers on another piece of paper if needed.*

11. Create a “Chemistry of the Seashore” infographic using information from the article. Be sure to discuss the chemistry behind the sea breeze and smells on the beach. Ocean acidification, increased ocean temperatures, and the composition of seashells and salt water.

# Graphic Organizer

Name: \_\_\_\_\_

**Directions:** As you read, complete the graphic organizer below to describe how chemistry can explain phenomena we experience at the seashore.

Phenomenon	Chemical explanation
Sea Breeze	
Ocean smell	
Salinity	
Osmosis	
Diffusion	
Sand color	
Patterns of color in seashells	
Seashell formation	
Coral Reefs	

**Summary:** On the back of this sheet, write three new things you learned about chemistry at the seashore.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. A gentle sea breeze is something that brings joy and nostalgia to beach lovers each summer. What science phenomena is responsible for the breeze we enjoy?

The sun heats the land faster than the sea due to the high heat capacity of the ocean water. As the temperature of the air above the land increases, it rises due to expansions (lower density). The cooler air above the ocean rushes in as wind takes the place of the rising warm air creating a wonderful cool breeze.

2. The smell of the ocean is very distinct. What chemicals contribute to the cabbage-like smell of the ocean?

The smell is due to the presence of dimethyl sulfide which comes from phytoplankton and algae.

3. Briefly explain the natural water cycle, also known as the hydrological cycle.

Energy from the sun causes water to evaporate from oceans, lakes, plants, etc. The water vapor rises into the atmosphere where it cools and condenses into clouds. The vapor eventually returns to the land as precipitation (rain or snow). The liquid water flows across land in the form of run-off, rivers, streams, etc, into bodies of water collecting minerals and salts along the way.

4. How do fish adapt to changing levels of salinity as they migrate through the oceans? What is the average amount of salt in one liter of ocean water?

Fish have kidneys that remove excess salt. Fish can also remove excess salt through their gills and skin. The average liter of ocean water contains 35 grams of dissolved salt.

5. What are the primary components of tropical and continental seaboard sand?

Tropical sand is typically composed of  $\text{CaCO}_3$  while continental seaboard sand is composed of  $\text{SiO}_2$

6. If you have ever walked on the beach on a windy day, you might have noticed ripples forming in the sand. What causes these ripples and what factors influence the size and spacing of the ripples.

The ripples are caused by wind. The amount of wind and amount of sand displacement determine the size and spaces of the ripples.

7. What are morphogens and how do they influence colors and patterns on seashells and animal skins?

Morphogens are compounds that impact the color of melanin. There are two types of morphogens, an inhibitor and an activator. The diffusion rate, concentration, and type of interactions between the inhibitor and activator morphogens are responsible for the wide variety of patterns we see on shells and animal hides.

8. Many sea creatures live in shells made out of primarily calcium carbonate. Natural ocean acidification is caused by carbon dioxide in the atmosphere reacting with water to produce carbonic acid ( $\text{H}_2\text{CO}_3$ ). In what ways have humans accelerated ocean acidification and what are the consequences of lowering the pH level of the ocean?



Acids dissolve calcium carbonate which would limit marine life's ability to build shells and skeletons. The burning of fossil fuels by humans has increased the amount of CO<sub>2</sub> in the atmosphere and thus the amount dissolved in the oceans. Ocean acidification could result in the loss of many marine species who are unable to adapt to changing pH and salt concentrations.

9. Ocean temperatures have gradually increased over the past few decades. This has negatively impacted many marine species and habitats, particularly coral reefs. How have humans contributed to increasing ocean temperatures and what are the consequences of declining coral reef habitats?

The burning of fossil fuels, cement production, and deforestation have increased the amount of greenhouse gasses in the atmosphere which are contributing factors of global warming, including warming of the oceans. Coral reefs are home to many marine species and losing coral reefs would disrupt many ocean food chains which is extremely problematic.

10. Consider the following scenario:

*You walk out of the forest and onto a long stretch of white sand.... the sand is very soft powder... imagine taking off your shoes, and walking through the hot, white sand toward the water....as you approach the water the sand cools and your feet start to feel better (less hot).*

Explain the scenario based on the principles of specific heat capacity and thermochemistry.

The sand when you first step onto the beach has very low water content due to the distance to the ocean. The heat capacity of silicon dioxide and other components of sand is significantly less than water and therefore heats up quickly in the sun. As you move closer to the ocean, the water content of the sand increases. Water has a high heat capacity and takes more energy to increase in temperature. This causes the sand near the ocean to be significantly cooler than the sand near the dunes.

11. Create a "Chemistry of the Seashore" infographic using information from the article. Be sure to discuss the chemistry behind the sea breeze and smells on the beach. Ocean acidification, increased ocean temperatures, and the composition of seashells and salt water.

Answers will vary.

# 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

### ❖ Articles and lesson plans

- Ocean Acidification Activity  
<https://teachchemistry.org/classroom-resources/how-do-pollutants-affect-our-oceans>
- Radioactive Decay and Seafloor Activity  
<https://teachchemistry.org/classroom-resources/radioactive-decay-and-seafloor-data>
- Ocean Plastic Article  
<https://teachchemistry.org/chemmatters/october-2020/the-search-for-hidden-plastics>
- Carbon Dioxide and Our Ocean Article  
<https://teachchemistry.org/chemmatters/february-2018/acidic-seas-how-carbon-dioxide-is-changing-the-oceans>
- Oil Spill Activity  
<https://teachchemistry.org/classroom-resources/how-do-we-clean-up-an-oil-spill>

## 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 been to the seashore, and what natural phenomena they might see there. Ask students how chemistry might explain some of their observations. 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 what we see and feel at the seashore.

# Chemistry Concepts and Standards

## Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Chemical properties
- Acids
- Gas laws
- Kinetic molecular theory
- Mixtures

## 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-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

### Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- PS.2.B: Types of Interactions
- ESS3.D: Global Climate Change

### Crosscutting Concepts:

- Patterns
- Cause and effect
- Systems and system models
- 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.

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