

ChemMatters™

Demystifying Everyday Chemistry

Teacher's Guide

February 2023

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February 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 a beautiful photo of chromophore crystals that look like a sunflower. Students will learn more about chromophores in the article "What's in Your Paintbox" on page 13. As students read the description of the photo, they will learn how mistakes can lead to interesting questions.
2. "Open for Discussion" on page 4 encourages students to compare in-school learning to online learning. You might consider asking students to make a list of the benefits and drawbacks of learning chemistry online vs. in person, then discuss their ideas.
3. "Quick Read: Chemistry and 'Magic'" on page 14 describes the chemistry behind two "tricks" students might have seen. It would be fun to have students demonstrate or try the tricks and explain the chemistry to others. The activities and reading will help students appreciate the importance of observation and reasoning in understanding surprising or unexpected phenomena.
4. The Chemistry in Person column on page 19 describes the work of three chemical technical professionals. As students read the article, they should look for how each of the featured professionals became interested their career path, the educational requirements, what they do, and how they can advance. You might ask students if any of the careers sound interesting to them, 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 in the article. See the individual Teacher's Guide for each article to learn more.
Evaluate	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

The Chemistry of Shaving

February 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. Removing hair has no effect on body odor.
		2. Hair is made of protein.
		3. Thin razor blades require more pressure when shaving.
		4. Razor blades are made of high carbon steel to increase hardness.
		5. Leaving razor blades wet will make them last longer.
		6. The first aerosol shaving cream was developed in the 1920s.
		7. When the button of the shaving cream can is pressed, the pressure decreases so the volume of the propellant gas increases.
		8. Shaving cream is basically air, water, and soap.
		9. Aftershave is antibacterial and also stops bleeding.
		10. The only way to permanently remove hair is using electrolysis to destroy the hair follicle.

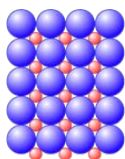
Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. How is being hairless considered hygienic?
2. Name and describe the main chemical in hair.
3. Define surfactant. How does a surfactant work when added to water?
4. How does water affect the sharpness of a razor blade?
5. How does electrolysis differ from other forms of hair removal?
6. Below is a particle diagram of an alloy of carbon (small spheres) and Iron (big spheres). Using this diagram, explain why adding carbon makes the iron alloy (called steel) much stronger.



7. Look at the figure of the molecule on page 7 of the article. Explain why the head is considered hydrophilic, and the tail is considered hydrophobic.
8. The article explains how chromium is resistant to corrosion (by forming a thin layer of chromium oxide). Aluminum undergoes a similar process. Explain why this allows aluminum to be useful for cooking and storing foods.
9. Explain how the endothermic process of evaporation allows alcohol to cool the face (or other skin on the body). (You may need to look up the definition of evaporation).
10. A metal's ability to avoid corrosion depends on how reactive it is. Look at the activity series of metals table below. Give some examples of metals that are resistant to corrosion. List some uses for these types of metals, which would not be possible without their corrosion resistance.

Most reactive ↓ Least reactive	lithium	Li
	rubidium	Rb
	potassium	K
	barium	Ba
	strontium	Sr
	calcium	Ca
	sodium	Na
	magnesium	Mg
	beryllium	Be
	aluminum	Al
	manganese	Mn
	zinc	Zn
	cadmium	Cd
	iron	Fe
	cobalt	Co
	nickel	Ni
	tin	Sn
	lead	Pb
	(hydrogen)	(H ₂)
copper	Cu	
mercury	Hg	
silver	Ag	
palladium	Pd	
platinum	Pt	
gold	Au	

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Some lasers used in hair removal use light pulses with short wavelengths, and some lasers use light pulses with longer wavelengths. Explain how the different wavelengths affect the energy of the light wave. State some possible pros and cons for using each type of wavelength in lasers for hair removal.

Graphic Organizer

Name: _____

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

	Chemicals involved	Purpose
Shaving blades		
Shaving cream		
Waxing		
Depilatory cream		

Summary: On the back of this sheet, write a short email (3-4 sentences) to a friend describing what you learned about the chemistry of shaving.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. How is being hairless considered hygienic?
Hairlessness was considered hygienic, especially in Egypt, where it was always very hot. Sweaty hair can grow bacteria, lice, and other infections. Armpit hair causes body odor.
2. Name and describe the main chemical in hair.
The main chemical in hair is keratin, which is a protein that has a very strong, tough fibrous structure.
3. Define surfactant. How does a surfactant work when added to water?
A surfactant is a chemical, that when added to water, breaks down the surface tension in the water. Adding a surfactant makes water "wetter", which means it can spread out over surfaces better.
4. How does water affect the sharpness of a razor blade?
Tap water contains ions and minerals, like calcium ions and carbonate ions. These ions can bond to the metal as calcium carbonate, causing the blade to become dull.
5. How does electrolysis differ from other forms of hair removal?
Electrolysis is different because the process actually destroys the follicle, which is where the hair begins its growth. All other methods destroy the hair, but not the follicle.
6. Below is a particle diagram of an alloy of carbon (small spheres) and Iron (big spheres). Using this diagram, explain why adding carbon makes the iron alloy (called steel) much stronger.
The carbon fills in the gaps between the iron atoms. This prevents the iron atoms from being able to move across each other as easily (AKA, malleable). Because of this, the metal is much more rigid and stronger (Note: this type of alloy is called "interstitial alloy").
7. Look at the figure of the molecule on page 7 of the article. Explain why the head is considered hydrophilic, and the tail is considered hydrophobic.
"Hydrophilic" means attracted to water. Water is a polar molecule, and the water molecule would be attracted to the hydrogen bonds of the -OH part of the head. There will also be some attraction to the polar oxygen atom on that end. The tail is "hydrophobic", or repels water. There are no hydrogen or dipole attractions on the tail to attract to a water molecule.
8. The article explains how chromium is resistant to corrosion (by forming a thin layer of chromium oxide). Aluminum undergoes a similar process. Explain why this allows aluminum to be useful for cooking and storing foods.
Aluminum, like chromium, forms a thin layer of aluminum oxide on the surface. This is very good for resisting corrosion. The aluminum would not react with any acidic foods, nor would it react with any moisture from the food.
9. Explain how the endothermic process of evaporation allows alcohol to cool the face (or other skin on the body). (You may need to look up the definition of evaporation).
Evaporation occurs when liquid molecules with high kinetic energy escape the surface as vapor. When these high KE molecules leave, the average KE of the remaining substance is lower. The cool feeling from the alcohol is the molecules of the alcohol absorbing heat from the body as it evaporates, and with this loss of heat, the person feels "cool".

10. A metal's ability to avoid corrosion depends on how reactive it is. Look at the activity series of metals table below. Give some examples of metals that are resistant to corrosion. List some uses for these types of metals, which would not be possible without their corrosion resistance.

The low end of the activity series contains metals that are very unreactive. Therefore, they are very resistant to corrosion. This is why copper is a very common metal in pipes. This is also why metals like gold, platinum, and silver are very popular in jewelry, because they do not tarnish as easily.

11. Some lasers used in hair removal use light pulses with short wavelengths, and some lasers use light pulses with longer wavelengths. Explain how the different wavelengths affect the energy of the light wave. State some possible pros and cons for using each type of wavelength in lasers for hair removal.

A good explanation can be found at this website: <https://www.laseraway.com/articles/hair-removal/types-of-lasers-for-hair-removal/>

In short: The shorter wavelengths have a greater frequency, and a higher energy. This makes the hair removal quicker, but could have some adverse effects like burning. The longer wavelengths have a lower frequency and energy, so they wouldn't be as harmful, but it does take longer to destroy the unwanted hair.

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

- <https://teachchemistry.org/classroom-resources/chemistry-of-art-through-alloys-and-metal-plating>
- <https://teachchemistry.org/classroom-resources/abe-goes-swimming>
- <https://teachchemistry.org/classroom-resources/sandy-beaches-a-foray-into-magic-sand>
- <https://teachchemistry.org/classroom-resources/activity-series-of-unknown-metals>

❖ Simulations

- <https://teachchemistry.org/classroom-resources/animation-activity-solubility>

❖ Lessons and lesson plans

- <https://www.compoundchem.com/2015/07/07/alloys/>

Teaching Strategies

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

- ❖ **Alternative to Anticipation Guide:** Before reading, ask students how they remove unwanted body hair, and how a knowledge of chemistry might be helpful in choosing which method to use. 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 razor blades, shaving cream, and other methods of removing body hair.
- ❖ After students have read and discussed the article, consider showing the ACS Reactions video “What Is Shaving Cream?” (5:19) <https://youtu.be/t7QD2NuxmbE>. The video reviews information in the article and provides more details about fatty acids and triglycerides.
- ❖ The activity “State Debate” (<https://www.acs.org/education/whatischemistry/adventures-in-chemistry/experiments/state-debate.html>) would be fun for students to try and home and report what they found out.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Mixtures (alloys)
- Pressure
- Volume
- Molecular structure

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.B: Developing Possible Solutions
- 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](#).

Teacher's Guide

Electric Vehicles! What's the Chemistry That Makes Them Go?

February 2023

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<u>Graphic Organizer</u>	18
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>	19
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	21
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article	
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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. Emissions from gas and diesel engines account for less than 5% of total greenhouse gas emissions in the United States.
		2. Electric vehicles have no tailpipes, so no greenhouse gas emissions.
		3. Lithium-ion batteries can be recharged.
		4. A lithium-ion battery contains fewer than 100 lithium-ion cells.
		5. Lithium is used in batteries because of its low atomic mass.
		6. Fast charging an EV battery causes it to degrade more quickly.
		7. Lithium is more plentiful in nature than magnesium or sodium.
		8. Lithium-ion batteries can catch fire if damaged.
		9. Fuel cells require hydrogen for fuel.
		10. EVs cannot accelerate as fast as gas-powered cars.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Which state will require all cars sold to be hydrogen-powered or electric by the year 2035?
2. What percentage of greenhouse gas emissions was caused by cars and light-duty vehicles in 2020?
3. Name two devices that contain secondary batteries.
4. What is lithium's reduction potential?
5. What units are used to measure battery capacity?
6. List the three primary metallic elements used in a lithium battery.
7. Describe the difference between primary and secondary batteries.
8. Name three metals that have a reduction potential below zero.
9. Name two benefits of solid-state batteries over lithium-ion batteries.
10. What are the products of the reaction that takes place in a fuel cell?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Describe at least two features of lithium that make it useful for batteries.
12. Explain why an EV battery contains thousands of individual lithium-ion cells.
13. List the four parts of a battery and the function of each.
14. Create an infographic, comic, or narrative to explain the path of a lithium ion as a lithium battery produces energy and then is recharged.

Graphic Organizer

Name: _____

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

Vocabulary	Relate to lithium-ion battery
Secondary battery	
Intercalation	
Capacity	
Energy density	
Reduction potential	
Hysteresis	
Future batteries	<i>Describe three ideas for future EV batteries.</i>

Summary: On the back of this sheet, write three important facts about the chemistry of EVs that you would like to share with a friend.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Which state will require all cars sold to be hydrogen-powered or electric by the year 2035?
California will require all cars sold to be electric or hydrogen-powered by 2035.
2. What percentage of greenhouse gas emissions was caused by cars and light-duty vehicles in 2020?
In 2020, emissions from passenger cars and light-duty vehicles accounted for 14% of greenhouse gas emissions.
3. Name two devices that contain secondary batteries.
Cellphones and EVs contain secondary batteries.
4. What is lithium's reduction potential?
Lithium's reduction potential is -3.05.
5. What units are used to measure battery capacity?
The capacity of a battery is measured in ampere-hours.
6. List the three primary metallic elements used in a lithium battery.
The elements used in a lithium battery are lithium, cobalt, and nickel.
7. Describe the difference between primary and secondary batteries.
Primary batteries cannot be recharged but secondary batteries can.
8. Name three metals that have a reduction potential below zero.
Three metals that have a reduction potential below zero are nickel, zinc, and lithium.
9. Name two benefits of solid-state batteries over lithium-ion batteries.
Solid-state batteries have higher energy density and are less flammable.
10. What are the products of the reaction that takes place in a fuel cell?
The products of the reaction that takes place in a fuel cell are electricity, heat, and water.
11. Describe at least two features of lithium that make it useful for batteries.
Lithium is the lightest element that can reversibly exchange electrons. Lithium has a high capacity and high energy density and low reduction potential.
12. Explain why an EV battery contains thousands of individual lithium-ion cells.
A single lithium battery produces 3.6 volts of electricity, so thousands of lithium batteries are needed to provide the amount of electricity needed to power a vehicle.
13. List the four parts of a battery and the function of each.
A battery consists of two electrodes, electrolytes, and a separator. The electrodes release and gain electrons. The electrolyte allows electrons to flow between the electrodes while the separator prevents contact between the anode and cathode.
14. Create an infographic, comic, or narrative to explain the path of a lithium ion as a lithium battery produces energy and then is recharged.
Student responses will vary but should include information about how energy flows through a battery and how the battery is recharged.

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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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

- [How Far Can We Go?](#) - This lesson plan will help students understand the relationship between electrochemical cell potentials and stored chemical energy.
- [Biofuels of the Future](#) - In this lesson, students demonstrate their understanding of alternative energy sources by creating an ebook.
- [How Fuel Cells Work](#) - This lesson incorporates an online animation to help students understand how fuel cells provide energy in vehicles.
- [What Powers Your World?](#) - In this lesson students examine various battery power sources and learn about oxidation-reduction reactions.

❖ Simulations

- [Circuit Construction Kit](#) - Students can explore this simulation to learn about electric circuits.

❖ Projects and extension activities

- [Hybrid and Electric Cars Video](#) - This video explains the chemistry that powers the batteries used in electric cars.

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 ridden in an electric car. Ask how EVs are different from a gas-powered car. 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 improving batteries for EVs.
- ❖ For further information, share the ACS Reactions video “How Do Hydrogen Fuel Cells Work?” (8:11) at <https://youtu.be/R6AdX-bdDaw>. Students will learn more about the theory behind fuel cells and the efficiency of power sources. EVs and fuel cell cars are compared near the end of the video.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Atomic mass
- Electrochemistry
- Anode
- Cathode
- Electrolytic cells
- Oxidation
- Reduction
- Reduction potential
- Half reaction

Correlations to Next Generation Science Standards

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

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Disciplinary Core Ideas:

- PS.1.A: Structure and Properties of Matter
- PS.2.B: Types of Interactions
- PS.3.A: Definitions of Energy
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.C: Optimizing the Design Solution

Crosscutting Concepts:

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

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

What's in Your Paintbox?

February 2023

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Anticipation Guide

Name: _____

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

Me	Text	Statement
		1. “Pigment” is another word for “paint.”
		2. Ancient paint colors were made of organic compounds.
		3. Some of the first paints were made from compounds in soil or ashes from fires.
		4. Many paints containing heavy metals are prohibited today.
		5. Synthetic organic pigments tend to be brighter and more intense than inorganic pigments.
		6. Both acrylic and watercolor paints are colloidal suspensions.
		7. Many inorganic pigments are compounds containing transition metals.
		8. All colors except blue are absorbed by blue pigments.
		9. The length of the carbon chains in organic pigments determine the color perceived.
		10. Azo compounds have double bonds between nitrogen atoms.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. One significant property of a pigment is that it is **insoluble** in its medium. Imagine two cups of water. Transfer some red drink mix powder (water soluble) into one and a red pigment (water insoluble) into the other. Describe how the drink mix mixture will look different from the red pigment mixture.
2. What is meant by the phrase “synthetic organic pigments”, and how are they different from naturally occurring pigments?
3. Consider a solution, like iced tea or your favorite sports drink.
 - a. Explain how you can tell that paint should not be classified as a solution.
 - b. In a colloid, particles of the “*dispersed medium*” are spread out among the “*continuous medium*” but are not dissolved. Using the two italicized terms, complete the following analogy to the parts of a solution:
 - i. Solution: Colloid
 - ii. Solvent: _____
 - iii. Solute: _____
4. Explain the differences between a colloid, an emulsion, and a suspension.
5. Complete the chart:

Paint Type	Liquid Medium	Binder
Oil Paint		
Acrylic Paint		
Water Paint		

6. What is the purpose of each paint component:
 - a. Liquid medium
 - b. Binder
 - c. Pigment
7. Consider the image on page 15 that shows light reflecting from a blue pigment, along with the explanations related to absorption of light. If red, green, and blue light all strike a blue pigment, why does only the blue get reflected? What happens to the red and green light in this scenario?
8. The energy of a visible light photon can be absorbed by a pigment if the photon’s energy has an appropriate magnitude to move an electron to a different location, or energy state, within the pigment.
 - a. What structural aspect of transition metal atoms allows them to be used in pigments?

- b. What bonding feature should an organic molecule have if it is to be used for a pigment?
9. Substances that are based primarily on chains of carbon are classified as “organic” compounds. Those not based on carbon are classified as “inorganic” compounds.
- a. Write the chemical formula for the following compounds that are found in naturally occurring pigments:
- The molecule in red ochre
 - The two main components of raw sienna
- b. Copy the structures of the organic compounds: alizarin, indigo, and the yellow azo dye. With a crayon or highlighter, identify, on each molecule, one example of where conjugation occurs.
- Why are these compounds classified as organic?
 - Why is the yellow dye classified as an azo dye, while the other two are not?
10. The three dye molecules, as pictured on page 16, each absorb photons in different ranges, leading to their different colors. Rank the photons best absorbed by each of the three dyes in order from lowest to highest energy.
11. The alizarin dye can absorb photons with a wavelength of 274 nm.
- Are these photons in the visible, infrared, or ultraviolet range?
 - What is the energy of a photon with this wavelength?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

12. Create a summary chart of the physical and chemical properties of the various types of paints. Then give an example of applications for each paint type. For example, when would an acrylic paint be chosen over an oil paint?
13. Discuss the ways that polymerization occurs in different types of paints.

Graphic Organizer

Name: _____

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

	Inorganic Pigments	Organic Pigments
Ancient		
Synthetic		
How do we perceive their color?		

	Components	Examples
Oil paint		
Acrylic or latex paint		
Watercolor paint		

Summary: On the back of this sheet, write three interesting facts you learned from the article to share with a friend who enjoys painting.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

- One significant property of a pigment is that it is **insoluble** in its medium. Imagine two cups of water. Transfer some red drink mix powder (water soluble) into one and a red pigment (water insoluble) into the other. Describe how the drink mix mixture will look different from the red pigment mixture.
The drink mix would look red and transparent. You'd be able to see through it, and it would look like a single red liquid.
The pigment mix would look like dirty water. You would see the solid floating around (and eventually settling) and you would not be able to see through the mixture.
- What is meant by the phrase "synthetic organic pigments", and how are they different from naturally occurring pigments?
Pigments that are made in the lab, rather than gathered from the earth or from an organism. Some synthetic pigments use naturally occurring pigments within the synthesis, but chemically change them to suit the needs of the experimenter. Naturally occurring pigments are colored compounds that exist naturally in an organism or in the earth.
- Consider a solution, like iced tea or your favorite sports drink.
 - Explain how you can tell that paint should not be classified as a solution.
You cannot see through paint. Solutions look like a single liquid, and have the particles of the solute completely surrounded by particles of the solvent.
 - In a colloid, particles of the "*dispersed medium*" are spread out among the "*continuous medium*", but are not dissolved. Using the two italicized terms, complete the following analogy to the parts of a solution:
 - Solution: Colloid
 - Solvent: continuous medium
 - Solute: dispersed medium
- Explain the differences between a colloid, an emulsion, and a suspension.
A suspension has large particles dispersed throughout another substance. The particles will eventually settle out of the mixture, due to gravity.
A colloid has smaller particles (but not as small as a solution) dispersed throughout another substance. The particles will stay dispersed in the mixture, just like they would in a solution.
An emulsion is a type of colloid where both the dispersed and the continuous media are in the liquid state, and the particles cannot mix with each other, like in a solution. An emulsion will separate into its individual liquids unless an emulsifying agent is added that can keep the two liquids mixed by interacting with each of the particle types.
- Complete the chart:

Paint Type	Liquid Medium	Binder
Oil Paint	Linseed oil	Linseed oil
Acrylic Paint	Water	Methyl Acrylate
Water Paint	Water	Gum Arabic

6. What is the purpose of each paint component:
- Liquid medium – Allows the binder/pigment to be spread onto a surface
 - Binder – Traps or bonds the pigment so it sticks to the painted surface
 - Pigment – Gives the color
7. Consider the image on page 15 that shows light reflecting from a blue pigment, along with the explanations related to absorption of light. If red, green, and blue light all strike a blue pigment, why does only the blue get reflected? What happens to the red and green light in this scenario?
The red and green light are absorbed into the pigment, so only the blue reflects away and is seen by the observer.
8. The energy of a visible light photon can be absorbed by a pigment if the photon's energy has an appropriate magnitude to move an electron to a different location, or energy state, within the pigment.
- What structural aspect of transition metal atoms allows them to be used in pigments?
The d-orbitals are in an energy state that allows electrons to move to new levels when absorbing light in the visible range of the electromagnetic spectrum.
 - What bonding feature should an organic molecule have if it is to be used for a pigment?
The molecule needs conjugation (alternating single and double bonds).
9. Substances that are based primarily on chains of carbon are classified as "organic" compounds. Those not based on carbon are classified as "inorganic" compounds.
- Write the chemical formula for the following compounds that are found in naturally occurring pigments:
 - The molecule in red ochre – Fe_2O_3
 - The two main components of raw sienna – FeO (or Fe_2O_3) and MgO
 - Copy the structures of the organic compounds: alizarin, indigo, and the yellow azo dye. With a crayon or highlighter, identify, on each molecule, one example of where conjugation occurs.
All three structures should be drawn and at least one adjacent single bond and double bond should be highlighted.
 - Why are these compounds classified as organic?
Because they are primarily chains of carbons.
 - Why is the yellow dye classified as an azo dye, while the other two are not?
Because it has a nitrogen – nitrogen double bond ($\text{N}=\text{N}$) and the others do not.
10. The three dye molecules, as pictured on page 16, each absorb photons in different ranges, leading to their different colors. Rank the photons best absorbed by each of the three dyes in order from lowest to highest energy.
Red (alizarin) < Yellow (azo dye) < Blue (indigo)
11. The alizarin dye can absorb photons with a wavelength of 274 nm.
- Are these photons in the visible, infrared, or ultraviolet range?
Ultraviolet
 - What is the energy of a photon with this wavelength?

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{J} \cdot \text{s})(2.998 \times \frac{10^8 \text{m}}{\text{s}})}{2.74 \times 10^{-7} \text{m}} = 7.25 \times 10^{-19} \text{J}$$

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

- 5E Laboratory Lesson: What Type of Mixture is Paint? <https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>
- 5E Laboratory Lesson: Exploring the Chemistry of Oil and Acrylic Paints <https://teachchemistry.org/classroom-resources/exploring-the-chemistry-of-oil-and-acrylic-paints>
- 5E Laboratory Lesson: Transition Metals Color the World <https://teachchemistry.org/classroom-resources/transition-metals-color-the-world>

❖ Simulations

- Chemistry of Color Video Series: https://teachchemistry.org/classroom-resources/collections/chemistry-of-color?utf8=%E2%9C%93&q%5Bresource_topics_topic_id_or_resource_topics_topic_parent_topic_id_in%5D%5B%5D=&q%5Bcontent_type_in%5D%5B%5D=video&q%5Bcontent_type_in%5D%5B%5D=&button=
- ACS Podcast: How Eggplants Inspired Sustainable Paint <https://www.acs.org/catalyzing-change/how-eggplants-inspired-sustainable-paint.html>
- Animation: The Electromagnetic Spectrum <https://teachchemistry.org/classroom-resources/the-electromagnetic-spectrum-animation>

❖ Lessons and lesson plans

- AACT Resource Collection “The Chemistry of Color” <https://teachchemistry.org/periodical/issues/september-2017/introducing-the-chemistry-of-color-a-resource-collection>
- What is Paint? A Paint Investigation <https://teachchemistry.org/classroom-resources/what-is-paint-a-paint-investigation>
- Isolation of Phytochrome <https://teachchemistry.org/classroom-resources/isolation-of-phytochrome>

❖ Projects and extension activities

- Fields of Specialization: Dyes, Paints, Pigments, Coatings <https://www.acs.org/careers/chemical-sciences/fields/dyes-paints-pigments-coatings-inks.html>

Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students if they enjoy painting and/or visiting art galleries and what types of paints they use or have heard about. 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 how chemistry can help artists create paintings for us to appreciate.
- After students have read and discussed the article, ask students what they would like to share with friends and family about paints.
- This article could be used when discussing basic types of matter and could be used with some of the above lessons to explore different types of mixtures.
- This article could be used when introducing light and the electromagnetic spectrum, and could be contrasted with the electron processes that occur in flame tests.
- This article could be used when addressing bonding to highlight differences between molecular and ionic compounds, along with polymer formation.
- AACT Webinar: “STEAM: Using Paint to Teach Stoichiometry and Solutions”
<https://teachchemistry.org/professional-development/webinars/steam-using-paint-to-teach-stoichiometry-and-solutions>

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

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

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
- PS.3.A: Definitions of Energy
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

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

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

What's Chocolate, and How Does Its Chemistry Inspire Such Cravings?

February 2023

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Activate students' prior knowledge and engage them before they read the article.	
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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.	
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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.	
<u>Answers</u>	40
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	43
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article	
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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. Each year, people in the United States eat more chocolate per person than any other country.
		2. Chocolate was discovered in Mexico.
		3. Chocolate manufacturers today begin processing cacao beans similar to how it was done more than a thousand years ago.
		4. Cacao liquor from roasting the cacao beans contains more than 50% cacao butter.
		5. Cacao butter is used to raise the fat content of eating chocolate.
		6. Dark, milk, and white chocolate contain the same percent of fat.
		7. Chocolate contains vitamins, antioxidants, and caffeine, in addition to other compounds.
		8. Roasting turns aldehydes into amino acids.
		9. The gray or white fat blooms that sometimes form on chocolate are dangerous to eat.
		10. X-ray crystallography studies indicate that fat blooms might be controlled by reducing the porosity of the chocolate.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What is the key component of chocolate? What is the source of the key ingredient and where can it be found?
2. Chocolate is a popular treat worldwide. However, its popularity seems to peak in regions of Europe. How and when was chocolate introduced to Europe?
3. Compare and contrast how ancient chocolate treats were prepared to modern preparation techniques.
4. List the compounds in chocolate responsible for creating chocolate “cravings” which make us want to consume more of the sweet treat.
5. What factors contribute to the taste of chocolate?
6. Explain the chemical changes that occur in chocolate due to roasting.
7. What are “fat blooms” and how do chocolate manufacturers try to limit/control the blooms in their products?
8. Select two of the compounds responsible for the addictive nature of chocolate (from question #4) and explain the compound's interactions in the body and why those compounds become addictive.
9. Chocolate is known to last a long time on shelves of stores and in people’s homes without going bad as long as simple storage precautions are followed. Are their preservatives found in chocolate? What prevents chocolate from spoiling?
10. The article mentions amino acids and triglycerides. Explain the importance of amino acids and triglycerides in the body.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Use the information in the article and additional information found online to create a “Chemistry of Chocolate” infographic. The article should discuss how chocolate is made, the difference between various types of chocolate such as milk, white, and dark chocolate, and the compounds found in chocolate.

Graphic Organizer

Name: _____

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

	How obtained	Chemicals
Cacao liquor		
Cacao butter		
Cocoa powder		
Eating chocolate (Dark, Milk, White)		
Compounds found in chocolate		
Fat blooms		

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. What is the key component of chocolate? What is the source of the key ingredient and where can it be found?

Cacao is the key component of chocolate which comes from the cacao tree. The cacao tree is native to Central America and is also cultivated in West Africa and Southeast Asia.

2. Chocolate is a popular treat worldwide. However, its popularity seems to peak in regions of Europe. How and when was chocolate introduced to Europe?

Chocolate was introduced to Europe during the 16th century when Spanish explorers brought chocolate back from the Aztecs.

3. Compare and contrast how ancient chocolate treats were prepared to modern preparation techniques. Ancient: The cacao pods are harvested, the beans are fermented, dried, roasted, and ground into a powder. The powder is mixed with water and other additives such as chili peppers.

Modern: The cacao pods are harvested, fermented, dried, roasted, ground. Additives such as milk, sugar, and other ingredients are added based on what manufacturers are making.

The modern process is very similar to ancient techniques with the major difference being the finishing techniques and products.

4. List the compounds in chocolate responsible for creating chocolate “cravings” which make us want to consume more of the sweet treat.

Caffeine, theobromine, phenylethylamine, anandamide

5. What factors contribute to the taste of chocolate?

Factors include the origin of the cacao, roasting conditions, processing techniques, and additives.

6. Explain the chemical changes that occur in chocolate due to roasting.

Tasteless and odorless amino acids are converted into 3-methyl butanal, phenylacetaldehyde and aldehydes which have flavor and pleasant aroma.

7. What are “fat blooms” and how do chocolate manufacturers try to limit/control the blooms in their products?

Fat blooms are white/gray film on the chocolate that impacts the appearance, taste, and texture of chocolate. Fat blooms are fat and oil molecules that move to the surface of the chocolate from the interior over time. Manufacturers try to control fat blooms by limiting porous holes in the interior of chocolate which allow fat and oil to migrate.

8. Select two of the compounds responsible for the addictive nature of chocolate (from question #4) and explain the compound's interactions in the body and why those compounds become addictive.

Answers may vary. Compounds become addictive when they affect the brain or nervous system which

increases a desire to consume the compound. An example would be an increased level in dopamine release after consuming a drug which causes people to “chase” that feeling.

9. Chocolate is known to last a long time on shelves of stores and in people’s homes without going bad as long as simple storage precautions are followed. Are their preservatives found in chocolate? What prevents chocolate from spoiling?

Chocolate does not contain preservatives. It contains high levels of fat, oil, and sugar and low levels of water which is not a conducive environment for mold growth.

10. The article mentions amino acids and triglycerides. Explain the importance of amino acids and triglycerides in the body.

Amino acids are responsible for synthesizing protein and other nitrogen containing compounds inside the body.

Triglycerides store extra calories and provide the body with energy.

11. Use the information in the article and additional information found online to create a “Chemistry of Chocolate” infographic. The article should discuss how chocolate is made, the difference between various types of chocolate such as milk, white, and dark chocolate, and the compounds found in chocolate.

Answers will vary. Check that students discussed all the necessary information.

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

- Related article: Chocolate the New Health Food
<https://teachchemistry.org/classroom-resources/chocolate-the-new-health-food>
- Lesson plan for the Related Article
<https://teachchemistry.org/news/love-is-in-the-air>
- Amino Acid Article
<https://teachchemistry.org/chemmatters/april-2015/left-life-right-life-chirality-in-action>
- Addictive Compound Article
<https://teachchemistry.org/chemmatters?page=27>

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 eating chocolate, and what types of chocolate they have used. Ask them how long they think people have been enjoying chocolate and how it is produced. 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 chocolate refining and the different kinds of chocolate.
- ❖ After reading, consider showing the ACS Reactions video “Is White Chocolate Actually Chocolate?” (3:16) <https://youtu.be/4ql8qbfTkys>. The video explains how chocolate is made, reinforcing information in the article.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Separating mixtures
- Molecular structure
- Saturated vs. unsaturated

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:

- 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](#).