

ChemMatters®

Demystifying Everyday Chemistry

Teacher's Guide

February 2024

<u>February Teacher's Guide Introduction</u>	2
<u>3D-Printed Foods</u>	4
<u>Caffeine: The Good, the Bad, and the Why</u>	17
<u>Cooking Chemistry: What's in the Pot?</u>	27
<u>Mad Scientists and Misinformation</u>	37



February Teacher's Guide Introduction

Lesson Ideas

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

Teaching Ideas for this issue:

1. "Chemistry in Pictures" on page 2 shows a photograph of 3-D hydrogel printing of an octopus. Before viewing the photo, ask students if they have used a 3-D printer, and what they created. Challenge them to think of future uses for 3-D printing. The photo relates to the article on pages 5-7 of this issue, "3-D Printed Food."
2. "Open for Discussion" on page 4 provides students with tools to learn how to spot misinformation, while acknowledging how easy it is to be misled. Suggest that students apply the SIFT method described in the article for evaluating information to one of the articles in this issue, or to a science article in popular media.
3. "Quick Read: Can Lightning Be Stolen?" on page 15 describes how lightning is formed, and discusses the possibility of tapping into the tremendous energy of lightning.
4. The "Chemistry in Person" column on page 19 showcases Trevor Cornish, an environmental engineer specializing in helping companies comply with environmental health and safety regulations. Encourage students to read the interview to learn about the path he took to find his career, and why his work is important. Ask them if they might enjoy this type of career, and why.
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.
 - o Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
 - o 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.

ChemMatters®

Demystifying Everyday Chemistry

Teacher's Guide

3D-Printed Foods

February 2024

Table of Contents

<u>Anticipation Guide</u>	5
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	6
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>	9
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>	10
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	14
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	16

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 Defense Department is working on 3-D meals matched to a person’s physiological and nutritional needs.
		2. 3-D printers have been used since the 1960s.
		3. Chocolate is not a good material for 3D printing.
		4. The lab that developed 3D printed food was working on creating batteries.
		5. Water has a high viscosity.
		6. Foods with high water content may need a thickening agent to be 3D printed.
		7. Scientists do not know how 3D printing will affect the nutritional value of foods.
		8. A company is currently working on 3D printed meat that has the structure, texture, and taste of beef.
		9. Foods are often cooked with lasers today.
		10. In the future, 3D printed foods may help improve nutrition in low-income areas.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. The printers you've most often encountered, that print words and images from a computer file onto paper, are two dimensional. Why is "3D-printing" considered to be three dimensional?
2. Filaments used in a 3D printer are analogous to the ink or toner used in a 2D printer. What type of material are filaments typically composed of?
3. Hod Lipson's research group began working with foods because they were cheaper and easier to work with than the variety of plastics and other materials they were using. What was the group doing with the foods, and what use did this bring to their work in printing machine components?
4. Out of curiosity, Lipson began experimenting with foods as he would with other non-food materials. He said that the properties of peanut butter are much more complicated than those of aluminum because peanut butter's properties are not linear. If they were linear, then how would you expect the flow of peanut butter to change with temperature? Explain.
5. Imagine you are asked to write your full name on the table with two different materials. You are given two syringes, one filled with ketchup, and one filled with peanut butter. Explain how this process would be different for the two materials in each of the following ways:
 - a. How fast you can write your name.
 - b. How thick the writing is in the letters of your name.
 - c. How hard you must push the syringe to extrude each material to write your name.
 - d. What happens at the points where you must cross over the material to finish your letter (making a 2nd layer at just that point).
6. Extrusion is the process of forcing a material through a small hole to come out the other side.
 - a. Now, imagine that you wanted the ketchup to extrude in a more similar way to peanut butter. Identify a kitchen ingredient that you could mix with the ketchup to adjust this property. Explain how your answer would change the property of the ketchup.
 - b. Next, imagine that you wanted the peanut butter to extrude in a more similar way to ketchup. Identify a kitchen ingredient that you could mix with the peanut butter to adjust this property. Explain how your answer would change the property of the peanut butter.
7. Since the material properties of different foods are widely different, researchers working with 3D printing food have minimal prior information from which to predict their behavior in a 3D printing environment. Scan the QR code in the article to watch the video from Columbia Engineering. Identify two different ways the engineers had to change their cheesecake design to accommodate differences in the material properties of the various ingredients.
8. Viscosity is an important consideration when choosing materials to use in 3D printing.

- a. What is viscosity?
 - b. Why is it significant in extrusion 3D printing?
 - c. Which is more viscous, ketchup or peanut butter? Explain.

9. Lauren Oleksyk's group, in the Food Engineering and Analysis Lab, conducts research to improve the quality and taste of compact, portable foods for soldiers. Oleksyk and her colleagues are currently 3D printing nutrient bars with the hopes that they will someday be able to tailor the nutrients to individual needs. They have found that using pastes ground from certain foods can help to hold together other foods that can't be formulated as pastes. Imagine grinding up an orange. Explain a barrier to using oranges to make a paste that can hold its shape.

10. Many older adults, and other people who suffer from brain disorders, suffer from dysphagia.
 - a. What is dysphagia?
 - b. How could 3D printing food help a person with dysphagia?

11. There are many potential areas mentioned in the article that could benefit from the further development of 3D Food Printing. Which of these areas do you think has the potential to develop the fastest? Explain.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

12. Food scientists, chefs, and other food enthusiasts experiment with how varying things like the texture and temperature of foods can vary the mouthfeel and the taste experience of the consumer. How can 3D food printing add to this burgeoning field?
13. Astronauts are another group of people who could potentially benefit from 3D printing foods. Explain some challenges of life in space that could affect the way foods are 3D printed?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to summarize information from the article.

	Provide an explanation or description and examples for each topic
3-D printing	
3-D printed food	
Viscosity	
Challenges in printing 3-D food	
Future uses for 3-D printed food	

Summary: On the back of this sheet, write a short text message to a friend stating what you learned about 3D printed food, and whether you would try it.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. The printers you've most often encountered, that print words and images from a computer file onto paper, are two dimensional. Why is "3D-printing" considered to be three dimensional?
3D printing prints 2D layers on top of each other, creating a three dimensional object.
2. Filaments used in a 3D printer are analogous to the ink or toner used in a 2D printer. What type of material are filaments typically composed of?
Plastics (or polymers)
3. Hod Lipson's research group began working with foods because they were cheaper and easier to work with than the variety of plastics and other materials they were using. What was the group doing with the foods, and what use did this bring to their work in printing machine components?
They were calibrating the 3D printers using foods that have properties similar to the other materials they would be working with. Calibrating the printers means that they had to figure out things like how fast to print, how much force to use for extrusion, what temperature changes would do to the material while printing or once printed on the print bed or on a previously printed layer. Since each food has very different properties, they needed to adjust the hardware for each difference. This allowed them to cheaply study these needs for the more expensive materials they'd use to make machine components.
4. Out of curiosity, Lipson began experimenting with foods as he would with other non-food materials. He said that the properties of peanut butter are much more complicated than those of aluminum because peanut butter's properties are not linear. If they were linear, then how would you expect the flow of peanut butter to change with temperature? Explain.
A linear relationship means there is a proportional change in both variables. Thus, we would expect the flow of the peanut butter to change gradually and consistently as the temperature is changed. This, however, is not what Lipson found to be the case.
5. Imagine you are asked to write your full name on the table with two different materials. You are given two syringes, one filled with ketchup, and one filled with peanut butter. Explain how this process would be different for the two materials in each of the following ways:
 - a. How fast you can write your name.
Ketchup would be faster because it can come out of the syringe faster since it is less viscous (a student would likely say it is "thinner" or "less sticky" or "more watery").
 - b. How thick the writing is in the letters of your name.
The peanut butter would come out of the syringe more thickly. It would also hold its shape, leaving a thicker layer. The ketchup would come out runnier, making it likely to spread, making a thicker (wider) mark on the table, but a thinner (less high) layer on the table.
 - c. How hard you must push the syringe to extrude each material to write your name.
The peanut butter would take more force than the ketchup.
 - d. What happens at the points where you must cross over the material to finish your letter (making a 2nd layer at just that point).

The peanut butter might stick to the previous layer and pull it out of place. It also would likely make the layer uneven as there would be bumps any time the lines cross over each other. The ketchup would probably not be affected by the previous layer but would spread on the table more because there would be more material to spread.

6. Extrusion is the process of forcing a material through a small hole to come out the other side.
 - a. Now, imagine that you wanted the ketchup to extrude in a more similar way to peanut butter. Identify a kitchen ingredient that you could mix with the ketchup to adjust this property. Explain how your answer would change the property of the ketchup.
Something to thicken it up. Students will likely think of things like flour or gelatin.
 - b. Next, imagine that you wanted the peanut butter to extrude in a more similar way to ketchup. Identify a kitchen ingredient that you could mix with the peanut butter to adjust this property. Explain how your answer would change the property of the peanut butter.
Something to allow it to flow more. Oil is appropriate.

7. Since the material properties of different foods are widely different, researchers working with 3D printing food have minimal prior information from which to predict their behavior in a 3D printing environment. Scan the QR code in the article to watch the video from Columbia Engineering. Identify two different ways the engineers had to change their cheesecake design to accommodate differences in the material properties of the various ingredients.
There were several things in the video, such as having to make a “bowl” to keep the jelly in the pie, and changing the layering so the sides could hold up to the weight of the ingredients in the middle.

8. Viscosity is an important consideration when choosing materials to use in 3D printing.
 - a. What is viscosity?
The resistance to flow.
 - b. Why is it significant in extrusion 3D printing?
More viscous materials would extrude more slowly and would require more force than less viscous materials.
 - c. Which is more viscous, ketchup or peanut butter? Explain.
Peanut butter. It is harder to spread or squeeze peanut butter than to squeeze or spread ketchup.

9. Lauren Oleksyk’s group, in the Food Engineering and Analysis Lab, conducts research to improve the quality and taste of compact, portable foods for soldiers. Oleksyk and her colleagues are currently 3D printing nutrient bars with the hopes that they will someday be able to tailor the nutrients to individual needs. They have found that using pastes ground from certain foods can help to hold together other foods that can’t be formulated as pastes. Imagine grinding up an orange. Explain a barrier to using oranges to make a paste that can hold its shape.
Oranges have a very high water content that would lead to a very low viscosity when ground up, because it would basically be orange juice. Since the nutrients are dissolved in the orange’s juice, you wouldn’t want to just squeeze out the water to make the paste. To make a paste, an orange could possibly be dehydrated before grinding it or it could be added to other substances that can absorb the excess liquid.

10. Many older adults, and other people who suffer from brain disorders, suffer from dysphagia.
- What is dysphagia?
Dysphagia means a person has difficulty swallowing, often due to a brain disorder.
 - How could 3D printing food help a person with dysphagia?
People with dysphagia must grind all their food up to be able to swallow it. This is something like only ever eating baby food. 3D food printing researchers are developing ways to give 3D printed foods textures that mimic those of real foods. If, for example, a piece of food is ground up, then printed back into a food-like shape, it can still maintain its softness, so swallowing will be easier, but it also gives the person the satisfaction of returning to a normal style of eating where they can use a fork and knife.
11. There are many potential areas mentioned in the article that could benefit from the further development of 3D Food Printing. Which of these areas do you think has the potential to develop the fastest? Explain.
Answers will vary. This question aims to get the students to think about what they are reading in a little more depth.
12. Food scientists, chefs, and other food enthusiasts experiment with how varying things like the texture and temperature of foods can vary the mouthfeel and the taste experience of the consumer. How can 3D food printing add to this burgeoning field?
3D food printing can be used to layer different flavors and textures of food ingredients. The cheesecake is an example of how layers of flavor would hit the palate as the cheesecake is consumed. Flavors of different foods will also be incorporated into different kinds of textures to accommodate the need for different viscosities. 3D food printing is another tool that the chef will have eventually to innovate with the organoleptic properties, flavors and mouthfeel of traditional and new foods.
13. Astronauts are another group of people who could potentially benefit from 3D printing foods. Explain some challenges of life in space that could affect the way foods are 3D printed?.
The lack of gravity would present some challenges for 3D printing in space. Right now, 3D printing is carried out such that the material is squeezed through a nozzle, and it sticks to the printing plate usually through both adhesive forces and gravity. The lack of gravity in space would mean adhesive forces would need to be greater to overcome the lack of gravity.

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

- Experiments with sodium alginate and calcium ions, such as:
 - ACS: Goo Worms <https://www.acs.org/education/outreach/activities/goo-worms.html>
 - ACS: Earth-Friendly Plastics <https://www.acs.org/education/outreach/celebrating-chemistry-editions/2020-ccew/earth-friendly-plastics.html>
- Experiments about the properties of materials, such as:
 - AACT: Give your Car Some Bounce <https://teachchemistry.org/classroom-resources/give-your-car-some-bounce>
 - AACT: Making Slime <https://teachchemistry.org/classroom-resources/making-slime>
 - AACT: Turn Milk Into Plastic <https://teachchemistry.org/classroom-resources/turn-milk-into-plastic>

❖ Lessons and lesson plans

- Investigate plastics in 3D printing
 - AACT: The Power of Polymers <https://teachchemistry.org/classroom-resources/the-power-of-polymers>

❖ Projects and extension activities

- Study the history of synthetic materials to learn how scientists of the past have developed materials that have desired properties. A similar path will be needed for 3D food printing to succeed.
 - AACT: Synthetic Materials Through History <https://teachchemistry.org/classroom-resources/synthetic-materials-through-history>
 - AACT: The Evolution of Materials Science in Everyday Products <https://teachchemistry.org/classroom-resources/the-evolution-of-materials-science-in-everyday-products>
- Read about 3D Printers
 - ChemMatters: <https://teachchemistry.org/chemmatters/february-2015/3d-printers-the-next-print-revolution>

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 used a 3-D printer, and how they used them. Ask if they have ever heard of 3-D printed food. Show the short video referenced in the article. It can also be found here: <https://youtu.be/ECCLUle3Lus?si=nMDzAVLxPev9-CJT>. 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 to engineers who are developing 3-D printed food.
- **Possible misconceptions:** Students may confuse viscosity with density, but there is no direct correlation. Water has a lower viscosity and higher density than oil.
- After reading the article and answering the questions, use an article like the one below to initiate a mini-research project where students take a side and decide whether 3D Food Printing is a phase that will fade or is something that will evolve and improve certain fields. This could be framed as though the students are the “Sharks” in “Shark Tank” (an ABC Reality television show, <https://abc.com/shows/shark-tank>) and must decide whether to invest in an independent 3D Food Printing company.
 - <https://www.foodunfolded.com/article/3d-printed-food-gimmick-or-game-changer>
- This article would be a great way to build interest in a unit on bonding types and material properties. Some potential related activities:
 - Have students try writing their names in ketchup and peanut butter, as suggested in the Comprehension Questions. This could be done with syringes or with simple condiment squeeze bottles. Just make sure to use the same kind of vessel for both foods.
 - Set out a variety of foods and ask students to classify the phase of matter for each. This will lead to the question of how to classify things like peanut butter, Jello, ketchup, or marshmallows. There are many ways to proceed from here.
 - Limit students to using solid, liquid, or gas to classify the various foods, and ask them for reasoning. This should lead to interesting conversations between students who classify them differently. This activity could end here, with the conclusion that not all things can be classified so simply. Or the lesson could continue, as below:
 - Discuss mixtures and learn classifications like colloids, gels, etc.
 - AACT: What Type of Mixture is Paint? <https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>
 - AACT: Elements, Compounds and Mixtures – Oh My! <https://teachchemistry.org/classroom-resources/elements-compounds-mixtures-oh-my>

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical change
- Intramolecular forces
- Intermolecular forces

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
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

- Scale, proportion, and quantity
- Structure and function

Science and Engineering Practices:

- Constructing explanations (for science) and developing 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

Caffeine: The Good, the Bad, and the Why

February 2024

Table of Contents

<u>Anticipation Guide</u>	18
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	19
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>	21
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>	22
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	25
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	26

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. Caffeine affects neurons in the brain.
		2. Caffeine comes from a variety of plants.
		3. Caffeine, capsaicin, cocaine, and strychnine are all alkaloids, which contain nitrogen.
		4. Caffeine attaches to the same protein receptors as adenosine, a chemical that makes you feel tired.
		5. It takes the average person one hour to break down half of the caffeine they consume.
		6. It is impossible to become dependent on caffeine.
		7. Caffeine does not interact with other drugs.
		8. The American Academy of Pediatrics recommends that children under 12 should not consume caffeine in any form.
		9. An 8-oz. cup of black tea has more caffeine than a 16-oz. fountain Coca-Cola drink.
		10. People have been consuming caffeine in one form or another for thousands of years.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What two chemicals in our body control how we feel?
2. What is the special characteristic that makes a molecule a member of the alkaloid group?
3. What characteristic makes a molecule a purine?
4. Where is the caffeine molecule typically found?
5. Define tolerance, and what happens to the body for it to achieve tolerance.
6. Look at the molecular structures on p. 8 of the article. Using those pictures, and your knowledge of Lewis structures, how many bonding sites does an atom of nitrogen have?
7. What is special about the caffeine molecule that allows it to replace adenosine on certain proteins?
8. Caffeine is used to make people feel “alert” and less sleepy. Specifically, what does the molecule do to the body’s chemistry to do this?
9. How does dopamine affect the human body? Can you think of other examples (either from previous knowledge, or some basic research) that affects dopamine in our bodies?
10. What happens when a person stops taking caffeine (both chemically and physically)? What is this term called?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Perform online research on the differences between caffeinated and decaffeinated coffee. Explain the differences in production, and if there are any differences in taste, looks, etc.
12. Research and list some of the common effects caffeine has on the body. Explain any effects that could be potentially hazardous to a person.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the chemicals mentioned in the article.

	What it is	What it does
Alkaloid		
Caffeine		
Adenosine		
Dopamine		

Write three new things you learned about the safety of consuming caffeine:

1	
2	
3	

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What two chemicals in our body control how we feel?
The two chemicals in our body that control how we feel are adenosine and dopamine.
2. What is the special characteristic that makes a molecule a member of the alkaloid group?
A molecule is considered to be a member of the alkaloid group if it has a nitrogen atom in its structure.
3. What characteristic makes a molecule a purine?
Purines are molecules with “fused rings”, one ring containing 6 atoms and the other 5 atoms. Nitrogen is a part of these fused rings.
4. Where is the caffeine molecule typically found?
The caffeine molecule is naturally occurring. It is commonly found in many different plants.
5. Define tolerance, and what happens to the body for it to achieve tolerance.
When your body gets used to a chemical, it undergoes tolerance, which means a person would need more of the chemical to achieve the same feelings.
6. Look at the molecular structures on p. 8 of the article. Using those pictures, and your knowledge of Lewis structures, how many bonding sites does an atom of nitrogen have?
According to the diagrams, the nitrogen atom can have 3 “bonding sites”, which means it can bond up to three times (either three single bonds, or 1 double bond and one single bond). In general nitrogen tends to have a lone pair of electrons and three bonds to complete its octet. The lone pair can also be involved as a Lewis base.
7. What is special about the caffeine molecule that allows it to replace adenosine on certain proteins?
The caffeine molecule and adenosine molecule are very similar in shape and structure. Because of this, the caffeine molecule will attach to the same protein receptors, which causes you to remain alert.
8. Caffeine is used to make people feel “alert” and less sleepy. Specifically, what does the molecule do to the body’s chemistry to do this?
The way caffeine makes people feel alert is by causing the blood vessels to constrict, and also increases activity in the nervous system. This causes the body to produce adrenaline which makes one feel more alert.
9. How does dopamine affect the human body? Can you think of other examples (either from previous knowledge, or some basic research) that affects dopamine in our bodies?
Dopamine is a chemical in the brain that encourages a person to seek desirable experiences. This provides a mental “reward system” that makes the body feel good. Other drugs can give the same feeling, as well as activities that a person enjoys, or seeing familiar people. (Which are healthier options).
10. What happens when a person stops taking caffeine (both chemically and physically)? What is this term called?
When too much caffeine is consumed, the body produces more adenosine and its receptors to compensate. With less/no caffeine, the body has too much adenosine, so it feels much less alert, for a longer period of time. This is typical with most other drugs that can be addictive.

11. Perform online research on the differences between caffeinated and decaffeinated coffee. Explain the differences in production, and if there are any differences in taste, looks, etc.
Decaffeinated coffee or other drinks are not 100% caffeine free (it's approximately 97% free). The beans are chemically "washed" to eliminate the caffeine. The taste and color could be different, but the nutritional value should still be the same. (<https://www.healthline.com/nutrition/decaf-coffee-good-or-bad#How-much-caffeine-is-in-decaf-coffee>)
12. Research and list some of the common effects caffeine has on the body. Explain any effects that could be potentially hazardous to a person.
Caffeine can cause insomnia, nervousness, restlessness, nausea, increased heart rate, and other side effects. It could take 4-6 hours for the caffeine to break down to normal levels in the body. Larger doses of caffeine can cause headaches, anxiety, and chest pain in some people. In very high doses, caffeine can cause irregular heartbeat and even death from complications.
(<https://www.webmd.com/vitamins/ai/ingredientmono-979/caffeine>)

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

❖ Lessons and lesson plans

- ChemMatters: Coffee: Brain Booster to Go?
<https://teachchemistry.org/chemmatters/december-2008/coffee-brain-booster-to-go>
- ChemMatters: Chocolate—How Sweet It Is!
<https://teachchemistry.org/chemmatters/december-1999/chocolate-how-sweet-it-is>
- Open for Discussion: Caffeine
<https://www.acs.org/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/caffeine.html>

❖ Projects and extension activities

- Compound Chemistry: Arabica vs Robusta
<https://www.compoundchem.com/2018/09/30/arabica-robusta/>
- Compound Chemistry: How is decaffeinated coffee made?
<https://www.compoundchem.com/2018/09/26/coffee-decaffeination/>
- YouTube: How Does Coffee Keep You Awake
<https://youtu.be/foLf5Bi9qXs?si=GTm0nps4I8ebCy9Z>
- AsapScience: Your Brain On Coffee
<https://youtu.be/4YOWEqGykDM?si=ewstspoJ6D9tfqVu>
- What's The Buzz About Caffeine? | Serving Up Science
<https://www.pbs.org/video/whats-the-buzz-about-caffeine-serving-up-science-bzohvp/>

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 enjoy drinks containing caffeine, and how the drinks make them feel. Ask if they have ever thought about the chemistry involved in consuming caffeine. 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 effects of caffeine on their bodies. Ask how they might use the information in the future.
- Consider showing the ACS Reactions Video “The Science of Caffeine: The World’s Most Popular Drug” (2:25): <https://youtu.be/YuJOhpNS0IY?si=0pZq2PaXBryXyCtU>. The video includes information from the article, as well as graphics to enhance understanding.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Functional groups
- Pharmaceuticals

Correlations to Next Generation Science Standards

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

HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- LS.1.A: Structure and Function

Crosscutting Concepts:

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

Science and Engineering Practices:

- Obtaining, evaluating, and communicating information.

Nature of Science:

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

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

Teacher's Guide

Cooking Chemistry: What's in the Pot?

February 2024

Table of Contents

<u>Anticipation Guide</u>	28
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	29
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>	31
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>	32
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	35
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	36

Anticipation Guide

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

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

Me	Text	Statement
		1. The best thermal conductor is diamond.
		2. Thicker pans take less time to heat up than thin pans.
		3. Heat energy is transferred quickly in metals because the atoms are closely packed.
		4. Copper pans hold heat longer than cast iron pans.
		5. Corning Glass Ceramic has a higher thermal conductivity than cast iron.
		6. Well-seasoned cast iron skillets are nonstick due to a polymer coating made from fats and oils used in cooking.
		7. Teflon is a polymer containing fluorine.
		8. Ovens cook food through convection.
		9. Thin metal pans are a good choice for cooking food in an oven.
		10. Microwave ovens use electromagnetic radiation to cook foods containing polar molecules such as fats and water.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Define thermal conductivity and give two examples of good thermal conductors and thermal insulators.
2. Explain why a metal doorknob feels colder than a wood door in the same room.
3. A piece of copper that is heated to 70 °C is placed next to a piece of aluminum at 25 °C. The two metals are touching. Draw a diagram that shows how heat is transferred from one metal to the other. Use circles to represent the atoms and label your diagram to show the direction of heat flow, which particles are moving fast and which ones are moving relatively slowly before the heat is transferred.
4. Compare metal and glass in terms of their structure and particle arrangement and ability to transfer energy.
5. What is specific heat capacity?
6. Use the Properties of Common Materials table to answer this question. If you have 1 gram of each substance in the table, which one will undergo the greatest temperature change when 100 Joules of energy is added to each substance?
7. What properties make cast iron a good choice for a skillet?
8. What is a polymer? What non-stick polymer has been used on frying pans since the 1950s?
9. Explain the three cooking methods: conduction, convection, and electromagnetic radiation and which type of pan is best for each method.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

10. Examine the image that shows the molecular structure of Teflon, PTFE. What is the full chemical name for PTFE? What part of the name indicates fluorine atoms? What part of the name indicates the number of fluorine atoms? What is the meaning of the letter n in the image? How can you tell from the image that Teflon is a polymer?
11. Research the discovery and uses of Teflon.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below examining different considerations when choosing materials for cooking.

		What is it?	Examples from the reading
Thermal Conductivity			
Heat Capacity			
Nonstick material			
Cooking Methods	Thermal conduction		
	Heat convection		
	Electromagnetic radiation		

Summary: On the back of this sheet, write three interesting facts you learned about the chemistry of choosing cooking materials.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Define thermal conductivity and give two examples of good thermal conductors and thermal insulators.
Thermal conductivity is a measure of how quickly heat moves through substances. Good conductors include copper and gold. Good insulators include glass and plastic.
2. Explain why a metal doorknob feels colder than a wood door in the same room.
Metals tend to transfer heat faster than wood, so heat moves quickly from your hand to the doorknob and more slowly from your hand to the wood. Therefore, the doorknob feels colder than the wood door despite the fact that they are at the same temperature.
3. A piece of copper that is heated to 70 °C is placed next to a piece of aluminum at 25 °C. The two metals are touching. Draw a diagram that shows how heat is transferred from one metal to the other. Use circles to represent the atoms and label your diagram to show the direction of heat flow, which particles are moving fast and which ones are moving relatively slowly before the heat is transferred.
4. Compare metal and glass in terms of their structure and particle arrangement and ability to transfer energy.
Metals atoms are close together and organized. As the atoms move, they collide with one another and transfer energy from one atom to its neighbor. In glass, there are more spaces and holes (amorphous structure) in the structure. There are not as many collisions so energy is not transferred as quickly.
5. What is specific heat capacity?
Specific heat capacity is the amount of energy it takes to increase the temperature of 1 gram of a substance by 1 °C.
6. Use the Properties of Common Materials table to answer this question. If you have 1 gram of each substance in the table, which one will undergo the greatest temperature change when 100 Joules of energy is added to each substance?
The substance with the lowest specific heat in the table, silver, will undergo the greatest change in temperature.
7. What properties make cast iron a good choice for a skillet?
Cast iron is a good thermal conductor and because of its high density, it holds more heat than other metals. In addition, fats used in cooking polymerize and fill in the nooks and crannies in the metal's surface. Over time, the pan becomes "seasoned" and very non-stick if cared for properly. Finally, cast iron is relatively inexpensive.
8. What is a polymer? What non-stick polymer has been used on frying pans since the 1950s?
Polymers are long chain molecules made up of repeating units of small molecules, called monomers. Teflon is a non-stick polymer coating used on frying pans.
9. Explain the three cooking methods: conduction, convection, and electromagnetic radiation and which type of pan is best for each method.
Thermal conduction is used when food is cooked in a skillet or pan in direct contact with the heat source. When the vibrating particles in the pan collide with the food particles, energy is transferred to the food. Metal pans that hold heat and distribute it evenly are a good choice for the stovetop.

Baking a cake or roast in the oven involves convection. Hot air in the closed oven rises, as gases expand when they are heated and become less dense. At the top of the oven, the air cools, becomes more dense and sinks. This circulation of air cooks the food. Glass pans that can withstand long cooking times and don't transfer heat too quickly are good choices so the outside of the food doesn't get overcooked while the inside is undercooked.

Microwave ovens make use of electromagnetic radiation to heat up polar molecules like water. The water molecules move to align their positive and negative ends with the poles of the electromagnetic waves. Some food particles do not align with the microwaves, which is why some foods are not recommended to be cooked in the microwave oven. In addition, some containers are "microwave safe" because they don't absorb microwave radiation. Otherwise, the container might melt.

10. Examine the image that shows the molecular structure of Teflon, PTFE. What is the full chemical name for PTFE? What part of the name indicates fluorine atoms? What part of the name indicates the number of fluorine atoms? What is the meaning of the letter n in the image? How can you tell from the image that Teflon is a polymer?

The full name for PTFE is polytetrafluoroethylene. The fluorine atoms are represented in the name with the component "fluoro". The four fluorine atoms are represented by the component "tetra". The letter n represents the number of "tetrafluoroethylene" units that make up the long polymer chain of PTFE. In this case, the value of n is greater than one million.

11. Research the discovery and uses of Teflon.

Answers will vary depending on student research. Teflon was accidentally discovered in 1938 by Dr. Roy Plunkett when a sample of frozen tetrafluoroethylene spontaneously polymerized. This inert, slippery substance is used in many industries including aerospace, architecture, and electronics in addition to its use as a coating for cookware and as a stain repellent for fabrics. Today, there are additional compounds in the Teflon "family". These compounds changed the plastics industry leading to many applications used today. Plunkett was recognized with several awards for his contributions.

Source: <https://www.teflon.com/en/news-events/history>

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

- Popcorn is popped using three different methods of heat transfer: conduction, convection, and microwave radiation.
 - <https://teachchemistry.org/classroom-resources/hot-popcorn>
- Students investigate specific heat by mixing different solutions.
 - <https://teachchemistry.org/classroom-resources/understanding-specific-heat>
- Students explore what happens when three different metals of equal mass change the temperature of a sample of water.
 - <https://www.flinnsci.com/specific-heat/dc11005/>

❖ Simulations

- Students investigate how water molecules interact with microwave radiation.
 - <https://phet.colorado.edu/en/simulations/microwaves>

❖ Lessons and lesson plans

- Students learn how polymers are made and how cross-linking molecules are utilized. There is also an opportunity for students to collect various types of plastic and collect data regarding the plastics we use every day.
 - https://www.teachengineering.org/lessons/view/csu_polymer_lesson01
- Infographic on the chemistry of Teflon
 - <https://www.compoundchem.com/2016/02/04/teflon/>

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 enjoy cooking. Ask them if they have ever considered the material they use to cook their food, and why it works for that recipe choice. 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 choosing the best cookware for the cooking task. Ask what questions they still have about the materials used in cookware.
- After students have read and discussed the article, ask students what information they would like to share with friends and family about cookware choices.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Heat
- Specific heat
- Heat Transfer
- Electromagnetic radiation

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:

- Cause and effect
- Energy and matter
- Structure and function

Science and Engineering Practices:

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

Nature of Science:

- Science models, laws, mechanisms, and theories explain natural phenomena.

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

Teacher's Guide

Mad Scientists and Misinformation

February 2024

Table of Contents

<u>Anticipation Guide</u>	38
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	39
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>	41
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>	42
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	45
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	46

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. Being scientifically literate helps people make good decisions about things such as nutrition and the environment.
		2. Fulminated mercury will explode if thrown on the ground.
		3. All unstable compounds are explosive.
		4. Hydrofluoric acid is the strongest acid.
		5. Hydrofluoric acid moves through skin easily.
		6. <i>MythBusters</i> busted the <i>Breaking Bad</i> scenarios in the episodes with fulminated mercury and hydrofluoric acid.
		7. The TV series <i>Breaking Bad</i> did not have a science advisor.
		8. Chemists can help find new ways to treat substance abuse disorder.
		9. The movie <i>Elemental</i> attempted to base the movie on real science, even though there were only four elements in the movie: fire, earth, air, water.
		10. Science and math experts are often hired by TV and movie companies to ensure special effects and depictions of scientists are realistic.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. How is fulminated mercury made?
2. What are the original four Greek elements?
3. Name three properties of explosive reactions.
4. What is activation energy?
5. What is fentanyl?
6. Name two of fluorine's characteristics that cause it to be highly reactive.
7. Why is scientific literacy important?
8. What does fulminated mercury decompose into after an explosive reaction?
9. What two goals did ACS have for establishing connections in Hollywood?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

10. Define Charles' Law.
11. Describe at least two ways that the entertainment industry and scientists can work together.
12. Explain the connection between four original Greek elements and the states of matter.
13. Chemistry is represented in a variety of media. Find an example of chemistry in the media (movies, television, social media, etc.) and do some fact checking. Describe the aspect of chemistry portrayed and analyze the accuracy of the portrayal.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe how people who understand science (including you!) can influence public opinions and ideas about science.

	Examples or Definition	How can science consultants increase public understanding of this topic?
"Mad Scientists"		
Scientific Literacy		
Chemistry in <i>Breaking Bad</i>		
Fentanyl		
Hollywood Stories and Special Effects		

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 is fulminated mercury made?
Fulminated mercury is made when red mercury oxide is dissolved in concentrated nitric acid and ethanol is added, it precipitates as a gray solid.
2. What are the original four Greek elements?
The four original Greek elements are fire, water, earth, and air.
3. Name three properties of explosive reactions.
Explosive reactions are fast, exothermic, and produce gasses that expand quickly.
4. What is activation energy?
Activation energy is the minimum amount of energy required to start a chemical reaction.
5. What is fentanyl?
Fentanyl is an opioid that is more potent than morphine.
6. Name two of fluorine's characteristics that cause it to be highly reactive.
Fluorine is highly reactive because of its small size and electronegativity.
7. Why is scientific literacy important?
Scientific literacy is important because it helps people make informed decisions about various aspects of their lives.
8. What does fulminated mercury decompose into after an explosive reaction?
After an explosive reaction, fulminated mercury decomposes into carbon dioxide, nitrogen gas, and metallic mercury.
9. What two goals did ACS have for establishing connections in Hollywood?
ACS wanted to influence Hollywood to include more science in the media and represent science in a more positive and realistic manner.
10. Define Charles' Law.
Charles' law states that when the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume will be directly proportional. Gasses expand when heated and contract when cooled.
11. Describe at least two ways that the entertainment industry and scientists can work together.
The entertainment industry can help bring the voices of scientists to the public in an accessible and realistic way. Scientists can help media with special effects as well as consulting to ensure the scientific accuracy of movies and shows.

12. Explain the connection between four original Greek elements and the states of matter.

The four elements align with the four states of matter: solid (earth), liquid (water), gas (air), and plasma (fire).

13. Chemistry is represented in a variety of media. Find an example of chemistry in the media (movies, television, social media, etc.) and do some fact checking. Describe the aspect of chemistry portrayed and analyze the accuracy of the portrayal.

Student 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

❖ Simulations

- [AACT Gas Laws Simulation](#) – Students can use this simulation to investigate Boyle’s Law, Charles’ Law and Gay-Lussac’s Law by visually examining the impact of changing the associated variables of pressure, volume, or temperature.
- [AACT Ionic and Covalent Bonding Simulation](#) - This simulation can be used to help students understand the bonds that fluorine can make with other elements, as described in the article.
- [PhET Gas Properties Simulations](#) - This simulation allows students to explore the relationships between a variety of characteristics of gasses.

❖ Lessons and lesson plans

- [The Gas Laws Unit Plan](#) - This AACT unit plan can be used to help students better understand gas laws through the exploration of videos, simulations, and activities.

❖ Projects and extension activities

- [Be Media Wise: How to Evaluate Scientific Claims Shared Online](#) – This PBS lesson teaches students to use lateral reading to identify false scientific claims.

Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students what scientific errors they have noted in movies or TV programs. Ask them why it’s important to separate real science from fiction. 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 scientific literacy, and how science advisors assist moviemakers and television producers to create more believable programs while keeping the programs entertaining.
- After reading, ask students how they might use information from the article when watching new movies and TV episodes in the future.
- Consider asking students to read the “Open for Discussion” article on page 4 of this issue to learn ways to evaluate scientific information for accuracy.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Strong vs. weak acids
- Chemical change
- Chemical properties
- Scientific literacy

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:

- 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](#).