

ChemMatters™

Demystifying Everyday Chemistry

Teacher's Guide

October 2022

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October 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. "Open for Discussion" on page 4 is very interesting, especially for students new to chemistry and those who speak languages other than English. Ask students how the Periodic Table might look different in other countries, then encourage them to read the article to find out more. After they read the article, discuss the advantages and drawbacks of using a periodic table in a student's native language.
2. "Quick Read" on page 11 describes the science and technology of braces, including the challenges of creating a durable metal for the inside of your mouth.
3. "Chemistry in Person" on page 19 provides a good example of an interesting career path for someone with a bachelor's degree in chemistry, and how social media can be used to encourage others in chemistry and other STEM subjects.
4. The first article, "Don't Sweat It: How Moisture-Wicking Fabrics Keep You Cool and Dry," relates to the theme for National Chemistry Week 2022: Fabulous Fibers. You can find related activities at <https://www.acs.org/content/acs/en/education/outreach/ncw.html>
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.
 - a. Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
 - b. 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 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 most 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. The videos are also listed below.
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/

Related ACS Reactions videos

Note: The videos are most appropriately shown after students have read the related articles.

The Opioid Epidemic:

- Can we make opioids less addictive? (5:34) - <https://youtu.be/8xoOF2x0XzM>
 - This video is a good overview of the history of opioids, including why new opioids were developed, the role of dopamine in addiction, and ideas for making opioids less addictive.
- What happens when you overdose? (5:51) - <https://youtu.be/xLSz3wEgwJ8>
 - This video describes the effects of overdoses for different drugs including depressants such as alcohol and benzodiazepines, opioids, and stimulants such as caffeine and methamphetamines.

Origin of Life:

- Did Comets Kickstart Life on Earth (4:14) - <https://youtu.be/FnuldVd99x8>
 - The video presents interesting theories regarding debris from the early solar system that is trapped in comets, as well as other possible sources of complex carbon molecules.
- What is Life? And how will we find it on other planets? (8:08) - <https://youtu.be/f44OWIsLeT0>
 - The video describes chemical systems that scientists are looking for on exoplanets in the search for life elsewhere in the universe.

Teacher's Guide

Don't Sweat It: How Moisture-Wicking Fabrics Keep You Cool and Dry

October 2022

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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. Cotton is the best choice for athletic clothing.
		2. Wool retains more water when wet than cotton.
		3. Water is a polar molecule because oxygen pulls on shared electrons more than hydrogen.
		4. Water molecules stick together well.
		5. Molecular polarity determines solubility.
		6. Cotton fibers are nonpolar.
		7. Nylon and polyester are good choices for sweat-wicking fabrics.
		8. Yarns with a circular cross section work best for sweat-wicking fabrics.
		9. Once a fabric is designed, wicking tests are done to make sure the fabric performs as expected.
		10. Evaporation of water from your skin cools you because weak cohesive bonds are broken as water evaporates.

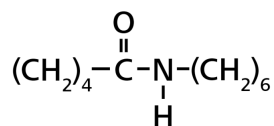
Student Reading

Comprehension Questions

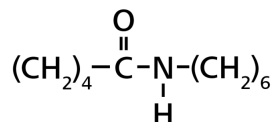
Name: _____

Directions: Use the article to answer the questions below.

1. Why do shirts made from cotton become uncomfortable when a person sweats?
2. A 150 gram sample of fabric is saturated with water and its saturated mass is determined to be 161 grams, what is the *moisture regain* value?
3. Three things that are considered to be *polar* are the earth, a battery, and a water molecule. Explain why each of these things can be classified as polar.
4. An electric field is set up such that the positive side is on the left and the negative side is on the right. Describe how a water molecule would be oriented when in that field.
5. All atoms are surrounded by electrons. Explain how a hydrogen atom in a water molecule can have a positive charge even though it is surrounded by electrons.
6. A water meniscus is formed when water is placed in a graduated cylinder. Is this an example of *cohesion* or *adhesion*? Explain.
7. List any observation about water that could serve as evidence that your skin contains polar molecules.
8. On the partial Lewis structure of nylon below, draw arrows on every bond that is polar, such that the arrowhead points toward a region of negative charge.



9. Model two separate examples of hydrogen bonding by drawing a water molecule properly oriented at each location and connected with a dashed line to the specific portion of the partial Nylon structure below where the interaction would be strongest.



10. Why is a purely hydrophobic material not the best choice for wearing during activities in which a person would sweat?
11. Explain how capillary action relates to moisture wicking.
12. Why is yarn with a circular cross section less efficient in wicking away moisture than yarn with cross sections of other shapes?
13. Why does your body cool down when your sweat evaporates from the shirt you are wearing?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

14. Moisture regain values are listed on the first page of the article for cotton, wool, nylon and polyester, as well as for a cotton/polyester blend. Find the molecular structures for each of the four unblended fabrics. Analyze the areas of each type of molecule that are likely to attract or to repel water. Justify the moisture regain values based on this analysis.
15. Research the effectiveness of two competing brands of moisture wicking clothing. Summarize and compare the types of fabrics and how the threads are engineered to maximize the wicking through the fabric.

Graphic Organizer

Name: _____

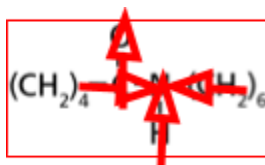
Directions: As you read, complete the graphic organizer below to describe how moisture-wicking fabrics work.

Term	Definition in <u>your</u> words	How the term applies to moisture-wicking fabrics
Molecular polarity		
Capillary action		
Adhesion		
Cohesion		
Cellulose		
Nylon		
Polyester		
Wool		
Wicking tests		

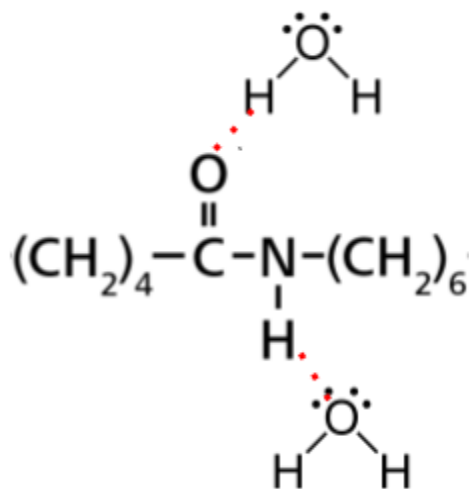
Summary: On the back of this sheet, write a one-sentence summary (18 words or less) of the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Why do shirts made from cotton become uncomfortable when a person sweats?
The cotton fibers are hydrophilic and attract the water molecules. This prevents them from evaporating and leaves the shirt wet, which feels uncomfortable.
2. A 150 gram sample of fabric is saturated with water and its saturated mass is determined to be 161 grams, what is the *moisture regain* value?
 $11\text{g water} / 150\text{g fabric} = 0.073 = 7.3\%$ moisture regains
3. Three things that are considered to be *polar* are the earth, a battery, and a water molecule. Explain why each of these things can be classified as polar.
The earth is a single object with opposite magnetic poles (north and south); A battery is a single object with opposite electric poles (positive and negative terminals of the battery); A water molecule is a single particle with opposite electric poles (the oxygen side has a negative charge and the hydrogen side has a positive charge).
4. An electric field is set up such that the positive side is on the left and the negative side is on the right. Describe how a water molecule would be oriented when in that field.
The oxygen atom of the water molecule would be oriented to the left and the two hydrogens would be pointing to the right.
5. All atoms are surrounded by electrons. Explain how a hydrogen atom in a water molecule can have a positive charge even though it is surrounded by electrons.
The electrons in the hydrogen atom are being drawn away by the more electronegative oxygen atom. This partially exposes the nucleus of the hydrogen atom, allowing its positive field to extend beyond the nucleus.
6. A water meniscus is formed when water is placed in a graduated cylinder. Is this an example of *cohesion* or *adhesion*? Explain.
Adhesion. The walls of the graduated cylinder are made from glass, which is a silicon oxide compound. The structure of the compound is polar and thus attracts the water molecules. This attraction is between two different substances, making it adhesion, rather than cohesion which is between molecules of the same substance.
7. List any observation about water that could serve as evidence that your skin contains polar molecules.
Example response: Water does not bead up on the skin, showing it has some attraction to the skin surface.
8. On the partial Lewis structure of nylon below, draw arrows on every bond that is polar, such that the arrowhead points toward a region of negative charge.



9. Model two separate examples of hydrogen bonding by drawing a water molecule properly oriented at each location and connected with a dashed line to the specific portion of the partial Nylon structure below where the interaction would be strongest.



10. Why is a purely hydrophobic material not the best choice for wearing during activities in which a person would sweat?

A purely hydrophobic material would resist water from both the inside and out. This would trap the water between the skin and the shirt, making the sweat build up, rather than evaporating.

11. Explain how capillary action relates to moisture wicking.

Capillary action is the result of adhesive forces between water and a columnar surface and cohesive forces between water molecules. Some water molecules attract to the surface and other water molecules attract to those, which results in an overall flow of water through the column. The diameter and shape of the column, compared to the size of the water molecules, affects the amount of capillary action that can result. Moisture wicking relies on capillary action, so the threads must be engineered to leave an empty space with an appropriate size to allow for maximum capillary action through the fabric.

12. Why is yarn with a circular cross section less efficient in wicking away moisture than yarn with cross sections of other shapes?

When the threads are all circular, the space between threads is very tight and does not allow enough attraction to draw the water molecules through the space and to the other side of the fabric.

13. Why does your body cool down when your sweat evaporates from the shirt you are wearing?

Water requires energy to evaporate because the forces attracting the water molecules together must be overcome to allow them to leave individually. The energy from your body goes into the sweat, giving it the necessary energy. Since the energy leaves your body, it cools you down.

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

- Lab- Put your fabric to the test: <https://www.acs.org/content/acs/en/education/outreach/celebrating-chemistry-editions/2022-ncw/put-your-fabric-to-the-test.html>
- Video- The Chemistry of Clothes: <https://www.calacademy.org/educators/the-chemistry-of-clothes>
- Demo- Making rayon: <https://edu.rsc.org/experiments/making-rayon/1745.article>

❖ Simulations

- Molecule Polarity: <https://phet.colorado.edu/en/simulations/molecule-polarity>

❖ Lessons and lesson plans

- Lesson T-Shirt Chromatography: <https://teachchemistry.org/periodical/issues/march-2019/teaching-essential-concepts-with-t-shirt-chromatography>
- Lesson What Makes Water So Special: <https://teachchemistry.org/classroom-resources/what-makes-water-so-special>

❖ Projects and extension activities

- Designing an Effective Respiratory Mask: <https://teachchemistry.org/classroom-resources/designing-an-effective-respiratory-cloth-mask>
- Tie Dye: <https://teachchemistry.org/classroom-resources/tie-dye>
- Video- Layered Fabrics in Heat Resistance: <https://teachchemistry.org/classroom-resources/ingenious-this-sandwich-will-save-your-life-in-a-n-arc-flash-video-questions>

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 buy clothing with sweat-wicking properties, and why. Ask how they think the fabrics in the clothing work. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
 - As they read, students can find information to confirm or refute their original ideas.
 - After they read, ask students what they learned about the properties of moisture-wicking fabrics.
- After students have read and discussed the article, ask students whether they will pay more to purchase moisture-wicking clothing, and how the information in the article informs their decision.
- This article relates to the theme for National Chemistry Week 2022: Fabulous Fibers. You can find related activities at <https://www.acs.org/content/acs/en/education/outreach/ncw.html>

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Physical properties
- Covalent bonding
- Electronegativity
- Intermolecular forces
- Molecular structure
- Functional groups

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

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 addresses questions about the natural and material world.

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

Teacher's Guide

What Are Glow Sticks, And What Is the Chemical Reaction That Makes Them Light Up?

October 2022

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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.	
<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>	22
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>	23

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 glass vial inside a glow stick contains water.
		2. Scientists have identified the high-energy intermediate compound in glow sticks.
		3. Light is emitted when a photon moves to a higher energy state.
		4. An anion is negatively charged.
		5. Energy is released when chemical bonds form.
		6. The U.S. government market for glow sticks is greater than that for the consumer novelty market.
		7. Different glow stick colors are produced by using different esters.
		8. The chemicals used in glow sticks have not changed since the discovery in the 1960s.
		9. Glow sticks work only at comfortable temperatures (10-30 °C).
		10. A catalyst can change the length of time of chemiluminescence.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.
Reading Comprehension Questions.

1. What causes the signature “snap” that starts the process of chemiluminescence and a glow stick illuminating light?
2. Briefly summarize the sequence of steps/reactions that take place inside a glow stick to produce light.
3. The article mentions how glow sticks are not only used for novelty purposes at parties. The U.S. government spends approximately \$35 million dollar a year on glow stick type technology. Why is glow stick technology and chemiluminescence important to the U.S. Government?
4. Explain how glow sticks have become safer since their invention in 1962.
5. How can the lifetime (amount of time a glow stick produces light) of a glow stick be controlled?

Connecting Concepts

6. What is a chemical catalyst? Explain how a catalyst increases the rate of a chemical reaction.
7. The article discusses that energy is required to break chemical bonds to start a reaction process and energy is produced when new, product bonds form. The breaking and forming of bonds in a chemical process can result in an endothermic process or exothermic process. Define both of those terms and give a real world example of each type of process.
8. Draw a reaction energy diagram for an exothermic process, you may research an example of a reaction energy diagram using online resources if needed. Define activation energy and indicate how the activation energy can be found on the diagram. The article discusses a reaction intermediate in the process of chemiluminescence. Label where reaction intermediates are found on your reaction energy diagram.
9. Light is just one form of electromagnetic radiation caused by the exciting and relaxing of electrons. Draw a simple sketch of the electromagnetic spectrum. Be sure to include the following forms of electromagnetic radiation; gamma, infrared, ultraviolet, visible, x-ray, microwave, radio.
10. What are some common chemicals found in fluorescent dyes? (Additional research may be required)

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

11. Fictional scenario: The glow stick market has hit an all time low. Sales are down and the CEO of the largest glow stick company has reached out to you, to develop a new and exciting product using glow stick technology to revitalize the market and increase sales. Design a new product using glow stick technology. Explain the uses for the product and draw a sketch of the prototype.
12. Create a “Chemistry of Glow Sticks” infographic or poster using the information learned in the article.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the chemistry of glow sticks (chemiluminescence).

Glow Stick Chemistry		
How and when discovered		
Reactants		
Catalyst		
Possible intermediate(s)		
Products		
Safety innovations		
Other innovations		

Summary: On the back of this sheet, write three new things you learned about glow sticks, and why you want to remember them (three sentences total).

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What causes the signature “snap” that starts the process of chemiluminescence and a glow stick illuminating light?
A walled vial filled with hydrogen peroxide breaks starting the chemiluminescence process.
2. Briefly summarize the sequence of steps/reactions that take place inside a glow stick to produce light.
Hydrogen peroxide reacts with oxalate ester to form an high energy reaction intermediate, possibly 1-2 dioxetanedione. The intermediate accepts electrons from the fluorescent dye, which causes electrons in the dye to move to an excited state. Light is released as electrons return to a relaxed state.
3. The article mentions how glow sticks are not only used for novelty purposes at parties. The U.S. government spends approximately \$35 million dollar a year on glow stick type technology. Why is glow stick technology and chemiluminescence important to the U.S. Government?
The U.S military uses glow stick technology in training exercises and field ops. Glow stick technology is also used in search and rescue missions for location marking purposes.
4. Explain how glow sticks have become safer since their invention in 1962.
Toxic oxalate esters have been replaced with safer compounds such as phthalates and butyl benzoate.
5. How can the lifetime (amount of time a glow stick produces light) of a glow stick be controlled?
The lifespan of a glow stick can be controlled by adjusting the salicylate catalyst concentration.

Connecting Concepts

6. What is a chemical catalyst? Explain how a catalyst increases the rate of a chemical reaction.
A catalyst is a substance that increases the rate of chemical reaction by providing an alternate mechanism for the reaction with a lower energy of activation which is the energy required to break the reactant bonds. The catalyst is not consumed during the process.
7. The article discusses that energy is required to break chemical bonds to start a reaction process and energy is produced when new, product bonds form. The breaking and forming of bonds in a chemical process can result in an endothermic process or exothermic process. Define both of those terms and give a real world example of each type of process.
An endothermic reaction is a reaction that absorbs heat from the surroundings. In an endothermic process, more energy is required to break reactant bonds than is produced by the formation of product bonds. An example of an endothermic process is water evaporating.

An exothermic reaction is a reaction that releases heat into the surrounding from the reaction. In an exothermic reaction, more energy is produced by the formation of product bonds than is put in to break reactant bonds. An example of exothermic reaction is mixing a strong acid and water.

8. Draw a reaction energy diagram for an exothermic process, you may research an example of a reaction energy diagram using online resources if needed. Define activation energy and indicate how the activation energy can be found on the diagram. The article discusses a reaction intermediate in the process of chemiluminescence. Label where reaction intermediates are found on your reaction energy diagram.

The energy diagram should have the reactant energy higher than the resulting product energy, which is present in an exothermic process. The activation energy is the energy required to break reactant bonds and can be seen on the diagram as the distance between the reactant energy and the peak of the graph. Reaction intermediates are present at the point when reactant bonds are breaking and new product bonds are forming, which is represented by the peak of the graph.

9. Light is just one form of electromagnetic radiation caused by the exciting and relaxing of electrons. Draw a simple sketch of the electromagnetic spectrum. Be sure to include the following forms of electromagnetic radiation; gamma, infrared, ultraviolet, visible, x-ray, microwave, radio.

Students can use online research to complete the spectrum.

10. What are some common chemicals found in fluorescent dyes? (Additional research may be required)

Answers may vary. Example: sulfonated cyanines

11. Fictional scenario: The glow stick market has hit an all time low. Sales are down and the CEO of the largest glow stick company has reached out to you, to develop a new and exciting product using glow stick technology to revitalize the market and increase sales. Design a new product using glow stick technology. Explain the uses for the product and draw a sketch of the prototype.

Answers will vary

12. Create a "Chemistry of Glow Sticks" infographic or poster using the information learned in the article.

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.
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Additional Resources and Teaching Strategies

Additional Resources

❖ Labs and demos

- [Activation Energy Lab](#)

❖ Simulations

- [Reaction Rate Simulation](#)

❖ Lessons and lesson plans

- [Light and Electromagnetic Radiation](#)

❖ Projects and extension activities

- [Thermochemistry Infographic](#)

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 think glow sticks work, including what chemicals are involved, as well as how they are used. 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 glow sticks.
- After students have read and discussed the article, ask students what questions they still have about glow sticks or the chemical reactions involved.
- Since the article is in the first issue of the school year, this is a good opportunity to investigate the effect of temperature on chemical reactions using this simple activity:
<https://www.acs.org/content/acs/en/education/outreach/celebrating-chemistry-editions/2021-ncw/slow-the-glow.html>

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Activation energy
- Bond energy
- Molecular structure

Correlations to Next Generation Science Standards

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

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.

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.1.B: Chemical Reactions
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

- Cause and effect
- Energy and matter: flows, cycles, and conservation
- Systems and system models

Science and Engineering Practices:

- Asking questions (for science) and defining problems (for engineering)

Nature of Science:

- Science is a human endeavor.

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

Teacher's Guide

The Opioid Epidemic: How Did It Get This Bad?

October 2022

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Anticipation Guide

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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. Opioid-related deaths are decreasing worldwide.
		2. Illicit drug use among teens in the U.S. has decreased.
		3. Opium poppies have been cultivated for thousands of years.
		4. The primary compound in opium is morphine.
		5. All opioid painkillers are addictive.
		6. Opioids block pain signals from getting to the brain.
		7. Oxycodone is a better painkiller than morphine.
		8. Opioids can affect nerves controlling respiration.
		9. Fentanyl is made using opium poppies.
		10. Naloxone works by blocking opioid receptors in nerves.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Which agency is responsible for monitoring and responding to public health threats?
2. Create a data table of fentanyl-related overdose deaths in teens in the United States in 2019, 2020, and 2021.
3. What is the scientific name for the opium poppy?
4. Which two medications can be used to treat opioid overdoses?
5. What is the trade name for diacetylmorphine?
6. What is the name of the compound used to create oxycodone?
7. Why are opioids prescribed even though they are addictive?
8. List at least three common symptoms of opioid withdrawal.
9. Describe the solubility differences between polar and nonpolar molecules. What is each type of molecule soluble in?
10. Explain how Naloxone works to prevent an opioid overdose.
11. Create a timeline that includes the dates of development and the company/person credited with developing the following: heroin, oxycodone, morphine, and fentanyl.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

12. Explain the impact of opioids on the nervous system.
13. When thinking about its chemical structure, why is fentanyl more lipid soluble than morphine?
14. Compare the production and effectiveness between fentanyl and morphine.
15. The last paragraph of the article explains some of the steps that federal, state, and local governments are taking to reduce the opioid epidemic. These include improving treatments for addiction, increasing the oversight of the opioid trade, developing non-addictive pain medications, and increasing the availability of overdose-reversing drugs. Select one of the steps to research and explain what is being done and its potential impact on the epidemic.
16. The blood brain barrier consists of a phospholipid bilayer. Identify at least three items that can cross the blood brain barrier and describe their chemical structures. What characteristics do they have that allow them to cross the blood brain barrier?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to compare the drugs described in the article.

Drug	Effectiveness as a painkiller (1=most effective; 5=least)	How addictive? (1=most addictive; 5=least)	At least 3 other facts about the drug, including the source, when it was first developed, and legitimate uses (if any).
Opium			
Morphine			
Heroin			
Oxycodone			
Fentanyl			

Summary: On the back of this sheet, write a short text to a friend describing what you learned about the chemistry of opioids from reading the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Which agency is responsible for monitoring and responding to public health threats?
The agency responsible for monitoring and responding to public health threats is the Centers for Disease Control and Prevention.
2. Create a data table of fentanyl-related overdose deaths in teens in the United States in 2019, 2020, and 2021.

Fentanyl-Related Overdose Deaths

Year	Number of Overdose Deaths
2019	492
2020	954
2021	1,146

3. What is the scientific name for the opium poppy?
The scientific name for the opium poppy is *Papaver somniferum*.
4. Which two medications can be used to treat opioid overdoses?
Naloxone and Narcan can be used to treat opioid overdoses.
5. What is the trade name for diacetylmorphine?
Heroin is the trade name for diacetylmorphine.
6. What is the name of the compound used to create oxycodone?
Thebaine is used to create oxycodone.
7. Why are opioids prescribed even though they are addictive?
Opioids are prescribed despite their addictive qualities because they can relieve severe pain.
8. List at least three common symptoms of opioid withdrawal.
Common symptoms of opioid withdrawal include body aches, diarrhea, vomiting, profuse sweating, fever, and shaking.
9. Describe the solubility differences between polar and nonpolar molecules. What is each type of molecule soluble in?
Polar molecules are soluble in water and nonpolar molecules are soluble in lipids.
10. Explain how Naloxone works to prevent an opioid overdose.
Naloxone binds to opioid receptors and displaces opioids.

11. Create a timeline that includes the dates of development and the company/person credited with developing the following: heroin, oxycodone, morphine, and fentanyl.

Year	1804	1874	1916	1960
Opioid	Morphine	Heroin	Oxycodone	Fentanyl
Person/Company responsible for development	Friedrich Wilhelm Serturmer	Bayer	Bayer	Paul Janssen

Questions for Further Learning

12. Describe the impact of opioids on the nervous system.
Opioids attach to opioid receptors and prevent pain signals from traveling to the brain. They also block the brain cells that turn off the release of dopamine.
13. When thinking about its chemical structure, why is fentanyl more lipid soluble than morphine?
Fentanyl is more lipid soluble because it is nonpolar and has a low molecular weight.
14. Compare the production and effectiveness of fentanyl and morphine.
Fentanyl is easier to mass produce because it does not require the growth of large fields of poppies, and it is more effective at blocking pain.
15. The last paragraph of the article explains some of the steps that federal, state, and local governments are taking to reduce the opioid epidemic. These include improving treatments for addiction, increasing the oversight of the opioid trade, developing non-addictive pain medications, and increasing the availability of overdose-reversing drugs. Select one of the steps to research and explain what is being done and its potential impact on the epidemic.
Student responses will vary.
16. The blood brain barrier consists of a phospholipid bilayer. Identify at least three items that can cross the blood brain barrier and write their chemical formulas. What characteristics do they have that allow them to cross the blood brain barrier?
Student responses 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

❖ Labs and demos

- [Diffusion Across Biological Membranes](#) - Students can use this lab to explore the process of diffusion.

❖ Simulations

- [How Pain works in the Body and the Brain](#) - This page includes an interactive simulation designed to help students learn about pain pathways. It also contains additional information and resources to explain different types of pain.
- [Opioids and the Physiology of Tolerance](#) - This interactive explains how opioid use can lead to tolerance and withdrawal.

❖ Lessons and lesson plans

- [The Opioid Epidemic](#) - In this lesson plan, students access a variety of resources to learn more about the opioid epidemic in the United States.
- [Cell Membrane Structure and Function](#) - While completing this lesson, students will learn more about cell membranes and the different ways that substances can move through them.

Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students what they know about opioids, including their names, and the opioid epidemic. 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 opioids.
- After students have read and discussed the article, ask students what surprised them and what they want to remember from the reading.
- These ACS Reactions videos may be used to guide class discussions after students have read the article. The first one is also a good summary of the information in the reading.
 - *Can we make opioids less addictive?* (5:34) - <https://youtu.be/8xoOF2x0XzM>
 - This video is a good overview of the history of opioids, including why new opioids were developed, the role of dopamine in addiction, and ideas for making opioids less addictive.
 - *What happens when you overdose?* (5:51) - <https://youtu.be/xLSz3wEgwJ8>
 - This video describes the effects of overdoses for different drugs including depressants such as alcohol and benzodiazepines, opioids, and stimulants such as caffeine and methamphetamines.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Intermolecular forces
- 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-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

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:

- LS.1.A: Structure and Function
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

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

Science and Engineering Practices:

- Obtaining, evaluating, and communicating information

Nature of Science:

- Science is a human endeavor.

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

Teacher's Guide

Origin of Life

October 2022

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This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
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Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
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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. Living and nonliving things obey the same physical laws.
		2. Only biologists and chemists study the origin of life on Earth.
		3. All life on Earth uses water as a solvent.
		4. DNA and RNA are polymers.
		5. Living things on Earth use more than 200 amino acids to make proteins.
		6. Stromatolites are rocks that may provide clues to when life began on Earth.
		7. Chemicals required for life have been found trapped inside meteorites that formed billions of years ago.
		8. DNA and RNA are made of proteins.
		9. Energy is required to sustain life.
		10. Prebiotic chemists agree about the chemistry of life's exact origins.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. State the six main elements that make up all living forms.
2. Define polymers and monomers. Explain how DNA is a polymer
3. What are proteins? How many proteins are needed for living things?
4. What is prebiotic chemistry?
5. Why do scientists think stromatolites are the key to the origins of life?
6. Explain how DNA works with RNA.
7. What happens to a living organism when it does not receive enough protein?
8. Explain 1 theory of how proteins and RNA were formed before they could make DNA.
9. Think about the structure of carbon, and how it bonds. Explain why there are so many different reactions with carbon-based molecules.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

Look up the 20 amino acids that human bodies need to function. Which are the “essential” amino acids? Why are they “essential”?

Graphic Organizer

Name: _____

Directions: As you read, look for the terms listed below, then list them in order from the simplest to the most complex. in the graphic organizer below.

Terms to use			
Amino acid	Protein	Elements	Nucleotide
DNA	RNA	Enzyme	Organism

Term (simplest to most complex)	Definition in your words	Examples from the article

Summary: On the back of this sheet, write a short explanation of how scientists search for evidence regarding the origin of life on Earth.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. State the six main elements that make up all living forms.
Carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur
2. Define polymers and monomers. Explain how DNA is a polymer.
A polymer is a large molecule made up of individual monomers. A monomer is the molecular building block of the polymer. DNA is a polymer because it is a large chain of nucleotides, which would be the monomers.
3. What are proteins? How many amino acids are needed to make proteins for living organisms?
Proteins are a group of smaller molecules (called amino acids) that are linked by chemical bonds. Living organisms typically need 20 different amino acids to make the proteins.
4. What is prebiotic chemistry?
Chemistry that could have been occurring before life existed on Earth.
5. Why do scientists think stromatolites are the key to the origins of life?
The oldest stromatolites are about 3.5 billion years old. These stromatolites are formed when single celled organisms secrete minerals such as limestone, and pyrite.
6. Explain how DNA works with RNA.
The genes from the DNA are transcribed to the RNA when the DNA and RNA are attached. The RNA takes these replicated genes and translated to proteins to help build new cells or the organisms
7. What happens to a living organism when it does not receive enough protein?
Not enough protein will have an adverse effect on the body. The proteins act as enzymes that help speed up the reactions to spread DNA or to help build cell membranes.
8. Explain 1 theory of how proteins and RNA were formed before they could make DNA.
One theory is that genes existed before living organisms were formed, and the genes replicated to make the organisms over time. Another theory is that RNA was the main molecule, used for replicating and supporting living organisms before proteins were evolved to take the job from RNA.
9. Think about the structure of carbon, and how it bonds. Explain why there are so many different reactions with carbon-based molecules.
The carbon atom has 4 bonding sites, so it can form 4 single bonds, or many variations of multiple (double and triple) bonds. (For upper level chemistry students: carbon can undergo sp^3 , sp^2 , and sp hybridizations, allowing for many combinations of bonds).

Questions for Further Learning

Look up the 20 amino acids that human bodies need to function. Which are the “essential” amino acids? Why are they “essential”?

The 20 amino acids are (essential are in boldface):

alanine arginine asparagine aspartic acid

cysteine glutamic acid glutamine glycine

histidine **isoleucine** **leucine** **lysine**

methionine **phenylalanine** proline serine

threonine **tryptophan** tyrosine **valine**

The 9 essential amino acids are the ones your body cannot produce on its own. In order for you to get these amino acids, you must eat the right foods that contain them.

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

- Turn milk into plastic: <https://teachchemistry.org/classroom-resources/turn-milk-into-plastic>
- Molecular Spaghetti: <https://teachchemistry.org/classroom-resources/molecular-spaghetti>
- Making Silly Putty: <https://www.pbs.org/parents/crafts-and-experiments/two-ingredient-silly-putty-video>
- Creating DNA: https://www.teachengineering.org/activities/view/cub_biomed_lesson09_activity2
- Everyday Polymers Lesson: https://www.teachengineering.org/lessons/view/csu_polymer_lesson01
- Polymers <https://teachchemistry.org/classroom-resources/the-power-of-polymers>

❖ Lessons and lesson plans

- Compound Chem: <https://www.compoundchem.com/2015/03/24/dna/>
- Silly Putty Polymer: <https://www.compoundchem.com/2015/11/10/sillyputty/>

Teaching Strategies

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

- **Alternative to Anticipation Guide:** Before reading, ask students what chemicals are required for life, and how they think scientists study origins of life. 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 study of the origin of life.
- After students have read and discussed the article, ask students how understanding chemistry is important for studying biology.
- The videos below may be of interest to students after they read the article to learn more about how scientists study the origin of life, including in places other than Earth.
 - Did Comets Kickstart Life on Earth? (4:14) - <https://youtu.be/FnuldVd99x8>
 - The video presents interesting theories regarding debris from the early solar system that is trapped in comets, as well as other possible sources of complex carbon molecules.
- What is Life? And how will we find it on other planets? (8:08) - <https://youtu.be/f44OWIsLeTQ>
 - The video describes chemical systems that scientists are looking for on exoplanets in the search for life elsewhere in the universe.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Organic chemistry
- Polymers
- Chemical change
- Nature of science

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
- LS1.A: Structure and Function

Crosscutting Concepts:

- Cause and effect
- Energy and matter: Flows, cycles, and conservation
- Stability and change
- Structure and function

Science and Engineering Practices:

- Planning and carrying out investigations
- Engaging in arguments from evidence

Nature of Science:

- Scientific knowledge is open to revision in light of new evidence.
- Scientific knowledge assumes an order and consistency in natural systems.
- Science addresses questions about the natural and material world.

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